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USATHAMA

U.S. Army Toxic and Hazardous Materials Agency

WEST VIRGINIA ORDNANCE WORKS
SUPPLEMENTAL REMEDIAL INVESTIGATION
FINAL REPORT

AUGUST 1987

REPORT NO. AMXTH-IR-CR-88001

PREPARED FOR:

U.S. ARMY TOXIC AND HAZARDOUS MATERIALS AGENCY
INSTALLATION RESTORATION DIVISION
ABERDEEN PROVING GROUND, MARYLAND 21010-5401

BY:

ENVIRONMENTAL SCIENCE AND ENGINEERING, INC.
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A supplemental Remedial Investigation (RI) was conducted at the second operable unit of the West Virginia Ordnance Works (WVOW). The RI summarily assessed ground water contamination at the Acids Area/Yellow Water Reservoir area, the Red Water Reservoirs area, and the Pond 13/Wet Well Area. The field effort was conducted from March 1986-August 1986. The study included the following elements:

1. Installation of nine ground water monitor wells and one water-level observation well (March 1986).
2. Sampling of 9 new monitor wells and 24 existing wells (April 1986).
3. Sampling of six sediment locations at the Red Water Reservoirs.
4. Time-series sampling of Wells GW27D and GW27 during a 48-hour pumping period (August 1986).
5. Resampling of six monitor wells and one water supply well (August 1986).

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Ground water contamination is limited to the shallow alluvial aquifer at the three areas of concern. The shallow aquifer is separated from a deep glacial outwash aquifer by a gray clay confining layer. This confining layer is present in all areas of concern at WVOW and acts as an effective barrier to preclude vertical contaminant migration.

Ground water flow in the shallow aquifer is to the west. A ground water divide exists for the deep aquifer; ground water flow is to the north (north of the Acids Area/ Yellow Water Reservoir) and to the south at Pond 13/Wet Well Area.

TNT, nitroaromatic

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LIST OF ACRONYMS AND ABBREVIATIONS

°C	degrees Celsius
$CaCO_3$	calcium carbonate
CE	U.S. Army Corps of Engineers
cm/sec	centimeters per second
1,3-DNB	1,3-dinitrobenzene
2,4-DNT	2,4-dinitrotoluene
2,6-DNT	2,6-dinitrotoluene
EPA	U.S. Environmental Protection Agency
ESE	Environmental Science and Engineering, Inc.
FS	Feasibility Study
ft	foot
ft/day	feet per day
ft/ft	feet per foot
ft-MSL	feet above mean sea level
ft/sec	feet per second
ft^2	square feet
ft^3	cubic feet
gal	gallons
gpm	gallons per minute
ID	inside diameter
McClintic Wildlife Station	Clifton F. McClintic State Wildlife Station
mg/L	milligrams per liter
mm	millimeters
N	nitrogen
NA	not analyzed
NIPDWR	National Interim Primary Drinking Water Regulations
OD	outside diameter
PAH	polynuclear aromatic hydrocarbons
PVC	polyvinyl chloride

QA	Quality Assurance
QC	Quality Control
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
SR	State Route
TNB	trinitrobenzene
1,3,5-TNB	1,3,5-trinitrobenzene
2,4,6-TNT	2,4,6-trinitrotoluene
µg/g	micrograms per gram
µg/L	micrograms per liter
µmho/cm	micromhos per centimeter
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
VC	vertical composite sample
WVOW	West Virginia Ordnance Works

EXECUTIVE SUMMARY

PURPOSE OF THE SUPPLEMENTAL REMEDIAL INVESTIGATION

The U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) issued Contract No. DAAK11-83-D-0007 to Environmental Science and Engineering, Inc. (ESE) to perform tasks relating to the Multi-Installation Eastern Sites Environmental Contamination Surveys Program. Task Number 0004, Delivery Order Number 0005, comprises a Remedial Investigation/ Feasibility Study (RI/FS) of the former West Virginia Ordnance Works (WVOW) to assess contamination and contamination migration in the soils, surface water, and ground water as a result of past 2,4,6-trinitrotoluene (2,4,6-TNT) manufacturing operations and to evaluate potential remedial action alternatives. The layout of the former industrial facility is shown in Fig. 1.

The Remedial Investigation (RI) report (ESE, 1986d) detailed the sitewide contamination status of WVOW. For certain areas of concern (specifically the Acids Area/Yellow Water Reservoir, the Red Water Reservoirs, and the Pond 13/Wet Well Area), important uncertainties remained regarding the source, extent, and migration potential of contaminated ground water. These uncertainties dictated that additional field data be collected to support remedial alternative decisionmaking.

To expedite implementation of source area remedial actions, WVOW was divided into two operable units. The first operable unit included the TNT Manufacturing Area, the Burning Grounds Area, and the industrial sewerlines. The second operable unit included the Acids Area/Yellow Water Reservoir, the Red Water Reservoirs area, and the Pond 13/Wet Well Area. The available data for the first operable unit were sufficient to complete the RI/FS process; all studies have been completed, and the Record of Decision (ROD) for the first operable unit is scheduled to be signed in April 1987.

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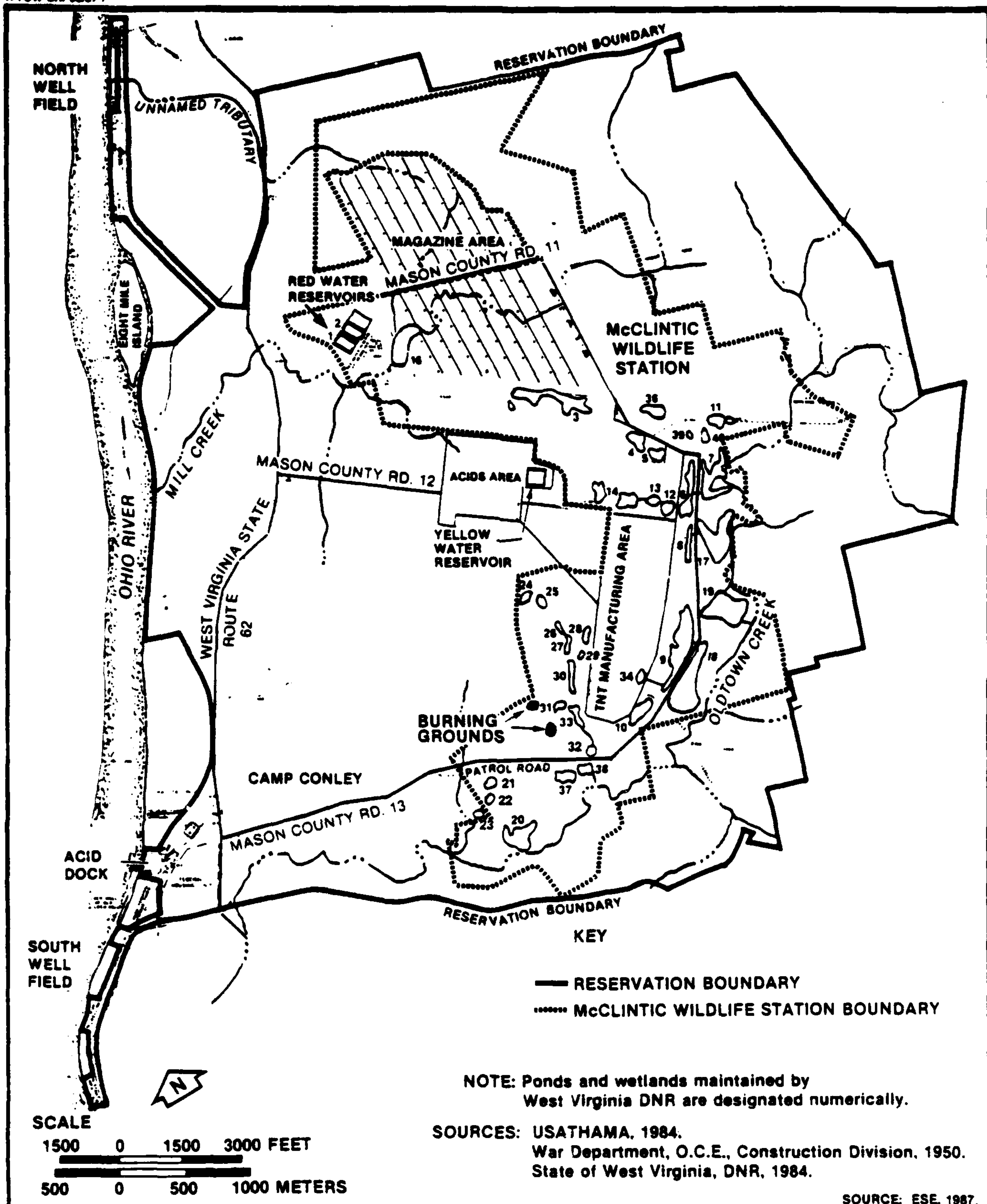

Figure 1
WVOW STUDY AREAS

WEST VIRGINIA ORDNANCE WORKS
Supplemental Remedial Investigation
Phase II Field Program

This report presents the findings of the supplemental RI survey and summarizes the Phase II field program (March through August 1986) conducted at WVOW in each area of concern in the second operable unit.

SUPPLEMENTAL RI OBJECTIVES

The objectives of the supplemental RI by area were:

1. Acids Area/Yellow Water Reservoir
   a. Determine the limit of contamination in the shallow alluvial aquifer.
   b. Verify the presence and thickness of the gray clay confining layer and assess the potential for downward vertical contaminant migration.
2. Red Water Reservoirs
   a. Refine estimate of contaminant source strength in the reservoir sediments.
   b. Determine the limit of contamination in the shallow alluvial aquifer.
   c. Verify the presence and thickness of the gray clay confining layer and assess the potential for downward vertical contaminant migration.
3. Pond 13/Wet Well Area
   a. Assess ground water flow direction in the shallow aquifer.
   b. Determine the limit of contamination in the shallow alluvial aquifer.
   c. Verify the presence and thickness of the gray clay confining layer and assess the potential for downward vertical contaminant migration.

SUPPLEMENTAL RI APPROACH AND SCOPE

The Phase II Supplemental RI included shallow and deep monitor well installation, water-level observation well installation, sediment sampling, water-level measurements, and ground water sampling. In addition to sampling the wells installed in the supplemental RI program, existing monitor wells were sampled in each of the three areas of concern to relate the data from the new wells to the existing data base.

The supplemental RI field program was initiated in March 1986. Ground water samples from three new deep monitor wells contained detectable nitroaromatics. The relative concentration of nitroaromatics in the deep wells compared with adjacent shallow contaminated wells indicated the probability that contaminated ground water from the shallow aquifer was carried into the deep aquifer during drilling.

To determine the source of the low levels of nitroaromatics observed in the deep monitor wells, a deep well resampling program was conducted in August 1986. One of the three wells was selected for time-series sampling. In the time-series sampling, the well was pumped continuously for an extended period of time and was sampled at periodic time steps throughout the pumping. Each successive pumped sample represented ground water quality at increasing distance from the pumped well. The pattern of contaminant arrival, concentration, and duration provided data relevant to the presence, strength, and location of the contaminant source. Selected deep and shallow monitor wells also were resampled.

The individual elements of the supplemental RI field program are presented in Table 1.

SUPPLEMENTAL RI RESULTS

The principal findings of the supplemental RI area of concern within the second operable unit are described in the following sections.

ACIDS AREA/YELLOW WATER RESERVOIR

1. Contaminant sources were identified in the Phase I survey and include the sediments of the Yellow Water Reservoir and contaminated soil in the vicinity of the neutralization chamber.
2. Nitroaromatic contamination exists in the shallow aquifer. The contamination is limited in areal extent.

Table 1. Supplemental RI Field Program

Area of Concern	Field Program Elements
Acids Area/Yellow Water Reservoir	1. Install one shallow monitor well. 2. Install one deep monitor well. 3. Sample new and existing wells. 4. Conduct time-series sampling of deep monitor well.
Red Water Reservoirs	1. Install three shallow monitor wells. 2. Install one deep monitor well. 3. Conduct sediment sampling of reservoirs. 4. Sample new and existing wells.
Pond 13/Wet Well Area	1. Install one shallow monitor well. 2. Install one deep monitor well. 3. Install one shallow water-level observation well. 4. Sample new and existing wells.
Other Tasks	1. Measure water levels at all wells and surface water gaging stations at WVOW (April 1986). 2. Resample Well GW36D (TNT Manufacturing Area). 3. Install shallow monitor well at north portion of TNT Manufacturing Area. 4. Sample deep water supply well at Clifton F. McClintic State Wildlife Station (McClintic Wildlife Station).

Source: ESE, 1987.

3. The gray clay confining layer is present at the Yellow Water Reservoir and acts as an effective barrier to vertical contaminant migration.
4. The contamination detected in the deep aquifer in April 1986 was attributed to shallow contamination being carried into the deep aquifer during drilling. The data obtained during the time-series sampling of GW27D and the resampling of GW36D confirmed this theory.
5. Ground water flow direction in the shallow aquifer is to the west; ground water flow in the deep aquifer is to the north.

RED WATER RESERVOIRS

1. The source strength of the sediments of Pond 1 and Pond 2 was refined through the sampling and analysis of deep sediment cores. Low levels of nitroaromatics were detected in several of the deeper sediment samples.
2. Nitroaromatic contamination was detected in the shallow ground water at Monitor Wells GW30, GW45, GW46, GW47, and SHW6. At SHW6, located at State Route (SR) 62, the contamination is present at very low levels [0.2 micrograms per liter (µg/L) of 2,4,6-TNT]; the downgradient limit of contamination is projected to occur at or immediately west of SR 62.
3. The gray clay confining layer is present at the Red Water Reservoirs and acts as an effective barrier to vertical contaminant migration.
4. The apparent low-level contamination detected in the deep aquifer in 1986 is attributed to shallow contamination being carried into the deep aquifer during drilling. The data obtained during the time-series sampling of GW27D and the resampling of GW36D confirm this theory.
5. Ground water flow direction in the shallow aquifer is to the northwest; ground water flow in the deep aquifer is expected to have a northerly component.

POND 13/WET WELL AREA

1. A major source of the contamination observed at Pond 13 is the nearby Wet Well W1.
2. The shallow sand aquifer appears to be areally limited and is bounded by clay-dominant sediments observed at GW48D to the north and GW22D to the east.
3. The gray clay confining layer is present at Pond 13 and acts as an effective barrier to vertical migration.
4. Based on the water levels measured in the RI (ESE, 1986d) and supplemental RI (ESE, 1986a), essentially no direction of ground water flow is apparent in the shallow aquifer.
5. The hydraulic head observed in the deep monitor wells is higher than those observed in the shallow aquifer, further substantiating the conclusion that vertical contaminant migration at Pond 13 is unlikely.

1.0 INTRODUCTION

The U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) issued Contract No. DAAK11-83-D-0007 to Environmental Science and Engineering, Inc. (ESE) to perform tasks relating to the Multi-Installation Eastern Sites Environmental Contamination Surveys Program. Task Number 0004, Delivery Order Number 0005, comprises a Remedial Investigation/ Feasibility Study (RI/FS) of the former West Virginia Ordnance Works (WVOW) to assess contamination and contamination migration in the soils, surface water, and ground water as a result of past 2,4,6-trinitrotoluene (2,4,6-TNT) manufacturing operations and to evaluate potential remedial action alternatives. The layout of the former industrial facility is shown in Fig. 1.0-1.

The Remedial Investigation (RI) report (ESE, 1986d) detailed the sitewide contamination status of WVOW. For certain areas of concern (specifically the Acids Area/Yellow Water Reservoir, the Red Water Reservoirs, and the Pond 13/Wet Well Area), important uncertainties remained regarding the source, extent, and migration potential of contaminated ground water. These uncertainties dictated that additional field data be collected to support remedial alternative decisionmaking.

To expedite implementation of source area remedial actions, WVOW was divided into two operable units. The first operable unit included the TNT Manufacturing Area, the Burning Grounds Area, and the industrial sewerlines. The second operable unit included the Acids Area/Yellow Water Reservoir, the Red Water Reservoirs area, and the Pond 13/Wet Well Area. The available data for the first operable unit were sufficient to complete the RI/FS process; all studies have been completed and the Record of Decision (ROD) for the first operable unit is scheduled to be signed in April 1987.

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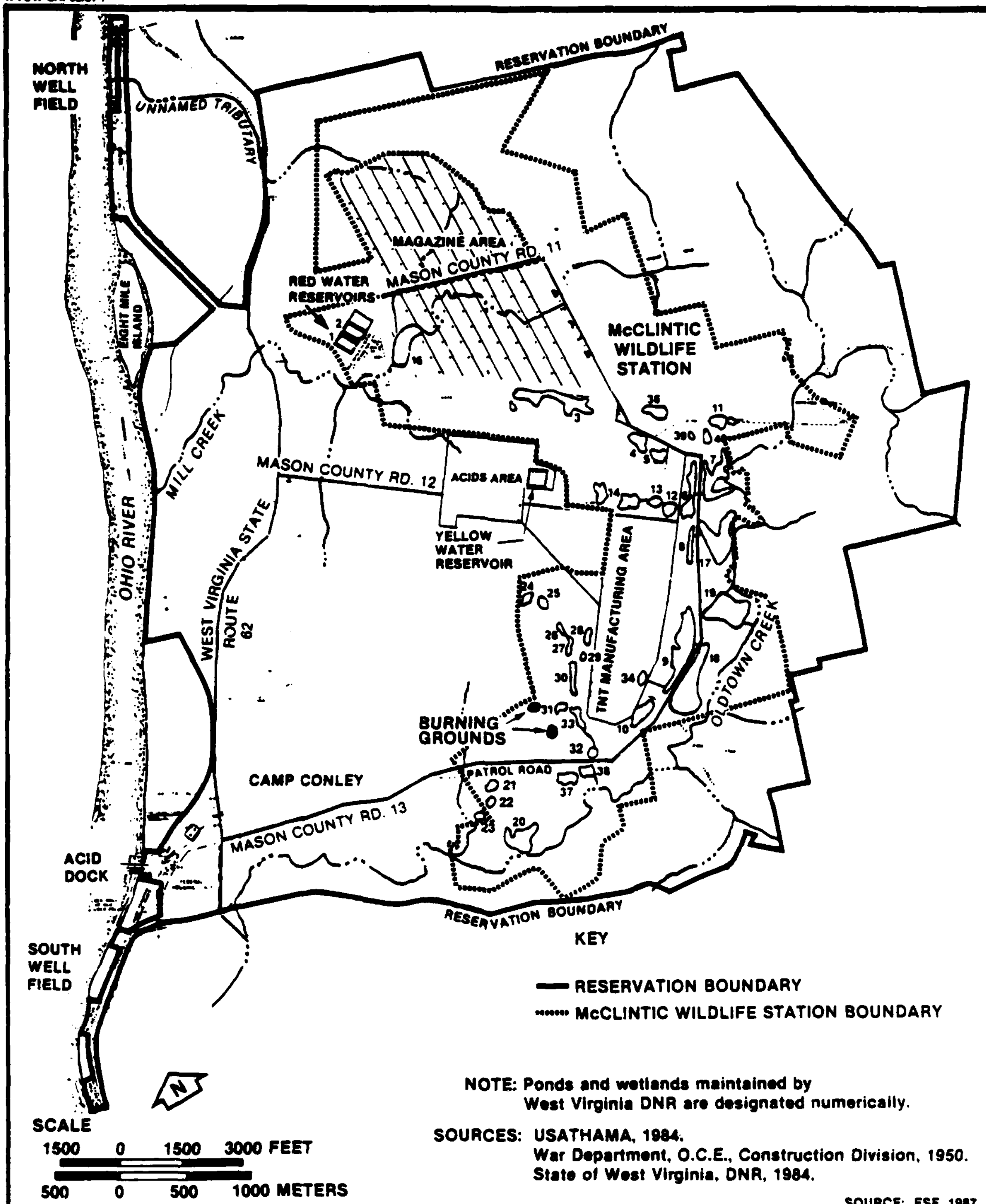

Figure 1.0-1
WVOW STUDY AREAS

WEST VIRGINIA
ORDNANCE WORKS
Supplemental Remedial Investigation
Phase II Field Program

This report presents the findings of the supplemental RI survey and summarizes the Phase II field program (March through August 1986) conducted at WVOW in each area of concern in the second operable unit.

1.1 SUMMARY OF CONTAMINATION STATUS

The following paragraphs are a summary of the overall site contaminant sources and contaminated media. The principal sitewide contaminants are nitroaromatic residues, and the predominant compound observed was 2,4,6-TNT; 1,3,5-trinitrobenzene (1,3,5-TNB) and 2,4-dinitrotoluene (2,4-DNT) were also widely distributed. The major nitroaromatic contaminant source areas are shown in Fig. 1.1-1 and include:

1. The surface and subsurface soils in the TNT Manufacturing Area,
2. The industrial sewerlines in the TNT Manufacturing Area and the trunk sewerlines leading from the Pond 13 area to the outfalls, and
3. The surface soils in the East and West Burning Grounds.

In these areas, concentrations ranging to the low-percent levels (<10 percent) were encountered. Fist-sized pieces of crystalline nitroaromatic residue were encountered in the Burning Grounds Area. These source areas contribute surface water and ground water contamination by nitroaromatics and represent a hazard to human beings and wildlife as a result of direct contact. A very small area [approximately 100 square feet (ft^2)] of surface soils in the Acids Area/Yellow Water Reservoir area is also contaminated with nitroaromatics to approximately the 1-percent level.

The Red Water Reservoirs sediments, Yellow Water Reservoir soils, and the Wet Well/Pond 13 seep area sediments are contaminated to a lesser degree and do not represent a direct contact threat, but contribute to surface water and ground water contamination. These source areas are shown in Fig. 1.1-1.

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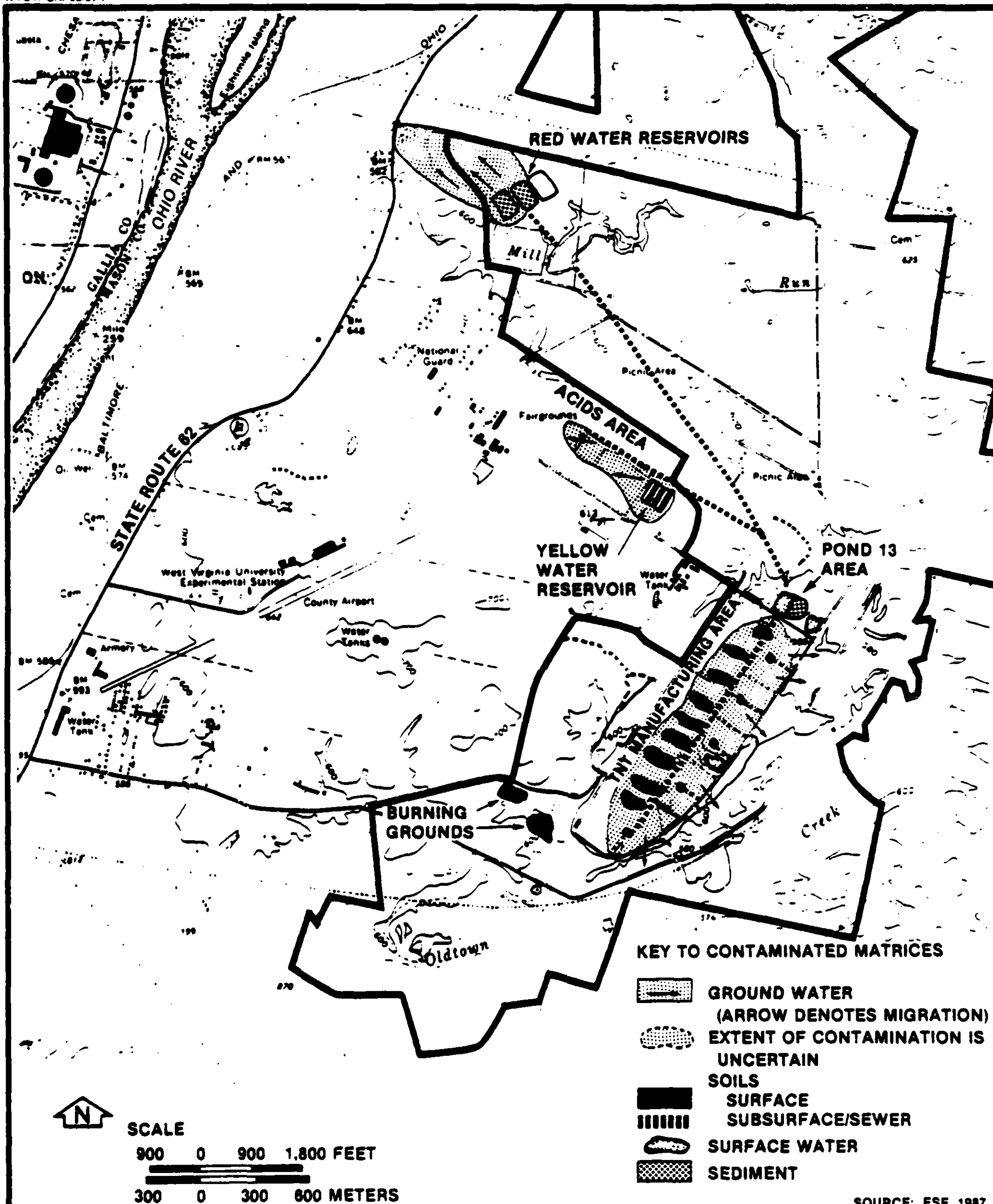

Figure 1.1-1 **OVERALL CONTAMINATION SUMMARY AT WVOW**	**WEST VIRGINIA ORDNANCE WORKS** Supplemental Remedial Investigation Phase II Field Program

Asbestos, disposed primarily at the West Burning Grounds, represents a direct contact hazard in this area. Surface water migration of asbestos is occurring into the drainage leading from this source area into Oldtown Creek. Waters of the drainage area and Oldtown Creek are not used as drinking water sources or for body contact recreation. Polynuclear aromatic hydrocarbons (PAHs) and lead also were observed in the West Burning Grounds. Although these contaminants represent a potential contact hazard in the source area, no generalized migration appears to have occurred. Asbestos also exists offsite in the powerhouses and Mason Furniture Co. Access to the south powerhouse is not restricted. Mason Furniture Co. is privately owned.

Table 1.1-1 indicates the maximum concentrations observed in various contaminated areas and media for categories of contaminants associated with the WVOW site. In each area, sampling strategy was designed to identify and sample the most contaminated areas, so the maximum concentrations are not necessarily representative of the typical concentration in each source area. In virtually all source areas, several samples were collected that were uncontaminated, thus realistically defining the extent of contamination. Details of the contaminant distribution in each source area are presented in the RI report (ESE, 1986d).

1.2 SUPPLEMENTAL RI OBJECTIVES

As stated previously, important uncertainties remained at the conclusion of the initial RI survey regarding the source, extent, and migration potential of contaminated ground water for the areas of concern within the second operable unit. Specific objectives were determined for each area of concern. The objectives of the supplemental RI by area are:

1. Acids Area/Yellow Water Reservoir
    a. Determine the limit of contamination in the shallow alluvial aquifer.
    b. Verify the presence and thickness of the gray clay confining layer and assess the potential for downward vertical contaminant migration.

Table 1.1-1. Summary of Contamination Status of the Second Operable Unit at WVOW

Environmental Medium	Contaminant	Maximum Concentration Detected*
Acids Area/Yellow Water Reservoir		
Soils	Nitroaromatics	1% (isolated area approximately 100 ft^2)
	Lead	100 µg/g
Sewerlines	Nitroaromatics	2,830 µg/g
Surface Water	Uncontaminated	--
Ground Water	Nitroaromatics	15 µg/L
Red Water Reservoirs		
Soils	Uncontaminated	--
Sewerlines	Nitroaromatics	0.2%
Surface Water	Uncontaminated	--
Sediments	Nitroaromatics	2,210 µg/g
Ground Water	Nitroaromatics	17 µg/L
Pond 13/Wet Well Area		
Soils	Nitroaromatics	5.5 µg/g
Sewerlines	Uncontaminated	--
Surface Water	Nitroaromatics	70 µg/L
	Lead	32 µg/L†

Table 1.1-1. Summary of Contamination Status of the Second Operable Unit at WVOW (Continued, Page 2 of 2)

Environmental Medium	Contaminant	Maximum Concentration Detected*
Pond 13/Wet Well Area (Continued)		
Sediments	Nitroaromatics	4,240 µg/g
Ground Water	Nitroaromatics	50,000 µg/L

Note: µg/g = micrograms per gram.
µg/L = micrograms per liter.

*In each area, sampling strategy was designed to identify and sample the most contaminated areas, so the maximum concentrations are not necessarily representative of the typical concentration in each source area. In virtually all source areas, several samples were collected that were uncontaminated, thus realistically defining the extent of contamination.

†Lead in ground and surface waters did not exceed relevant standards or criteria [e.g., National Interim Primary Drinking Water Regulations (NIPDWR) = 50 µg/L].

Source: ESE, 1987.

2. Red Water Reservoirs
   a. Refine estimate of contaminant source strength in the reservoir sediments.
   b. Determine the limit of contamination in the shallow alluvial aquifer.
   c. Verify the presence and thickness of the gray clay confining layer and assess the potential for downward vertical contaminant migration.
3. Pond 13/Wet Well Area
   a. Assess ground water flow direction in the shallow aquifer.
   b. Determine the limit of contamination in the shallow alluvial aquifer.
   c. Verify the presence and thickness of the gray clay confining layer and assess the potential for downward vertical contaminant migration.

1.3 SUPPLEMENTAL RI APPROACH AND SCOPE

To address the data gaps listed in Sec. 1.1, the Phase II Supplemental RI included shallow and deep monitor well installation, water-level observation well installation, sediment sampling, water-level measurements, and ground water sampling. In addition to sampling the wells installed in the supplemental RI program, existing monitor wells were sampled in each of the three areas of concern to relate the chemical data from the new wells to the existing data base.

The supplemental RI field program was initiated in March 1986. Ground water samples from three new deep monitor wells contained detectable nitroaromatics. The relative concentration of nitroaromatics in the deep wells compared with adjacent shallow contaminated wells indicated the probability that contaminated ground water from the shallow aquifer was carried into the deep aquifer during drilling.

To determine the source of the low levels of nitroaromatics observed in the deep monitor wells, a deep well resampling program was conducted in August 1986. One of the three wells was selected for time-series sampling. In the time-series sampling, the well (GW27D) was pumped continuously for an extended period of time and was sampled at periodic time steps throughout the pumping. Each successive pumped sample represents ground water quality at increasing distance from the pumped well. The pattern of contaminant arrival, concentration, and duration provided data relevant to the presence, strength, and location of the contaminant source. Selected deep and shallow monitor wells also were resampled.

The individual elements of the supplemental RI field program are presented in Table 1.3-1.

1.4 SUPPLEMENTAL RI REPORT ORGANIZATION

This supplemental RI report is structured in general accordance with format guidance from the U.S. Environmental Protection Agency (EPA) (EPA, 1985). The overall format of data presentation is grouped by major area of concern.

Sec. 1.0 (Introduction) presents an overview of previous studies conducted at the site, a summary of the supplemental RI survey, and the structure of the RI report.

Sec. 2.0 (Field Methodology) describes the technical activities and investigations performed during the supplemental RI survey. This section also includes the site selection rationale for sediment sampling and monitor well installation. The specific field and analytical procedures (e.g., monitor well drilling, borehole logs, chemical analyses) employed in the supplemental RI survey followed those procedures employed in the initial RI survey. As such, these detailed procedures are incorporated by reference (ESE, 1986d) and are not presented in detail in this report.

Table 1.3-1. Supplemental RI Field Program

Area of Concern	Field Program Elements
Acids Area/Yellow Water Reservoir	1. Install one shallow monitor well. 2. Install one deep monitor well. 3. Sample new and existing wells. 4. Conduct time-series sampling of deep monitor well.
Red Water Reservoirs	1. Install three shallow monitor wells. 2. Install one deep monitor well. 3. Conduct sediment sampling of reservoirs. 4. Sample new and existing wells.
Pond 13/Wet Well Area	1. Install one shallow monitor well. 2. Install one deep monitor well. 3. Install one shallow water-level observation well. 4. Sample new and existing wells.
Other Tasks	1. Measure water levels at all wells and surface water gaging stations at WVOW (April 1986). 2. Resample Well GW36D (TNT Manufacturing Area). 3. Install shallow monitor well at north portion of TNT Manufacturing Area. 4. Sample deep aquifer water supply well at Clifton F. McClintic Wildlife Station (McClintic Wildlife Station).

Source: ESE, 1987.

Sec. 3.0 (Ground Water Hydrology) presents the results of the supplemental hydrogeologic investigation for each area of concern. A discussion of sitewide hydrogeology as it affects nitroaromatic contaminant distribution and migration potential is also included.

Sec. 4.0 (Contamination Assessment) presents the results of the supplemental sampling and analysis program for each area of concern.

Sec. 5.0 (Summary and Conclusions) presents the significant results of the supplemental RI survey for each area of concern.

2.0 SUPPLEMENTAL RI FIELD PROGRAM METHODOLOGY

The supplemental RI field and laboratory programs were carried out from March through September 1986 to refine the nature and extent of ground water contamination to meet the objectives described in Sec. 1.2. The protocols and methodologies for the field and laboratory programs were the same as those used in the initial RI program; these procedures are described in the following appendixes of the initial RI report (ESE, 1986d):

App. A--Geotechnical Investigation Methodology (well drilling and installation, ground water sampling, water-level measurements)

App. B--Surface Water and Sediment Investigation Methodology (sediment sampling)

App. D--Laboratory Procedures and Data Reduction (chemical analysis, sample control, data management)

App. E--Quality Assurance [Project Quality Assurance (QA) Plan]

These appendixes of the initial RI report are not reproduced herein.

The supplemental RI program included water-level observation well installation, monitor well installation, water-level measurements, sediment sampling, monitor well sampling, and laboratory analyses of water and sediment samples.

2.1 SITE SELECTION RATIONALE

2.1.1 SEDIMENT SAMPLING LOCATIONS

Additional sediment samples were collected during the supplemental RI program in order to refine the contaminant source strength in the sediments of Ponds 1 and 2, the Red Water Reservoirs. At Pond 1, samples were collected at the north end, at the center, and at the former outlet flow structure. At Pond 2, sampling stations were located at the north end, at the center, and at the former inlet structure. The six sampling locations are shown in Fig. 2.1-1.

WVOW SRI 03/87 P

Figure 2.1-1
PHASE II SEDIMENT SAMPLING LOCATIONS IN THE RED WATER RESERVOIRS

WEST VIRGINIA ORDNANCE WORKS
Supplemental Remedial Investigation
Phase II Field Program

2.1.2 WATER-LEVEL OBSERVATION WELL LOCATION

One additional water-level observation well (OW32S) was installed at the Pond 13/Wet Well Area during the supplemental RI program. The well, which is located west of Wet Well No. 1 and northwest of Well EPA04, is completed in the shallow aquifer. The well location was selected to provide additional areal coverage to aid in the definition of shallow ground water flow patterns. The observation well location is shown in Fig. 2.1-2.

2.1.3 MONITOR WELL LOCATIONS

Nine monitor wells were installed during the supplemental field RI program. The locations of all WVOW monitor wells are shown on Fig. 2.1-3. The site selection rationale for each Phase II monitor well is shown in Table 2.1-1.

2.2 WATER-LEVEL MEASUREMENTS

Water-level measurements were taken periodically throughout the field program. One complete set of water levels for all surface water and ground water stations was collected on Apr. 22, 1986; partial sets of ground water level measurements were collected on Aug. 11, 1986, and Aug. 14, 1986. Water levels were measured using either the wetted-tape method or an electric probe.

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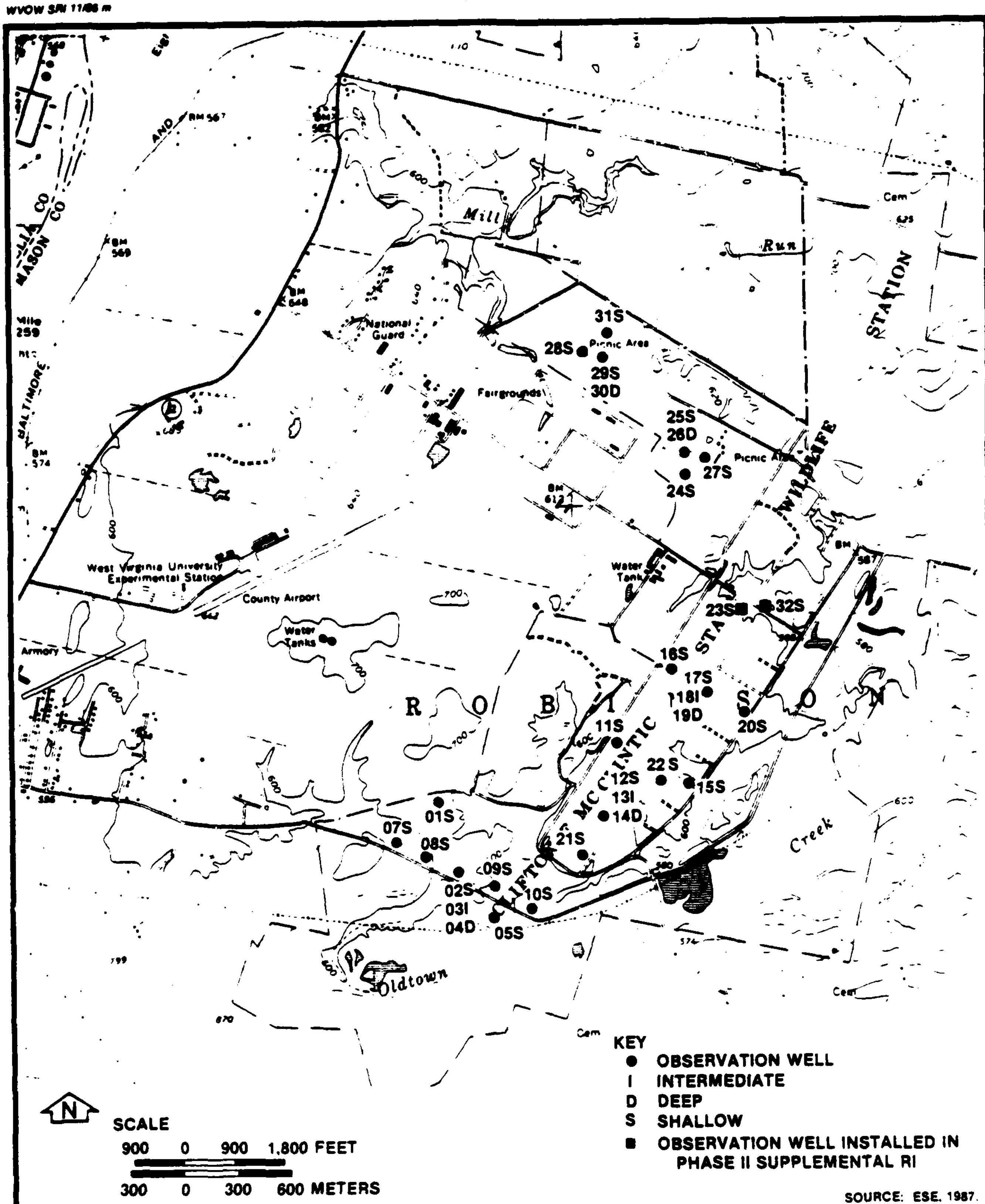

Figure 2.1-2
LOCATIONS OF WATER-LEVEL OBSERVATION WELLS

WEST VIRGINIA ORDNANCE WORKS
Supplemental Remedial Investigation
Phase II Field Program

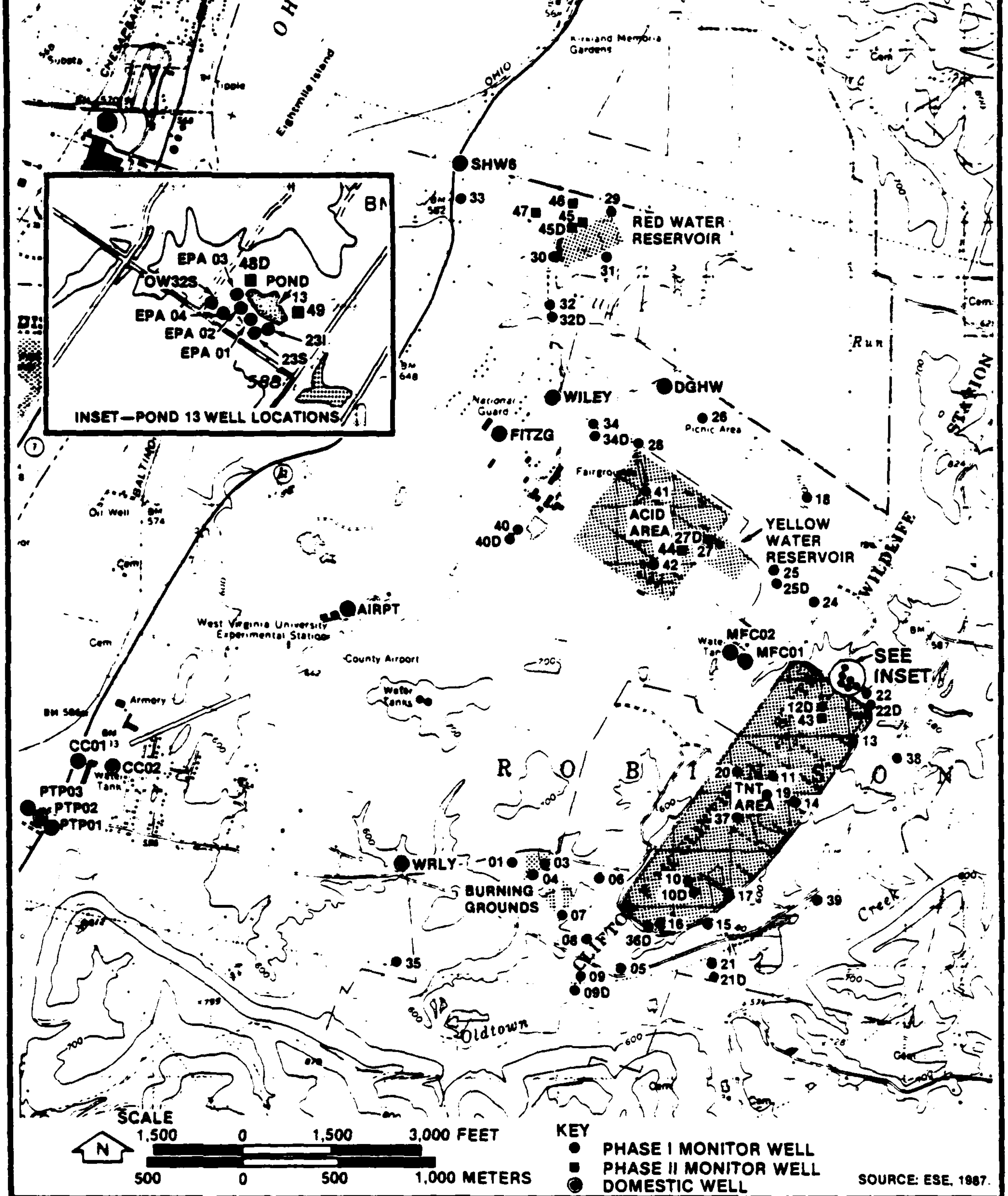

Figure 2.1-3
LOCATIONS OF MONITOR WELLS, EPA WELLS, AND OFFSITE DOMESTIC WELLS

WEST VIRGINIA ORDNANCE WORKS
Supplemental Remedial Investigation
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Table 2.1-1. Monitor Well Site Selection Rationale, Phase II Field Program

Well Designation	Selection Rationale
Yellow Water Reservoir	
GW27D	Located adjacent to Yellow Water Reservoir near Well GW27; verify presence and thickness of gray clay layer; assess water quality in deep aquifer; determine vertical hydraulic gradient.
GW44	Shallow well downgradient of Yellow Water Reservoir; define downgradient limit of contamination in shallow aquifer.
Red Water Reservoirs	
GW45, GW45D	Well pair immediately downgradient of Red Water Reservoirs; verify presence and thickness of gray clay layer; assess water quality in shallow and deep aquifers; determine vertical hydraulic gradient.
GW46, GW47	Shallow downgradient wells; provide better definition of ground water flow rate and direction.
Pond 13/Wet Well Area	
OW32S	Shallow water-level observation well northwest of EPA04. Provide additional definition of shallow aquifer extent and ground water movement.
GW43 (TNT Manufacturing Area)	Shallow well installed adjacent to GW12D. Determine shallow aquifer water quality in northern TNT Manufacturing Area near Pond 13; establish vertical hydraulic gradient.

Table 2.1-1. Monitor Well Site Selection Rationale, Phase II Field Program (Continued, Page 2 of 2)

Well Designation	Selection Rationale
GW48D	Assess ground water quality in deep aquifer; verify presence and thickness of gray clay layer; determine hydraulic head in deep aquifer. Originally intended as a well pair, the proposed shallow Well GW48 was not drilled when GW48D encountered only the deep aquifer. At GW48D, clay deposits extended from the surface to 75-foot (ft) depth; the shallow alluvial aquifer was not present.
GW49	Shallow aquifer monitor well east of Pond 13; provide better definition of ground water flow rate and direction.

Source: ESE, 1987.

2.3 WELL INSTALLATION

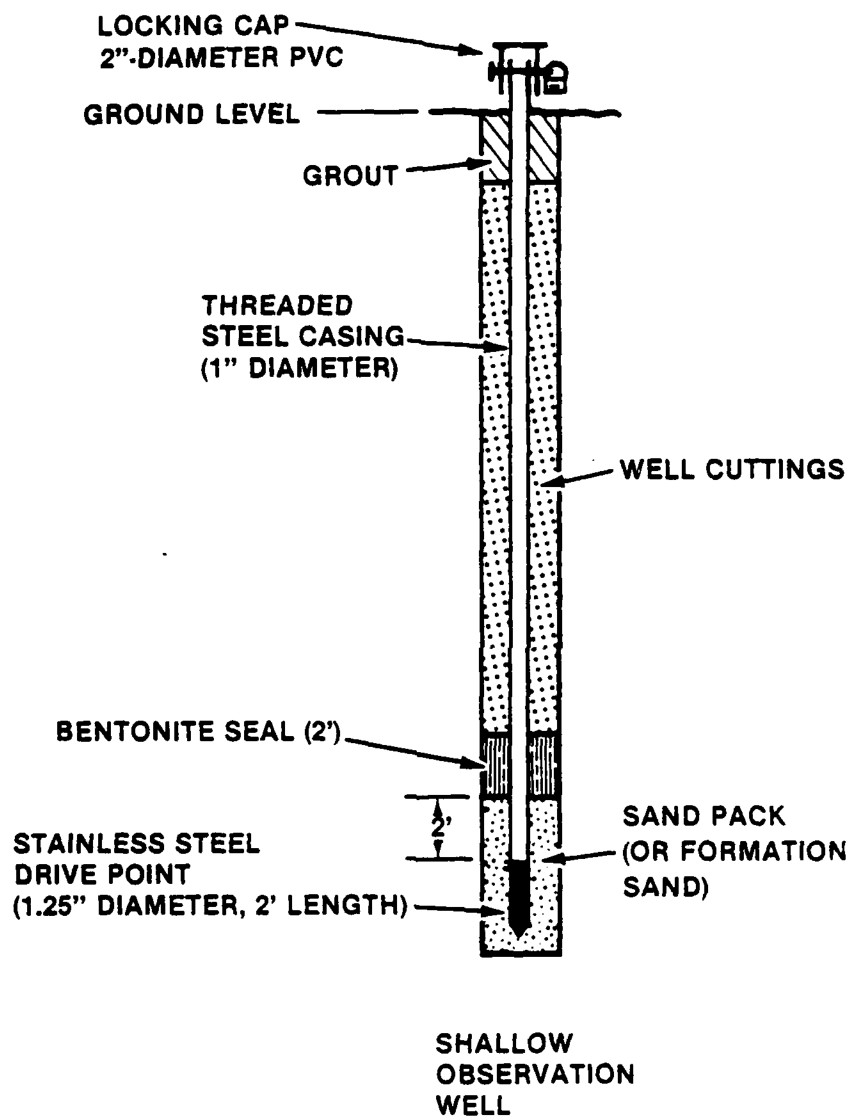
2.3.1 WATER-LEVEL OBSERVATION WELL

A single water-level observation well (OW32S) was installed at the Pond 13/Wet Well Area. The borehole was advanced by hand using a stainless-steel bucket auger. Borehole logging and documentation procedures and construction of the shallow observation well followed the detailed methodology contained in the initial RI report, App. A, Sec. A.2 (ESE, 1986d). Observation well construction is shown in Fig. 2.3-1.

2.3.2 GROUND WATER MONITOR WELLS

All monitor wells were constructed in accordance with the Geotechnical Requirements for Drilling, Monitor Wells, Data Acquisition, and Reports (USATHAMA, 1983). Drilling was performed under contract to Bowser-Morner Testing, Inc., Dayton, OH. All wells were drilled by Patterson Well Drilling (a subcontractor to Bowser-Morner), Dayton, OH, using a Bucyrus-Erie 22W cable-tool drilling rig. Drilling procedures, borehole logging and documentation, well construction, and well development specifications followed the detailed methodology contained in App. A, Sec. A.2 of the initial RI report (ESE, 1986d). A summary table listing materials used in well construction is shown in Table 2.3-1. Typical well construction is shown in Fig. 2.3-2. Well construction specifications for all WVOW monitor wells are shown in Table 2.3-1. Summary data from the monitor well development program are included in App. A. Well logs are included in App. B.

Joseph L. Leach, a land surveyor registered in the State of West Virginia (Registration No. 183), surveyed all ground water sampling stations associated with this sampling and analysis program. In addition, existing monitor well EPA02 was resurveyed for elevation. U.S. Army Corps of Engineers (CE) benchmarks GA-47 and GA-53 were used as the reference markers for horizontal control at WVOW. Vertical control was obtained from U.S. Coast and Geodetic Survey markers Q104 and R104 along State Route (SR) 62. Location and description of all temporary



SOURCE: ESE. 1987.

Figure 2.3-1 PHASE II OBSERVATION WELL CONSTRUCTION (OW32S)	WEST VIRGINIA ORDNANCE WORKS Supplemental Remedial Investigation Phase II Field Program

Table 2.3-1. Well Construction Materials

Material	Description/Brand	Source/Supplier
PVC Casing (Monitor Wells)	4.5-inch OD, Schedule 40, flush threaded	Diedrich Drilling Equipment, Inc., LaPorte, IN
PVC Screen (Monitor Wells)	4.5-inch OD, Schedule 40, flush threaded, 0.020-inch slot	Diedrich Drilling Equipment, Inc., LaPorte, IN
Stainless Steel Screen (Observation Well)	1.25-inch ID, Johnson Redhead®, stainless-steel drive point, wire wound, 0.010-inch slot	Johnson UOP, Inc., St. Paul, MN
Steel Casing (Observation Well)	1.0-inch ID, external couplings	Bowser-Morner Testing, Inc., Dayton, OH (locally obtained)
Bentonite (Powder)	Quik-gel® (western sodium bentonite)	NL Baroid, Houston, TX
Bentonite (Pellets)	Volclay® tablets (0.5-inch diameter)	American Colloid Company, Skokie, IL
Sand Pack	Best Sand, Grade 430	Best Sand Corporation, Chardon, OH
Cement	Portland® Type I, Lone Star Cement	Louisville Cement Co., Louisville, KY
Drilling Water	Glacial outwash (probable--no well log available)	"Doghouse" Well, located adjacent to a barracks-type building, 3,600 ft northwest of Ranger Station

Note: PVC = polyvinyl chloride.
OD = outside diameter.
ID = inside diameter.

Source: ESE, 1986a.

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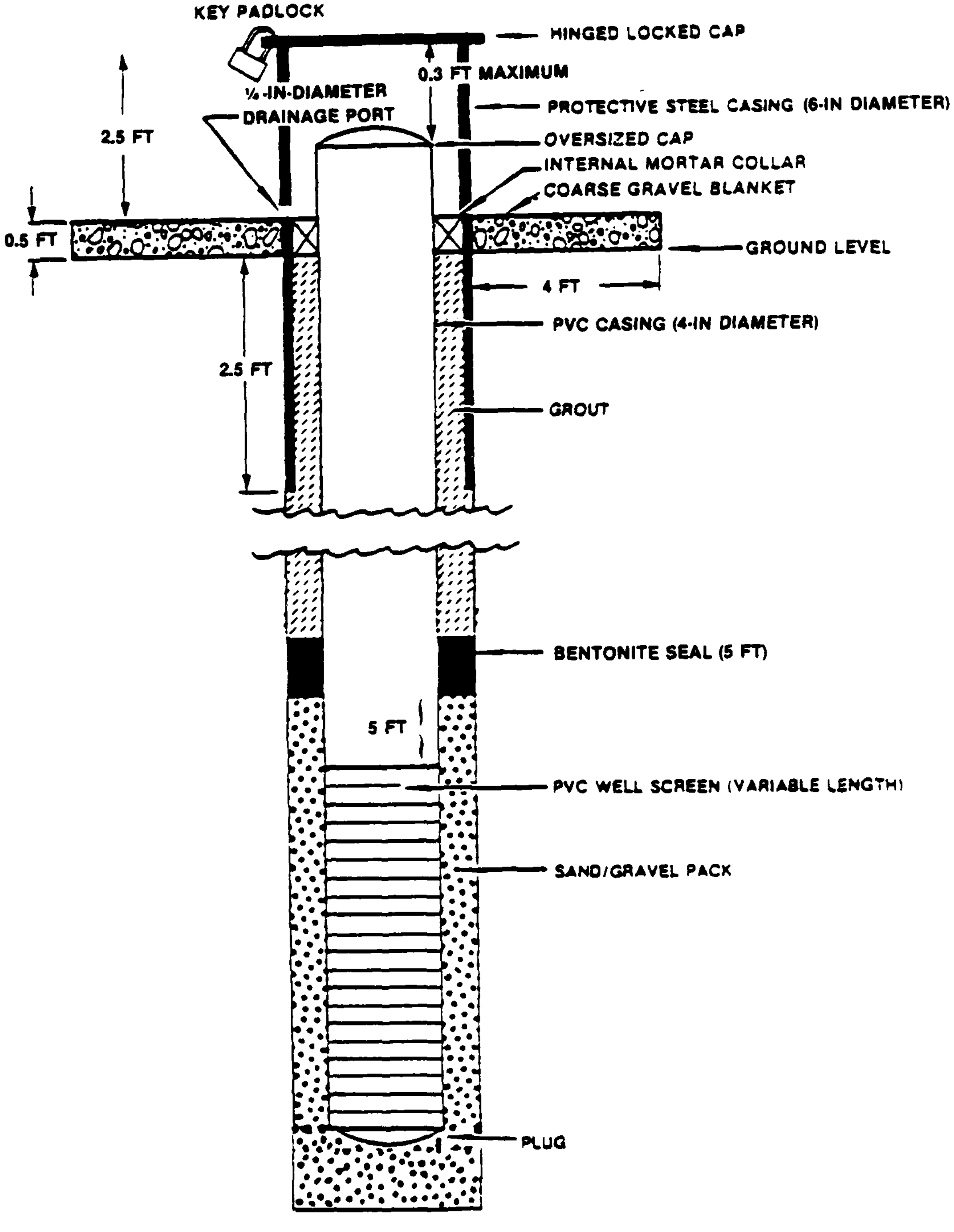

NOT TO SCALE

SOURCE: ESE, 1987.

Figure 2.3-2 TYPICAL MONITOR WELL CONSTRUCTION	WEST VIRGINIA ORDNANCE WORKS Supplemental Remedial Investigation Phase II Field Program

benchmarks are included in the surveyor's field notes. All surveying data were recorded in state planar coordinates. All survey calculations, map location and description of permanent benchmarks, and documentation of survey closure accuracy are contained in the surveyor's report (App. D).

2.4 GROUND WATER SAMPLE COLLECTION PROGRAM

The ground water sampling program consisted of sampling all new monitor wells and selected existing monitor wells in April 1986. An additional sampling program which focused on the deep monitor wells was conducted in August 1986. The locations of the wells sampled during Phase II are shown in Fig. 2.4-1. The August program included time-series sampling of GW27D and GW27 and routine sampling of additional shallow and deep monitor wells. With the exception of the time-series sampling, single-well sampling followed the procedures described in App. A, Sec. A.5 of the initial RI report (ESE, 1986d).

The time-series sampling program was initiated when low levels of nitroaromatics were detected in deep Monitor Wells GW27D, GW45D, and GW48D in the April 1986 samples. A similar situation had occurred in the initial 1984-85 field program, wherein GW36D (TNT Manufacturing Area) contained trace levels of 2,4,6-TNT. It was believed that the low levels of contaminants in GW36D had been carried from the contaminated shallow aquifer into the deep aquifer. Resampling of GW36D in April 1986 indicated that no detectable contamination was present in the deep aquifer at this location.

Resampling of the deep monitor wells was conducted in August 1986. In addition to the conventional sampling of GW45D, GW48D, and DGHW, time-series sampling was conducted at GW27D. Well GW27D was pumped continuously for 48 hours and was sampled at periodic time steps throughout the pumping. In this manner, successive pumped samples represent ground water quality at increasing distances from the pumped well (Keely and Wolf, 1983). The pattern of contaminant arrival, concentration, and duration provided data relevant to the presence, strength, and location of the contaminant source. In addition to GW27D, GW27 was sampled at similar time steps.

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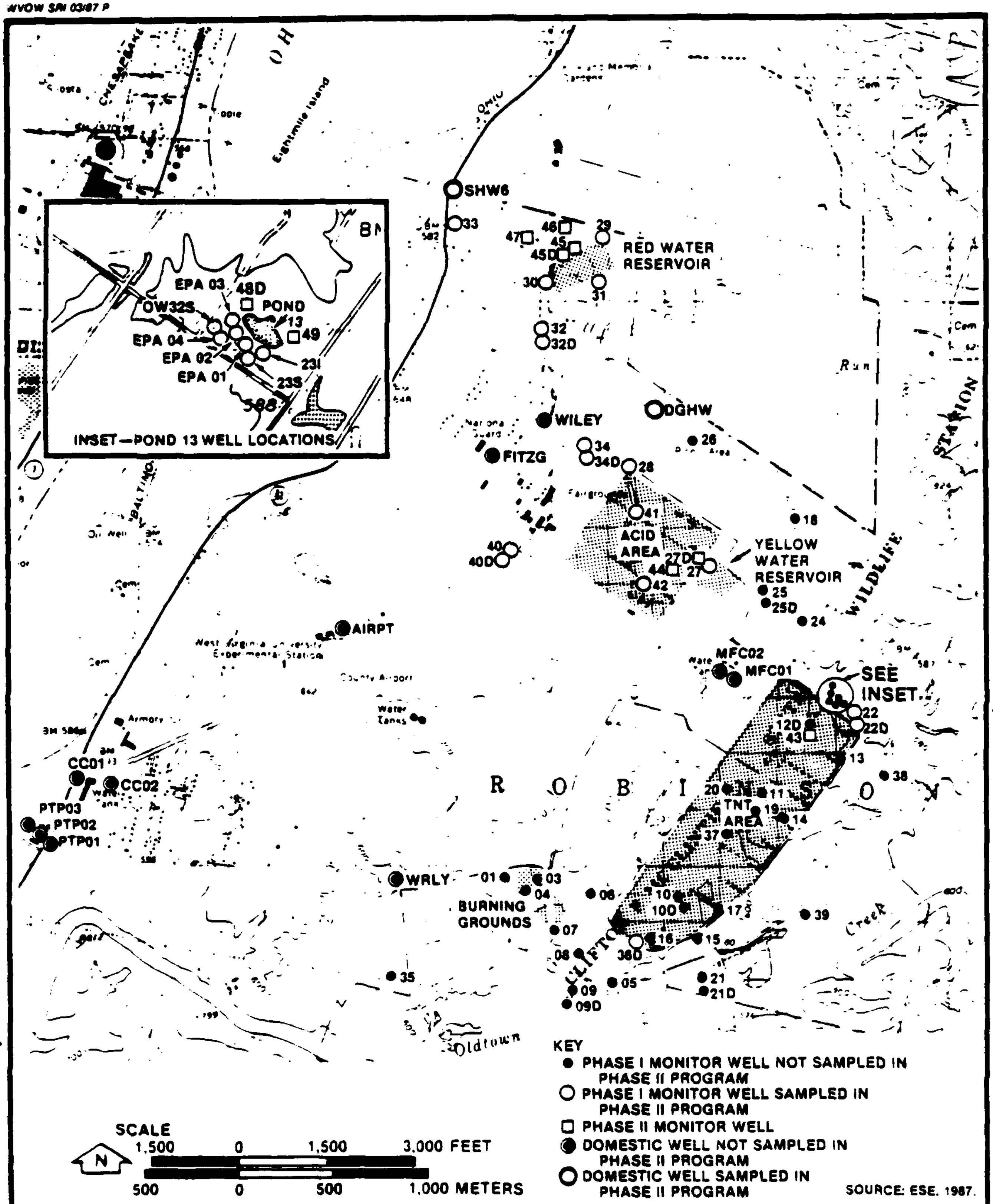

Figure 2.4-1
LOCATIONS OF WELLS SAMPLED DURING PHASE II

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During the time-series sampling, Well GW27D was pumped with a submersible pump; the pump intake was located approximately 4 ft above the bottom of the well. Periodically during the sampling, the pump was slowly raised while pumping to mix the water column in the well bore. Each sample was collected with a dedicated bottom-filling 2-inch diameter PVC bailer. The bailer was submerged approximately 5 to 10 ft in the water column for sample collection. The pump was running when samples were collected. Prior to initiation of pumping, a sample was collected in Wells GW27D and GW27. Since these wells had not been pumped, the water sample may not have been representative of true aquifer composition.

Summary in situ measurements regarding well sampling are shown in Table 2.4-1. Laboratory analysis methods followed the procedures described in App. D of the initial RI report (ESE, 1986d). Details of sample containers, sample volumes, and preservation techniques followed the procedures described in App. E of the initial RI report (ESE, 1986d).

The matrix of parameters analyzed in the ground water sampling program is shown in Table 2.4-2.

Table 2.4-1. Phase II Ground Water Sampling Summary

Well Designation	Parameter* pH	Conductivity (umho/cm)	Temperature (°C)	Well Purging Equipment+	Number of Well Volumes Removed**
April 1986 Sampling					
GW22	6.5	167	16.4	B	5.1
GW22D	6.6	154	15.3	B	5.4
GW23S	6.3	236	12.9	C	9.6
GW23I	5.8	133	13.7	C	5.1
GW27	5.3	126	14.0	C	6.1
GW27D	6.6	212	15.2	B	7.0
GW28	5.4	065	12.4	C	5.7
GW29	6.0	243	15.3	B	7.4
GW30	5.8	214	13.8	B	16.0
GW31	5.7	225	13.7	B	6.7
GW32	6.2	212	16.9	C	5.0
GW32D	6.8	196	12.0	B	6.6
GW33	6.7	606	12.3	A	5.1
GW34	5.3	430	14.8	C	7.2
GW34D	6.5	205	14.8	B	6.4
GW36D	6.9	226	13.5	B	6.0
GW40	5.0	207	13.8	B	5.4
GW40D	6.5	187	14.6	B	5.4
GW41	5.4	205	13.6	C	5.7
GW42	5.3	055	13.7	C	8.3
GW43	5.0	075	12.4	B	7.3
GW44	5.9	086	14.3	C	6.0
GW45	5.8	264	15.2	B	5.7
GW45D	8.0	287	15.3	B	5.4
GW46	6.3	286	15.2	B	8.4
GW47	6.1	401	13.8	B	13.3
GW48D	6.7	178	16.0	B	5.9
GW49	5.8	059	13.5	C	7.1
EPA01	6.4	188	20.2	C	5.4
EPA02	5.9	221	14.0	C	10.4
EPA03	6.6	184	12.2	A	5.7
EPA04	6.3	716	14.7	C	5.6
SHW6	7.3	500	16.6	B	5.4

Table 2.4-1. Phase II Ground Water Sampling Summary (Continued, Page 2 of 2)

Well Designation	Parameter* pH	Conductivity (umho/cm)	Temperature (^{o}C)	Well Purging Equipment+	Number of Well Volumes Removed**
August 1986 Sampling-Time Series Sampling: GW27D, GW27++					
GW27D-1	8.3	180	17.0	A	0.0
GW27D-2	8.0	201	18.0	B	1.0
GW27D-3	7.0	209	16.0	B	5.0
GW27D-4	7.3	215	15.5	B	4 hr***
GW27D-5	6.9	220	14.0	B	8 hr***
GW27D-6	9.1	265	16.0	B	24 hr***
GW27D-7	9.2	280	17.0	B	48 hr***
GW27-1	6.6	089	16.5	A	0.0
GW27-2	5.9	088	16.2	A	0.0
GW27-3	6.0	094	16.0	A	0.0
GW27-4	6.4	110	14.0	A	0.0
GW27-5	6.3	110	13.0	A	0.0
GW27-6	6.9	102	16.0	A	0.0
GW27-7	6.1	102	16.2	A	0.0
August 1986 Sampling--Single Well Sampling					
GW41	5.4	175	14.0	C	7.0
GW44	6.1	057	14.0	C	6.1
GW45	6.4	210	15.0	B	9.8
GW45D	8.1	232	16.0	B	5.4
GW47	6.5	291	16.0	B	7.1
GW48D	6.6	136	16.0	B	6.3
DGHW	6.8	250	16.5	D	5.2

*Measured at end of presampling purging.
+Well purging equipment:
A = dedicated PVC bailer.
B = 3-inch submersible pump.
C = 2-inch centrifugal pump.
D = permanent pump in well.
**Well volume--standing water in well casing plus saturated annulus (30-percent porosity).
++Pumping rate of GW27D was 8 to 9 gallons per minute; GW27 was not pumped. Note that subsamples 1 through 7 for GW27 were taken concurrently with subsamples 1 through 7 from GW27D.
***Refers to elapsed time of pumping GW27D during time-series sampling.

Note: umho/cm = micromhos per centimeter.
^{o}C = degrees Celsius.

Source: ESE, 1987.

Table 2.4-2. Ground Water Sample Analysis Schedule

Well Designation	Type of Chemical Analysis* April 1986	August 1986
GW22	A	--
GW22D	A	--
GW23S	A	--
GW23I	A	--
GW27	A	A
GW27D	A	A,B,C,D,E,F,G
GW28	A	--
GW29	A	--
GW30	A	--
GW31	A	--
GW32	A	--
GW32D	A	--
GW33	A	--
GW34	A	--
GW34D	A	--
GW36D	A	--
GW40	A	--
GW40D	A	--
GW41	A	A
GW42	A	--
GW43	A	--
GW44	A	A

Table 2.4-2. Ground Water Sample Analysis Schedule
(Continued, Page 2 of 2)

Well Designation	Type of Chemical Analysis* April 1986	August 1986
GW45	A	A
GW45D	A	A,B,C,D,E,F,G
GW46	A	--
GW47	A	A
GW48D	A	A,B,C,D,E,F,G
GW49	A	--
EPA01	A	--
EPA02	A	--
EPA03	A	--
EPA04	A	--
SHW6	A	--
DGHW	A	A,B,C,D,E,F,G

* A = Nitroaromatics [nitrobenzene, 1,3-dinitrobenzene (1,3-DNB), 1,3,5-TNB, 2,4-DNT, 2,6-dinitrotoluene (2,6-DNT), and 2,4,6-TNT].
B = Nitrite plus nitrate as nitrogen.
C = Total alkalinity.
D = Bicarbonate alkalinity.
E = Bicarbonate ion.
F = Carbonate alkalinity.
G = Carbonate ion.
-- = Not sampled.

Source: ESE, 1986a.

2.5 SEDIMENT SAMPLE COLLECTION PROGRAM

As stated in Sec. 2.1.1, six sediment samples were collected in the Red Water Reservoirs. Sediment samples were collected by using a stainless-steel bucket auger. Vertical composite samples were collected in each borehole at an interval below that which had been sampled in the initial RI field program. The purpose of the sampling was to provide additional data regarding the vertical distribution of nitroaromatics and to refine the contaminant source strength at Ponds 1 and 2. Sample handling, sample containers, volumes, and preservation techniques followed the procedures described in App. E of the initial RI report (ESE, 1986d). Sediment samples were analyzed for nitroaromatics as described in App. D of the initial RI report (ESE, 1986d).

3.0 GROUND WATER HYDROLOGY

3.1 REVIEW OF AREAWIDE HYDROGEOLOGY FOR THE ACIDS AREA/YELLOW WATER RESERVOIR, RED WATER RESERVOIRS, AND POND 13/WET WELL AREA--PHASE I SURVEY

3.1.1 AQUIFER CHARACTERISTICS

In the Phase I RI field program, a number of distinct hydrogeologic flow systems were characterized at WVOW. In the Acids Area/Yellow Water Reservoir, the shallow aquifer consists of a medium- to coarse-grained sand containing approximately 5- to 10-percent gravel. This sand is overlain by a silty clay layer varying in some areas to clay and ranging in thickness from approximately 10 to 15 ft. The sand aquifer is uniform in texture and gradation throughout the area. Two apparently discontinuous clay and silty clay layers were observed in monitor wells screened in the shallow aquifer beneath the Acids Area/Yellow Water Reservoir area. The clay layers do not form a continuous confining layer, and the sand aquifer exists in an unconfined or semiconfined state. In deep monitor wells drilled at the adjacent north and south powerhouses, a gray clay with textural and physical characteristics similar to the gray clay confining layer observed in the first operable unit (TNT Manufacturing Area and Burning Grounds Area) was encountered.

At the Red Water Reservoirs, surface sediment consists primarily of silty clay extending to a 10- to 15-ft depth. At two of the monitor wells, the clay is overlain by a medium-grained sand. A second sequence of clays and silty clays is present and varies in thickness from 2 ft at GW29 to 20 ft at GW32. As shown in the geologic cross section for the Red Water Reservoirs, a high degree of lithologic variation (both areally and vertically) is present at this area of concern. Sand and clay units are both generally discontinuous over this area of concern with the exception of one continuous water-bearing sand unit (the shallow alluvial aquifer) at elevation 580 feet above mean sea level (ft-MSL).

In addition to the wells drilled in the vicinity of the Red Water Reservoirs, five wells were drilled along the red water sewerline. In these wells, the top 2 to 5 ft of sediment consists of fine-grained materials, below which are fine- to coarse-grained sands. At one well pair, GW25 and GW25D, a silty fine sand was present from the surface elevation of 634 ft-MSL to elevation 606 ft-MSL. A silty clay confining layer occurred at elevation 591 ft-MSL. Below this clay, a second water-bearing sand unit occurred until the well was terminated at elevation 573.5 ft-MSL.

At the Pond 13/Wet Well Area, two markedly different hydrogeologic environments are present in the area surrounding Pond 13. At Pond 13, near-surface sediments consist of a thin veneer (5 to 10 ft) of sandy, silty clay underlain by a permeable, water-bearing shallow aquifer. At GW23I, the shallow aquifer is underlain by a thin clay layer, the areal extent of which is unknown. A second sand layer occurs below this clay layer; below this second sand layer, interbedded fine-grained sediments are present. In the lowermost portion of GW23I, the same gray clay as noted in the TNT Manufacturing Area was encountered, although the borehole extended only a short distance into the clay.

In contrast, the sediments encountered at nearby Wells GW22 and GW22D indicate a markedly different hydrogeologic environment. At these wells, the first permeable zone was not encountered until 526 ft-MSL, approximately 60 ft below ground surface. The gray clay confining layer is present beginning at 560-ft MSL and extending 25 ft in thickness. The distance between GW23I and GW22D is approximately 300 ft. The actual boundary between these two lithologic and hydrogeologic environments is not known.

The shallow aquifer at the Acids Area/Yellow Water Reservoir and the shallow aquifer along the red water sewerline are similar in lithologic and textural characteristics and represent similar depositional environments. At Pond 13, the physical characteristics of the shallow sand aquifer in the immediate vicinity of the pond are similar to the TNT Manufacturing Area shallow aquifer; however, the hydrogeologic environment changes abruptly to an extensive clay deposit at ground surface at GW22.

In the deep monitor wells drilled throughout the site, the majority of wells were screened in sediments of alluvial origin (e.g., GW25D and GW12D). Several wells such as GW21D and GW32D encountered glacial outwash material. According to published information (Wilmoth, 1966), the glacial outwash aquifer represents a single, continuous aquifer system. However, given the limited number of wells which penetrated the glacial outwash aquifer throughout the site during the Phase I investigation, it was not possible to verify this information.

3.1.2 GROUND WATER/SURFACE WATER INTERACTION

The interaction of ground water flow systems with surface water flow throughout the site was assessed in the initial RI survey by the use of a stream gaging program coupled with information obtained from selected monitor wells installed adjacent to surface water drainage flow systems. For those areas on the site with adjacent surface water gaging stations and monitor wells, comparison was made between surface water station elevations (from staff gage data) and the first permeable layer encountered during monitor well drilling. These data are presented in Table 3.1-1. For comparison purposes, surface water station elevations from measurements collected on Oct. 16, 1984; Jan. 7, 1985; Mar. 11, 1985; and Apr. 22, 1986, are included. These data show that the range of surface water elevations varies less than 3 ft throughout the study.

The extensive surficial clay deposits found in the southern portions of the site are not present in the northern portion; however, surface water elevations at stations MC1, MC5, P2, P3, and P13 are identical to or lower than the elevations of the first permeable layer encountered in the adjacent monitor wells. However, during the October 1984 gaging, no flow

Table 3.1-1. Comparison of Surface Water Station Elevations and Elevations of First Permeable Layer Encountered in Adjacent Monitor Wells

Area of Concern	Surface Station Identification	Elevation of Surface Water (ft-MSL) 10/16/84	01/07/85	03/11/85	04/22/86	Adjacent Monitor Well	Elevation of Permeable Layer (ft-MSL)	ΔX*
Red Water Reservoirs	MC1	568.5	568.4	568.9	566.0	GW33	576.0	-7
Red Water Reservoirs	MC2	581.9	582.1	582.7	582.3	GW32	564.2	+17
Acids Area/ Yellow Water Reservoir	MC5	596.1	596.5	596.5	596.4	GW28	595.8	0
Red Water Reservoirs	P1	602.2	603.0	603.2	602.4	GW30	591.8	+10
Red Water Reservoirs	P2	599.9	600.7	600.8	601.0	GW31	606.9	-7
Pond 13/ Wet Well Area	P13	586.5	588.4	588.8	588.9	GW23S/ GW23I	586.4/ 585.2	0

*ΔX = (surface water station elevation) - (elevation of first permeable layer encountered in monitor well construction).

Sources: ESE, 1986a, d.

was occurring at Station MC5 (Acids Area); therefore, baseflow into this system was negligible at this station although an interconnection between MC5 and the permeable layer encountered at GW28 would be expected based on elevation comparisons with GW28. No flow was observed downstream at MC3. At the Red Water Reservoirs, the water-table elevation at GW31 (adjacent to P2) during a high-flow period was 18 ft below the elevation of surface water at P2. At Pond 13, surface water levels were coincident with the observed water levels at Wells GW23S and GW23I.

The hydrologic interconnection present from the intersection of surface drainage with the permeable strata at these portions of the site suggests that, as ground water elevations increase, a significant ground water component should be present in flows observed in Mill Creek.

In most ponds at the site, ground water discharge into the ponds or recharge by the ponds into the ground water is also substantially minimized by the presence of extensive clay deposits in the pond bottoms. Sediment grab samples (approximately 6 to 8 inches in depth) and sediment core samples (1 to 3 ft in depth) in the ponds consisted primarily of stiff clay with a thin, overlying layer of decomposed, organic, detrital material. In many cases, field observations indicated that the bottom portion of even the shallow (6- to 8-inch) core ranged in moisture content from dry to slightly moist, whereas sediments in the top 1 to 2 inches of the core were wet. During the October 1984 gaging, no surface water outflow was occurring from any of the ponds. Because of the lack of interconnection with the ground water, the potential for input to or output from the ponds is generally small. However, rising ground water levels and surface runoff during a wet season greatly increase the potential for ground water discharge to the northern ponds.

In the northern portions of WVOW, the Mill Creek flow system receives ground water discharged during high-flow conditions. The Mill Creek stations are downstream from both a treatment plant and Pond 16. Pond 16 is located immediately upgradient of the Red Water Reservoirs. The results of the Phase I RI study indicate that Pond 16, through leakage, recharges the shallow aquifer at the Red Water Reservoirs.

3.2 OVERVIEW OF METHODOLOGY AND AQUIFER CHARACTERISTICS EMPLOYED IN THE PHASE II SURVEY

The purpose of the hydrogeological assessment was to characterize the ground water flow system(s) at each area of concern to identify characteristics relevant to the definition of contaminant migration pathways. The overall objectives of the hydrogeologic program by area of concern are presented in Sec. 1.1.

The hydrogeologic analysis is presented on an area-by-area basis for the areas of concern at WVOW. In each subsection, results of the geotechnical program are presented to characterize the individual aquifers present at each area of concern, describe aquifer properties, and assess contaminant migration pathways.

For an overall perspective of the monitoring network installed at WVOW, the locations of observation wells are shown in Fig. 3.2-1, and the locations of monitor wells installed by ESE and EPA and municipal/domestic supply wells are shown in Fig. 3.2-2. To identify aquifers present at each area of concern, the data produced during the drilling program were used to prepare geologic cross sections for each area of concern. The locations of the geologic cross sections for the overall project area are shown on Fig. 3.2-3. Well construction summaries for each of the monitor wells are shown in Table 3.2-1.

Water-level measurements were taken for all observation wells and monitor wells throughout the study for determination of hydraulic gradients. Ground water elevation data are summarized in Tables 3.2-2 and 3.2-3.

Various methods of aquifer testing were employed in the Phase I study to determine aquifer characteristics at each area of concern. The aquifer testing program encompassed all areas at WVOW. Since the Phase I data base provided sufficient data at the Acids Area/Yellow Water Reservoir, Red Water Reservoir, and Pond 13/Wet Well Area, additional aquifer

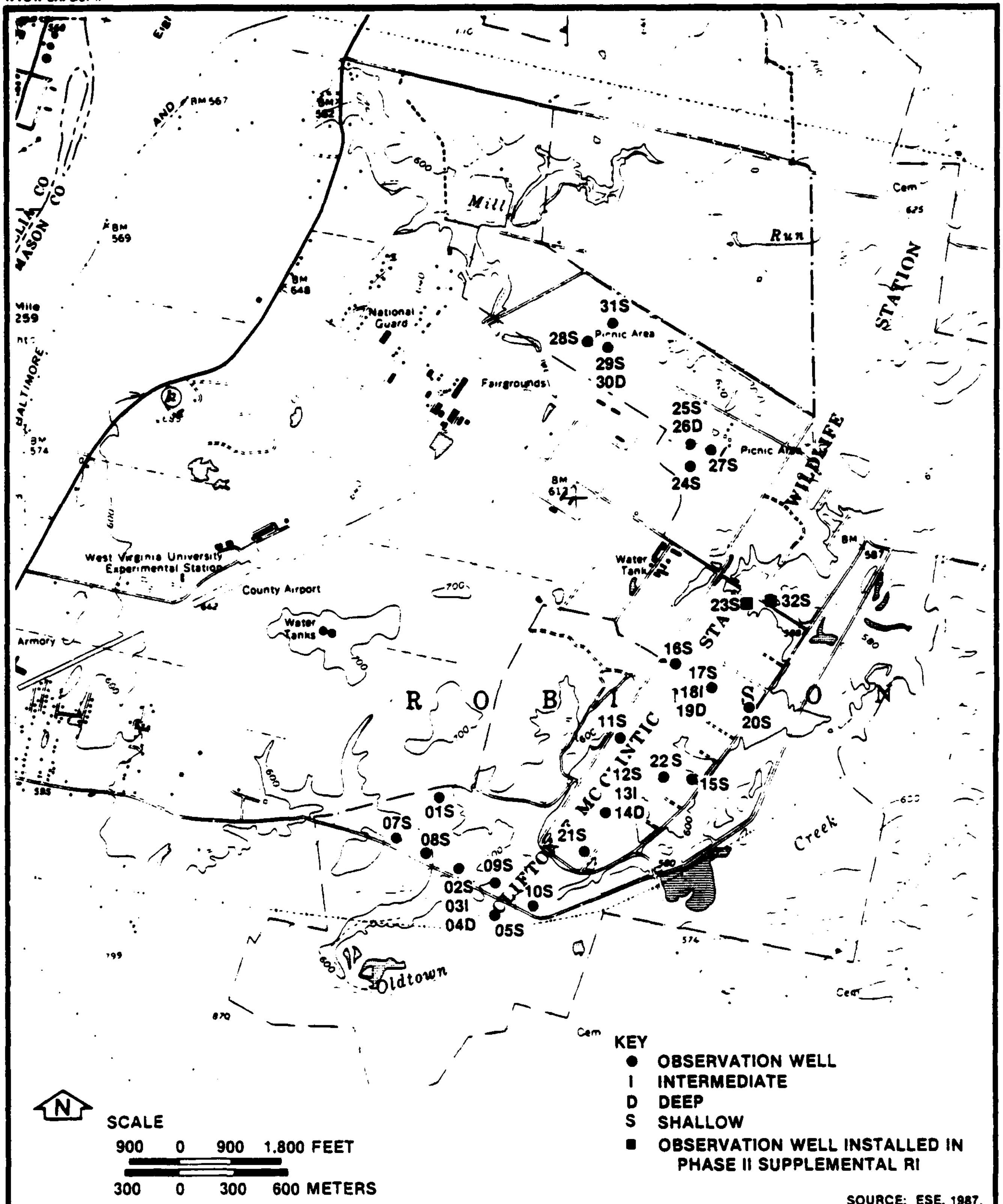

Figure 3.2-1 **LOCATIONS OF WATER-LEVEL OBSERVATION WELLS**	**WEST VIRGINIA ORDNANCE WORKS** Supplemental Remedial Investigation Phase II Field Program

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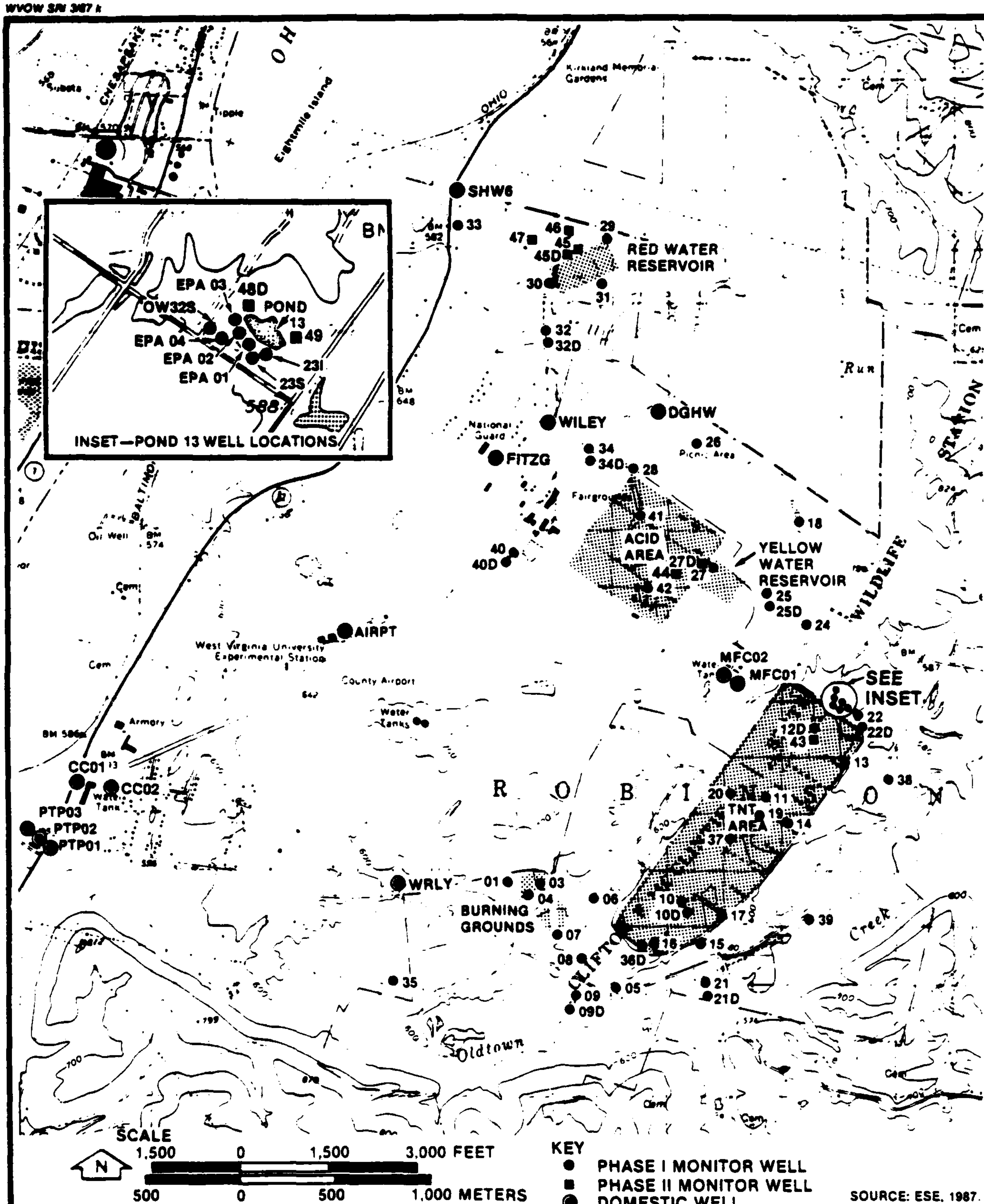

Figure 3.2-2
LOCATIONS OF MONITOR WELLS, EPA WELLS, AND OFFSITE DOMESTIC WELLS

WEST VIRGINIA
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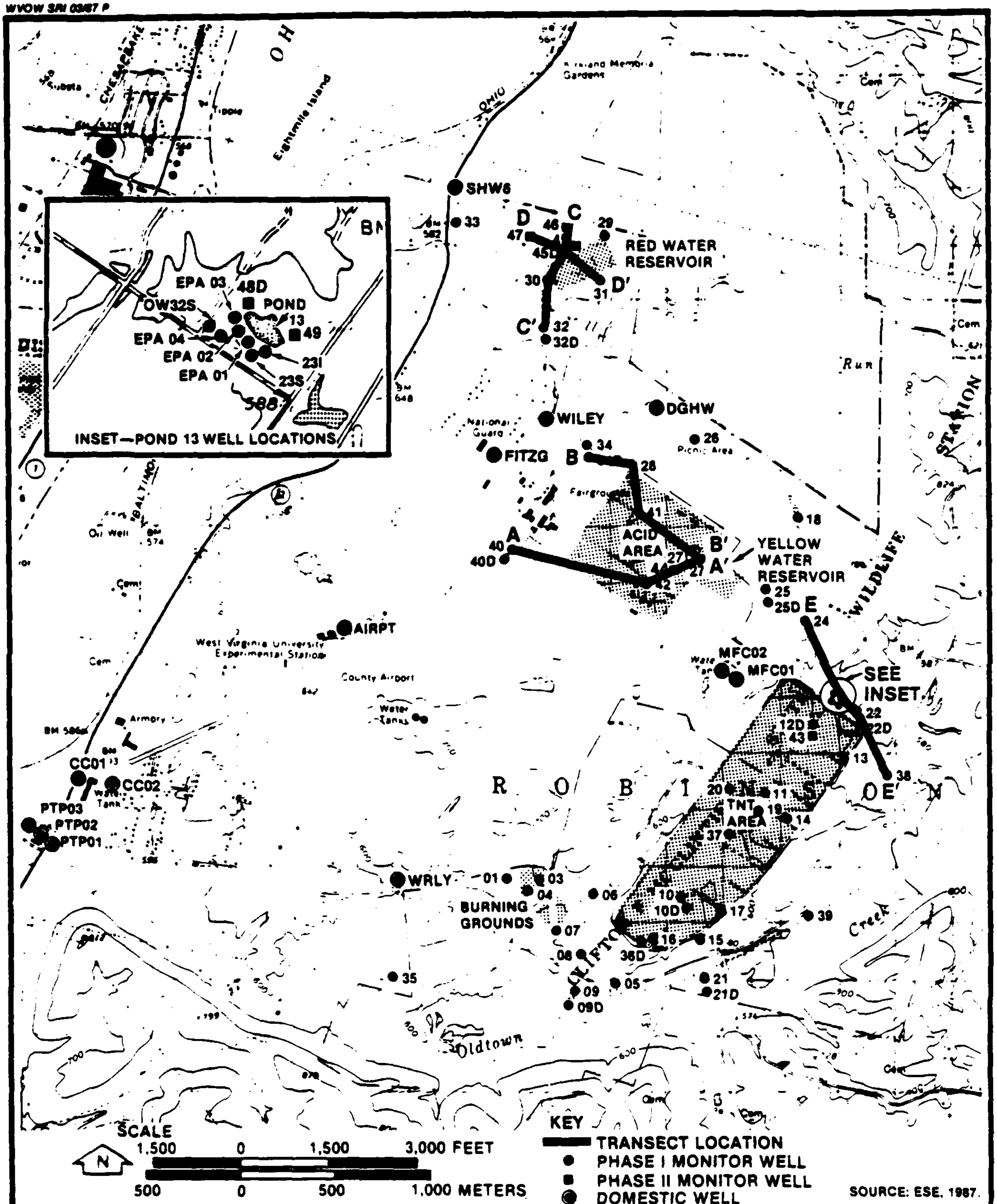

Figure 3.2-3
GEOLOGIC CROSS-SECTION INDEX MAP

WEST VIRGINIA
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Table 3.2-1. Monitor Well Construction—Phase I and Phase II

Well Designation	Installation Date*	Total Borehole Depth	Depth of Casing and Screen	Screened Interval	Filter Pack Interval	Bentonite Interval	Type of Drilling Rig†
Phase I Monitor Wells							
GW1	10/24-10/25	91.5	89.70	74.7-89.7	69-90	64-69	C
GW3	10/25-10/25	28.5	28.5	13.35-28.35	9-28.5	4-9	C
GW4	10/21-10/22	46.5	46.5	31.5-46.5	26.5-46.5	21.5-26.5	C
GW5	11/26-11/27	67.0	66.98	51.98-66.48	46-67	41-46	C
GW6	11/06-11/07	45.0	43.8	28.8-43.8	23-45	17.5-23	C
GW7	10/29-10/31	87.0	87.0	72-87	64-87	58-64	C
GW8	10/29-10/29	30.5	29.2	14.2-29.2	9-30.5	5-9	C
GW9	10/27-10/27	35.0	34.2	19.2-34.2	14-35	9-14	C
GW9D	10/26-10/27	82.7	82.7	67.7-82.7	61.5-82.7	56.5-61.5	C
GW10	10/16-10/16	31.55	31.55	16.55-31.55	11.25-31.55	6.25-11.25	C
GW10D	10/15-10/16	90.0	89.85	74.85-89.85	70-90	65-70	C
GW11	10/17-10/17	37.5	37.0	22-37	15-37	10-15	C
GW12D	10/19-10/21	95.0	94.45	79.45-94.45	75-95	70-75	C
GW13	10/21-10/22	46.0	40.0	25-40	20-40	15-20	A
GW14	10/19-10/19	32.5	32.40	17.4-32.4	12.4-32.4	7.4-12.4	C
GW15	11/13-11/14	24.0	24.0	14.0-24.0	8.5-24.0	3-8.5	A
GW16	10/24-10/24	24.5	15.3	10.3-15.3	5.5-24.5	2.3-5.5	A
GW17	10/24-10/24	28.0	27.0	12.0-27.0	7-28	2-7	A
GW18	11/15-11/15	15.5	14.0	4.0-14.0	3-15.5	1-3	A
GW19	10/18-10/18	32.0	31.5	16.5-31.5	11.5-32	6.5-11.5	C
GW20	10/18-10/18	37.8	37.8	22.8-37.8	17.8-37.8	11.8-17.8	C
GW21	10/25-10/25	27.0	25.7	15.7-25.7	10.7-27	5.7-10.7	A
GW21D	11/07-11/08	60.0	59.7	44.7-59.7	40-60	35-40	C
GW22	10/13-10/14	70.6	70.6	55.6-70.6	50-70.6	45-50	C
GW22D	10/08-10/12	106	105.75	90.75-105.75	85.75-105.75	80.75-85.75	C
GW23S	10/30-10/30	16.0	14.5	4.5-14.5	3-16	1-3	A
GW23I	10/30-10/31	29.5	24.5	9.5-24.5	4.5-29.5	1.5-4.5	A
GW24	11/01-11/01	24.5	24.0	9-24	5-24.5	1-5	A
GW25	11/11-11/11	29.0	29.0	14-29	9-29	4-9	C
GW25D	11/08-11/11	60.5	60.0	45-60	39-60	33-39	C
GW26	11/02-11/02	24.5	23.0	13-23	8-23	3-8	A
GW27	10/20-10/21	40.0	38.5	23.5-38.5	15.5-40	10.5-15.5	A
GW28	11/02-11/02	24.5	24.0	9-24	5-24.5	1-5	A
GW29	10/16-10/17	49.0	45.4	30.4-45.4	25.4-49	20.4-25.4	A
GW30	10/18-10/18	41.0	35.5	25.5-35.5	20.5-41	15.5-20.5	A
GW31	10/17-10/18	47.0	46.5	26.5-46.5	21.5-47.0	16.5-21.5	A
GW32	10/19-10/20	41.0	38.0	23-38	15-41	10-15	A
GW32D	11/29-11/30	66.0	66.0	51-66	46-66	41-46	C
GW33	12/01-12/01	25.0	22.5	7.5-22.5	6-25	4-6	C

Table 3.2-1. Monitor Well Construction—Phase I and Phase II (Continued, Page 2 of 2)

Well Designation	Installation Date*	Total Borehole Depth	Depth of Casing and Screen	Screened Interval	Filter Pack Interval	Bentonite Interval	Type of Drilling Rig†
Phase I Monitor Wells (Continued)							
GW34	11/14-11/14	34.5	34.5	14.5-34.5	8.5-34.5	3-8.5	A
GW34D	11/12-11/14	114	114	99-114	87-114	82-87	C
GW35	10/31-11/01	44.5	44.5	29.5-44.5	24.5-44.5	19.5-24.5	A
GW36D	11/27-11/29	92.8	92.8	77.8-92.8	72-92.8	67-72	C
GW37	11/12-11/13	35.0	32.5	22.5-32.5	17-32.5	11-17	A
GW38	11/05-11/06	36.0	32.5	17.5-32.5	12-36	7-12	A
GW39	11/06-11/07	32.0	30.0	10-30	7.5-32	2.5-7.5	A
GW40	11/16-11/16	38.5	37.3	22.3-37.3	16.5-38.5	11-16.5	A
GW40D	11/16-11/17	90.5	90.5	70.5-90.5	65-90.5	60-65	C
GW41	11/03-11/03	27.0	26.0	11-26	6-27	1.5-6	A
GW42	11/08-11/08	25.0	24.3	9.3-24.3	5-25	1-5	A
Phase II Monitor Wells							
GW27D	3/30-4/1	104.0	102.5	87.5-102.5	81-104	76-81	C
GW43	3/12-3/12	35.5	35.0	20-35	14.7-35.5	9.7-14.7	C
GW44	4/2-4/2	36.5	35.0	20-35	15-36.5	10-15	C
GW45	3/16-3/17	56.5	55.0	40-55	32-56.5	26-32	C
GW45D	3/13-3/16	106.5	106.0	91-106	83.5-106.5	77.5-83.5	C
GW46	3/17-3/18	56.5	55.0	40-55	34-56.5	28-34	C
GW47	4/2-4/3	65.0	64.0	49-64	44-65	39-44	C
GW48D	3/21-3/23	110.0	107.0	87-107	81-110	76-81	C
GW49	3/18-3/19	36.5	34.0	19-34	13.5-36.5	8-13.5	C

Note: All measurements are feet from ground surface.

*Phase I monitor wells were installed in 1984; Phase II wells in 1986.
†Type of drilling rig:
A = hollow-stem auger, and
C = cable tool.

Sources: ESE, 1986a, d.

Table 3.2-2. Ground Water Levels for Monitor Wells—Phase I and Phase II

Well Designation	Ground Water Elevations (ft-MSL) Before Development	After Development (24-hour)	01/07/85*	03/11/85	4/22/86*	08/11/86†
Phase I Monitor Wells						
GW1	568.90	568.33	570.27	586.07**	570.12	††
GW3	586.18	587.32	586.47	589.50	589.26	††
GW4	587.46	587.26	589.25	589.84	589.49	††
GW5	573.20	573.92	574.67	574.80	574.39	††
GW6	574.85	574.25	576.09	576.67	576.77	††
GW7	566.97	565.87	568.04	568.03	567.80	††
GW8	574.74	575.40	576.85	579.11	579.43	††
GW9	564.08	565.08	566.69	567.28	567.00	††
GW9D	566.18	565.63	567.71	568.16	567.72	††
GW10	595.34	595.69	595.36	595.96	595.59	††
GW10D	585.26	585.93	586.27	586.37	585.87	††
GW11	595.85	595.90	595.88	596.06	595.87	††
GW12D	589.43	589.33	590.61	591.00	590.29	††
GW13	594.38	590.88*	592.70	592.70	592.66	††
GW14	594.43	593.93	594.38	594.64	594.64	††
GW15	593.47	593.17	593.61	593.98	594.01	††
GW16	593.89	593.49*	594.30	594.49	594.51	††
GW17	592.54	592.42	593.03	593.33	593.28	††
GW18	614.09	614.31	615.19	615.60	615.12	††
GW19	595.73	595.74	595.73	595.79	595.64	††
GW20	596.37	596.39	596.58	596.90	597.64	††
GW21	565.92	564.15	571.26	571.61	571.55	††
GW21D	Flowing	Flowing	580.76	††	579.20	††
GW22	587.43	587.57	588.47	588.38	587.97	††
GW22D	Flowing	Flowing	589.35	††	589.20	††
GW23S	588.08	587.96	588.66	588.76	588.59	††
GW23I	588.56	588.82	589.18	589.42	588.98	††
GW24	615.68	615.68	616.38	617.58	617.49	††
GW25	616.33	616.13	616.88	617.56	617.88	††
GW25D	597.15	596.65	598.30	597.92	597.80	††
GW26	612.78	612.80	613.71	615.56	615.66	††
GW27	597.15	597.04	597.34	597.53	597.29	596.83
GW28	595.84	595.78	596.80	597.23	596.64	595.91
GW29	576.07	576.07	575.23	575.93	577.27	576.80
GW30	581.86	581.86	581.41	581.97	582.54	582.21
GW31	582.28	582.28	582.78	584.29	585.28	583.26
GW32	579.81	579.51	580.66	581.37	582.41	581.30
GW32D	576.79	577.39	577.86	578.55	579.54	578.64

Table 3.2-2. Ground Water Levels for Monitor Wells—Phase I and Phase II (Continued, Page 2 of 2)

	Ground Water Elevations (ft-MSL)					
Well Designation	Before Development	After Development (24-hour)	01/07/85*	03/11/85	4/22/86*	08/11/86†
Phase I Monitor Wells (Continued)						
GW33	568.59	569.59	569.79	569.02	568.59	567.66
GW34	594.13	594.93	595.03	595.32	594.78	594.31
GW34D	587.03	583.33	586.78	586.99	588.38	587.07
GW35	564.11	563.46	565.83	565.06	564.84	††
GW36D	574.84	575.23	576.13	576.24	575.87	††
GW37	594.76	595.31	595.56	592.22	595.62	††
GW38	580.19	581.92	581.74	580.92	581.47	††
GW39	578.41	577.66	578.31	578.25	577.90	††
GW40	595.12	594.72	595.72	595.78	595.32	595.02
GW40D	594.61	593.51	594.63	594.62	594.28	593.91
GW41	581.50	581.42	596.86	597.13	596.57	596.05
GW42	593.82	596.16	596.54	596.64	596.37	596.06
EPA01	†††	†††	588.42	588.58	588.64	††
EPA02	†††	†††	585.68	585.86	588.64	††
EPA03	†††	†††	588.90	587.83	588.67	††
EPA04	†††	†††	589.11	588.18	588.63	††
Phase II Monitor Wells						
GW43	595.02	594.97	††	††	594.85	††
GW44	596.98	596.94	††	††	596.92	596.37
GW45	571.90	571.88	††	††	572.10	572.14
GW45D	567.74	567.63	††	††	569.09	567.88
GW46	567.61	567.56	††	††	567.81	567.99
GW47	562.85	562.35	††	††	564.00	563.11
GW48D	589.47	589.45	††	††	590.47	††
GW49	589.56	589.41	††	††	589.46	††
GW27D	595.82	595.78	††	††	596.62	596.10

*Stabilized ground water circuit.
†Wells GS29, GW30, GW31, GW32, GW32D, GW45D, GW46, GW47 measured on 8/14/86.
**Probable measurement error.
††Not measured.
***Not a 24-hour measurement.
†††Existing wells, not developed.

Sources: ESE, 1986a, d.

Table 3.2-3. Ground Water Levels for Observation Wells—Phase I and Phase II

Well Designation	Ground Water Elevation (ft-MSL)					
	10/10/84	10/25/84	11/18/84	01/07/85*	03/11/85	04/22/86*
OW01S	596.23	595.93	596.83	596.70	596.91	597.19
OW02S	593.20	592.46	593.17	603.66	604.24	600.44
OW03I	569.14	568.94	569.62	573.69	575.40	571.78
OW04D	566.19	566.05	566.39	567.09	568.08	567.00
OW05S	565.95	565.91	566.34	569.10	567.27	568.24
OW07S	590.21	590.22	590.17	589.43	588.39	589.49
OW08S	590.92	590.81	590.85	596.26	598.30	596.52
OW09S	574.65	574.35	574.74	577.09	578.95	578.64
OW10S	570.89	571.08	571.65	573.36	573.35	572.83
OW11S	596.85†	605.78**	596.59	596.42	596.66	596.42
OW12S	596.06	586.91	589.52	591.16	592.59	592.18
OW13I	595.01	594.92	594.83	594.56	595.17	594.67
OW14D	583.20**	596.07	597.25	595.75	596.01	595.80
OW15S	593.74	593.70	593.65	593.65	594.26	593.84
OW16S	597.30†	597.21	597.04	596.80	597.49	596.76
OW17S	595.71†	595.64	595.49	595.41	595.97	595.41
OW18I	595.93†	595.79	595.73	595.48	595.73	595.46
OW19D	595.54†	595.09	595.05	594.80	594.98	595.84
OW20S	594.59	594.53	594.48	594.32	594.47	594.49
OW21S	594.36	594.24	594.40	594.45	595.17	594.66
OW22S	595.17†	595.14	595.73	594.87	594.98	595.14
OW23S	592.72	592.71	592.91	592.94	593.16	592.69
OW24S	616.87	616.82	††	617.03	617.70	617.98
OW25S	616.37	616.97	††	616.27	616.98	617.42
OW26D	597.77	597.66	††	597.74	597.96	600.79
OW27S	617.19	617.01	††	617.09	617.76	618.14
OW28S	596.90	596.80	††	597.25	597.09	597.40
OW29S	612.76	612.66	††	613.16	614.45	614.58
OW30D	597.03	596.87	††	597.23	597.62	597.48
OW31S	613.46	613.32	††	613.81	616.10	615.76
OW32S***	††	††	††	††	††	586.99

*Stabilized ground water circuit.
†Taken October 11, 1984.
**Probable measurement error.
††Not measured.
***Phase II observation well.

Sources: ESE, 1986a, d.

testing was not conducted during the Phase II supplemental RI field program. The following paragraphs describe the methods employed in the Phase I survey to derive aquifer characteristics.

Hydraulic conductivity was assessed for each area by employing slug tests and falling-head permeability tests and by using Hazen's rule. Data obtained from slug tests of selected shallow and deep wells throughout the site were analyzed using an ESE-developed, computer-assisted data management program to tabulate and plot data and calculate hydraulic conductivity using methodology described in Hvorslev (1951) and in Bouwer and Rice (1976). Calculated values for hydraulic conductivity are shown in Table 3.2-4.

In addition to the slug tests, alternative methods of calculating hydraulic conductivity were employed for comparison purposes. For 10 of the 20 wells evaluated by slug tests, composite sediment samples were obtained during drilling from the screened interval for each well. The composite samples were analyzed for moisture content, grain-size distribution, and falling-head permeability. Three trials of falling-head permeability values were arithmetically averaged for hydraulic conductivity. Individual values for the tests and average values (arithmetic means) are shown in Table 3.2-5. Grain-size distribution was determined by sieve analysis; from the grain-size distribution plot, hydraulic conductivity estimates were determined using Hazen's rule (Hazen, 1892). Hazen's method is applicable for uniformly graded sands and is essentially an empirical relationship which is based on the following power-law relation between conductivity and soil texture:

Table 3.2-4. Sediment Hydraulic Conductivity Properties

Well Designation	Hydraulic Conductivity (ft/sec) — Slug Tests: I = Slug In, O = Slug Out	Slug Tests: Bouwer and Rice Method	Slug Tests: Hvorslev Method	Permeameter Test*	Hazen's Rule†	Moisture Content (percent of dry weight)
GW04	I	1.8×10^{-5}	2.5×10^{-5}	—	—	—
	O	1.5×10^{-5}	2.2×10^{-5}	—	—	—
GW06	I	1.4×10^{-5}	1.8×10^{-5}	—	—	—
	O	1.0×10^{-5}	1.5×10^{-5}	—	—	—
GW10	I	1.2×10^{-4}	5.8×10^{-4}	2.8×10^{-5}	1.2×10^{-4}	22.5
	O	2.7×10^{-4}	4.6×10^{-4}	—	—	—
GW10D	I	7.8×10^{-6}	1.0×10^{-5}	2.3×10^{-5}	5.2×10^{-5}	21.4
	O	7.8×10^{-6}	9.3×10^{-6}	—	—	—
GW15	I	1.1×10^{-4}	3.1×10^{-4}	2.0×10^{-4}	4.6×10^{-4}	22.9
	O	8.0×10^{-5}	1.1×10^{-4}	—	—	—
GW16	I	1.0×10^{-4}	1.8×10^{-4}	—	—	—
	O	1.1×10^{-4}	1.8×10^{-4}	—	—	—
GW19	I	1.7×10^{-4}	3.3×10^{-4}	5.6×10^{-5}	2.7×10^{-4}	26.9
	O	1.9×10^{-3}	2.5×10^{-3}	—	—	—
GW23I	I	2.4×10^{-5}	4.4×10^{-5}	1.6×10^{-7}	—	24.8
	O	2.3×10^{-5}	3.8×10^{-5}	—	—	—
GW25	I	1.0×10^{-4}	2.3×10^{-4}	1.2×10^{-4}	4.0×10^{-4}	24.5
	O	1.5×10^{-4}	1.8×10^{-4}	—	—	—
GW25D	I	2.7×10^{-4}	3.1×10^{-4}	7.9×10^{-5}	7.2×10^{-4}	28.7
	O	1.0×10^{-4}	1.4×10^{-4}	—	—	—
GW26	I	1.9×10^{-4}	3.1×10^{-4}	—	—	—
	O	2.2×10^{-4}	3.0×10^{-4}	—	—	—
GW27	I	3.7×10^{-4}	3.8×10^{-4}	3.3×10^{-5}	2.8×10^{-4}	24.8
	O	2.6×10^{-4}	3.5×10^{-4}	—	—	—
GW30	I	1.3×10^{-4}	3.0×10^{-4}	2.9×10^{-4}	7.2×10^{-4}	23.5
	O	1.6×10^{-4}	2.2×10^{-4}	—	—	—

Table 3.2-4. Sediment Hydraulic Conductivity Properties (Continued, Page 2 of 2)

Well Designation	Hydraulic Conductivity (ft/sec)					Moisture Content (percent of dry weight)
	Slug Tests					
	I = Slug In, O = Slug Out	Bouwer and Rice Method	Hvorslev Method	Permeameter Test*	Hazen's Rule†	
GW32	I	6.9×10^{-6}	1.0×10^{-5}	—	—	—
	O	3.9×10^{-6}	5.7×10^{-6}	—	—	—
GW32D	I	1.9×10^{-5}	3.9×10^{-5}	—	—	—
	O	1.7×10^{-5}	2.4×10^{-5}	—	—	—
GW34	I	9.1×10^{-5}	3.9×10^{-5}	—	—	—
	O	9.3×10^{-5}	1.4×10^{-4}	—	—	—
GW34D	I	5.3×10^{-6}	5.1×10^{-6}	—	—	—
	O	3.9×10^{-6}	4.0×10^{-6}	—	—	—
GW36D	I	3.6×10^{-5}	4.9×10^{-5}	—	—	—
	O	3.2×10^{-5}	4.0×10^{-5}	—	—	—
GW37	I	4.0×10^{-6}	6.1×10^{-6}	1.7×10^{-4}	1.0×10^{-3}	23.3
	O	4.5×10^{-6}	6.3×10^{-6}	—	—	—
GW41	I	2.6×10^{-4}	4.6×10^{-4}	—	—	—
	O	3.0×10^{-4}	5.1×10^{-4}	—	—	—

Note: — = Not analyzed.

*Falling-head permeability test [U.S. Army Engineer Waterways Experiment Station (WES), 1970]. Average of 3 trials except for GW15 (average of 4 trials).

†Hydraulic conductivity $K = Ad_{10}^2$, where: A = 1.0 when K is in centimeters per second (cm/sec) and d_{10} is in millimeters (mm); values converted to feet per second (ft/sec) (Freeze and Cherry, 1979).

Source: ESE, 1987.

Table 3.2-5. Physical Analysis of Aquifer Sediments*

Well Designation	Moisture Content: Percent of Dry Weight†	Moisture Content: Percent of Total Weight	Permeability (cm/sec)†: Trial 1	Trial 2	Trial 3	Average
GW10	22.5	18.4	9.0×10^{-4}	8.3×10^{-4}	8.6×10^{-4}	8.6×10^{-4}
GW10D	21.4	17.6	7.3×10^{-4}	7.0×10^{-4}	6.9×10^{-4}	7.1×10^{-4}
GW15**	22.9	18.6	7.7×10^{-3}	5.8×10^{-3}	5.0×10^{-3}	6.1×10^{-3}
GW19	26.9	21.2	1.2×10^{-3}	1.9×10^{-3}	1.9×10^{-3}	1.7×10^{-3}
GW23I	24.8	19.8	3.5×10^{-6}	5.6×10^{-6}	5.2×10^{-6}	4.8×10^{-6}
GW25	24.5	19.7	3.8×10^{-3}	3.5×10^{-3}	3.3×10^{-3}	3.5×10^{-3}
GW25D	28.7	22.3	2.1×10^{-3}	2.6×10^{-3}	2.4×10^{-3}	2.4×10^{-3}
GW27	24.8	19.9	9.1×10^{-4}	1.1×10^{-3}	1.0×10^{-3}	1.0×10^{-3}
GW30	23.5	19.0	8.6×10^{-3}	8.8×10^{-3}	9.7×10^{-3}	9.0×10^{-3}
GW37	23.3	18.9	4.7×10^{-3}	5.7×10^{-3}	5.5×10^{-3}	5.3×10^{-3}

*Composite sample of sediment from the screened interval for each well obtained during drilling.
†Methodology for moisture content and falling-head permeability test from U.S. Army Engineer WES, 1970.
**For GW15, four trials were conducted, and the permeability for the fourth trial was 6.0×10^{-3}.

Source: ESE, 1986d.

$$K = Ad_{10}^2$$

where: K = hydraulic conductivity (cm/sec);

A = coefficient, equal to 1.0 when K is in centimeters per second and d is in millimeters; and

d_{10} = grain-size diameter (mm) at which 10 percent by weight of the soil particles are finer and 90 percent are coarser.

Hazen's approximation provides a rough estimate of hydraulic conductivity which can be used to confirm other methods of analysis (Freeze and Cherry, 1979). Hydraulic conductivity values obtained by this method are included in Table 3.2-4.

The physical analysis program also included moisture-content analysis. Methodology followed procedures described in U.S. Army Engineer Manual 1110-2-1906 (1970). The moisture-content values obtained are listed in Table 3.2-5; values for moisture content by dry weight can be used as an estimate of aquifer porosity (Fetter, 1980). For the purposes of the RI, moisture content values were employed in ground water flow rate calculations and were assumed to be equivalent to aquifer effective porosity.

The various methods described resulted in reliable estimates of hydraulic conductivity and porosity of aquifer materials which can be employed in contaminant migration rate calculations. The values obtained are measurements of aquifer properties in the immediate vicinity of the well bore (in the case of slug tests) or are values obtained from analysis of material from individual boreholes (physical analysis program). As such, the aquifer parameters obtained do not necessarily reflect areawide aquifer properties and should be considered accurate only to within one order of magnitude. As noted by Bouwer (1978), "...it is not uncommon to find that replicate tasks in seemingly uniform material yield K values that differ by an order of magnitude, especially if the material has a low permeability."

3.3 ACIDS AREA/YELLOW WATER RESERVOIR

3.3.1 REVIEW OF PHASE I RI RESULTS

As determined in the Phase I RI study, a single shallow sand aquifer under unconfined, or possibly semi-confined, conditions is present in this study area. The presence of the gray clay in this area could not be determined because no deep wells were drilled in the immediate vicinity of the Acids Area/Yellow Water Reservoir. In addition, the Phase I contamination assessment determined that the shallow aquifer in the vicinity of Wells GW27 and GW41 was contaminated by low levels of nitroaromatics. The nearest downgradient shallow aquifer well, GW42, was uncontaminated; however, the downgradient extent of shallow aquifer contamination could not be verified.

3.3.2 PHASE II RESULTS

To better define the horizontal extent of shallow aquifer ground water contamination, the Phase II investigation in this area included the installation of one additional shallow monitor well, GW44. As shown in Fig. 3.2-2, this well was located approximately midway between the contaminated shallow well, GW27, and the nearest uncontaminated shallow downgradient well, GW42. In addition, Well GW27D was drilled adjacent to Well GW27 at the Yellow Water Reservoir to verify the presence and thickness of the gray clay layer and to monitor ground water quality in the deep aquifer below the previously documented contamination in the shallow aquifer. It should be noted that Well GW27D was originally sited as 44D to avoid drilling through a high-risk area. However, due to problems with access, the well was relocated and the well designation was changed to 27D.

Based on the information obtained during drilling of GW27D and GW44, two geologic cross sections were prepared. As shown in the geologic cross-section index map for the Acids Area/Yellow Water Reservoir (Fig. 3.3-1), cross section A-A' extends approximately west-east, and cross section B-B' extends approximately northwest-southeast. These cross sections are shown in Fig. 3.3-2 and Fig. 3.3-3, respectively.

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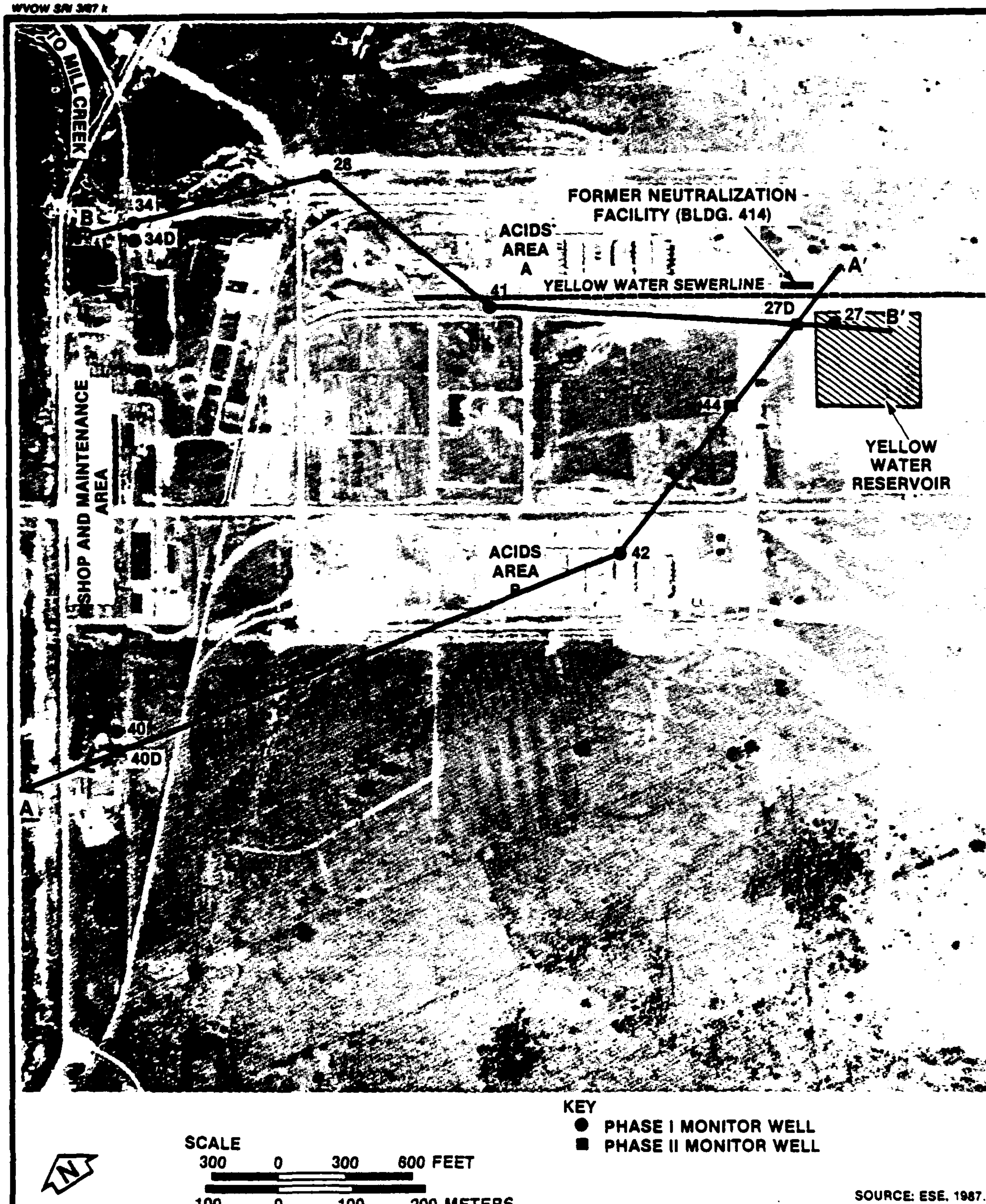

Figure 3.3-1
GEOLOGIC CROSS-SECTION LOCATIONS IN THE ACIDS AREA/YELLOW WATER RESERVOIR

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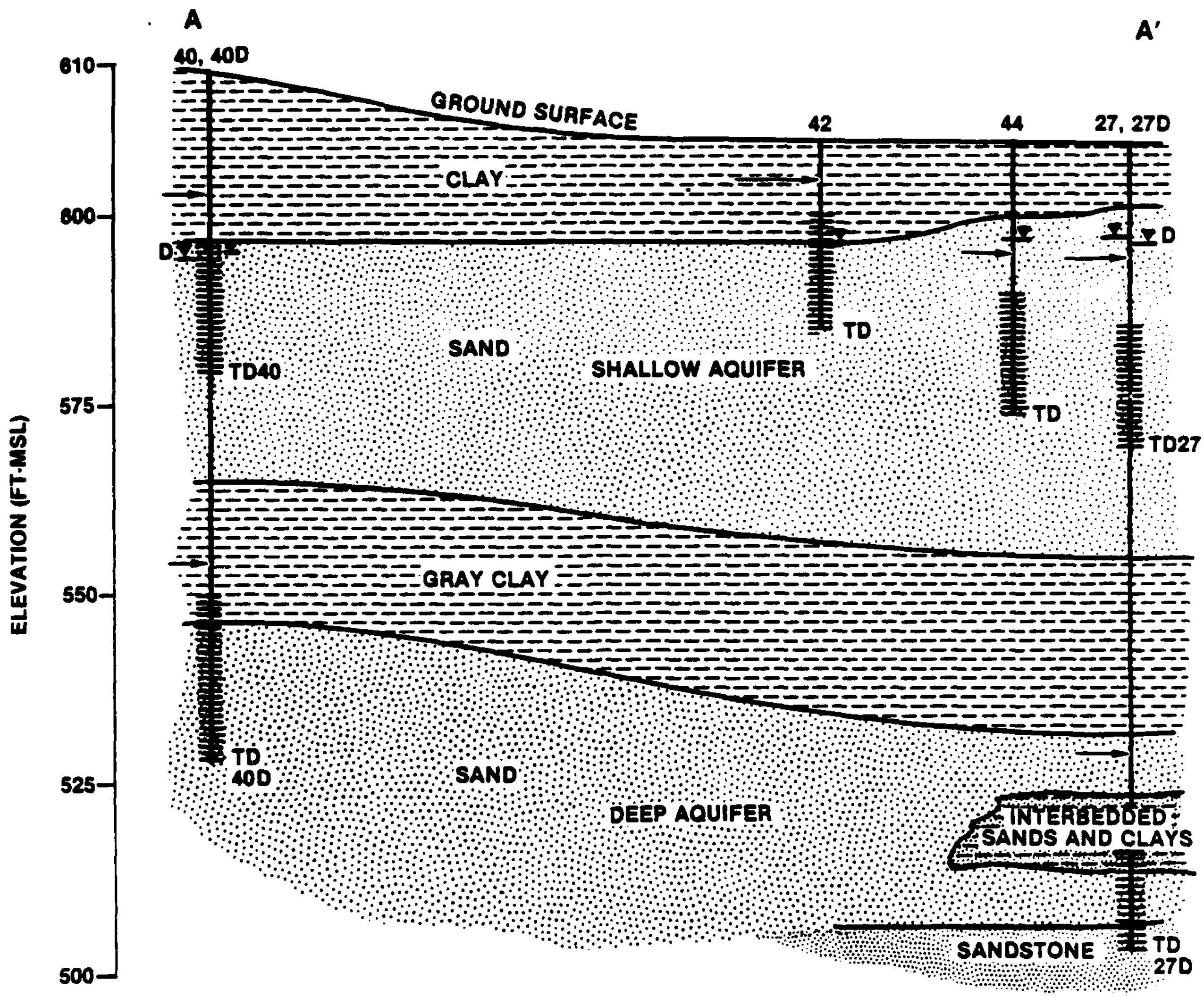

KEY

WATER LEVEL 4/22/86

D WATER LEVEL DEEP AQUIFER 4/22/86

BOTTOM OF BENTONITE SEAL

WELL CASING

SCREEN

TD TOTAL DEPTH OF BOREHOLE

SOURCE: ESE, 1987.

Figure 3.3-2
GEOLOGIC CROSS-SECTION A - A',
ACIDS AREA/YELLOW WATER RESERVOIR

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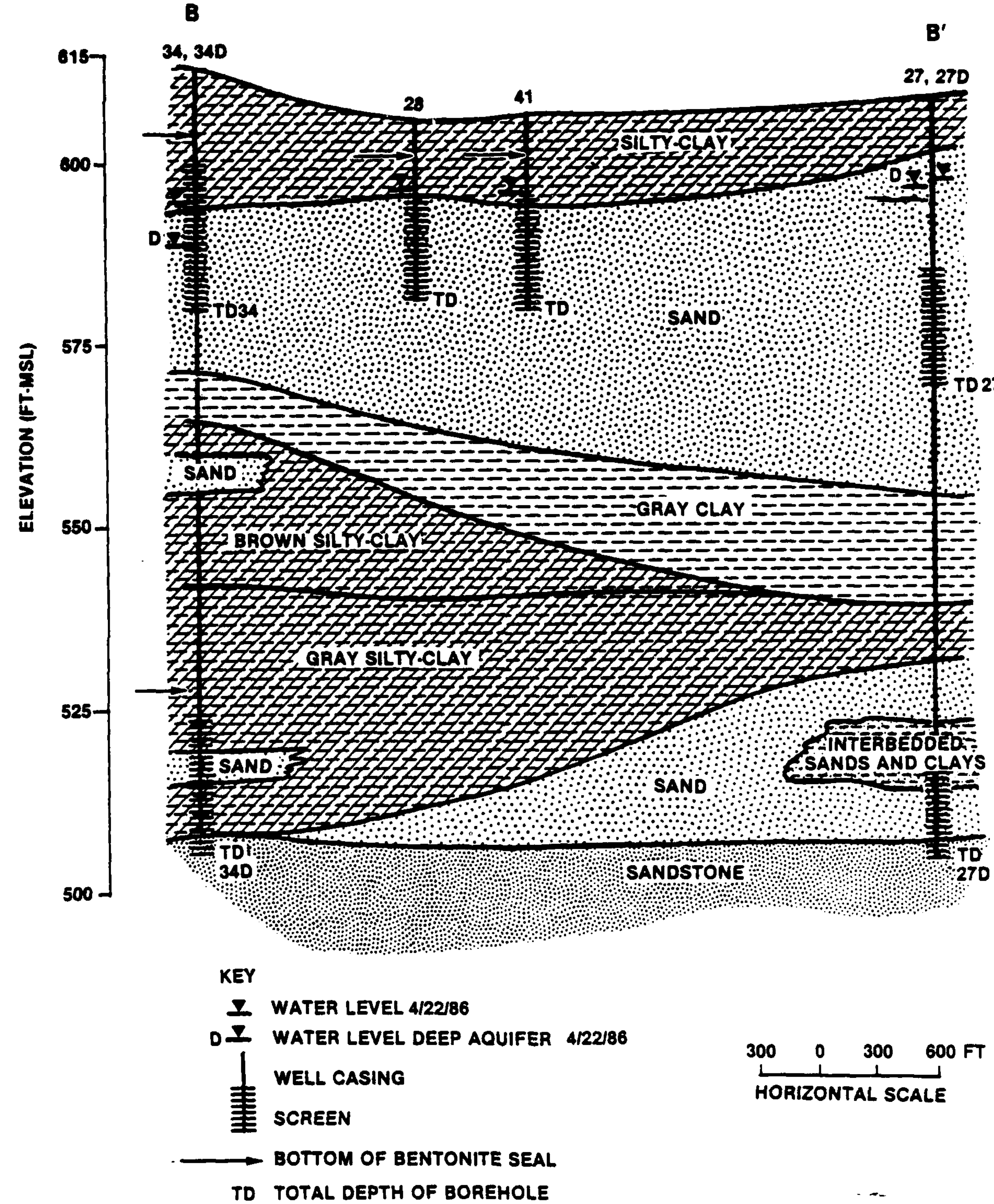

SOURCE: ESE, 1987.

Figure 3.3-3
GEOLOGIC CROSS–SECTION B - B',
ACIDS AREA/YELLOW WATER RESERVOIR

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GW44 is completed in the shallow aquifer. The physical characteristics of the shallow aquifer at GW44 were similar to those encountered at the remaining shallow monitor wells. These shallow sand aquifers are uniform in texture and gradation throughout this area and represent a continuous unconfined, or possibly semiconfined, aquifer.

Below the shallow sand aquifer at GW27D, a stiff gray clay, similar in textural and physical characteristics to the gray clay confining layer seen elsewhere at WVOW, was encountered at elevation 556 ft-MSL. The gray clay extends to elevation 533 ft-MSL, consistent with the thickness observed at the nearby powerhouses in Wells GW34D and GW40D. From elevations 533 to 507 ft-MSL, a deep aquifer primarily of sand with occasional interbedded clay lenses was encountered. At depth, this aquifer consists of typical glacial outwash sediments. At elevations 507 to 506 ft-MSL, bedrock was encountered, consisting of sandstone. The bottom of Well G /D was situated at 506 ft-MSL.

Ground water level data collected during both phases of the RI survey for monitor wells in the Acids Area/Yellow Water Reservoir are presented in Table 3.2-2. During the Phase II investigation, water levels were measured on Apr. 22, 1986, and Aug. 11, 1986. For the purpose of this discussion, ground water levels measured on Apr. 22, 1986, will be employed for ground water movement calculations. Fig. 3.3-4 and Fig. 3.3-5 represent 2-dimensional plots showing ground water contours measured on Apr. 22, 1986, and Aug. 11, 1986, respectively. The data indicate that ground water flow is primarily to the west in the Acids Area/Yellow Water Reservoir, consistent with conditions observed in the Phase I investigation.

The approximate horizontal ground water flow rate can be calculated using the data and the aquifer values in the Phase I studies by employing the ground water flow equation:

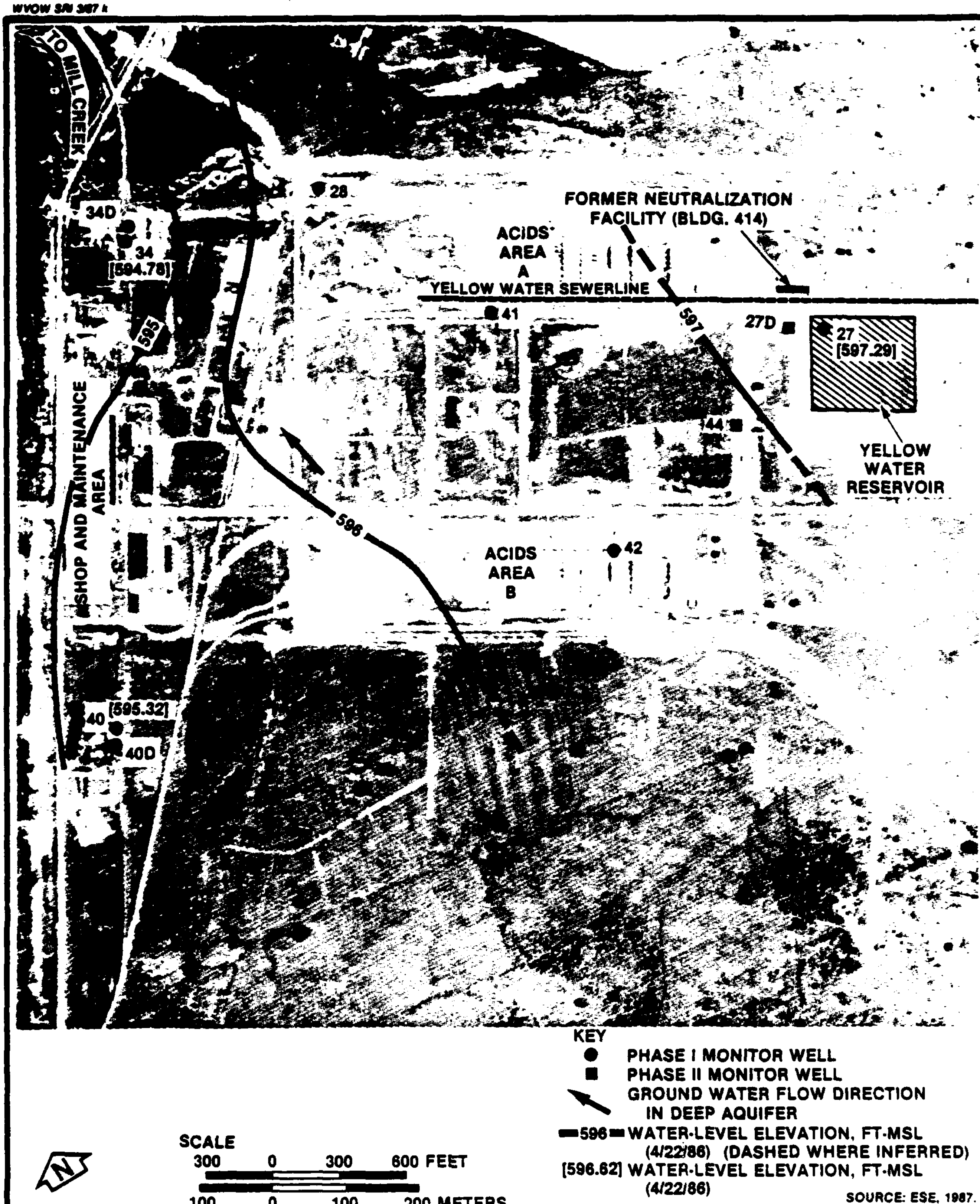

Figure 3.3-4 WATER-LEVEL CONTOURS, SHALLOW AQUIFER, ACIDS AREA/YELLOW WATER RESERVOIR — APRIL 22, 1986	WEST VIRGINIA ORDNANCE WORKS Supplemental Remedial Investigation Phase II Field Program

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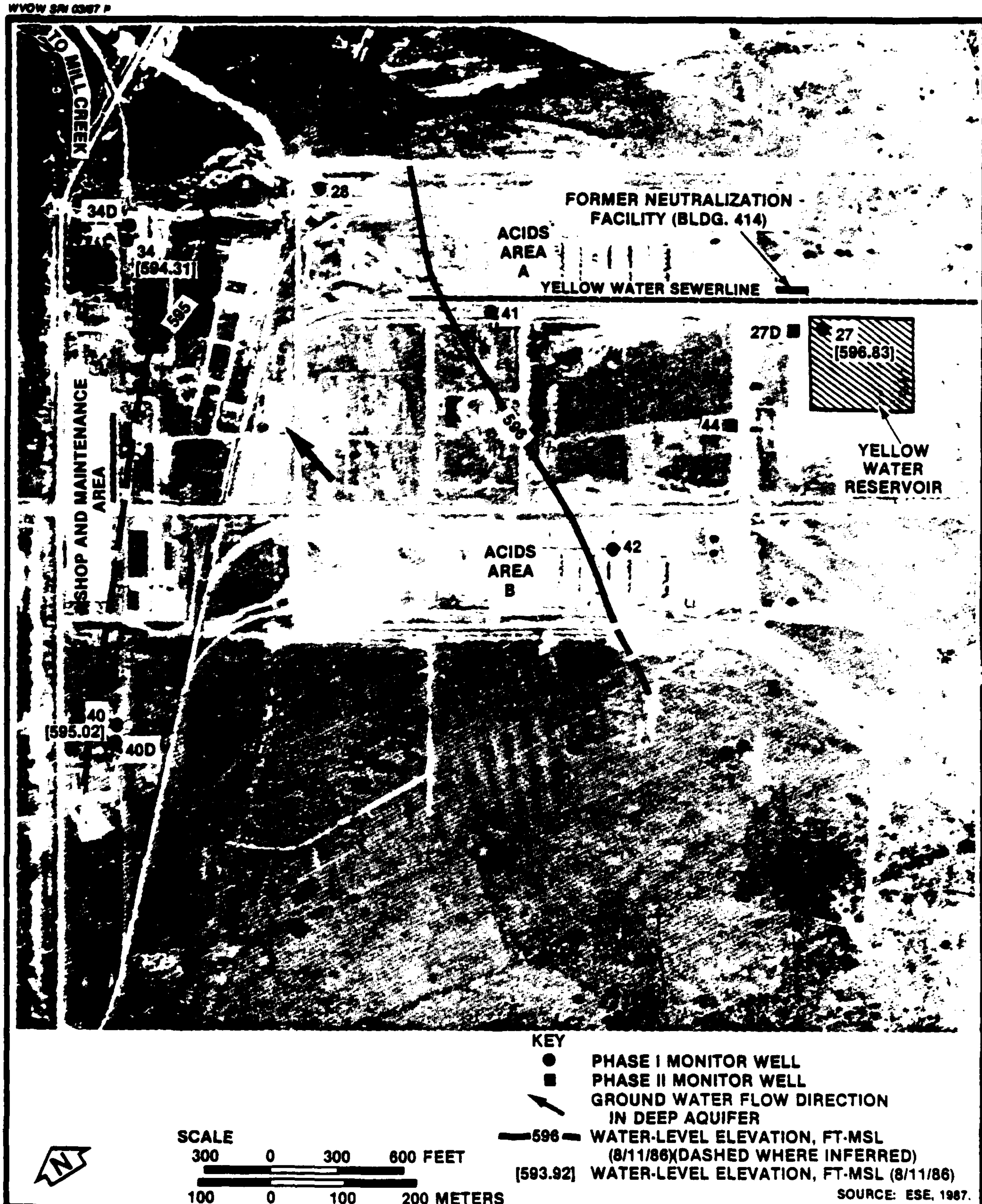

Figure 3.3-5
WATER-LEVEL CONTOURS, SHALLOW AQUIFER, ACIDS AREA/YELLOW WATER RESERVOIR — AUGUST 11, 1986

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$$V = \frac{K}{n} \times i$$

where: V = ground water flow rate (ft/sec),
K = hydraulic conductivity (ft/sec),
n = effective porosity (dimensionless), and
i = hydraulic gradient in feet per foot (ft/ft).

$$= \frac{5 \times 10^{-4} \text{ ft/sec}}{0.25} \; (5.8 \times 10^{-4} \text{ ft/ft})$$

$$= 1.2 \times 10^{-6} \text{ ft/sec}$$

$$= 0.1 \text{ foot per day (ft/day)}$$

The water levels measured on Apr. 22, 1986, correspond to a hydraulic gradient (i) of 1 ft/1,740 ft for 5.8×10^{-4} ft/ft. Ground water velocity is calculated at 0.1 ft/day, which is the same rate of horizontal ground water flow observed in the Phase I study.

A vertical gradient for the Acids Area/Yellow Water Reservoir can be estimated by utilizing the head relationship observed at the well pair GW27 and GW27D. In this case, the hydraulic gradient employed is taken as the head difference of the well pair divided by the distance between the midpoints of the respective saturated filter packs. The water levels observed on Apr. 22, 1986, were used in this calculation. The water level observed in GW27 on Apr. 22, 1986, was 0.67 ft higher than that observed in Well GW27D. The corresponding downward vertical gradient, therefore, is 0.67 ft/63.74 ft, or approximately 0.01. Vertical permeability through the gray clay layer was not directly calculated; it should be noted that the stratigraphic interval between these two aquifers consists of the gray clay confining layer which is 23 ft thick and would be expected to have a very low K value. If a value of 1×10^{-7} ft/sec and an effective porosity value of 0.50 are assumed for the clay, vertical flow rate would be calculated as follows:

$$V = \frac{K}{n} \times i$$

$$= \frac{1 \times 10^{-7}\ \text{ft/sec}}{0.50}\ (0.01\ \text{ft/ft})$$

$$= 2.0 \times 10^{-9}\ \text{ft/sec}$$

$$= 1.7 \times 10^{-4}\ \text{ft/day}$$

It can be concluded that a minimal vertical flow potential exists in the Acids Area/Yellow Water Reservoir. Furthermore, given the physical characteristics of the gray clay and its apparent continuity throughout the site, it is concluded that the clay acts as an effective barrier for vertical migration and should preclude any contamination of the shallow aquifer from migrating to the deep aquifer.

Horizontal ground water flow in the deep aquifer in the vicinity of the Acids Area/Yellow Water Reservoir has been determined using the water levels measured on Apr. 22, 1986, at Wells GW27D, GW34D, and GW40D. Since the ground water flow direction has been determined by analysis of water levels at only three observation points, a ground water contour map has not been prepared. The direction of ground water flow based on this analysis is north-northwest; the flow direction is indicated by the arrow shown in Fig. 3.3-4.

The approximate horizontal ground water flow rate in the deep aquifer can be calculated using the water levels of Apr. 22, 1986, coupled with aquifer values from the Phase I investigation. Since the three water-level measurements essentially define a plane, an estimated gradient was established based on the water-level elevations. The ground water flow equation would be applied as follows:

$$V = \frac{K}{n} \times i$$

$$= \frac{4.6 \times 10^{-6} \text{ ft/sec}}{0.25} \ (3.8 \times 10^{-3} \text{ ft/ft})$$

$$= 7.0 \times 10^{-8} \text{ ft/sec}$$

$$= 6.0 \times 10^{-3} \text{ ft/day}$$

3.4 RED WATER RESERVOIRS

3.4.1 REVIEW OF PHASE I RI RESULTS

In the Phase I survey, the geologic setting of the Red Water Reservoirs area was defined using lithologic information obtained from three wells located adjacent to the reservoirs (GW29, GW30, and GW31), a well pair located south-southwest of the reservoirs along Mill Creek (GW32 and GW32D), and one well located west of the reservoirs where Mill Creek crosses SR 62 (GW33). A shallow aquifer is present at the Red Water Reservoirs consisting of a medium to coarse sand, which is overlain by silty clay surficial sediments. At GW30, GW31, and GW32D, the shallow aquifer was underlain by the gray clay confining layer. The thickness of the clay was 13 ft at GW32D.

The Phase I survey established the general hydrogeologic setting in the vicinity of the Red Water Reservoirs. General direction and rate of horizontal ground water flow in the shallow aquifer were determined. However, the Phase I monitor well network was installed on the assumption that shallow ground water flow was to the southwest toward Mill Creek. Ground water flow defined in the Phase I survey indicated that shallow ground water flow direction was to the northwest toward SR 62 and the Ohio River. Given this direction of ground water flow, no shallow monitor wells were present downgradient of the reservoirs. Ground water flow rate and direction were defined only for the immediate vicinity of the reservoirs, since no monitor wells were located at a substantial distance downgradient (northwest). In addition, no deep monitor wells were installed at the Red Water Reservoirs to define the vertical hydraulic head relationships or to verify the presence and thickness of the gray clay confining layer.

3.4.2 PHASE II RESULTS

To address the data gaps at the Red Water Reservoirs, a comprehensive Phase II hydrogeologic program was implemented in this study area. Three shallow monitor wells (GW45, GW46, and GW47) were installed downgradient of the Red Water Reservoirs (see Fig. 3.2-2). To determine shallow aquifer water quality and to provide water-level data, GW46 and GW47 were installed at the McClintic Wildlife Station property boundary. In addition, a well pair (GW45, GW45D) was installed immediately downgradient and adjacent to the Red Water Reservoirs. Well GW45 was completed in the shallow sand aquifer to assess water quality immediately downgradient of the reservoirs and to determine water levels in order to refine ground water flow direction and rate. Well GW45D was installed adjacent to GW45 and was completed in the deep aquifer to monitor water quality in the potable aquifer, verify the presence and thickness of the gray clay layer, and determine the vertical hydraulic gradient.

In addition to monitor well installation, additional sediment samples were collected in Pond 1 and Pond 2. The purpose of the sediment samples was to supplement the vertical contaminant distribution obtained during the Phase I survey as well as to provide further information on the integrity of the clay liners in both ponds. The sediment data are discussed in Sec. 4.2 of this report.

The shallow monitor wells (GW45, GW46, and GW47) confirmed that the shallow sand aquifer present in the Phase I monitor wells extends downgradient of the reservoirs. At Well GW47, located approximately 500 ft downgradient of the Red Water Reservoirs, the gray clay confining layer was encountered in the last 0.5 ft drilled. The gray clay confining layer at GW45D was encountered at elevation 556 ft-MSL. The gray clay layer extended to an elevation of 533 ft-MSL, a thickness of 23 ft at the Red Water Reservoirs. Below the gray clay layer, sand and gravel sediments extended to the total depth of the borehole (507 ft-MSL). The lower aquifer present in this vicinity consists of glacial outwash materials consistent in appearance with the glacial outwash observed at several other deep monitor wells at WVOW.

Fig. 3.4-1 shows the locations of the geologic cross sections in the Red Water Reservoirs area, and Figs. 3.4-2 and 3.4-3 consist of general geologic cross sections of the Red Water Reservoirs area. As shown on the geologic cross section index map for the Red Water Reservoirs (Fig. 3.4-1), cross section C-C' extends north to south through the Red Water Reservoirs, and cross section D-D' extends northwest to southeast through the Red Water Reservoirs area.

Aquifer characteristics in the Red Water Reservoir area were defined in the Phase I field survey. The lithologic information obtained during drilling of the Phase II monitor wells indicated that the shallow aquifer present in Phase I monitor wells extends to the northwest and exhibits similar character. Therefore, the aquifer characteristics determined for the shallow aquifer in the Phase I survey were employed in the Phase II investigation.

Ground water level data collected during the Phase II RI are presented in Tables 3.2-2 and 3.2-3. Fig. 3.4-4 and Fig. 3.4-5 are 2-dimensional plots showing ground water contours measured on Apr. 22, 1986, and Aug. 14, 1986, respectively. As evident on the figures, ground water flow is primarily to the northwest. The flow patterns observed in the April 1986 and August 1986 measurements contrast markedly with the near-radial type flow pattern observed in the 1985 Phase I survey. To illustrate this difference, the Phase I water-level contours of Jan. 7, 1985, as plotted in the initial RI survey, are reproduced in Fig. 3.4-6.

It should be noted that the location of Well GW31 was plotted in error in the Phase I report (ESE, 1986d). The actual location of Well GW31 is correct as indicated on the Phase II results figures and on the revised Phase I figure.

The additional monitor wells installed during the Phase II survey have nearly doubled the data base available for interpretation of water-level flow direction and rate. Consequently, the water-level flow patterns

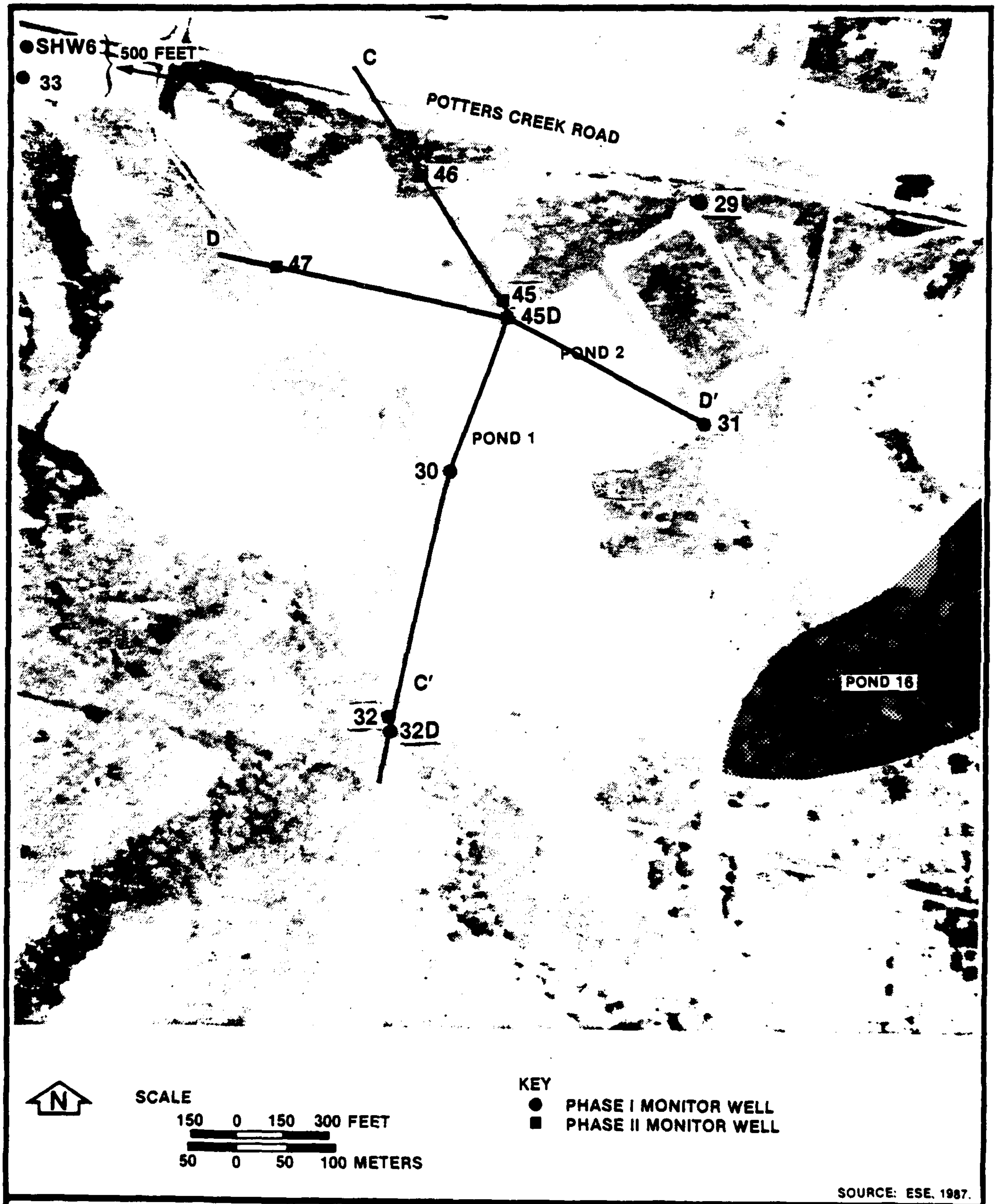

Figure 3.4-1
GEOLOGIC CROSS-SECTION LOCATIONS IN THE RED WATER RESERVOIRS AREA

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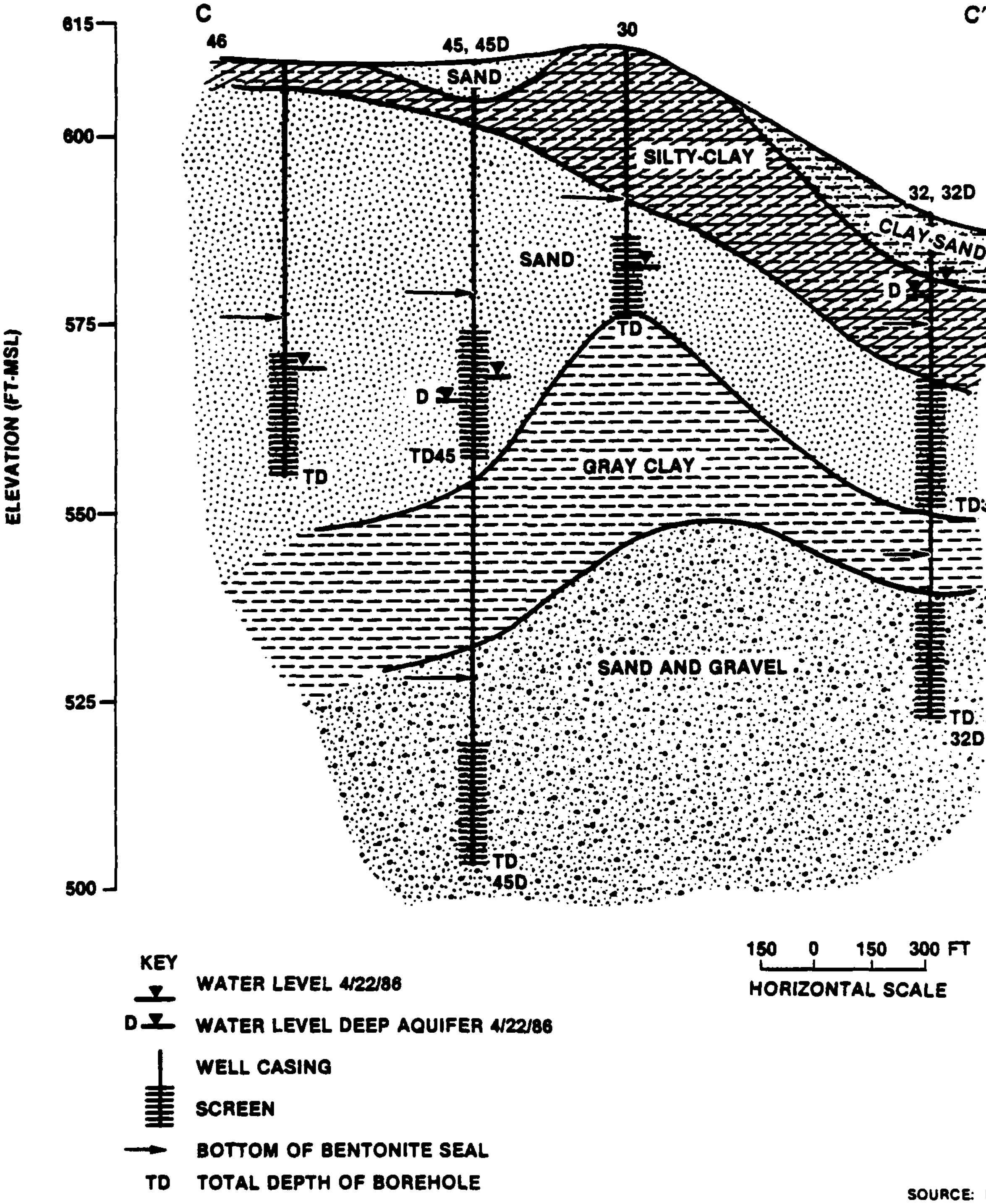

SOURCE: ESE, 1987.

Figure 3.4-2
GEOLOGIC CROSS-SECTION C - C', RED WATER RESERVOIRS

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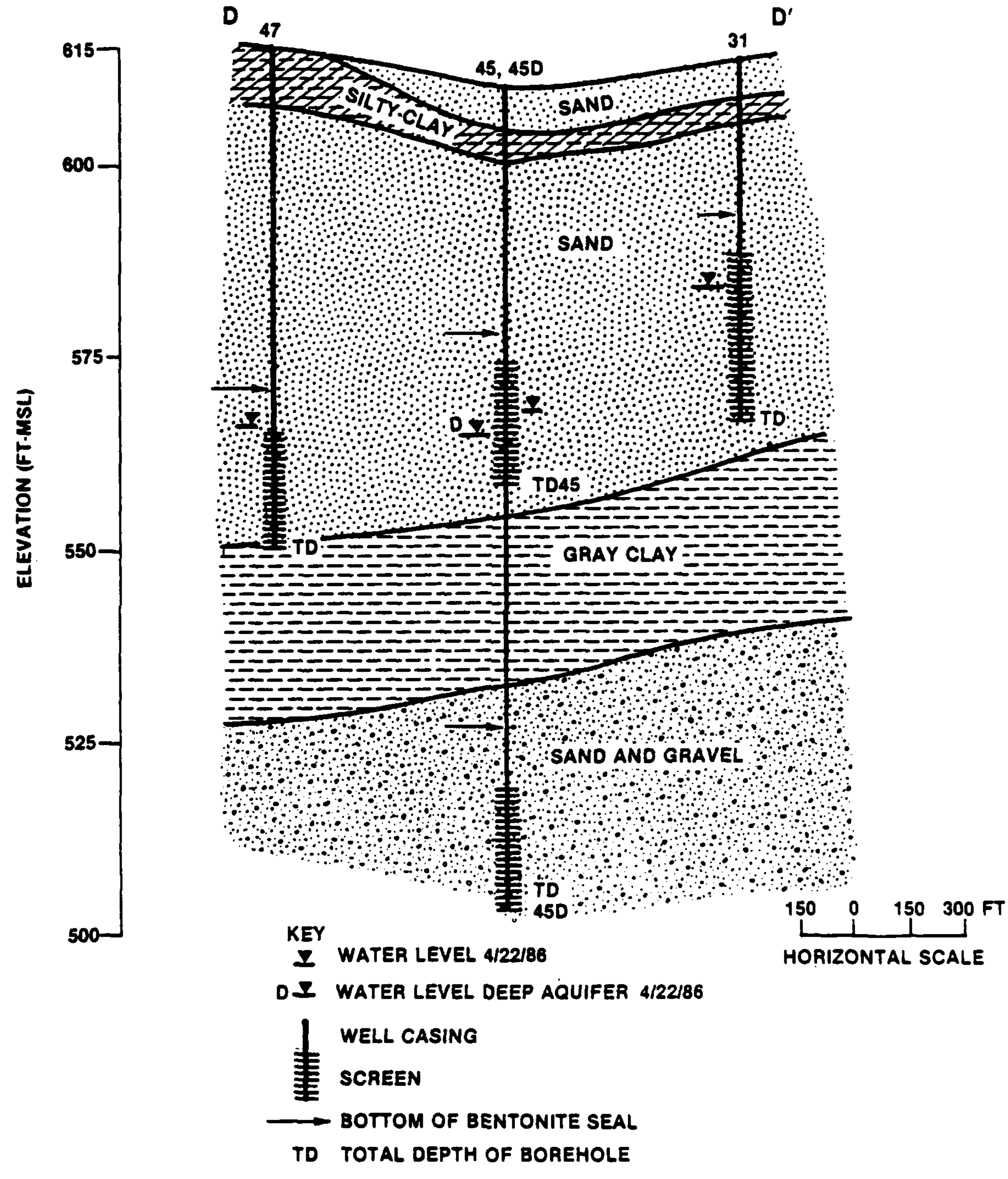

SOURCE: ESE, 1987.

Figure 3.4-3 GEOLOGIC CROSS-SECTION D–D'. RED WATER RESERVOIRS	WEST VIRGINIA ORDNANCE WORKS Supplemental Remedial Investigation Phase II Field Program

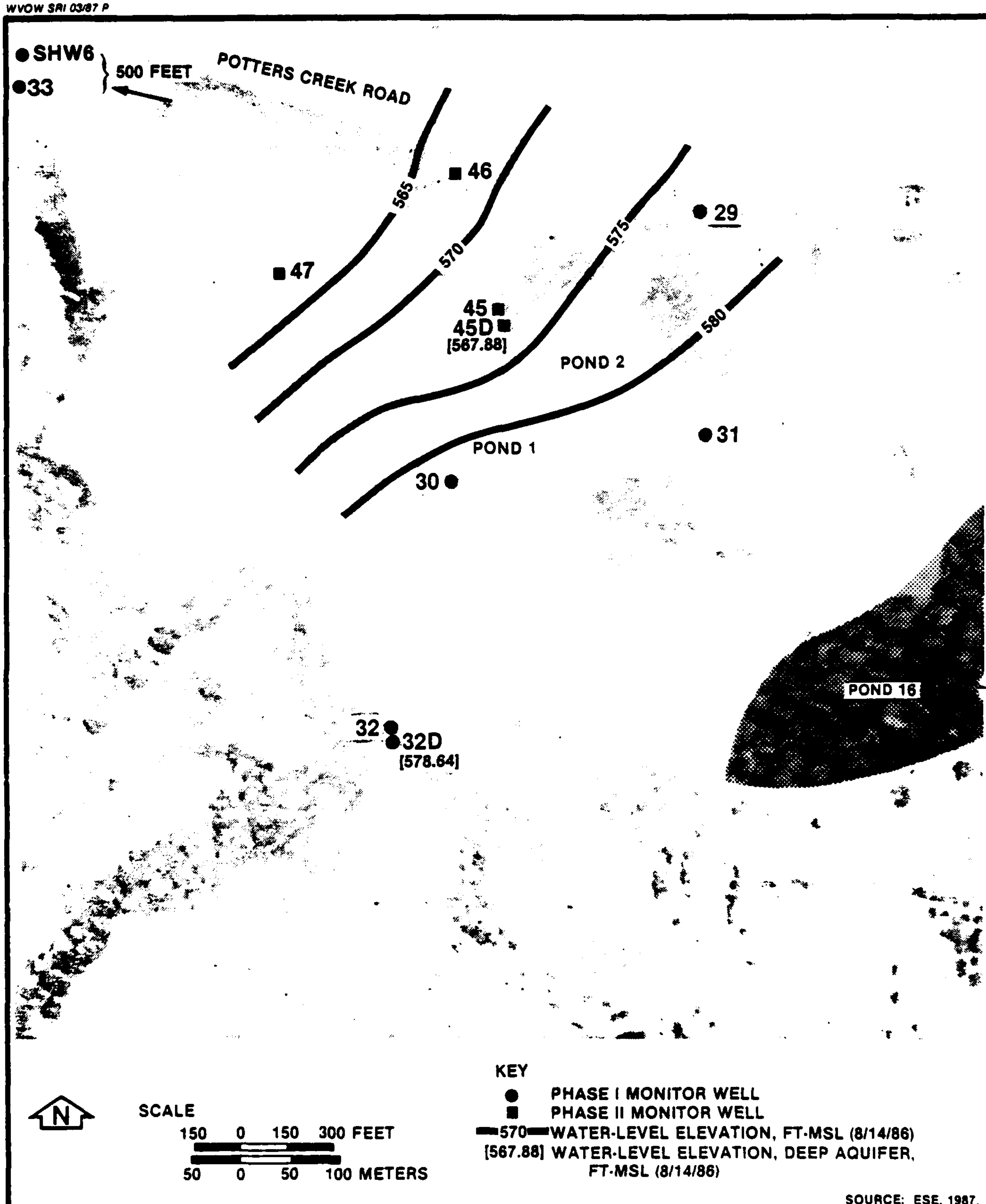

Figure 3.4-4
WATER-LEVEL CONTOURS, SHALLOW AQUIFER, RED WATER RESERVOIRS — AUGUST 14, 1986

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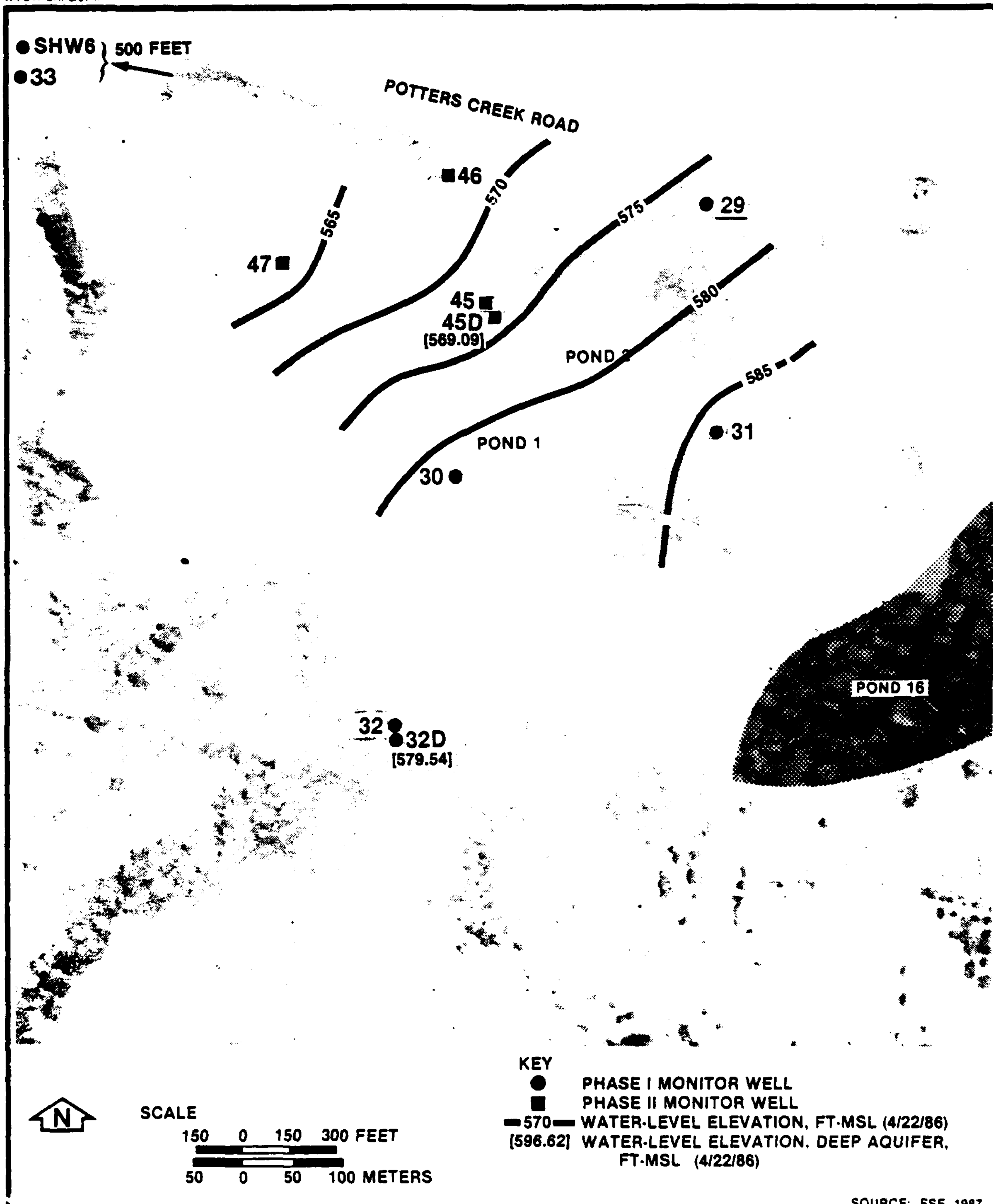

Figure 3.4-5
WATER-LEVEL CONTOURS, SHALLOW AQUIFER, RED WATER RESERVOIRS — APRIL 22, 1986

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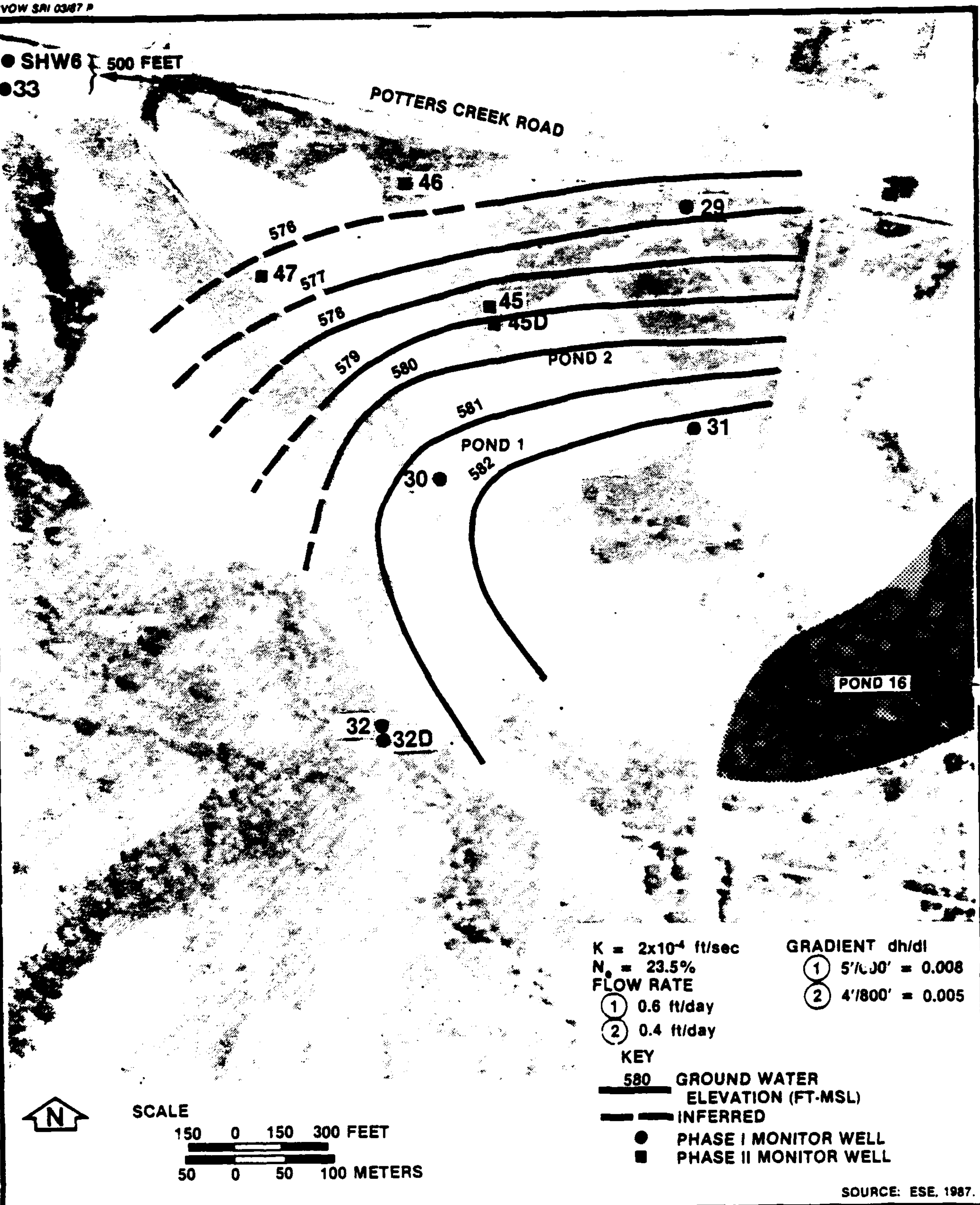

Figure 3.4-6
WATER-LEVEL CONTOURS, RED WATER RESERVOIRS — JANUARY 7, 1985

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observed in the Phase II survey represent a more accurate estimate of actual ground water flow patterns in the vicinity of the Red Water Reservoirs. The Phase I survey monitoring network lacked adequate downgradient monitor wells to provide a definitive flow pattern determination.

Ground water flow rate in the shallow aquifer can be determined by employing the water-level flow patterns of the Phase II survey in conjunction with the aquifer characteristic parameters determined in the Phase I survey. The hydraulic gradients observed in the April 1986 and August 1986 measurements were nearly identical; the hydraulic gradient determined is 0.02 ft/ft. Using the aquifer porosity and permeability values obtained in the Phase I survey, an estimate of ground water flow rate in this shallow aquifer is calculated as follows:

$$V = \frac{K}{n} \times i$$

$$= \frac{2.4 \times 10^{-4} \text{ ft/sec}}{0.24} \quad (0.02 \text{ ft/ft})$$

$$= 2 \times 10^{-5} \text{ ft/sec}$$

$$= 1.7 \text{ ft/day}$$

The defined shallow ground water flow rate measured using the 1986 data is approximately three times greater than that determined in the 1984-1985 Phase I survey (0.5 ft/day). There are several reasons for this apparent discrepancy between the two surveys. In the Phase I survey, the ground water flow gradient was determined using the difference in hydraulic head as measured between Wells GW31 and GW29. As stated previously, location for GW31 was plotted in error on the figures and was subsequently employed in the flow-rate calculations. Additionally, the inadequate density of the monitor well network in the Phase I survey led to the incorrect assumption (as shown in Fig. 3.4-6) that Well GW29 was directly downgradient of Well GW31. As is evident in the figures depicting ground water flow patterns observed in 1986, Well GW29 is not directly downgradient of Well GW31 but is located midway between a downgradient and cross-gradient position. The difference in well location for GW-31, coupled with the position of GW29 in the flow field, accounts for this apparent discrepancy in hydraulic gradients calculated in the Phase I versus the Phase II surveys.

At the well pair, GW45 and GW45D, the potential of vertical downward migration can be assessed. The hydraulic gradient employed is taken as the head difference of the well pair divided by the distance between the midpoints of the respective saturated filter packs. In this well pair, the hydraulic head difference is relatively small--approximately 3 ft. The vertical gradient, therefore, is 3 ft/51 ft, or approximately 0.06. Although vertical permeability through the gray clay confining layer was not directly calculated, a very low permeability value would be expected for the gray clay. As used in previous calculations, a permeability value of 1×10^{-7} ft/sec and an effective porosity value of 0.50 were assumed for the gray clay. The vertical flow potential is calculated as follows:

$$V = \frac{K}{n} \times i$$

$$= \frac{1 \times 10^{-7} \text{ ft/sec}}{0.50} \ (0.06 \text{ ft/ft})$$

$$= 1.2 \times 10^{-8} \text{ ft/sec}$$

$$= 1 \times 10^{-3} \text{ ft/day}$$

The low vertical flow rate estimated at 1×10^{-3} ft/day coupled with the vertical extent of the gray clay layer at this well pair (23 ft) indicates that the downward vertical flow potential and contaminant migration from the shallow aquifer to the deep aquifer are minimal.

With the addition of GW45D, two deep wells completed in the glacial outwash aquifers are present in the vicinity of the Red Water Reservoirs. Although a flow rate and accurate determination of ground water flow direction are not feasible, a general tendency of flow direction can be established.

The water level in GW32D is approximately 11 ft higher than that observed in GW45D. It can be concluded that ground water flow direction in the deep aquifer has a strong northerly component. These results are consistent with the ground water flow direction in the deep aquifer observed at the Acids Area/Yellow Water Reservoir. If it is assumed for purposes of discussion that the gradient observed between Wells GW32D and GW45D is directly along ground water flow lines, a rough approximation of ground water flow rate can be determined as follows:

$$V = \frac{K}{n} \times i$$

$$= \frac{2.5 \times 10^{-5} \text{ ft/sec}}{0.25 \text{ (assumed)}} \quad (0.03 \text{ ft/ft})$$

$$= 3 \times 10^{-6} \text{ ft/sec}$$

$$= 0.3 \text{ ft/day}$$

3.5 POND 13/WET WELL AREA

3.5.1 REVIEW OF PHASE I RI RESULTS

In the Phase I RI survey, the geologic setting of the Pond 13/Wet Well Area was defined using lithologic information obtained from two well pairs installed by ESE and from four shallow monitor wells installed in 1982 by an EPA contractor. The data from these monitor wells indicated that two markedly different hydrogeologic environments were present in the area surrounding Pond 13 (Fig. 3.5-1). At Pond 13, near-surface sediments consist of a thin (5- to 10-ft) layer of sandy, silty clay underlain by a permeable, water-bearing shallow aquifer. At Well GW23I, this shallow aquifer is underlain by a thin, probably discontinuous, clay layer. A second, interconnected sand layer occurs; below the second sand, a gray clay confining layer is present. Because the borehole extended only a short distance into the clay before it was terminated, the thickness of the gray clay layer could not be determined. To the southeast, Wells GW22 and GW22D were completed in a markedly different geologic environment. At this location, clay extends from the ground surface to a depth of approximately 60 ft. The gray clay layer is present beginning at 560 ft-MSL and extends 25 ft in thickness. At the well pair GW22 and GW22D, the shallow aquifer present at Pond 13 is absent. The only water-bearing aquifer at this location is the glacial outwash which extends from approximately 70 to 105 ft in depth and terminates at the top of bedrock which was encountered in Well GW22D.

Water levels measured during the Phase I survey indicated a possible ground water flow direction to the north, opposite the observed surface water flow direction in the area. With the absence of additional data points to the north of Pond 13, it was not possible to verify the actual ground water flow patterns in this area. It was believed that the hydraulic gradients indicated in the Phase I study were not indicative of a substantial hydraulic gradient to the north.

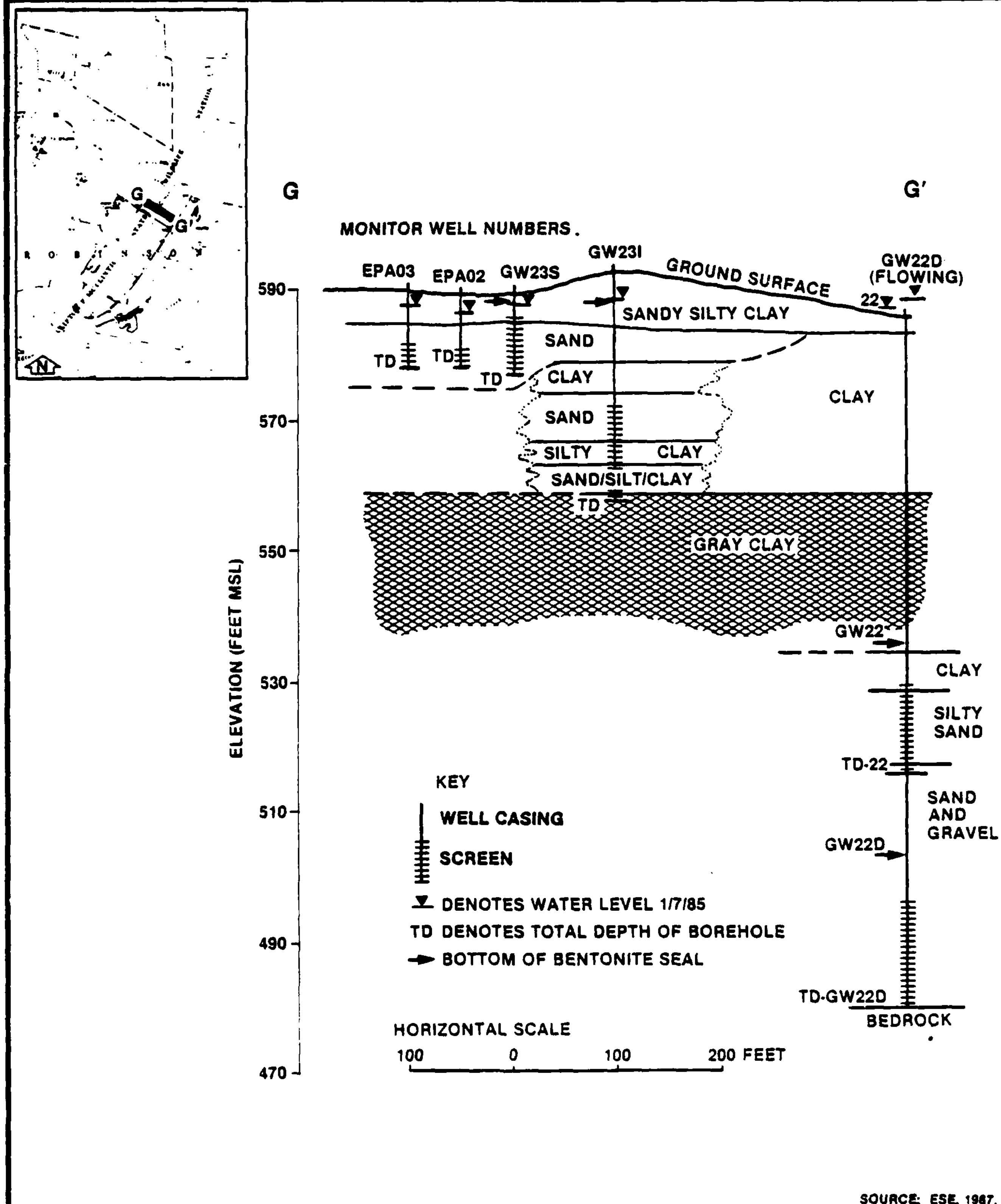

Figure 3.5-1
WEST-TO-EAST GEOLOGIC CROSS SECTION IN THE POND 13 AREA

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Two distinct hydrogeologic settings were evident in the vicinity of Pond 13. However, neither the areal extent of the shallow sand aquifer at the Pond 13 seep area nor the areal extent of the setting observed at GW22 and GW22D could be determined.

In addition, the water-level elevations observed at EPA02 were several feet lower than adjacent wells completed in the same aquifer. This apparent discrepancy was attributed to a surveying error.

3.5.2 PHASE II RESULTS

To address the data gaps from the Phase I field survey, the Phase II program consisted of shallow and deep monitor well installation and a resurvey of EPA02.

Monitor well locations for the Phase II survey are shown in Fig. 3.5-2. Both shallow and deep monitor wells were installed in the vicinity of Pond 13 to provide additional areal coverage to refine the shallow ground water flow patterns and to document the thickness of the gray clay layer. In addition, a water-level observation well (OW32S) was installed northwest of Wet Well No. 1 and EPA04 to provide additional areal coverage of ground water flow patterns. At location GW48D, a planned well pair, the shallow well GW48 was not drilled when conditions consistent with those observed at GW22 and GW22D were encountered (i.e., the shallow aquifer was not present and only the deep glacial outwash aquifer existed at this location). Well GW49 is a shallow aquifer monitor well located north of Pond 12, between Pond 13 and Pond 12. Based on the information obtained during the Phase II drilling program, a generalized geologic cross section has been prepared of the Pond 13/Wet Well Area. As shown on the geologic cross-section index map (see Fig. 3.2-3), cross section E-E' extends approximately north to south through the Pond 13/Wet Well Area.

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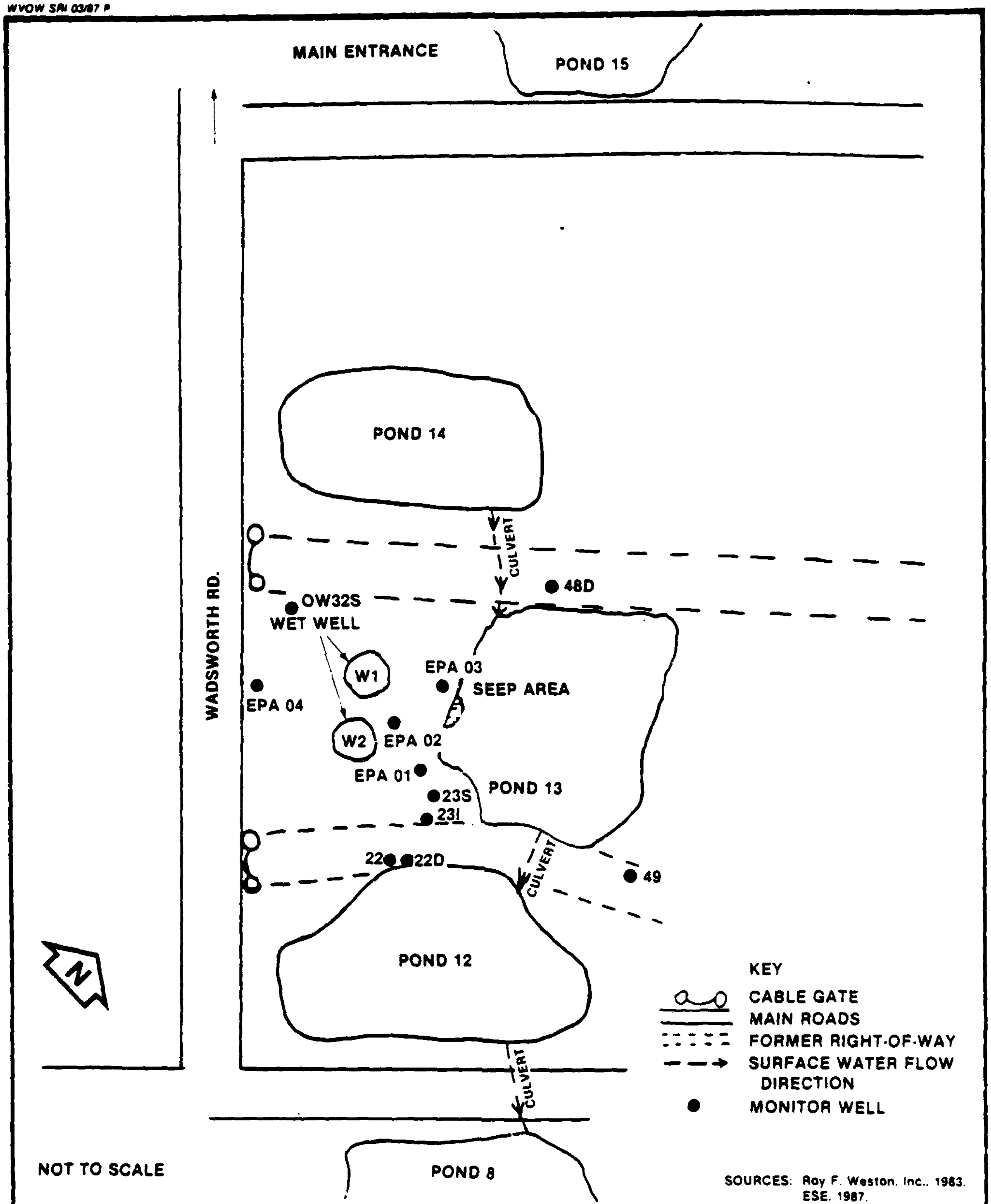

Figure 3.5-2
LOCATIONS OF GROUND WATER MONITOR AND OBSERVATION WELLS IN THE POND 13/WET WELL AREA

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As shown on the cross section (Fig. 3.5-3), the additional monitor wells drilled in the Phase II program have served to verify the areal extent of the two distinct hydrogeologic environments present at Pond 13. The shallow aquifer encompassing the seep area is depicted as the sand unit on the figure below monitor well GW24. The shallow sand aquifer is underlain by the gray clay layer in the area surrounding Pond 13. The gray clay layer, as is evident throughout the rest of WVOW, is continuous at Pond 13 and is approximately 30 to 40 ft thick.

The ground water level measurements collected during the Phase II RI survey are presented in Tables 3.2-2 and 3.2-3. For the purposes of this discussion, ground water levels measured during the Apr. 22, 1986 sampling episode will be employed. During the resurvey of Well EPA02, it was determined that a surveying error had occurred in the Phase I program, and the corrected elevation is employed in this study.

In the Phase I investigation, a confident estimate of ground water flow rate and direction was not possible. Water levels measured at the monitor wells at Pond 13 provided inconclusive data for ground water flow direction determination. The additional wells installed during the Phase II program provided a substantially greater data base to determine the areal extent of the aquifers present and the flow direction. All available data indicate that the shallow aquifer is of limited extent, and, based on the water-level measurements, essentially no direction of ground water flow can be established for the shallow sand aquifer. As indicated by the water-level elevations plotted in Fig. 3.5-4, ground water elevations at Wells EPA01 through EPA04 and at Wells GW23S and GW23I are essentially the same.

The shallow aquifer terminates to the north, as evidenced by the substantial clay thicknesses observed at Well GW48D. At GW49, a shallow well to the east of Pond 13, water levels are approximately 0.8 ft higher than at the Pond 13 Area, indicating that ground water flow is not in this direction.

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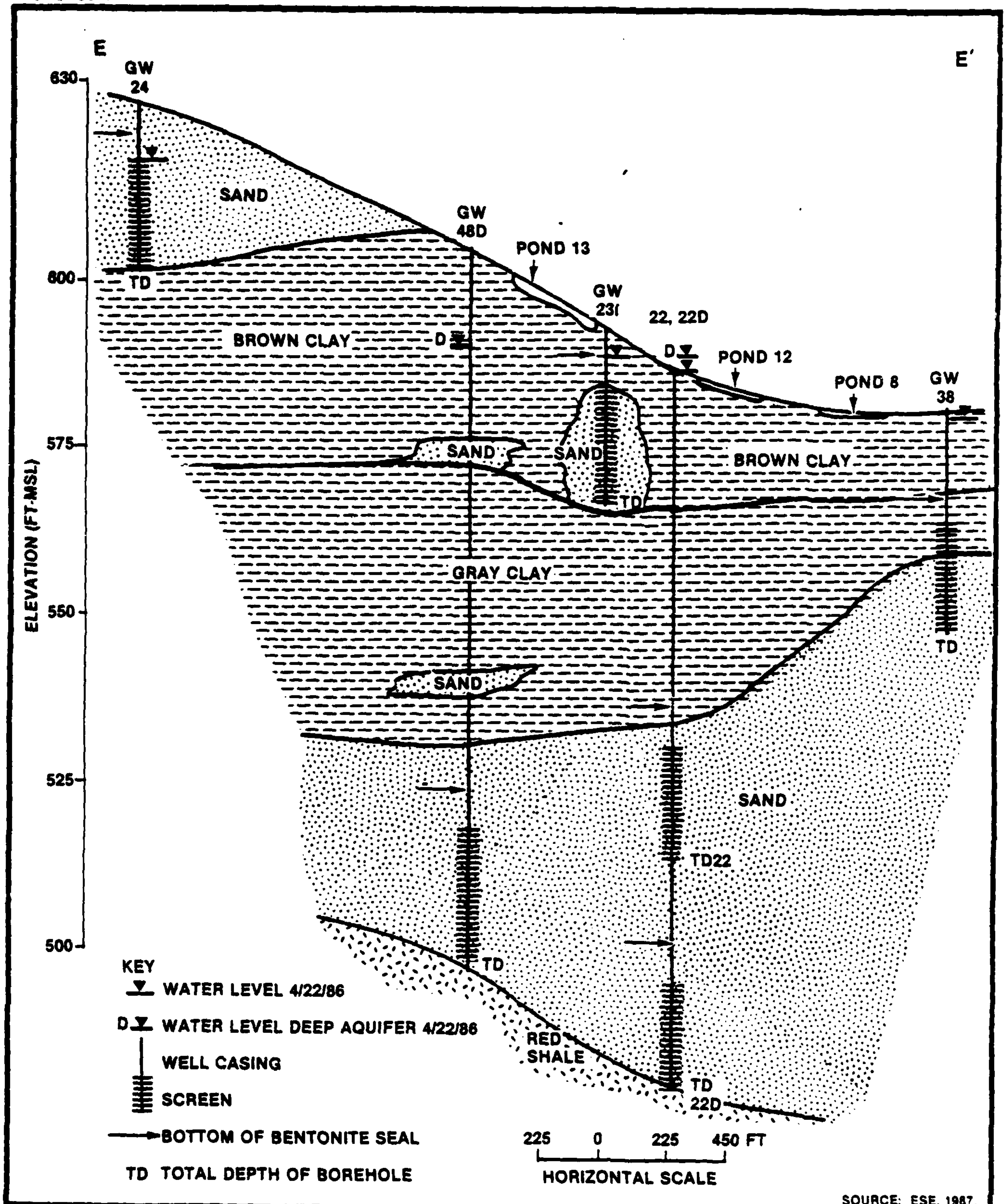

SOURCE: ESE. 1987.

Figure 3.5-3 GEOLOGIC CROSS SECTION E - E', POND 13/WET WELL AREA	**WEST VIRGINIA ORDNANCE WORKS** Supplemental Remedial Investigation Phase II Field Program

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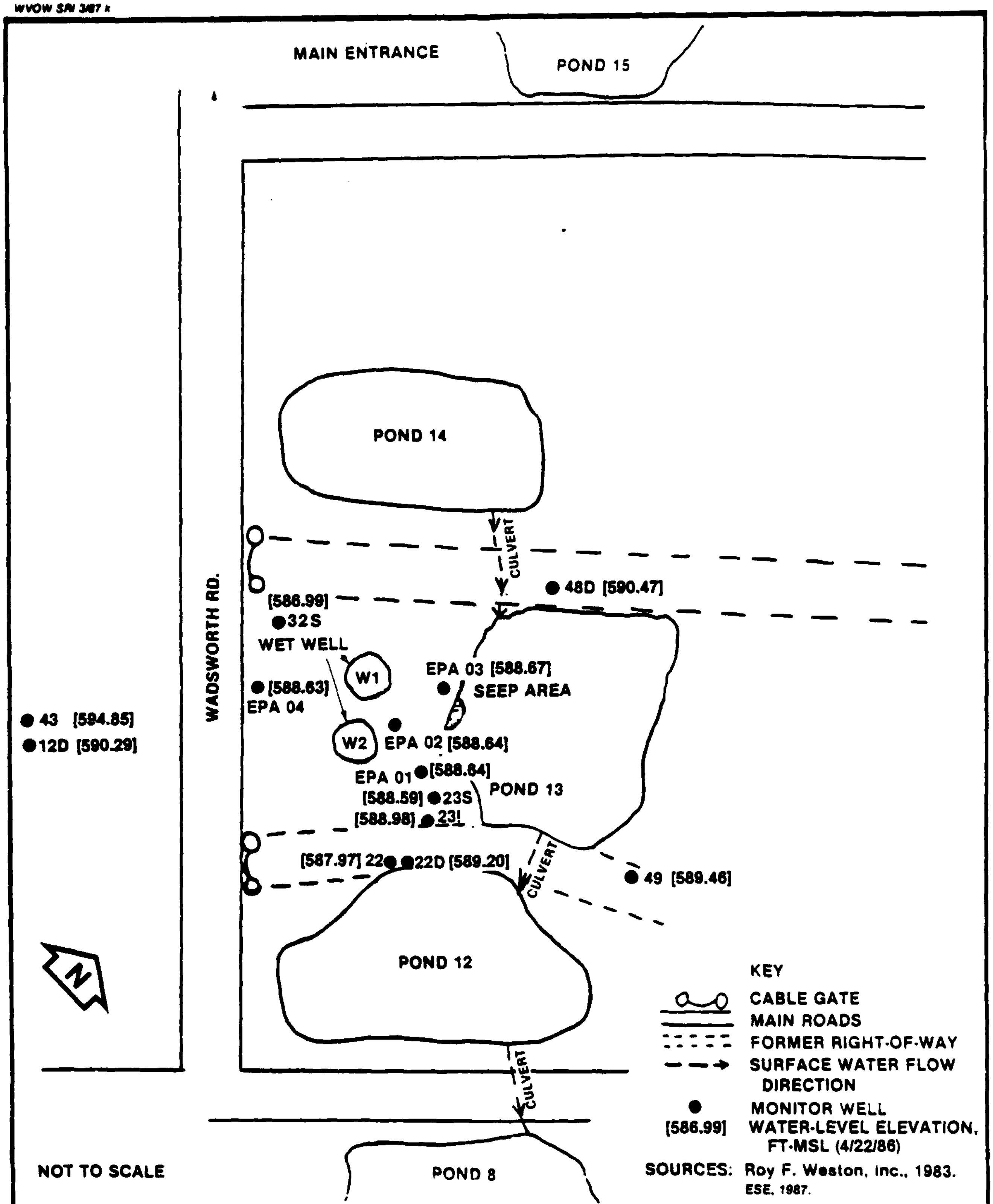

Figure 3.5-4
GROUND WATER LEVELS, POND 13/ WET WELL AREA — APRIL 22, 1986

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The shallow aquifer is not present at Wells GW48D and GW22/GW22D. The shallow aquifer at Pond 13 is bounded by vertically and areally extensive clay deposits to the north and to the south. The gray clay confining layer has been determined to be present at Pond 13 and is of sufficient thickness to preclude vertical contaminant migration. Furthermore, it should be noted that the hydraulic head values for the deep-aquifer monitor wells GW22D and GW48D are higher than those observed at the shallow sand aquifer monitor wells at Pond 13. Essentially, a minor upward gradient is present between the shallow aquifer and the deep glacial outwash aquifer. This further substantiates the conclusion that vertical downward migration in the contaminated shallow aquifer at the Pond 13/Wet Well Area is not possible.

3.6 SURFACE WATER ELEVATIONS

The initial RI survey (ESE, 1986d) at WVOW contained a comprehensive surface water program including stream gaging, flow measurements, and pond gaging. The program analyzed surface water processes in the Mill Creek and Oldtown Creek drainage basins and most ponds at the McClintic Wildlife Station. The physical hydrologic characteristics of the site, as addressed in the contamination assessment, determined that surface water contaminant migration was not a major exposure pathway at WVOW.

The Phase II program consisted of one round of surface water level measurements at all stream and pond gaging stations. The water level measurements collected in the Phase II field program are shown in Table 3.6-1. The locations of surface water gaging stations are shown in Fig. 3.6-1. The Phase II water levels were consistent with the 1984-1985 data obtained in the initial RI survey (ESE, 1986d). Representative surface water levels for the three areas of concern as assessed in the Phase I Survey are discussed in Sec. 3.1.

Table 3.6-1. Surface Water Elevations--April 22, 1986

Sampling Station	Water-Level Elevation (ft-MSL)
Pond Gages	
P1	602.40
P2	601.01
P3	614.07
P6	579.49
P8	580.26
P9	579.61
P10	--
P13	588.88
P14	593.56
P15	610.75
P16	--
P17	--
P18	575.90
P19	--
P24	620.46
P28	591.93
P29	588.12
P30	586.06
P31	585.32
P32	--
P33	578.73
Mill Creek Stations	
MC1	566.01
MC2	582.31
MC4	585.26
MC5	596.41
MC8	607.99
Oldtown Creek Stations	
OTC1	555.27
OTC3	559.74
OTC4	559.05
OTC5	582.74
OTC6	558.25

-- = Staff gage missing.

Source: ESE, 1986a.

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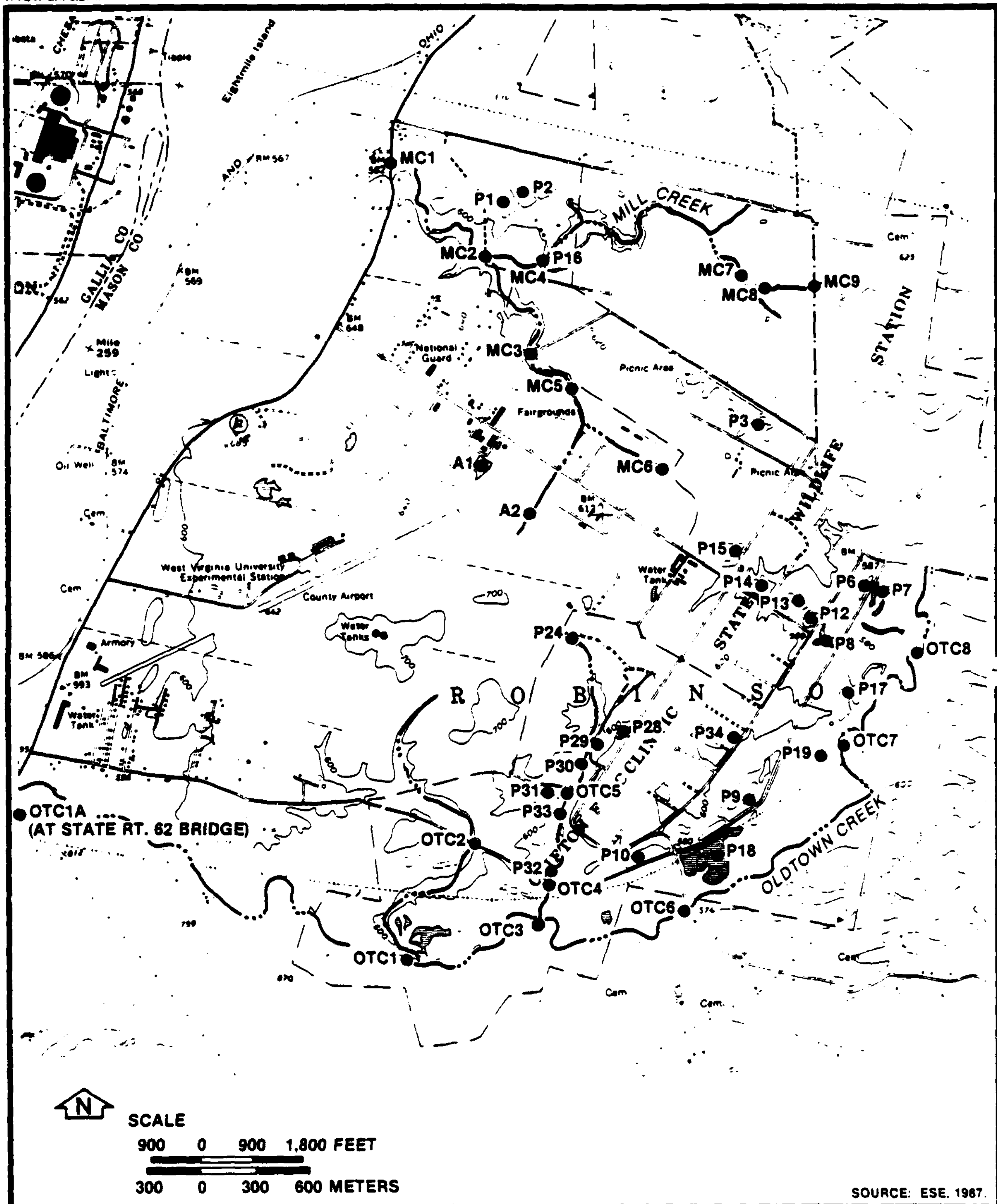

Figure 3.6-1
LOCATIONS OF SURFACE WATER GAGING STATIONS

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3.7 SITEWIDE HYDROGEOLOGY--PHASE II RESULTS

The supplemental RI survey has provided valuable information regarding the areal and vertical extent of the aquifer systems present at WVOW. At most areas of concern, a 2-aquifer system is present in the unconsolidated sediments. At the Acids Area/Yellow Water Reservoir and the Red Water Reservoirs, a shallow alluvial aquifer is separated from the deep glacial outwash aquifer by the gray clay confining layer. The glacial outwash aquifer is present at all site areas of concern at similar physical characteristics. According to published information (Wilmoth, 1966), the glacial outwash aquifer represents a single, continuous, aquifer system. The data obtained in the WVOW field investigations appear to confirm this statement.

The gray clay confining layer which separates the alluvial aquifer from the deep glacial outwash aquifer is present in all areas of concern at WVOW. The clay has been detected in 23 boreholes in the field investigations. Of the 23 boreholes, 21 penetrated the entire thickness of the clay unit, allowing quantification of the sitewide variations in thickness of the clay. The clay ranges in thickness from 5 to 42 ft across the site. The average (mean) thickness is 18.3 ft; the median thickness is 14 ft. The data indicate that the gray clay persists throughout WVOW and acts as an effective barrier to vertical contaminant migration. The clay was typically uniform in color (dark gray), lithology, and consistency. The extent, composition, and thickness indicate that the clay provides an effective barrier to potential vertical contaminant migration. The extent and characteristics of the gray clay are listed in Table 3.7-1. Fig. 3.7-1 and Fig. 3.7-2 show the thickness of the gray clay and the elevation of the top of the unit across the site, respectively.

Water levels measured in the shallow alluvial aquifer and the deep glacial outwash aquifer on Apr. 22, 1986, were used to prepare sitewide water-level contours. Fig. 3.7-3 and Fig. 3.7-4 are 2-dimensional plots

Table 3.7-1. Gray Clay Confining Layer--Extent and Characteristics

Well Designation	Top-of-Clay Elevation (ft-MSL)	Thickness (ft)
GW01	571	9
GW04	575	8
GW05	555	17
GW06	562	8
GW07	557	13
GW09	551	21
GW10	574	36
GW12	569	33
GW21	561	37
GW22	560	25
GW27	556	23
GW30	578	5
GW32	551	13
GW34	562	6
GW35	565	14
GW36	561	19
GW38	570	9
GW39	566	10
GW40	560	13
GW45	556	23
GW48	573	42

Source: ESE, 1986a.

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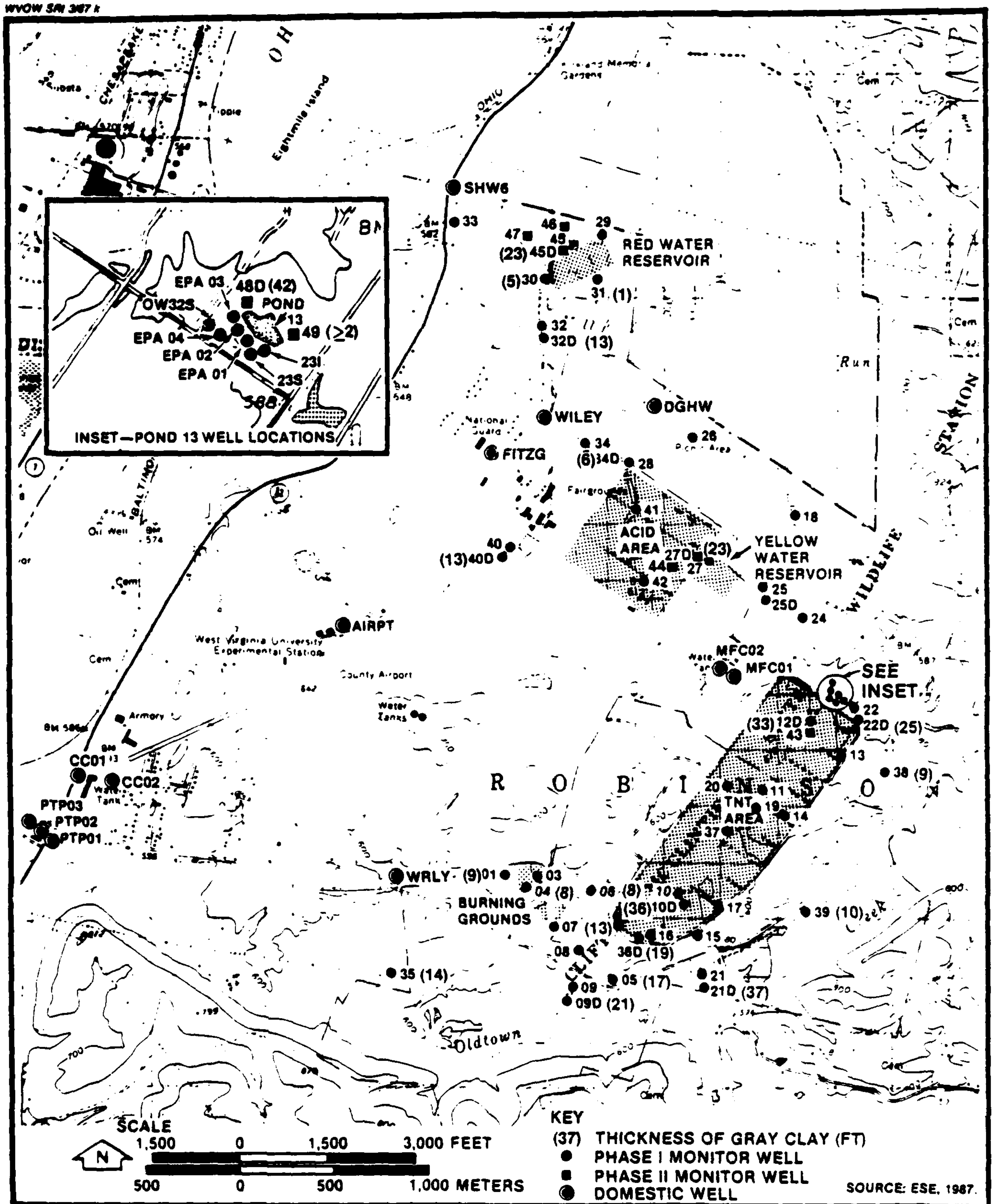

Figure 3.7-1
THICKNESS OF GRAY CLAY CONFINING LAYER

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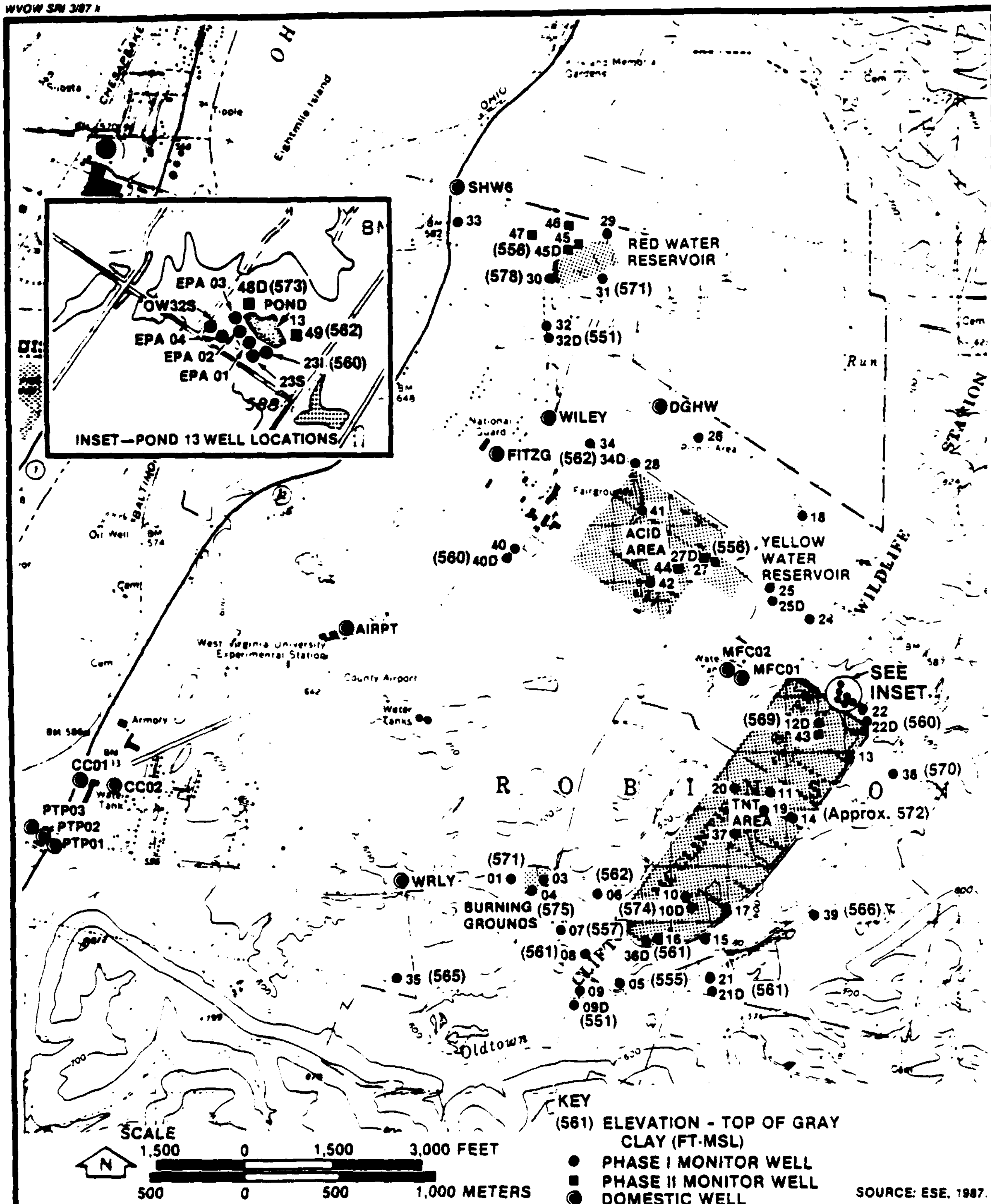

Figure 3.7-2
ELEVATION—TOP OF GRAY CLAY CONFINING LAYER

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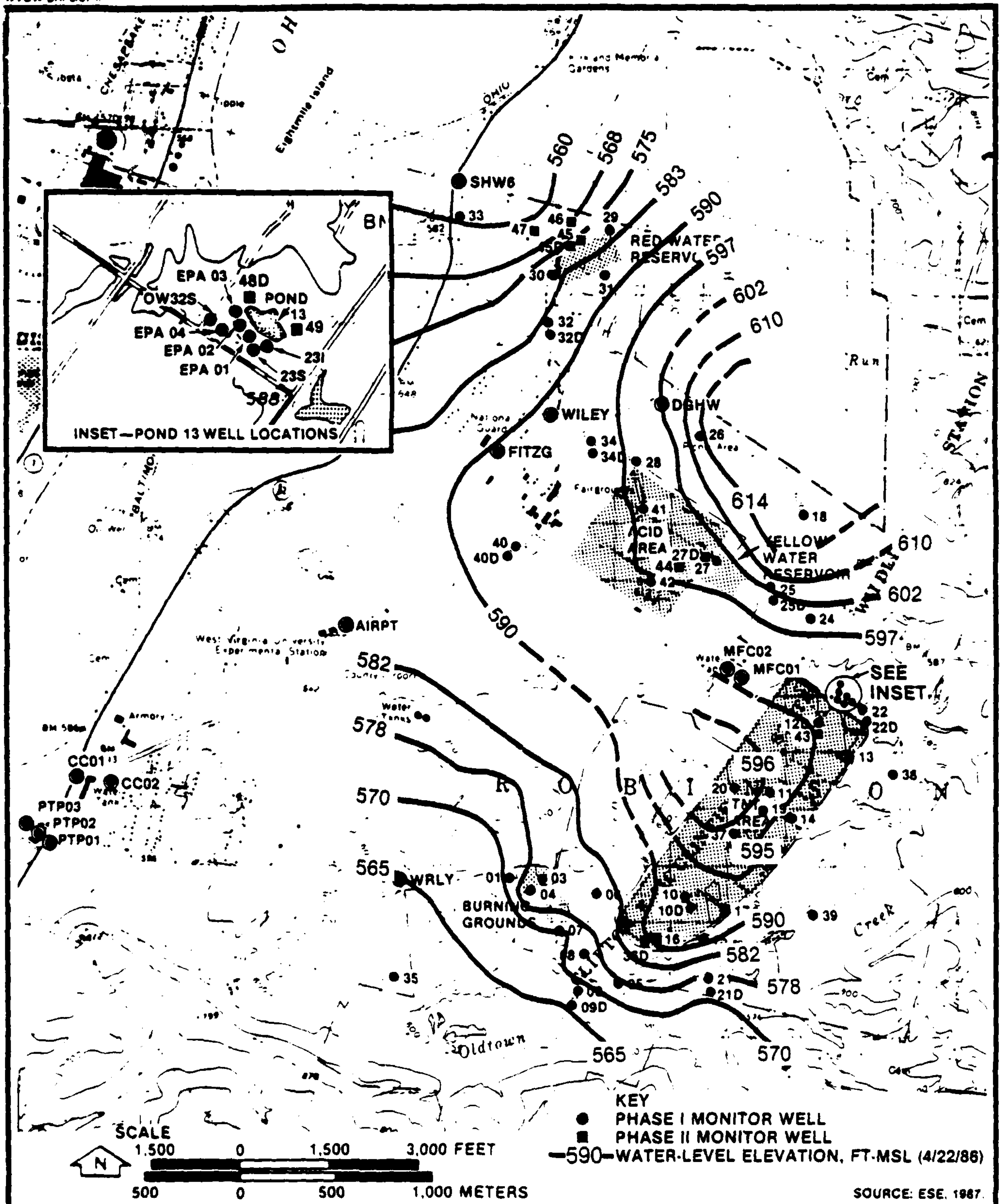

Figure 3.7-3
SITEWIDE GROUND WATER LEVEL CONTOURS, SHALLOW AQUIFER — APRIL 22, 1986

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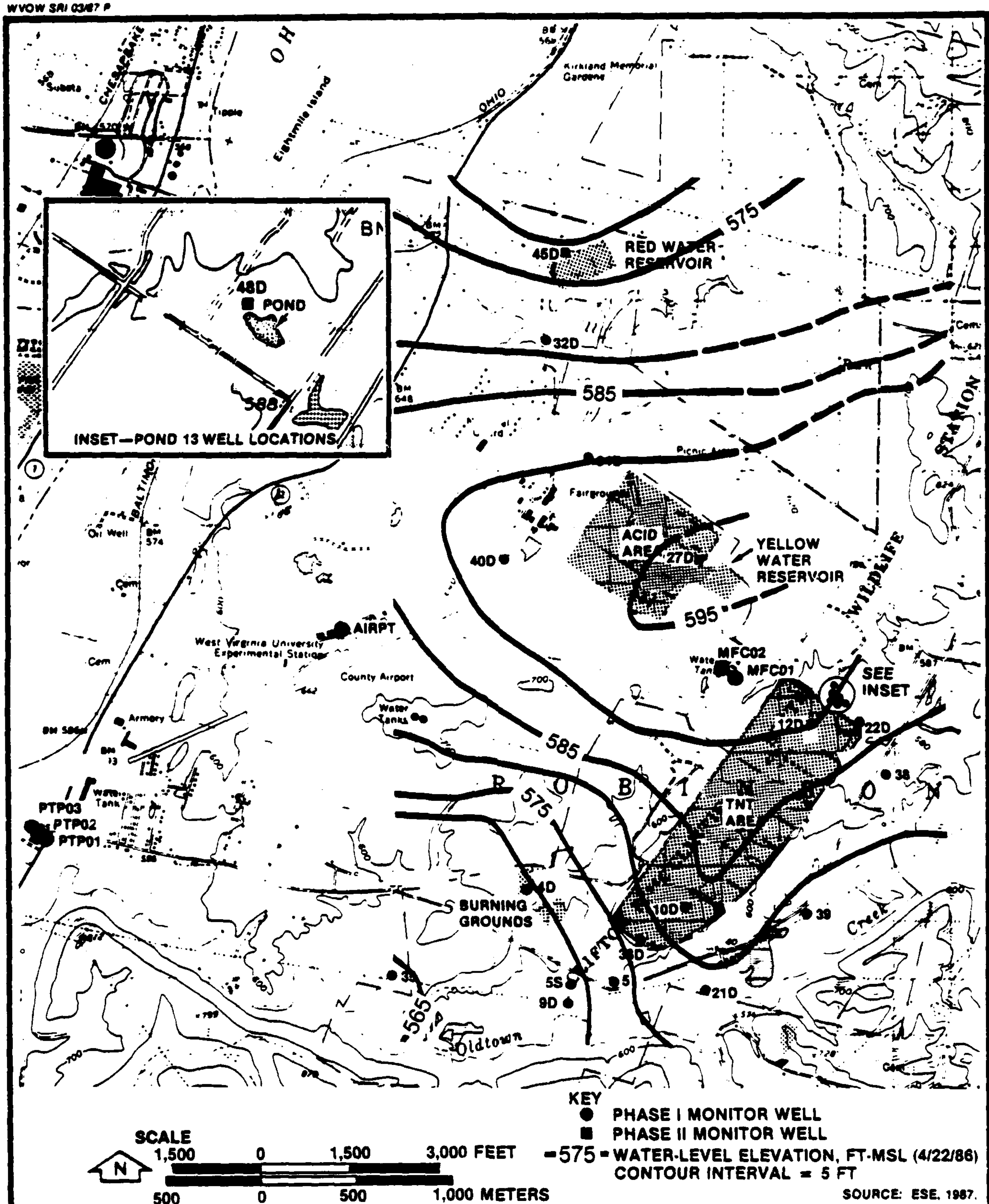

Figure 3.7-4
SITEWIDE POTENTIOMETRIC CONTOURS, DEEP AQUIFER — APRIL 22, 1986

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showing ground water contours in the shallow alluvial aquifer and deep glacial outwash aquifer, respectively. In the shallow aquifer, ground water flow is predominantly westward. At the Red Water Reservoirs, a northwest flow is evident, whereas a southwest flow is evident in the vicinity of the Burning Grounds Area. In the deep aquifer, a flow divide is apparent in the vicinity of the Acids Area/Yellow Water Reservoir. This divide extends approximately west to east; ground water flows to the north in the northern portion of the site, and flow is to the south and southwest in the southern portion of WVOW.

4.0 CONTAMINATION ASSESSMENT

4.1 PHASE II RESULTS

Phase II ground water and sediment samples were analyzed for nitroaromatics using USATHAMA Methods C2 and D2, respectively. According to USATHAMA protocol, C2 was classified as a semiquantitative method based on 1-day analyses of the standard matrix samples spiked at specific levels. Data resulting from a semiquantitative method are reported to one significant digit. Method D2 was classified as a quantitative method based on a 4-day analysis of the spiked samples. Data are presented to two significant digits. Certified detection limits, Quality Control (QC) spiking levels, and the certified range were derived from the standard matrix sample spike analyses. The QC spiking levels for Methods C2 and D2 were approximately 2.5 and 10 times the certified detection limit. Calibration standards, sample concentrations, and daily QC spikes should all be within the certified range of the compounds.

In the data review discussed in the folowing sections, the detection limits may vary from sample to sample and in certain instances are greater than the certified detection limit.

In cases where the concentration of an analyte was greater than the highest calibration standard, the sample was diluted in order to be within the certified range. Dilution of a multielement sample can raise the detection limit of a compound to a concentration greater than the detection limit by the appropriate dilution factor.

A second explanation for detection limit variance occurred during the April 1986 analyses of the EPA wells and GW33, GW41, and GW44. In this case, to compensate for low spike recoveries for 1,3,5-TNB and 2,4,6-TNT, the detection limits for these two compounds were raised. The detection limit for 1,3,5-TNB was raised from 2 to 10 μg/L, and for 2,4,6-TNT the limit changed from 0.08 to 2 μg/L. Appropriate dilution factors were then applied.

4.2 ACIDS AREA/YELLOW WATER RESERVOIR

4.2.1 REVIEW OF PHASE I RI RESULTS

As described in the Phase I RI report (ESE, 1986d), detectable levels of nitroaromatic compounds were observed during 1985 in the shallow aquifer at Monitor Well GW27 in the area of the former Yellow Water Reservoir and in Well GW41, which was located along the route of the underground yellow water sewerline. The contamination of the shallow ground water apparently is related to the storage of yellow water in the former reservoir and leakage of yellow water from the sewerline. Soils underlying the Yellow Water Reservoir and soils along the bed of the yellow water sewerline were found to contain nitroaromatic compounds during the Phase I RI (ESE, 1986d).

4.2.2 PHASE II RESULTS

To better define the horizontal and vertical extent of ground water contamination, the Phase II investigation in this area included the installation and sampling of two additional monitor wells (GW27D and GW44) plus the resampling of the eight wells that were installed in the fall of 1984. The locations of the two additional wells and the existing wells are shown in Fig. 4.2-1. Monitor Well GW44 was installed to better define the horizontal extent of contamination in the shallow aquifer downgradient of the Yellow Water Reservoir, and Monitor Well GW27D was installed adjacent to the shallow monitor well, GW27, to monitor the ground water in the deep aquifer below the previously documented contamination in the shallow aquifer.

The results of the April 1986 sampling of the 10 wells in the Acids Area/Yellow Water Reservoir area are provided in Table 4.2-1. The spatial distribution of total nitroaromatics (the arithmetic sum of the individual nitroaromatic isomers) is shown in Fig. 4.2-2. Nitroaromatic contamination of the shallow aquifer followed a pattern similar to that observed in the Phase I RI (ESE, 1986d). As shown in Table 4.2-1 and Fig. 4.2-2, nitroaromatic contamination of the shallow aquifer has

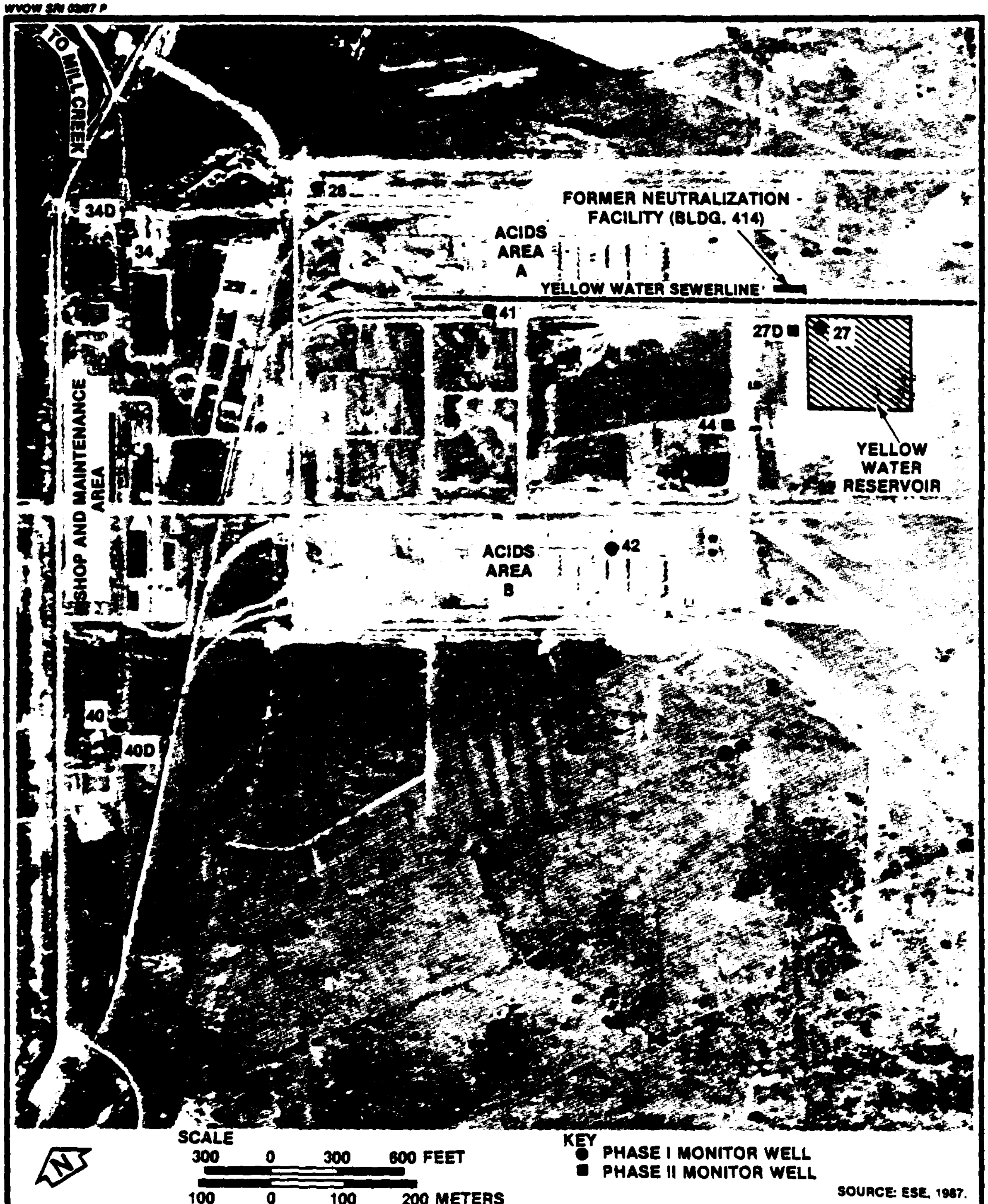

Figure 4.2-1
LOCATIONS OF GROUND WATER MONITOR WELLS IN THE ACIDS AREA/YELLOW WATER RESERVOIR

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Table 4.2-1. Phase II Chemical Data for Ground Water in the Acids Area/Yellow Water Reservoir

Parameter	Monitor Well and Sampling Date									
	GW34 4/25/86	GW34D 4/25/86	GW40 4/26/86	GW40D 4/28/86	GW28 4/28/86	GW41 4/28/86	GW42 4/25/86	GW27 4/28/86	GW27D 4/28/86	GW44 4/28/86
pH, field (standard units)	5.30	6.50	5.00	6.50	5.40	5.40	5.30	5.30	6.60	5.90
Specific conductance, field (μmho/cm)	430	205	207	187	65.0	205	55.0	126	212	86.0
Water temperature (°C)	15	15	14	15	12	14	14	14	15	14
Nitrobenzene (μg/L)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
1,3-DNB (μg/L)	<0.2	<0.2	<0.2	<0.2	<0.2	0.8	<0.2	<0.2	4	<0.2
TNB (μg/L)	<2	<2	<2	<2	<2	<10*	<2	30	7	<10*
2,4-DNT (μg/L)	<0.3	<0.3	<0.3	<0.3	<0.3	7	<0.3	7	0.5	<0.3
2,6-DNT (μg/L)	<0.8	<0.3	<0.8	<0.8	<0.8	3	<0.8	<0.8	<0.8	<0.8
2,4,6-TNT (μg/L)	<0.08	<0.08	<0.08	<0.08	<0.08	4	<0.08	20	5	<0.2*
Total nitroaromatics* (μg/L)	<3.9	<3.9	<3.9	<3.9	<3.9	10	<3.9	60	20	<12

*Refer to Sec. 4.1, paragraph 3 regarding elevated detection limit.
†Arithmetic sum of the six nitroaromatic isomers (calculated).

Note: μg/L = micrograms per liter.

Source: ESE, 1987.

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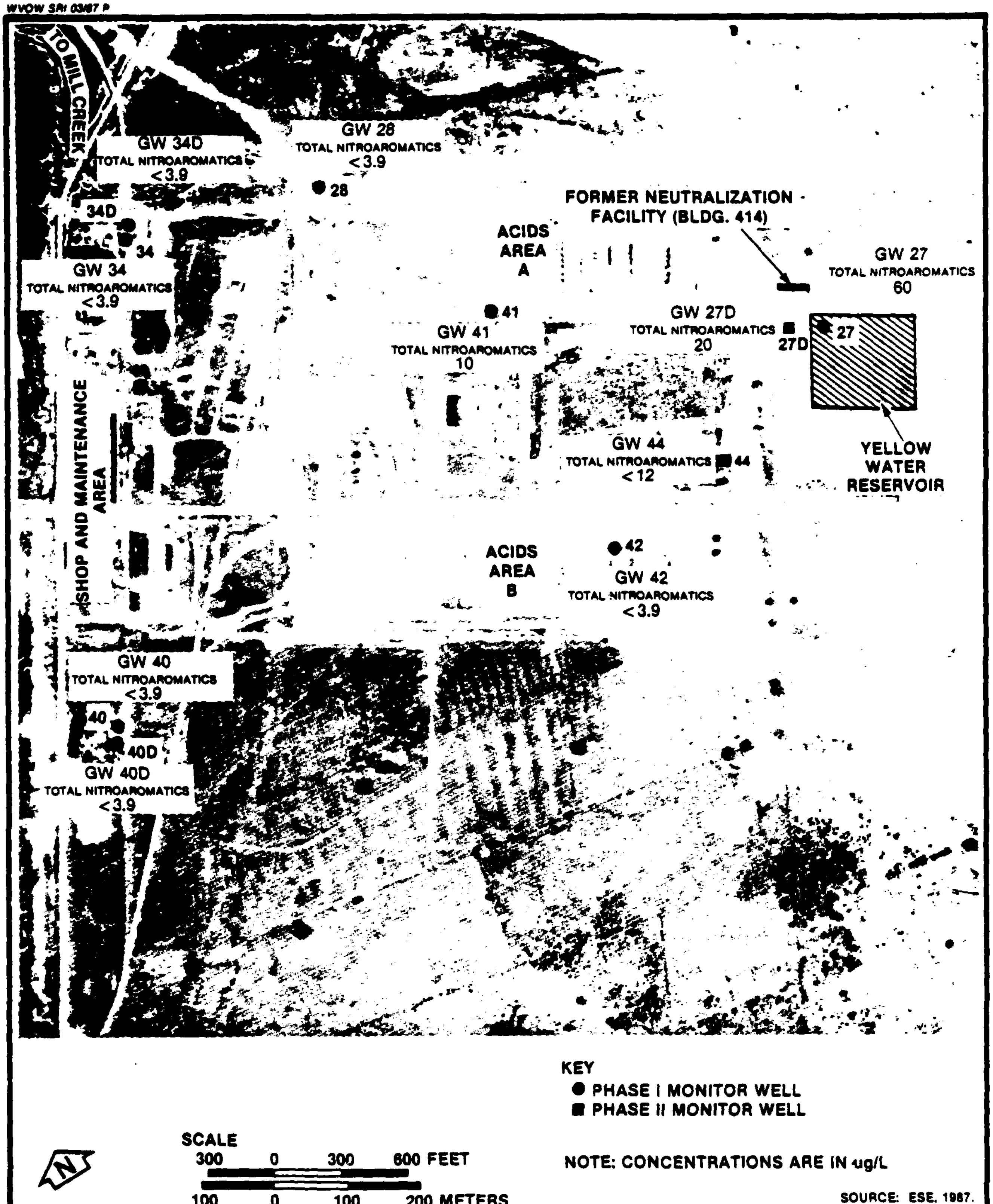

Figure 4.2-2
TOTAL NITROAROMATIC CONCENTRATIONS IN THE GROUND WATER — ACIDS AREA/ YELLOW WATER RESERVOIR, APRIL 1986

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occurred at Monitor Wells GW27 and GW41, with higher concentrations observed at GW27. Phase II resampling confirmed that contamination of ground water had occurred beyond the McClintic Wildlife Station boundary. The shallow aquifer in this area is not currently used as a source of drinking water.

As shown in Table 4.2-1 and Fig. 4.2-2, no nitroaromatic compounds were detected in any of the other shallow wells in this area. These results are similar to the Phase I sampling. Monitor Well GW44, installed several hundred feet downgradient of the Yellow Water Reservoir, also did not contain detectable levels of nitroaromatics. The elevated detection limit at GW44 in the Phase II survey is discussed in Sec. 4.1. In this instance, the detection limits for 2,4,6-TNT and 1,3,5-TNB were raised to compensate for low spike recoveries in the QC samples. Specifically, the 2,4,6-TNT detection limit was raised to the 2X level from 0.08 µg/L to 0.2 µg/L), and the 1,3,5-TNB detection limit was raised to the 5X level (from 2 µg/L to 10 µg/L). The 8-µg/L increase in the 1,3,5-TNB detection limit accounted for most of the increase in the detection limit for total nitroaromatics. It is important to note that the total nitroaromatics values used throughout this report are simply the arithmetic sum of the individual constituents and are not values produced in a specific chemical analysis. To assess the impact of the elevated detection limits, the values of the individual nitroaromatic isomers at GW44 were compared with the values observed at GW27, located at the Yellow Water Reservoir. In both wells (April 1986 sampling), levels of nitrobenzene, 1,3-DNB and 2,6-DNT were below detection limits. The concentration of TNB at GW27 decreased from 30 µg/L to less than 10 µg/L at GW44. For 2,4-DNT, the concentration at GW27 of 7 µg/L decreased to less than 0.3 µg/L at GW44. For 2,4,6-TNT, the concentration of 20 µg/L at GW27 decreased to less than the detection limit of 0.2 µg/L at GW44. It was concluded that the absence of contamination observed at GW44 effectively defines the extent of contamination downgradient of the Yellow Water Reservoir.

These data indicate that ground water contamination is occurring only in the immediate vicinity of the Yellow Water Reservoir and is more attributable to the yellow water sewerline. As described in the Phase I RI (ESE, 1986d), soils underlying the Yellow Water Reservoir and along the bed of the yellow water sewerline were found to contain nitroaromatic contaminants. Additionally, soils collected in the Yellow Water Reservoir during the September 1985 reactivity sampling were found to contain up to 2,830 µg/g (dry-weight) of 2,4,6-TNT. This residual nitroaromatic contamination in the soils and sediments is a continuing source for nitroaromatic contamination of the ground water. No ground water contamination is occurring from either the Acids Area or the north and south powerhouses.

The sample of reservoir sediment analyzed for reactivity was determined to be nonreactive. The reactivity testing program was described in the Feasibility Study (FS) report for the first operable unit at WVOW (ESE, 1986c).

The deep well (GW27D) installed near the Yellow Water Reservoir contained detectable levels of 1,3-DNB, trinitrobenzene (TNB), 2,4-DNT, and 2,4,6-TNT (see Table 4.2-1). It should be noted that this well is screened in the aquifer that is used as a potable source in this area. Nitroaromatic compounds have not been detected in either of the deep wells at the powerhouses (GW40D and GW34D) or in the deep well at the McClintic Wildlife Station (DGHW). The deep wells are screened in the same aquifer as GW27D.

The observed contaminant levels and the relative concentration of the various nitroaromatic compounds (compared with those observed in the shallow well, GW27) indicate the possibility that some contaminated ground water from the shallow aquifer may have leaked to the deep aquifer during the installation of Well GW27D. Review of the drilling log for GW27D indicates that three separate borings were attempted before the well could be installed. The first two borings, located approximately 30 ft west and 36 ft southwest of GW27D, were abandoned by grouting.

The primary difficulty in the construction of this well was related to breaks in the steel drive casing which occurred as the casing was driven ahead of the drill bit or as the casing was removed during well construction. The logs for the first two attempts to install Well GW27D indicate that the casing breaks occurred at depth intervals either within or below the gray clay zone. The problems encountered during placement and/or removal of the drive casing may have been partially or completely attributable to increased skin friction or adhesion between the casing and the gray clay. When the first two borings were abandoned, grout was pumped into the drive casing before the casing was removed, resulting in a positive pressure gradient from the boring into both aquifer zones. Therefore, at no time did a direct connection between the shallow contaminated aquifer and deeper potable aquifer exist.

The third and final attempt to install Well GW27D also encountered difficulties related to parting of the drive casing; however, the circumstances were significantly different from those for the first two attempts. The drive casing broke at a depth of 30 ft below the land surface, which was approximately 14 to 15 ft below the elevation of the shallow ground water surface. Shallow ground water was able to migrate down the drive casing into the deeper aquifer during the period of time the break was below the shallow ground water level. Review of the boring log indicates that once the break in the drive casing was identified, an immediate attempt to pull the casing up (i.e., to a position above the shallow ground water level) was initiated. Approximately 2 hours elapsed before this procedure was completed. During this period of time, shallow ground water was able to flow downward through the drive casing into the deeper aquifer. The presence of contaminants in the deeper aquifer (Well GW27D) is attributed to this temporary interconnection of the two water-bearing zones.

4.2.3 TIME-SERIES SAMPLING RESULTS

In August 1986, a time-series sampling of Well GW27D was conducted to determine if the nitroaromatic contaminants had been dispersed in the deep aquifer or if the concentrations observed in the April 1986 sampling persisted. During the time-series sampling, Well GW27D was pumped continuously for 51 hours at the rate of 8 to 9 gallons per minute (gpm) to achieve a continuous drawdown goal of approximately 40 ft. During the pumping, seven samples were collected using a bailer. Samples were also collected from the shallow well, GW27, to coincide with the GW27D samples. Water-level measurements were also made in GW27. Well GW27 was not pumped during this sampling. Water-level measurements for both wells are shown in Table 4.2-2.

The results of the time-series sampling for Wells GW27 and GW27D are given in Tables 4.2-3 and 4.2-4, respectively. Fig. 4.2-3 shows the relationship of total nitroaromatics as a function of time for both wells. As shown, levels of total nitroaromatics in the deep aquifer decreased from 70 to 5 µg/L during the time-series pumping. The prepumping sample containing 70 µg/L of total nitroaromatics is likely not representative of true aquifer water quality. The early pumping phases samples containing 40 µg/L are considered representative.

The geochemical and geohydrological data sets derived from the time-series sampling indicate that the shallow aquifer is not a continuous source of the contamination detected in the deeper aquifer. During the pumping of GW27D, the concentration of nitroaromatic compounds in the shallow aquifer (Well GW27) remained relatively constant at approximately 60 µg/L. In addition, no water-level fluctuations were observed in the shallow aquifer even though drawdown of 40 ft was maintained in the underlying aquifer. These data strongly suggest that no hydraulic connection exists between the two aquifers in this study area.

Table 4.2-2. Time-Series Sampling Water-Level Measurements--
August 11-13, 1986

Date	Time	Water Level*	Comments
Well GW27			
8/11/86	1138	14.71	Prepumping
	1929	14.75	
	2225	14.83	
8/12/86	0053	14.77	
	0858	14.82	
	1210	14.77	
	1350	14.76	
	1607	14.79	
	1902	14.79	
	2245	14.78	
8/13/86	1425	14.78	
	1709	14.78	
	1811	14.79	
Well GW27D			
8/11/86	1733	16.67	Prepumping water level
	1733	16.67	Pump on; flow rate 20 gpm
	1734	43.0	
	1735	55.98	
	1736	80+	Pump wiring and hose interfering with probe access
	1740	104+/-	Water level at pump intake
	1740	104+/-	Pump off
	1822	17.38	End recovery; pump on
	1823	33.20	
	1825	51.82	10 gpm
	1826	56.30	
	1828	60.09	9 gpm
	1829	61.25	8.5 gpm
	1831	62.55	
	1834	56.32	7 gpm, adjusting flow
	1837	55.26	8 gpm
	1841	58.81	9 gpm

Table 4.2-2. Time-Series Sampling Water-Level Measurements--
August 11-13, 1986 (Continued, Page 2 of 2)

Date	Time	Water Level*	Comments
Well GW27D (Continued)			
	1844	61.11	
	1921	31.10	Discharge valve clogged
	2000	59.8	9 gpm
	2034	—	Generator out of gas
	2053	23.0	Restart
	2145	43.53	8 gpm
8/12/86	0340	47.48	
	0853	57.04	
	1216	59.85	8 gpm
	1354	59.70	8 gpm
	1605	60.46	8 gpm
	1900	61.25	
	2243	53.75	8 gpm
8/13/86	0053	54.23	8 gpm
	0555	55.07	
	1330	55.66	9 gpm
	1430	55.75	
	1707	56.02	
	1808	56.48	9 gpm
	1830	56.59	Pump off

*Water-level measurements in feet from top of PVC casing.

Source: ESE, 1987.

Table 4.2-3. Chemical Results of Time-Series Sampling of Monitor Well GW27 (Shallow Aquifer)

Parameter	Date:	08/11/86				08/12/86		08/13/86
	Time:	1805	1830	1910	2232	0740	1830	1845
pH, field (standard units)		5.94	6.62	6.00	6.40	6.29	6.94	6.06
Specific conductance, field (μmho/cm)		88.0	89.0	94.0	110	110	102	102
Water temperature (°C)		16	17	16	14	13	16	16
Nitrobenzene (μg/L)		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
1,3-DNB (μg/L)		<1*	<0.5	0.9	0.9	0.9	0.9	0.7
TNB (μg/L)		40	30	20	30	30	40	30
2,4-DNT (μg/L)		6	4	5	6	5	6	5
2,6-DNT (μg/L)		<4*	2	5	<8*	<8*	<8*	<8*
2,4,6-TNT (μg/L)		30	30	10	20	20	20	20
Total nitroaromatics† (μg/L)		80	70	40	60	60	70	60
Nitrate + nitrite (μg/L as N)		1,000	1,000	1,000	1,000	1,000	1,000	1,000

*Refer to Sec. 4.2.2, paragraph 3.
†Arithmetic sum of the six nitroaromatic isomers (calculated).

Note: N = nitrogen.

Source: ESE, 1987.

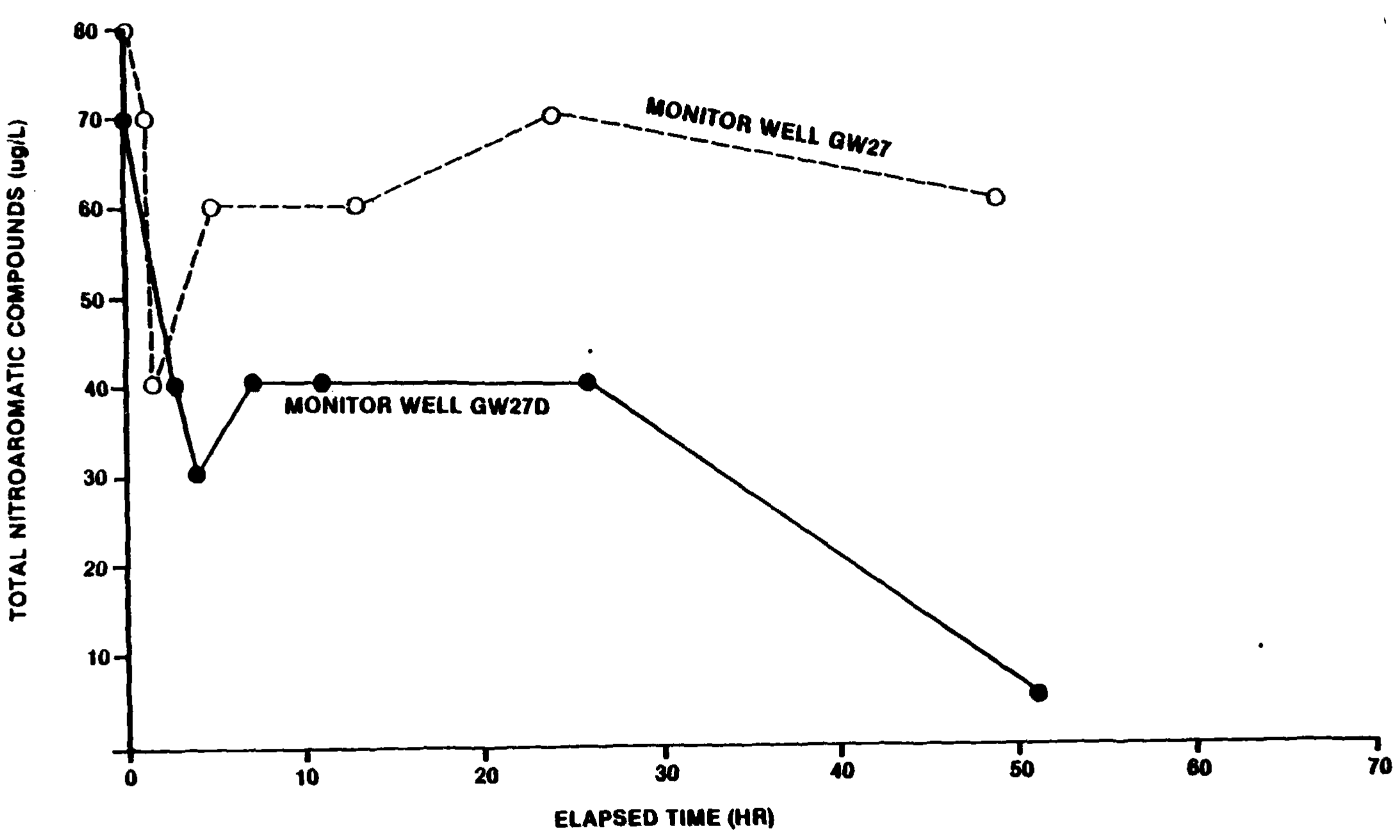
Table 4.2-4. Chemical Results of Time-Series Sampling of Monitor Well GW27D (Deep Aquifer)

Parameter	Date:	08/11/86				08/12/86		08/13/86
	Time:	1512	1748	1855	2215	0210	1757	1810
pH, field (standard units)		8.30	8.00	7.02	8.30	6.94	9.07	9.20
Specific conductance, field (μmho/cm)		180	201	209	215	220	265	280
Water temperature (°C)		17	18	16	26	14	16	17
Nitrobenzene (μg/L)		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
1,3-DNB (μg/L)		5	3	2	2	2	3	2
TNB (μg/L)		50	30	20	30	30	30	<2
2,4-DNT (μg/L)		0.8	0.6	0.7	0.7	0.9	0.5	0.6
2,6-DNT (μg/L)		<4*	<4*	<4*	<4*	<4*	1	<4*
2,4,6-TNT (μg/L)		10	7	7	6	6	5	2
Total nitroaromatics† (μg/L)		70	40	30	40	40	40	5
Nitrate + nitrite (μg/L as N)		700	500	400	500	500	600	500
Alkalinity, total (mg/L as $CaCO_3$)		37.0	57.0	70.0	71.0	81.5	114	110

*Refer to Sec. 4.2.2, paragraph 3.
†Arithmetic sum of the six nitroaromatic isomers (calculated).

Note: $CaCO_3$ = calcium carbonate.
mg/L = milligrams per liter.

Source: ESE, 1987.



SOURCE: ESE, 1987.

Figure 4.2-3
RESULTS OF TIME-SERIES SAMPLING OF MONITOR WELLS
GW27 AND GW27D — YELLOW WATER RESERVOIR

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The gray clay layer, with an average thickness of approximately 20 ft, was identified on the drilling logs from the three deep wells in the area (GW27D, GW34D, and GW40D). The data from these wells provide sufficient detail to accurately define the continuity of the clay at this study area. Vertical flow from the shallow contaminated aquifer to the deeper zone, through the clay layer, was estimated to occur at a rate of 1.7×10^{-4} ft/day (see Sec. 3.3). It is unlikely, therefore, that the contaminant levels detected in Well GW27D are the result of shallow contamination migrating through the clay layer. The break in the drive casing described in Sec. 4.1.3 is the most realistic source of the observed contamination in the deeper aquifer.

Using the geohydrological parameters developed for the Yellow Water Reservoir and the timing of certain key events, the radius of the area around Well GW27D affected by the drilling and time-series sampling can be estimated. The ground water flow rate in the deeper aquifer at this study area was found to be 6×10^{-3} ft/day. Approximately 4 months (122 days) elapsed between the temporary interconnection of the deep and shallow aquifers and the initiation of the time-series sampling. During this time, contaminants introduced during drilling at GW27D may have migrated up to 1 ft from the well under the influence of the natural ground water gradient. Therefore, it may be assumed that the contaminants introduced at Well GW27D had not migrated a significant distance from the well by the time the time-series sampling was initiated.

During the time-series sampling, approximately 26,000 gallons (gal) of water was extracted from the deeper aquifer. A first approximation of the volume of saturated aquifer affected by this quantity of pumping can be calculated as follows:

$$V = \frac{\text{volume of water extracted (gal)}}{[7.48 \text{ gal/ cubic feet } (ft^3)] \text{ porosity}}$$

$$V = \frac{26{,}000}{(7.48) \times (0.25)}$$

$$V = 13{,}900 \ ft^3$$

where: V = volume of aquifer affected by pumping.

Using the assumption that the thickness of the aquifer that yielded water to Well GW27D during the pumping was equal to the thickness of the screened interval (15 ft), the radius of a circular area around the well affected by the pumping can be estimated as follows:

$$r = \sqrt{\frac{\text{volume of aquifer } (ft^3)}{\text{effective thickness (ft)} \times (\pi)}}$$

$$r = 17 \ ft$$

where: r = radius of aquifer affected by pumping.

Additional data which would allow further refinement of the calculation of the radius of the affected area around the well are not available.

Well GW27D is located approximately 30 ft east (upgradient) of the locations of the first two attempts to construct the well. The well log, described previously, seems to indicate that no contamination was introduced to the deeper aquifer during the drilling at the first two well sites. Therefore, the ground water in the vicinity of the two borings may be expected to be free from nitroaromatic contamination. Additionally, because each of the two initial well bores was abandoned by grouting, an unnatural source of high alkalinity and pH (i.e., the grout) is present in the vicinity of the abandoned borings. The low ground water gradient in the deeper aquifer would not have allowed this source of high alkalinity and pH to dissipate in the period of time since emplacement of the grout.

Review of the geochemical data from the time-series sampling indicates the following:

1. After initial fluctuations in the concentration of total nitroaromatics caused by initiation of pumping, the contaminant level temporarily equilibrated at a value of approximately 40 µg/L.
2. The final sample obtained just prior to cessation of pumping indicated a dramatic reduction in the level of total nitroaromatic contamination.
3. Coincident with the reduction of detected nitroaromatic contamination, an increase in both alkalinity and pH was detected.
4. Throughout the duration of the time-series pumping, the nitrate + nitrite levels remained constant.

The equilibrium (temporary) value of 40 µg/L of total nitroaromatics in the deeper aquifer is representative of the level of contamination in the vicinity of the well bore caused by the temporary interconnection of the shallow and deeper aquifers during well construction. Estimates of potential migration of this contamination away from the vicinity of the well bore under the influence of the natural gradient presented previously indicate that insufficient time had elapsed from the time of drilling to initiation of the time-series sampling to allow significant migration of contaminants from the immediate vicinity of the well.

The first approximation (17 ft) of the radius of the aquifer zone around Well GW27D affected by the pumping may be underestimated. The increase in alkalinity and pH detected in samples collected in the later portion of the pumping period strongly suggests that ground water from the vicinity of the first two well bores was reaching Well GW27D at a much earlier time than that indicated by the approximation. As stated previously, the well logs for the first two borings do not indicate that an interconnection between the two aquifer zones was ever operative, suggesting that the ground water in the vicinity of the bores was free from nitroaromatic contamination. If the increases in alkalinity and pH are attributed to arrival of "clean" water from 30 ft away, a decrease in the levels of nitroaromatic contamination would also be expected during the later stages of pumping as the "clean" water reached the pumped well. The chemical data for nitroaromatic compounds are consistent with this model. In comparison, levels of a naturally occurring chemical constituent of the deeper ground water (nitrate + nitrite) remained constant during the period of pumping.

The time-series sampling effectively demonstrated that the contamination of the deeper aquifer was the result of the documented temporary interconnection of the contaminated shallow aquifer with the deeper aquifer, and that the contamination has been significantly reduced by the pumping of the deeper aquifer.

4.3 RED WATER RESERVOIRS

4.3.1 REVIEW OF PHASE I RI RESULTS

During the Phase I RI, six monitor wells were installed in the vicinity of the Red Water Reservoirs. Three wells were installed immediately adjacent to the reservoirs, and three wells were installed along the lower Mill Creek drainage. As described in the Phase I RI report (ESE, 1985d), no nitroaromatic contamination was observed along the Mill Creek drainage. Contamination, however, was detected in the shallow aquifer adjacent to the former reservoirs.

4.3.2 PHASE II RESULTS

4.3.2.1 Ground Water

The Phase II RI investigations in the Red Water Reservoirs area included the installation and sampling of four additional wells plus the resampling of the six existing wells that had been installed during the initial RI survey. The locations of the four additional wells (GW45, GW45D, GW46, and GW47) are shown in Fig. 4.3-1. As shown, these wells are located northwest of the former reservoirs. Monitor wells GW45 and GW45D are a monitor well pair designed to monitor the shallow aquifer as well as the deep, confined aquifer adjacent to and downgradient of the former reservoirs. Monitor Wells GW46 and GW47 were installed to monitor the shallow aquifer downgradient of the former reservoirs. These additional wells were installed based on the pronounced ground water gradient that was observed during the Phase I RI survey. The location of the Schwartz (SHW6) well and GW33 relative to the Red Water Reservoirs area is shown on Fig. 2.1-3.

The results of the April 1986 sampling of the 10 wells in this area are given in Table 4.3-1. The areal concentration distribution of total nitroaromatics (the arithmetic sum of the individual nitroaromatic isomers) is shown in Fig. 4.3-2. The pattern of contamination observed in April 1986 was similar to the previous sampling conducted during the Phase I RI survey. As shown, no contamination was observed in Monitor

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Figure 4.3-1
LOCATIONS OF GROUND WATER MONITOR WELLS IN THE RED WATER RESERVOIRS, APRIL 1986

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Table 4.3-1. Phase II Chemical Data for Ground Water in the Red Water Reservoirs, April 1986

Parameter	Monitor Well Number and Sampling Date										
	GW29 4/24/86	GW30 4/28/86	GW31 4/24/86	GW32 4/27/86	GW32D 4/23/86	GW33 4/29/86	GW45 4/28/86	GW45D 4/26/86	GW46 4/28/86	GW47 4/28/86	SHW6 4/26/86
pH field, standard units	6.00	5.80	5.70	6.20	6.80	6.70	5.80	8.00	6.30	6.10	7.30
Specific conductance, field (μmho/cm)	243	214	225	212	196	606	264	287	286	401	500
Water temperature (°C)	15	14	14	17	12	12	15	15	15	14	17
Nitrobenzene (μg/L)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5*	<0.5
1,3-DNB (μg/L)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	2	0.4	2	1
TNB (μg/L)	<2	10	<2	2	<2	<10.0†	90	<2	<2	<20*	<2
2,4-DNT (μg/L)	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	7	<0.3	<0.3	30	<0.3
2,6-DNT (μg/L)	<0.8	2	<0.8	<0.8	<0.8	<0.8	20	<0.8	<0.8	<8*	<0.8
2,4,6-TNT (μg/L)	<0.08	2	<0.08	<0.08	<0.08	<0.2†	30	0.3	1	5	0.2
Total nitroaromatics** (μg/L)	<3.9	10	<3.9	<3.9	<3.9	<11.8	100	2	1	40	1

*Refer to Sec. 4.1, paragraph 3.
†Refer to Sec. 4.1, paragraph 4.
**Arithmetic sum of the six nitroaromatic isomers (calculated).

Source: ESE, 1987.

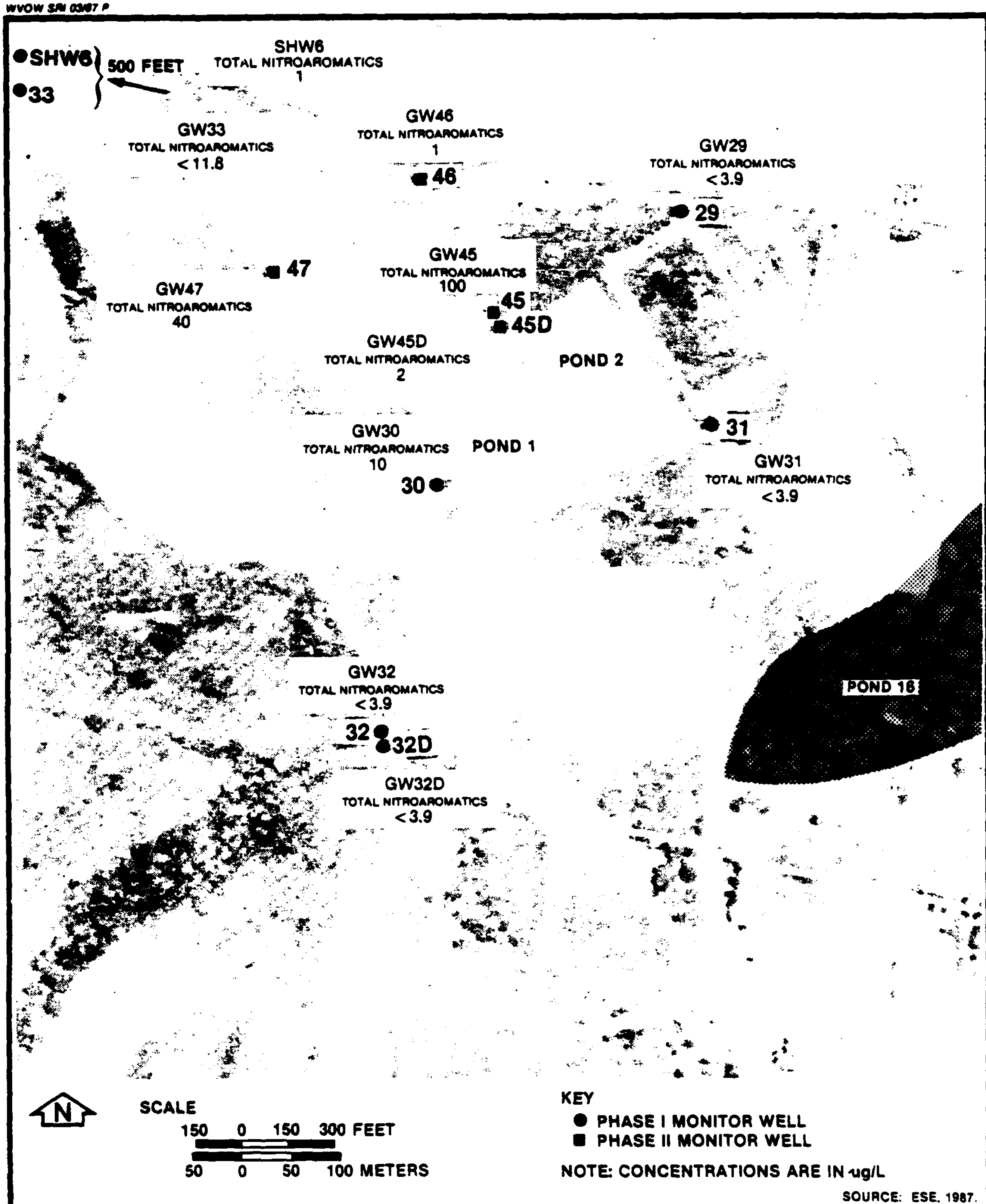

Figure 4.3-2
TOTAL NITROAROMATIC CONCENTRATIONS IN THE GROUND WATER IN THE RED WATER RESERVOIRS, APRIL 1986

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Wells GW29, GW31 (located adjacent to but upgradient of the reservoirs) and GW32, GW32D, or GW33 (located along the Mill Creek drainage). The April 1986 sample from Monitor Well GW33 did not contain detectable nitroaromatics. Because of low spike recoveries in the QC samples, the detection limits for 2,4,6-TNT and TNB were raised to the 2X and 5X detection limits, respectively (where X represents the analytical detection limit for the certified method). Although the detection limits were elevated for this sample, the 2,4,6-TNT limit of 0.16 µg/L provides an adequate data point to indicate that the well is unaffected by nitroaromatic contamination.

As shown in Table 4.3-1 and Fig. 4.3-2, nitroaromatic compounds were detected in Monitor Wells GW30, GW45, GW45D, GW46, GW47, and SHW6, all of which are located downgradient of the former reservoirs. Well SHW6 and GW33 are off the scale of Fig. 4.3-2 and are shown on the site map, Fig. 2.1-3. Total nitroaromatic compounds ranged from 2 to 200 µg/L in the downgradient shallow aquifer. The concentration of nitroaromatics observed in Monitor Well GW30 (10 µg/L) was approximately the same as the level reported during the previous RI survey (16.6 µg/L). The highest concentration (200 µg/L) was observed in the shallow aquifer at Monitor Well GW45, which is located immediately downgradient of the former reservoirs.

These additional data indicate contaminant migration has occurred beyond the McClintic Wildlife Station property boundary. In addition, the April 1986 sampling of the Shwartz well revealed low but detectable levels of 1,3-DNB (1 µg/L) and 2,4,6-TNT (0.2 µg/L). No nitroaromatic contamination of the Shwartz well was reported in the 1985 sampling. A review of the chromatograms generated during the 1985 analysis indicated that contaminant peaks were identifiable but were below the 1985 certified detection limits. This well is not utilized as a potable source.

The deep well (GW45D) installed downgradient of the former reservoirs contained detectable levels of 1,3-DNB and 2,4,6-TNT (see Table 4.3-1). This well was screened in the deep aquifer below the gray clay confining bed. This well and Monitor Wells GW45 and GW47 were resampled during August 1986 (see Table 4.3-2). Contaminant levels observed in GW45 and GW47 were consistent with the results of the April 1986 sampling. The concentrations observed in the deep well GW45D warranted a thorough evaluation. In GW45D, the concentration of total nitroaromatics increased from 2 µg/L in April to 7 µg/L in August. The increase was due to a marked rise in the 1,3-DNB concentration, which increased from 2 µg/L in April 1986 to 7 µg/L in August 1986. However, during this same period, the concentration of 2,4,6-TNT decreased from 0.3 µg/L to below the detection limit of 0.08 µg/L. Although one constituent increased, the only other constituent detected in the April sample decreased to below the detection limit in this 4-month period. The remaining nitroaromatic compounds were below the detection limits in the April and August samples.

At these trace levels, an increase of 5 µg/L in total nitroaromatics concentration cannot be considered significant given the analytical uncertainty associated with summing the analytical results for six individual constituents. Based on the April and August results, it can be concluded that no apparent increase was evident in nitroaromatic concentration.

The areal extent and thickness of the gray clay confining layer was defined using information from Wells GW30, GW32D, GW45D, and GW47. At GW45D, the clay extended to a thickness of 23 ft. Employing water-level data from GW45 and GW45D, a vertical flow potential of 1×10^{-3} ft/day was calculated.

The continuity and thickness of the gray clay should effectively limit vertical contaminant migration to the lower aquifer. The results of the

Table 4.3-2. Phase II Chemical Data for Ground Water in the Red Water Reservoirs, August 1986

Parameter	Monitor Well GW45	GW45D	GW47
pH, field (standard units)	6.36	8.13	6.53
Specific conductance, field (µmho/cm)	210	232	291
Water temperature (°C)	15	16	16
Nitrobenzene (µg/L)	<0.5	<0.5	<0.5
1,3-DNB (µg/L)	<0.2	7	1
TNB (µg/L)	100	<2.0	<20*
2,4-DNT (µg/L)	1	<0.3	20
2,6-DNT (µg/L)	20	<0.8	<8*
2,4,6-TNT (µg/L)	40	<0.08	6
Total nitroaromatics† (µg/L)	200	7	30
Nitrite + nitrate (µg/L as N)	3,000	10	4,000
Total alkalinity (mg/L as $CaCO_3$)	NA	128	NA

*Refer to Sec. 4.2.2, paragraph 3.
†Arithmetic sum of the six nitroaromatic isomers (calculated).

Note: NA = Not analyzed.

Source: ESE, 1987.

time-series sampling at GW27D in the Yellow Water Reservoir area indicated that the low levels of contaminants may have been introduced into the deeper aquifer during well installation. A similar situation had also occurred at GW36D in the TNT Manufacturing Area. Resampling of GW36D in April 1986 indicated that contamination was not present in the deep aquifer at the TNT Manufacturing Area. Based on these circumstances, it appears likely that the contaminants were introduced to the deep aquifer during well installation.

4.3.2.2 Sediments

Sediment sampling of Ponds 1 and 2 during the initial RI survey revealed low levels of nitroaromatics in the sediments of both ponds (ESE, 1986d). In the Phase II program, vertical composite samples were collected below the interval of each Phase I sample. In addition, a large areal composite sample was collected at Pond I during the reactivity sampling program in September 1985.

The nitroaromatic concentrations observed in the Phase I and Phase II surveys were consistent (Table 4.3-3); however, the 2,4,6-TNT concentration in the reactivity composite sample (2,210 µg/g dry weight) was several orders of magnitude higher than the Phase I or II results. The samples collected in the Phase I program were discrete samples; in Phase II, vertical composite samples were collected by coring below the interval of each Phase I sample. In contrast, the reactivity areal composite sample was collected from a trench dug in a dry area of the pond during low-water conditions. The difference in the sample collection procedures may account for the difference in the observed concentrations in the reactivity program compared to the results of the Phase I and II samples. The higher concentrations observed in the sample are likely due to hot spots in the sediments encountered during the composite sampling. Further information describing the reactivity testing program in detail is contained in the FS report for the first operable unit at WVOW (ESE, 1986c).

Table 4.3-3. Phase II Chemical Data for Sediments in the Red Water Reservoirs

Parameter	Sample Designation					
	P1F	P1F2	P1F3	P2F	P2F2	P2F3
Sampling Date:	04/25/86	04/24/86	04/24/86	04/23/86	04/24/86	04/24/86
Sample Type:	VC*	VC	VC	VC	VC	VC
Sampling Interval (ft)†:	2.0 - 3.5 4.2 - 5.4**	2.0 - 3.5	2.0 - 3.5	1.7 - 4.8	2.0 - 3.8	2.0 - 3.5
Nitrobenzene (µg/g)	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
1,3-DNB (µg/g)	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
1,3,5-TNB (µg/g)	<1.6	<1.6	<1.6	<1.6	<1.6	<1.6
2,4-DNT (µg/g)	<0.10	<0.10	0.26	<0.10	1.2	0.51
2,6-DNT (µg/g)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
2,4,6-TNT (µg/g)	<0.10	<0.10	<0.10	<0.10	0.36	<0.10
Moisture (% Wet Weight)	20.4	23.5	6.4	14.2	5.2	0.9

*VC = vertical composite sample.
†Sampling interval measured from top of sediment.
**Interval from 3.5 to 4.2 ft not included in composite sample.

Source: ESE, 1987.

The concentrations observed in the Pond 1 and 2 sediments were shown to be a source of shallow ground water contamination at the Red Water Reservoirs area. In addition, the red water sewerline is considered a source of ground water contamination at other areas of WVOW and is considered a contributing source of ground water contamination at the Red Water Reservoir. The observed nitroaromatics concentration in the pond sediments, along with the contribution of the red water sewerline, is adequate to account for the observed nitroaromatic contamination in the ground water.

4.4 POND 13/WET WELL AREA

4.4.1 REVIEW OF PHASE I RI RESULTS

The Phase I investigation (ESE, 1986d) in the Pond 13/Wet Well Area involved sampling eight monitor wells: the four previously installed EPA monitor wells (NUS, 1983) plus four wells installed in the fall 1984 (ESE, 1986d). Nitroaromatic contamination was observed during the 1985 RI (ESE, 1986d) in five of the eight monitor wells. Highest concentrations were measured in the shallow, water-table aquifer near the route of the underground red/yellow water trunk sewerline and the two Wet Well Area holding basins.

4.4.2 PHASE II RESULTS

During the Phase II RI (ESE, 1986a), two additional monitor wells (GW48D and GW49) were installed to better delineate the complex geologic characteristics of this area and to provide additional areal coverage and vertical data on the extent of the contaminant plume that was observed during the 1985 sampling. As shown in Fig. 4.4-1, monitor well GW48D was installed just north of Pond 13, and GW49 was installed north and east of Pond 12. A shallow aquifer monitor well also was planned adjacent to the GW48D. The plans for installation of this well, however, were abandoned when clay was encountered during the drilling of GW48D from ground surface to a depth of approximately 75 ft. The Phase II program also included installation of a shallow water-level observation, Well OW32S, west of Well EPA04.

The results of the April 1986 sampling of all 10 wells in the Pond 13/Wet Well Area are presented in Table 4.4-1. Total nitroaromatics values indicated in Table 4.4-1 are the sum (calculated) of the six nitroaromatic compounds. The total nitroaromatic concentrations are plotted in Fig. 4.4-2 to show the spatial distribution of contamination in the shallow aquifer. The pattern of contamination shown in Fig. 4.4-2 is similar to the distribution observed during the 1985 sampling (ESE, 1986d). Highest levels of nitroaromatics (principally 2,4,6-TNT) occur

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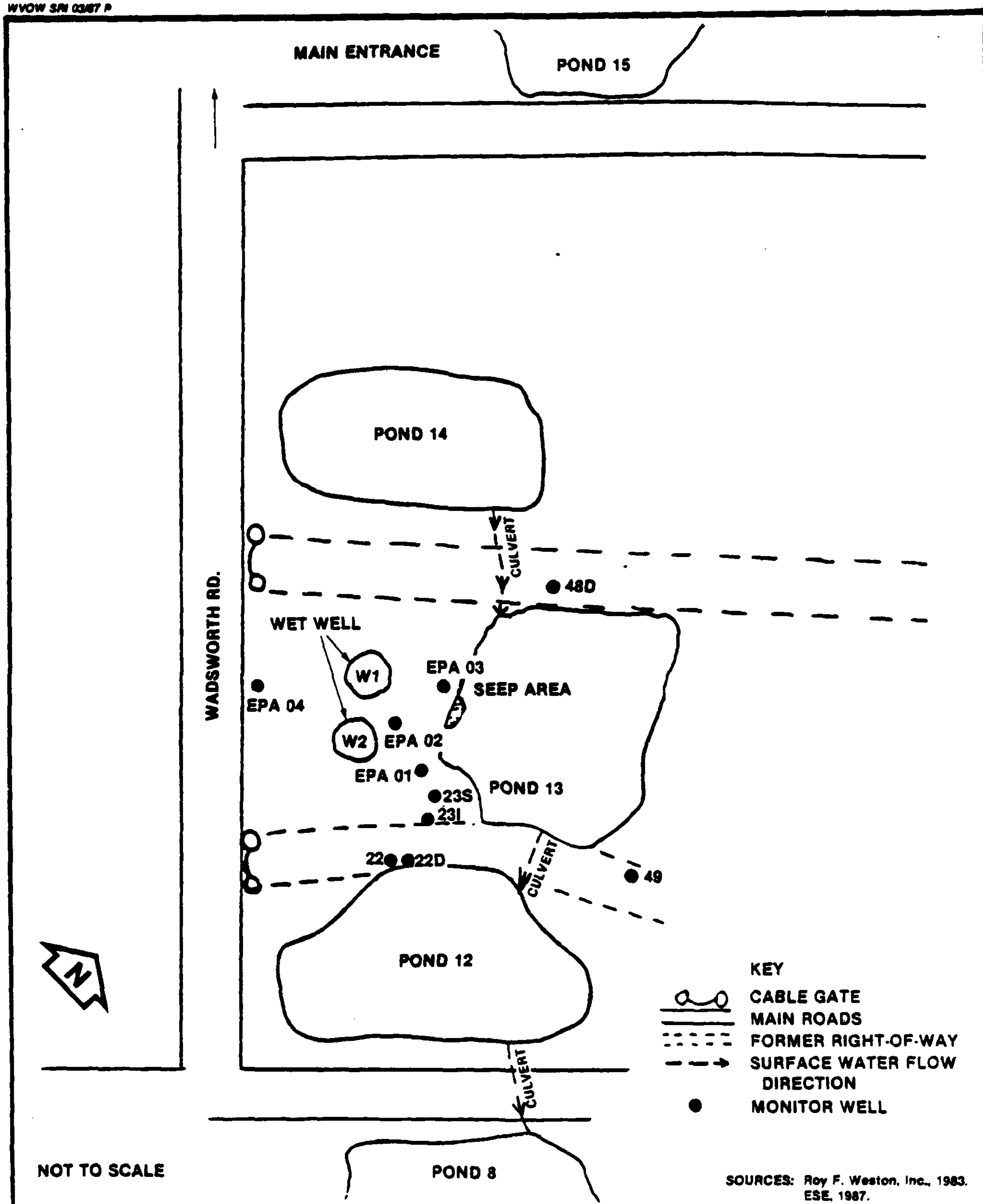

Figure 4.4-1
LOCATIONS OF GROUND WATER MONITOR WELLS IN THE POND 13/WET WELL AREA

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Table 4.4-1. Phase II Chemical Data for Ground Water in the Pond 13/Wet Well Area

Parameter	Monitor Well Number and Sampling Date										
	EPA01 4/29/86	EPA02 4/29/86	EPA03 4/29/86	EPA04 4/29/86	GW22 4/27/86	GW22D 4/26/86	GW23S 4/26/86	GW23I 4/26/86	GW48D 4/27/86	GW48D 8/13/86	GW49 4/28/86
pH, field (standard units)	6.40	5.90	6.60	6.30	6.50	6.60	6.30	5.80	6.70	6.56	5.80
Specific conductance, field (μmho/cm)	188	221	189	716	167	154	236	133	178	136	59
Water temperature (°C)	20	14	12	15	16	15	13	14	16	16	14
Nitrobenzene (μg/L)	<0.5	<5*	<50*	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
1,3-DNB (μg/L)	0.5	6	<20*	<10*	<0.2	<0.2	0.6	0.7	0.9	8	<0.2
TNB (μg/L)	<10††	40	<200†	<10†	<2	<2	<2	<2	<2	<2	<2
2,4-DNT (μg/L)	6	200	800	50	<0.3	<0.3	4	20	<0.3	<0.3	<0.3
2,6-DNT (μg/L)	<20*	20	200	<40*	<0.8	<0.8	2	5	<0.8	<0.8	<0.8
2,4,6-TNT (μg/L)	5	300	2,000	2	<0.08	<0.08	0.6	1	0.08	<0.08	<0.08
Total nitroaromatics** (μg/L)	11.5	600	3,000	50	<3.9	<3.9	7	30	1	8	<3.9

*Refer to Sec. 4.1.2, paragraph 3.
†Refer to Sec. 4.1.2, paragraph 4.
**Arithmetic sum of the six nitroaromatic isomers (calculated).

Source: ESE, 1987.

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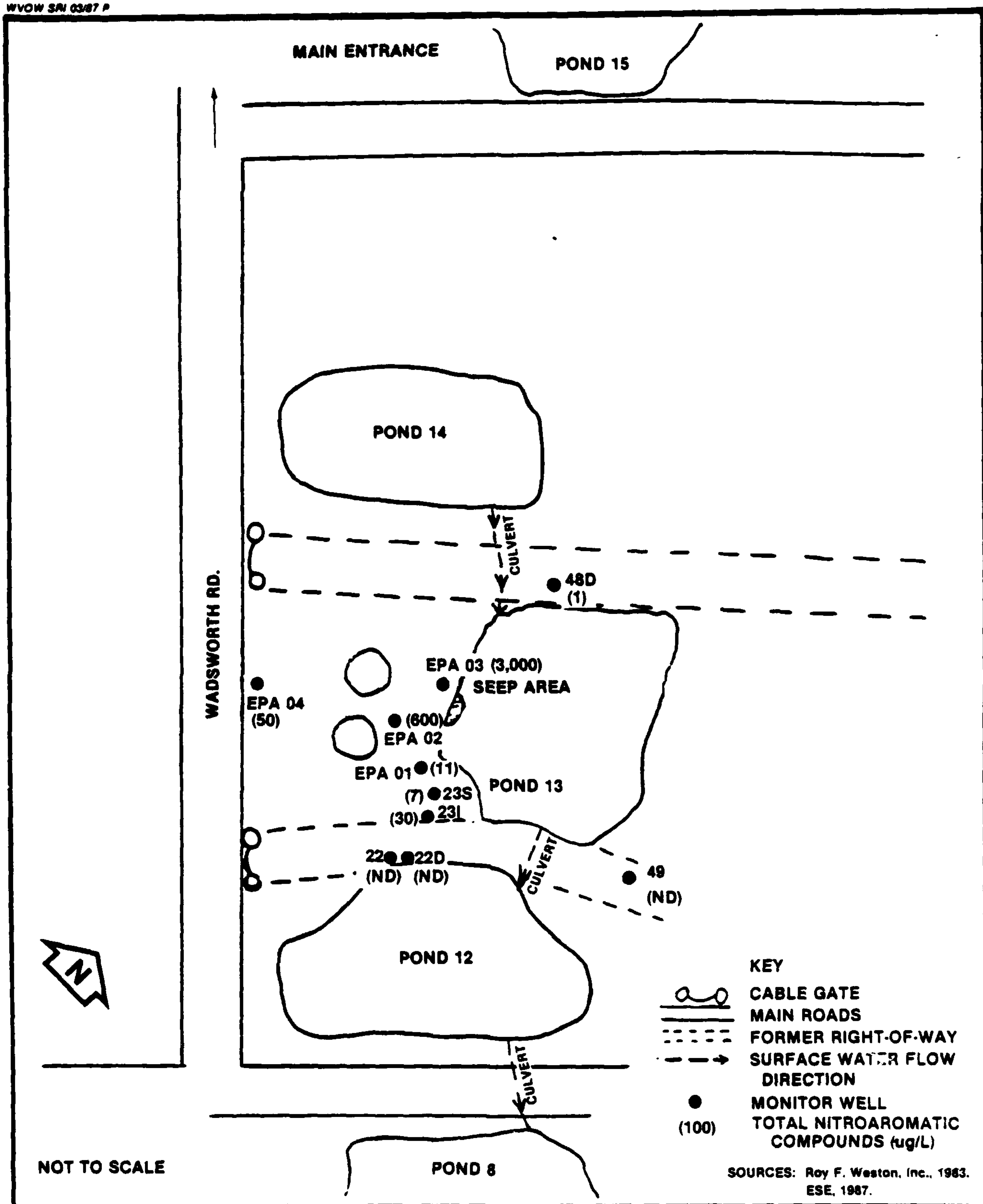

Figure 4.4-2
CONCENTRATIONS OF TOTAL NITROAROMATIC COMPOUNDS IN MONITOR WELLS AND EPA WELLS IN THE POND 13/ WET WELL AREA

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in the shallow aquifer at EPA monitor wells EPA02 and EPA03 located downgradient of the Wet Well Area and red/yellow water trunk sewerline. As shown in Fig. 4.4-2, these wells are located immediately adjacent to the area of Pond 13 in which red water seepage has occurred. No contamination was observed in GW22 or GW22D during the 1985 sampling, and no nitroaromatics were observed in these wells during the April 1986 Phase II RI. As shown in Fig. 4.4-2, no nitroaromatic contamination was detected in the new monitor well (GW49) that was installed in the shallow aquifer northeast of Pond 12.

The levels of nitroaromatic contaminants observed in April 1986 sampling are lower than the concentrations reported during the Phase I RI (ESE, 1986d). For example, the 2,4,6-TNT concentration in EPA03 was 3,000 µg/L in April 1986; in 1985, the level was 21,000 µg/L. Decreased levels of nitroaromatics also were observed for EPA02. The decreased levels in these wells during April 1986 may be attributable to differences in hydrological regimes. The 1985 sampling occurred in January (winter), and the 1986 sampling occurred in the spring (April). Additionally, the lower levels may be due to dilution by surface runoff. It was very wet during the April 1986 sampling, and a large amount of surface runoff was occurring. The grouting around EPA02 and EPA03 is cracked and deteriorating; therefore, surface runoff is not prevented from leaking into the ground water around the casing.

Based on the spatial distribution of nitroaromatic contaminant concentrations shown in Fig. 4.4-2, the contaminant plume appears to be confined to the immediate vicinity of the two wet wells at the Pond 13 area. Previous studies in this area (NUS, 1983; ESE, 1986d) confirmed that contaminant migration from the shallow aquifer was occurring in the seep area into the surface water of Pond 13. The highly contaminated shallow aquifer in the vicinity of the Wet Wells is upgradient of Pond 13. As described in the initial Phase I RI (ESE, 1986d), the concentrations of nitroaromatics in Pond 13 are greatest in the vicinity of the seep and decrease to low levels in the central and eastern portions of the pond. The observed decrease in concentration is presumably due to dilution, photolysis, and/or biodegradation.

The predominant sources of the high concentrations of nitroaromatics observed in the shallow ground water in the vicinity of Pond 13 are contaminated sediments along the sewer trunkline, contaminated subsurface soils along the bed of the trunk sewerline, and/or the sediments of the Wet Wells. The Phase I RI confirmed the existence of contaminated residues in the sewerlines and subsurface soils along the trunk sewerlines. The sediments of Wet Well No. 1 (W1) have been sampled twice--once during the Phase I RI (ESE, 1986d) and again during the reactivity sampling program. The Phase I RI sediment samples showed low levels of nitroaromatics. The sediment samples collected in September 1985 during the reactivity program, however, showed high levels of 2,4,6-TNT (4,240 μg/g). These samples were collected at a greater depth than previously sampled. During sediment coring, a strong nitroaromatic odor was apparent. Only 2,4,6-TNT was quantified analytically during the reactivity program. Based on this high level and the upgradient location, the sediments of Wet Well No. 1 may be the principal contributing source of nitroaromatic contaminants to the shallow ground water aquifer and the Pond 13 seep.

Given the uncertainty of ground water flow direction beyond the immediate vicinity of Pond 13, additional monitor well installation was considered to provide additional information to refine the shallow ground water flow gradient and to fully define the extent of contamination. While it would be helpful to expand the areal coverage of monitor wells in this area, the existing data base has adequately defined the sources of contamination, source strength, and limit of contamination. Since sufficient data exist for the purposes of the FS (and any potential remedial action, if necessary), further investigation was deemed unnecessary.

Particular attention was given to the low levels of nitroaromatics observed at Well GW48D, since this well is screened in the glacial outwash used as a potable source in the surrounding area.

As shown in Figure 3.5-1, cross section E-E' shows that a shallow sand layer was encountered at approximately the same elevation as the contaminated shallow aquifer present at the EPA wells and Well GW23S. The well log for GW48D indicates that the sand at this interval was a dark gray, fine-grained clayey sand with approximately 5 percent gravel. This sand was saturated; its thickness was 3 ft. The sand aquifer present at the EPA wells was a medium- to coarse-grained brown sand. Given this substantial difference in lithology, it was concluded that the sand present at GW48D was discontinuous and was not part of the shallow aquifer at Pond 13. As such, it seems unlikely that the isolated sand unit at GW48D would be contaminated such that this layer could account for the observed contamination at GW48D.

It is interesting to note that the contamination pattern observed at GW48D in the April 1986 and August 1986 samples is remarkably similar to that observed at GW45D. In April, the sample contained 1,3-DNB (0.9 µg/L) and 2,4,6-TNT (0.08 µg/L); total nitroaromatics concentration was 1 µg/L. In August, the DNB value increased to 8 µg/L, whereas the 2,4,6-TNT value decreased to below the detection limit. The remaining constituents were below the detection limits in both sampling rounds.

The concentrations of nitroaromatics observed in the August samples in GW45D and GW48D could be indicative of an analytical error; however, analytical procedures were thoroughly reviewed and no errors were detected.

The nature of the shallow sand layer indicates that it is unlikely to be the source of the contamination observed at GW48D. The analytical data are considered valid. However, the gray clay confining layer is present at Pond 13 and is of adequate areal extent and thickness such that vertical contamination should not be likely.

Water levels measured in the Phase II survey show that a minor upward gradient exists; water levels at the EPA wells are 1.5 ft lower than the observed water levels in GW22D and GW48D. This upward gradient would serve to further minimize the potential for vertical contaminant migration.

Nitroaromatic contaminants were never detected in GW22D or GW22, which are completed in the lower and upper portions of the deep aquifer. These wells are located in proximity to the wet wells; if contamination was present in the deep aquifer, it is likely that nitroaromatics would have been present in these wells.

An additional shallow monitor well, GW43, was installed adjacent to GW12D in the northern portion of the TNT Manufacturing Area (Fig. 2.1-3). Analytical results revealed the presence of low levels of 2,4-DNT and 2,4,6-TNT (App. C). The ground water elevation and contaminant levels were consistent with the levels observed elsewhere in the TNT Manufacturing Area.

5.0 SUMMARY AND CONCLUSIONS

This section summarizes the principal findings of the supplemental RI and is organized by area of concern within the second operable unit. Contaminant sources are identified, and observed levels of contamination are indicated. Contaminant extent and migration potential are discussed.

5.1 ACIDS AREA/YELLOW WATER RESERVOIR

1. Contaminant sources were identified in the Phase I survey and include the sediments of the Yellow Water Reservoir and contaminated soil in the vicinity of the neutralization chamber.
2. Nitroaromatic contamination exists in the shallow aquifer. The contamination is limited in areal extent.
3. The gray clay confining layer is present at the Yellow Water Reservoir and acts as an effective barrier to vertical contaminant migration.
4. The contamination detected in the deep aquifer in April 1986 was attributed to shallow aquifer contamination being carried into the deep aquifer during drilling. The data obtained during the time-series sampling of GW27D and the resampling of GW36D confirmed this theory.
5. Ground water flow direction in the shallow aquifer is to the west; ground water flow in the deep aquifer is to the north.

5.2 RED WATER RESERVOIRS

1. The source strength of the sediments of Pond 1 and Pond 2 was refined through the sampling and analysis of deep sediment cores. Low levels of nitroaromatics were detected in several of the deeper sediment samples.
2. Nitroaromatic contamination was detected in the shallow ground water at Monitor Wells GW30, GW45, GW46, GW47, and SHW6. At SHW6, located at SR 62, the contamination is present at very low

levels (0.2 µg/L 2,4,6-TNT); the downgradient limit of contamination is projected to occur at or immediately west of SR 62.

3. The gray clay confining layer is present at the Red Water Reservoirs and acts as an effective barrier to vertical contaminant migration.
4. The apparent low-level contamination detected in the deep aquifer in 1986 is attributed to shallow contamination being carried into the deep aquifer during drilling. The data obtained during the time-series sampling of GW27D and the resampling of GW36D support this theory.
5. Ground water flow direction in the shallow aquifer is to the northwest; ground water flow in the deep aquifer is expected to have a northerly component.

5.3 POND 13/WET WELL AREA

1. The highest levels of nitroaromatics (principally 2,4,6-TNT) occur in the shallow aquifer downgradient of the Wet Well Area and red/yellow water trunk sewerline.
2. The contaminant plume appears to be confined to the immediate vicinity of the two wet wells at the Pond 13 area.
3. The shallow sand aquifer appears to be areally limited and is bounded by clay-dominant sediments observed at GW48D to the north and GW22D to the east.
4. The gray clay confining layer is present at Pond 13 and acts as an effective barrier to vertical migration.
5. Based on the water levels measured in the RI (ESE, 1986d) and supplemental RI (ESE, 1986a), essentially no direction of ground water flow can be established for the shallow aquifer.
6. The hydraulic head observed in the deep monitor wells is higher than those observed in the shallow aquifer, further substantiating the conclusion that vertical contaminant migration at Pond 13 is unlikely.

7. Although the substantial clay deposits below the contaminated shallow aquifer should constitute an effective barrier to downward contaminant migration, low levels of nitroaromatics were observed in the deep aquifer at GW48D.
8. The contamination observed at GW48D appears to be an isolated, localized occurrence.

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Table A-1. WWOW Monitor Well Development Data—Installation and Development Dates, Static Water Level, and Net Fluid Loss During Drilling

Well Desig- nation	Dates* Installation	Development	Static Water Level† Before Development (ft)	After Development (ft)	Net Fluid Loss During Drilling (gal)
Phase I Monitor Wells					
GW1	Oct. 24-25	Nov. 8, 10	43.73	44.3	39
GW3	Oct. 25	Oct. 30	8.6	7.5	23
GW4	Oct. 21-22	Oct. 30	17.7	17.9	35
GW5	Nov. 26-27	Dec. 10-11	14.9	14.2	48
GW6	Nov. 6-7	Nov. 13	13.2	13.5	20
GW7	Oct. 29-31	Nov. 14	45.4	46.5	60
GW8	Oct. 29	Nov. 3-Dec. 13	19.1	18.4	30
GW9	Oct. 27	Oct. 31-Nov. 17	17.5	16.5	26
GW9D	Oct. 26-27	Oct. 31	26.4	27.0	37
GW10	Oct. 16	Oct. 21	22.1	21.8	20
GW10D	Oct. 15-16	Oct. 22, 24	32.6	32.4	55
GW11	Oct. 17	Oct. 25	27.1	27.0	28
GW12D	Oct. 19-21	Nov. 12-13	25.0	25.1	85
GW13	Oct. 21-22	Oct. 27	13.7	17.2	115
GW14	Oct. 19	Oct. 21	23.4	23.9	25
GW15	Nov. 13-14	Nov. 15	19.3	19.6	0
GW16	Oct. 24	Oct. 27-29	11.5	11.9	150
GW17	Oct. 24	Oct. 29-Dec. 14	16.3	16.4	0
GW18	Nov. 15	Nov. 16-17	7.9	7.7	70
GW19	Oct. 18	Oct. 24	24.3	24.3	31
GW20	Oct. 18	Oct. 31	31.3	31.2	33
GW21	Oct. 25	Oct. 30-Nov. 26	8.8	10.6	100
GW21D	Nov. 7-8	Nov. 8-11	Flowing	Flowing	50
GW22	Oct. 13-14	Oct. 19	1.7	1.6	47
GW22D	Oct. 8, 12	Oct. 17, 21	Flowing	Flowing	40
GW23S	Oct. 30	Nov. 6	5.7	5.8	25
GW23I	Oct. 30-31	Nov. 5-6	6.8	6.4	70
GW24	Nov. 1	Nov. 5	13.1	13.2	60
GW25	Nov. 11	Nov. 14	20.4	20.6	18
GW25D	Nov. 8, 11	Nov. 14	38.9	39.4	26
GW26	Nov. 2	Nov. 5	17.5	17.5	0
GW27	Oct. 20-21	Oct. 25	14.3	14.5	325
GW28	Nov. 2	Nov. 7	12.8	12.9	65
GW29	Oct. 16-17	Oct. 26	38.1	38.1	150
GW30	Oct. 18	Oct. 26	32.2	32.2	0
GW31	Oct. 17-18	Oct. 26	33.8	33.8	200
GW32	Oct. 19-20	Oct. 27-Dec. 20	10.2	11.80	300

Table A-1. WVOW Monitor Well Development Data—Installation and Development Dates, Static Water Level, and Net Fluid Loss During Drilling (Continued, Page 2 of 2)

Well Desig-nation	Dates*		Static Water Level†		Net Fluid Loss During Drilling (gal)
	Installation	Development	Before Development (ft)	After Development (ft)	
Phase I Monitor Wells (Continued)					
GW32D	Nov. 29-30	Dec. 11	14.2	13.6	34
GW33	Dec. 1	Dec. 12-20	10.3	9.3	5
GW34	Nov. 14	Nov. 16	21.0	20.2	125
GW34D	Nov. 12, 14	Nov. 16	28.3	32.0	60
GW35	Oct. 31-Nov. 1	Nov. 8-11	2.9	3.6	200
GW36D	Nov. 27, 29	Dec. 11	30.8	20.4	54
GW37	Nov. 12-13	Nov. 15-Dec. 20	25.4	24.8	75
GW38	Nov. 5-6	Nov. 9-Dec. 14	3.2	1.9	125
GW39	Nov. 6-7	Nov. 13-15	3.3	4.1	75
GW40	Nov. 16	Nov. 18	26.4	26.8	70
GW40D	Nov. 16-17	Nov. 18	27.0	28.1	0
GW41	Nov. 3	Nov. 7	14.0	14.0	75
GW42	Nov. 8	Nov. 15	17.8	15.5	75
Phase II Monitor Wells					
GW27D	Mar. 30-Apr. 1	Apr. 3	16.4	17.0	324
GW43	Mar. 12	Mar. 19	20.0	20.1	44
GW44	Apr. 2	Apr. 4	14.0	14.0	50
GW45	Mar. 16-17	Mar. 20	42.5	42.5	69
GW45D	Mar. 13-16	Mar. 20	45.6	46.6	169
GW46	Mar. 17-18	Mar. 20	42.1	42.2	70
GW47	Apr. 2-3	Apr. 5	49.9	50.4	80
GW48D	Mar. 21-23	Mar. 25	7.3	7.3	218
GW49	Mar. 18-19	Mar. 21	8.6	8.7	85

*Phase I wells were installed and developed in 1984; Phase II wells were installed and developed in 1986.
†Water levels measured from top of casing.

Sources: ESE, 1986a, d.

Table A-2. WVOW Monitor Well Development Data—Fluid in Well Prior to Development, Well Depth, Screen Length, and Stickup

Well Designation	Fluid in Well Prior to Development (gal)		Well Depth—Top of Casing to Bottom of Screen (ft)	Screen Length (ft)	Well Depth—Top of Casing to Top of Sediment (ft)		Stickup (ft)
	Casing	Annulus			Before	After	
Phase I Monitor Wells							
GW1	39.0	9.0	92.2	15.0	91.2	92.2	2.5
GW3	14.5	15.4	31.0	15.0	29.9	30.8	2.5
GW4	20.2	15.4	48.7	15.0	48.6	48.7	2.15
GW5	34.5	21.6	69.4	14.5	63.6	69.0	2.4
GW6	21.7	25.7	46.3	15.0	46.2	46.3	2.5
GW7	28.5	20.5	89.5	15.0	87.6	89.7*	2.5
GW8	12.0	19.0	31.7	15.0	30.75	31.7	2.5
GW9	9.0	9.0	36.5	15.0	36.1	36.2	2.3
GW9D	38	15.4	85.0	15.0	85.0	85.0	2.3
GW10	12	7.6	33.8	15.0	33.3	33.6	2.2
GW10D	39	15.4	92.4	15.0	91.2	91.5	2.5
GW11	9.0	12.0	39.5	15.0	39.5	39.5	2.5
GW12D	48.0	10.0	97.0	15.0	91.9	97.1*	2.5
GW13	18.8	29.6	42.5	15.0	41.2	42.1	2.5
GW14	11.9	7.6	35.0	15.0	34.8	34.9	2.6
GW15	4.8	15.4	26.6	10.0	26.7	26.5	2.6
GW16	4.1	7.7	17.8	5.0	17.4	17.4	2.5
GW17	9.0	14.2	29.5	15.0	28.6	29.1	2.5
GW18	5.6	15.4	16.6	10.0	16.3	16.8*	2.6
GW19	6.5	9.0	34.0	15.0	33.7	33.7	2.5
GW20	8.4	9.0	40.3	15.0	40.4	40.4*	2.5
GW21	7.8	8.4	28.2	10.0	27.9	29.0†	2.5
GW21D	40.8	20.6	62.2	15.0	62.3	62.4*	2.5
GW22	46	15.4	73.1	15.0	68.6	72.2	2.5
GW22D	70	15.4	108.3	15.0	106.8	106.9	2.5
GW23S	37	58.3	17.0	10.0	16.3	17.0	2.5
GW23I	66	104	27.0	15.0	25.5	26.8	2.5
GW24	43.5	68.5	26.5	15.0	26.5	26.6*	2.5
GW25	7.0	20.6	31.5	15.0	31.1	31.2	2.5
GW25D	15.0	21.6	62.5	15.0	61.8	61.9	2.5
GW26	4.9	26.0	25.5	10.0	25.4	25.2	2.5
GW27	17.4	15	41.0	15.0	40.5	40.8	2.5
GW28	44.7	70.5	26.5	15.0	26.1	26.2	2.5
GW29	6.4	10.0	47.9	15.0	46.8	47.7	2.5
GW30	4.0	7.0	38.0	10.0	37.8	37.8	2.5
GW31	9.8	15.4	49.0	20.0	48.9	48.9	2.5
GW32	19.8	26.8	40.5	15.0	39.3	40.4	2.5

Table A-2. WVCW Monitor Well Development Data—Fluid in Well Prior to Development, Well Depth, Screen Length, and Stickup (Continued, Page 2 of 2)

Well Designation	Fluid in Well Prior to Development (gal)		Well Depth—Top of Casing to Bottom of Screen (ft)	Screen Length (ft)	Well Depth—Top of Casing to Top of Sediment (ft)		Stickup (ft)
	Casing	Annulus			Before	After	
Phase I Monitor Wells (Continued)							
GW32D	35.4	20.0	68.5	15.0	67.5	68.2	2.5
GW33	9.6	15.0	25.0	15.0	25.0	24.8	2.5
GW34	9.8	20.4	37.0	20.0	36.0	36.9	2.5
GW34D	60.5	25.7	116.5	15.0	120.9	115.3	2.5
GW35	28.8	45.3	47.0	15.0	46.2	47.5†	2.5
GW36D	40.5	20.1	95.0	15.0	91.2	94.6	2.2
GW37	6.3	15.4	35.0	10.0	32.8	34.4	2.5
GW38	20.8	20.6	35.0	15.0	33.4	34.8	2.5
GW39	25.7	18.9	32.5	20.0	31.5	32.2	2.5
GW40	8.8	20.1	39.9	15.0	39.6	39.8	2.6
GW40D	43.0	26.0	93.0	20.0	88.8	91.4	2.5
GW41	47.2	74.4	28.5	15.0	28.4	28.5	2.5
GW42	6.0	20.6	26.8	15.0	27.3*	27.0*	2.5
EPA01**	NA	NA	13.0	5.0	NA	NA	3.92
EPA02	NA	NA	10.5	5.0	NA	NA	3.50
EPA03	NA	NA	12.33	5.0	NA	NA	3.00
EPA04	NA	NA	24.0	5.0	NA	NA	4.00
Phase II Monitor Wells							
GW27D	57.2	13.5	104.7	15.0	102.8	102.8	2.2
GW43	12.2	11.0	37.2	15.0	37.2	37.2	2.2
GW44	15.0	11.8	37.2	15.0	37.0	37.1	2.2
GW45	9.9	9.0	57.2	15.0	56.6	57.3	2.2
GW45D	40.3	13.6	108.2	15.0	107.4	107.4	2.2
GW46	9.9	8.9	57.2	15.0	56.8	57.1	2.2
GW47	10.4	9.4	66.2	15.0	65.8	66.1	2.2
GW48D	65.4	17.0	109.2	20.0	107.5	107.7	2.2
GW49	18.0	12.7	36.2	15.0	35.9	36.1	2.2

* Measurement errors of $\leq$0.2 ft due to difficulty in sounding wells to determine sediment thickness.

† Probable measurement error by field personnel.

**EPA well construction details are included for comparison purposes.

NA = Not applicable.

Sources: ESE, 1986a, d.

Table A-3. WVOW Monitor Well Development Data—Required Volume, Quantity Removed, Time for Removal, Type of Pump Used for Development, and Physical Characteristics of Water Before and After Development

Well Designation	Required Volume (gal)	Quantity Removed (gal)	Time for Removal	Type of Pump Used for Development	Physical Characteristics of Water: Before Development	Physical Characteristics of Water: After Development
GW1	435	1,641	3.2 hr	Submersible	Turbid/red silty solids	Slightly turbid/ red sility solids
GW3	210	320	1.1 hr	Centrifugal	Turbid/red-brown suspended solids	Clear
GW4	353	375	1.3 hr	Submersible	Turbid/gray suspended solids and sediment	Slight turbidity/ trace suspended solids
GW5	520	608	1.4 hr	Submersible/ Centrifugal	Very turbid/gray silty suspended solids	Slight turbidity/ gray silty solids
GW6	337	374	2.0 hr	Submersible	Turbid/brown silty suspended solids	Clear/trace suspended solids
GW7	545	823	3.4 hr	Submersible	Turbid/gray silty solids	Clear/fine gray silty solids
GW8	305	300	8 days	Centrifugal	Turbid/light brown silty suspended solids	Clear
GW9	220	226	6 days	Centrifugal/ Submersible	Very turbid/light gray suspended solids	Turbid/gray suspended solids
GW9D	452	632	1.3 hr	Submersible	Very turbid/gray suspended solids	Less turbid/gray suspended solids
GW10	198	300	1 hr	Centrifugal	Very turbid/red-brown suspended solids	Clear/slight red-brown suspended solids
GW10D	547	920	2.0 days	Submersible	Very turbid/gray suspended solids	Less turbid/gray suspended solids
GW11	245	920	1.9 hr	Submersible	Very turbid/red-brown suspended solids	Clear/slight red-brown suspended solids
GW12D	715	1,008	2.0 days	Submersible	Very turbid/red-gray silty solids	Clear
GW13	817	840	2.5 hr	Submersible	Highly turbid/ brown very silty solids	Clear
GW14	222	250	1 hr	Centrifugal	Very turbid/red-brown suspended solids	Clear/trace of red-brown settleables
GW15	101	231	1.2 hr	Submersible	Very turbid/red-suspended solids	Clear
GW16	810	820	3 days	Submersible	Very turbid/yellow-brown silty solids	Clear

Table A-3. WVOW Monitor Well Development Data—Required Volume, Quantity Removed, Time for Removal, Type of Pump Used for Development, and Physical Characteristics of Water Before and After Development (Continued, Page 2 of 4)

Well Designation	Required Volume (gal)	Quantity Removed (gal)	Time for Removal	Type of Pump Used for Development	Physical Characteristics of Water: Before Development	Physical Characteristics of Water: After Development
GW17	492	495	27 days	Centrifugal	Very turbid, dark brown, silty	Clear
GW18	455	455	2.0 days	Centrifugal	Very turbid/red silty suspended solids	Clear
GW19	235	525	1.8 hr	Centrifugal	Very turbid/red-brown suspended solids	Clear/no visible solids
GW20	250	530	1.3 hr	Submersible	Very turbid/red-brown suspended solids	Clear
GW21	397	314	14 days	Centrifugal	Very turbid/gray suspended solids	Slightly turbid/gray suspended solids
GW21D	557	2,440	3 days	Centrifugal	Turbid/gray-brown suspended solids	Slightly turbid/gray-brown fines
GW22	542	570	3.0 hr	Submersible	Very turbid/gray suspended solids	Clear
GW22D	627	2,120	2 days	Centrifugal	Very turbid/gray suspended solids	Clear/slight gray suspended solids
GW23S	220	323	0.5 hr	Centrifugal	Very turbid/red-gray suspended solids	Clear
GW23I	551	680	1.8 hr	Centrifugal	Very turbid/gray suspended solids	Clear
GW24	412	440	0.8 hr	Centrifugal	Very turbid/red suspended solids	Clear
GW25	230	480	1 hr	Submersible	Very turbid/red suspended solids	Clear/slight red suspended solids
GW25D	313	623	1.4 hr	Submersible	Very turbid/red suspended solids	Clear
GW26	39	198	0.5 hr	Centrifugal	Very turbid/red suspended solids	Clear
GW27	1,787	2,340	2.0 hr	Centrifugal	Very turbid/red-brown suspended solids	Clear/slight yellow tint to water
GW28	440	509	0.9 hr	Centrifugal	Very turbid/red-gray suspended solids	Slight cloudy appearance
GW29	832	900	1.5 hr	Submersible	Turbid/brown silty solids	Slightly turbid/yellow-brown solids

Table A-3. WVCW Monitor Well Development Data—Required Volume, Quantity Removed, Time for Removal, Type of Pump Used for Development, and Physical Characteristics of Water Before and After Development (Continued, Page 3 of 4)

Well Designation	Required Volume (gal)	Quantity Removed (gal)	Time for Removal	Type of Pump Used for Development	Physical Characteristics of Water: Before Development	Physical Characteristics of Water: After Development
GW30	55	300	1.0 hr	Submersible	Very turbid/brown silty solids; sand	Slightly turbid/ light yellow
GW31	1,126	1,200	2.0 hr	Submersible	Very turbid/brown silty solids	Slightly turbid/ brown silty solids
GW32	1,740	1,197	22 days	Centrifugal	Turbid/slight brown suspended solids	Clear
GW32D	448	800	1.5 hr	Submersible	Turbid/gray suspended solids	Clear to gray-cloudy
GW33	148	149	5 days	Centrifugal	Turbid/red silty suspended solids	Slight silty suspended solids
GW34	776	927	1.7 hr	Submersible	Turbid/brown silty suspended solids	Clear
GW34D	735	832	3.5 hr	Submersible	Very turbid/brown silty suspended solids	Slightly turbid/ brown suspended solids
GW35	1,245	1,300	3.0 days	Centrifugal	Very turbid/gray suspended solids and sediments	Clear
GW36D	573	805	1.9 hr	Submersible	Very turbid/gray-brown silty solids	Slightly turbid/ gray-brown solids
GW37	290	290	11 days	Submersible	Turbid/gray suspended solids	Gray suspended solids
GW38	832	840	12 days	Centrifugal	Turbid/gray suspended solids	Clear
GW39	598	865	2 days	Centrifugal	Turbid/brown silty solids	Clear
GW40	495	855	1.6 hr	Submersible	Very turbid/red suspended solids	Clear
GW40D	573	769	8.0 hr	Submersible	Very turbid/gray silty suspended solids	Clear/light turbid gray silt
GW41	497	840	1.0 hr	Centrifugal	Very turbid/red suspended solids and sediment	Clear
GW42	510	936	1.8 hr	Submersible	Very turbid/red suspended solids	Clear/slight red silty residue

Table A-3. WVOW Monitor Well Development Data—Required Volume, Quantity Removed, Time for Removal, Type of Pump Used for Development, and Physical Characteristics of Water Before and After Development (Continued, Page 4 of 4)

Well Designation	Required Volume (gal)	Quantity Removed (gal)	Time for Removal	Type of Pump Used for Development	Physical Characteristics of Water: Before Development	Physical Characteristics of Water: After Development
27D	2,447	3,945	8.8 hr	Submersible	Turbid, organge color, heavy suspended solids.	Clear
43	336	368	55 min	Centrifugal	Turbid, strong brown, heavy suspended solids.	Very slight suspended solids, clear.
44	383	384	1.1 hr	Centrifugal	Turbid, strong brown, moderate suspended solids.	Very slight suspended solids, clear.
45	440	510	51 min	Submersible	Turbid, strong brown, heavy suspended solids.	Very low suspended solids, yellowish color.
45D	871	1,060	1.8 hr	Submersible	Turbid, very heavy suspended solids, dark gray.	Very low suspended solids, clear.
46	444	600	1.0 hr.	Submersible	Turbid, heavy suspended solids, strong brown.	Slight turbidity, strong brown, moderate suspended solids.
47	334	494	1.1 hr	Submersible	Turbid, heavy suspended solids, orange.	Slight turbidity, yellowish color.
48D	797	1,495	5 hr	Submersible	Turbid, dark gray to brown, heavy suspended solids.	Slight turbidity, yellow suspended solids.
49	578	848	1.8 hr	Centrifugal	Ver turbid, heavy suspended solids, strong brown.	Very slight turbidity, very low suspended solids.

Sources: ESE, 1986a, d.

Table A-4. WVOW Monitor Well Development Data—Temperature, Conductivity, and pH

Well Designation	Temperature (°C) Before*	During*		After*	Conductivity (µmhos/cm) Before*	During*		After*	pH Before*	During*		After*
Phase I Monitor Wells												
GW1	12.9	13.5	13.2	13.0	456	477	449	426	9.0	8.1	7.0	6.9
GW3	13.7	13.4	13.4	13.3	940	1,390	1,497	1,519	7.2	6.9	7.0	6.9
GW4	13.3	13.4	13.1	13.1	697	1,051	1,162	1,125	7.4	6.7	6.7	6.7
GW5	13.0	13.8	14.1	13.4	253	221	219	221	9.0	7.7	7.7	7.5
GW6	11.6	13.1	11.2	12.8	461	433	431	439	7.2	6.9	7.0	7.0
GW7	12.9	13.4	13.1	13.7	614	636	588	528	12.5	7.6	7.2	7.2
GW8	12.5	12.7	14.4	15.7	594	621	578	560	6.9	7.2	7.3	7.0
GW9	14.1	13.0	12.5	11.9	527	822	790	772	7.3	6.7	6.9	7.1
GW9D	13.0	12.8	12.8	12.9	263	252	251	250	8.2	7.5	7.5	7.4
GW10	14.9	14.3	13.8	14.2	355	246	226	208	7.8	7.3	6.0	5.6
GW10D	13.9	13.7	13.3	13.1	12,870	278	277	270	12.3	9.4	8.5	8.1
GW11	13.4	12.7	12.8	12.6	176	156	154	154	6.1	5.7	5.5	5.4
GW12D	12.2	12.6	11.7	12.8	446	287	239	234	10.5	10.0	9.4	9.3
GW13	13.5	12.9	13.0	13.0	245	153	135	139	7.5	5.9	5.9	5.5
GW14	15.1	15.0	15.1	15.0	355	195	187	193	6.6	6.6	5.6	5.6
GW15	12.4	13.1	13.1	13.0	237	187	187	185	5.7	4.8	5.4	5.3
GW16	17.0	15.0	16.0	15.0	250	162	161	161	6.6	5.5	5.3	5.0
GW17	15.0	14.2	15.1	16.5	223	81	176	255	6.5	6.3	5.6	5.8
GW18	13.4	13.7	14.6	14.9	271	101	101	99	6.5	6.5	5.5	5.8
GW19	15.0	14.1	13.9	13.7	303	293	269	262	6.0	5.8	6.1	5.5
GW20	13.0	12.6	12.5	12.6	181	138	130	136	5.7	5.4	5.4	5.4
GW21	14.2	13.2	17.5	15.3	483	573	537	330	6.7	6.9	7.2	6.8
GW21D	12.0	12.1	11.9	12.5	200	200	202	211	6.6	6.1	6.3	6.4
GW22	14.7	14.5	14.4	13.6	295	238	199	205	9.3	8.8	8.3	7.9
GW22D	18.2	14.1	14.1	15.2	2,280	184	181	178	11.2	8.3	7.3	6.8
GW23S	14.6	15.5	15.6	15.6	152	172	164	158	5.9	5.8	5.7	5.7
GW23I	14.4	16.5	17.0	16.9	377	202	155	138	6.6	5.8	5.6	5.4
GW24	†	†	†	†	230	64	56	49	6.2	5.6	5.3	5.2
GW25	12.3	12.5	12.5	12.5	333	81	67	60	8.7	7.4	5.7	5.5
GW25D	12.6	12.6	12.6	12.4	238	102	92	88	6.9	6.2	5.9	5.7
GW26	14.1	13.9	13.8	13.6	112	53	41	39	5.5	5.1	5.1	5.1
GW27	14.8	13.6	13.5	13.3	181	145	142	141	5.8	5.3	5.1	5.1
GW28	13.3	13.4	13.4	13.4	96	69	58	61	5.5	5.1	5.1	5.0
GW29	16.0	14.0	14.0	14.0	310	247	250	240	5.6	6.3	6.4	6.5
GW30	15.0	13.3	13.0	13.0	230	151	154	162	6.4	6.1	5.6	5.6
GW31	15.0	14.0	13.7	14.0	240	170	170	168	6.8	6.5	5.7	5.7
GW32	12.7	14.9	13.7	12.9	404	419	256	308	6.6	6.2	6.7	6.7
GW32D	11.6	11.8	12.2	12.0	2,460	220	205	195	13.8	8.4	7.0	6.8
GW33	13.6	†	14.9	12.0	630	†	579	537	7.1	†	7.1	7.0
GW34	11.7	11.9	11.9	†	168	300	351	†	6.4	5.7	5.8	†

Table A-4. WVOW Monitor Well Development Data—Temperature, Conductivity, and pH (Continued, Page 2 of 2)

Well Designation	Temperature (°C) Before*	During*		After*	Conductivity (µmhos/cm) Before*	During*		After*	pH Before*	During*		After*
Phase I Monitor Wells (Continued)												
GW34D	12.9	12.5	12.8	12.9	572	258	245	227	7.5	7.0	7.1	7.0
GW35	12.7	12.3	12.1	12.3	419	312	307	306	6.6	7.3	7.1	7.0
GW36D	12.7	12.9	13.0	12.8	5,500	302	245	229	12.4	9.6	8.3	7.4
GW37	12.8	11.3	12.5	12.3	339	361	364	391	6.4	5.8	5.9	5.9
GW38	13.5	13.4	14.1	18.1	345	321	286	244	6.7	6.8	7.5	7.1
GW39	14.4	14.1	14.2	13.9	278	283	290	286	5.9	5.8	6.6	6.3
GW40	12.0	12.5	12.4	12.7	222	201	201	200	-2.0	5.0	3.9	5.6
GW40D	12.9	12.1	13.5	†	269	169	225	†	11.5	†	7.7	†
GW41	16.6	17.0	13.9	13.9	232	194	192	190	5.5	5.1	5.1	5.0
GW42	12.9	12.5	12.7	12.6	283	63	55	49	6.1	5.9	5.4	5.4
Phase II Monitor Wells												
GW27D	18.5	20.0	19.0	19.0	325	145	140	135	10.8	6.8	6.1	6.2
GW43	14.5	13.8	14.7	14.3	088	073	075	074	5.9	5.3	5.3	5.2
GW44	18.0	18.0	18.0	18.0	285	125	090	100	10.0	7.5	6.6	6.8
GW45**	10.5	9.0	8.0	9.0	220	195	180	180	6.7	6.4	6.1	6.1
GW45D	12.0	12.0	13.0	13.0	475	230	225	215	9.8	7.7	7.5	7.2
GW46	0††	12.6	12.4	12.0	602	342	333	330	7.6	6.9	6.9	6.6
GW47	18.0	18.0	16.5	17.0	370	345	345	340	7.2	7.4	7.0	7.4
GW48D	14.0	14.5	16.0	175	125	130	130	130	7.3	6.9	6.9	7.0
GW49	10.0	10.0	11.0	11.0	075	075	055	050	6.0	6.2	6.0	6.2

*Stage of development.
†Not measured.
**Temperature readings suspect. Air temperature was -2°C, discharge was cooled as water passed through approximately 50 ft of hose at surface.
††Probe malfunction.

Sources: ESE 1986a, d.

APPENDIX C--PHASE II

CHEMICAL ANALYSES

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF CSE SAMPLES
COLLECTED FROM LOCATION: P1F (SITE TYPE - POND)

SURFACE ELEVATION (FEET)	SAMPLE ELEVATION (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
1200.8	1198.8	1.97	04/25/86	D2	NB	LT	.50000000	UGG
					13DNB	LT	.20000000	UGG
					135TNB	LT	1.59999999	UGG
					24DNT	LT	.10000000	UGG
					246TNT	LT	.10000000	UGG
					26DNT	LT	.10000000	UGG

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF CSE SAMPLES
COLLECTED FROM LOCATION: P1F2 (SITE TYPE - POND)

SURFACE ELEVATION (FEET)	SAMPLE ELEVATION (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
1200.8	1198.8	1.97	04/24/86	D2	NB	LT	.50000000	UGG
					13DNB	LT	.20000000	UGG
					135TNB	LT	1.59999999	UGG
					24DNT	LT	.10000000	UGG
					246TNT	LT	.10000000	UGG
					26DNT	LT	.10000000	UGG

ATE: 20 MAR 87

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF CSE SAMPLES
COLLECTED FROM LOCATION: P1F3 (SITE TYPE - POND)

ON	SAMPLE ELEVATION (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
.8	1198.8	1.97	04/24/86	02	NB	LT	.50000000	UGG
					13DNB	LT	.20000000	UGG
					135TNB	LT	1.59999999	UGG
					24DNT		.26500000	UGG
					246TNT	LT	.10000000	UGG
					26DNT	LT	.10000000	UGG

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF CSE SAMPLES
COLLECTED FROM LOCATION: P2F (SITE TYPE - POND)

SURFACE ELEVATION (FEET)	SAMPLE ELEVATION (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
1200.8	1197.8	2.95	04/23/86	D2	NB	LT	.50000000	UGG
					13DNB	LT	.20000000	UGG
					135TNB	LT	1.59999999	UGG
					24DNT	LT	.10000000	UGG
					246TNT	LT	.10000000	UGG
					26DNT	LT	.10000000	UGG

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF CSE SAMPLES
COLLECTED FROM LOCATION: P2F2 (SITE TYPE - POND)

SURFACE ELEVATION (FEET)	SAMPLE ELEVATION (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
1200.8	1198.8	1.97	04/24/86	D2	NB	LT	.50000000	UGG
					13DNB	LT	.20000000	UGG
					135TNB	LT	1.59999999	UGG
					24DNT		1.16000000	UGG
					246TNT		.35800000	UGG
					26DNT	LT	.10000000	UGG

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF CSE SAMPLES
COLLECTED FROM LOCATION: P2F3 (SITE TYPE - POND)

SURFACE ELEVATION (FEET)	SAMPLE ELEVATION (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
1200.8	1198.8	1.97	04/24/86	D2	NB	LT	.50000000	UGG
					13DNB	LT	.20000000	UGG
					135TNB	LT	1.59999999	UGG
					24DNT		.50600000	UGG
					246TNT	LT	.10000000	UGG
					26DNT	LT	.10000000	UGG

RUN DATE: 20 MAR 87

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL DGHW

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
		.00	34.2	08/13/86	C2	NB	LT	.50000000	UGL
			34.2			13DNB	LT	.20000000	UGL
			34.2			135TNB	LT	2.00000000	UGL
			34.2			24DNT	LT	.30000000	UGL
			34.2			246TNT	LT	.08000000	UGL
			34.2			26DNT	LT	.80000000	UGL
			34.2		K8	NIT	LT	10.00000000	UGL

RUN DATE: 20 MAR 87

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL EPA01

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
589.4	.0	.00	2.3	04/29/86	C2	NB	LT	.50000000	UGL
			2.3			13DNB		.50000000	UGL
			2.3			135TNB	LT	10.00000000	UGL
			2.3			24DNT		6.00000000	UGL
			2.3			246TNT		5.00000000	UGL
			2.3			26DNT	LT	20.00000000	UGL

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL EPA02

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
592 2	.0	.00	1.5	04/29/86	C2	NB	LT	5.00000000	UGL
			1.5			13DNB		6.00000000	UGL
			1.5			135TNB		40.00000000	UGL
			1.5			24DNT		200.00000000	UGL
			1.5			246TNT		300.00000000	UGL
			1.5			26DNT		20.00000000	UGL

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL EPA03

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
590.1	.0	.00	2.4	04/29/86	C2	NB	LT	50.00000000	UGL
			2.4			13DNB	LT	20.00000000	UGL
			2.4			135TNB	LT	200.00000000	UGL
			2.4			24DNT		800.00000000	UGL
			2.4			246TNT		2000.00000000	UGL
			2.4			26DNT		200.00000000	UGL

RUN DATE: 20 MAR 87

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL EPA04

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
593.9	.0	.00	17.5	04/29/86	C2	NB	LT	.50000000	UGL
			17.5			13DNB	LT	10.00000000	UGL
			17.5			135TNB	LT	10.00000000	UGL
			17.5			24DNT		50.00000000	UGL
			17.5			246TNT		2.00000000	UGL
			17.5			26DNT	LT	40.00000000	UGL

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL GW22

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
1200.8	63.1	14.99	63.3	04/27/86	C2	NB	LT	.50000000	UGL
			63.3			13DNB	LT	.20000000	UGL
			63.3			135TNB	LT	2.00000000	UGL
			63.3			24DNT	LT	.30000000	UGL
			63.3			246TNT	LT	.08000000	UGL
			63.3			26DNT	LT	.80000000	UGL

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL GW22D

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
1200.8	98.3	14.99	98.4	04/26/86	C2	NB	LT	.50000000	UGL
			98.4			13DNB	LT	.20000000	UGL
			98.4			135TNB	LT	2.00000000	UGL
			98.4			24DNT	LT	.30000000	UGL
			98.4			246TNT	LT	.08000000	UGL
			98.4			26DNT	LT	.80000000	UGL

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL GW23I

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
1200.8	17.0	14.99	17.0	04/26/86	C2	NB	LT	.50000000	UGL
			17.0			13DNB		.70000000	UGL
			17.0			135TNB	LT	2.00000000	UGL
			17.0			24DNT		20.00000000	UGL
			17.0			246TNT		1.00000000	UGL
			17.0			26DNT		4.00000000	UGL

RUN DATE. 20 MAR 87

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL GW23S

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
1200.8	9.5	10.01	9.5	04/26/86	C2	NB	LT	.50000000	UGL
			9.5			13DNB		.59999999	UGL
			9.5			135TNB	LT	2.00000000	UGL
			9.5			24DNT		4.00000000	UGL
			9.5			246TNT		.59999999	UGL
			9.5			26DNT		2.00000000	UGL

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF CGW SAMPLES
COLLECTED FROM LOCATION: GW27 (SITE TYPE - WELL)

SURFACE ELEVATION (FEET)	SAMPLE ELEVATION (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
609.4	571.0	38.39	04/28/86	C2	NB	LT	5.00000000	UGL
					13DNB	LT	2.00000000	UGL
					135TNB		30.00000000	UGL
					24DNT		7.00000000	UGL
					246TNT		20.00000000	UGL
					26DNT	LT	8.00000000	UGL
		38.39	08/11/86	C2	NB	LT	.50000000	UGL
					NB	LT	.50000000	UGL
					NB	LT	.50000000	UGL
					NB	LT	.50000000	UGL
					13DNB		.89999999	UGL
					13DNB		.50000000	UGL
					13DNB	LT	1.00000000	UGL
					13DNB		.89999999	UGL
					135TNB		40.00000000	UGL
					135TNB		30.00000000	UGL
					135TNB		20.00000000	UGL
					135TNB		30.00000000	UGL
					24DNT		4.00000000	UGL
					24DNT		6.00000000	UGL
					24DNT		5.00000000	UGL
					24DNT		6.00000000	UGL
					246TNT		10.00000000	UGL
					246TNT		20.00000000	UGL
					246TNT		30.00000000	UGL
					246TNT		30.00000000	UGL
					26DNT		5.00000000	UGL
					26DNT		2.00000000	UGL
					26DNT	LT	4.00000000	UGL
					26DNT	LT	8.00000000	UGL
				K8	NIT		1180.00000000	UGL
					NIT		1159.99998474	UGL
					NIT		1200.00000000	UGL
					NIT		1239.99998474	UGL
		38.39	08/12/86	C2	NB	LT	.50000000	UGL
					NB	LT	.50000000	UGL
					13DNB		.89999999	UGL
					13DNB		.89999999	UGL
					135TNB		30.00000000	UGL
					135TNB		40.00000000	UGL
					24DNT		5.00000000	UGL
					24DNT		6.00000000	UGL
					246TNT		20.00000000	UGL
					246TNT		20.00000000	UGL
					26DNT	LT	8.00000000	UGL
					26DNT	LT	8.00000000	UGL
				K8	NIT		1230.00000000	UGL
					NIT		1219.99998474	UGL

38.39	08/13/86	C2	NB	LT	.50000000	UGL
			13DNB		.70000000	UGL
			135TNB		30.00000000	UGL
			24DNT		5.00000000	UGL
			246TNT		20.00000000	UGL
			26DNT	LT	8.00000000	UGL
		K8	NIT		1200.00000000	UGL

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF CGW SAMPLES
COLLECTED FROM LOCATION: GW270 (SITE TYPE - WELL)

SURFACE ELEVATION (FEET)	SAMPLE ELEVATION (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
610.4	515.3	95.14	04/28/86	C2	NB	LT	.50000000	UGL
					13DNB		4.00000000	UGL
					135TNB		7.00000000	UGL
					24DNT		.50000000	UGL
					246TNT		5.00000000	UGL
					26DNT	LT	.80000000	UGL
		95.14	08/11/86	C2	NB	LT	.50000000	UGL
					NB	LT	.50000000	UGL
					NB	LT	.50000000	UGL
					NB	LT	.50000000	UGL
					13DNB		5.00000000	UGL
					13DNB		3.00000000	UGL
					13DNB		2.00000000	UGL
					13DNB		2.00000000	UGL
					135TNB		30.00000000	UGL
					135TNB		30.00000000	UGL
					135TNB		50.00000000	UGL
					135TNB		20.00000000	UGL
					24DNT		.80000000	UGL
					24DNT		.59999999	UGL
					24DNT		.70000000	UGL
					24DNT		.70000000	UGL
					246TNT		6.00000000	UGL
					246TNT		7.00000000	UGL
					246TNT		7.00000000	UGL
					246TNT		10.00000000	UGL
					26DNT	LT	4.00000000	UGL
					26DNT	LT	4.00000000	UGL
					26DNT	LT	4.00000000	UGL
					26DNT	LT	4.00000000	UGL
				K8	NIT		507.99999619	UGL
					NIT		724.00000000	UGL
					NIT		449.00000000	UGL
					NIT		458.99999619	UGL
		95.14	08/12/86	C2	NB	LT	.50000000	UGL
					NB	LT	.50000000	UGL
					13DNB		2.00000000	UGL
					13DNB		2.00000000	UGL
					135TNB		30.00000000	UGL
					135TNB		30.00000000	UGL
					24DNT		.89999999	UGL
					24DNT		.50000000	UGL
					246TNT		5.00000000	UGL
					246TNT		6.00000000	UGL
					26DNT	LT	4.00000000	UGL
					26DNT		1.00000000	UGL
				K8	NIT		552.99999237	UGL
					NIT		518.99999237	UGL

95.14	08/13/86	C2	NB	LT	.50000000	UGL
			130DNB		1.00000000	UGL
			135TNB	LT	2.00000000	UGL
			24DNT		.59999999	UGL
			246TNT		2.00000000	UGL
			26DNT	LT	4.00000000	UGL
		K8	NIT		544.99999237	UGL

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL GW28

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
1200.8	16.5	15.03	5.7	04/28/86	C2	NB	LT	.50000000	UGL
			5.7			13DNB	LT	.20000000	UGL
			5.7			135TNB	LT	2.00000000	UGL
			5.7			24DNT	LT	.30000000	UGL
			5.7			246TNT	LT	.08000000	UGL
			5.7			26DNT	LT	.60000000	UGL

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL GW29

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
1200.8	37.9	14.99	38.1	04/24/86	C2	NB	LT	.50000000	UGL
			38.1			13DNB	LT	.20000000	UGL
			38.1			135TNB	LT	2.00000000	UGL
			38.1			24DNT	LT	.30000000	UGL
			38.1			246TNT	LT	.08000000	UGL
			38.1			26DNT	LT	.80000000	UGL

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL GW30

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
1200.8	30.5	10.01	30.5	04/28/86	C2	NB	LT	.50000000	UGL
			30.5			130NB	LT	.20000000	UGL
			30.5			135TNB		10.00000000	UGL
			30.5			24DNT	LT	3.00000000	UGL
			30.5			246TNT		2.00000000	UGL
			30.5			26DNT		2.00000000	UGL

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL GW31

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
1200.6	36.5	19.98	36.4	04/24/86	C2	NB	LT	.50000000	UGL
			36.4			13DNB	LT	.20000000	UGL
			36.4			135TNB	LT	2.00000000	UGL
			36.4			24DNT	LT	.30000000	UGL
			36.4			246TNT	LT	.08000000	UGL
			36.4			26DNT	LT	.80000000	UGL

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL GW32

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
1200.8	30.5	14.99	13.6	04/27/86	C2	NB	LT	.50000000	UGL
			13.6			13DNB	LT	.20000000	UGL
			13.6			135TNB	LT	2.00000000	UGL
			13.6			24DNT	LT	.30000000	UGL
			13.6			246TNT	LT	.08000000	UGL
			13.6			26DNT	LT	.80000000	UGL

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL GW32D

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
1200.8	58.5	15.03	65.9	04/23/86	C2	NB	LT	.50000000	UGL
			65.9			13DNB	LT	.20000000	UGL
			65.9			135TNB	LT	2.00000000	UGL
			65.9			24DNT	LT	.30000000	UGL
			65.9			246TNT	LT	.08000000	UGL
			65.9			26DNT	LT	.80000000	UGL

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL GW33

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
1200.8	15.0	14.99	15.0	04/29/86	C2	NB	LT	.50000000	UGL
			15.0			13DNB	LT	.20000000	UGL
			15.0			135TNB	LT	10.00000000	UGL
			15.0			24DNT	LT	.30000000	UGL
			15.0			246TNT	LT	.20000000	UGL
			15.0			26DNT	LT	.80000000	UGL

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL GW34

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
1200.8	24.5	20.01	19.5	04/25/86	C2	NB	LT	.50000000	UGL
			19.5			13DNB	LT	.20000000	UGL
			19.5			135TNB	LT	2.00000000	UGL
			19.5			24DNT	LT	.30000000	UGL
			19.5			246TNT	LT	.08000000	UGL
			19.5			26DNT	LT	.80000000	UGL

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL GW34D

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
1200.8	106.5	14.99	106.6	04/25/86	C2	NB	LT	.50000000	UGL
			106.6			13DNB	LT	.20000000	UGL
			106.6			135TNB	LT	2.00000000	UGL
			106.6			24DNT	LT	.30000000	UGL
			106.6			246TNT	LT	.08000000	UGL
			106.6			26DNT	LT	.80000000	UGL

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL GW36D

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
1200.8	85.3	15.03	92.8	04/24/86	C2	NB	LT	.50000000	UGL
			92.8			13DNB	LT	.20000000	UGL
			92.8			135TNB	LT	2.00000000	UGL
			92.8			24DNT	LT	.30000000	UGL
			92.8			246TNT	LT	.08000000	UGL
			92.8			26DNT	LT	.80000000	UGL

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL GW40

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
1200.8	29.8	14.99	10.2	04/26/86	C2	NB	LT	.50000000	UGL
			10.2			13DNB	LT	.20000000	UGL
			10.2			135TNB	LT	2.00000000	UGL
			10.2			24DNT	LT	.30000000	UGL
			10.2			246TNT	LT	.08000000	UGL
			10.2			26DNT	LT	.80000000	UGL

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL GW40D

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
1200.8	80.5	19.98	27.7	04/26/86	'C2	NB	LT	.50000000	UGL
			27.7			13DNB	LT	.20000000	UGL
			27.7			135TNB	LT	2.00000000	UGL
			27.7			24DNT	LT	.30000000	UGL
			27.7			246TNT	LT	.08000000	UGL
			27.7			26DNT	LT	.80000000	UGL

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF CGW SAMPLES
COLLECTED FROM LOCATION: GW41 (SITE TYPE - WELL)

SURFACE ELEVATION (FEET)	SAMPLE ELEVATION (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
607 5	580.0	27.49	04/28/86	C2	NB	LT	.50000000	UGL
					13DNB		.80000000	UGL
					135TNB	LT	10.00000000	UGL
					24DNT		7.00000000	UGL
					246TNT		4.00000000	UGL
					26DNT		3.00000000	UGL
		27.49	08/13/86	C2	NB	LT	.50000000	UGL
					13DNB	LT	.20000000	UGL
					135TNB	LT	2.00000000	UGL
					24DNT		7.00000000	UGL
					246TNT		3.00000000	UGL
					26DNT	LT	8.00000000	UGL
				K8	NIT		961.00000000	UGL

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WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL GW42

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
1200.8	16.8	15.03	5.8	04/25/86	C2	NB	LT	.50000000	UGL
			5.8			13DNB	LT	.20000000	UGL
			5.8			135TNB	LT	2.00000000	UGL
			5.8			24DNT	LT	.30000000	UGL
			5.8			246TNT	LT	.08000000	UGL
			5.8			26DNT	LT	.80000000	UGL

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL GW43

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
612.9	16.8	.00	27.5	04/28/86	C2	NB	LT	.50000000	UGL
			27.5			13DNB	LT	.20000000	UGL
			27.5			135TNB	LT	2.00000000	UGL
			27.5			24DNT		2.00000000	UGL
			27.5			246TNT		3.00000000	UGL
			27.5			26DNT	LT	.80000000	UGL

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL GW44

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
608.6	16.8	.00	12.6	04/28/86	C2	NB	LT	.50000000	UGL
			12.6			13DNB	LT	.20000000	UGL
			12.6			135TNB	LT	10.00000000	UGL
			12.6			24DNT	LT	.30000000	UGL
			12.6			246TNT	LT	.20000000	UGL
			12.6			26DNT	LT	.80000000	UGL
			12.6	08/13/86		NB	LT	.50000000	UGL
			12.6			13DNB		2.00000000	UGL
			12.6			135TNB	LT	2.00000000	UGL
			12.6			24DNT	LT	.30000000	UGL
			12.6			246TNT	LT	.08000000	UGL
			12.6			26DNT	LT	.80000000	UGL
			12.6		K8	NIT		90.39999962	UGL

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF CGW SAMPLES
COLLECTED FROM LOCATION: GW45 (SITE TYPE - WELL)

SURFACE ELEVATION (FEET)	SAMPLE ELEVATION (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
612.2	564.6	47.57	04/28/86	C2	NB	LT	5.00000000	UGL
					13DNB	LT	2.00000000	UGL
					135TNB		90.00000000	UGL
					24DNT		7.00000000	UGL
					246TNT		30.00000000	UGL
					26DNT		20.00000000	UGL
		47.57	08/14/86	C2	NB	LT	.50000000	UGL
					13DNB	LT	.20000000	UGL
					135TNB		100.00000000	UGL
					24DNT		1.00000000	UGL
					246TNT		40.00000000	UGL
					26DNT		20.00000000	UGL
				K8	NIT		2509.99996948	UGL

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WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL GW45D

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
612.0	16.8	.00	98.4	04/26/86	C2	NB	LT	.50000000	UGL
			98.4			13DNB		2.00000000	UGL
			98.4			135TNB	LT	2.00000000	UGL
			98.4			24DNT	LT	.30000000	UGL
			98.4			246TNT		.30000000	UGL
			98.4			26DNT	LT	.80000000	UGL
			98.4	08/14/86		NB	LT	.50000000	UGL
			98.4			13DNB		7.00000000	UGL
			98.4			135TNB	LT	2.00000000	UGL
			98.4			24DNT	LT	.30000000	UGL
			98.4			246TNT	LT	.08000000	UGL
			98.4			26DNT	LT	.80000000	UGL
			98.4		K8	NIT		14.69999993	UGL

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL GW46

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
607.6	16.8	.00	47.6	04/28/86	C2	NB	LT	.50000000	UGL
			47.6			13DNB		.40000000	UGL
			47.6			135TNB	LT	2.00000000	UGL
			47.6			24DNT	LT	.30000000	UGL
			47.6			246TNT		1.00000000	UGL
			47.6			26DNT	LT	.80000000	UGL

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF CGW SAMPLES
COLLECTED FROM LOCATION: GW47 (SITE TYPE - WELL)

SURFACE ELEVATION (FEET)	SAMPLE ELEVATION (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
610.6	554.2	56.43	04/28/86	C2	NB	LT	5.00000000	UGL
					13DNB		2.00000000	UGL
					135TNB	LT	20.00000000	UGL
					24DNT		20.00000000	UGL
					246TNT		5.00000000	UGL
					26DNT	LT	8.00000000	UGL
		56.43	08/13/86	C2	NB	LT	.50000000	UGL
					13DNB		1.00000000	UGL
					135TNB	LT	20.00000000	UGL
					24DNT		20.00000000	UGL
					246TNT		6.00000000	UGL
					26DNT	LT	8.00000000	UGL
				K8	NIT		4079.99996948	UGL

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL GW48D

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
594.7	16.8	.00	97.1	04/27/86	C2	NB	LT	.50000000	UGL
			97.1			13DNB		.89999999	UGL
			97.1			135TNB	LT	2.00000000	UGL
			97.1			24DNT	LT	.30000000	UGL
			97.1			246TNT		.08000000	UGL
			97.1			26DNT	LT	.80000000	UGL
			97.1	08/13/86		NB	LT	.50000000	UGL
			97.1			13DNB		8.00000000	UGL
			97.1			135TNB	LT	2.00000000	UGL
			97.1			24DNT	LT	.30000000	UGL
			97.1			246TNT	LT	.08000000	UGL
			97.1			26DNT	LT	.80000000	UGL
			97.1		K8	NIT		21.99999976	UGL

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL GW49

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
595.9	16.8	.00	26.5	04/28/86	C2	NB	LT	.50000000	UGL
			26.5			13DNB	LT	.20000000	UGL
			26.5			135TNB	LT	2.00000000	UGL
			26.5			24DNT	LT	.30000000	UGL
			26.5			246TNT	LT	.08000000	UGL
			26.5			26DNT	LT	.80000000	UGL

WEST VIRGINIA ORDNANCE WORKS
ANALYTICAL RESULTS OF GROUND WATER SAMPLES
COLLECTED FROM WELL SHW6

SURFACE ELEVATION (FEET)	MID SCREEN DEPTH (FEET)	SCREEN LENGTH (FEET)	SAMPLE DEPTH (FEET)	SAMPLE DATE	TEST METHOD NUMBER	COMPOUND		CONCENTRATION	UNITS
		.00	25.7	04/26/86	C2	NB	LT	.50000000	UGL
			25.7			13DNB		.89999999	UGL
			25.7			135TNB	LT	2.00000000	UGL
			25.7			24DNT	LT	.30000000	UGL
			25.7			246TNT		.20000000	UGL
			25.7			26DNT	LT	.80000000	UGL