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INSTALLATION RESTORATION PROGRAM

FINAL
SITE INVESTIGATION REPORT

VOLUME I

110TH FIGHTER GROUP
MICHIGAN AIR NATIONAL GUARD
W.K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

NOVEMBER 1993

HAZWRAP SUPPORT CONTRACTOR OFFICE
Oak Ridge, Tennessee 37831
Operated by MARTIN MARIETTA ENERGY SYSTEMS, INC.
For the U.S. DEPARTMENT OF ENERGY under contract DE-AC05-840R21400

INSTALLATION RESTORATION PROGRAM

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SITE INVESTIGATION REPORT

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MICHIGAN AIR NATIONAL GUARD
W.K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

November 1993

Submitted to
AIR NATIONAL GUARD READINESS CENTER
Andrews Air Force Base, Maryland

Prepared by
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Prepared for
HAZARDOUS WASTE REMEDIAL ACTIONS PROGRAM
Oak Ridge, Tennessee 37831-7606
Managed by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400

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LIST OF ACRONYMS

ANG	Air National Guard
ANGB	Air National Guard Base
ANGSC	Air National Guard Support Center
ARARs	Applicable or Relevant and Appropriate Requirements
ASTM	American Society for Testing and Materials
BC	Battle Creek
BETX	Benzene, Ethylbenzene, Toluene, Xylenes
BLS	Below Land Surface
CAG	Carcinogenic Assessment Group
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CLP	Contract Laboratory Protocol
CNS	Central Nervous System
CWA	Clean Water Act
DCA	Dichloroethane
DCE	Dichloroethylene
DD	Decision Documents
DERA	Defense Environmental Restoration Account
DOD	Department of Defense
DQOs	Data Quality Objectives
EA	Environmental Assessment
EECA	Engineering Evaluation and Cost Analysis
EPA	Environmental Protection Agency
ES	Engineering-Science, Inc.
FB	Field Blank
FFS	Focused Feasibility Study
FS	Feasibility Study
FTA	Fire Training Area
GC	Gas Chromatograph
GC/MS	Gas Chromatography/Mass Spectrometry
GI	Gastrointestinal
HAZWRAP	Hazardous Waste Remedial Actions Program
HEAST	Health Effect Assessment Summary Team
HLCSC	Human Life Cycle Safe Concern
HMTC	Hazardous Materials Technical Center
HPLC	High Performance Liquid Chromatography

LIST OF ACRONYMS--Continued

ID	Inside Diameter
IRIS	Integrated Risk Information System
IRP	Installation Restoration Program
LDH	Lactic Dehydrogenase
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MSL	Mean Sea Level
MS/MSD	Matrix Spike/Matrix Spike Duplicate
MW	Monitoring Well
NGB	National Guard Bureau
PA	Preliminary Assessment
PAH	Polynuclear Aromatic Hydrocarbon
PNA	Polynuclear Aromatic
PVC	Polyvinyl Chloride
QA	Quality Assurance
QC	Quality Control
RA	Remedial Action
RB	Rinsate Blank
RBC	Red Blood Cells
RD	Remedial Design
RfC	Reference Concentration
RfD	Reference Dose
RI/FS	Remedial Investigation/Feasibility Study
RM	Remedial Measures
RPD	Relative Percent Difference
SB	Soil Boring
SED	Sediment
SDWA	Safe Drinking Water Act
SGOT	Serum Glutamic-oxalactic Transaminase
SI	Site Investigation
SMCL	Secondary Maximum Contaminant Level
SOW	Statement of Work
SW	Surface Water
TASG	Tactical Air Support Group
TB	Trip Blank
TCA	Trichloroethane
TCE	Trichloroethylene

LIST OF ACRONYMS--Continued

TetCA	Tetrachloroethane
TPH	Total Petroleum Hydrocarbons
TCL	Target Compound List
VOA	Volatile Organic Analysis
VOC	Volatile Organic Compound
WP	Work Plan

EXECUTIVE SUMMARY

A Site Investigation (SI) was conducted at the 110th Fighter Group of the Michigan Air National Guard, located at W.K. Kellogg Memorial Airport, Battle Creek, Michigan. The SI was performed under the National Guard Bureau's Installation Restoration Program. The objectives of the SI were to confirm the presence or absence of contaminants and to evaluate the potential for contaminant migration.

The Base is located in Calhoun County, Michigan, on a plain of glacial deposits, consisting of till, outwash, and channel deposits. The Base is underlain by interbedded alluvial sands, gravels, and clays which comprise the surficial aquifer. The glacial deposits are estimated to extend to a depth of 110 to 135 feet at the Base and overly sandstone bedrock. Groundwater was encountered at a depth of approximately 40 feet below land surface at the developed portion of the Base. Groundwater flow is primarily to the north and northwest, with a radial pattern exhibited on the northeast portion of the Base.

SI activities were conducted at six sites at the Base:

- Site 1 - Fuel Tank Farm;
- Site 2 - Drainage Swale;
- Site 3 - Fire Training Area;
- Site 4 - Abandoned Landfill;
- Site 5 - Former Coal Storage Area; and
- Site 6 - Fuel Spill.

The Base boundary was investigated to evaluate groundwater quality in the surficial aquifer upgradient and downgradient of the Base. The southern boundary investigation provided background contaminant data, while the northern boundary investigation provided information on contaminant migration off the Base.

Twelve monitoring wells were installed along the northern boundary and three were installed along the southern boundary. Groundwater samples were analyzed for volatile organic compounds (VOCs) and priority pollutant metals.

Toluene was detected in one upgradient groundwater sample and zinc was detected in two upgradient samples. Downgradient of the Base, VOCs were detected in six of the nine samples from the upper portion of the surficial aquifer. VOCs were also detected in two of the three samples from the lower portion of the surficial aquifer.

Site 1 - Fuel Tank Farm was used for gasoline storage until 1949 and for the storage of heating fuel in 1973 and 1974. Leaking of fuel was reported in 1973-74. The tanks were removed in 1988.

Soil samples were collected at Site 1, but the analytical data was rejected due to poor laboratory quality control procedures. However, hydrocarbon odors were noted during drilling and soil staining is evident, indicating the presence of petroleum products in the soil.

A groundwater study was not conducted but a monitoring well was installed downgradient of Site 1 for the Site 2 investigation. Groundwater from the surficial aquifer was sampled from this well and analyzed for VOCs and priority pollutant metals. No VOCs were detected in sample and zinc was the only metal to be detected.

Site 2 - Drainage Swale is a topographic depression that receives storm water runoff from the northern half of the Base. Surface water collecting in the swale evaporates or percolates into the ground.

One upgradient monitoring well was installed at Site 2. A background sample was collected from this well and downgradient samples were obtained from two Base boundary wells. The samples were analyzed for VOCs and priority pollutant metals. Surface water and sediment samples were collected from the swale and from drainage ditches leading into the swale. The surface water and sediment samples were analyzed for VOCs, semi-volatile organics, and priority pollutant metals.

No VOCs were detected in surface water from the swale and only one semi-volatile was detected. Toluene was detected in one sample of water flowing into the swale. Elevated semi-volatile concentrations were found in all sediment samples. VOCs were detected in the downgradient groundwater samples.

Site 3 - Fire Training Area is a bermed earthen area used for fire training activities between 1977 and 1986. Wastes oils, jet fuel, hydraulic fluids, and spent solvents were reportedly floated on water, ignited, and extinguished.

Soil samples were collected from borings at Site 3 and analyzed for VOCs and TPH. Six monitoring wells were installed and groundwater samples were collected for VOC and priority pollutant metal analyses.

The soil analytical data was rejected due to laboratory quality control problems, but results reported by the laboratory indicate the presence of VOCs and TPH in the soil, even though the concentrations could not be quantified. VOCs were detected in downgradient groundwater samples.

Site 4 - Abandoned Landfill was used for the disposal of concrete and asphalt during runway repairs. Empty drums and paint cans were found at the site during an earlier investigation.

Four monitoring wells were installed at Site 4 and groundwater samples from these wells were analyzed for VOCs and priority pollutant metals. No VOCs or metals were detected in the samples.

Site 5 - Former Coal Storage Area was used for the storage of coal. The coal was exposed to the environment and may have resulted in the leaching of contaminant into the ground or surface water.

Soil samples were collected from borings at the site and one monitoring well was installed downgradient of the Site. Groundwater from this well was sampled and analyzed for VOCs and priority pollutant metals.

The soil analytical data was rejected due to poor laboratory quality control. Low concentrations of VOCs were detected in groundwater, but groundwater flow patterns indicate that the contaminants probably originated from Site 3.

Site 6 - Fuel Spill is the location of an underground jet fuel storage area. An electrical system failure resulted in a 2,000-gallon fuel spill on the ground surface.

Soil samples were collected at Site 6 and were analyzed for VOCs and TPH. Three monitoring wells were installed downgradient of the site and groundwater samples were collected for VOC and priority pollutant metal analyses.

Toluene was detected in three of the five site soil samples, but was also found in the background soil sample at a similar concentration. Low concentrations of TPH were found in four of the five site samples. Low VOC concentrations were detected in the downgradient groundwater samples.

The contaminant concentrations in the various media were evaluated with respect to ARARs, health-based criteria, current and future uses of the Base, and physical characteristics such as groundwater flow patterns. An analysis of all data and information has led to the formulation of the following recommendations:

- Remediate contaminated soils at Site 1, then sample and analyze soils to verify removal of contaminants;
- Conduct an FS at Site 2 to evaluate the need for, and potential alternatives for remediation of sediments and groundwater;
- Conduct an FS at Site 3 to evaluate the need for and alternatives for groundwater remediation; the FS should include soil sampling and analysis, and aquifer pumping tests;
- Prepare a Decision Document for no further action at Site 4,
- Remove surface soil containing coal particles at Site 5, sample to verify removal, then prepare a Decision Document for no further action;
- Prepare a Decision Document for no further action at Site 6.

SECTION 1
INTRODUCTION

The Department of Defense (DOD) has developed a program to identify and evaluate sites on DOD property where contamination may be present due to past spills or hazardous waste disposal practices. This program is the Installation Restoration Program (IRP), and its purpose is to identify the presence of hazardous contaminants and to control hazards to health, welfare, or the environment that may result.

The Air National Guard Readiness Center (ANGRC) headquartered in Washington, DC, manages the IRP for the Air National Guard (ANG) facilities throughout the country. The Hazardous Waste Remedial Action Program (HAZWRAP) is assisting the NGB in identifying, investigating, and remediating environmental contamination through the IRP. Engineering-Science, Inc. (ES) was assigned the task of investigating six disposal/spill sites at the 110th Fighter Group (FG) of the Michigan Air National Guard located at W.K. Kellogg Memorial Airport in Battle Creek, Michigan, hereinafter referred to as the Base. ES conducted a Site Investigation (SI) at the Base to confirm the presence or absence of contaminants.

1.1 INSTALLATION RESTORATION PROGRAM

The IRP is an environmental program developed by the DOD. The objectives of the IRP are to evaluate DOD installations and:

- Identify former waste, spill, storage, and disposal sites.
- Evaluate the extent and nature of contamination if present.
- Initiate appropriate remedial action.

Figure 1.1* presents the IRP decision flow chart which illustrates the components of the IRP and the various decision points that exist.

1.1.1 Preliminary Assessment (PA)

A PA is the initial step in the IRP process; it is the method used to identify areas which are potentially contaminated with hazardous materials. The PA is conducted at DOD installations where hazardous wastes have been reportedly disposed of or stored. The steps in conducting a PA are as follows:

---

* Please note that all figures and tables are located following the text for each section.

1. Conduct record search of past disposal practices.
2. Conduct interviews with employees.
3. Conduct a site investigation.
4. Determine further action.
    - No Further Action -- Decision Documents (DD)
    - Further Action -- Site Investigation (SI)

1.1.2 Site Investigation (SI)

The objectives of the SI include:

- Confirm the presence/absence of contamination which may threaten human health and the environment.
- Identify the nature of contaminants.
- Provide some contamination quantification and determine preliminary risk.
- Provide a hydrogeological study of the Base.

Field investigation activities may include the drilling of soil borings, collection of soil samples in source areas, the installation of monitoring wells and the collection of groundwater, surface water and sediment samples for chemical analysis. Following the laboratory analysis of field samples, an evaluation of the data is conducted, and an SI report is prepared.

Successful completion of the SI will aid in the following:

1) Elimination of non-hazardous sites from further investigation.
2) Completion of a hydrogeologic study.
3) Further definition of the nature of contamination.
4) Establishment of priority for future IRP work.
5) Implementation of Remedial Measures (RM) if necessary.
6) Completion of Decision Documents.

Following the SI segment, each site will be recommended for:

1) No further action (Decision Document);
2) A Focused Feasibility Study (FFS) and RM;
3) A Remedial Investigation/Feasibility Study (RI/FS); or
4) Immediate response.

1.1.3 Preliminary Risk Evaluation

A preliminary risk evaluation is conducted in conjunction with the SI. The purpose of the preliminary risk evaluation is to assess the need for immediate or subsequent remedial actions at a site or to support the preparation of a decision document.

The preliminary risk evaluation identifies all known contaminant sources, routes of migration, and receptors. Impacts are evaluated by reviewing State and Federal limits, advisories, and recommended limits on contaminant concentrations in the affected media.

The results of the preliminary risk evaluation are used to determine further actions. If the preliminary risk evaluation identifies an imminent threat to human health or the environment, an FFS or RM may be necessary. Long-term or potential threats may require initiation of an FS. No further action may be indicated if the preliminary risk evaluation concludes that no current or potential threat is posed by contaminants. These decisions may be applied to the Base as a whole or to individual operable units.

1.1.4 Remedial Investigation (RI)

If the SI confirms the presence of contamination at the Base, a RI will be conducted. The purpose of the RI is to further define the magnitude and extent of contamination and to evaluate the potential for contaminant migration. The RI may include the installation of additional monitoring wells, collection of additional soil, groundwater, surface water, and sediment samples, performance of aquifer tests, and/or biota sampling. The data collected in the RI are used to perform a baseline public health evaluation (PHE). The PHE quantifies the risks to public health and the environment due to existing site conditions.

1.1.5 Feasibility Study (FS)

Following completion of the RI, an FS would be conducted to develop and evaluate alternatives for remediation of contamination at the Base. A range of alternatives would be developed for various media and source areas. The alternatives may include no-action, off-site or on-site disposal, and treatment.

The remedial alternatives would be evaluated in terms of effectiveness, implementability, and cost. Each alternative would be compared to the remedial objectives for the site and the alternatives would be compared to one another. The final objective of the FS is to provide information which is sufficient to support the selection of a remedial alternative.

1.1.6 Remedial Design/Remedial Action (RD/RA)

Remedial Design/Remedial Action (RD/RA) follows the selection of a remedial alternative. The RD would be developed on the basis of the FS. The RD is a detailed design of the selected remedial action and includes a and design drawings. The RD is used to implement the RA.

The RA is the implementation of the remedial alternative(s) selecteu Base. This action may include several technologies and may affect one or seve media and source areas.

1.1.7 Focused Feasibility Study (FFS) and Remedial Measures (RM)

A FFS is a feasibility study of one or more operable units. An operable unit may be a particular media, such as soil or groundwater, or may be one source, such as a drainage swale or spill area. The purpose of the FFS is to develop a range of measures which may be employed to remediate contamination at the operable unit. These measures, termed remedial alternatives, are evaluated on technical, cost, and environmental considerations. The FFS is used to select the most appropriate remedial alternative for an operable unit, to prepare cost estimates, and to initiate the remedial design.

RMs may be taken to alleviate immediate threats to human health or the environment. A RM may be implemented for an operable unit; for example, a waste pile may be covered or fenced in to prevent human contact with hazardous substances.

FFSs and RMs may be initiated at any point in the IRP process if the need for a FFS or RM becomes obvious. FFSs for several operable units may be combined to produce an FS for the entire Base.

1.1.8 Regulatory Involvement

Throughout all segments of the IRP, the NGB attempts to work closely with the U.S. Environmental Protection Agency (EPA) and the state regulatory agencies. The IRP encourages the early and continuous participation of federal and state regulatory agencies during meetings and review of work plans and reports. Installations considered for the IRP are prioritized under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) also known as Superfund, with respect to health risks, hazard level, and Defense Environmental Restoration Account (DERA) funding availability.

1.2 BACKGROUND INFORMATION

1.2.1 Facility Description

The Base is located at the W.K. Kellogg Regional Airport in southwest Battle Creek, Calhoun County, Michigan. Battle Creek, located in south-central Michigan, lies about 100 miles west of Detroit and 20 miles east of Kalamazoo. The Base occupies the northwestern portion of the airport and the runway facilities are used by both organizations. Railroad tracks run northeast to southwest through the western part of the Base. Industrial shops and support facilities for the Base are separate from the commercial operations at the airport. The regional location of the airport is shown on Figure 1.2.

The money to purchase the airport site and make improvements was donated by W. K. Kellogg in 1928. In 1942, the airport was converted to military status. The Army Air Corps used the airport to train pilots and crews, and to stage crews for overseas operations. In 1946, the 172nd Fighter Squadron of the Michigan Air National Guard was formed with Kellogg Field designated as headquarters. The 110th TASG was established in 1971. The mission of the unit is to assist the Army in accomplishing its objectives on the battlefield by providing tactical air support. In 1986, the land used by the 110th TASG was increased from 90 acres to 315 acres.

Plans for future expansion of the Base are presented in the Base Master Plan (ANGSC 1988). These plans include expansion of the base onto property west of the railroad tracks, construction of additional buildings, and extension of current roadways onto the western portion of the Base.

1.2.2 Project Scope

Three field efforts were conducted during the SI at the Base: the first field effort was conducted in November 1988 through January 1989; the second field effort was conducted in August through September 1989; and the third field effort was conducted in March 1991.

The first field effort included the installation of monitoring wells at Sites 2, 3, 4, 5, and 6, and the collection and laboratory analysis of groundwater, soil, surface water, and sediment samples. During the second field effort, additional wells were installed at Site 3 and along the Base boundary, and groundwater samples were collected from all existing monitoring wells. The third field effort consisted of the collection and analysis of groundwater samples from all existing monitoring wells, soil samples from Site 6, and surface water and sediment samples from Site 2.

In addition to the field efforts, the SI included the reduction and interpretation of all data derived from the field investigations and laboratory analyses. These data were used to evaluate the nature and magnitude of contamination at the six sites and along the Base boundary. The data were also used to conduct a preliminary risk evaluation which evaluates threats to human health and the environment from contaminants detected at the Base.

The results of the SI are presented in this report. Section 2 discusses the physical characteristics of the study area. The field investigation program is discussed in Section 3, which presents the methods that were used in the investigation. Section 4 presents the results of the field investigation and discusses site-specific data in regard to geology, hydrogeology, and environmental media contamination. The preliminary risk evaluation, which assess potential threats to human health and the environment, is contained in Section 5. Conclusions and recommendations are presented in Section 6. Finally, references used in the report are found in Section 7.

Appendices to this report contain supporting information. Monitoring well construction records and boring logs are contained in Appendix A. Soil boring logs are contained in Appendix B. Environmental fate and toxicity information for chemicals of concern is in Appendix C. Aquifer testing information is found in Appendix D. Data validation reports are provided in Appendices E, F, and G. Laboratory data reports are found in Appendices H, I, and J.

1.3 SUMMARY OF PREVIOUS IRP ACTIVITIES

An IRP Phase I Preliminary Assessment was conducted in 1987 to identify and assess past operations at the Base that may have involved storage or disposal of hazardous materials or wastes (HMTC, 1987). The purpose of the assessment was to evaluate the potential for environmental releases from hazardous materials and waste management practices. Six sites were identified as potential sources for release of contaminants.

Upon completion of the PA, an Immediate Response Investigation (ES, 1988) was conducted to assess groundwater quality at the Base boundary. Ten monitoring wells along the northern Base boundary and upgradient of the Base were sampled and the groundwater samples were analyzed for volatile organic compounds, base/neutral/acid extractables, and priority pollutant metals. Volatile organic compounds and elevated concentrations of metals were detected in several of the samples.

After the Immediate Response Investigation report was finalized, the analytical data became suspect. A laboratory audit showed numerous problems with the laboratory's quality assurance (QA) and quality control (QC) procedures. These problems are addressed in the QA report for the SI analyses conducted in 1988 (Appendix E). Due to the laboratory's QA problems, the Immediate Response Investigation data cannot be evaluated and is not addressed in this SI report.

In addition to the IRP activities at the Base, an Environmental Assessment (EA) of the Base area was conducted by Hickok and Associates (Hickok, 1985). The EA evaluated the environmental impacts of expanding the Base. The EA did not address potential contamination due to past activities of existing facilities on the Base.

1.4 IRP SITE IDENTIFICATION AND DESCRIPTION

The SI included investigation of the following six sites at the Base.

- Site 1 -Fuel Tank Farm
- Site 2 -Drainage Swale
- Site 3 -Fire Training Area

- Site 4 -Abandoned Landfill
- Site 5 -Former Coal Storage Area
- Site 6 -Fuel Spill

In addition to these sites, the groundwater quality along the Base boundary was investigated. The locations of the six IRP sites are shown on Figure 1.3.

1.4.1 Site 1 - Fuel Tank Farm

Four 25,000-gallon aboveground fuel tanks were located near the drainage swale, northwest of the Motor Pool parking lot. Prior to 1949, the tanks were used for storage of gasoline. The tanks were not used between 1949 and 1973. These tanks were used by the City of Battle Creek for storage of No. 4 heating fuel during 1973 and 1974. The tanks were patched prior to use by the city and leakage of heating fuel reportedly occurred at some of the patches. Containment berms were leveled and spread on the surrounding land area in 1985. The tanks were dismantled and removed from the Base in 1988. The old foundations still remain.

1.4.2 Site 2 - Drainage Swale

The drainage swale is a low-lying depression on the northern edge of the base, in the central portion of the base boundary. Stormwater runoff from the northern half of the base is discharged to the drainage swale. Stormwater collected in the swale either evaporates or percolates into the ground. The environmental concern at this site is that contaminants may have been transported to this site with the stormwater drainage from areas where hazardous materials have been used or where hazardous wastes have been stored prior to disposal.

1.4.3 Site 3 - Fire Training Area

Site 3 is located on the western part of the base, southwest of the Civil Engineering storage yard. The fire training area is approximately 85 feet in diameter and surrounded by an earthen berm. Fire training exercises were conducted at this site from approximately 1977 to 1986. Approximately 54,000 to 74,000 gallons of a mixture of waste JP-4, waste oils, waste hydraulic fluid and spent cleaning solvents were reportedly burned during fire training exercises (HMTC, 1987). The mixture of wastes was floated on top of water, ignited, and extinguished. An area where drums of waste were stored prior to utilization in fire training exercises is located north of the fire training area.

1.4.4 Site 4 - Abandoned Landfill

The Site 4 landfill is located southwest of the Site 3 fire training area. Large pieces of concrete and asphalt are present at the surface of the landfill. The concrete and asphalt were disposed of at this site at the time of a runway repair project. Empty 55-gallon drums and 1 gallon paint cans are present at this site. There is no information that indicates whether or not the drums and cans were empty at the time of disposal at the landfill. The landfill was abandoned in about 1987-1988.

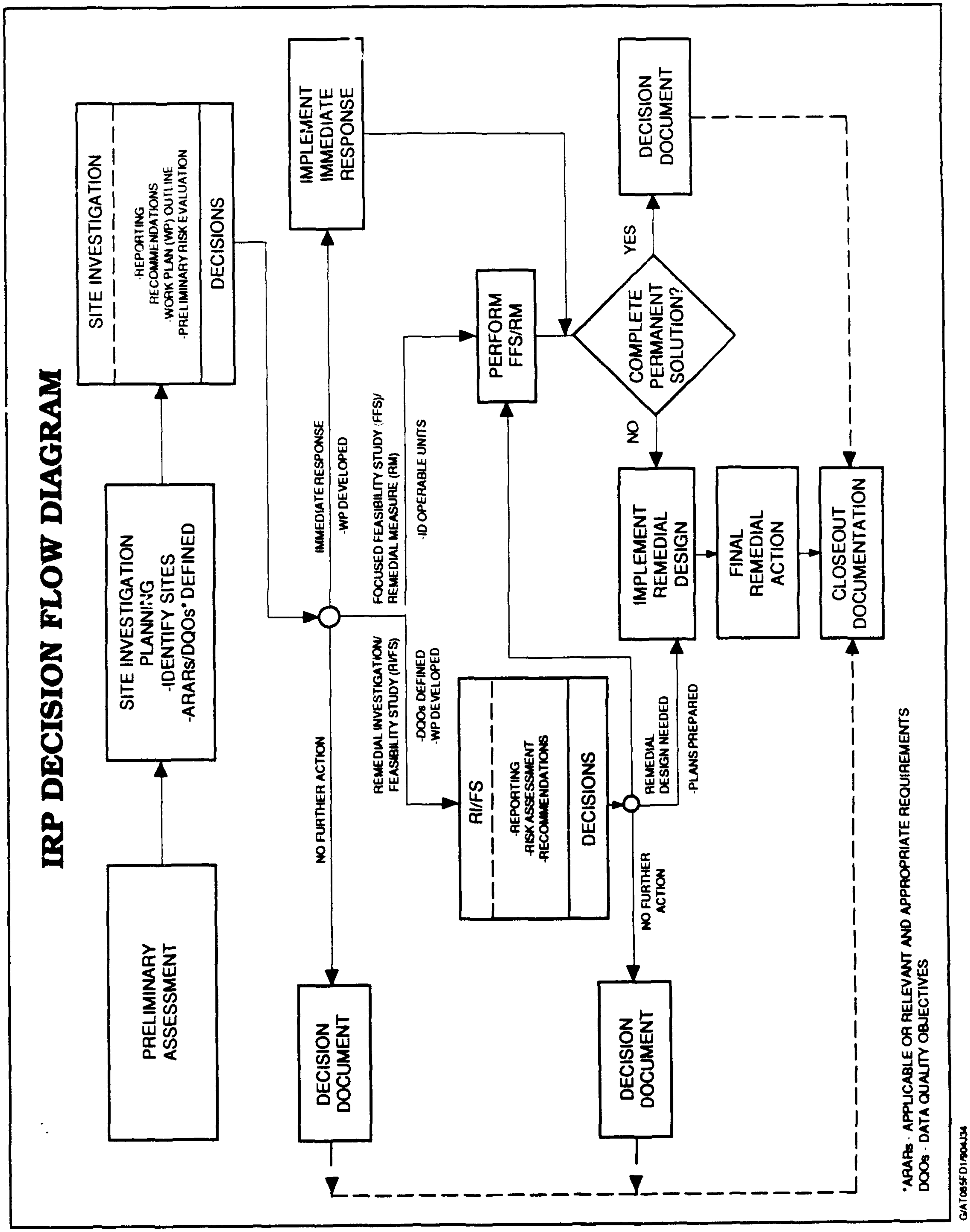
1.4.5 Site 5 - Former Coal Storage Area

A former coal storage area is located between the Site 3 fire training area and the Site 1 fuel tank farm. A 1943 map of the Base shows that the storage area extended from the current Civil Engineering storage yard to the current Base Supply storage yard. A rail spur was used for transporting coal into the storage area. Contaminants leached from the coal may have been transported from the site by surface runoff or may have percolated into the ground.

1.4.6 Site 6 - Fuel Spill

An underground fuel storage tank located southeast of Building 6910 is used for storage of JP-4. An electrical pumping system is used to transfer the fuel from the tanks to fuel trucks. On at least once occasion in the 1970s approximately 2,000 gallons of fuel were reportedly pumped onto the ground due to an electrical system failure. Other spills of this magnitude reportedly may have occurred at this site.

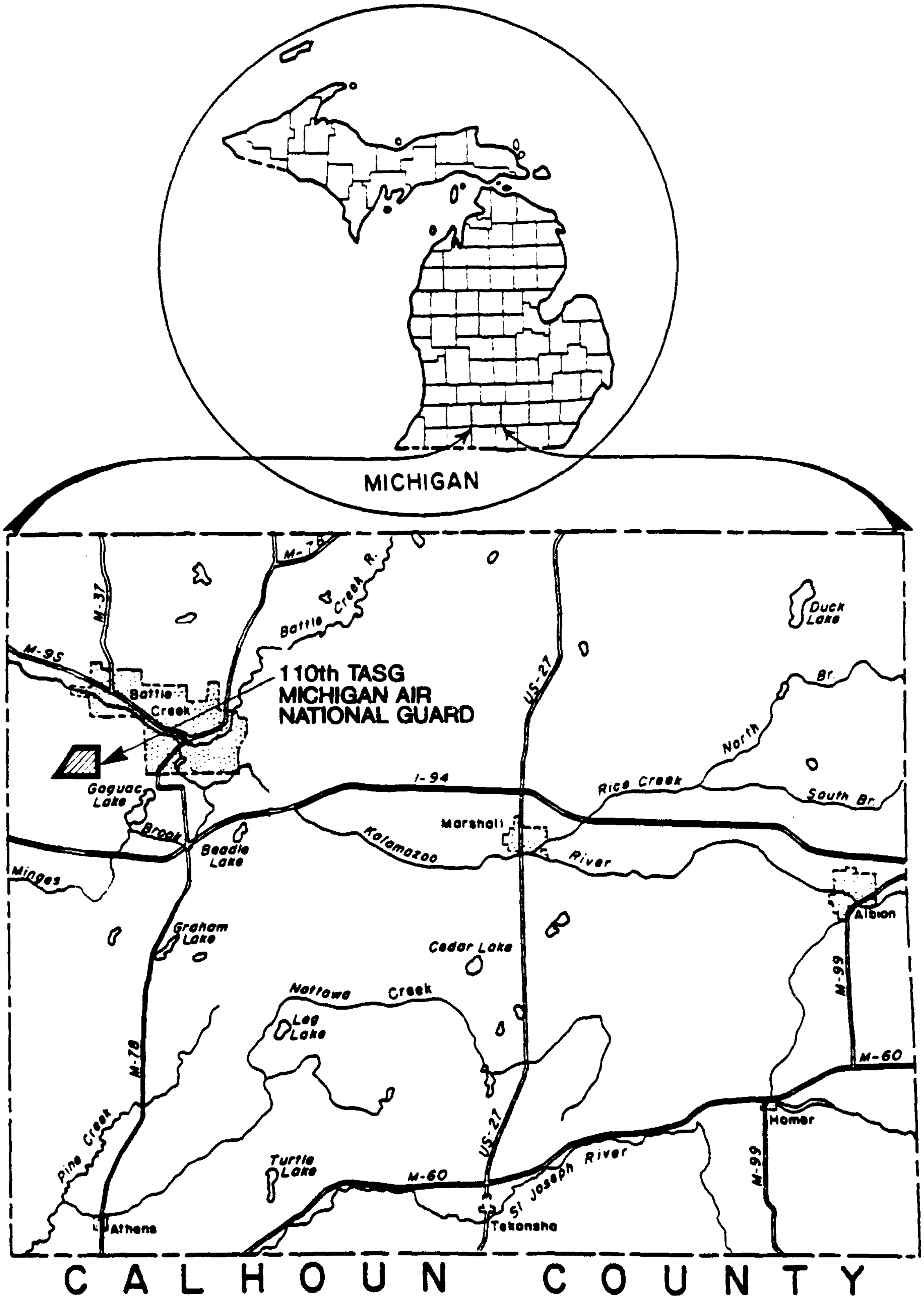
Figure 1.1



*ARARs - APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS
DQOs - DATA QUALITY OBJECTIVES

FIGURE 1.2

MICHIGAN NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
REGIONAL LOCATION MAP



SOURCE: Vanlier, 1966

MICHIGAN AIR NATIONA
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IRP SITE LOC

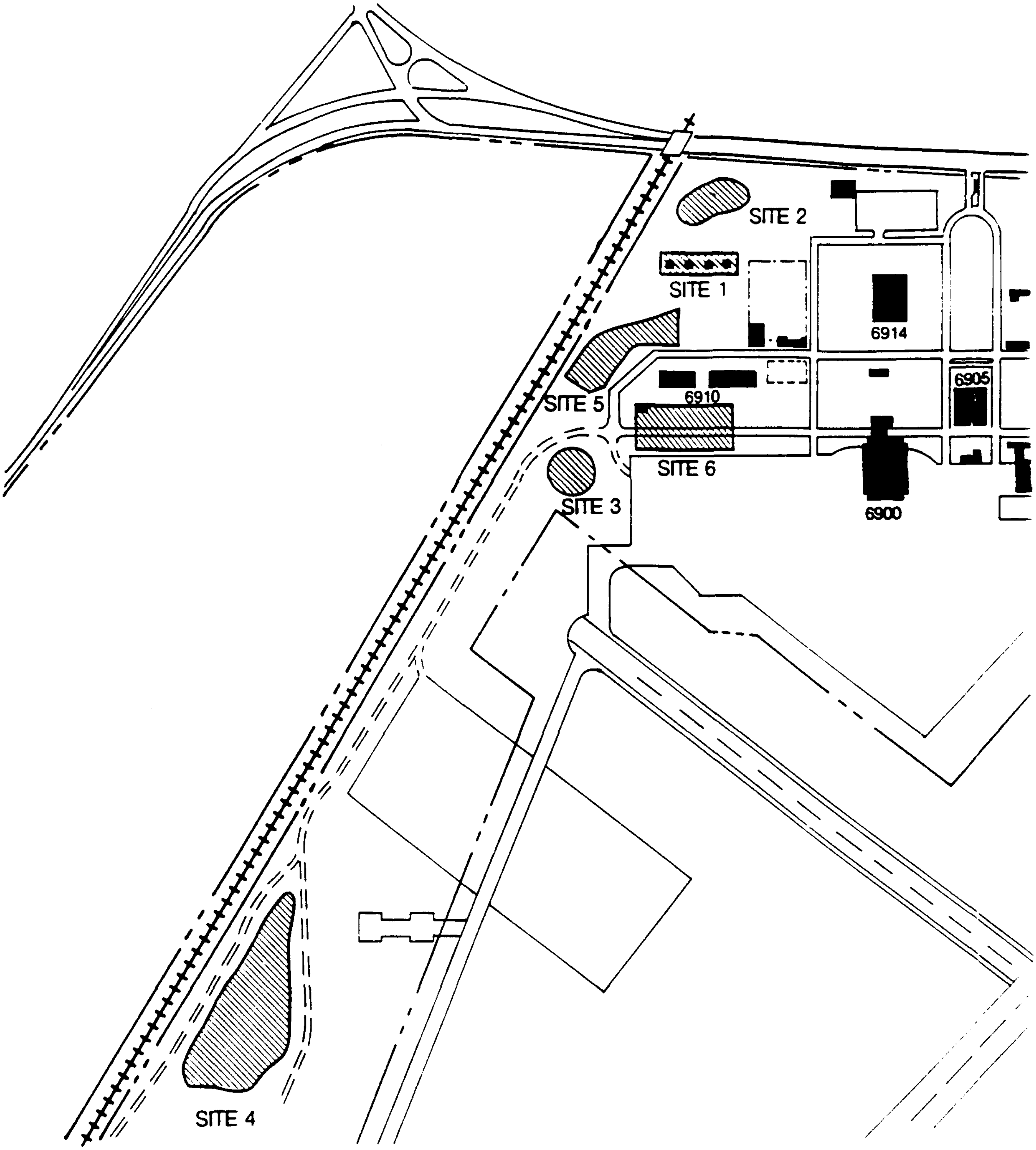
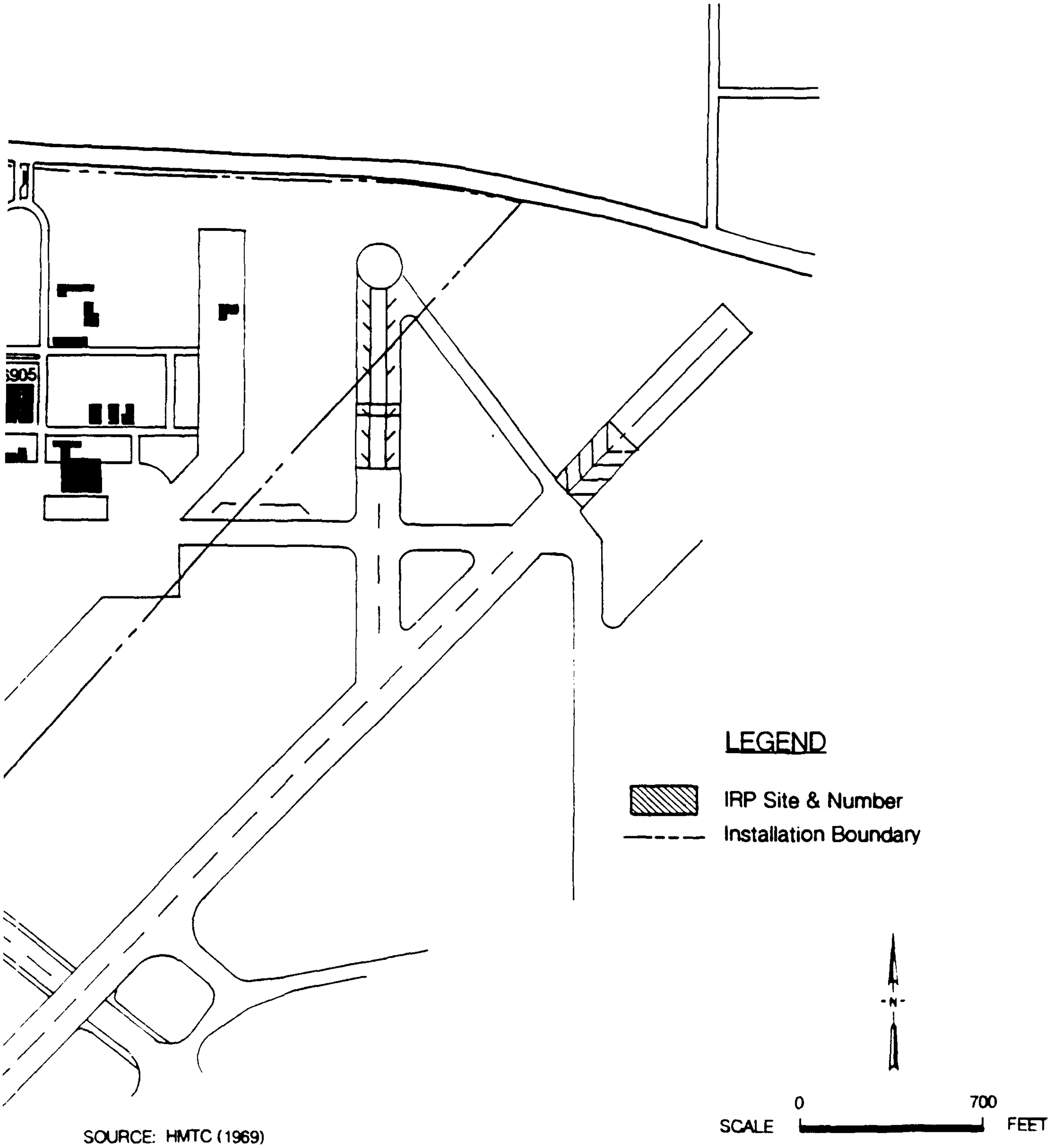


Figure 1.3

TIONAL GUARD BASE
EEK, MICHIGAN

LOCATIONS



SOURCE: HMTC (1969)

SECTION 2
ENVIRONMENTAL SETTING

2.1 CLIMATE

The Battle Creek area is located in a climate which varies between continental and semi-maritime. Strong winds from the Great Lakes often alter a continental-type climate, which is characterized by extremely cold winters and hot summers, to a semi-maritime climate of moderate temperatures in winter and summer. Data for the five-year period 1982 through 1986 (U.S. Department of Commerce, 1982-1986) indicate an average annual mean temperature of 48.6°F with an average annual mean maximum of 58.7°F and an average annual mean minimum of 38.4°F. The highest daily temperatures usually occur in July while the lowest temperatures occur in January.

Precipitation is fairly uniform throughout the year. The average annual precipitation for 1982 to 1986 was 39.6 inches (30.7 inches for the period 1956 to 1985), and the wettest months have been May and July. Snowfall for the same 5-year period averaged 62.6 inches (U.S. Dept. of Commerce, 1982-1986). The annual net precipitation at the base is reported to be 0.73 inches based on the period 1956 to 1985 (HMTC, 1987).

2.2 PHYSIOGRAPHY AND TOPOGRAPHY

The Base is located within the Central Lowland Physiographic Province of the Interior Plains. This region is characterized by its vast plain, relatively low altitude of 500 to 2000 feet above mean sea level (MSL), and slight local relief.

The Base consists of large paved areas and has a gently rolling to nearly flat topography, as shown on the regional topographic map, Figure 2.1. The mean elevation of the airport area is 941 feet MSL (Hickok, 1985). Wet swampy areas occur in the portion of the installation west of the railroad tracks, where elevations range from 890 to 920 feet MSL.

2.3 SOILS

The soils on the base are generally comprised of Ustemo, Brady, and Houghton series (Hickok, 1985). All, except the Houghton series, are sandy loam formed from glacial deposits. Permeabilities range from moderate to high. Soils of the Houghton series are found in low areas on the western part of the Base and are composed of organic material. These soils are very poorly drained and are formed in depressions within outwash plains, lake plains, till plains, and moraines.

2.4 SURFACE WATER HYDROLOGY

The major surface water features of the area are the Kalamazoo River, Harts Lake, and Goguac Lake, shown on Figure 2.1. The Kalamazoo River is located approximately 1.5 miles north of the Base. The Battle Creek River flows into the Kalamazoo River in the City of Battle Creek approximately 2 miles east of the Base. Goguac Lake is located approximately 2 miles southeast of the Base, and Harts Lake is located approximately 0.5 miles west of the Base. Localized ponding and wet areas occur throughout the Battle Creek area. Most streams in the area discharge into the Kalamazoo River.

Surface flow and runoff on the Base collect in low areas or infiltrate into the soil. This water eventually leaves the base as groundwater flow or as surface flow which discharges into the Kalamazoo River. Runoff on the western portion of the base flows into wetlands located in that area. These wetlands eventually feed into small streams which flow north into the Kalamazoo River. Groundwater and small surface streams on the Base drain into the Kalamazoo River.

2.5 GEOLOGY

2.5.1 Regional Geology

South-central Michigan, including the Base, is located within the Michigan Basin of the Central Lowland Physiographic Province. A plain of Wisconsin glacial advance deposits covers the Battle Creek area. Valleys and morainal ridges arranged in concentric arcs around the ends of the Great Lakes interrupt this plain.

Bedrock in the Michigan Basin is Pennsylvanian-aged in the center and Cambrian-aged at the outer boundary of the basin. The geologic structure of the basin is expressed as small folds, fractures, and faults. These minor structural features appear to trend northwestward in the Battle Creek area. Offsets in the trend of buried valleys and major bends in the Battle Creek River suggest folds, fractures, faults, or a combination of all three (Grannemann and Twenter, 1985).

In southern Michigan, the Pleistocene-aged glacial deposits consist of till, outwash, and channel deposits derived principally from fragments of sandstone and shale deposited as the last continental glacier retreated across Michigan. Composition and mode of deposition (glacier or meltwater) differentiated these deposits of sand, silt, clay, gravel, and boulders. The glacial deposits in the area range in thickness from a few feet to greater than 100 feet. The glacial deposits overlie Paleozoic sedimentary bedrock consisting of sandstone, siltstone, and shale. A regional stratigraphic column is shown on Figure 2.2.

In the Battle Creek area, the Marshall Formation underlies the glacial deposits. The Marshall Formation is a very fine- to coarse-grained sandstone containing layers of siltstone, shale, and sandy shale (Grannemann and Twenter, 1985). The sandstones can be either hard or soft. The soft sandstones may have been less well-cemented or have had the cement material weathered away leaving loose-grained sands. The cemented or hard sandstones contain fractures and joints. The Marshall Formation ranges in thickness from about 10 feet to 140 feet in the Battle Creek area.

The Marshall Formation overlies the Coldwater Shale. This formation may be up to 1,300 feet thick and may contain thin layers of sandstone, limestone, and cherty limestone (Vanlier, 1966).

2.5.2 Local Geology

The Base is underlain by a mantle of Pleistocene-aged glacial drift material, approximately 100 feet thick or greater, overlying the Mississippian-aged Marshall Formation. These materials consist of layers of sand, sand and gravel, and clay. The sands range from very fine-grained to very coarse-grained with a predominance of fine to medium-grained sand. Sand layers are from 10 to 15 feet thick. Beds of sand and gravel are interlayered with the sand layers and are generally 10 to 20 feet thick.

Thin clay layers and silty or sandy clay layers are present in the deeper sections of the glacial drift material. Rock fragments are also common in deeper sections and may be derived from the loosely-cemented Marshall Formation.

Grey clay layers, mainly sandy or silty, exist locally at depths of 65 to 115 feet. The clay layers usually directly overlie the Marshall Formation, which is a blue, soft, medium-grained, loosely-cemented sandstone. The Marshall Formation has an irregular rolling and hilly surface due to preglacial stream erosion.

Site-specific results of the field investigation are reported in Section 4.

2.6 HYDROGEOLOGY

2.6.1 Regional Hydrogeology

Groundwater occurs in usable quantities in both the glacial deposits and the Marshall Formation in the Battle Creek area. These two aquifers are reported to be connected hydraulically, although relatively impermeable clay layers may be present locally in sufficient thickness to retard water movement between the glacial materials and the Marshall Formation. In some areas the two aquifers function as a single hydraulic unit. Most of the water that enters the glacial aquifer eventually moves to the Marshall Formation and is discharged to stream flow or as well withdrawals (Vanlier, 1966).

Although it is generally used for domestic supplies, the glacial aquifer produces water of sufficient quality and quantity for municipal supplies. Depth to groundwater in the glacial aquifer varies with topography, and flow directions generally follow topographic gradients and surface water flow patterns. The glacial aquifer is recharged directly from precipitation and infiltration. Horizontal conductivities in the glacial aquifer range from 15 to 110 ft/day (Grannemann and Twenter, 1985). The variations in conductivities over the area are due to the presence or absence of clay lenses.

The Marshall Formation is the major water supply source in the Battle Creek area, supplying water to domestic, industrial, and municipal wells. Water is produced from the "upper sandstone" and "lower sandstone" units. The Marshall Formation has a hydraulic conductivity that ranges from about 150 ft/day in the upper unit to 550 ft/day in the lower unit (Grannemann and Twenter, 1985). The Marshall Formation is recharged by precipitation and infiltration directly from the overlying glacial aquifer. The flow direction in the Marshall Sandstone aquifer is similar to the flow direction in the glacial aquifer (Grannemann and Twenter, 1985).

2.6.2 Local Hydrogeology

Groundwater at the Base occurs in the surficial glacial drift and in the Marshall sandstone under unconfined conditions. The glacial aquifer at the Base consists of very fine to coarse sand, gravel, and silty and sandy clay. Limited data indicate that the glacial aquifer is approximately 110 to 135 feet thick. Some of these deposits include significant amounts of clay and silt-sized materials which reduce permeability in these areas. However, in other areas, these finer particles have been washed out of the sand and gravel deposits which increases the permeability of these deposits.

The potentiometric surface of groundwater in the glacial aquifer ranges in depth from approximately 10 to nearly 40 feet below land surface (BLS) at the Base. Groundwater elevations range from approximately 899 feet above MSL at Site 4 to approximately 884 feet above MSL at the northern Base boundary. The general groundwater flow direction across the Base is to the northwest, although a radial pattern is exhibited at the central portion of the northern Base boundary.

Figure 2.3 shows water-level contours and flow directions at the Base in March 1991. Recharge to the surficial aquifer is due to infiltration of precipitation and surface water. Movement of water into the Marshall sandstone may be hampered where the glacial drift material has a high clay content. A thick clay layer is present under portions of the Base but is not extensive over the entire area. The water table elevations from 1987-1989 show a pattern similar to that on Figure 2.3.

A 160-foot deep well set into the Marshall Sandstone aquifer supplied the Base's water until 1986. Presently, the Base uses water supplied by the City of

Battle Creek. Many private wells, completed in glacial deposits or the Marshall Formation, exist in the vicinity of the base.

2.6.3 Groundwater Quality

Groundwater from both the glacial aquifer and the Marshall Sandstone aquifer is generally considered to be of good quality. Both aquifers are used as water supply sources in the Battle Creek area. Water from the Marshall Sandstone is generally hard to very hard and sometimes has a high iron content. Hydrogen sulfide in the water sometimes gives it a "rotten egg" odor. Groundwater from the glacial aquifer is generally similar to water from the Marshall Sandstone aquifer which is high in iron and characteristically hard (Vanlier, 1966).

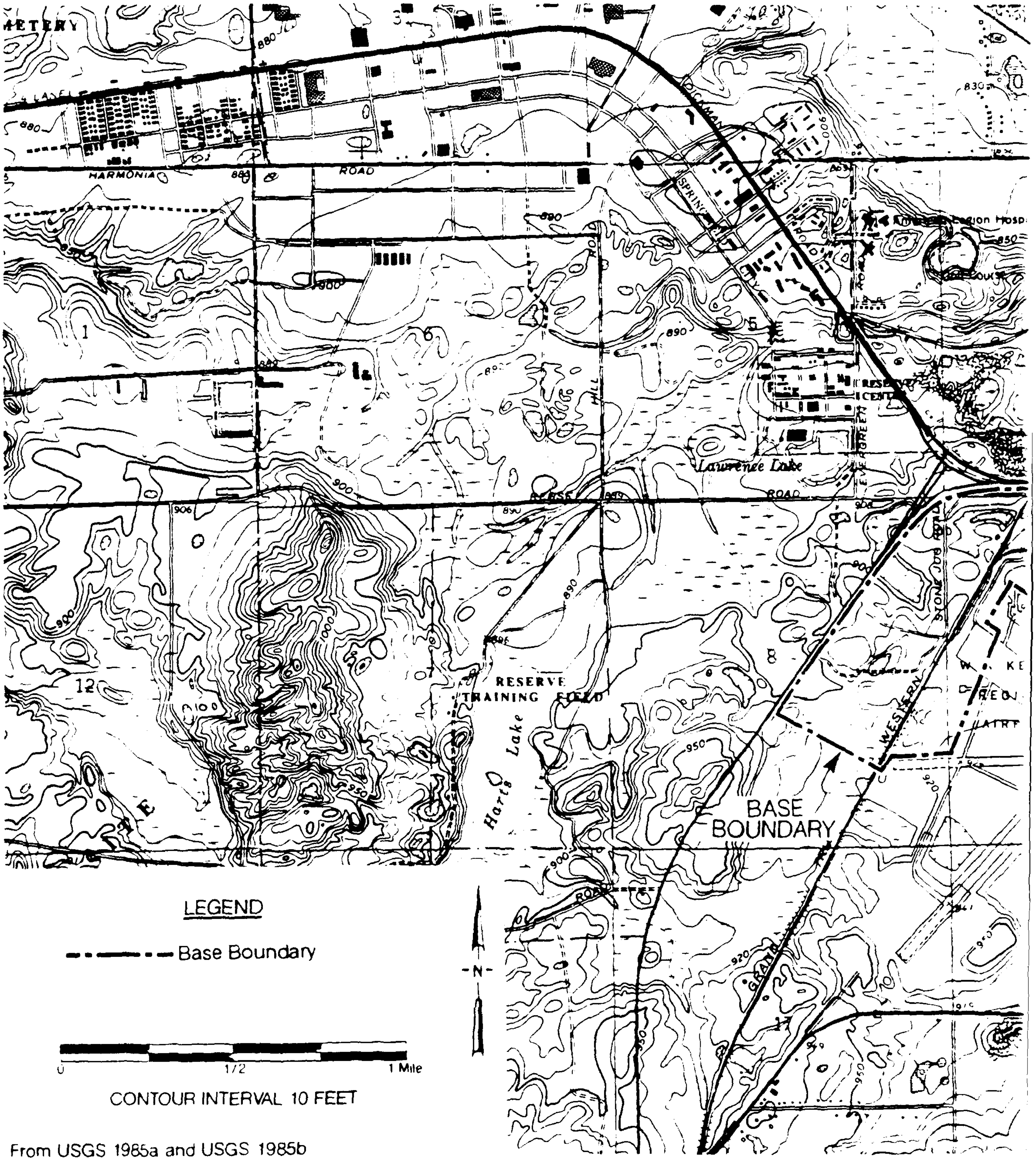
The Calhoun County Health Department has sampled private wells located north of the airport and organic contaminants have been detected in four of the private wells. A discussion of the results of analyses of private well samples and locations of the private wells is presented in Appendix K.

2.7 SUMMARY OF THE ENVIRONMENTAL SETTING

- Average annual precipitation in the Battle Creek area is approximately 33 inches per year (39 inches for the period 1982 to 1986). Approximately 10 inches of this enters the subsurface as infiltration or leaves the base as surface runoff. The calculated net precipitation is less than one inch per year (HMTC, 1987).
- Surface water on the base is drained by ditches and storm drains. Surface flow on the northern portion of the base and Dickman road enters a drainage swale where it either evaporates or infiltrates into the subsurface. Surface flow on the western portion of the Base flows to wetlands and eventually leaves the area as streamflow to the Kalamazoo River or as groundwater flow.
- The soils at the Base are derived from glacial materials and are generally sandy and moderately to highly permeable. The subsurface materials consist of unconsolidated sands, gravels, and clays overlying the Marshall Formation, which is composed of interbedded sandstones and shales.
- Groundwater occurs in the glacial aquifer under unconfined conditions. The glacial aquifer at some locations is separated from the Marshall Sandstone aquifer by a clay layer. Where this clay layer is present the Marshall Sandstone aquifer is locally semi-confined. However, this clay is not continuous and is not present under the western portion of the Base. Groundwater flow is generally to the north. Recharge to this aquifer system is from direct infiltration.
- Groundwater is used for private and municipal drinking water supplies. Numerous private water supply wells in both aquifers exist around the base. Water quality is generally good with a high iron content.

MICHIGAN AIR NATION
BATTLE CREEK

REGIONAL TOPO



From USGS 1985a and USGS 1985b
Battle Creek and Augusta, Mich. Quadrangles

NAL GUARD BASE
K, MICHIGAN

GRAPHIC MAP

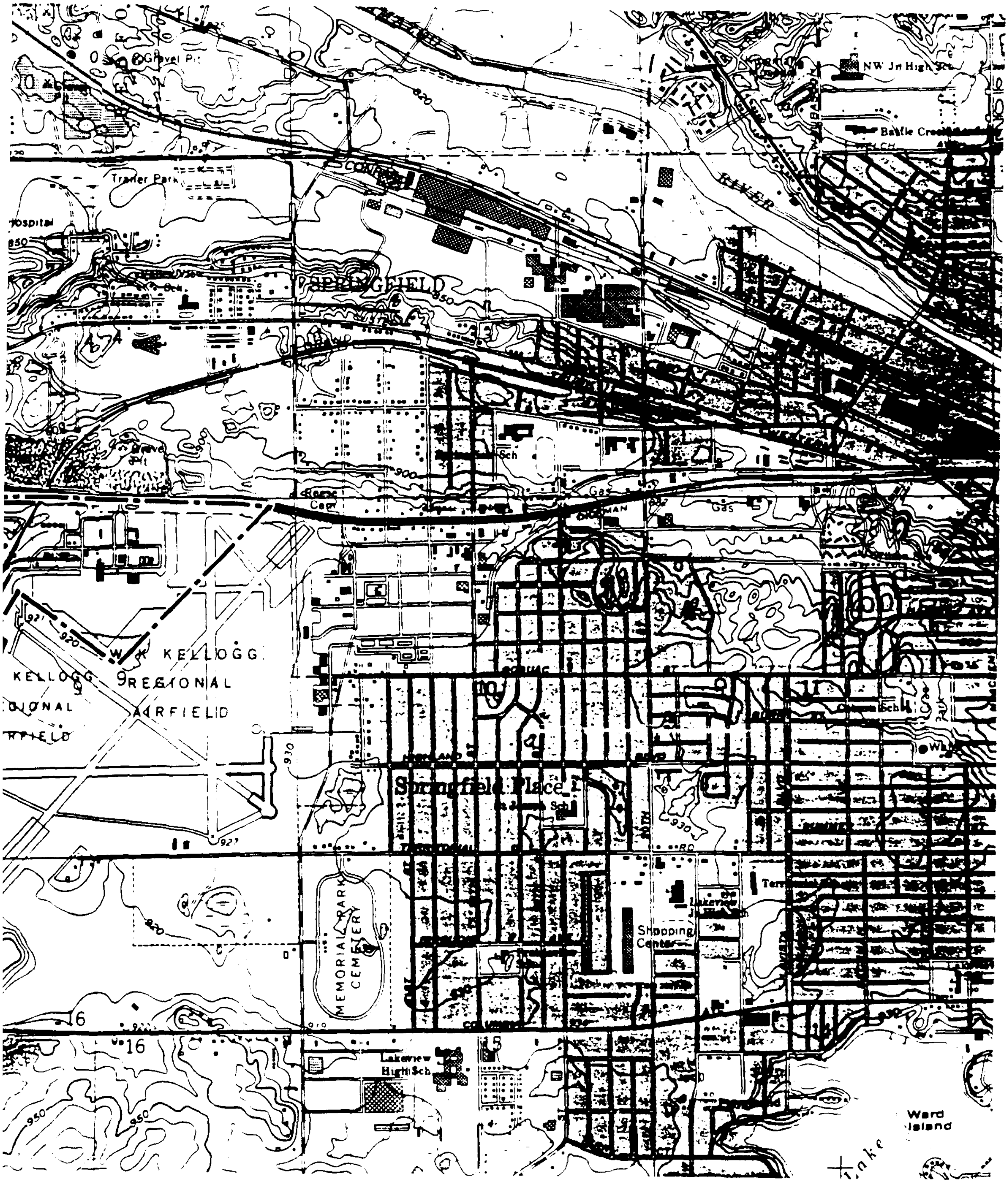
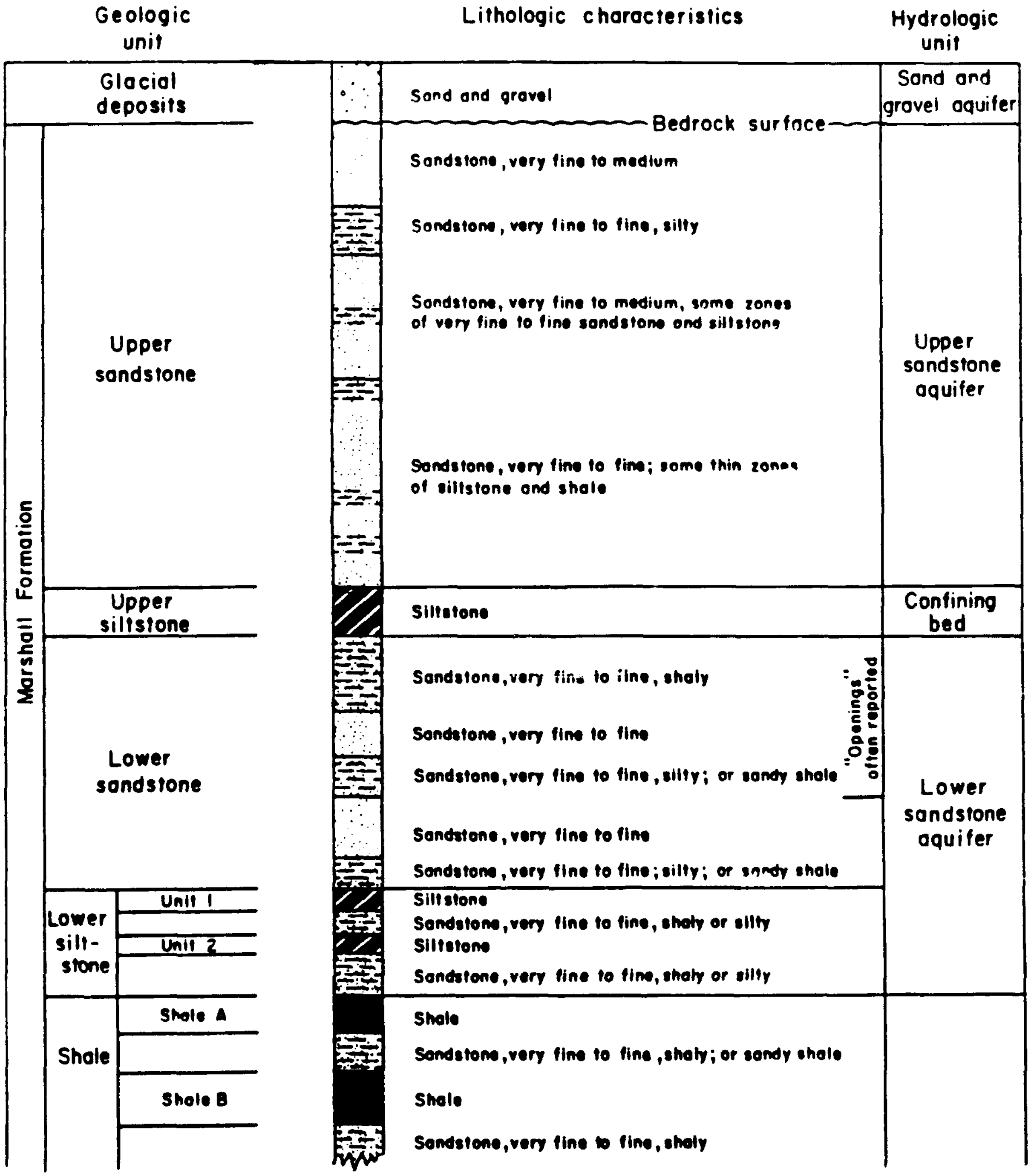


Figure 2.2

MICHIGAN NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN

TYPE LITHOLOGIC COLUMN IN BATTLE CREEK AREA



From Granneman and Twenter, 1985.

MICHIGAN NATI
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BASE-WIDE GROUND
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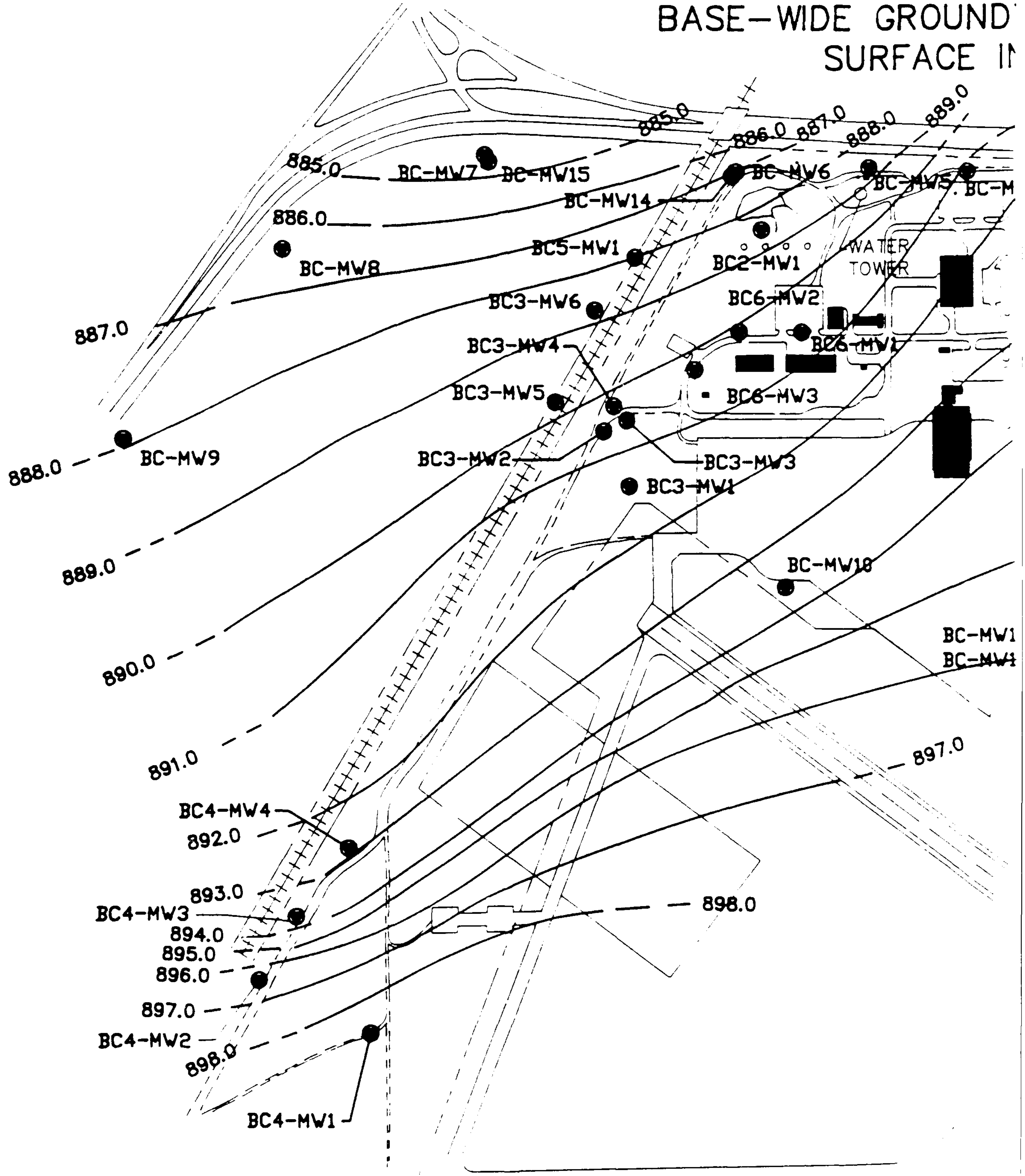

NATIONAL GUARD BASE
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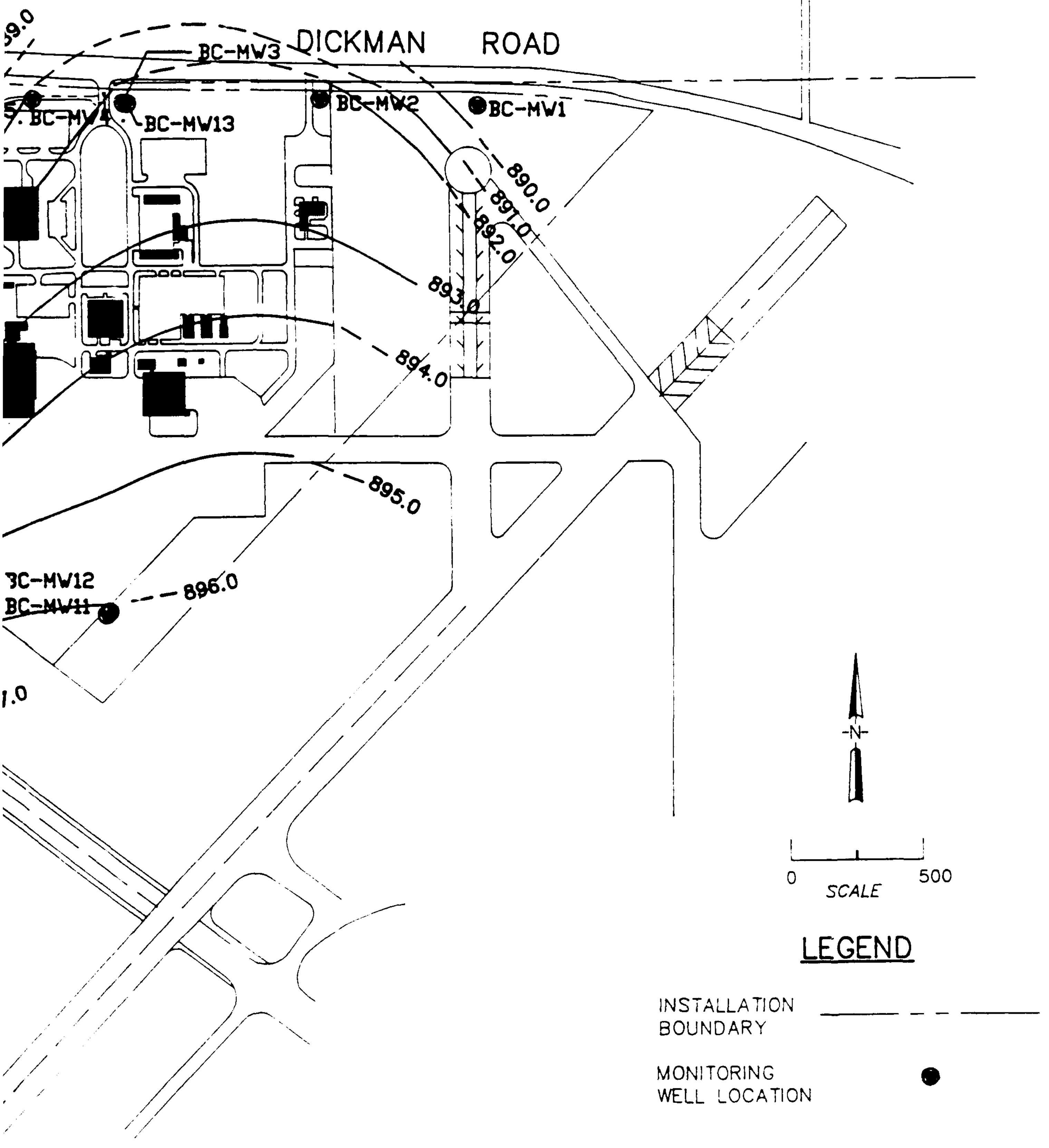

SECTION 3
FIELD INVESTIGATION PROGRAM

The SI included the study of six sites at the Base. This section discusses the scope of the investigations and the procedures and methodology used in the field program, which consisted of obtaining site specific hydrogeologic and geologic data. The field investigation included the collection of soil samples, surface water and sediment samples, and groundwater samples for chemical analysis. Table 3.1 summarizes the activities which were carried out at each site as well as the analytical parameters.

3.1 PROGRAM IMPLEMENTATION

The field program consisted of three separate events conducted by ES personnel. The first field event was conducted from November 1988 through January 1989 and included soil boring and sampling, monitoring well installation and groundwater sampling, surface water and sediment sampling, and aquifer testing. The second field event was conducted in August and September 1989 and included monitoring well installation and groundwater sampling. Also, an interview of Base personnel was conducted in order to identify any additional sources or spills of waste solvents. The third field event was conducted in March 1991 and consisted of groundwater sampling, surface water and sediment sampling, and soil sampling.

Laboratory analytical services were provided by metaTRACE of Earth City, Missouri, for the first event, and by Savannah Laboratories of Savannah, Georgia, for the second and third events. Monitoring wells and soil borings were installed by Fox Drilling of Chicago, Illinois.

3.2 SOIL BORING AND SAMPLING

3.2.1 Field Event 1 - November 1988 to January 1989

3.2.1.1 Soil Boring and Sampling Procedure

Soil borings were advanced and a total of 62 soil samples collected at Sites 1, 3, 5, and 6. All borings were advanced with a truck-mounted rig using continuous-flight hollow-stem augers. Borings that were converted to monitoring wells were advanced with augers having 6-inch minimum inside diameters (ID). Borings only for the collection of soil samples were made with augers with 3.75-inch minimum ID.

Soil samples were collected continuously from the surface to approximately 15 feet BLS in all borings. The samples were collected using either a continuous soil corer with a 5-foot sample barrel or by following Standard Penetration Test procedures (ASTM Method D-1586) using a 3-inch diameter split-spoon In borings deeper than 15 feet, samples were collected at 5-foot intervals from 15 feet to termination using split-spoon samplers. Organic vapors were monitored during drilling operations using an HNu® organic vapor meter and recorded on the boring logs.

Samples from each 5-foot interval were transferred from the sampling device to appropriate sample containers using stainless steel spoons. Organic vapor readings and visual signs of contamination were used to select samples for laboratory analysis. The soil samples were numbered, handled, packaged and shipped as described in Subsections 3.6 and 3.7.

Soils were classified visually with respect to type, grain size, mineralogy (when pertinent), color, moisture content and odor. After visual classification, the lithologic samples were placed in glass jars and stored for future reference. The on-site geologist logged each boring during drilling operations.

The soil borings were located on Base maps with reference to U.S. Geological Survey or U.S. Geodetic Survey benchmarks. The ground surface elevation at each soil boring was surveyed to the nearest ±0.1 foot. The horizontal location of each soil boring was surveyed to the nearest ±1 foot.

3.2.1.2 Decontamination Procedures

Care was taken to prevent cross-contamination between sampling locations as well as between individual samples. Drill rigs were cleaned with high-pressure steam prior to their initial use at the Base. Drill bits, augers, drill rods, split spoon samplers and other down-hole equipment were decontaminated prior to each use. The decontamination procedure consisted of the following:

- Rinse with high-pressure steam;
- Wash and scrub with phosphate-free laboratory-grade detergent in potable water;
- Rinse with high-pressure steam and potable water;
- Rinse with methanol;
- Rinse with HPLC-grade analyte-free water;
- Air dry; and
- Cover with plastic sheeting before transportation to the drill site.

Equipment utilized more than once at a boring location was cleaned at that location using the above procedure except that high pressure rinses were not used.

3.2.1.3 Borehole Abandonment

Following completion of each borehole, the boring was abandoned to prevent rapid infiltration of surface water which might enhance possible contamination migration. A tremie pipe was placed at the bottom of the borehole while grout was pumped into the borehole. The pipe was slowly withdrawn as the borehole was filled. The grout mixture consisted of approximately 95 pounds of Portland Type 1 cement, 5 pounds of Quick Gel-type bentonite and 6 gallons of water. This mixture was thoroughly mixed using a grout pump. After pumping into the borehole, the grout was allowed to settle and infiltrate into the natural formation and was later topped off with a similar mixture.

3.2.2 Field Event 2 - August and September 1989

No soil boring or soil sampling was conducted during the second field event.

3.2.3 Field Event 3 - March 1991

3.2.3.1 Soil Sampling Procedures

Eleven soil samples were collected at Site 6 in March 1991 to confirm the analytical data from the first sampling event. The samples were collected with a hand-operated core-barrel sampler with two aluminum sleeve inserts.

Samples were collected at two-foot intervals from ground surface to 4 feet BLS. Between sampling depths, the borehole was advanced using a stainless-steel bucket auger. Upon collection of a sample, the sample barrel was removed and the two filled inserts were removed. The ends of one sleeve were immediately covered with Teflon tape, capped with plastic end caps, and sealed with tape. A portion of soil from the other sleeve was transferred to a small glass jar, which was then covered with aluminum foil. After all samples were collected from a borehole, headspace readings were taken on the soil in the glass jars using an HNu® photoionization detector. The soil-filled sleeves corresponding to the two highest headspace readings were shipped for laboratory analysis. Sampling packaging procedures are provided in Section 3.7.

3.2.3.2 Decontamination Procedures

The core barrel sampler was decontaminated prior to collection of each sample and the bucket auger was decontaminated prior to use in each borehole. The sleeve inserts for the sampler were also decontaminated before use. The following procedure was used:

- Wash with phosphate-free laboratory-grade detergent in potable water and scrub with a stiff brush;
- Rinse in potable water;
- Rinse with pesticide-grade methanol;
- Rinse with HPLC-grade analyte-free water;

- Allow to air dry.

Decontaminated equipment was placed on clean aluminum foil.

3.3 MONITORING WELL INSTALLATION

3.3.1 Monitoring Well Construction

Twenty monitoring wells were installed at Sites 2, 3, 4, 5, and 6, and along the Base boundary[1]. The monitoring well boreholes were drilled using 6.25-inch ID hollow-stem augers in unconsolidated sands at or above the water table, and 6-inch outer diameter rotary bits below the water table. During drilling, continuous split-spoon sampling was performed following Standard Penetration Test procedures (ASTM Test D-1586) to collect soil samples for lithologic evaluation.

A typical monitoring construction diagram is shown on Figure 3.1 The monitoring wells were constructed inside the augers to maintain the integrity of the boreholes during installation and to ensure that the filter pack was equally distributed in the annular space. The monitoring wells were constructed of new, two-inch ID, Schedule 40 PVC casing and screen. The screen had a slot size of 0.010 inches. All casings and screens had threaded flush joints. End caps were used at the top and bottom of the well. The casing and screen were set at the selected depth and the sand pack was placed in the annular space from approximately two feet below the bottom of the screen to at least 3 feet above the top of the screen.

A one to two-foot bentonite seal was placed above the sand pack. Clean potable water was added to the bentonite and the bentonite seal was allowed to hydrate for a minimum of four hours. The hole was then backfilled using a tremie pipe to within a few feet of the surface with a cement/bentonite grout mixture.

The monitoring wells were completed above ground, with approximately two feet of PVC casing extending above the ground surface. A locking steel protective casing was suspended over each PVC casing. Cement was placed into the annular space between the protective casing and the borehole wall. A concrete pad was constructed on the ground surface to direct water drainage away from the well. Steel guard posts were erected around each of the protective steel casings. All casings were painted and marked with well identification numbers.

The monitoring well locations were located on Base maps with reference to U.S. Geological Survey or U.S. Geodetic Survey benchmarks. The elevations of all new wells were surveyed to the nearest ±0.01 foot. The horizontal location of each monitoring well was surveyed to the nearest ±1 foot. The survey work was performed by a registered land surveyor.

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[1] Ten monitoring wells had been installed during a previous investigation at the Base. A total of 30 wells now exist and all were utilized for the project.

3.3.2 Monitoring Well Development

Monitoring well development was performed after the wellhead completions had set for a minimum of 24 hours. Initially the static water levels and total well depths from the top of casings were measured. The wells were developed by airlifting, surging, or pumping until the discharged water was clear and free of sediment as determined by the on-site geologists. Well development continued until temperature, pH, and conductivity measurements had stabilized to within 10% of the previous measurement for three consecutive measurements. Physical characteristics such as color, odor, turbidity, the presence of separate phases, odors, etc. were recorded throughout well development operations. The duration of different development methods and estimated quantities of water removed were also recorded.

3.3.3 Decontamination Procedures

Decontamination for all drilling and sampling activities consisted of combinations of steam cleaning, laboratory-grade detergent (Liquinox) wash, pesticide-grade methanol rinse, and HPLC-grade water rinse. Decontamination fluids were discharged into a waste solvents tank. Decontamination fluids resulting from on-site decontamination (e.g., split-spoons, etc.) were collected and transported to the designated area for disposal.

Decontamination was conducted in a manner that guarded against cross-contamination of equipment. Augers, drill rods, and other large pieces of equipment were placed on plastic sheeting to keep them from touching the ground. Smaller items were placed on clean plastic sheeting or on surfaces covered with aluminum foil. Personnel wore clean vinyl or neoprene gloves during decontamination of equipment. All decontamination procedures performed during the course of the field investigation were documented in the site-specific field logbook.

The drilling rig was thoroughly cleaned when it first arrived at the Base. Prior to beginning work at each particular site, the drilling platform area was cleaned with a steam cleaner.

All drilling equipment, including well screen and casing, augers, bits, drilling and sampling rods, and other non-sampling equipment was cleaned before each use by steam cleaning, washing with detergent, and rinsing with potable water. This method of cleaning was also used for other miscellaneous equipment such as pumps, piping, and fittings used to develop wells.

3.4. GROUNDWATER SAMPLING

3.4.1 Groundwater Sampling Procedures

Groundwater samples were collected from the 20 monitoring wells installed in 1989 and from the 10 existing wells. Groundwater samples were collected during all three field events. Water levels were measured prior to purging the wells and again immediately after collecting the samples.

Each monitoring well was purged with a Teflon bailer or a submersible pump. During purging, temperature, pH, and specific conductance were monitored. Purging was completed when these readings had stabilized and a minimum of three casing volumes of water had been purged from the well.

Groundwater samples were collected immediately after each well was purged. During the third field event samples for priority pollutant metals analyses were filtered in the field using 0.45 micron filters. A new inline filter was attached to the submersible pump discharge line at each well that was purged with the submersible pump. At wells purged with a bailer, the sample was transferred from a Teflon bailer to an unpreserved sample container. A peristaltic pump and Tygon® tubing were then used to pass the water sample through an inline filter into a preserved sample container, which was packaged as discussed in Section 3.7.

All samples collected during the first and second field events and samples collected for organics analyses during the third field event were collected using Teflon bailers attached to new nylon rope. Preservatives, when used, were added to the containers before filling with the water samples.

3.4.2 Decontamination Procedures for Groundwater Sampling

The submersible pump was decontaminated prior to use at each well. Decontamination was conducted according to the following procedure:

- Wash external surfaces of pump and line with phosphate-free laboratory-grade detergent in potable water and scrub with stiff brush;
- Rinse in potable water;
- Place pump in potable water with phosphate-free laboratory-grade detergent and run pump until the water and detergent have filled the entire line;
- Pump fresh potable water through line until all detergent has discharged;
- Reverse the pump to empty water from the line; and
- Rinse external areas of pump with HPLC-grade analyte-free water.

Teflon bailers were decontaminated between uses. After using a decontaminated bailer for purging, a different decontaminated bailer was used for sampling. The following procedure was used for bailer decontamination:

- Wash with phosphate-free laboratory-grade detergent in potable water and scrub with a stiff brush;
- Rinse in potable water;
- Rinse with pesticide-grade methanol;

- Rinse with HPLC-grade analyte-free water;
- Allow to air dry; and
- Wrap in aluminium foil.

3.5 SURFACE WATER AND SEDIMENT SAMPLING

3.5.1 Sample Collection Procedures

Two surface water samples were collected at Site 2 during the first event and four surface water samples were collected during the third field event. Grab samples were collected by immersing the sample container below the water surface and filling it to its full capacity. The samples were packaged as described in Subsection 3.7.

Seven sediment samples were collected at Site 2 during the first and third field events. In the first event, samples were prepared by compositing small portions of sediment collected in the immediate area of the sampling station. The sample was first placed in a decontaminated stainless steel bowl, mixed, then placed in the appropriate sample container prior to shipping. Sediment samples recovered for analysis of volatile organic compounds were not composited. In the third event, samples were collected with a slide-hammer core sampler. These core samples are enclosed in a stainless steel sleeve with both ends covered with Teflon® tape and plastic covers.

3.5.2 Decontamination Procedures

Procedures for decontamination of the core sampler are provided in Section 3.2.3.2. Decontamination of other sampling equipment was in accordance with the procedures for bailer decontamination, provided in Section 3.4.2.

3.6 SAMPLE NUMBERING SYSTEM

Each sample collected for analysis was assigned a unique identification number that described where the sample was collected. Each number consisted of a group of letters and numbers. For example a groundwater sample may be labeled: **BC4-MW1-3.**

In this example **BC** stands for the project name (Battle Creek), **4** is the site (Site 4, Abandon Landfill), **MW1** is the sampling location (Monitoring Well No. 2, or MW2), and the final **3** is the sequential number of the field effort. Other sampling location descriptions include SB (soil boring), SW (surface water), and SED (sediment). For soil samples only, the final number represents the depth of the top of the sample.

The identification number was recorded on the sample label and chain of custody forms. The number was also recorded in the field logbook along with any additional comments relative to the sample description and collection methodology.

QA samples were labeled with **RB** for rinseate blanks, **TB** for trip blanks, or **FB** for field blanks, followed by the sequential number of the sample and the field event identifier. For example, a sample labelled BC-TB2-3 would indicate the second trip blank collected during the third field event.

Field duplicates assigned unique identifiers which were indistinguishable from the sample identifiers: a site number and well number was assigned with no corresponding well or site location in the field. For example, a blind duplicate of the groundwater sample BC2-MW1-3 would be BC7-MW1-3, where Site 7 dues not exist. Records of all such QA samples were kept in the field log books.

3.7 SAMPLE HANDLING, PACKAGING, AND SHIPMENT

3.7.1 Sample Handling

All samples and duplicates were placed in pre-cleaned bottles for shipping to the laboratories. These bottles (Series 300) were prepared according to EPA procedures by I-CHEM Research of Hayward, California (first and second field events) and Environmental Sampling Supply of Oakland, California (third field event). Individual sample bottles were labeled with the following information:

- Project identifier;
- Sample identifier (as described above);
- Preservatives added (specific for analytical method);
- Date of sample collection;
- Time of sample collection; and
- Required analytical method (specific for each container).

Each sample bottle was sealed with a Teflon®-lined cap that was taped shut using polyethylene tape (Teflon® tape on samples for volatile organics analysis) to ensure it remained sealed during shipment. Individual bottles were then wrapped in bubble pack to prevent breakage during shipment. Sample bottles were placed in plastic ziploc bags, sealed, and placed into insulated shipping coolers, along with sealed plastic bags containing ice. A chain-of-custody form was completed and sealed inside each cooler in a waterproof envelope prior to shipping.

3.7.2 Sample Custody

Proper sample custody procedures are needed to ensure that samples have been obtained from the locations stated and that they have reached the laboratory without alteration. All sample bottles were maintained in a locked storage area prior to use. Evidence of the sample traceability from collection to shipment, laboratory receipt, and laboratory custody was documented. A sample was considered to be in a person's custody if the sample is:

- In a person's actual possession;

- In view after being in a person's possession;
- Locked so that no one could tamper with it after having been in physical custody; or
- In a secured area, restricted to authorized personnel.

The field team leader was responsible for overseeing and supervising the implementation of proper sample custody procedures in the field. He was also designated as the field sample custodian and is responsible for ensuring sample custody until the samples had been transferred to a courier.

Once the samples were received by the laboratory, a designated person was responsible for maintaining a file of all the original documents (e.g., chain of custody forms, traffic reports, special analytical services request form, etc.) pertinent to sample custody and sample analysis protocol.

A Chain-of-Custody Record accompanied the sample during shipment to the laboratory, and through the laboratory. When transferring samples, the individuals relinquishing and receiving signed, dated and noted the time on the record. The laboratory maintains a file copy, and the completed original was returned to the project manager as a part of the final analytical report. This record is used to document sample custody transfer from the sampler to the laboratory.

Shipments were sent by overnight express carrier and air bills were kept as receipt of shipment. Air bills have been retained as part of the permanent documentation.

- Project identifier;
- Name and signature of person who collected the samples;
- Sample identifiers (for all samples in the cooler);
- Date and time of sample collection;
- Number of individual bottles for each sample; and
- Required analytical methods for each sample.

The coolers were shipped for overnight delivery to the laboratory.

3.8 WATER LEVEL MEASUREMENTS

The water levels were measured to the nearest 0.01 feet using an electric water level indicator referenced to the surveyor's mark made on the top of the PVC riser. The elevation of this mark was determined to the nearest 0.01 foot and referenced to an established datum. Water levels were measured in the new monitoring wells at the time of completion and after development. Water levels were measured in all wells immediately prior to purging and sampling and again after all field work was completed for each field event.

3.9 AQUIFER TESTING

Hydrological characteristics of the surficial aquifer were estimated by slug tests. Slug tests were performed on 14 monitoring wells at the Base. These tests were performed by causing an instantaneous change in the water levels of wells by the introduction and removal of a PVC or stainless-steel rod (slug). During the tests, water levels and time intervals were recorded using an In-situ Hermit 1000® recorder with a pressure transducer submerged in the wells. The hydraulic conductivities and transmissivities of the materials immediately surrounding the wells were estimated by the analytical method of Bouwer (1987) using the rates at which water levels changed following the introduction and removal of the slug. A complete description of the tests with all field data and interpretative plots are included as Appendix C.

3.10 ANALYTICAL METHODS

The number of samples collected, the types of analyses performed, and the number of QA samples collected during each of the three field events are outlined in Table 3.2. Analytes and practical quantitation limits for each analysis are provided in Table 3.3.

Environmental Protection Agency methods were used as the basis for all analyses for which methods exist. The EPA methods are contained in *Test Methods for Evaluation, Solid Waste, SW846*, 3rd edition; *Methods for the Analysis of Water and Wastes,* EPA 600/4-79-020 (revised March 1983), and *CLP Statement of Work (SOW) for Organic Analyses* (February 1988). Target compounds and detection limits for the analytical methods which were used in the SI are discussed in Section 4.

3.11 QUALITY ASSURANCE AND QUALITY CONTROL

3.11.1 Quality Control Samples

During each sampling effort, a number of QC samples were collected and submitted for laboratory analysis. A list of the types of QC samples that were collected along with a brief description of each sample type is outlined in the following sections.

3.11.1.1 Trip Blanks

Trip blanks were collected for chemical analysis of volatile organics. The analytical results serve as a Baseline measurement of volatile organic contamination that samples have been exposed to during packaging, transport and laboratory storage prior to analysis.

The trip blanks originated in the laboratory. They were composed of analyte-free deionized water which was placed in sample containers by the subcontracting laboratory, transported to the sample collection site, handled along with the samples, and returned to the laboratory along with the samples of water and/or soil collected for volatile organic analysis. The trip blank containers were not opened in the field.

One trip blank was included in each shipping container containing samples for volatile organics analysis. It was stored in the laboratory with the samples and analyzed by the laboratory for volatile organic compounds. In one shipment, the trip blank was inadvertently left out of the shipping container. The trip blank was shipped with the following day's samples.

3.11.1.2 Rinseate Blanks

Rinseate blanks were collected from sampling equipment when devices other than the sample bottle itself is required. The analysis of these blanks serves to verify that cross-contamination of samples did not occur due to improperly decontaminated equipment.

Rinseate blanks were comprised of HPLC-grade water which was transported to the sample collection site, poured into the sampling device following equipment decontamination procedures, transferred to the sample bottles, and shipped to the laboratory for analysis. The rinseate blanks were analyzed for the same parameters as the associated samples. During the second and third field event, one rinseate blank was collected for every 10 environmental samples collected per matrix, per sampling event.

3.11.1.3 Field Blanks

Field blanks were collected for each type of water used to decontaminate drilling and sampling equipment. One sample from each event and each source of water was collected and analyzed. A separate field blank was collected for each lot of HPLC water.

3.11.1.4 Field Duplicates

Analysis of duplicates provides statistical information relating to sample variability and serves as a check on the precision of any sample collection method as it pertains to the sampled area. Duplicate samples were obtained from a location immediately following the collection of the original sample, with the exception of the samples for analysis of volatile organics. These samples were obtained as close as possible to the initial sample source.

Ten percent of all samples from each matrix for each event were collected in duplicate and submitted for laboratory analysis. Field duplicates were labeled in such a manner so that persons performing laboratory analyses were not able to distinguish duplicates from other collected samples.

3.11.1.5 Matrix Spikes and Matrix Spike Duplicates

Matrix spike (MS) samples and matrix spike duplicate (MSD) samples were collected to assess the accuracy and precision of the analytical data. One MS sample and one MSD sample was collected for every 20 environmental samples of each matrix per event.

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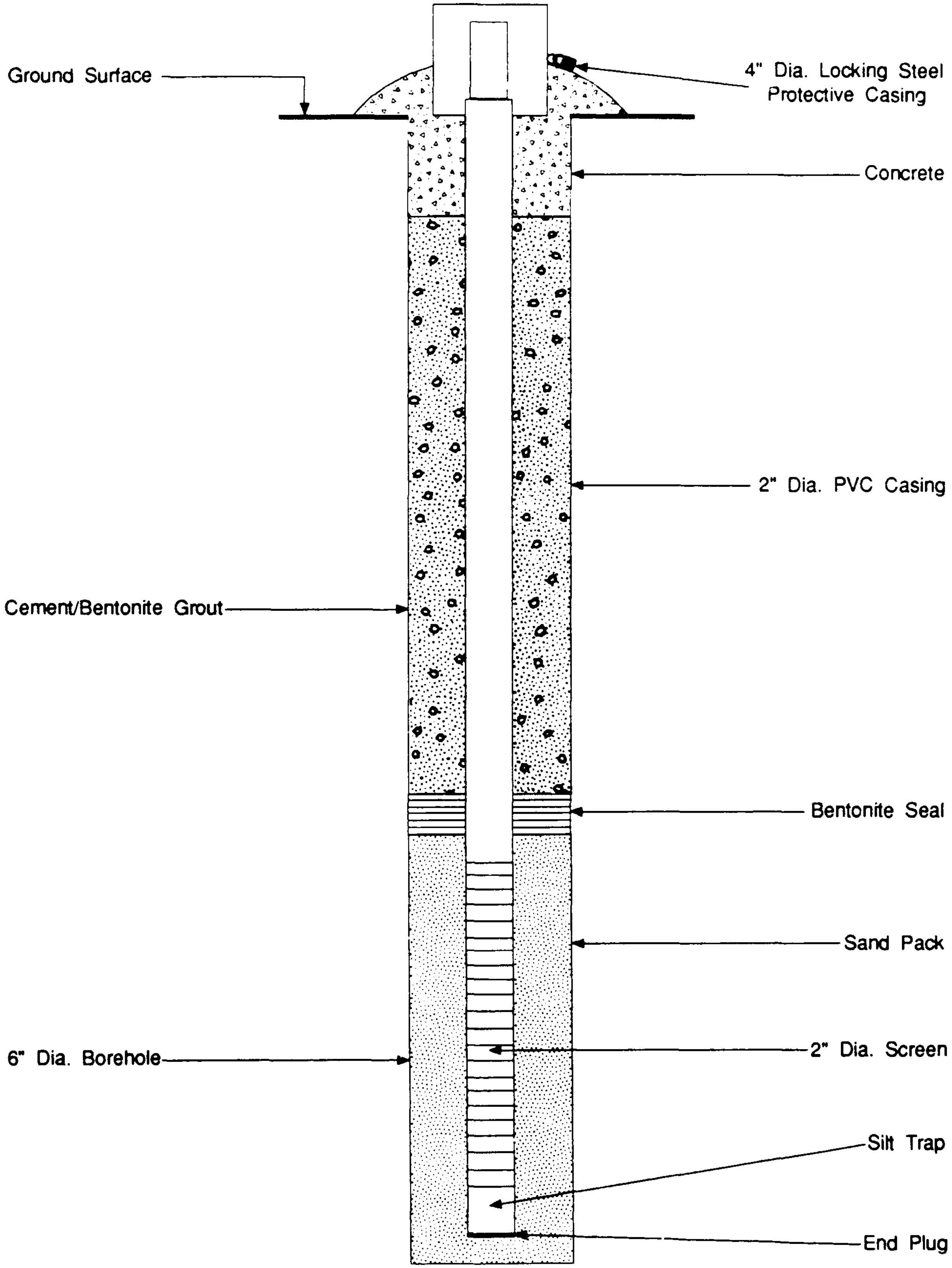
TYPICAL MONITORING WELL CONSTRUCTION DIAGRAM



(Not To Scale)

TABLE 3.1
SUMMARY OF FIELD PROGRAM
110TH FG, MICHIGAN AIR NATIONAL GUARD
W.K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Site	Field Event No. 1 November 1988 - January 1989	Field Event No. 2 August - September	Field Event No. 3 March 1991
1 - Fuel Tank Farm	• Drilled 13 soil borings, collected soil samples		
2 - Drainage Swale	• Installed 1 shallow monitoring well; collected 1 groundwater sample. • Collected 4 sediment samples and 2 surface samples.	• Collected 1 groundwater sample.	• Collected 1 groundwater sample. • Collected 7 sediment samples and 4 surface water samples.
3 - Fire Training Area	• Drilled 5 soil borings collected in soil samples. • Installed 3 shallow monitoring wells and 1 deep monitoring well, collected 4 groundwater samples. • Performed slug tests on 3 monitoring wells.	• Collected 6 groundwater samples. • Installed 2 shallow monitoring wells.	• Collected 6 groundwater samples.
4 - Abandoned Landfill	• Installed 4 shallow monitoring wells; collected 4 groundwater samples. • Performed slug tests on 2 monitoring wells.	• Collected 4 groundwater samples.	• Collected 4 groundwater samples.

TABLE 3.1--Continued
SUMMARY OF FIELD PROGRAM
110TH FG, MICHIGAN AIR NATIONAL GUARD
W.K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Site	Field Event No. 1 November 1988 - January 1989	Field Event No. 2 August - September	Field Event No. 3 March 1991
5 - Former Coal Storage Area	• Drilled 6 soil borings; collected soil samples. • Installed 1 shallow monitoring well; collected 1 groundwater sample. • Conducted aquifer test	• Collected 1 groundwater sample.	• Collected 1 groundwater sample.
6 - Fuel Storage Tanks	• Drilled 5 soil borings, collected soil samples. • Installed 3 shallow monitoring wells; • Performed slug tests on 3 monitoring wells.	• Collected 3 groundwater samples.	• Collected 3 groundwater samples. • Collected 11 soil samples from 6 borings.
Base Boundary	• Collected 10 groundwater samples.	• Installed 5 monitoring wells. • Collected 15 groundwater samples.	• Collected 15 groundwater samples.

TABLE 3.2
SUMMARY OF ANALYSES PERFORMED
110TH FG, MICHIGAN AIR NATIONAL GUARD
W.K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Matrix/Analysis[1]	Method	Field Event [a]						
		Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Base Boundary
Soil								
Volatile Organic Compounds	SW8240	1^b	--	1^b	--	--	1^b	--
Polynuclear Aromatic Hydrocarbons	SW8100	--	--	--	--	1^b	--	--
BETX	SW8020	--	--	--	--	--	3	--
Semivolatile Organic Compounds	SW8270	--	--	1^b	--	--	--	--
TPH	E418.1	1^b	--	--	--	--	1^b, 3	--
Priority Pollutant Metals	SW6010 & 7000 series	--	--	1^b	--	1^b	--	--
Sediment								
Volatile Organic Compounds	SW8240	--	1^b	--	--	--	--	--
	CLP SOW	--	3	--	--	--	--	--
Semivolatile Organic Compounds	SW8270	--	1^b	--	--	--	--	--
	CLP SOW	--	3	--	--	--	--	--
Priority Pollutant Metals	SW6010 & 7000 series	--	1^b,3	--	--	--	--	--
Groundwater								
Volatile Organic Compounds	SW8010/SW8020	--	1^b,2	1^b,2	1^b,2	1^b,2	1^b,2	1^b,2
	CLP/SOW	--	3	3	3	3	3	3

TABLE 3.2--Continued
SUMMARY OF ANALYSES PERFORMED
110TH FG, MICHIGAN AIR NATIONAL GUARD
W.K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Matrix/Analysis[1]	Method	Field Event [a]						
		Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Base Boundary
Groundwater (Continued)								
Semivolatile Organic Compound	SW8270	--	1^b	1^b	1^b	1^b	--	1^b
Priority Pollutant Metals	SW6010/ & 7000 series	--	$1^b,2^c,3^e$	$1^b,2^c,3^e$	$1^b,2^d,3^e$	$1^b,2^c,3^e$	$1^b,2^c,3^e$	$1^b,2^c,3^e$
TPH	E418.1	--	--	--	--	--	1^b	--
Surface Water								
Volatile Organic Compounds	SW8010/SW8020	--	1^b	--	--	--	--	--
	CLP SOW	--	3	--	--	--	--	--
Semivolatile Organic Compounds	SW8270	--	1^b	--	--	--	--	--
	CLP SOW	--	3	--	--	--	--	--
Priority Pollutant Metals	SW6010/ 7000 series	--	1^b, 3	--	--	--	--	--

Notes:

a. 1 November 88 - January 89
   2 August-September 89
   3 March 91

b. Data is rejected.

c. Lead only.

d. Lead and chromium only

e. Dissolved fraction (filtered sample - 0.45I)

	Prep Method	
Analysis	Liquids	Soils
VOA (8240)	SW 5030	SW 5030
ICP-Metals (6010)	SW 3010	SW 3050
As (7060)	SW 3020	SW 3050
Pb (7421)	SW 3020	SW 3050
Se (7740)	SW 3020	SW 3050
Tle (7841)	SW 3020	SW 3050
Hg (7470/7471)	SW 7470	SW 7471
SVOA (8270)	SW 3520	SW 3550
TPH (418.1)	E-418.1	SW 3540
Purgeables (602)	SW 5030	SW 5030

TABLE 3.3
TARGET COMPOUNDS AND PRACTICAL QUANTITATION LIMITS(1)

	Practical Quantitation Limit[1] Water Samples (µg/L)	Practical Quantitation Limit[1] Soil Samples (µg/kg)
SW8010 - Halogenated Volatile Organics (1989 Sampling Event)		
Benzyl chloride	1.0	NA
Bis(2-chloroethoxy)methane	1.0	NA
Bis(2-chloroisopropyl)ether	1.0	NA
Bromobenzene	1.0	NA
Bromodichloromethane	1.0	NA
Bromoform	1.0	NA
Bromoethane	1.0	NA
Carbon tetrachloride	1.0	NA
Chloroacetaldehyde	1.0	NA
Chlorobenzene	1.0	NA
Chloroethane	1.0	NA
Chloroform	1.0	NA
1-Chlorohexane	1.0	NA
2-Chloroethyl vinyl ether	1.0	NA
Chloromethane	1.0	NA
Chloromethylmethyl ether	1.0	NA
Chlorotoluene	1.0	NA
Dibromochloromethane	1.0	NA
Dibromomethane	1.0	NA
1,2-Dichlorobenzene	1.0	NA
1,3-Dichlorobenzene	1.0	NA
1,4-Dichlorobenzene	1.0	NA
Dichlorodifluoromethane	1.0	NA
1,1-Dichloroethane	1.0	NA
1,2-Dichloroethane	1.0	NA
1,1-Dichloroethylene	1.0	NA
trans-1,2-Dichloroethylene	1.0	NA
Dichloromethane	1.0	NA
1,2-Dichloropropane	1.0	NA
trans-1,3-Dichloropropylene	1.0	NA
1,1,2,2-Tetrachloroethane	1.0	NA
Tetrachloroethylene	1.0	NA
1,1,1-Trichloroethane	1.0	NA
1,1,2-Trichloroethane	1.0	NA
Trichloroethylene	1.0	NA
Trichlorofluoromethane	1.0	NA
Trichloropropane	1.0	NA
Vinyl chloride	1.0	NA

TABLE 3.3--Continued
TARGET COMPOUNDS AND PRACTICAL QUANTITATION LIMITS(1)

	Practical Quantitation Limit1 Water Samples (μg/L)	Practical Quantitation Limit1 Soil Samples (μg/kg)
<u>SW8020 - Aromatic Volatile Organics (1989 Sampling Event)</u>		
Benzene	1.0	NA
Chlorobenzene	1.0	NA
1,2-Dichlorobenzene	1.0	NA
1,3-Dichlorobenzene	1.0	NA
1,4-Dichlorobenzene	1.0	NA
Ethyl Benzene	1.0	NA
Toluene	1.0	NA
Xylenes	1.0	NA
<u>SW8020 - Purgeable Aromatic Hydrocarbons</u> (BTEX) (1989 Sampling Event)		
Benzene	2.0	2.0
Ethyl Benzene	2.0	2.0
Toluene	2.0	2.0
Xylenes (o, m, p, isomers)	2.0	4.0
<u>CLP SOW Volatile Organics (1991 Sampling Event)</u>		
Chloromethane	10.0	10.0
Bromomethane	10.0	10.0
Vinyl Chloride	10.0	10.0
Chloroethane	10.0	10.0
Methylene Chloride	5.0	5.0
Acetone	10.0	10.0
Carbon Disulfide	5.0	5.0
1,1-Dichloroethene	5.0	5.0
1,1-Dichloroethane	5.0	5.0
1,2-Dichloroethene (Total)	5.0	5.0
Chloroform	5.0	5.0
1,2-Dichloroethane	0.36	5.0
2-Butanone	10.0	10.0
1,1,1-Trichloroethane	5.0	5.0
Carbon Tetrachloride	2.0	5.0
Vinyl Acetate	10.0	10.0
Bromodichloroemethane	5.0	5.0
1,2-Dichloropropane	5.0	5.0
cis-1,3-Dichloropropene	5.0	5.0
Trichloroethene	1.1	5.0
Dibromochloromethane	5.0	5.0
1,1,2-Trichloroethane	5.0	5.0
Benzene	0.26	5.0
trans-1,3-Dichloropropene	5.0	5.0

TABLE 3.3--Continued
TARGET COMPOUNDS AND PRACTICAL QUANTITATION LIMITS(1)

	Practical Quantitation Limit1 Water Samples (µg/L)	Practical Quantitation Limit1 Soil Samples (µg/kg)
CLP SOW Volatile Organics cont. (1991 Sampling Event)		
Bromoform	5.0	5.0
4-Methyl-2-pentanone	10.0	10.0
2-Hexanone	10.0	10.0
Tetrachloroethene	2.0	5.0
Toluene	0.4	5.0
1,1,2,2-Tetrachloroethane	5.0	5.0
Chlorobenzene	5.0	5.0
Ethyl Benzene	5.0	5.0
Styrene	5.0	5.0
Xylenes (Total)	5.0	5.0
CLP SOW Semi-Volatile Organics		
1,2,4-Trichlorobenzene	10	330
1,2-Dichlorobenzene	10	330
1,3-Dichlorobenzene	10	330
1,4-Dichlorobenzene	10	330
2,4,5-Trichlorophenol	50	1600
2,4,6-Trichlorophenol	10	330
2,4-Dichlorophenol	10	330
2,4-Dimethylphenol	10	330
2,4-Dinitrophenol	50	1600
2,4-Dinitrotoluene	10	330
2,6-Dinitrotoluene	10	330
2-Chloronaphthalene	10	330
2-Chlorophenol	10	330
2-Methylnaphthalene	10	330
2-Methylphenol	10	330
2-Nitroaniline	50	1600
2-Nitrophenol	10	330
3,3'-Dichlorobenzidine	20	660
3-Nitroaniline	50	1600
4,6-Dinitro-2-methylphenol	50	1600
4-Bromophenyl-phenylether	10	330
4-Chloro-3-methylphenol (para-chloro-meta-cresol)	10	330
4-Chloroaniline	10	330
4-Chlorophenyl-phenyl ether	10	330
4-Methylphenol	10	330
4-Nitroaniline	50	1600
4-Nitrophenol	50	1600
Acenaphthene	10	330

TABLE 3.3--Continued
TARGET COMPOUNDS AND PRACTICAL QUANTITATION LIMITS(1)

	Practical Quantitation Limit1 Water Samples (μg/L)	Practical Quantitation Limit1 Soil Samples (μg/kg)
<u>CLP SOW Semi-Volatile Organics cont.</u>		
Acenaphthylene	10	330
Anthracene	10	330
Benzo(a)anthracene	10	330
Benzo(a)pyrene	10	330
Benzo(b)fluoranthene	10	330
Benzo(g,h,i)perylene	10	330
Benzo(k)fluoranthene	10	330
Benzoic acid	50	1600
Benzyl alcohol	10	330
bis(2-Chloroethoxy) methane	10	330
bis(2-Chloroethyl) ether	10	330
bis(2-Chloroisopropyl) ether	10	330
bis(2-Ethylhexyl)phthalate	10	330
Butylbenzyphthalate	10	330
Chrysene	10	330
Di-n-butylphthalate	10	330
Di-n-octylphthalate	10	330
Dibenz(a,h)anthracene	10	330
Dibenzofuran	10	330
Diethylphthalate	10	330
Dimethylphthalate	10	330
Fluoranthene	10	330
Fluorene	10	330
Hexachlorobenzene	10	330
Hexachlorobutadiene	10	330
Hexachlorocyclopentadiene	10	330
Hexachloroethane	10	330
Indeno(1,2,3-cd)pyrene	10	330
Isophorone	10	330
N-Nitroso-di-n-dipropylamine	10	330
N-nitrosodiphenylamine	10	330
Naphthalene	10	330
Nitrobenzene	10	330
Pentachlorophenol	50	1600
Phenanthrene	10	330
Phenol	10	330
Pyrene	10	330

TABLE 3.3--Continued
TARGET COMPOUNDS AND PRACTICAL QUANTITATION LIMITS(1)

	Practical Quantitation Limit1 Water Samples (μg/L)	Practical Quantitation Limit1 Soil Samples (μg/kg)
Petroleum Hydrocarbons (1991 Sampling Event)	**1,000**	**100,000**
<u>Inorganics</u> (1991 Sampling Event)		
13 Priority Pollutant Metals(2)		
Antimony (SW6010)	50	5000
Arsenic (SW7060)	10	1000
Beryllium (SW6010)	5	500
Cadmium (SW6010)	5	500
Chromium (SW6010)	10	1000
Copper (SW6010)	10	1000
Lead (SW7421)	5	500
Mercury (SW7470/7471)	0.2	30
Nickel (SW6010)	10	1000
Selenium (SW7740)	5	500
Silver (SW6010)	10	1000
Thallium (SW7841)	5	1000
Zinc (SW6010)	10	1000

(1) Specific quantitation limits are highly matrix dependent. The quantitation limits listed herein are provided for guidance and may not always be achievable. Refer to the data reports in Appendices I and J for sample specific detection limits.

(2) The extraction method for soil is SW 3050, except for Mercury. The extraction methods for water are SW 3010 for ICAP methods and SW 3020 for graphite furnace methods. Mercury does not have an extraction method.

SECTION 4
INVESTIGATION RESULTS

4.1 INTRODUCTION

4.1.1 Data Organization

This section presents the results of the SI conducted at the Base. The investigations included the installation of groundwater monitoring wells, aquifer testing, and sampling of groundwater, soil, sediment, and surface water. Each site discussion presents an explanation of site activities and results of the field investigation. Field investigation results include geologic and hydrogeologic findings, and assessments of soil, groundwater, surface water and/or sediment contamination.

4.1.2 Analytical QA/QC

4.1.2.1 Field Event 1 - November 1988 to January 1989

metaTRACE Laboratories, Inc. of Earth City, Missouri, provided analytical services for all samples obtained during the 1988 field effort. ES conducted a detailed laboratory audit of the work conducted for this project. Various portions of the raw analytical data were reviewed to assess the quality of the data. The laboratory audit included review of analytical documentation, instrument calibrations, internal standards preparations and analyses, integrations, chromatograms, and quality control criteria. Problems identified included failure to meet quality control criteria, poor chromatography and improper integrations and documentation.

Positive results obtained by gas chromatograph/mass spectrometry (GC/MS) instrumentation for the VOC analyses (SW8240) and semi-volatile organics analyses (SW8270) were assessed to be estimated. VOC concentrations reported for GC analyses (methods SW8010 and SW8020) are also suspect due to wide-spread evidence of cross-contamination. Results of GC analyses for polynuclear aromatic hydrocarbons (PAH) (SW8100) were not specifically reviewed but could have experienced the same types of problems as the other organic analyses. The results reported for metals analyses were questionable due to apparent laboratory contamination problems. These results have been qualified based on contamination problems identified. Due to the extensive problems with data quality and the lack of QA/QC procedures, the 1988 analytical data is not presented in this report. The analytical results in this section are based on the 1989 and 1991 field events.

4.1.2.2 Field Event 2 - August and September 1989

The samples collected in 1989 were analyzed by Savannah Laboratories. A QA/QC review was conducted on the data provided by the laboratory. This data was found to meet the required QA/QC criteria. The data validation report is contained in Appendix F.

4.1.2.3 Field Event 3 - March 1991

The samples collected in 1991 were analyzed by Savannah Laboratories. A QA/QC review was conducted on the data provided by the laboratory. The review revealed calibration problems with 2-butanone and 2-hexanone. Positive results of these compounds were flagged as estimated, and negative results were rejected. Xylenes, bis(2-ethylhexyl)phthalate, acetone, and 2-butanone were detected in blanks; however, by using the 5x/10x rule, no results were flagged. Other QC problems were more specific and generally affected a limited number of samples. A complete description of the data quality is contained in Appendix G.

4.1.2.4 Data Qualifiers

In instances where QC problems affect the quality of the data, the affected analytical results have been flagged to indicate the quality of that data. Flags and symbols used in this report are defined as follows:

U- The compound was not present in the sample above the detection limit.

J- The number preceding is estimated. The qualitative analysis is acceptable but the value cannot be considered as accurate.

N- Presumptive evidence of presence of material (tentative information). There is evidence that the material is present, but for some reason or combination of reasons, it has not been confirmed.

R- Data is rejected and is totally unusable. The only way to obtain useful data is to resample and reanalyze.

B- The compound was detected in the blank as well as in the sample.

4.2 BASE BOUNDARY

4.2.1 Field Program

Ten monitoring wells were installed along the northern and southern Base boundaries during the Immediate Response Investigation [ES, 1988]. The following activities were conducted during the SI:

- Collected ten groundwater samples (Field Event 1),
- Installed five monitoring wells (Field Event 2),
- Conducted aquifer tests at five monitoring wells (Field Event 2), and
- Collected 15 groundwater samples during each of two field events (Field Events 2 and 3).

Twelve of the Base boundary monitoring wells are located along the northern boundary, as shown on Figure 4.1. Monitoring well construction details are provided in Table 4.1 and boring logs are contained in Appendix A. Three of the northern boundary wells, BC-MW13, BC-MW14, and BC-MW15, are screened in the lower portion of the surficial aquifer at intervals ranging from 857 to 830 feet MSL. The remaining northern boundary wells are screened in the upper portion of the surficial aquifer at intervals ranging from 896 to 874.5 feet MSL. Each well is screened through a 15-foot interval.

Three monitoring wells are located along the southern Base boundary at the locations shown on Figure 4.1. One well, BC-MW12, is screened in the lower portion of the surficial aquifer at an interval of 847 to 837 feet MSL. The remaining wells are screened in the upper portion of the surficial aquifer at intervals ranging from 911.5 to 882.5 feet MSL. Each well is screened through a 15-foot interval.

Aquifer testing was conducted through the use of slug tests at monitoring wells BC-MW1, BC-MW3, BC-MW6, BC-MW7, and BC-MW9. Slug test data is contained in Appendix C.

All existing monitoring wells were sampled during each of the field events. The groundwater samples were analyzed for the following parameters:

- Field Event 1 - VOCs, semivolatile organics, total priority pollutant metals;
- Field Event 2 - VOCs, total lead;
- Field Event 3 - VOCs, dissolved priority pollutant metals.

4.2.2 Results of Field Program

4.2.2.1 Geology and Hydrogeology

The southern Base boundary, at monitoring wells BC-MW11 and BC-MW12, is underlain by fine to coarse sand with a few clay lenses. Thin clay layers were encountered at approximately 13 feet BLS and 29 feet BLS. Another clay layer was encountered at a depth of 83 feet BLS and extends to at least 90 feet BLS. The horizontal extent of the clay layers is not known.

At monitoring well BC-MW10, the area is also underlain by fine to coarse sand and medium to coarse gravel. Clay layers were not encountered at less than the total boring depth of 40 feet BLS.

The lithology of the southern Base boundary is illustrated on Figure 4.2, which is a hydrogeologic cross-section extending across the southern boundary, through Site 3, to the northwestern corner of the Base.

The northern Base boundary is underlain by fine to coarse sand with some beds of sand and gravel. A clay layer is present at a depth of approximately 80 feet BLS at either end of the northern boundary, but the subsurface investigation did not reveal whether this layer is continuous in this area. Thin clay lenses were also encountered at depths of approximately 50 feet BLS at some monitoring well borings. These lenses are limited in horizontal extent. A hydrogeologic cross-section extending across the northern Base boundary is shown on Figure 4.3.

Groundwater in the surficial aquifer occurs at approximate depths of 20 to 30 feet BLS at the southern Base boundary and 30 to 40 feet BLS at the northern Base boundary. As discussed in Section 2, groundwater flows in a northwesterly direction across the Base, with a radial pattern exhibited beneath the eastern portion of the Base. The southern boundary wells are located hydraulically upgradient of all Base areas and groundwater samples from these wells provide background water quality data. Groundwater elevations during the SI field events are provided in Table 4.2.

4.2.2.2 Groundwater Contamination Assessment

Concentrations of VOCs and metals which were detected in Base boundary groundwater samples are provided in Table 4.3. Figure 4.4 illustrates the VOCs detected in the Base boundary samples.

No VOCs were detected in groundwater samples collected from monitoring wells BC-MW10 or BC-MW11, screened in the upper portion of the surficial aquifer, upgradient of the Base.

Toluene was detected at an estimated concentration of 0.14 μ/L in a sample from the upgradient well BC-MW12, screened in the lower portion of the surficial aquifer. Zinc was the only inorganic substance detected in upgradient samples and was found at concentrations of 10.4 μg/L and 12 μg/L in samples from two of the three wells.

Downgradient of the Base, along the northern Base boundary, VOCs were detected in samples from six of the nine wells screened in the upper portion of the surficial aquifer. Acetone, 2-butanone, trichloroethylene (TCE); 1,1,1-trichloroethane (1,1,1-TCA); tetrachloroethane (1,1,2,2-TetCA), cis/trans-1,2-dichloroethylene (DCE), toluene and chloroform were detected at concentrations ranging from 0.6 μg/L to 92 μg/L. In samples from BC-MW4 and BC-MW5, TCE and/or 1,1,1-TCA were detected in 1989 and 1991. In samples from the remaining shallow wells, VOCs were detected only in 1991.

VOCs were detected in samples collected from two of the three deep monitoring wells in the surficial aquifer. Benzene was detected at an estimated concentration of 0.23 μg/L in the sample from BC-MW14. At both sampling locations, VOCs were detected only in 1991.

Zinc was the only priority pollutant metal to be detected in samples from the northern Base boundary. Concentrations ranged from below detection limits in five of the 12 wells, to 132 μg/L in the sample from BC-MW5.

MICHIGAN NA
BATTLE

LOCATIONS OF M
BASE BOUNDA

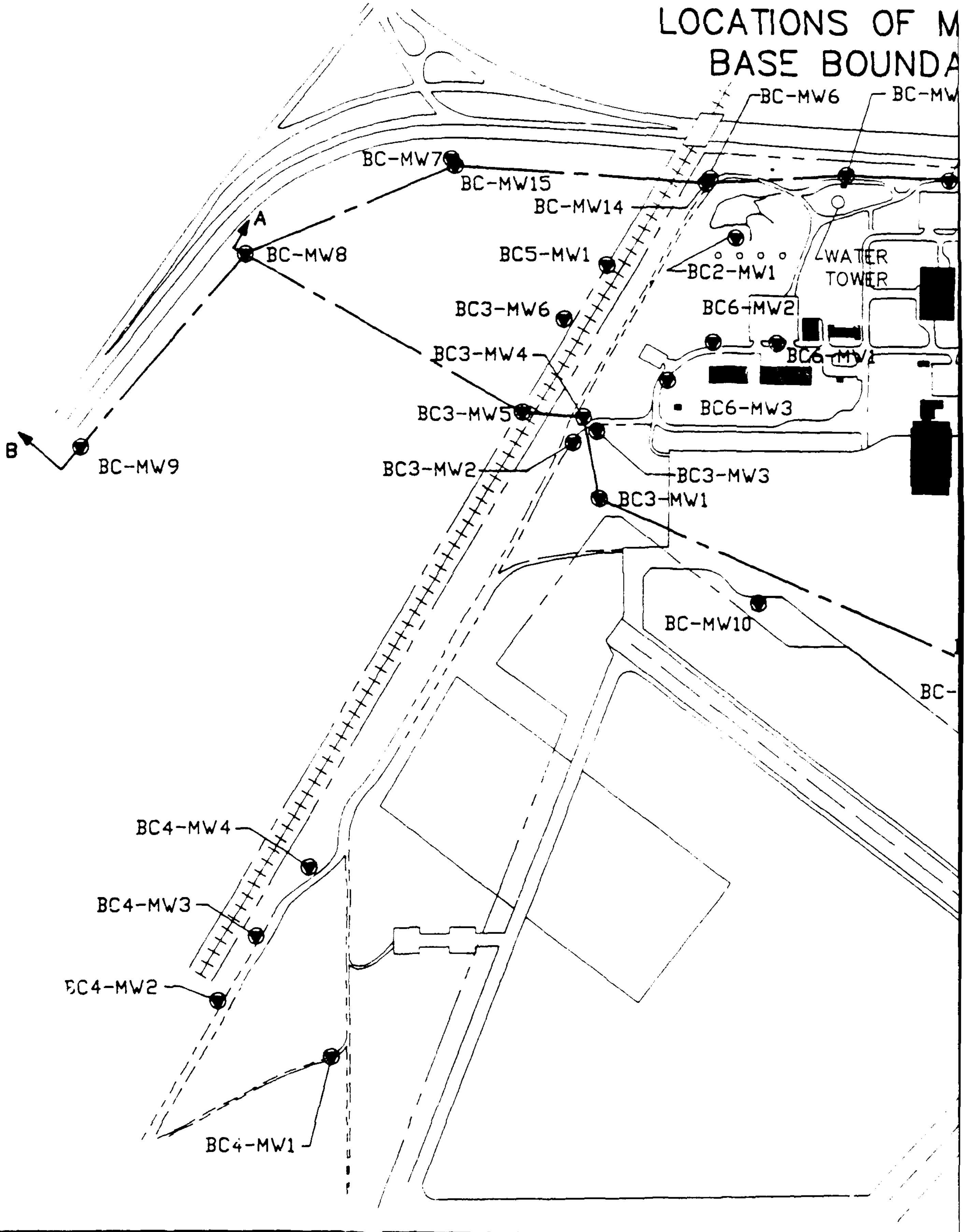


FIG4-1, 06/28/91 at 09:24

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MONITORING WELLS AND
DARY CROSS-SECTIONS

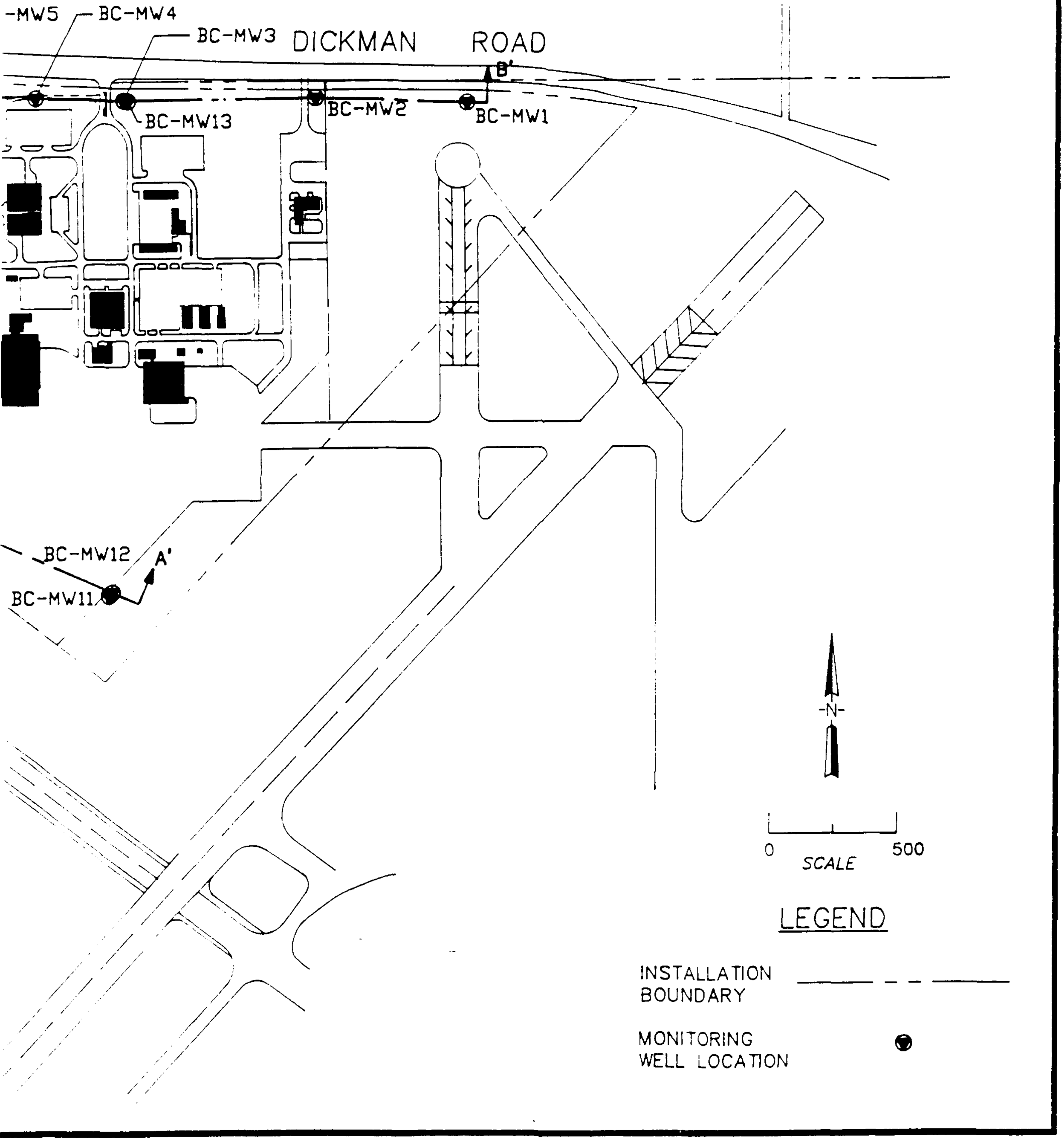


Figure 4 2

MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
GENERALIZED HYDROGEOLOGIC CROSS-SECTION A-A'
AT THE SOUTHERN BASE BOUNDARY

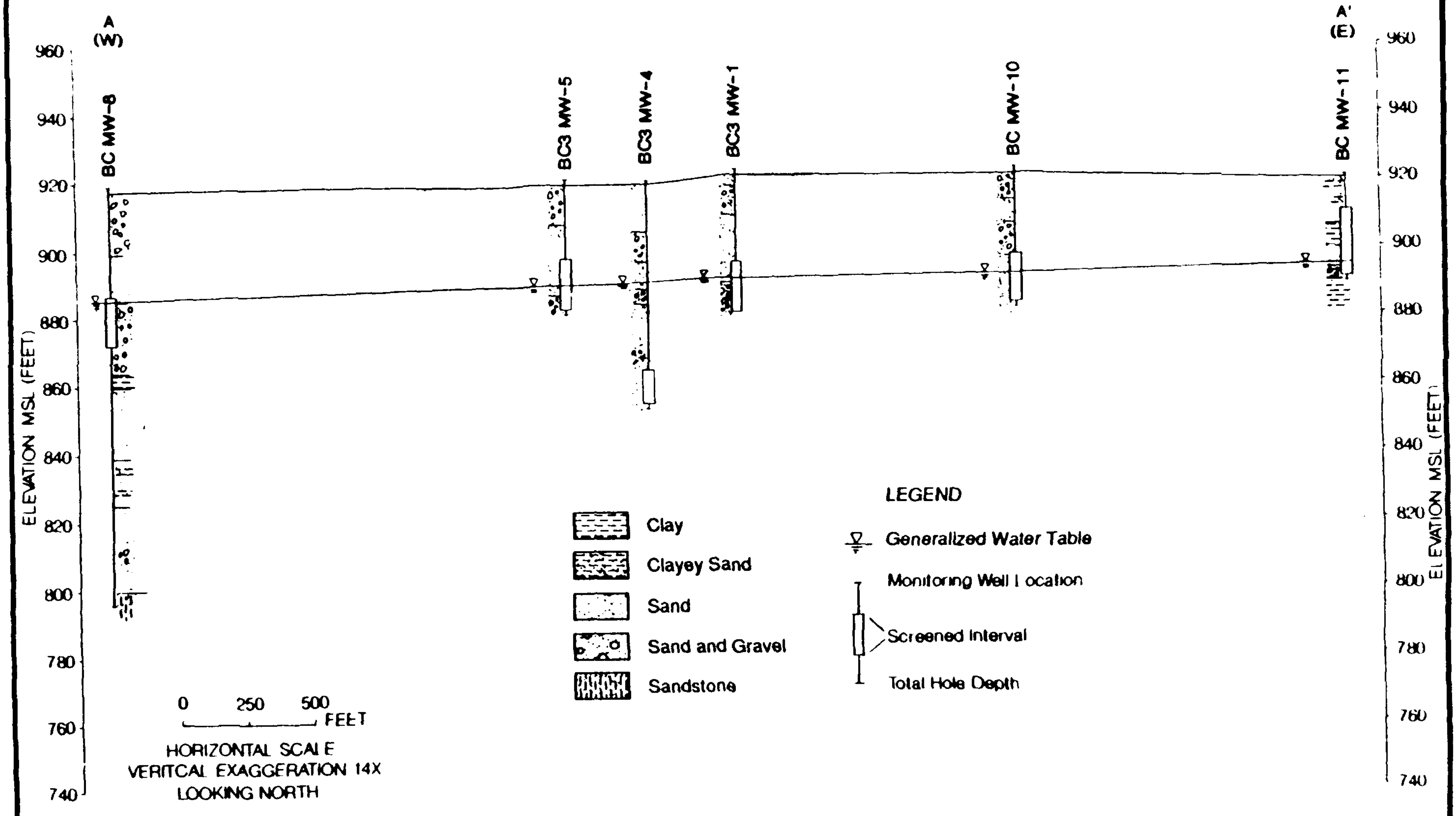
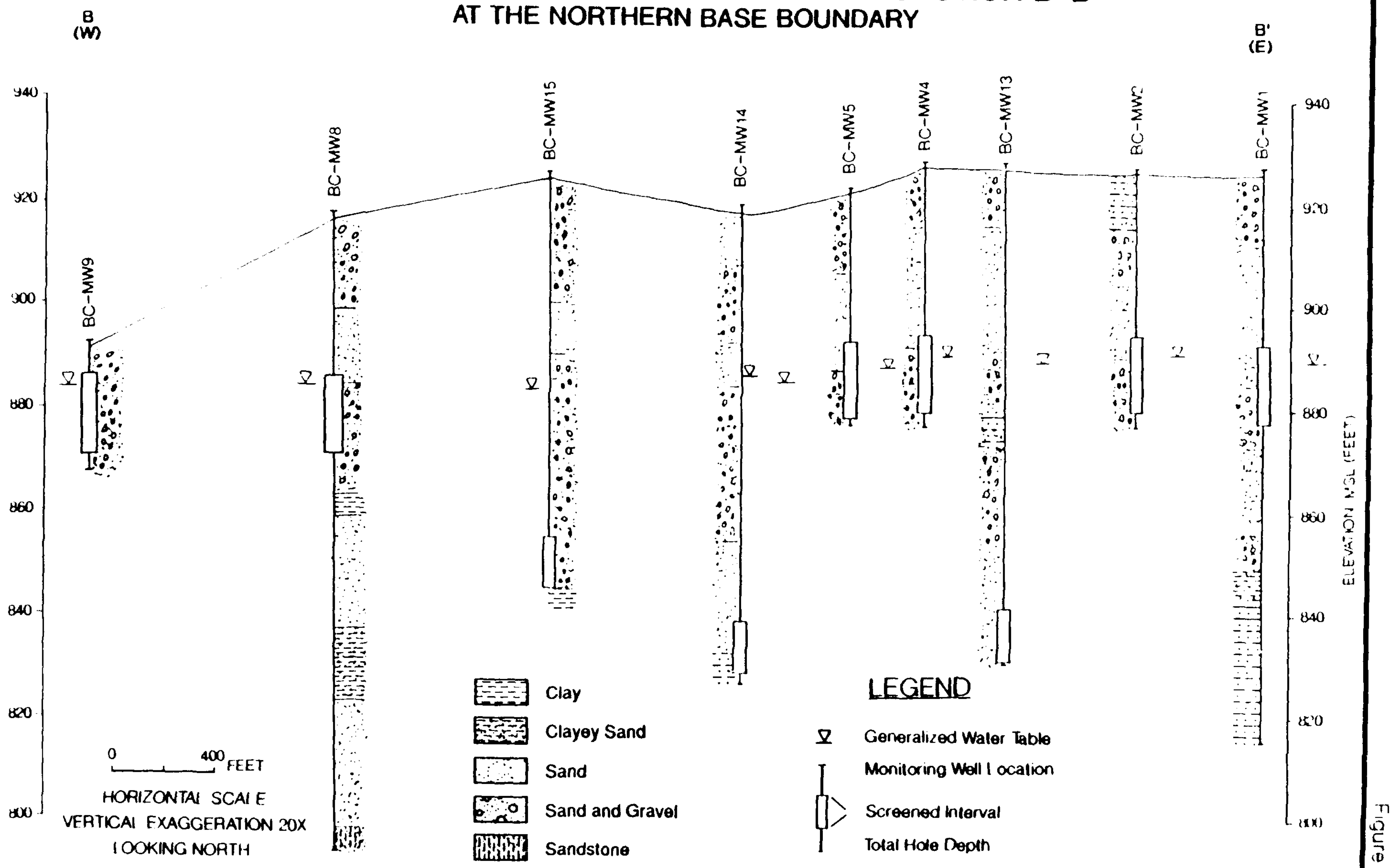


Figure 4.3

MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
GENERALIZED HYDROGEOLOGIC CROSS-SECTION B-B'
AT THE NORTHERN BASE BOUNDARY



MICHIGAN NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SUMMARY OF VOLATILE ORGANIC COMPOUNDS IN GROUNDWATER AT THE BASE BOUNDARY

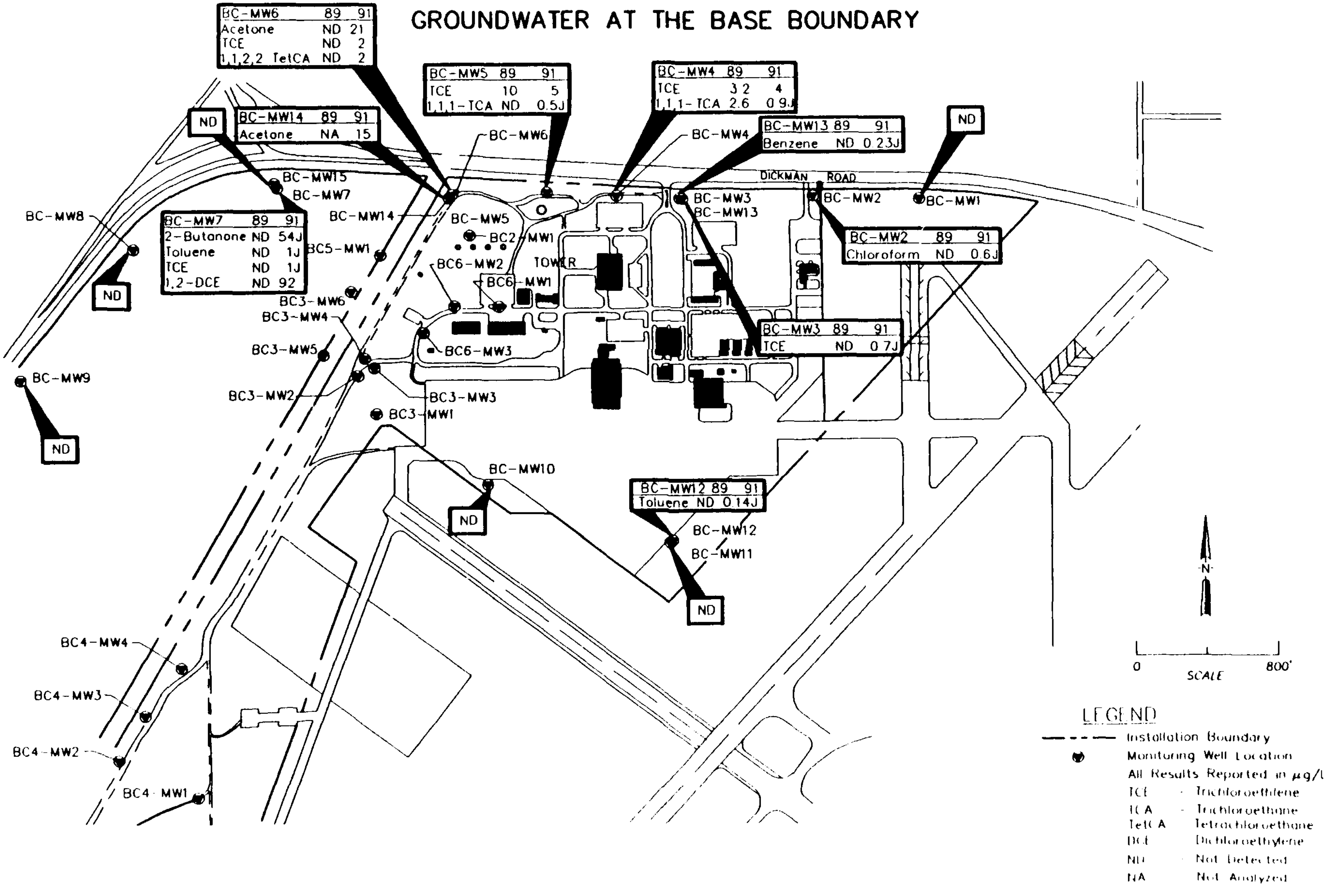


TABLE 4.1
MONITORING WELL CONSTRUCTION DETAILS
110th FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Well ID	Date Complete	Elevation Top of Casing (feet MSL)	Total Hole Depth (feet BSL)	Well Completion Depth (feet BSL)	Screen Interval (feet BSL)	Screen Interval (feet MSL)
BC-MW1	10/87	928.30	110	47	32-47	892-877 (approx)
BC-MW2	10/87	928.37	48	46	31-46	893.5-878.5 (approx)
BC-MW3	10/87	929.03	48	46	31-46	896-881
BC-MW4	10/87	929.19	50	48	33-48	892-877 (approx)
BC-MW5	10/87	923.60	45	44	29-44	890.5-875.5 (approx)
BC-MW6	10/87	918.52	43	42	27-42	889.5-874.5
BC-MW7	10/87	925.71	53	51	36-51	889-874
BC-MW8	10/87	917.16	119	43	28-43	885-870 (approx)
BC-MW9	10/87	894.38	23	20	5-20	885.5-870.5 (approx)
BC-MW10	10/87	923.93	39	38	23-38	897.5-882.5 (approx)
BC-MW11	8/89	921.09	30	29	9-29	911.5-891.5
BC-MW12	8/89	922.32	84.5	83.5	73.5-83.5	847-837
BC-MW13	8/89	928.40	93.5	93.5	83.5-93.5	843.5-833.5
BC-MW14	8/89	918.89	91	87	77-87	840-830
BC-MW15	8/89	926.68	80	78	68-78	857-847
BC2-MW1	11/88	915.43	43	38	23-38	891-876
BC3-MW1	11/88	923.16	41	41	26-41	896-881
BC3-MW2	11/88	920.73	40	39	24-39	895.5-880.5
BC3-MW3	11/88	920.30	40	39	24-39	895.5-880.5
BC3-MW4	11/88	920.42	76	65	55-65	863.5-853.5
BC3-MW5	8/89	920.28	40	37	22-37	896.5-881.5
BC3-MW6	8/89	913.42	33.5	33.5	18.5-33.5	893.5-878.5
BC4-MW1	11/88	917.12	30	29	14-29	901.5-886.5
BC4-MW2	11/88	906.39	25	21	6-21	898.5-883.5
BC4-MW3	11/88	907.02	23	22	7-22	898.5-883.5
BC4-MW4	11/88	915.69	35	33	18-33	896.2-881.2
BC5-MW1	11/88	901.81	24	23	8-23	892.5-877.5
BC6-MW1	11/88	921.89	41	38	23-38	898-883
BC6-MW2	11/88	918.29	39	37	22-37	895-880
BC6-MW3	11/88	919.51	40	37	22-37	896-881

MSL - Above Mean Sea Level
BLS - Below Land Surface

TABLE 4.2
WATER LEVELS AND POTENTIOMETRIC SURFACE ELEVATIONS
110TH FG MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Well ID	Potentiometric Surface Elevation (feet) Dec-87	Potentiometric Surface Elevation (feet) Dec-88	Potentiometric Surface Elevation (feet) Sep-89	Potentiometric Surface Elevation (feet) Mar-91
BC-MW1	888.42	888.62	889.30	889.52
BC-MW2	890.97	889.00	891.75	892.02
BC-MW3	891.34	891.48	892.12	892.25
BC-MW4	890.19	890.51	890.99	891.16
BC-MW5	887.31	887.93	888.28	888.50
BC-MW6	885.39	886.07	886.36	886.59
BC-MW7	882.50	883.06	883.54	884.08
BC-MW8	884.61	885.42	885.43	886.23
BC-MW9	886.38	884.38	887.12	887.99
BC-MW10	892.29	892.56	893.30	893.48
BC-MW11	NA	NA	895.93	896.07
BC-MW12	NA	NA	895.75	895.96
BC-MW13	NA	NA	889.64	890.11
BC-MW14	NA	NA	886.37	886.71
BC-MW15	NA	NA	883.39	884.03
BC2-MW1	NA	887.85	888.53	888.81
BC3-MW1	NA	890.80	891.07	891.51
BC3-MW2	NA	890.23	890.45	890.92
BC3-MW3	NA	890.25	890.46	890.84
BC3-MW4	NA	889.66	889.86	890.33
BC3-MW5	NA	NA	889.50	890.06
BC3-MW6	NA	NA	888.44	888.94
BC4-MW1	NA	898.16	898.40	899.01
BC4-MW2	NA	896.03	895.99	896.79
BC4-MW3	NA	892.90	893.00	893.57
BC4-MW4	NA	891.48	891.92	892.36
BC5-MW1	NA	887.40	887.67	888.00
BC6-MW1	NA	889.77	890.14	890.45
BC6-MW2	NA	889.59	889.94	890.24
BC6-MW3	NA	889.85	890.17	890.51

NA - Not applicable; monitoring well not installed as of this date.

TABLE 4.3
GROUNDWATER ANALYTICAL DATA SUMMARY - BASE BOUNDARY
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Parameter	BC-MW1		BC-MW2		BC-MW3		BC-MW4		BC-MW5		BC-MW6		BC-MW7		BC-MW8	
	1989	1991	1989	1991	1989	1991	1989	1991	1989	1991	1989	1991	1989	1991	1989	1991
Volatiles (ug/l)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
GENERAL	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
2-Butanone	NA	R	NA	R	NA	R	NA	R	NA	R	NA	R	NA	**54J**	NA	R
Acetone	NA	U	NA	U	NA	U	NA	U	NA	U	NA	**21**	NA	U	NA	U
Toluene	U	U	U	U	U	U	U	U	U	U	U	U	U	**1J**	U	U
Trichloroethylene	U	U	U	U	U	**0.7J**	**3.2**	**4**	**10**	**5**	U	**2**	U	**1J**	U	U
Benzene	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
cis/trans-1,2-Dichloroethylene	U	U	U	U	U	U	U	U	U	U	U	U	U	**92**	U	U
Chloroform	U	U	U	**0.6J**	U	U	U	U	U	U	U	U	U	U	U	U
1,1,2,2-Tetrachloroethane	U	U	U	U	U	U	U	U	U	U	U	**2**	U	U	U	U
1,1,1-Trichloroethane	U	U	U	U	U	U	**2.6**	**0.9J**	U	**0.5J**	U	U	U	U	U	U
Xylenes	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Priority Pollutant Metals (ug/l)	(c)	(d)	(c)	(d)	(c)	(d)	(c)	(d)	(c)	(d)	(c)	(d)	(c)	(d)	(c)	(d)
GENERAL	NA	U	NA	U	NA	U	NA	U	NA	U	NA	U	NA	U	NA	U
Lead	U	U	U	U	U	U	U	U	U	U	U	U	**10.**	U	U	U
Zinc	NA	**41.4**	NA	**10.8**	NA	**68.3**	NA	U	NA	**132**	NA	U	NA	U	NA	**49.7**

NA - Not analyzed
R - Rejected
J - Estimated
U - Undetected

911145 T 4 3 XLS

TABLE 4.3--Continued
GROUNDWATER ANALYTICAL DATA SUMMARY - BASE BOUNDARY
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Parameter	BC-MW9		BC-MW10		BC-MW11		BC-MW12		BC-MW13		BC-MW14		BC-MW15	
	1989	1991	1989	1991	1989	1991	1989	1991	1989	1991	1989	1991	1989	1991
Volatiles (ug/l)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
GENERAL	U	U	U	U	U	U	U	U	U	U	U	U	U	U
2-Butanone	NA	R	NA	R	NA	R	NA	R	NA	R	NA	R	NA	R
Acetone	NA	U	NA	U	NA	U	NA	U	NA	U	NA	**15**	NA	U
Toluene	U	U	U	U	U	U	U	**0.14J**	U	U	U	U	U	U
Trichloroethylene	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Benzene	U	U	U	U	U	U	U	U	U	**0.23J**	U	U	U	U
cis/trans-1,2-Dichloroethylene	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Chloroform	U	U	U	U	U	U	U	U	U	U	U	U	U	U
1,1,2,2-Tetrachloroethane	U	U	U	U	U	U	U	U	U	U	U	U	U	U
1,1,1-Trichloroethane	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Xylenes	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Priority Pollutant Metals (ug/l)	(c)	(d)	(c)	(d)	(c)	(d)	(c)	(d)	(c)	(d)	(c)	(d)	(c)	(d)
GENERAL	NA	U	NA	U	NA	U	NA	U	NA	U	NA	U	NA	U
Lead	U	U	**5**	U	U	U	U	U	U	U	U	U	U	U
Zinc	NA	**25.3**	NA	**10.4**	NA	U	NA	**12**	NA	U	NA	U	NA	U

NA - Not analyzed
R - Rejected
J - Estimated
U - Undetected

(a) - Analytical method: SW8010 and SW8020
(b) - Analytical method: CLP SOW (2/88)
(c) - Analyzed for lead only (SW7421)
(d) - Dissolved fraction (filtered samples)

4.3 SITE 1 - FUEL TANK FARM

4.3.1 Field Program

During the first SI field event (1988), thirteen soil borings were drilled and sampled around the old fuel tank foundations at the locations shown on Figure 4.5. Borings were placed in the center of the old tank foundation and in areas where the surface soils were discolored. All soil borings were drilled to 15 feet BLS with the exception of BC1-SB4 which encountered cobbles and refusal at 12.5 feet BLS.

One to three samples per boring were selected for laboratory analysis. Hydrocarbon odors and staining were noted in some borings during drilling activities. Appendix B presents the logs for each soil boring and contains complete lithologic descriptions, HNu readings, and observations.

4.3.2 Results of Field Investigation

4.3.2.1 Geology and Hydrogeology

Site 1 is underlain by medium- to coarse-grained sand, gravel, and cobbles which generally coarsen with depth. Silty, gravelly clay was encountered at some locations, but no clay layers were found to be continuous across the site. The materials are interbedded and cannot be correlated between boreholes.

A groundwater study was not conducted at Site 1 and the geologic characterization extends to a depth of only 15 feet BLS. However, hydrogeologic information from other sites at the Base indicates that the groundwater potentiometric surface in the surficial glacial aquifer would likely be encountered at an elevation of approximately 889 feet MSL, which is approximately 25 feet BLS. Basewide groundwater flow patterns show groundwater flow beneath Site 1 to be in a northwesterly direction.

4.3.2.2 Soil Contamination Assessment

Analytical data for the soil samples collected in 1988 is not useable due to poor data quality and lack of QA/QC procedures in the laboratory. Therefore, soil contaminant levels at Site 1 cannot be quantified. However, the data did indicate the presence of petroleum products in the soil. Soil staining and petroleum odors were also noted during drilling at the site.

4.3.2.3 Groundwater Contamination Assessment

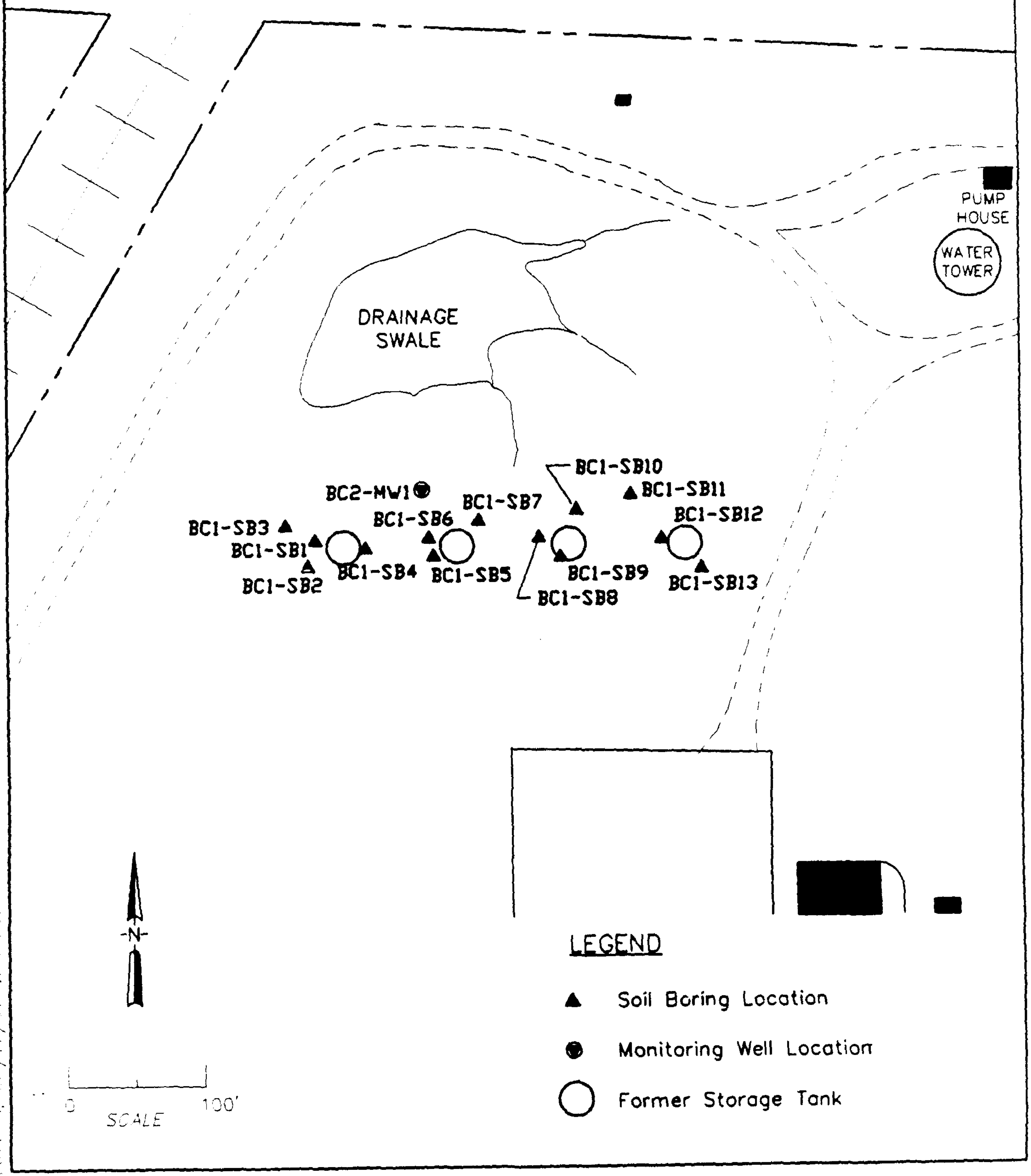
Although a site-specific groundwater investigation was not conducted at Site 1, the Site 2 well, BC2-MW1, is downgradient of Site 1 and provides information on groundwater quality at Site 1.

No VOCs were detected in groundwater from this downgradient well. Zinc was detected at a concentration of 13 µg/L in 1991.

Figure 4.5

MICHIGAN NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN

LOCATIONS OF SOIL BORINGS AT SITE 1



4.4 SITE 2 - DRAINAGE SWALE

4.4.1 Field Programs

The following activities were conducted during the SI:

- Installed one monitoring well (Field Event 1-1988);
- Collected one groundwater sample during each of the three field events (Field Events 1-1988, 2-1989 and 3-1991);
- Collected four sediment and two surface water samples (Field Event 1-1988); and
- Collected seven sediment and four surface water samples (Field Event 3-1991).

The monitoring well is located upgradient of Site 2 and downgradient of Site 1, at the location shown on Figure 4.6. The well is screened in the upper portion of the surficial aquifer at an interval of 23 to 38 feet BLS. Monitoring well construction details are provided in Table 4.1.

Two Base boundary wells, BC-MW6 and BC-MW14, are located immediately downgradient of Site 2. One well is screened in the upper portion of the surficial aquifer at a depth of 27 to 42 feet BLS and the other is screened in the lower portion of the surficial aquifer at an interval of 77 to 87 feet BLS.

The downgradient boundary wells were sampled during the first field event and all three wells were sampled during the second and third field events. The groundwater samples were analyzed for the following parameters:

- Field Event 1 - VOCs, semivolatile organics, total priority pollutant metals;
- Field Event 2 - VOCs, total lead;
- Field Event 2 - VOCs, dissolved priority pollutant metals.

Surface water and sediment samples were collected from the center of the drainage swale where runoff collects. Sediment samples were collected at three locations where runoff enters the swale from Site 1, from the motor pool, and from off-site. Surface water was also collected from these locations during the third field event. Additional surface water and sediment samples were collected along Dickman Road, north of the Base, where surface water from the highway enters the Base. The surface water and sediment samples were analyzed for the following parameters:

- Field Event 1 - VOCs, semivolatile organics, total priority pollutant metals;
- Field Event 3 - VOC, semivolatile organics, total priority pollutant metals

4.4.2 Results of Field Investigation

4.4.2.1 Geology and Hydrogeology

Site 2 is underlain by fine to coarse sand with small amounts of gravel. A layer of silt and sand was encountered at a depth of 13 to 16 feet BLS in the boring for well BC2-MW1. A clayey silt layer at an approximate depth of 90 feet was encountered in the boring for well BC-MW14. The lithology of Site 2 is illustrated on Figure 4.7, which is a hydrogeologic cross-section extending across Site 2.

Groundwater in the surficial aquifer occurs at an approximate depth of 25 feet BLS. As shown on the potentiometric surface map, Figure 4.8, groundwater in the surficial aquifer flows northwesterly across the site. The hydraulic gradient, as calculated from March 1991 data, is 9×10^{-3} ft/ft.

4.4.2.2 Surface Water and Sediment Contamination Assessment

Concentrations of organic compounds and metals detected in surface water samples are provided in Table 4.4. Organic compound concentrations are as shown on Figure 4.9.

Surface water within the drainage swale, characterized by sample SW2, contained no detectable concentrations of VOCs; fluoranthene, at an estimated concentration of 6 µg/L was the only semivolatile detected in the sample. At the time of sampling in 1991, water was flowing into the swale from Site 1 (represented by sample SW3) and from the motor pool parking area, (represented by sample SW4). No VOCs or semivolatiles were detected in sample SW3; toluene, at a concentration of 0.49 µg/L, was the only organic compound detected in sample SW4. Water also enters the swale from Dickman Road. Sample SW1 was collected from a drainage ditch along Dickman Road; no organic compounds were detected in this sample.

Seven priority pollutant metals were detected in sample SW2: chromium, copper, nickel, lead, mercury, thallium, and zinc. Concentrations ranged from 0.20 to 200 µg/L. Each of these metals, except chromium and nickel, was detected at a similar concentration in SW3 or SW4. Lead, copper, and zinc were detected at significantly lesser concentrations in SW1, while chromium was detected at a concentration similar to that in SW2.

Concentrations of organic compounds and metals detected in sediment samples are provided in Table 4.5. Organic compound concentrations are also shown on Figure 4.9.

Sediments within the drainage swale are characterized by samples SED4, SED5, and SED6. One of these samples, SED4, contained 12 µg/kg acetone, and 8 µg/kg toluene; no other VOCs were detected. PAHs were detected in all the samples, with the greatest concentrations found in SED5. PAH concentrations in the sample totalled 193,700 µg/kg for the 11 PAH compounds that were detected. Total PAH concentrations in SED4 and SED6 were 13,450 μg/kg and 92,200 μg/kg. In addition to PAHs, di-n-butylphthalate and bis(2-ethylhexyl)phthalate were detected in SED5.

SED2, collected in the drainage ditch leading from the motor pool parking lot, contained PAHs and bis(2-ethylhexyl)phthalate at concentrations similar to those detected in SED5, from the drainage swale. SED3, collected in the drainage ditch leading from Site 1, contained PAHs of concentrations in order of magnitude lower than the concentrations in SED5, but at concentrations similar to these in SED4 and SED6. SED1 and SED7 were collected along Dickman Road and in the drainage ditch leading from Dickman Road to the drainage swale. PAH concentrations in these sediment samples were approximately an order of magnitude lower than the concentrations in samples from the drainage swale.

Ten priority pollutant metals were detected in the sediment samples. Beryllium was detected only in SED5; the other metals were detected in all samples. The greatest concentrations were found in SED5.

4.4.2.3 Groundwater Contamination Assessment

A summary of groundwater analytical data is provided in Table 4.6 and shown on Figure 4.10.

No VOCs were detected in groundwater samples from the Site 2 monitoring well, BC2-MW1. Of the 13 priority pollutant metals, only zinc was detected at a concentration of 13 μg/L. Acetone was detected in 1991 in the two downgradient boundary wells, BC-MW6 and BC-MW14, at concentrations of 21 and 15 μ/L. This compound was not an analyte during the 1989 sampling event. No other VOCs or metals were detected in 1989. In 1991, TCE and 1,1,2,2-TCA were detected in groundwater from the well screened in the upper portion of the surficial aquifer, BC-MW6, at concentrations of 2 μg/L.

Figure 4.6

MICHIGAN NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN

LOCAITONS OF MONITORING WELLS, SEDIMENT SAMPLES, SURFACE WATER SAMPLES AND CROSS–SECTIONS AT SITE 2

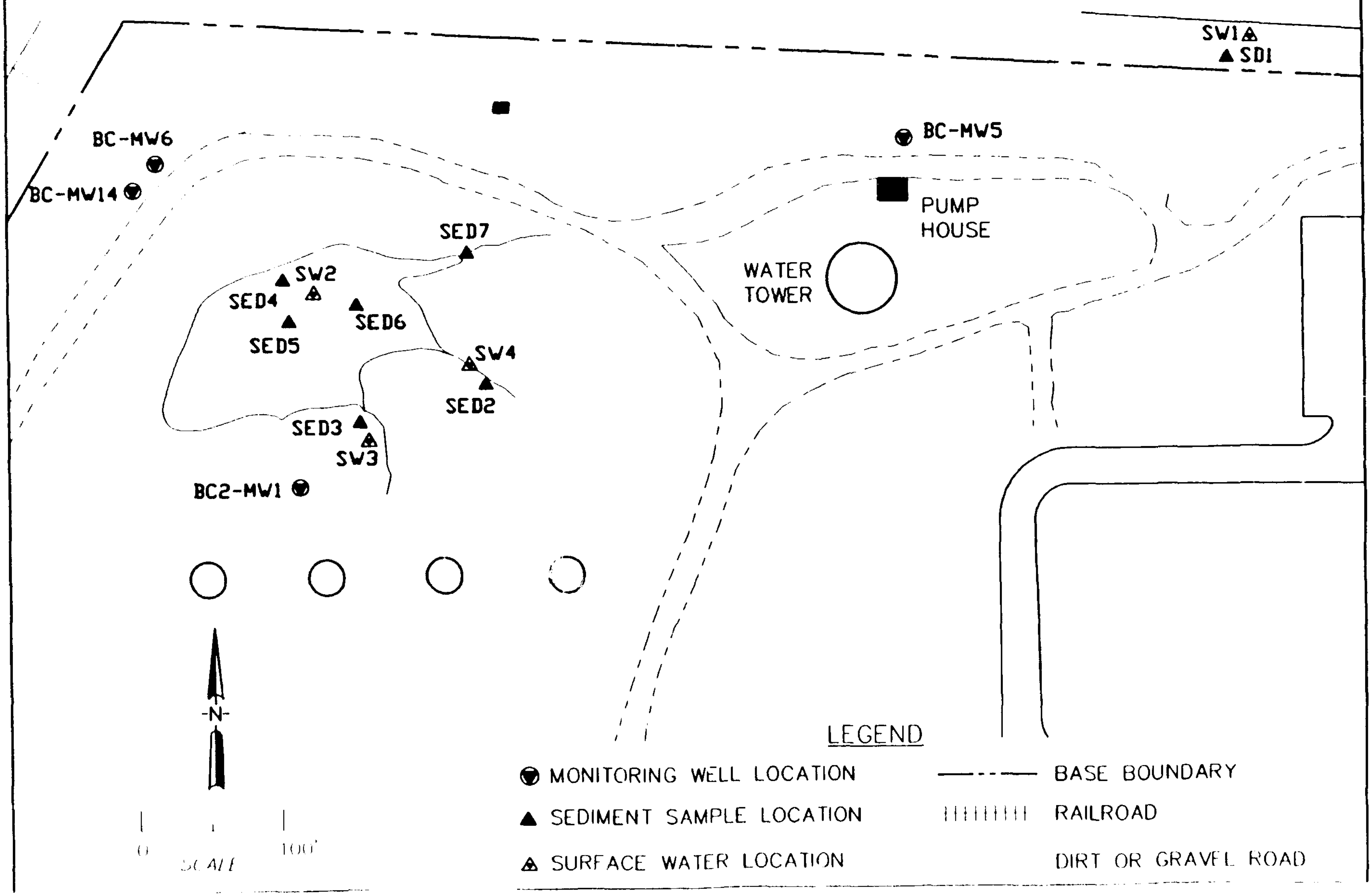


Figure 4.7

MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
GENERALIZED HYDROGEOLOGIC CROSS-SECTION C-C' AT SITE 2

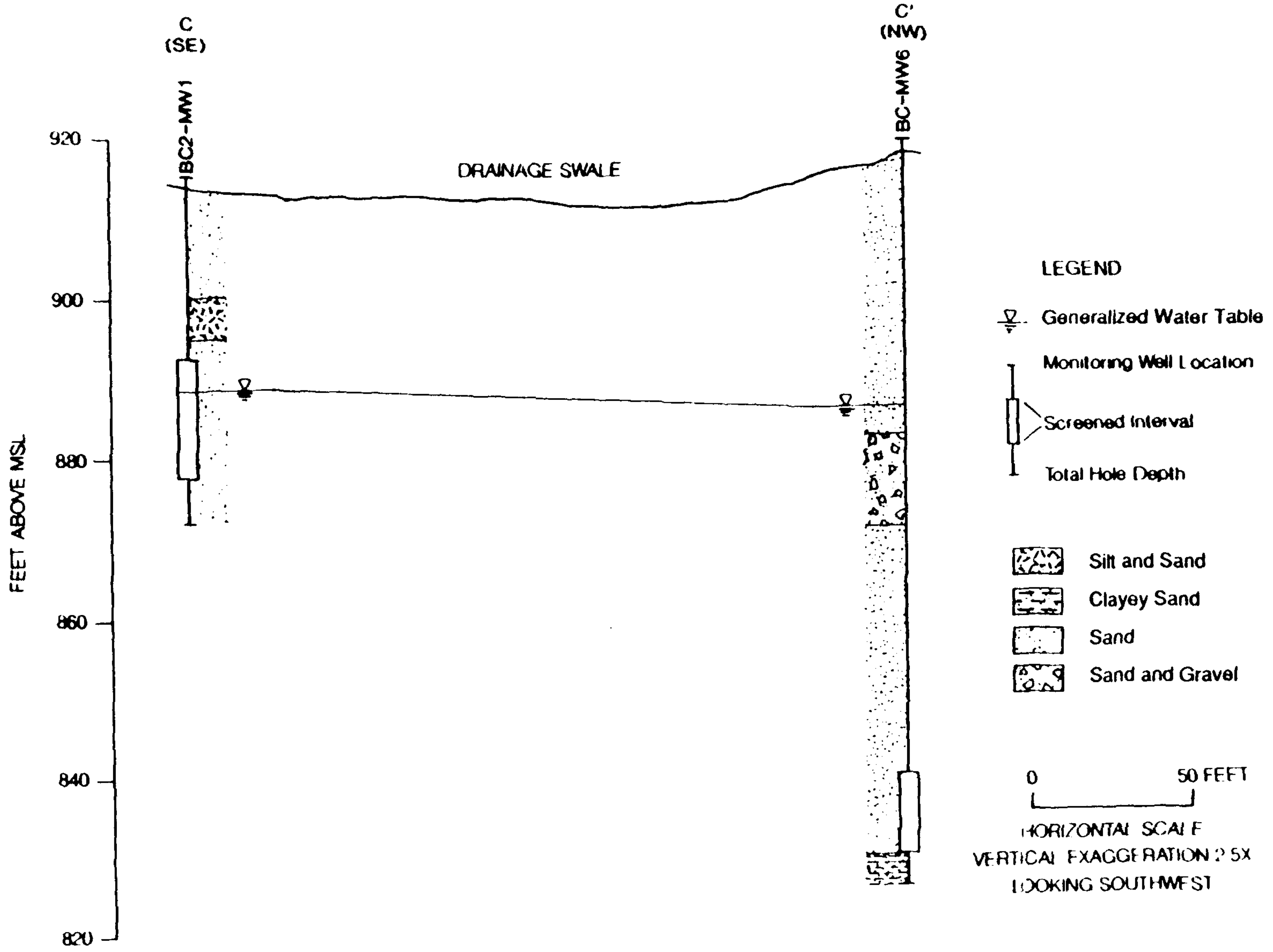
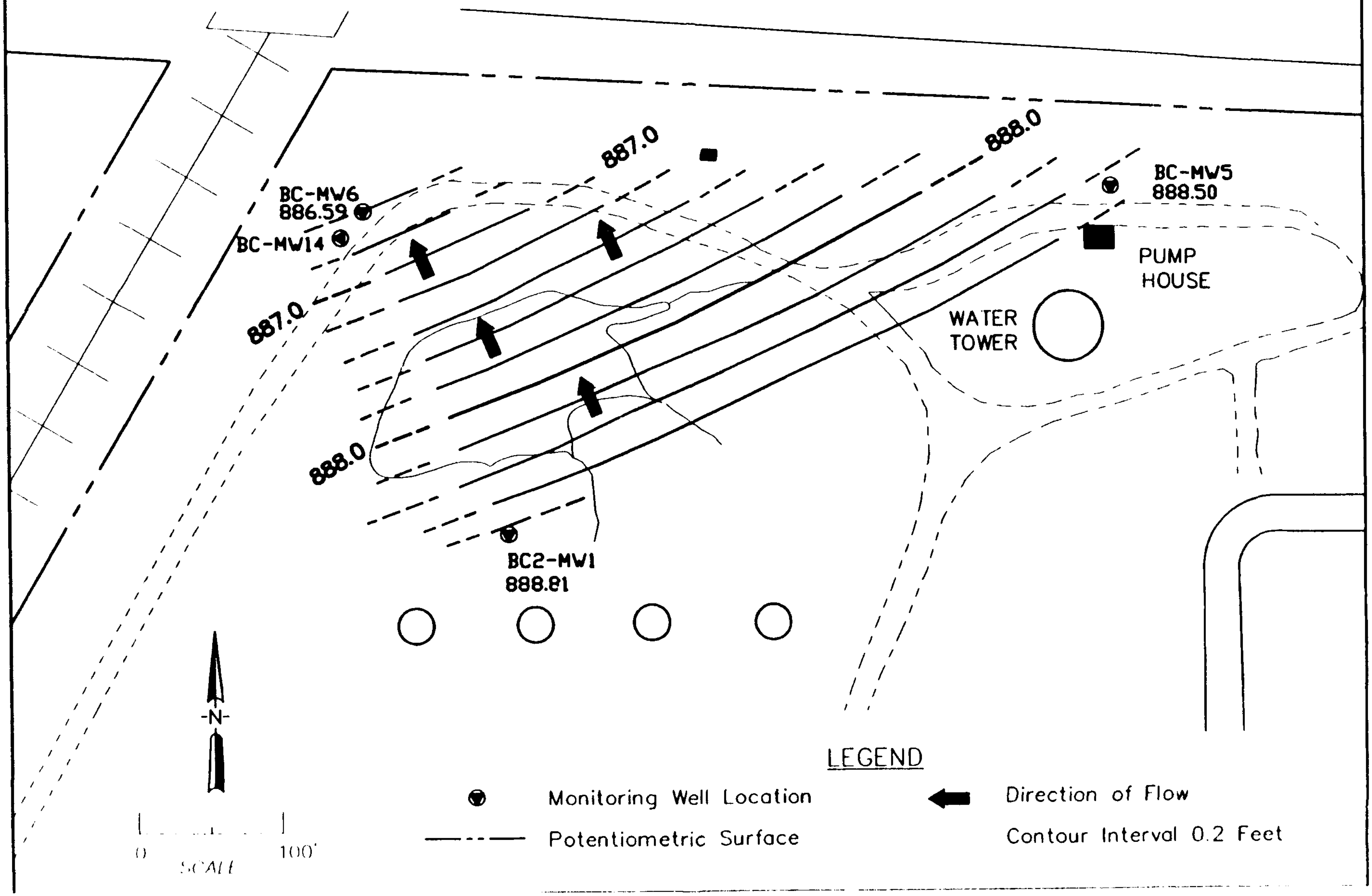


Figure 4.8

MICHIGAN NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN

GROUNDWATER POTENTIOMETRIC SURFACE AT SITE 2 IN MARCH 1991

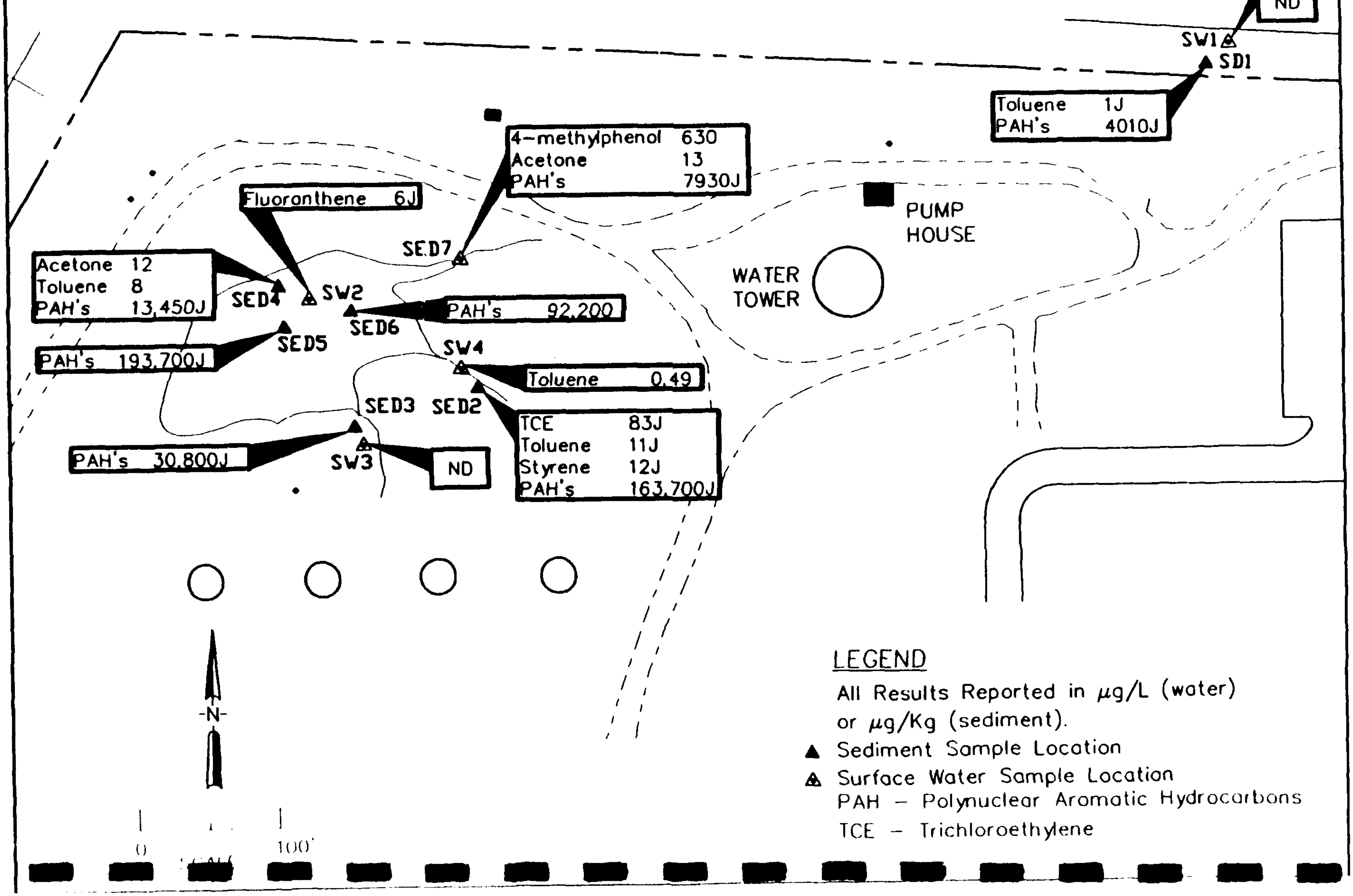


ES ENGINEERING-SCIENCE

Figure 4.9

MICHIGAN NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN

ORGANIC COMPOUNDS DETECTED IN SURFACE WATER AND SEDIMENT AT SITE 2 – MARCH 1991

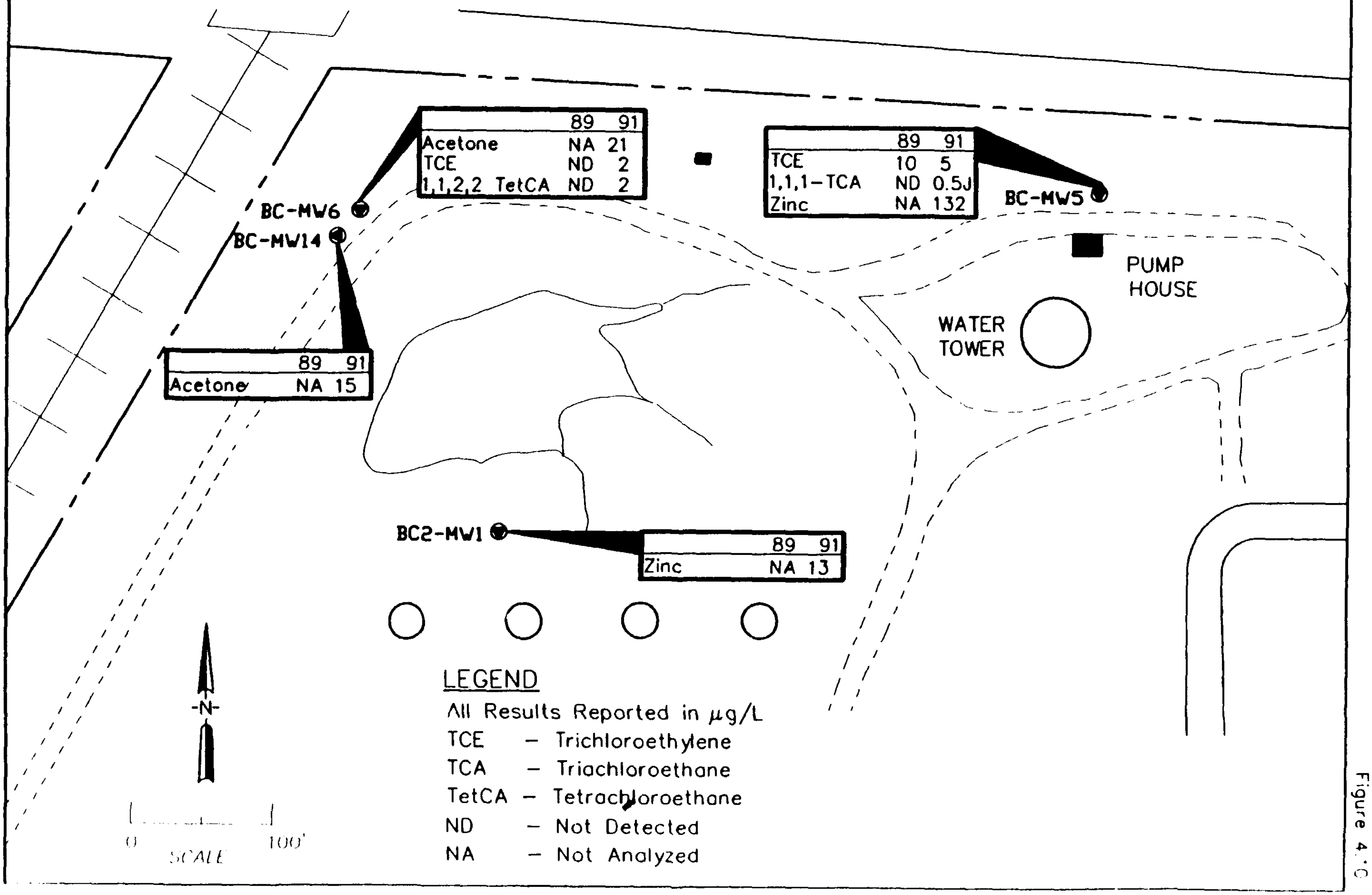


ES ENGINEERING-SCIENCE

Figure 4.10

MICHIGAN NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN

CONTAMINANTS DETECTED IN GROUNDWATER AT SITE 2



LEGEND

All Results Reported in μg/L
TCE – Trichloroethylene
TCA – Triachloroethane
TetCA – Tetrachloroethane
ND – Not Detected
NA – Not Analyzed

C:\AT561\FIG4-10, 11/07/91 at 09 03

TABLE 4.4
SURFACE WATER ANALYTICAL DATA SUMMARY
FOR SITE 2 - 1991
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Parameter	SW1	SW2	SW3	SW4
Volatiles (CLP SOW) (ug/l)				
General	U	U	U	U
Toluene	U	U	U	0.49
Semivolatiles(SW8270) (ug/l)				
General	U	U	U	U
Fluoranthene	U	6J	U	U
Priority Pollutant Metals (ug/l)				
Chromium	10.4	13.9	U	U
Copper	15.9	77.3	U	187
Nickel	U	13.6	U	U
Lead	9.6	96.9	23.7	70.5
Mercury	U	0.20	U	0.20
Thallium	U	56	51.4	U
Zinc	54.7	200	60.7	134

J - Estimated

U - Not detected

TABLE 4.5
SEDIMENT ANALYTICAL DATA SUMMARY FOR SITE 2 - 1991
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Parameter	SED1	SED2	SED3	SED4	SED5	SED6	SED7
Volatile Organics (SW8240) (ug/kg)							
Acetone	UJ	UJ	UJ	12	UJ	UJ	13
Carbon Disulfide	UJ	UJ	0.8J	U	UJ	UJ	U
Tetrachloroethene	UJ	83J	UJ	U	UJ	UJ	U
Toluene	1J	11J	UJ	8	UJ	UJ	U
Styrene	UJ	12J	UJ	U	UJ	UJ	U
Semivolatiles (SW8270) (ug/kg)							
4-Methylphenol (p-cresol)	UJ	U	U	U	U	UJ	630
Dimethylphthalate	2700J	U	U	U	U	UJ	U
Fluorene	UJ	3,200J	U	U	U	UJ	U
Phenanthrene	330J	24,000	3,900	1,100	17,000	8500J	570
Anthracene	UJ	5,100	U	U	2700J	UJ	U
Di-n-butylphthalate	UJ	U	U	U	32,000	UJ	U
Fluoranthene	620J	30,000	6,300	2,000	30,000	15000J	1,200
Pyrene	1100J	27,000J	5500J	2000J	17000J	15000J	1200J
Butylbenzylphthalate	3000J	U	U	U	U	UJ	U
Benzo(a)anthracene	*350J*	*13,000*	*3,000J*	*1,200*	*17,000*	5000J	620
bis(2-Ethylhexyl)phthalate	350J	6,200	U	U	3,300J	UJ	U
Chrysene	420J	14,000	3,700	1,500	22,000	8200J	880
Benzo(b)fluoranthene	510J	7,400	2800J	1,600	25,000	11000J	830
Benzo(k)fluoranthene	420J	11,000	3000J	1,300	18,000	8400J	850
Benzo(a)pyrene	260J	13,000	2600J	1,200	19,000	6800J	770
Indeno(1,2,3-cd)pyrene	UJ	7,900	U	770	13,000	6900J	500
Benzo(g,h,i)perylene	UJ	8,100	U	780	13,000	7400J	510
Priority Pollutant Metals (mg/kg)							
Beryllium	U	U	U	U	0.74	U	U
Cadmium	1.6	21.1	1.0	1.2	14.4	4.9	1.1
Chromium	17.3	60.7	5.3	10.8	39.6	40.1	51.2
Copper	20.2	65.8	12.1	16.7	161	185	23.8
Nickel	7.4	8.5	8.6	11.6	28.2	11.5	10
Silver	3.7	2.2	3.6	3.4	8.5	3.2	5.7
Zinc	78.2J	289J	59.6J	72.3J	324J	190J	66.8J
Arsenic	5.5J	6.4J	6.7	14.1	68.0J	20.3	24.3
Lead	105	105	15.6	43.4	250	180	193
Mercury	0.02J	0.06J	0.01J	0.08J	0.21J	0.12J	0.06J

J - Estimated

U - Not detected

TABLE 4.6
GROUNDWATER ANALYTICAL DATA SUMMARY - SITE 2
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Parameter	BC2-MW1	
	1989	1991
Volatiles (ug/l)	(a)	(b)
GENERAL	U	U
Priority Pollutant Metals (ug/l)	(c)	(d)
GENERAL	U	U
Zinc	NA	13

(a) - Analytical method: SW8010 and SW8020
(b) - Analytical method: CLP SOW
(c) - Analyzed for lead only
(d) - Dissolved fraction (filtered samples)
NA - Not analyzed
U - Not detected

4.5 SITE 3 - FIRE TRAINING AREA

4.5.1 Field Program

The following activities were conducted during the SI:

- Drilled five soil borings and collected soil samples (Field Event 1-1988);
- Installed six monitoring wells (Field Events 1-1988 and 2-1989);
- Collected groundwater samples during each of the three field events (Field Events 1-1988, 2-1989, and 3-1991); and
- Conducted aquifer tests at three monitoring wells (Field Event 1-1988).

One monitoring well, BC3-MW1, is located hydraulically upgradient of Site 3 at the location shown on Figure 4.11. Three other monitoring wells are immediately downgradient of the site and the two remaining wells are further downgradient. One well, BC3-MW4, is screened in an intermediate portion of the surficial aquifer at an interval of 55 to 65 feet BLS. The remaining wells are screened in the upper portion of the surficial aquifer at intervals ranging from 22 to 41 feet BLS. Monitoring well construction details are provided in Table 4.1.

Aquifer testing was conducted at monitoring wells BC3-MW1, BC3-MW2, and BC3-MW3, using slug testing methods. A complete description of the testing, including interpretive methods, field data, and data plots, is presented in Appendix C.

The four monitoring wells in existence during the first field event, BC3-MW1 through BC3-MW4, were sampled at that time. All Site 3 monitoring wells were sampled during the second and third field events. The groundwater samples were analyzed for the following parameters:

- Field Event 1 - VOCs, semivolatile organics, total priority pollutant metals;
- Field Event 2 - VOCs, total lead;
- Field Event 3 - VOCs, dissolved priority pollutant metals.

Two of the soil borings were placed inside the burn pit and two borings were placed outside the burn pit in areas of suspected contamination. The fifth boring was placed away from the burn pit and associated activities in a "background" area. Soil boring locations are shown on Figure 4.11. Two borings, BC3-SB2 and BC3-SB5, were terminated at 24 feet BLS because of auger refusal due to the presence of cobbles. The other three borings were drilled to total depths of 35 feet BLS. Soil boring logs containing complete lithologic descriptions are contained in Appendix B.

Two to three soil samples were collected from each boring. These samples were analyzed for VOCs, semivolatile organics, and priority pollutant metals.

4.5.2 Results of Field Investigation

4.5.2.1 Geology and Hydrogeology

Site 3 is underlain by fine to coarse silty sands interlayered with gravel and cobbles. Downgradient of the site, at monitoring wells BC3-MW5 and BC3-MW6, fine, loamy sand with some pebbles was encountered throughout the borings for these wells. The lithology of Site 3 is illustrated on Figure 4.12, which is a hydrogeologic cross-section extending across Site 3.

Groundwater in the surficial aquifer occurs at a depth of approximately 30 feet BLS. As shown on the potentiometric surface map, Figure 4.13, groundwater in the surficial aquifer flows in a northwesterly direction across the site. The hydraulic gradient, as calculated from March 1991 data, is approximately 3×10^{-3} ft/ft..

Aquifer tests provided hydraulic conductivity estimates ranging from 18 ft/day to 60 ft/day. The estimated groundwater flow velocity at this site, assuming a porosity of 20 percent, ranges from 100 to 330 ft/yr. While generally accepted techniques were used to obtain the hydraulic conductivity values, data obtained by different means may provide different values.

4.5.2.2 Soil Contamination Assessment

Analytical data for the soil samples collected at Site 3 in 1988 is not quantifiable due to poor data quality and lack of QA/QC procedures in the laboratory. Although the data is not quantifiable, the results reported by the laboratory indicate the presence of fuel constituents at the FTA. The laboratory reported concentrations of BETX (benzene, ethylbenzene, toluene, and xylenes) as high as approximately 7,000 mg/kg; the value was reported for sample BC3-SB4-15-20.

VOC concentrations reported by the laboratory, though not reliable, are shown on Figure 4.14 to illustrate the potential extent of VOCs in soil at Site 3.

4.5.2.3 Groundwater Contamination Assessment

Groundwater analytical data for Site 3 is summarized in Table 4.7. VOCs and metals detected in groundwater are shown on Figure 4.15.

No VOCs or priority pollutant metals were detected in the groundwater samples from monitoring well BC3-MW1, located upgradient of Site 3. The sample from BC3-MW2, located adjacent to the fire training area, contained 1,2-DCE, benzene, ethylbenzene, and xylenes in 1989; in 1991, the concentrations of these compounds increased by a factor of four or more, and acetone, 2-butanone, TCE and toluene were also detected. VOCs in 1991 were detected at concentrations of 3 µg/L to 1200 µg/L.

The sample from BC3-MW3, also located adjacent to the FTA, contained benzene, ethylbenzene, toluene, and xylenes at concentrations of 0.18 µg/L to 0.7 µg/L. These compounds were not detected in 1989 but were detected in 1991.

Dissolved arsenic was also detected in 1991 at an estimated concentration of 91.5 μg/L in the sample from monitoring well BC3-MW2.

Further downgradient, the sample from BC3-MW4 contained TCE, toluene, and xylenes at concentrations of 0.43 μg/L to 1 μg/L. This sample was collected from an intermediate portion of the surficial aquifer.

No VOCs were found in the sample from BC3-MW5, but total lead was detected at a concentration of 9.4 μg/L in 1989. Dissolved lead was not detected in 1991.

The samples from the furthest downgradient well, BC3-MW6, contained toluene in 1991 at an estimated concentration of 0.2 μg/L.

Figure 4.11

MICHIGAN NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN

LOCATIONS OF MONITORING WELLS, SOIL BORINGS, AND CROSS-SECTIONS AT SITE 3

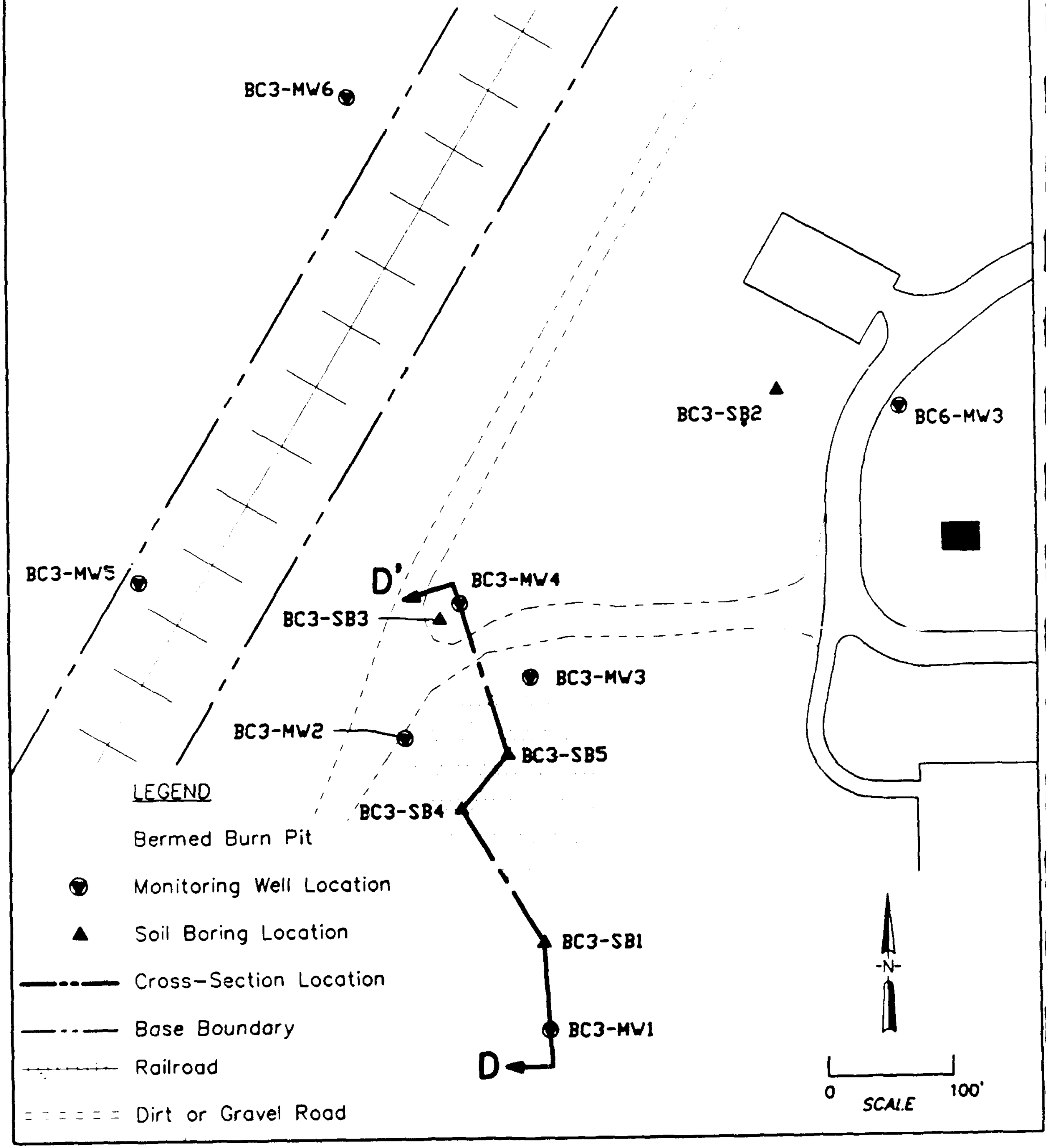


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Figure 4.12

MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
GENERALIZED HYDROGEOLOGIC CROSS-SECTION D-D' AT SITE 3

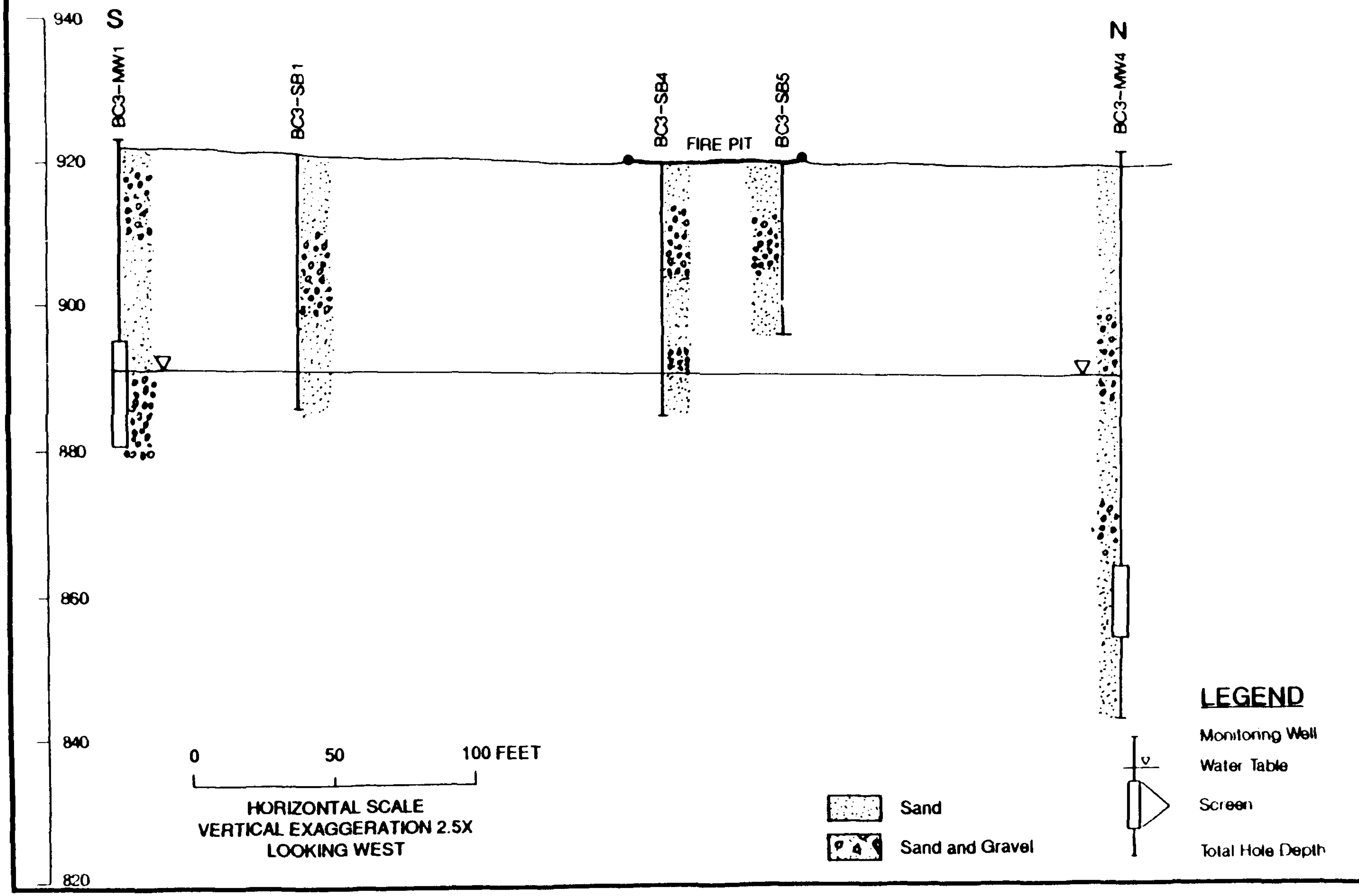
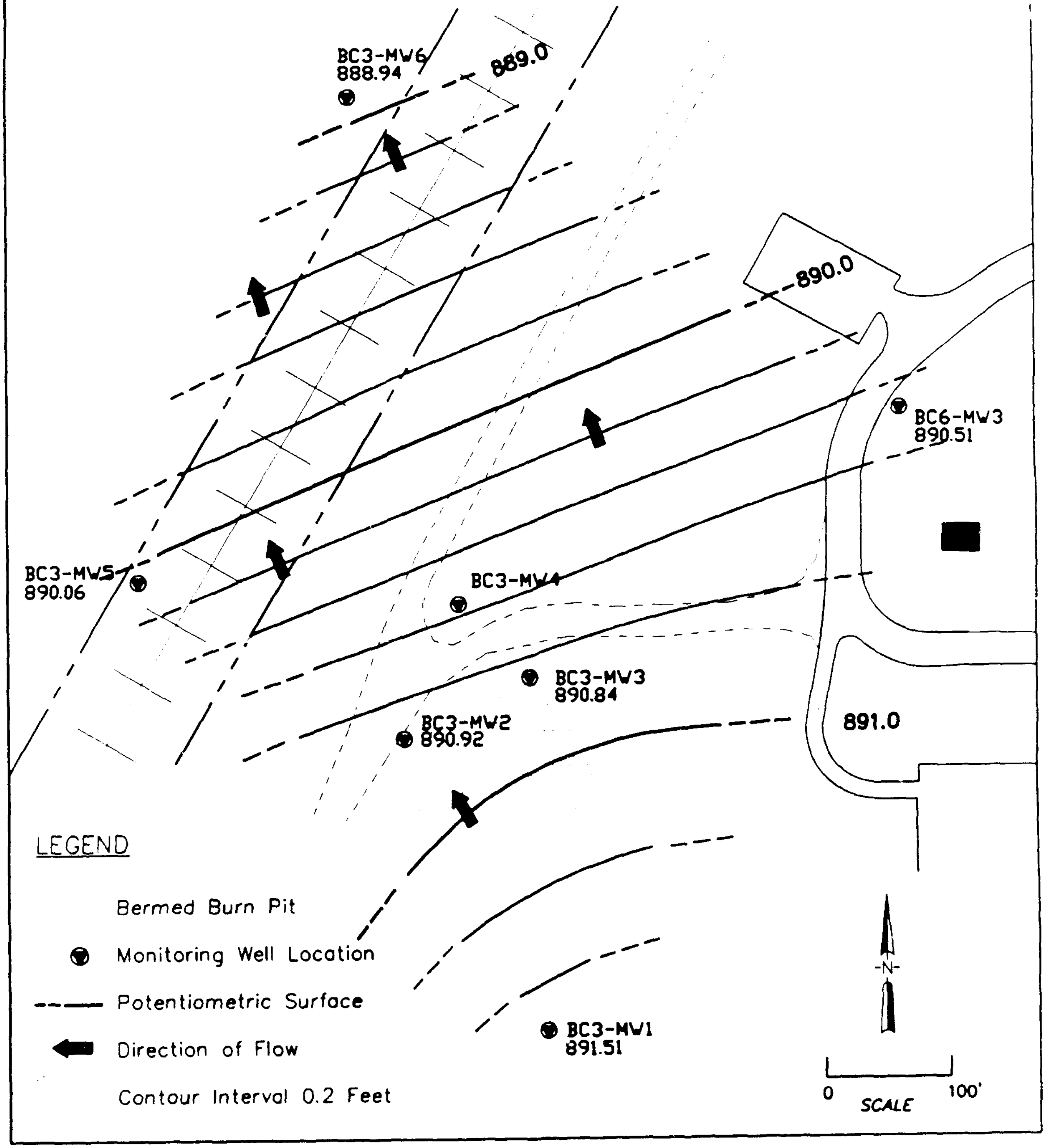


Figure 4.13

MICHIGAN NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN

GROUNDWATER POTENTIOMETRIC AT SITE 3 IN MARCH 1991

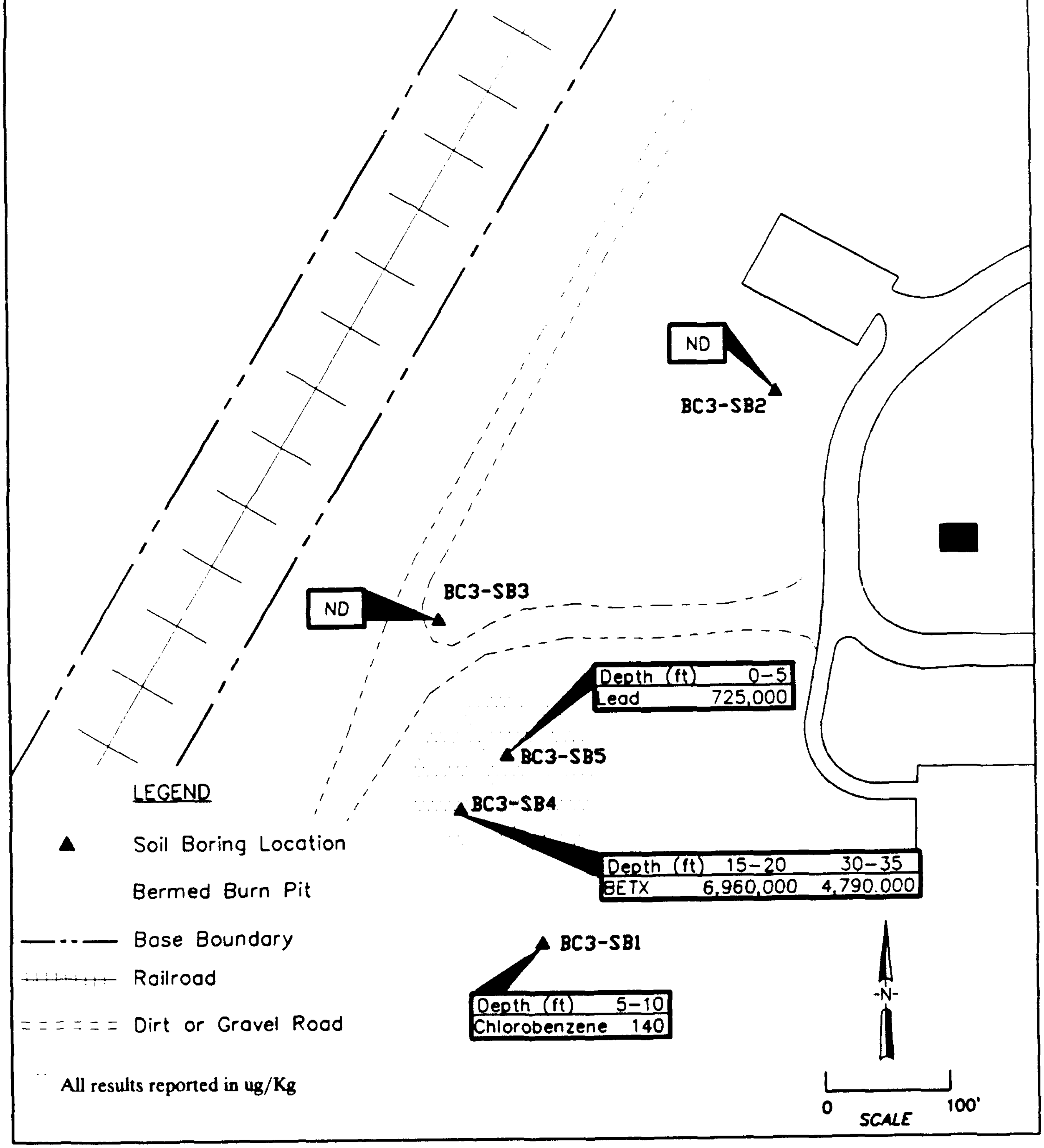


ES ENGINEERING-SCIENCE

Figure 4.4

MICHIGAN NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN

ESTIMATED CONCENTRATIONS OF CONTAMINANTS REPORTED FOR SOIL SAMPLES AT SITE 3 IN 1988

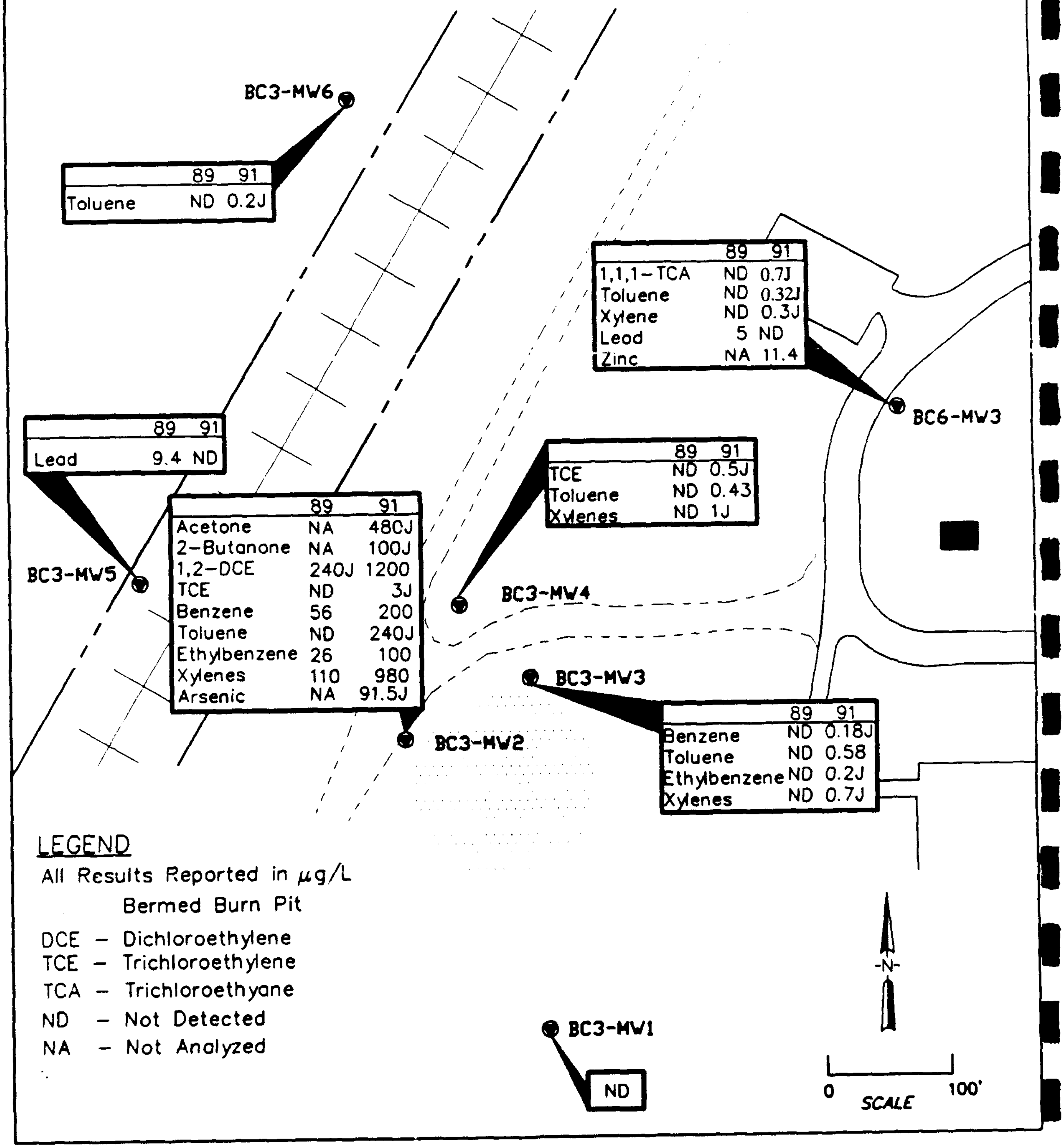


All results reported in ug/Kg

Figure 4-[illegible]

MICHIGAN NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN

CONTAMINANTS DETECTED IN GROUNDWATER AT SITE 3



BC3-MW6

	89	91
Toluene	ND	0.2J

BC3-MW5

	89	91
Lead	9.4	ND

BC3-MW2

	89	91
Acetone	NA	480J
2-Butanone	NA	100J
1,2-DCE	240J	1200
TCE	ND	3J
Benzene	56	200
Toluene	ND	240J
Ethylbenzene	26	100
Xylenes	110	980
Arsenic	NA	91.5J

BC6-MW3

	89	91
1,1,1-TCA	ND	0.7J
Toluene	ND	0.32J
Xylene	ND	0.3J
Lead	5	ND
Zinc	NA	11.4

BC3-MW4

	89	91
TCE	ND	0.5J
Toluene	ND	0.43
Xylenes	ND	1J

BC3-MW3

	89	91
Benzene	ND	0.18J
Toluene	ND	0.58
Ethylbenzene	ND	0.2J
Xylenes	ND	0.7J

BC3-MW1

ND

LEGEND

All Results Reported in μg/L

Bermed Burn Pit

DCE – Dichloroethylene
TCE – Trichloroethylene
TCA – Trichloroethyane
ND – Not Detected
NA – Not Analyzed

[illegible] 15, 06/21/91 at 11:14

ES ENGINEERING-SCIENCE

TABLE 4.7
GROUNDWATER ANALYTICAL DATA SUMMARY - SITE 3
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Parameter	BC3-MW1		BC3-MW2		BC3-MW3		BC3-MW4		BC3-MW5		BC3-M
	1989	1991	1989	1991	1989	1991	1989	1991	1989	1991	1989
Volatiles (ug/l)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)
GENERAL	U	U	U	U	U	U	U	U	U	U	U
Acetone	NA	U	NA	**480J**	NA	U	NA	U	NA	U	NA
2-Butanone	NA	R	NA	**100J**	NA	R	NA	R	NA	R	NA
trans-1,2-Dichloroethylene	U	U	**240J**	**1200**	U	U	U	U	U	U	U
Trichloroetheylene	U	U	U	**3J**	U	U	U	**0.5J**	U	U	U
Benzene	U	U	**56**	**200**	U	**0.18J**	U	U	U	U	U
Toluene	U	U	U	**240J**	U	**0.58**	U	**0.43**	U	U	U
Ethylbenzene	U	U	**26**	**100**	U	**0.2J**	U	U	U	U	U
Xylenes	U	U	**110**	**980**	U	**0.7J**	U	**1J**	U	U	U
Priority Pollutant Metals (ug/l)	(c)	(d)	(c)	(d)	(c)	(d)	(c)	(d)	(c)	(d)	(c)
Lead	U	U	U	U	U	U	U	U	**9.4**	U	U
Arsenic	NA	UJ	NA	**91.5J**	NA	UJ	NA	UJ	NA	U	NA

(a) Analytical method: SW8010 and SW8020
(b) Analytical method: CLP SOW
(c) - Analyzed for lead only
(d) - Dissolved fraction (filtered samples)
J = Estimated
NA = Not analyzed
R = Rejected
U = Not detected
UJ = Not detected; detection limit estimated

4.6 SITE 4 - ABANDONED LANDFILL

4.6.1 Field Program

The following activities were conducted during the SI:

- Installed four monitoring wells (Field Event 1-1988);
- Conducted aquifer tests at two monitoring wells (Field Event 1-1988); and
- Collected groundwater samples during each of the three field events (Field Events 1-1988, 2-1989, and 3-1991).

One monitoring well, BC4-MW1, is located hydraulically upgradient of Site 4 at the location shown on Figure 4.16. The other three wells are located immediately downgradient of the landfill. All wells are screened in the upper portion of the surficial aquifer at intervals ranging from 6 to 33 feet BLS. Monitoring well construction details are provided in Table 4.1.

Aquifer testing was conducted at monitoring wells BC4-MW2 and BC4-MW4 using slug test methods. A complete description of the testing, including interpretive methods, field data, and data plots, is presented in Appendix C.

The four monitoring wells were sampled during each of the three field events. The groundwater samples were analyzed for the following parameters:

- Field Event 1 - VOCs, semivolatile organics, total priority pollutant metals;
- Field Event 2 - VOCs, total lead, total chromium;
- Field Event 3 - VOCs, dissolved priority pollutant metals.

4.6.2 Results of Field Investigation

4.6.2.1 Geology and Hydrogeology

Site 4 is underlain by fine to coarse, silty sand with occasional layers of sand and gravel. The lithology of Site 4 is illustrated in Figure 4.17, which is a hydrogeologic cross-section extending across Site 4.

Groundwater in the surficial aquifer occurs at depths of approximately 8 to 22 feet BLS. As shown on the potentiometric surface map, Figure 4.18, groundwater in the surficial aquifer flows in a westerly direction across the site. The hydraulic gradient, as calculated from March 1991 data, is approximately 1×10^{-2} ft/ft.

Aquifer tests provided a hydraulic conductivity estimate of 3 ft/day at monitoring well BC4-MW2. Data from aquifer testing at BC4-MW4 was insufficient for analysis. The estimated groundwater flow velocity at the site, assuming a porosity of 20 percent, is estimated to be approximately 55 ft/yr. While generally accepted techniques were used to obtain the hydraulic conductivity value, data obtained by different means may provide a different value.

4.6.2.2 Groundwater Contamination Assessment

A summary of the analytical data is presented in Table 4.8 and shown on Figure 4.19. No VOCs or priority pollutant metals were detected in groundwater at Site 4.

Figure 4.16

MICHIGAN NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
LOCATIONS OF MONITORING WELLS AND CROSS-SECTION AT SITE 4

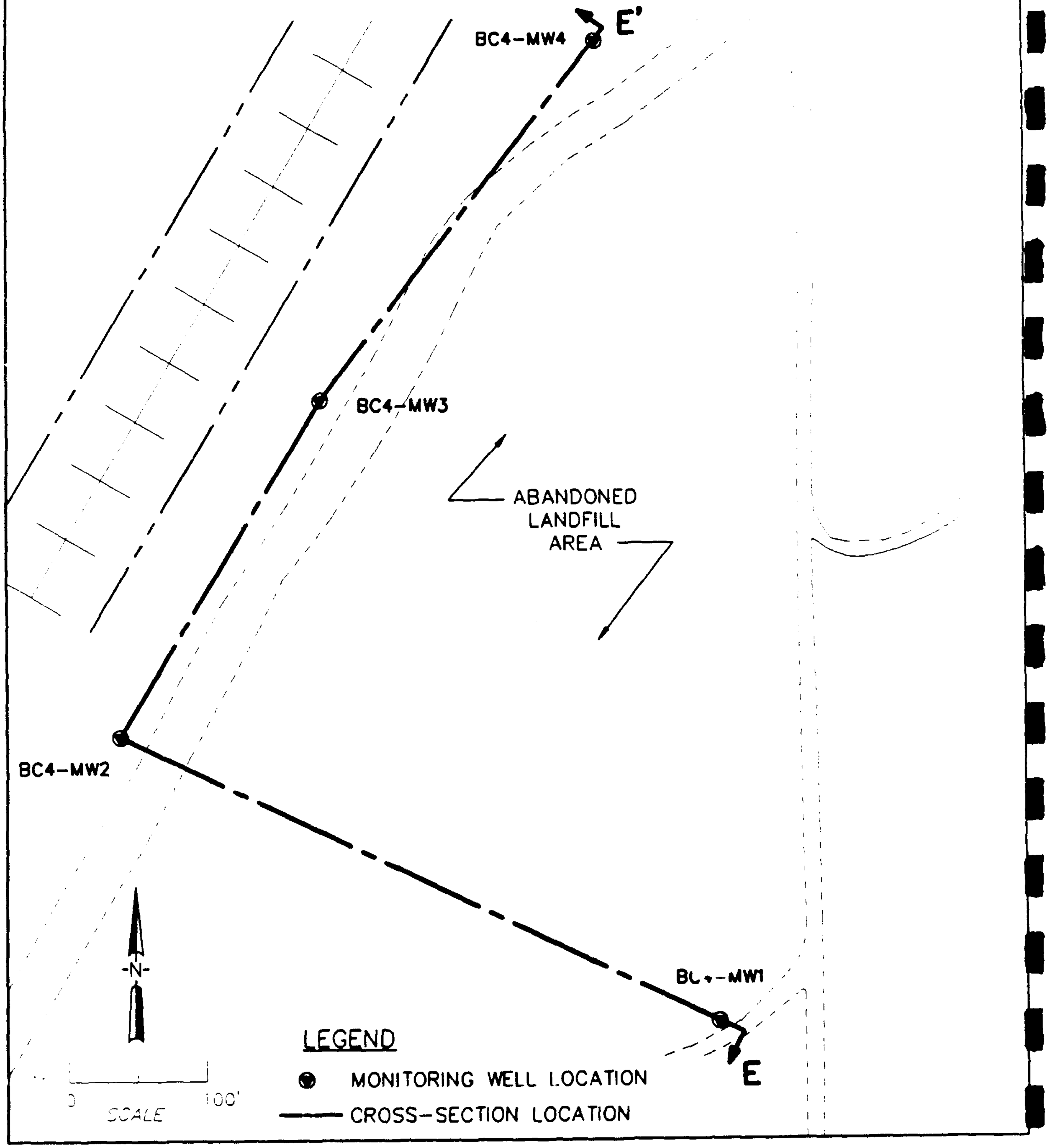


FIG4 16, 06/19/91 at 16:59

Figure 4 [illegible]

MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
GENERALIZED HYDROGEOLOGIC CROSS-SECTION E-E' AT SITE 4

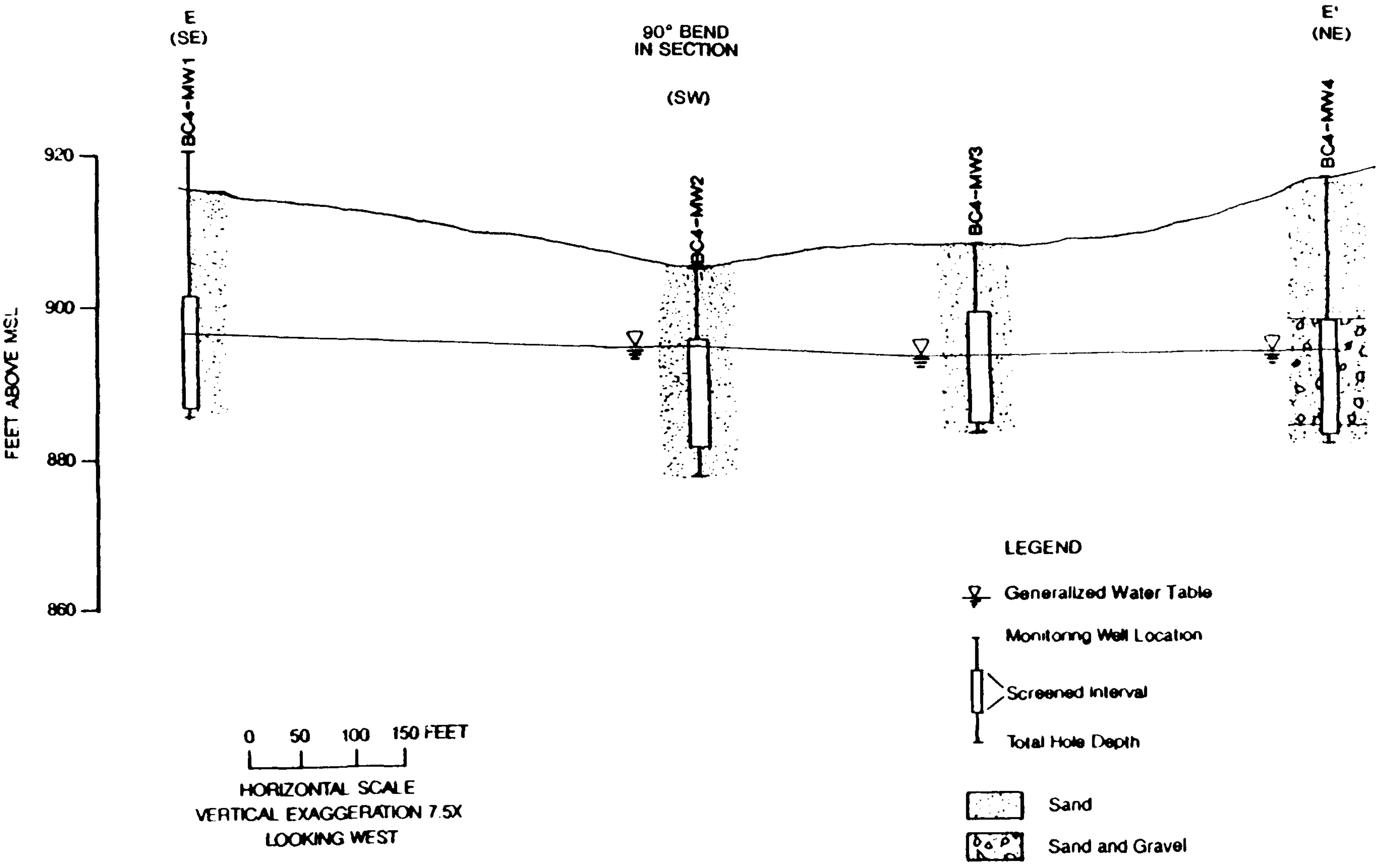
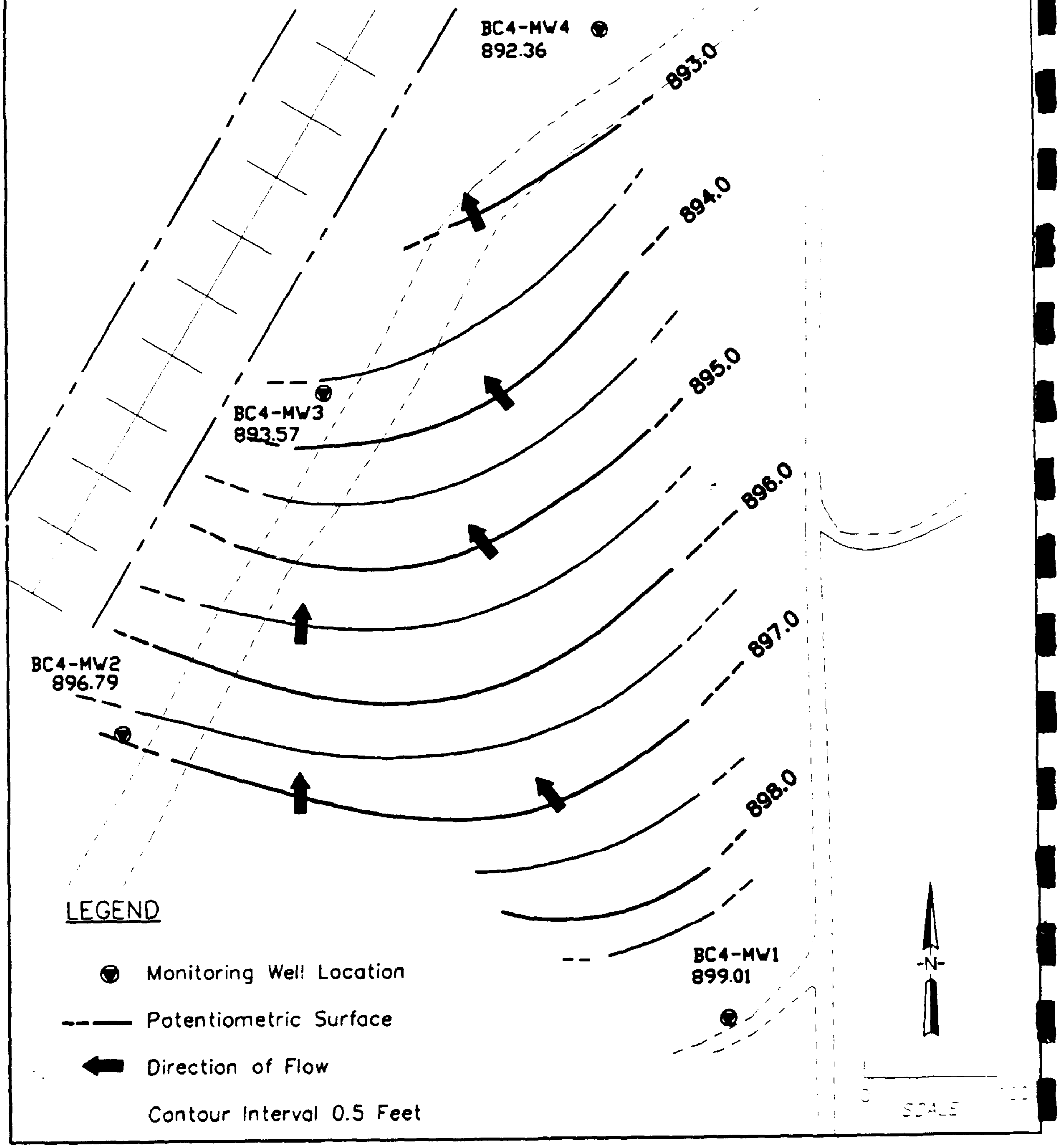


Figure 4 '3

MICHIGAN NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
GROUNDWATER POTENTIOMETRIC SURFACE AT SITE 4 IN MARCH 1991

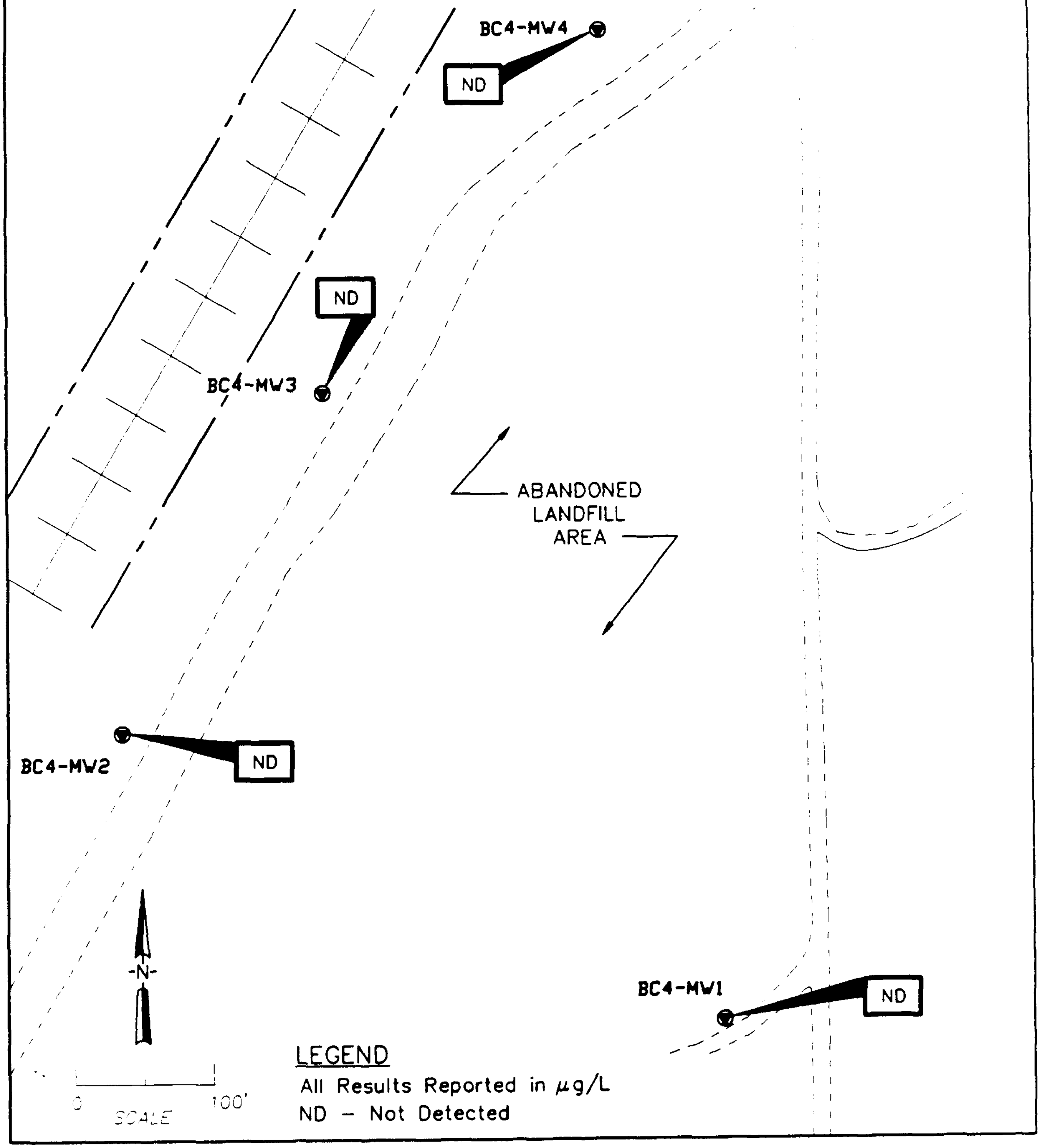


HC4-19, 06/19/91 at 17:42

Figure 4.19

MICHIGAN NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN

CONTAMINANTS DETECTED IN GROUNDWATER AT SITE 4



LEGEND

All Results Reported in µg/L

ND – Not Detected

FIG4-19, 06/19/91 at 17:32

ES ENGINEERING-SCIENCE

TABLE 4.8
GROUNDWATER ANALYTICAL DATA SUMMARY - SITE 4
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Parameter	BC4-MW1		BC4-MW2		BC4-MW3		BC4-MW4	
	1989	1991	1989	1991	1989	1991	1989	1991
Volatiles (ug/l)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
General	U	U	U	U	U	U	U	U
Priority Pollutant Metals (u	(c)	(d)	(c)	(d)	(c)	(d)	(c)	(d)
General	U	U	U	U	U	U	U	U

(a) - Analytical method: SW8010/SW8020

(b) - Analytical method: CLP SOW

(c) - Analyzed for lead and chromium only

(d) - Dissolved fraction (filtered samples)

U - Not detected

4.7 SITE 5 - FORMER COAL STORAGE AREA

4.7.1 Field Program

The following activities were conducted during the SI:

- Installed one monitoring well (Field Event 1-1988),
- Conducted an aquifer test (Field Event 1-1988),
- Drilled six soil borings and collected 12 soil samples (Field Event 1-1988),
- Collected a groundwater sample during each of the three field events.

The monitoring well is located hydraulically downgradient of Site 5 at the location shown on Figure 4.20. This well is screened in the upper portion of the surficial aquifer at an interval of 8 to 23 feet BLS. Monitoring well construction details are provided in Table 4.1. Two Site 6 monitoring wells, BC6-MW2 and BC6-MW3, are located immediately upgradient of Site 5 and are also screened in the upper portion of the surficial aquifer at intervals of 22 to 37 feet BLS.

An aquifer test was conducted at monitoring well BC5-MW1 using slug test methods. A complete description of the testing, including interpretive methods, field data, and data plots is presented in Appendix C.

Six soil borings were placed in the vicinity of the old coal storage area at the locations shown on Figure 4.20. Boring BC5-SB5 was terminated at 13 feet BLS because of auger refusal due to cobbles and boulders. The remaining borings were terminated at depths of 15 feet BLS. Two soil samples were collected from each boring and were analyzed for PAHs and priority pollutant metals. Boring logs are provided in Appendix B.

The monitoring well was sampled during each of the three field events. The groundwater samples were analyzed for the following parameters:

- Field Event 1 - VOCs, semivolatile organics, total priority pollutant metals;
- Field Event 2 - VOCs, total lead, total chromium;
- Field Event 3 - VOCs, dissolved priority pollutant metals.

4.7.2 Results of Field Investigation

4.7.2.1 Geology and Hydrogeology

Site 5 is underlain a layer of coal and gravel fill just below the ground surface. This fill overlies medium to coarse sands that are interbedded with sand and gravel. The lithology of Site 5 is illustrated in Figure 4.21, which is a hydrogeologic cross-section extending across Site 5.

Groundwater in the surficial aquifer occurs at a depth of approximately 12 feet BLS. As shown on the potentiometric surface map, Figure 4.22, groundwater in the surficial aquifer flows in a northwesterly direction across the site. The hydraulic gradient, as calculated from March 1991 data, is approximately 5 x 10^{-5} ft/ft.

The data collected from the aquifer test could not be interpreted due to problems encountered during testing. However, data from aquifer testing of surrounding sites indicate that the hydraulic conductivity of the surficial aquifer may range from 17 to 60 ft/day. The estimated groundwater flow velocity of the site is 160 to 550 ft/yr.

4.7.2.2 Soil Contamination Assessment

Analytical data for the soil samples collected in 1988 is not useable due to poor data quality and lack of QA/QC procedures in the laboratory. Therefore, characterization of soil contamination at Site 5 is not possible.

4.7.2.3 Groundwater Contamination Assessment

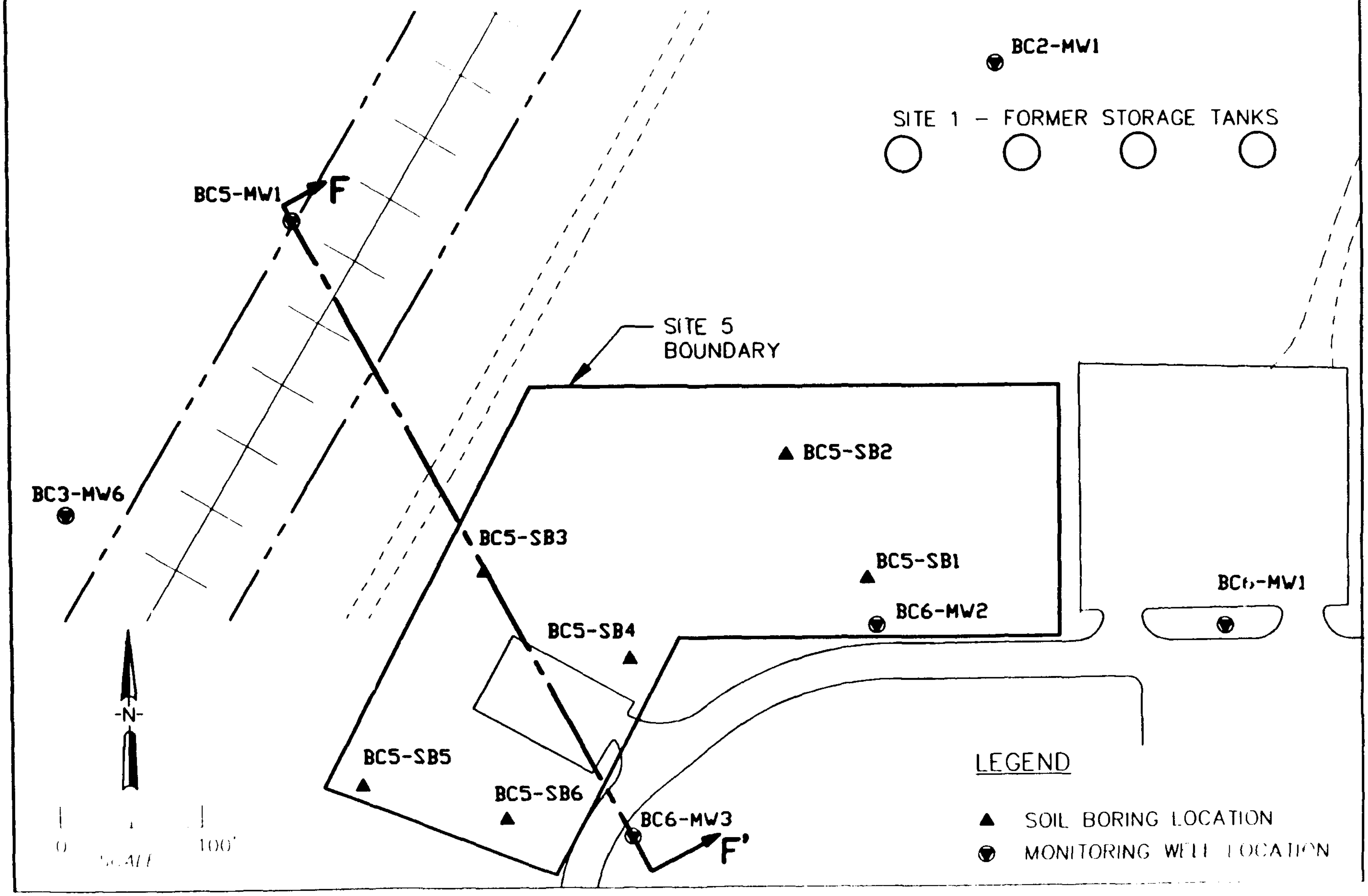
Analytical results are summarized in Table 4.9 and shown on Figure 4.23.

No VOCs were detected in groundwater collected in 1989 from BC5-MW1, located downgradient of Site 5. In 1991, groundwater from BC5-MW1 contained 1,1,1-TCA at an estimated concentration of 0.4 µg/L and xylenes at an estimated concentration of 0.2 µg/L. Priority pollutant metals were not detected. Groundwater flow patterns indicate that the groundwater contaminants probably originate from Site 3.

Figure 4.20

MICHIGAN NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN

LOCATIONS OF MONITORING WELLS, SOIL BORINGS, AND CROSS SECTION AT SITE 5



ES ENGINEERING-SCIENCE

Figure 4 2

MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
GENERALIZED HYDROGEOLOGIC CROSS-SECTION F-F' AT SITE 5

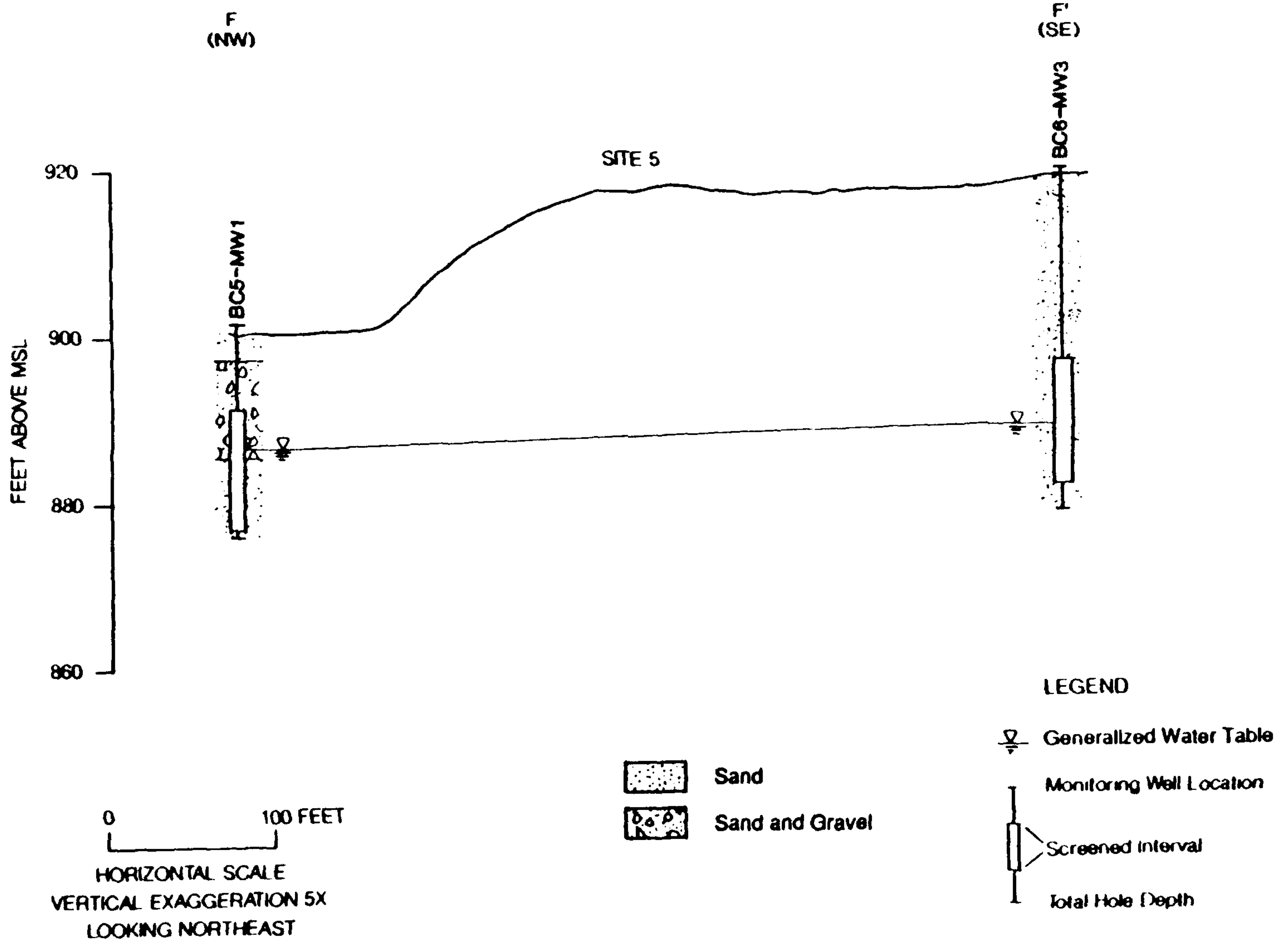


Figure 4.22

MICHIGAN NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN

GROUNDWATER POTENTIOMETRIC SURFACE AT SITE 5 IN MARCH 1991

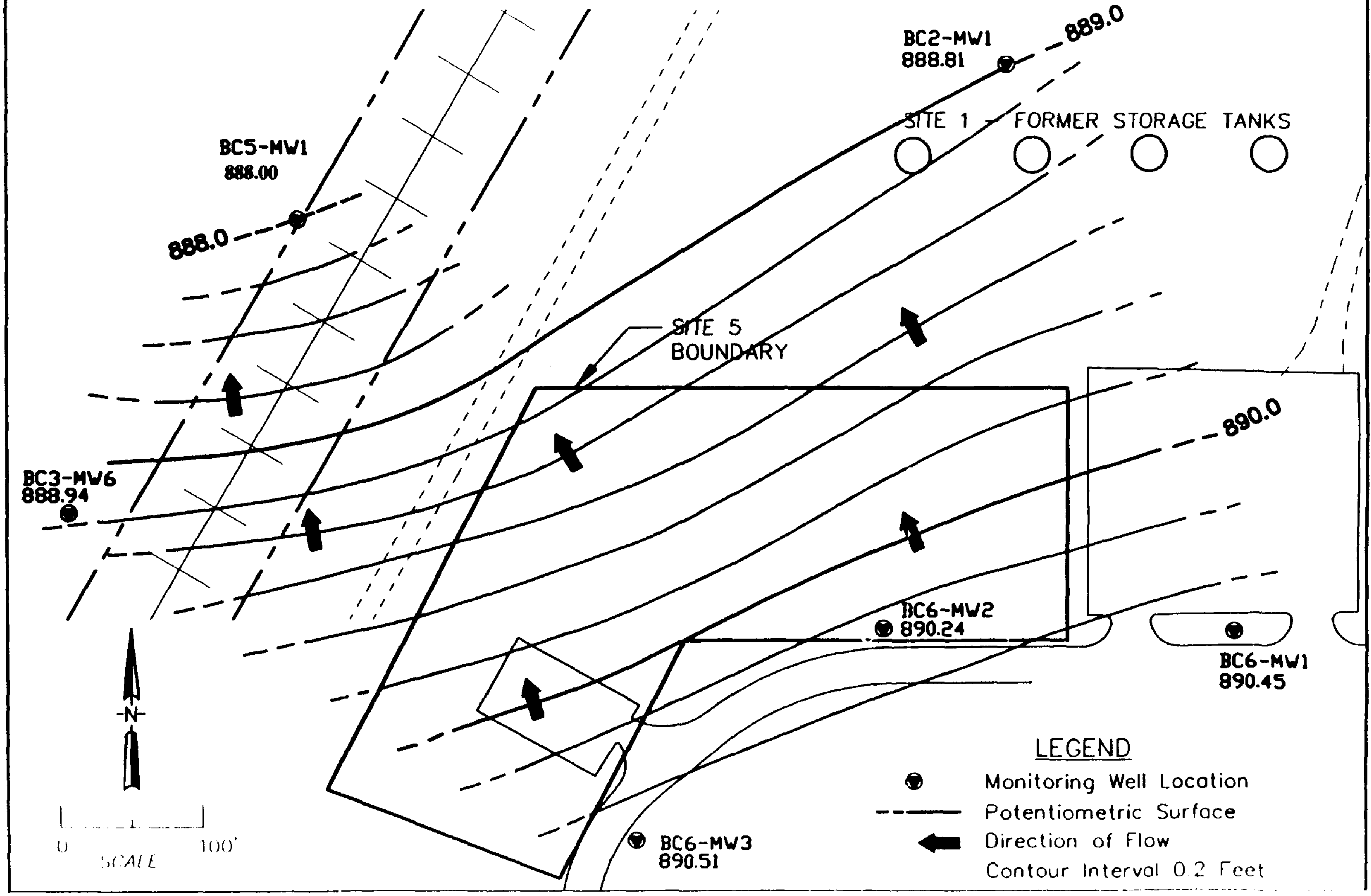


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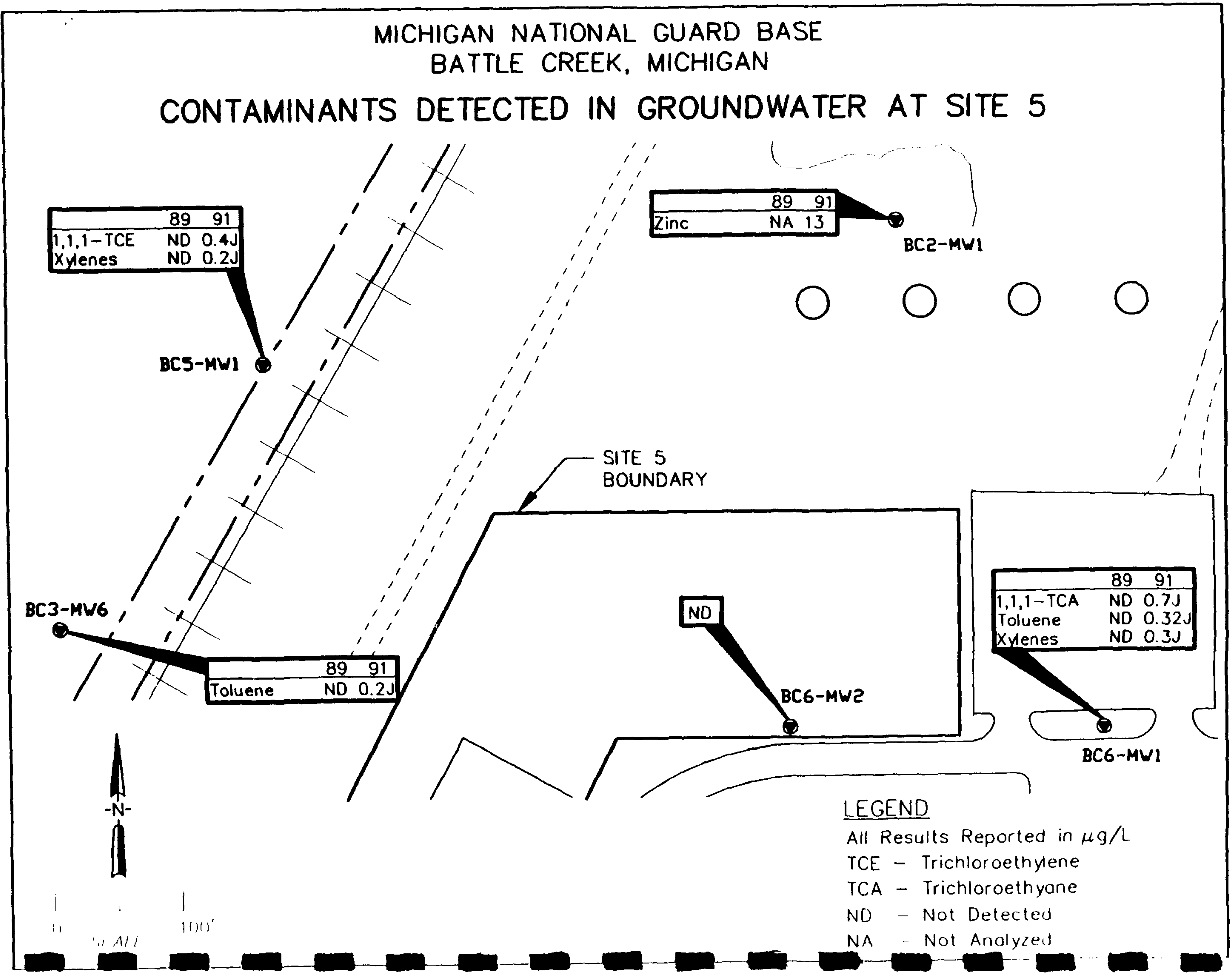
FIG4-22, 06/19/91 at 11:26

Figure 4.23

MICHIGAN NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN

CONTAMINANTS DETECTED IN GROUNDWATER AT SITE 5



LEGEND
All Results Reported in μg/L
TCE – Trichloroethylene
TCA – Trichloroethyane
ND – Not Detected
NA – Not Analyzed

fig4-23, 06/19/91 at 10:56

ES ENGINEERING-SCIENCE

TABLE 4.9
GROUNDWATER ANALYTICAL DATA SUMMARY - SITE 5
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Parameter	BC5-MW1	
	1989	1991
Volatiles (ug/l)	(a)	(b)
GENERAL	U	U
1,1,1-Trichloroethane	U	**0.4J**
Xylenes	U	**0.2J**
Priority Pollutant Metals (ug/l)	(c)	(d)
GENERAL	U	U

(a) - Analytical method: SW8010 and SW8020
(b) - Analytical method: CLP SOW
(c) - Analyzed for lead only
(d) - Dissolved fraction (filtered samples)
U - Not detected
J - Estimated

4.8 SITE 6 - FUEL SPILL

4.8.1 Field Program

The following activities were conducted during the SI:

- Installed three monitoring wells (Field Event 1),
- Drilled five soil borings and collected nine samples (Field Event 1),
- Hand-augered six soil borings and collected 11 soil samples (Field Event 3),
- Conducted aquifer tests at three monitoring wells (Field Event 1), and
- Collected groundwater samples during each of the three field events.

The three monitoring wells are located hydraulically downgradient of Site 6 at the locations shown on Figure 4.24. The wells are screened in the upper portion of the surficial aquifer at intervals ranging from 22 to 38 feet BLS. Monitoring well construction details are provided in Table 4.1.

An aquifer test was conducted at all three monitoring wells using slug test methods. A complete description of the testing, including interpretive methods, field data, and data plats, is presented in Appendix C.

Five soil borings were drilled during the first field event. Borings BC6-SB1 through BC6-SB5 were advanced to depths of 15 feet BLS. One to two soil samples were collected from each boring and were analyzed for VOCs and TPH. The soil boring locations are shown on Figure 4.24.

At the time of the third field event, borings BC6-SB4 and BC6-SB5 had been covered with excavated soil from a tank removal and these locations could not be resampled. Five soil borings were hand-augered to 2 to 6 feet BLS. Two samples were collected from each boring and were analyzed for BETX and TPH. An additional sample was collected from a background area near the parking apron and was also analyzed for VOCs and TPH.

The monitoring wells were sampled during each of the three field events. The groundwater samples were analyzed for the following parameters:

- Field Event 1 - VOCs, TPH, total priority pollutant metals;
- Field Event 2 - VOCs, total lead;
- Field Event 3 - VOCs, dissolved priority pollutant metals.

4.8.2 Results of Field Investigation

4.8.2.1 Geology and Hydrogeology

Site 6 is underlain by fine to coarse silty sands with some interlayered beds of sand and gravel. The lithology of Site 6 is illustrated in Figure 4.25 which is a hydrogeologic cross-section extending across the site.

Groundwater in the surficial aquifer occurs at a depth of approximately 27 to 31 feet BLS. As shown on the potentiometric surface map, Figure 4.26, groundwater in the surficial aquifer flows in a northeasterly direction across the site. The hydraulic gradient, as calculated from March 1991 data, is approximately 3 x 10^{-3} ft/ft.

Aquifer testing provided hydraulic conductivity estimates ranging from 16.58 ft/day to 37.04 ft/day. The estimated groundwater flow velocity at this site, assuming a porosity of 20 percent, ranges from 90 to 200 ft/yr. While generally accepted techniques were used to obtain the hydraulic conductivity values, data obtained by different means may provide different values.

4.8.2.2 Soil Contamination Assessment

Soil analytical data is summarized in Table 4.10. Compounds detected in soil are shown on Figure 4.27.

Toluene was detected in the Site 6 background soil sample at a concentration of 13 μg/Kg. Toluene was also found in three of the five soil samples at concentrations of 16 μg/Kg to 52 μg/Kg.

TPH was detected in four of the five samples at concentrations of 12 μg/kg to 21 μg/kg. Samples from boring SB3 contained TPH in both the 0′-0.5′ interval and the 2′-2.5′ interval. TPH was not detected in the background sample.

4.8.2.3 Groundwater Contamination Assessment

Groundwater analytical results are summarized in Table 4.11. VOCs detected in groundwater are shown on Figure 4.28.

TCE, tetrachloroethylene, and benzene were detected in the 1991 sample from well BC6-MW1 at concentrations of 0.36 μg/L to 1 μg/L[1]. No VOCs were detected in 1989. 1,1,1-TCA, toluene, and xylenes were detected in the 1991 sample from BC6-MW3. No VOCs were detected in 1989. VOCs were not detected in the sample from BC6-MW2 during either sampling event. Data from the 1988 field event was rejected due to QC problems.

Metals were detected only in the sample from BC6-MW3, where total lead was detected in 1989 and dissolved zinc was detected in 1991.

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[1] These detection limits were achieved by modifying the CLP procedures as explained in Appendix G.

Figure 4.24

MICHIGAN NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN

LOCATIONS OF MONITORING WELLS, SOIL BORINGS AND CROSS-SECTION AT SITE 6

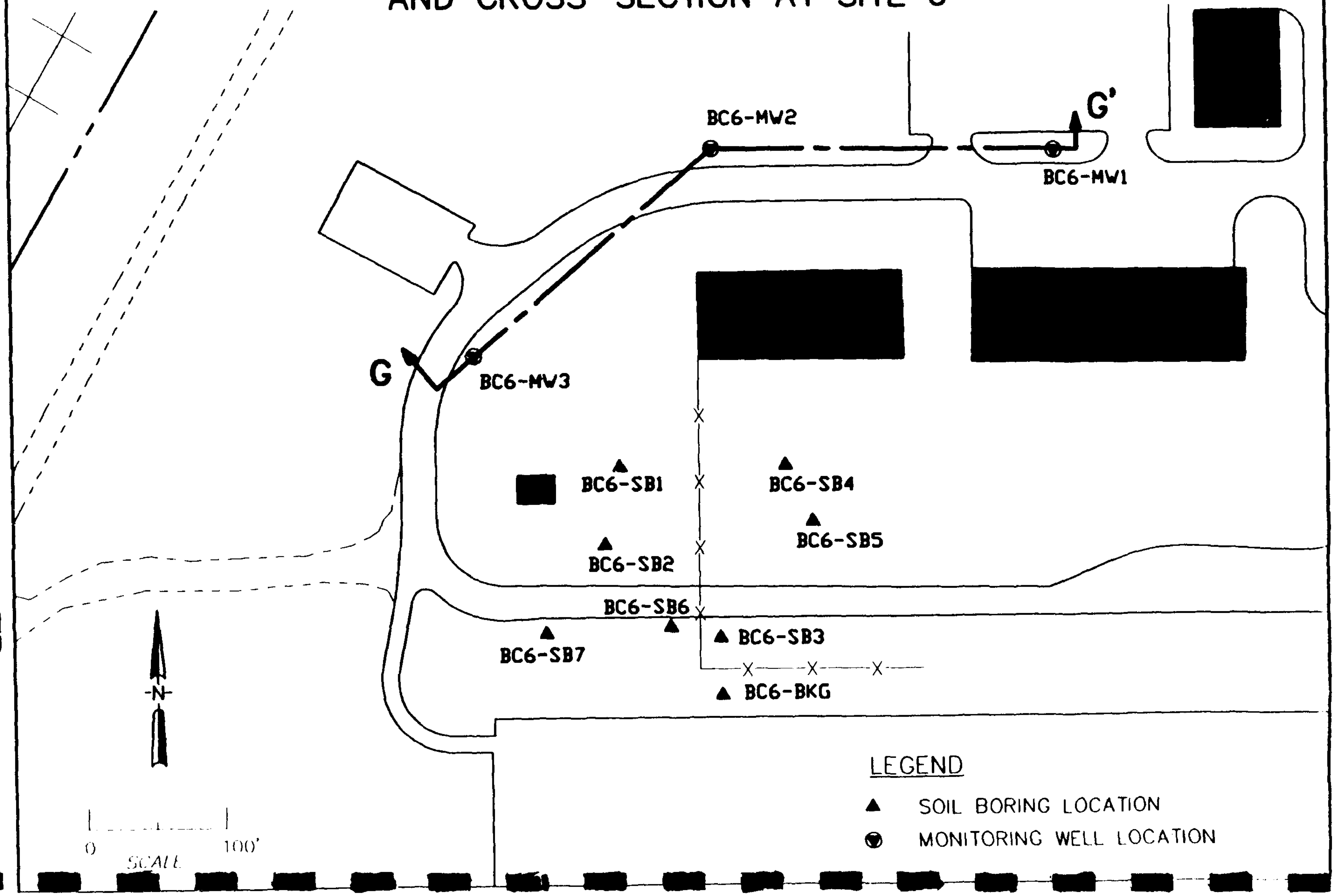

Figure 4.25

MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
GENERALIZED HYDROGEOLOGIC CROSS-SECTION G-G' AT SITE 6

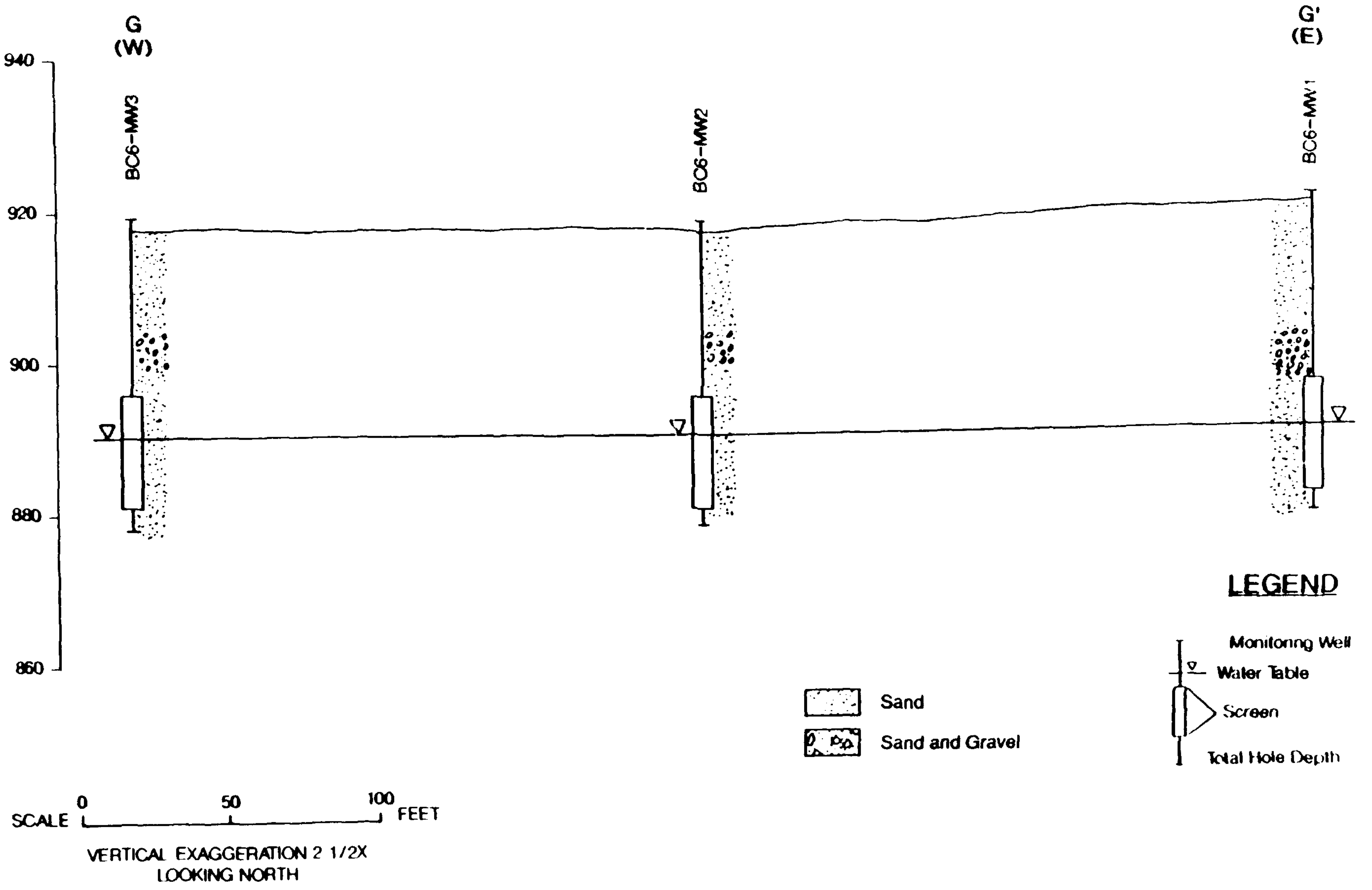

Figure 4.25

MICHIGAN NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN

GROUNDWATER POTENTIOMETRIC SURFACE AT SITE 6 IN MARCH 1991

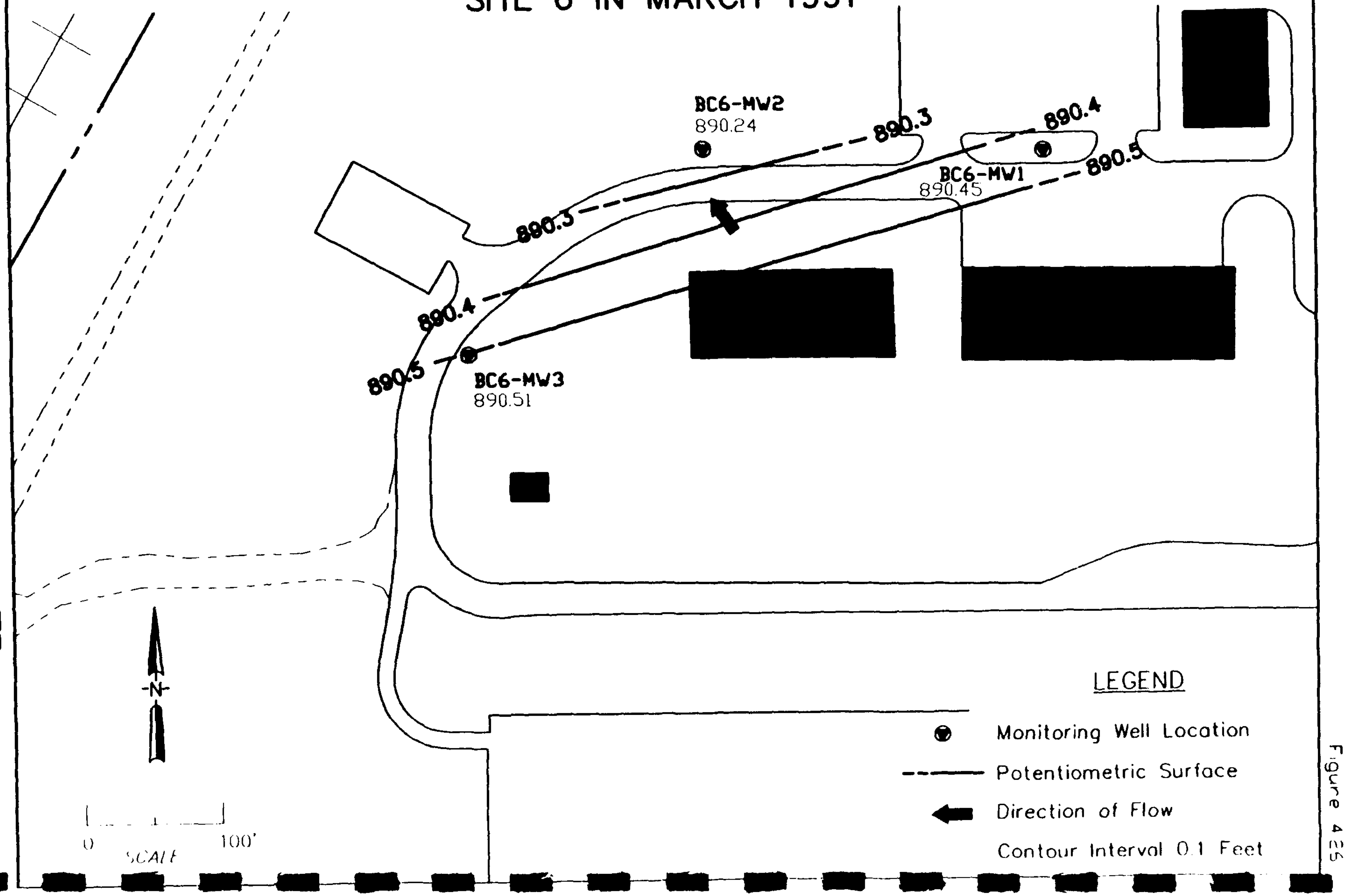

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Figure 4.37

MICHIGAN NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN

CONTAMINANTS DETECTED IN SOIL – 1991 AT SITE 6

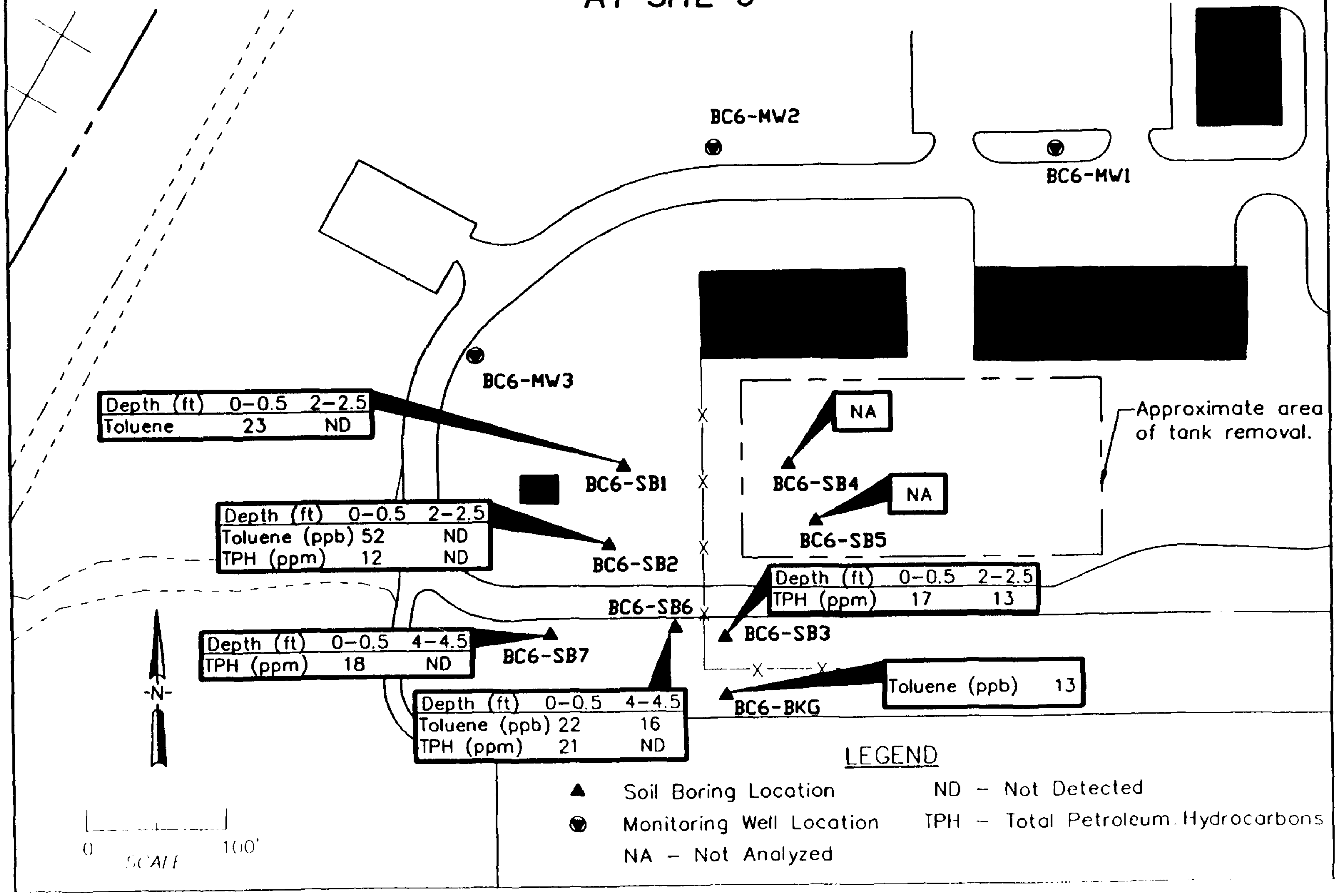

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Figure 4.28

MICHIGAN NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN

CONTAMINANTS DETECTED IN GROUNDWATER AT SITE 6

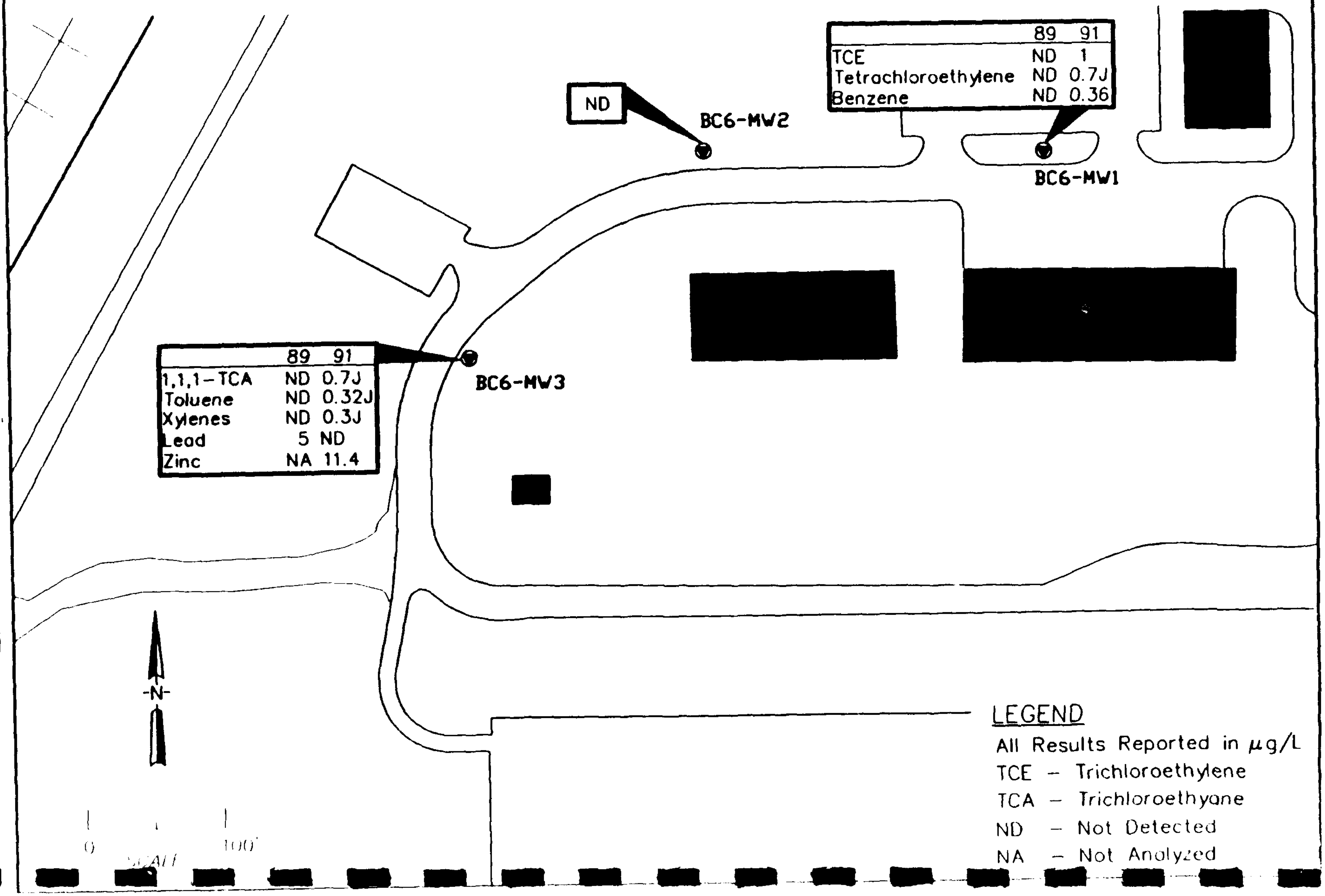

TABLE 4.10
SOIL ANALYTICAL DATA SUMMARY - SITE 6
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Parameter	BKGD	SB1		SB2		SB3		SB6		SB7	
		0'-0.5'	2'-2.5'	0'-0.5'	2'-2.5'	0'-0.5'	2'-2.5'	0'-0.5'	4'-4.5'	0'-0.5'	4'-4.5'
Volatiles (SW8020) (ug/kg)											
GENERAL	U	U	U	U	U	U	U	U	U	U	U
Toluene	13	23	U	52	U	U	U	22	16	U	U
TPH (418.1) (mg/kg))											
Result	U	U	U	12	U	17	13	21	U	18	U

U - Not detected

TABLE 4.11
GROUNDWATER ANALYTICAL DATA SUMMARY - SITE 6
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Parameter	BC6-MW1		BC6-MW2		BC6-MW3	
	1989	1991	1989	1991	1989	1991
Volatiles (ug/l)	(a)	(b)	(a)	(b)	(a)	(b)
GENERAL	U	U	U	U	U	U
1,1,1-Trichloroethane	U	U	U	U	U	**0.7J**
Trichloroetheylene	U	**1**	U	U	U	U
Tetrachloroethylene		**0.7J**	U	U	U	U
Benzene	U	**0.36**	U	U	U	U
Toluene	U	U	U	U	U	**0.32J**
Xylenes	U	U	U	U	U	**0.3J**
Priority Pollutant Metals (ug/l)	(c)	(d)	(c)	(d)	(c)	(d)
GENERAL						
Lead	U	U	U	U	**5**	U
Zinc	NA	U	NA	U	NA	**11.4**

(a) - Analytical method: SW8010 and SW8020

(b) - Analytical method: CLP SOW

(c) - Analyzed for lead only

(d) - Dissolved fraction (filtered samples)

J = Estimated

NA = Not analyzed

U = Not detected

SECTION 5
PRELIMINARY RISK EVALUATION

5.1 INTRODUCTION

The preliminary risk evaluation provides an evaluation of the potential risks to human health and the environment posed by the contaminants detected at the six sites investigated during the SI at the Base. The data used in this evaluation was collected during the SI and presented in previous sections of this report. These previously-presented data include demographic, land use, climatic, and ecological information (Section 2); the site history and the results of the investigative program, including contaminant concentrations and geologic and hydrogeologic information (Section 4). The objectives of the preliminary risk evaluation are to provide qualitative information on the potential risks to human and environmental receptors due to the release or threat of release of hazardous substances from the six sites; to aid in identifying additional data needed to complete a quantitative risk assessment during the RI; or to provide information for the determination that no further action is required if risks to human and environmental receptors are not identified.

The results of the medium-specific investigations described in the previous sections were used to identify contaminants of concern, chemical concentrations within the release, general release characteristics, the affected environmental media, and exposed or potentially-exposed human or environmental receptors.

The initial steps of the preliminary evaluation were to:

- Summarize the available chemical sampling data.
- Establish criteria for selecting chemicals that are or may be related to the site, and that may have an adverse affect on human health or the environment in the concentrations present.
- Review the factors that affect migration of contaminants, and identify and evaluate the potential migration pathways.
- Evaluate the potential toxicities associated with exposure to the selected chemicals by human or environmental receptors.
- Identify potential hazards to human or environmental receptors that may be affected by the migration of contaminants along identified pathways.

The SI is the initial investigation of a site and its purpose is to confirm or deny the presence of contamination. Therefore, detailed calculations to quantify risk to human health and the environment from the sites were not performed. Instead a qualitative approach was taken in which all potential receptors and exposure pathways were evaluated, and the potential importance of each exposure pathway was ascertained based on a comparison with standards or criteria and an evaluation of the likelihood of pathway completion. This evaluation was based on existing site information concerning migration pathways, the location and types of contaminants present, and the location of current and possible future receptors. Conservative assumptions were employed to ensure that potential exposure pathways were not excluded from consideration.

5.2 SELECTION OF CONTAMINANTS OF CONCERN

During the selection of the chemicals of concern, available information regarding the hazards of substances present at the sites were evaluated. Data used in selecting chemicals of concern for this preliminary human health evaluation were compiled from the three phases of field work performed at the Base. Summaries compiling the results of detected compounds from the investigations are provided in Section 4.

Common laboratory contaminants were eliminated from consideration if they were present in samples at concentrations less than ten times the highest concentration detected in the appropriate QA samples. In addition, inorganic chemicals were excluded from further analysis if the concentration detected was less than twice the background concentrations detected in the appropriate QA samples.

Contaminants detected in soil and groundwater samples collected from the six sites and boundary wells included chlorinated solvents, volatile fuel components, petroleum hydrocarbons, polynuclear aromatic hydrocarbons, and metals. The compounds detected in the soils and groundwater at each site are summarized in Table 5.1.

Analytical data were reviewed by medium to characterize contamination at each of the six sites and the boundary wells. Not all compounds were detected at all sites or in all media. The maximum concentrations at each site provide an indication of the magnitude of chemical contamination in the analyzed samples. The maximum values are used in subsequent sections to estimate the potential for adverse health affects.

5.2.1 Chemical and Physical Properties of the Chemicals of Concern

Physical and chemical properties of the chemicals of concern will affect fate and transport of those chemicals in the environment. Table 5.2 summarizes several important physical and chemical properties for many of the selected chemicals of concern.

The water solubility of a substance is a critical property affecting environmental fate. Highly-soluble chemicals can be rapidly leached from wastes and soils and are generally mobile in groundwater. Solubilities can range from less than 1 mg/L to totally miscible, with most common organic chemicals falling between 1 mg/L and 1,000,000 mg/L [Lyman et al., 1982]. The solubility of chemicals which are not readily soluble in water may become enhanced in the presence of organic solvents (e.g., toluene), which themselves are more soluble in water. As shown in Table 5.2, acetone, 1,2-dichloroethene, benzene and dimethylphthalate have the highest solubilities of any of the contaminants found on the Base. Because of their relatively high solubilities (greater than 1000 mg/L) these compounds are expected to be mobile in the soil.

Volatilization of a compound will depend on its vapor pressure, water solubility, and air diffusion coefficient. Highly water-soluble compounds generally have lower volatilization rates from water unless they also have high vapor pressures. Vapor pressure, a relative measure of the volatility of chemicals in their pure state, ranges from roughly 0.001 to 760 millimeters of mercury (mm Hg) for liquids. The Henry's Law Constant, which combines vapor pressure with solubility, is more appropriate than vapor pressure alone for estimating releases from water to air for compounds having Henry's Law Constants. Compounds with Henry's Law Constants greater than 10^{-3} atmospheres - cubic meter per mole (atm-m^3/mole) can be expected to readily volatilize from water; those with values ranging from 10^{-3} to 10^{-5} are associated with moderate volatilization, while compounds with values less than 10^{-5} will only volatilize from water to a limited extent [Lyman et al., 1982]. Trichloroethlene, anthracene, tetrachloroethlene and 1,1,1-trichloroethane have the highest Henry's Law Constants of any of the contaminants detected on site.

The organic carbon partition coefficient (K_{oc}) reflects the propensity of a compound to sorb to organic matter found in soil. The normal range of K_{oc} values is 1 to 10^7 milliliters per gram (mL/g), with higher values indicating greater sorption potential. Chemicals which have a strong tendency to sorb to organic matter (i.e., chemicals with high K_{oc} values) will move more slowly in the environment than chemicals with low K_{oc} values. The polynuclear aromatic hydrocarbons have the highest K_{oc} values of any compounds identified at the Base. These compounds would therefore be expected to be strongly adsorbed by organic matter present in the soil and have relatively low mobilities.

Chemicals of concern were classified into several categories according to their similarity in chemical structure and/or physiochemical properties (factors which would influence mobility in the environment) as follows:

- **volatile organics**: acetone, cis/trans-1,2-dichloroethene, 2-butanone, 1,1,2,2-tetrachloroethane, carbon disulfide, benzene, ethylbenzene, 1,1,1-trichloroethane, trichloroethene, tetrachloroethene, toluene, styrene, xylenes.
- **semivolatile organics**: 4-methylphenol (p-cresol), fluoranthene, fluorene, dimethylphthalate, anthracene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, butylbenzylphthalate, bis(2-

ethylhexyl)phthalate, chrysene, indeno(1,2,3-cd)pyrene, pyrene, phenanthrene, di-n-butylphthalate, benzo(g,h,i)perylene.

- **other**: total petroleum hydrocarbons (TPH).
- **metals**: arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, thallium, zinc.

5.2.2 Contaminant Fate and Transport

The previous subsection described the important physical and chemical properties of the contaminants detected at the Base. This subsection describes how these properties affect the persistence and transport of these compounds in the environment.

5.2.2.1 Volatile Organics

Volatile organic compounds are low molecular weight compounds whose presence in soil and water samples collected at the Base is due to their widespread use as solvents and fuel additives. These compounds generally have high Henry's Law Constants, moderate to high solubilities and low K_{oc} values. This indicates that these compounds can be expected to be mobile in the environment. While ethylbenzene and styrene are included with the volatile organics, these compounds have much higher K_{oc} values than the other compounds in this class. Therefore, these compounds would be expected to be more strongly adsorbed by soils and therefore less mobile than the other compounds in this class.

The soils at the Base are derived from glacial materials and are generally sandy and moderately to highly permeable. The subsurface materials consist of unconsolidated sands, gravels, and clays overlying the Marshall Formation, which is interbedded sandstones and shales. Groundwater occurs in the glacial aquifer under water table conditions and is found at approximately 30 to 40 feet bls (below land surface). The glacial aquifer is generally separated from the Marshall Sandstone aquifer by a clay layer. However, this clay layer is not continuous under the western portion of the Base. These geological and hydrogeological characteristics indicate that the migration of these compounds to the groundwater is likely. As described in Section 4, several volatile compounds have been detected in the groundwater.

The properties that enhance the mobilities of these compounds also make them more available for degradation. Because of their high vapor pressures these compounds would be expected to volatilize from surface soils.

5.2.2.2 Semi-Volatile Organics

Semi-volatile organic compounds detected in soil and water collected at the Base consisted of polynuclear aromatics (PNAs) and phthalate esters. The semi-volatile organics have higher molecular weights than the volatile compounds. They also have lower vapor pressures, lower solubilities, and higher K_{oc} values. These compounds are expected to be strongly adsorbed by site soils and therefore less mobile in the environment. While the semi-volatile compounds are not soluble in water, they are soluble in non-water solvents such as fuels. The application of fuels to the ground could enhance the mobility of these compounds.

5.2.2.3 Petroleum Hydrocarbons

Petroleum hydrocarbon concentrations are measured using fluorocarbon-113 extraction of organic compounds with medium to high molecular weights. Low molecular weight compounds and light fuels, such as gasoline, volitize during the analysis and, therefore, have low recoveries. The aliphatic organics which constitute most of the recoverable petroleum hydrocarbons are generally less toxic than the volatile organic compounds. The primary health concern associated with chronic exposure is through ingestion of contaminated food and water.

The fate of petroleum hydrocarbons in soils is affected primarily by their distribution, volatility, and leaching potential. Low molecular weight aromatic hydrocarbons such as benzene, toluene, and xylenes partially evaporate. The remaining hydrocarbons will migrate to different depths in the soil column and possibly to groundwater.

The aliphatic organics which represent the residual compounds have negligible water solubilities, low vapor pressures and high adsorption coefficients. The proportion of petroleum hydrocarbons that will adsorb to soil particles rather than continue migration depends on the type of soil, the particular petroleum product involved, the volume of the release, and the amount of rainfall. In general, leaching to groundwater is favored by high rainfall and permeable soils, and increases for petroleum compounds with high solubility and low adsorption coefficients.

Most compounds measured as petroleum hydrocarbons are relatively persistent in the environment. Biodegradation is the main elimination mechanism, but rates are fairly slow, especially for cyclic or aromatic hydrocarbons. Complete biodegradation of petroleum hydrocarbons may require many years or decades [API, 1986].

5.2.2.4 Metals

Metals occur naturally in the environment, principally as cations within the crystal lattice structure of minerals. Unlike the organic compounds discussed above, metals, which are chemical elements are not degradable through biological or chemical actions, and can be considered infinitely persistent in the environment. However, metals can be oxidized or reduced through the actions of microorganisms that can change their chemical and physical properties and therefore their mobility. For example, biomethylation of lead and mercury (the addition of a methyl group) can greatly increase their mobility and reduce their soil-sorption potential.

The mobility of metals in the environment is generally low, with sorption being the factor most important in controlling their movement [Versar, 1979]. Most of the metals detected at the Base have a high potential for sorption in the soil and therefore, normally have low mobilities. Exceptions are arsenic in the highly soluble oxyanion form (AsO_4^{-3}) and nickel, which has the highest mobility of all the heavy metals listed. Environmental factors which influence the mobility of metals include: soil type (metals are readily sorbed by clay minerals and organic matter); pH (metals are more soluble at low pHs); biomethylation; and chemical oxidation and reduction.

5.3 ARAR IDENTIFICATION

In evaluating the degree of contamination at a site, consideration must be given to applicable or relevant and appropriate requirements (ARARs) of Federal and State environmental laws. Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations that specifically address a hazardous substance, contaminant, remedial action, or other circumstance at a site. Relevant and appropriate requirements are those standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations that, while not "applicable", address problems or situations sufficiently similar to those encountered at the site that their use is well suited to the particular site.

Potential ARARs for water quality at the Base include Michigan Cleanup Standards, the Safe Drinking Water Act, and the Clean Water Act. Standards and criteria promulgated under these programs are provided in Table 5.3 for potential contaminants of concern at the Base.

5.3.1 Michigan Cleanup Standards

The Michigan 307 regulation establishes three degrees of cleanup: Types A, B, and C, in increasing degree of complexity. Type A criteria are media and chemical specific. Type B criteria are media and endpoint specific but not site specific. Type C criteria are used if Types A and B criteria are exceeded. Type C criteria are developed on the basis of a site specific risk assessment under similar guidance to the EPA Risk Assessment Guidance. These criteria are used in a logical progression. If type A criteria are exceeded, the site concentrations are compared to Type B criteria. If Type B criteria are exceeded, a risk assessment is performed to determine the Type C criteria and then site concentrations are compared to these site-specific criteria.

To comply with Type A cleanup criteria in any environmental media, the hazardous substance concentration must either not exceed the background concentration or must not exceed the method detection limit for that substance. Background is defined as site specific background; county or national background is not considered acceptable for comparison.

For groundwater, there are four kinds of Type B criteria depending on the toxicological endpoint. If a hazardous substance is designated a genotoxic teratogen or a germ-line mutagen, no Type B criteria can be calculated, and a site-specific risk assessment must be performed. If a substance is considered a carcinogen in Michigan (all Class A and B carcinogens and some Class C carcinogens under the EPA's weight of evidence criteria), the Type B criteria is the concentration which represents an increased cancer risk of 1 in 1,000,000 for a 70 kg adult drinking 2 liters of water per day. Guidelines are given in the regulation for selecting a carcinogenic potency factor based on available toxicological data. For noncarcinogens, the Type B criterion is the "human life cycle safe concentration" (HLSC), which is based on a 70 kg adult ingesting 2 liters of water per day, assuming 20 percent of the chemical intake is derived from drinking water. Similar guidance is given in selecting toxicological data. The other two potential Type B criteria for groundwater are aesthetic criteria. The first is the secondary Maximum Containment Level (MCL), if it exists. The second is the concentration which is documented as the taste and odor threshold or the concentration below which appearance or other aesthetic characteristics are not adversely affected. This last criterion only applies if it is lower than the toxicologically based criteria.

Type B criteria for soils are designed to be protective of other media and of human health through direct contact with soils. For the protection of groundwater, the concentration of the hazardous substance in soil must be below that which generates a leachate that is equal to the highest of the groundwater criteria or below the leachate concentration generated by background soil. If the total concentration of that substance does not exceed twenty times the Type A or B criteria in groundwater (in parts per billion), leachate testing is not required. For the protection of human health due to direct contact, soil criteria are calculated using toxicological data and ingestion and dermal exposure assumptions.

Surface water Type B criteria are defined as not to exceed "levels which are or may become injurious to the public health, safety, or welfare; plant and animal life; or the designated uses of those waters." In the State of Michigan, all waters of the state are designated for all of the following uses:

(a) Agriculture,

(b) Navigation,

(c) Industrial water supply,

(d) Public water supply at the point of water intake,

(e) Warmwater fish,

(f) Other indigenous aquatic life and wildlife, and

(g) Partial body contact recreation.

Also, all waters are designated for total body contact recreation from May 1 to October 31.

Under the 307 regulation, for carcinogens in surface water the risk level is defined as not to exceed 1 in 100,000 with no mixing rule. An HLSC is defined in surface water as well. For a surface water which is designated as a potential source of drinking water, a water consumption of 2 L/day is assumed. If the surface water is designated for recreational use only, an ingestion of 0.01 L/day is assumed. Fish consumption is also accounted for by multiplying the concentration in water by the fish bioconcentration factor and assuming a consumption of 6.5 grams of fish per day. Toxicological constants are selected as for groundwater. The surface water quality standards developed under the Clean Water Act are based on the same methodology.

For the purpose of this *Preliminary Risk Evaluation* the Type B criteria developed in June, 1990 by the state of Michigan for several selected compounds in both soil and groundwater will be used as relevant and appropriate. Also, the surface water quality standards developed under the Clean Water Act will be used as the state Type B criteria for surface water.

5.3.2 Safe Drinking Water Act

The Safe Drinking Water Act (SDWA) mandates EPA to establish regulations to protect human health from contaminants in drinking water. EPA has promulgated drinking water standards which generally apply to community water systems. Primary drinking water standards include MCLs and maximum contaminant level goals (MCLGs). MCLs are set at levels that are protective of human health, while taking into account available treatment technologies and the costs to large public water systems. MCLGs are strictly health-based and do not take cost or feasibility into account. Secondary drinking water regulations consist primarily of secondary maximum contaminant levels (SMCLs) for specific contaminants or water characteristics that may affect the aesthetic qualities of drinking water (i.e., color, odor, and taste).

MCLs and MCLGs for contaminants of concern at the Base are provided in Table 5.3. Proposed MCLs and proposed MCLGs are also identified. The concentrations provided are potential ARARs.

5.3.3 Clean Water Act

The Clean Water Act (CWA) requires the establishment of guidelines and standards to control the direct or indirect discharge of pollutants to waters of the United States. The standards required by the CWA include water quality criteria for specific pollutants. EPA has developed two kinds of water quality criteria: one for the protection of human health and another for the protection of aquatic life. These criteria are non-enforceable guidelines used by the States to set water quality standards for surface water. These non-enforceable standards are potential ARARs when the state has not promulgated water quality standards for the specific pollutants and water bodies of concern.

Table 5.3 provides the water quality criteria for the potential contaminants of concern at the Base. Although these concentrations are not applicable, they may be relevant and appropriate because groundwater at the Base may discharge to surface waters of the Kalamazoo River.

5.4 PRELIMINARY HUMAN HEALTH EVALUATION

The previous subsections have described the physical and chemical properties of contaminants found at the Base and the effect these properties will have on environmental fate and transport mechanisms as well as identifying ARARs that can be used to evaluate the significance of the SI results. This subsection provides the preliminary human health evaluation which includes an assessment of exposure routes, a description of contaminant toxicities and presents the initial human health risk screening for each site.

5.4.1 Exposure Assessment

The presence of a contaminant in a particular environmental medium does not necessarily indicate that human exposure will occur. In order for human exposure to occur, a complete exposure pathway must exist. A complete exposure pathway consists of the following:

- a contaminant source and mechanism for release;
- an environmental transport medium;
- an exposure point; and
- a human receptor and a feasible route of exposure at the exposure point.

If any of the items listed above are missing the exposure pathway is incomplete. The following paragraphs describe the transport mechanism and exposure pathways for the six sites and the boundary wells located at the Base.

5.4.1.1 Mechanisms of Migration

The media into which a contaminant migrates affects the types of human and environmental exposures which may occur. The previous subsections have described the physical and chemical properties of concern. This subsection discusses the mechanisms of contaminant migration and potential exposure routes for the Base.

Contaminants have been detected in several types of media at the six sites on Base. Soil and groundwater contamination have been detected at Sites 2 and 6. Surface water contamination has been detected in the swale at Site 2. No contamination has been detected at Site 4. Groundwater contamination has also been detected at Sites 3 and 5, and in the boundary wells. Several mechanisms exist through which contaminants from these areas may migrate.

Migration into Air. Contaminants may migrate into the air through three primary mechanisms: volatilization; soil gas migration; and suspension of soil particles (wind erosion or mechanical disturbances).

Volatilization is the mass transfer of a compound from a specific medium (soil or water) to the air. Environmental factors that affect volatilization include temperature, soil porosity, soil water content, soil organic carbon content, and depth of contamination [Jury et al., 1983]. Volatilization may be an important migration pathway for contaminants having high vapor pressures (greater than 100 mm Hg) or high Henry's Law Constants (greater than 10^{-3} atm-m^{-3}/mole). Contaminants detected at the Base which are in this category include the chlorinated aliphatics (trichloroethylene, 1,2-dichloroethene, etc.) and aromatics (benzene, xylenes, toluene, etc.). Some other chemicals of concern while having lower vapor pressures may still have a tendency to volatilize. The polynuclear aromatic hydrocarbons (PAHs) fall in this category. Volatilization is a potential migration pathway for Sites 2 and 6 since volatile organic compounds and PAHs are present in the shallow soils or sediments.

Fugitive dust emissions from wind or vehicle disturbances may occur from sites on the Base. Environmental factors that influence wind erosion are wind speed, soil moisture content, vegetative cover, snow cover, and soil composition. Contaminated surface soils or sediments were detected at Sites 2 and 6. These sites also have a vegetative cover to minimize the dispersal of contaminants by wind erosion. However, any construction or change in the vegetative coverings at the sites will increase the potential for fugitive dust emissions from the site.

Leaching into Groundwater. The percolation of rainwater through the soils at the six sites could leach soil contaminants into the groundwater. It appears that leaching has occurred at Sites 2, 3, and 6, due to the elevated concentrations of contaminants in the groundwater.

Once the contaminants have reached the groundwater, the different contaminants will have different migration routes. Compounds with low water solubilities and high organic partition coefficients, such as the semi-volatile compounds will be transported in the direction of groundwater flow but at a slower rate than the groundwater. The volatile organic compounds which have much higher solubilities and lower Koc values will have higher mobilities in the groundwater. This is evident in the boundary wells, because high levels of volatile organic compounds have been detected in downgradient wells as compared to the levels of semi-volatile organic compounds.

Migration in Surface Water. Surface water runoff at the base primarily collects in low areas and percolates into the soil. This water primarily leaves the Base as groundwater flow which could discharge into the Kalamazoo River. However, runoff on the newly acquired western portion of the Base flows into low swampy areas which eventually feed small streams. These streams flow north into the

Kalamazoo. This migration pathway is unlikely due to the manmade structures (i.e. railroads, buildings) which deflect the path of the runoff and the distance to any surface water body.

Upon reaching surface water the contaminants may remain in the water column, volatilize, or adsorb to bottom or suspended sediments. Volatilization of contaminants has been described previously. Contaminants with low solubilities such as the semi-volatile organics and petroleum hydrocarbons will be expected to associate with the sediments. Behavior of inorganic contaminants is affected by water quality parameters such as pH, hardness, temperature, and dissolved oxygen.

5.4.1.2 Pathways of Exposure

Potential pathways of exposure to chemicals of concern at all six sites at the Base have been summarized in Tables 5.5 through 5.15. Demographic and land use information presented in Section 2 was used in developing exposure pathways. The EPA requires that hypothetical future use of a site be considered as well as current use. Therefore, these tables present current-use and future-use pathways.

Current-use pathways include exposure to air, groundwater, surface water, soil and sediments by base personnel, visitors, trespassers, and nearby residents.

Air pathways involve the inhalation of fugitive dust emissions and any volatized gases. As discussed previously, Sites 2 and 6 have a vegetative cover which is expected to retard *wind erosion and the generation of fugitive dust emissions.* However, volatization is a possible pathway when VOCs are detected in elevated surface soils.

Groundwater is considered to be a primary medium of exposure. Groundwater is used for private and municipal drinking water supplies. Potable water wells are completed in both the shallow water table aquifer and the Marshall Sandstone aquifer. Water quality is generally good in both aquifers. In 1987, organic contaminants were detected in four private wells located downgradient of the site. Current pathways of exposure associated with groundwater include:

- Ingestion of groundwater from a contaminated potable groundwater supply.
- Inhalation of VOCs released during showering from private supply wells.
- Dermal contact with water drawn from a contaminated water supply.

Elevated levels of contaminants were detected in the groundwater collected from Sites 2, 3, and 6. Migration of the contaminants has been documented from the elevated levels of contaminants detected in the downgradient boundary wells.

A low potential exists for contact with contaminated soils at each of the sites due to infrequent incidental contact by workers and the fact that access to the base is restricted. The potential for contact with soil at Site 2 is further limited by the intermittent presence of overlying water. However, the elevated levels of contaminants detected in the soils at Site 2 increase the potential of adverse health effects.

Surface water runoff at each of the six sites primarily migrates to low areas, where it either evaporates or percolates into the ground. This migration is evident at Site 2 which is a drainage swale for the Base. However, a small percentage of the site's runoff might migrate to the west of the Base into a swampy lowland area, which eventually could drain to the Kalamazoo River. The groundwater also might discharge into the Kalamazoo River. However, the potential for detectable concentrations of contamination reaching the river is thought to be low due to the distance to the river, and the expected dilution and dispersal of contaminants. The river is approximately 1.75 miles north of the Base.

Future-use pathways include exposure to contaminated air, groundwater, surface water, soils, and sediments by hypothetical residents, trespassers, and construction workers. The probability of future-use pathway completion is higher than that for current use, based primarily on the remote possibility of future development of the base for residential or commercial use. Any construction or disturbance of soils would increase the potential of oral or inhalation exposure. However, by the time development might occur at the base, contaminant concentrations will probably have diminished significantly from current levels as a result of natural processes such as degradation and dispersion.

5.4.2 Toxicity Assessment

The objective of the toxicity assessment is to weigh available evidence regarding the potential for particular contaminants to cause adverse effects in exposed individuals and to provide, where possible, an estimate of the relationship between the extent of exposure to a contaminant and the increased likelihood and/or severity of adverse effects. The types of toxicity information considered in this assessment include the slope factor to evaluate carcinogenic potential and the reference dose (RfD) or reference concentration (RfC) used to evaluate noncarcinogenic effects.

5.4.2.1 Health Criteria for Carcinogenic Effects

For chemicals that exhibit carcinogenic effects, most authorities recognize that one or more molecular events can evoke changes in a single cell or a small number of cells that can lead to tumor formation. This is the nonthreshold theory of carcinogenesis which purports that any level of exposure to a carcinogen can result in some finite possibility of generating the disease. Generally, regulatory agencies assume the non-threshold hypothesis for carcinogens in the absence of information concerning the mechanisms of action for the chemical.

EPA's Carcinogen Assessment Group (CAG) has developed slope factors (i.e., dose-response values) for estimating excess lifetime cancer risks associated with various levels of lifetime exposure to potential human carcinogens. The carcinogenic slope factors can be used to estimate the lifetime excess cancer risk associated with exposure to a potential carcinogen. Risks estimated using slope factors are considered unlikely to underestimate actual risks, but they may overestimate actual risks. Excess lifetime cancer risks are generally expressed in scientific notation and are probabilities. An excess lifetime cancer risk of $1x10^{-6}$ represents the probability that one individual out of one million will develop cancer as a result of exposure to a carcinogenic chemical over a 70-year lifetime under specified exposure conditions. EPA has suggested developing remedial alternatives for cleanup of Superfund sites using total excess lifetime cancer risks ranging from 10^{-4} to 10^{-6}.

In practice, slope factors are derived from the results of human epidemiology studies or chronic animal bioassays. The data from animal studies are generally fitted to the linearized multistage model and dose-response curve is obtained. The 95th percentile upper confidence limit slope of the dose-response curve is subjected to various adjustments and an interspecies scaling factor is applied to conservatively derive the slope factor for humans. Thus, the actual risks associated with exposure to a potential carcinogen quantitatively evaluated based on animal data are not likely to exceed the risks estimated using these slope factors, but they may be much lower. Dose-response data derived from human epidemiological studies are fitted to dose-time-response curves on an ad hoc basis. These models provide rough but plausible estimates of the upper limits on lifetime risk. Slope factors based on human epidemiological data are also derived using very conservative assumptions and, as such, they too are considered unlikely to underestimate risks. In summary, while the actual risks associated with exposures to potential carcinogens are unlikely to be higher than the risks calculated using a slope factor, they could be considerably lower.

In addition, there are varying degrees of confidence in the weight of evidence for carcinogenicity of a given chemical. EPA has proposed a system for characterizing the overall weight of evidence for a chemical's carcinogenicity based on the availability of animal, human, and other supportive data [EPA, 1986a]. The weight-of-evidence classification is an attempt to determine the likelihood that an agent is a human carcinogen and thus qualitatively affects the estimation of potential health risks. Three major factors are considered in characterizing the overall weight of evidence for carcinogenicity: (1) the quality of evidence from human studies and (2) the quality of evidence from animal studies, which are combined into a characterization of the overall weight of evidence for human carcinogenicity; and (3) other supportive information which is assessed to determine whether the overall weight of evidence should be modified. EPA's final classification of the overall weight of evidence includes the following five categories:

- **Group A - - Human Carcinogen**

  This category indicates that there is sufficient evidence from epidemiological studies to support a casual association between an agent and cancer.

- **Group B - - Probable Human Carcinogen**

  This category generally indicates that there is at least limited evidence from epidemiological studies of carcinogenicity to humans (Group B1) or that, in the absence of adequate data on humans, there is sufficient evidence of carcinogenicity in animals (Group B2).

- **Group C - - Possible Human Carcinogen**

  This category indicates that there is limited evidence of carcinogenicity in animals in the absence of data on humans.

- **Group D - - Not Classified**

  This category indicates that the evidence for carcinogenicity in animals is inadequate.

- **Group E - - No Evidence of Carcinogenicity to Humans**

  This category indicates that there is no evidence for carcinogenicity in at least two adequate animal tests in different species, or in both epidemiological and animal studies.

Slope factors are developed based on epidemiological or animal bioassay data for a specific route of exposure, either oral or inhalation. For some chemicals, sufficient data are available to develop route-specific slope factors for inhalation and ingestion. For chemicals with only one route-specific slope factor but for which carcinogenic effects may also occur via another route, EPA has used the available value to evaluate risks associated with both potential routes of exposure.

Several of the selected chemicals of concern have been classified as potential carcinogens by EPA, and each of these has also been assigned a carcinogenicity weight-of-evidence category (Table 5.16). Some of these chemicals are:

- **Group A - - Human Carcinogens**

  Benzene

  Arsenic

  Chromium (IV)

  Nickel

- **Group B - - Probable Human Carcinogens**

  Tetrachloroethene

  Trichloroethene

Styrene

Benzo(a)anthracene

Benzo(b)fluoranthene

Benzo(k)fluoranthene

Benzo(a)pyrene

Bis(2-ethyl hexyl)phthalate

Chrysene

Indeno(1,2,3-cd)pyrene

Beryllium

Cadmium

Lead

- **Group C - - Possible Human Carcinogens**

Butylbenzlphthalate

1,1,2,2-Tetrachloroethane

4-Methyl phenol

Potential carcinogenic effects and slope factors for chemicals of concern identified at the Base are shown in Table 5.16.

5.4.2.2 Health Criteria for Noncarcinogenic Effects

For chemicals that exhibit noncarcinogenic effects, many authorities consider organisms to have repair and detoxification capabilities that must be exceeded by some critical concentration (threshold) before the health effect is manifested. For example, an organ can have a large number of cells performing the same or similar functions that must be significantly depleted before the effect on the organ is seen. This threshold view holds that a range of exposures from just above zero to some finite value can be tolerated by the organism without an appreciable risk of adverse effects.

Health Criteria for chemicals exhibiting noncarcinogenic effects for use in risk assessment are generally developed using EPA RfDs. In general, the RfD is an estimate of route-specific average daily intake (dose) for individuals (including sensitive individuals) below which there will not be an appreciable risk of adverse health effects. The RfD is derived using conservative safety factors (e.g., to adjust from animals to humans and to protect sensitive subpopulations) to ensure that it is unlikely to underestimate the potential for adverse noncarcinogenic effects to occur. The purpose of the RfD is to provide a benchmark against which the sum of other doses (e.g., those projected from human exposure to various environmental conditions) might be compared. Doses that are higher than the RfD may indicate that an adverse health effect could occur.

EPA has developed oral and inhalation RfDs for many of the chemicals of concern selected for the Base. In addition, the chemicals of concern may affect different target organs in the body. Some of the chemicals of concern that may have noncarcinogenic effects following long-term exposure, and the target organs that are most sensitive to these chemicals, are as follows:

- Chemicals That May Adversely Affect The Liver
  - Ethylbenzene
  - Bis(2-Ethylhexyl)phthalate
  - Acetone
  - Toluene
  - 1,1,1-Trichloroethane
- Chemicals That May Adversely Affect the Kidney
  - Acetone
  - Ethylbenzene
  - Di-n-octylphthalate
  - Toluene
  - Fluoranthene
  - Mercury
  - Pyrene
- Chemicals That May Adversely Affect the Nervous System
  - 4-Methylphenol
  - Toluene
  - Xylenes
- Chemicals That May Adversely Affect the Blood
  - 1,2-Dichloroethene
  - Fluorene
  - Zinc
- Chemicals That May Adversely Affect Other Systems
  - Silver may cause argyria
  - Copper may cause local GI irritation
  - Carbon disulfide may cause reduce fetal body weight
  - Dimethylphthalate might affect growth

Potential noncarcinogenic effects with RfDs of chemicals of concern identified at the Base are shown on Table 5.17.

No RfDs or slope factors are available for the dermal route of exposure. In some cases, however, noncarcinogenic or carcinogenic risks associated with dermal exposure can be evaluated using an oral RfD or an oral slope factor. Exposures via the dermal route generally are calculated and expressed as absorbed doses. These absorbed doses are compared to an oral toxicity value that is also expressed as an absorbed dose. This requires quantitative estimates of both oral and dermal exposure and is only appropriate for chemicals causing systemic toxicity.

5.4.3 Toxicity Profiles For the Chemicals of Concern

Environmental Fate and Toxicity information for both human and environmental receptors is included in Appendix D.

5.4.4 Health and Environmental Criteria

In this section concentrations of chemicals of concern are compared with appropriate criteria to provide a rough estimation as to whether the contaminants pose a risk. The most stringent enforceable federal or state standard is chosen as the applicable (ARAR) criteria to use as a comparison guideline. The method is intended as a preliminary screening tool rather than a detailed evaluation of risks posed by contaminants at the site. The six sites and the boundary wells are evaluated separately. Where ARARs are not developed, other information may be needed to determine what is protective of human health and the environment. Other criteria to be used for comparison purposes include health-based levels which are derived from toxicity data and explained below.

Current information on the health and environmental effects of various toxicants, including slope factors, RfDs, and RfCs were obtained from HEAST (Health Effects Assessment Summary Tables) from FY-1991. HEAST contains health risk assessment information on chemicals that have undergone a detailed review of toxicity data by work groups composed of EPA scientists from several agency program offices, and represents an EPA consensus. Information includes slope factors and RfDs for systemic toxicants. These values are used to calculate human health-based criteria according to EPA guidelines.

As previously described, human health-based criteria for carcinogens represent an upper bound estimate of the average daily dose of a carcinogenic substance that corresponds to a specified excess cancer risk for lifetime exposure. The criteria were calculated from slope factors (Table 5.9) in the following manner:

$$C_i = (R/q1^*) \times (W/I)$$

where:

C_i = the criterion concentration for the constituent of interest;

R = the specified risk level (e.g., 10^{-6});

$q1^*$ = the carcinogenic slope factor in $(mg/kg/day)^{-1}$ developed by EPA;

W = the assumed weight of the exposed individual; and

I = the intake amount for a given time period.

The carcinogen criteria for soil or water ingestion was calculated to a specified risk level of 10^{-6}. The assumed intake amount for a given time period for soil is 0.2

gram per day (g/day) and is based on a 5-year exposure period for a 16-Kg child. When groundwater or surface water was the medium of concern the carcinogenic criteria for water were used unless MCLs existed. The assumed intake amount for a given time period for water ingestion is 2 liters per day (L/day) for a 70-Kg person.

Human health-based criteria for (i.e., noncarcinogenic) toxicants are an estimate of the daily exposure an individual (including sensitive individuals) can experience without appreciable risk of health effects during a lifetime, and are based on EPA-derived RfDs (Table 5.10).

For water ingestion, the systemic criteria are calculated for a 70-Kg adult ingesting 2 L/day over a chronic lifetime exposure period (i.e., 70 years). For soil ingestion, the assumed intake rate of 0.2 g/day is based on a 5-year exposure period for a 16-Kg child. These exposure assumptions for soil are reflective of an average scenario in which children ages one to six (who exhibit the greatest tendency to ingest soil) are assumed to ingest an average amount of soil on a daily basis. Human health-based criteria were calculated for the selected exposure routes, as shown in the following equation:

$$C_i = (RfD) \times (W/I)$$

where

C_i = Criterion concentration for constituent of interest;

RfD = Reference Dose developed by EPA;

W = the assumed weight of the exposed individual; and

I = the intake amount for a given time period.

The systemic criteria for the water (ingestion) route of exposure should be used in the absence of MCLs or State Water Quality Standards. For other routes of exposure (e.g., soil ingestion), carcinogen criteria should be used in the absence of other EPA criteria. Where toxicants caused both carcinogenic and noncarcinogenic effects, the value based on carcinogenic effects was used for human health assessment.

5.4.5 Preliminary Human Health Evaluation Summaries

5.4.5.1 Site 1 - Fuel Tank Farm

The soil samples collected at this site in 1989 have been determined to be unsuitable due to the inadequate QA/QC. No other samples have been collected at this site. No determination can be made concerning the soil, surface water or groundwater pathways, due to a lack of suitable data.

5.4.5.2 Site 2 - Drainage Swale

A variety of chemicals were detected in the sediment, groundwater, and surface water samples collected from Site 2. A comparison of chemical concentrations in each media with appropriate health criteria or ARARs are presented in Tables 5.18, 5.19 and 5.20. Chemicals were detected in each media in excess of health criteria or ARARs indicating the potential of adverse health effects for receptors at Site 2.

Eleven organic compounds detected in the sediments of Site 2 exceeded the soil standards developed by the state of Michigan. These soil standards are designed to be protective of other media, such as groundwater or surface water, and of human health through direct contact with soils. The following compounds were found to exceed the Michigan soil standards: fluoranthene, benz(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, benzo(k)fluoranthene, chrysene, indeno(1,2,3-cd)pyrene, pyrene, tetrachloroethene, and di-n-butylphthalate. Bis(2-ethylhexyl)phthlate and styrene exceeded the health criteria derived from oral slope factor on the basis of soil ingestion. Dimethylphthalate and 4-methylphenol exceeded the health criteria derived from oral reference dose on the basis of soil ingestion. The semi-volatile organic compounds are expected to be strongly adsorbed by site soils and not very mobile in the environment. These characteristics limit the potential of exposure through volatization or movement into the groundwater. Fugitive dust emissions could create adverse health effects, although the vegetative growth and the intermittent surface water covering the soils/sediments should retard the affects of soil erosion. Styrene and tetrachloroethene (VOCs) have relatively high vapor pressures, which increases the potential of exposure to these compounds through volatilization or movement into the groundwater.

Eight metals detected in the sediments also exceeded the health criteria derived from soil oral RfDs on the basis of soil ingestion. Exposure via inhalation or dermal contact could cause adverse health effects, although the vegetative growth and surface water covering the soils/sediments will retard the affects of soil erosion.

Zinc was the only compound found in the groundwater samples associated with Site 2. The maximum concentration of zinc exceeded the health criteria developed from the water oral RfD on the basis of ingestion. No enforceable or nonenforceable standards have been developed by either state or federal agencies for zinc. Since no standards exist, the RfD of zinc is the applicable standard because the RfD is the agency's preferred toxicity value for evaluation noncarcinogenic effects resulting from exposure at Superfund sites.

Toluene and fluoranthene are the organic chemicals of concern detected in the surface water at Site 2. The maximum concentrations of both organics did not exceed health based criteria. Seven metals were also detected in the surface water at Site 2. Mercury exceeded the criteria developed under the Clean Water Act. The surface water quality standards developed under the Clean Water Act are being used as the applicable standard for these metals, because no other criteria has been developed for surface water. In addition, the state of Michigan uses the same method to develop their enforceable 307 type B surface water criteria. The maximum concentration of zinc exceeded health criteria developed from the water oral RfD on the basis of ingestion.

Exposure via ingestion or dermal contact with either surface water or groundwater is possible. Potable drinking water wells are located downgradient of the site. Surface water will primarily percolate into the groundwater or migrate to the Kalamazoo River, which is used for recreational purposes including fishing. Adverse health effects are possible if the semivolatile organics and metals move through the soil into the groundwater and migrate to the downgradient drinking water wells or the Kalamazoo River. The migration of the organic compounds is also possible, indicating that further investigation is necessary to determine the effect of this site on the downgradient potable water supply.

5.4.5.3 Site 3 - Fire Training Area

The significant exposure pathways of Site 3 includes the ingestion, inhalation and direct contact with groundwater. A comparison of chemical concentrations in groundwater with appropriate health criteria or ARARs is presented in Table 5.21. Chemicals were detected in the groundwater in excess of health criteria or ARARs indicating the potential of adverse health effects for receptors at Site 3.

The chemicals of concern detected in the groundwater at Site 3 include seven organic compounds and two metals. Five of the seven organic compounds detected were found to exceed the state of *Michigan remediation* standards. These five organic compounds include xylenes, toluene, benzene, trichloroethene, cis/trans 1,2, dichloroethene, and ethylbenzene. Arsenic and lead were detected at Site 3 and both exceeded the state of Michigan criteria. The groundwater standards developed by the state of Michigan are based on a toxicological endpoint such as carcinogenic potency factor, HLSC for noncarcinogens, or aesthetic criteria. In addition, the maximum concentrations of both benzene and lead exceeded the MCL, and the maximum concentration of 1,2-dichloroethene exceeded the proposed MCL.

The soil samples collected at this site in 1989 have been determined to be unsuitable due to the inadequate QA/QC. No other soil samples have been collected at this site. No determination can be made concerning the soil, or surface water pathways, due to a lack of suitable data.

The elevated concentrations of contaminants detected in the groundwater at Site 3 indicate that the potable drinking water wells located downgradient of the Base may become contaminated. Ingestion of these contaminants could cause adverse health effects over a period of time. Further investigation is needed to determine the extent of the contamination in the aquifers providing a potable water supply.

5.4.5.4 Site 4 - Abandon Landfill

Groundwater was the only medium sampled at this site and no contaminants were detected in any of the samples. Since no contaminants were detected in the groundwater, this pathway is unlikely to be complete. No determination can be made concerning the soil pathway, due to lack of data.

5.4.5.5 Site 5 - Former Coal Storage Area

Exposure via groundwater is the potentially significant pathway at Site 5. A comparison of chemical concentrations detected in groundwater with appropriate health criteria or ARARs are presented in Table 5.22.

1,1,1-Trichloroethane and xylene were detected in the well located downgradient of Site 5. As discussed in Section 4, these contaminants probably originated from the Site 3, Fire Training Area. Maximum concentrations for these volatile organic compounds did not exceed health criteria or Michigan remediation standards. Since the maximum groundwater concentrations did not exceed health criteria, adverse health effects associated with groundwater are unlikely.

The soil samples collected at this site in 1989 have been determined to be unsuitable due to the inadequate QA/QC. No other soil samples have been collected at this site. No determination can be made concerning the soil or surface water pathways, due to a lack of suitable data.

5.4.5.6 Site 6 - Fuel Spill

Exposure via soils and groundwater are potentially pathways of concern at Site 6. A comparison of concentrations of chemicals detected in soils and groundwater at Site 6 with Health Criteria ARARs are presented in Tables 5.23 and 5.24.

Toluene and TPH were detected in Site 6 soils. The maximum concentration of toluene exceeded the state of Michigan remediation standards. This standard is based on noncarcinogenic criteria. No criteria is available or could be developed for total petroleum hydrocarbons. Exposure through inhalation or dermal exposure to the surface soils could result in adverse health effects. However, the vegetative covering the soils at Site 6, would limit the dermal exposure to the soils and retard the effects of soil erosion.

Benzene, 1,1,1-trichloroethane, trichloroethene, toluene, tetrachloroethene, xylene, and zinc were found in concentrations greater than in upgradient wells and QA samples. The maximum concentration of zinc exceeded the health criteria based on the oral RfD, and groundwater ingestion. No enforceable or nonenforceable standards have been developed by either state or federal agencies for zinc. Since no standards exist, the RfD for zinc was used to develop a criteria for the evaluation of noncarcinogenic effects.

The maximum concentration of the other compounds detected in the groundwater at Site 6 did not exceed any established health-based criteria. Private drinking water wells are located downgradient of the Base. Exposure through ingestion of a contaminated water supply could cause adverse health effects. The potential impact on the downgradient wells should be investigated to insure an uncontaminated potable water supply.

5.4.5.7 Boundary Wells

Several contaminants were detected in the groundwater collected from the boundary wells. A comparison of the detected concentrations of chemicals in groundwater with health-based criteria and ARARs is presented in Table 5.25.

Toluene, trichloroethene, 1,2-dichloroethene, 1,1,1,-trichloroethane, acetone, 1,1,2,2,-tetrachloroethane, chloroform, 2-butanone, benzene, lead and zinc were the chemicals of concern detected in the groundwater collected from the boundary wells. The maximum concentration of trichloroethene exceeded both the groundwater cleanup standard developed by the state of Michigan and the MCL. The maximum concentrations of 1,1,2,2-tetrachloroethane and zinc also exceeded health-based criteria developed from the oral slope factor and RfD, respectively. No enforceable or nonenforceable standards have been developed by either state or federal agencies for these compounds. Since no standards exist, the RfD or the slope factor are the applicable standards because the RfD is the agency's preferred toxicity value for evaluation of noncarcinogenic effects and the slope factor is the preferred toxicity for evaluation of carcinogenic effects.

5.4.6 Uncertainties in Risk Screening

In quantifying carcinogenic and noncarcinogenic risks for exposures to multiple chemicals by a number of different pathways, EPA generally assumes that the total risk is essentially the sum of the risks incurred for each chemical and pathway of exposure. Thus, the potential for adverse effects in a given receptor will increase with the number of chemicals detected at the site and the number of pathways by which the receptor could be exposed.

The preliminary risk assessment methodology employed here uses health criteria which were developed as though each chemical in question were present at the site by itself and as though exposure would occur through only one pathway (oral exposure to the medium of concern). Thus the risk screening process employed in this assessment considers only oral exposure pathways and does not apportion risks among the total number of chemicals detected at the site. Both the dermal and inhalation exposure pathways are possible risks at this Base; however, this assessment only considers the oral exposure risks. If risks were apportioned among the total number of chemicals present and all possible pathways of exposure, Health Criteria values would be lower and site-specific.

Since the purpose of this evaluation procedure is to determine which sites may have potential problems, the procedure is adequate when the risk screening yields positive (yes) results. However, the absence of the detected concentrations for a given medium in excess of health criteria does not necessarily indicate that the lack of potential risks in association with the medium in question at the site. If a baseline risk assessment were conducted in accordance with EPA guidance documents, the total risks for each receptor would be summed across all chemicals and pathways of exposure. Thus it is possible that unacceptable risks could be calculated in a baseline assessment even though the preliminary risk screening indicated that potential adverse health effects were not likely to occur. A negative risk screen thus should not be used as the sole basis for eliminating a site from further investigation or concern.

5.5 PRELIMINARY ECOLOGICAL EVALUATION

The purpose of this Preliminary Ecological Evaluation is to determine the potential effects of site contaminants on plant and animal species, and to determine if any data gaps exist which may need to be addressed in future investigations.

The Preliminary Human Health Evaluation is used as a basis for this Ecological Evaluation, including the sections discussing data evaluation, environmental fate and transport, and chemicals of concern. Selection of contaminants of concern were described in Subsection 5.2. Tables 5.18 through 5.25 summarize the results of sampling of groundwater, soils, surface water and sediments at the six sites and boundary wells, and present a comparison of maximum concentrations of indicator chemicals in relation to ARARs and human health criteria.

5.5.1 Non-Human Receptors

The 110th TAG Michigan Air National Guard Base and surrounding area is comprised primarily of an upland farming hardwood oak-type community. The majority of this area has been logged in the past and is presently an urban or second generation hardwood community. An urban community lies primarily to the north and northeast, while the Custer Reserve Forces Training site lies to the south and west and has primarily remained a second generation hardwood community. Small pockets of swampy marshes are also found throughout this second generation hardwood community. In addition, the Kalamazoo River is located approximately 1.75 miles north of the Base. This river is bordered by large marsh areas.

Both game and nongame species, such as deer, wild turkey, beaver, raptors and several types of small mammals, are prevalent throughout the hardwood forest and marsh areas. These communities are secure at this time and no sensitive communities are known to exist in the Base area. There have been no known sightings of federal and state threatened or endangered species according to the Michigan Natural Feature Inventory. However, the inventory indicated that a prairie wetland complex including threatened plants is located approximately 1.5 miles north of the base and a special concern fish is known to occur in Hart Lake located roughly 1.5 miles to the west. Also, several federal and state protected species are known to exist in Calhoun and Kalamazoo counties. The Indiana bat, least shrew, white lady-slipper, swamp rose-mallow, small-fruited panic-grass and the king rail include a few of the special status species know to exist in these counties. It is not known if the habitat of any of the protected species exist on or adjacent to the Base. The inventory does not provide a definitive statement on the presence or absence, or condition of all the natural features (special status species) in the state because not all areas of the state have been thoroughly surveyed. Only an onsite inspection can verify their absence or existence.

5.5.2 Identification of Exposure Pathways

Groundwater, surface water, soil and sediments are considered as potential release sources at these four sites. Potential transport media considered include air, surface water, groundwater, soils and sediments. Potential release mechanisms include volatilization of organic compounds, fugitive dust generation, site leaching, tracking, surface runoff, and groundwater seepage. Tracking refers to the dispersal of contaminants from animals and humans picking up contaminated soil on their feet and moving it to other areas.

Because the occurrence and location of sensitive plant and animal communities and species are unknown at this time, this evaluation is very general. An analysis of potential current use pathways of exposure to chemical of concern at all six sites have been summarized in Table 5.26. EPA requires that hypothetical future use of a site be considered, Table 5.27 presents the additional future use pathways. The potential future use envisioned includes the possibility of the base being developed at some point in the future. It is also remotely possible that the Base may be developed for residential use or as a wildlife sanctuary.

The potentially complete pathways considered for these sites are as follows:

- Contact of animals, plants, and waterfowl with contaminated surface water. This is a worst case scenario for exposure of flora and fauna to contaminants.
- Contact of animals and plants with contaminated soils.
- Contact of animals, plants, and waterfowl with contaminated sediments.
- Contact of plants, animals, and aquatic life with contaminated groundwater discharging to the Kalamazoo River.

5.5.3 Risk Screening

Important pathways for flora and fauna exposure at the sites have been presented in this evaluation. No EPA criteria are known to exist for flora and fauna exposure to contaminated water, soil, or air. However, analysis performed on soils, groundwater, surface water and sediment collected from Sites 2, 3, 5, and 6 detected chemical levels in all media in excess of human health based criteria and the state of Michigan remediation standards. This indicates the potential for adverse health effects to terrestrial wildlife, plants, and birds exposed to contaminated surface soil, groundwater and surface water; and to benthic organisms exposed to contaminated sediments.

5.5.4 Uncertainty

The preliminary ecological evaluation is a conditional estimate based on many uncertainties. These uncertainties include those mentioned in the Preliminary Risk Evaluation, the lack of EPA criteria for flora and fauna, and the lack of information on sensitive biotic communities and species that may be present in the area of the Michigan ANGB.

5.5.5 Preliminary Ecological Evaluation Summary

An evaluation of the potential risks to biotic communities excluding humans was performed for the six sites at the Base using the data generated during the SI. A qualitative approach was used in this evaluation because of the uncertainties that exist. To date, no criteria have been established for flora and fauna exposed to contaminated groundwater, surface water, soil or air. Levels of contaminants in these media were shown to be in excess of human health criteria. However, no sensitive plant or animal communities are known to exist in the area, and no sitings of federal or state threatened or endangered species have been reported.

5.6 PRELIMIANRY HUMAN HEALTH AND ECOLOGICAL EVALUATION CONCLUSIONS

5.6.1 Site 1 - Fuel Tank Farm

The soil samples collected at this site in 1989 have been determined to be unsuitable due to the inadequate QA/QC. No other samples have been collected at this site. No determination can be made concerning the soil, surface water or groundwater pathways, due to a lack of data.

5.6.2 Site 2 - Drainage Swale

A variety of chemicals were detected in sediments, groundwater, and surface water samples collected at Site 2. The maximum concentration of several organic compounds and inorganic metals exceeded human health criteria in the sediments of Site 2. Exposure via ingestion and/or adsorption could result in adverse health effects of the immediate surrounding fauna and flora. In addition, the contaminated sediments could adversely effect any migrating water fowl feeding in the area.

Several organic compounds were detected in the surface water at concentration in excess of background. Several metals were found in levels which exceeded the ambient water quality standards for consumption of water and organisms under the Clean Water Act. Thus, exposure to the surface water could also adversely effect any immediately surrounding fauna and flora, including any migrating water fowl. The surface water also percolates into the groundwater, which discharges into the Kalamazoo River located roughly 1.75 miles north of the base. However, the potential for detectable concentrations of contamination reaching the river is thought to be low due to the distance to the river, and the expected dilution and dispersal of contaminants. Zinc was detected in the groundwater in levels which exceeded human health criteria.

5.6.3 Site 3 - Fire Training Area

The pathway of concern at Site 3 is the adsorption of contaminants detected in the groundwater. Several organic compounds and a metal detected in the groundwater exceeded human health criteria or the remediation standards developed by the state of Michigan. Exposure via adsorption could results in stress on the surrounding flora. The contaminated groundwater could also migrate and discharge into the Kalamazoo River. However, the potential for detectable concentrations of contamination reaching the river is thought to be low due to the distance to the river, and the expected dilution and dispersal of contaminants.

The soil samples collected at this site in 1989 have been determined to be unsuitable due to the inadequate QA/QC. No other soil samples have been collected at this site. No determination can be made concerning the soil, or surface water pathways, due to a lack of data.

5.6.4 Site 4 - Abandon Landfill

Groundwater was the only medium sampled at this site and no contaminants were detected in any of the samples. Since no contaminants were detected in the groundwater, this pathway is unlikely to be complete. No determination can be made concerning the soil pathway, due to a lack of data.

5.6.5 Site 5 - Former Coal Storage Area

The pathways of concern at Site 5 is the adsorption of contaminants detected in the groundwater. Exposure via adsorption could result in adverse health effects of the immediately surrounding fauna and flora. The maximum concentrations of the organic compounds detected in the groundwater at Site 5 did not exceed any human health criteria or the Michigan remediation standards. Thus, any adverse environment biotic effects associated with groundwater is unlikely.

The soil samples collected at this site in 1989 have been determined to be unsuitable due to the inadequate QA/QC. No other soil samples have been collected at this site. No determination can be made concerning the soil, or surface water pathways, due to a lack of data.

5.6.6 Site 6 - Fuel Spill

Pathways of concern at Site 6 include the ingestion and adsorption of contaminants detected in the soils and groundwater. The maximum concentration of toluene exceeded the remediation standards developed by the state of Michigan in the soils of Site 3. Exposure via ingestion and adsorption could result in adverse health effects of the immediately surrounding fauna and flora. Several organic compounds and a metal detected in the groundwater exceeded the remediation standards developed by the state of Michigan. Exposure via adsorption could result in stress on the surrounding flora. The contaminated groundwater could also migrate and discharge into the Kalamazoo River. However, the potential for detectable concentrations of contamination reaching the river is thought to be low due to the distance to the river, and the expected dilution and dispersal of contaminants.

TABLE 5.1
SUMMARY OF CONTAMINANTS DETECTED DURING THE 1989 AND 1990 INVESTIGATIONS
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Parameters	Sediments	Site 2 Surface water	Ground-water	Site 3 Ground-water	Site 4 Ground-water	Site 5 Ground-water	Site 6 Soils	Site 6 Ground-water	Boundary Wells Ground-water
Volatile	**µg/kg**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/kg**	**µg/l**	**µg/l**
Acetone	13	-	-	480J	-	-	-	-	21
2 butanone	-	-	-	10CJ	-	-	-	-	54J
Carbon Disulfide	0.8J	-	-	-	-	-	-	-	-
trans-1,2dichloroethane	-	-	-	1200	-	-	-	-	92
Benzene	-	-	-	200	-	-	-	0.36	0.23J
Ethylbenzene	-	-	-	100	-	-	-	-	-
Tetrachloroethene	83J	-	-	-	-	-	-	0.7J	-
Toluene	11J	0.49	-	240J	-	-	52	0.32J	1J
Styrene	12J	-	-	-	-	-	-	-	-
Trichloroethene	-	-	-	3J	-	-	-	-	10
Xylenes	-	-	-	980	-	0.2J	-	0.3J	-
1,1,1-Trichloroethane	-	-	-	-	-	0.4J	-	0.7J	2.6
Chloroform	-	-	-	-	-	-	-	-	0.6J
1,1,2,2-Tetrachloroethane	-	-	-	-	-	-	-	-	2
Semivolatiles	**µg/kg**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/kg**	**µg/l**	**µg/l**
4-methylphenol	630	-	-	-	-	-	-	-	-
Dimethylphthalate	2700J	-	-	-	-	-	-	-	-
Fluorene	3200J	-	-	-	-	-	-	-	-
Phenanthrene	24,000	-	-	-	-	-	-	-	-
Anthracene	5100	-	-	-	-	-	-	-	-
Di-n-butylphthalate	32,000	-	-	-	-	-	-	-	-

TABLE 5.1-Continued
SUMMARY OF CONTAMINANTS DETECTED DURING THE 1989 AND 1990 INVESTIGATIONS
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

		Site 2		Site 3	Site 4	Site 5	Site 6		Boundary Wells
Parameters	Sediments	Surface water	Ground-water	Ground-water	Ground-water	Ground-water	Soils	Ground-water	Ground-water
Semivolatiles (Cont'd)	**µg/kg**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/kg**	**µg/l**	**µg/l**
Fluoranthene	30,000	6J	-	-	-	-	-	-	-
Pyrene	27,000	-	-	-	-	-	-	-	-
Butylbenzlphthalate	3,000	-	-	-	-	-	-	-	-
Benzo(a)anthracene	17,000	-	-	-	-	-	-	-	-
bis(2-ethylhexyl)phthalate	6200	-	-	-	-	-	-	-	-
Chrysene	22,000	-	-	-	-	-	-	-	-
Benzo(b)fluoranthene	25,000	-	-	-	-	-	-	-	-
Benzo(k)fluoranthene	18,000	-	-	-	-	-	-	-	-
Benzo(a)pyrene	19,000	-	-	-	-	-	-	-	-
Indeno(1,2,3-cd)pyrene	13,000	-	-	-	-	-	-	-	-
Benzo(g,h,i)perylene	13,000	-	-	-	-	-	-	-	-
Metals	**mg/kg**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/kg**	**µg/l**	**µg/l**
Beryllium	0.74	-	-	-	-	-	-	-	-
Cadmium	21.1	-	-	-	-	-	-	-	-
Chromium	60.7	13.9	-	-	-	-	-	-	-
Copper	185	187	-	-	-	-	-		-
Nickel	28.2	13.6	-	-	-	-	-	-	-
Silver	8.5	-	-	-	-	-	-	-	-
Zinc	324J	200	13	-	-	-	-	11.4	132
Arsenic	68J	-	-	91.5J	-	-	-		

TABLE 5.1-Continued
SUMMARY OF CONTAMINANTS DETECTED DURING THE 1989 AND 1990 INVESTIGATIONS
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

		Site 2		Site 3	Site 4	Site 5	Site 6		Boundary Wells
Parameters	**Sediments**	**Surface water**	**Ground-water**	**Ground-water**	**Ground-water**	**Ground-water**	**Soils**	**Ground-water**	**Ground-water**
Metals (Cont'd)	**mg/kg**	**μg/l**	**μg/l**	**μg/l**	**μg/l**	**μg/l**	**μg/kg**	**μg/l**	**μg/l**
Lead	250	96.9	-	0.0094	-	-	-	0.005	0.01
Mercury	0.21J	0.20	-	-	-	-	-	-	-
Thallium	-	56	-	-	-	-	-	-	-
	mg/kg	mg/l	mg/l	mg/l	mg/l	mg/l	mg/kg	mg/l	mg/l
Total Petroleum Hydrocarbons (TPH)	-	-	-	-	-	-	21	-	-

TABLE 5.2
RELEVANT PHYSICAL AND CHEMICAL PROPERTIES
110TH FG, MICHIGAN AIR NATIONAL GUARD
W.K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Chemical	CAS Number	Water Solubility (mg/L)	Vapor Pressure (mmHg)	Henry's Law Constant (atm-m^3/mol)	K_{oc} (ml/g)
Acetone	67-64-1	1.00E+06	2.70E+02	2.06E-05	2.2
Anthracene	120-12-7	4.50E-02	1.95E-04	1.02E-03	14,000
Arsenic	7440-38-2	ND	0.00E+00	ND	ND
Benz(a)anthracene	56-55-3	5.70E-03	2.20E-08	1.16E-06	1,380,000
Benzene	71-43-2	1.75E+03	9.52E+01	5.59E-03	83
Benzo(b)fluoranthene	205-99-2	1.40E-02	5.00E-07	1.19E-05	550,000
Benzo(k)fluoranthene	207-08-9	4.30E-03	5.10E-07	3.94E-05	550,000
Benzo(g,h,i)perylene	191-24-2	7.00E-04	1.03E-10	5.34E-08	1,600,000
Benzo(a)pyrene	50-32-8	1.20E-03	5.60E-09	1.55E-06	5,500,000
Beryllium	7440-41-7	ND	0.00E+00	ND	ND
Bis(2-ethylhexyl)phthalate	117-81-7	3.00E-01	6.45E-06	1.10E-05	ND
2-Butanone	78-93-3	2.39E+05	9.06E-01	1.05E-05	34
Butylbenzylphthalate	85-68-7	2.69E+00	8.60E-06	1.30E-06	68-350
Cadmium	7740-43-9	Insoluble	0.00E+00	ND	ND
Carbon disulfide	75-15-0	2.1E+04	2.97E+02	1.4E-03	63
Chromium	7440-47-3	Insoluble	ND	ND	ND
Chrysene	218-01-9	1.80E-03	6.30E-09	1.05E-06	200,000
Copper	7440-50-8	ND	ND	ND	ND
cis-1,2-Dichloroethene	540-59-0	3.50E+03	2.08E+02	7.58E-03	49
trans-1,2-Dichloroethene	540-59-0	6.30E+03	3.24E+02	6.56E-03	59
Dimethylphthalate	131-11-3	4.00E+03	1.65E-03	1.10E-07	44-160
Ethylbenzene	100-41-4	1.52E+02	7.00E+00	6.43E-03	1,100
Fluoranthene	206-44-01	2.06E-01	5.00E-06	6.46E-06	38,000
Fluorene	86-73-7	1.69E+00	7.10E-04	6.42E-05	7,300
Indeno(1,2,3-c,d)pyrene	193-39-5	5.30E-04	1.00E-10	6.86E-08	1,600,000
Lead	7439-92-1	Insoluble	0.00E+00	ND	ND
Mercury	7439-97-6	Insoluble	2.00E-03	ND	ND
4-Methylphenol	106-44-5	2.26E+01	1.30E-01	9.60E-07	ND

TABLE 5.2-Continued
RELEVANT PHYSICAL AND CHEMICAL PROPERTIES
110TH FG, MICHIGAN AIR NATIONAL GUARD
W.K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Chemical	CAS Number	Water Solubility (mg/L)	Vapor Pressure (mmHg)	Henry's Law Constant (atm-m^3/mol)	K_{oc} (ml/g)
Nickel	7440-02-0	ND	0.00E+00	ND	ND
Phenanthrene	85-01-8	1.00E+00	6.80E-04	1.59E-04	14,000
Pyrene	129-00-0	1.32E-01	2.50E-06	5.04E-06	38,000
Silver	7440-22-4	Insoluble	0.00E+00	ND	ND
Styrene	100-42-5	3.00E+02	2.81E-03	270	
1,1,2,2-Tetrachloroethane	79-35-5	2.96E+04	4.9E+00	5.0E-04	79
Tetrachloroethene	127-18-4	1.50E+02	1.78E+01	2.59E-02	364
Thallium	7440-28-0	ND	0.00E+00	ND	ND
Toluene	108-88-3	5.35E+02	2.81E+01	6.37E-03	300
1,1,1-Trichloroethane	71-55-6	1.50E+03	1.23E+02	1.44E-02	152
Trichloroethene	79-01-6	1.10E+03	5.79E+01	9.10E-03	126
Xylenes (mixed)	1330-20-7	1.98E+02	1.00E+01	7.04E-03	240
Zinc	7440-66-6	Insoluble	0.00E+00	ND	ND

ND = No data.

References:

(1) EPA, "Superfund Public Health Evaluation Manual," Office of Emergency and Remedial Response, Washington, D.C., EPA 540/1-86/060, 1986.

(2) Howard, P.H., "Fate and Exposure Data for Organic Chemicals," Volumes I and II, Lewis Publishers, Chelsea, MI, 1990.

(3) Versar, Inc., "Water-Related Environmental Fate of 129 Priority Pollutants," Prepared for the Environmental Protection Agency, Washington, D.C., 1979.

TABLE 5.3
APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

	Safe Drinking Water Act (1)				Clean Water Act (2)		State of Michigan PA 307, Type B Criteria (3)	
	Current		Proposed		For Consumption of			
Chemical	MCL (µg/l)	MCLG (µg/l)	MCL (µg/l)	MCLG (µg/l)	Water and Organisms (µg/l)	Organism Only (µg/l)	Ground-Water (µg/l)	Soil (µg/kg)
Acetone	-	-	-	-	-	-	700	14,000(e)
Benzene	5	0	-	-	1.2(c)(d)	71(c)(d)	1.0	20(e)
cis-1,2-Dichloroethene	-	-	70	70	0.38(c)(d)	99(c)(d)	-	-
trans-1-2-Dichloroethene	-	-	100	100	0.38(c)(d)	99(c)(d)	140	2.800(e)
Ethylbenzene	-	-	700	700	3100(c)	29,000(c)	30(f)	600(e)
Tetrachloroethene	-	-	-	-	0.8	8.85	0.7	14(e)
1,1,1-Trichloroethane	200	200	-	-	3100(c)	170000(c)	200	4,000(e)
Trichloroethene	5	0	-	-	2.7(d)	81(d)	3	60(e)
Xylene (total)	-	-	10,000	10,000	-	-	20(f)	400(e)
Toluene		-	1000	1000	10000(c)	300000(c)	40(f)	800(e)
4-methylphenol (p-cresol)	-	-	-	-	-	-	-	-
Fluoranthene	-	-	-	-	42	54	300	6,000(e)
Fluorene	-	-	-	-	0.0028(d)	0.031(d)	300	6,000(e)
Dimethyl phthalate	-		-	-	313000	2900000	-	-
Anthracene	-	-	-	-	0.0028(d)	0.0311(d)	2000	400000(e)
Benzo(a)anthracene	-	-	0.1(b)	0(b)	0.0028(d)	0.0311(d)	0.003	100(g)
Benzo(b)fluoranthracene	-	-	0.2(b)	0(b)	-	-	0.003	100(g)
Benzo(a)pyrene	-	-	0.2(b)	0(b)	0.0028(d)	0.0311(d)	0.003	100(g)
Benzo(k)fluoranthracene	-	-	0.2(b)	0(b)	0.0028(d)	0.0311(d)	0.003	100(g)
Butylbenzylphthalate	-	-	100(a)	100(a)	3000(c)	5200(c)	1,400	28,000(e)
Bis(2-ethylhexyl)phthalate	-	-	-	-	1.8(c)(d)	5.9(c)(d)	-	
Chrysene	-	-	0.2(b)	0(b)	0.0028(d)	0.0311(d)	0.003	100(g)
Indeno(1,2,3-cd)pyrene	-	-	0.4(b)	0(b)	0.0028(d)	0.0311(d)	0.003	100(g)
Pyrene	-	-	-	-	0.0028(d)	0.0311(d)	200	4,000(e)
Phenanthrene	-	-	-	-	0.0028(d)	0.0311(d)		

TABLE 5.3–Continued
APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Chemical	Safe Drinking Water Act (1) Current MCL (µg/l)	Safe Drinking Water Act (1) Current MCLG (µg/l)	Safe Drinking Water Act (1) Proposed MCL (µg/l)	Safe Drinking Water Act (1) Proposed MCLG (µg/l)	Clean Water Act (2) For Consumption of Water and Organisms (µg/l)	Clean Water Act (2) For Consumption of Organism Only (µg/l)	State of Michigan PA 307, Type B Criteria (3) Ground-Water (µg/l)	State of Michigan PA 307, Type B Criteria (3) Soil (µg/kg)
Benzo(g,h,i)perylene	-	-	-	-	0.0028(d)	0.0311(d)	-	-
Carbon disulfide	-	-	-	-	-	-	-	-
D-n-butylphthalate	-	-	-	-	2700(c)	12000(c)	700	14,000(e)
2-Butanone	-	-	-	-	-	-	350	7,000(e)
Chloroform	100	-	-	-	5.7(c)(d)	470(c)(d)	6	120(e)
1,1,2,2-Tetrachloroethane	-	-	-	-	0.17(c)(d)	11(c)(d)	-	-
Styrene	-	-	100	100	-	-	-	-
Metals								
Arsenic	50	-	-	-	0.018(c)(d)	0.14(c)(d)	0.02(f)	-
Beryllium	-	-	0.001	0	0.0078(d)	0.131(d)	-	-
Cadmium	100	-	5	5	10(c)	170(c)	4(i)	(h)
Chromium (III)	50	-	100	100	33000(c)	670000(c)	-	-
Chromium (IV)	50	-	100	100	170(c)	3400(c)	-	-
Copper	-	-	-	-	1300(c)	-	-	-
Lead	50	-	-	-	50	-	5.0(f)	(h)
Mercury	2	-	2	2	0.14	0.15	2	(h)
Nickel	-	-	0.1	0.1	510(c)	3800(c)	-	-
Silver	50	-	-	-	91(c)	-	-	-
Thallium	-	-	0.001	0.0005	2.0(c)	7.2(c)	-	-
Zinc	-	-	-	-	-	-	-	-

TABLE 5.3-Continued
APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

	Safe Drinking Water Act (1)				Clean Water Act (2)		State of Michigan PA 307, Type B Criteria (3)	
	Current		Proposed		For Consumption of			
Chemical	MCL (µg/l)	MCLG (µg/l)	MCL (µg/l)	MCLG (µg/l)	Water and Organisms (µg/l)	Organism Only (µg/l)	Ground-Water (µg/l)	Soil (µg/kg)
Other								
Total Petroleum Hydrocarbons	-	-	-	-	-	-	-	-

(1)"Fact Sheet: Drinking Water Regulations under the Safe Drinking Water Act," Criteria and Standards Division Office of Drinking Water, U.S. EPA, Washington D.C., May 1990. "Phase II Fact Sheet National Primary Drinking Water Regulations for 38 Inorganic any Synthetic Organic Chemicals", Office of Drinking Water, U.S. EPA, Washington D.C. January 1991. 55 FR page 30371 thru 30425, Wednesday, July 25, 1990.

(2)"ARARs Q's and A's: Compliance with Federal Water Criteria," Office of Solid Waste and Emergency Response, U.S. EPA June 1990.

(3)State of Michigan Environmental Response Act 307, Selected Type B Remediation Criteria Values as Calculated June 22, 1990.

(a)FR 30371, July 25, 1990, Vol 55. EPA request public comment on whether butylbenzylphthalate should also be regulated. The MCLG and MCL for this compound would be 0.1 mg/l.

(b)FR 30371 July 25, 1990, Vol 55. EPA also proposes as an option for public comment the establishment of MCLGs and MCLs for six additional PAHs classified as B2 probable human carcinogen. The MCLG would be zero for these PAHs: Benz(a)anthracene, Benzo(b)fluoranthracene, Benzo(k)fluoranthracene, Chrysene, Dibenzo(a,h)anthracene and Indenopyrene. The MCL would be equal to the PQL for each PAH.

(c)Criteria revised to reflect current agency q*. RFD as contained in the Integrated Risk Information System.

(d)Criteria based on carcinogenicity.

(e)Basis for Soil Criteria - 20X Groundwater Criteria.

(f) Secondary Maximum Contaminant Level or Task/Order Threshold Valve, if lower than Toxicologically-Based Standard

(g)Basis for Soil Criteria - Direct Contract Hazard

(h)Local background

(i) If local background is greater than these health - based criteria, the average local background can be used as a final cleanup goal

(j) Concentration is for total trihalomethanes

TABLE 5.4
MATRIX OF POTENTIAL EXPOSURE PATHWAYS - CURRENT USE
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

SITE 1 - FUEL TANK FARM

Transport Medium	Source and Release Mechanism	Primary Exposure Point	Potential Receptors	Primary Exposure Route	Probability of Pathway Completion
Current Use					
Air	Affected soils/fugitive dust generation, volatilization	Michigan ANGB & areas downwind	Base personnel, nearby workers and residents	Inhalation Dermal	Unknown. Useable soil data not available. Surface soils could release airborne contaminants.
Groundwater	Affected soils, groundwater, site leaching	Wells used for drinking	Private well users	Ingestion Inhalation Dermal	Unknown. No useable data available. Private drinking water wells are located downgradient.
Surface water	Affected soils, groundwater or seepage to groundwater, surface runoff	Nearby wetlands Kalamazoo River	Base personnel, nearby residents	Dermal Ingestion	Unknown. No useable data available. Contaminants are unlikely to reach surface water exposure points.
Soils	Affected soils, groundwater and site leaching, runoff	Surface soils	Base personnel trespassers, residents	Dermal Ingestion	Unknown. No useable data available. Incidental contact with soil would be infrequent. Access to the base is restricted.

TABLE 5.5
MATRIX OF POTENTIAL EXPOSURE PATHWAYS - FUTURE USE
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

SITE 1 - FUEL TANK FARM

Transport Medium	Source and Release Mechanism	Primary Exposure Point	Potential Receptors	Primary Exposure Route	Probability of Pathway Completion
Future Use					
Air	Affected soils/fugitive dust generation, volatilization	Michigan ANGB & areas downwind	Base personnel, nearby workers and residents, Hypothetical (future) residents	Inhalation Dermal	Unknown. Useable soil data not available. Surface soils could release airborne contaminants.
Groundwater	Affected soils, groundwater/site leaching	Wells used for drinking	Private well users, Hypothetical (future) residents	Ingestion Inhalation Dermal	Unknown. No useable data available. Private drinking water wells are located downgradient.
Surface water	Affected soils, groundwater or seepage to groundwater, surface runoff	Nearby wetlands Kalamazoo River	Base personnel, nearby residents Hypothetical (future) residents	Dermal Ingestion	Unknown. No useable data available. Contaminants are unlikely to reach any surface water exposure points.

TABLE 5.5–Continued
MATRIX OF POTENTIAL EXPOSURE PATHWAYS - FUTURE USE
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

SITE 1 - FUEL TANK FARM

Transport Medium	Source and Release Mechanism	Primary Exposure Point	Potential Receptors	Primary Exposure Route	Probability of Pathway Completion
Soils	Affected soils, groundwater and site leaching, runoff	Surface soils	Hypothetical (future) construction workers Hypothetical (future) residents Trespassers	Dermal Ingestion	Unknown. No useable data available. Incidental contact with soil would be infrequent.

TABLE 5.6
MATRIX OF POTENTIAL EXPOSURE PATHWAYS - CURRENT USE
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

SITE 2 - DRAINAGE SWALE

Transport Medium	Source and Release Mechanism	Primary Exposure Point	Potential Receptors	Primary Exposure Route	Probability of Pathway Completion
Current Use					
Air	Affected soils/fugitive dust generation, volatilization	Michigan ANGB & areas downwind	Base personnel, nearby workers and residents	Inhalation Dermal	Low. Fugitive dust generation is unlikely since the sediments are overlain by vegetation. Concentrations of volatiles are low enough so that the detectable levels of volitilization is unlikely.
Groundwater	Affected soils, groundwater/site leaching	Wells used for drinking	Private well users	Ingestion Inhalation Dermal	Low - moderate. Concentrations found in groundwater are relatively low; however, private wells are located downgradient of this site.
Surface water	Affected soils, groundwater or seepage to groundwater, surface runoff	Nearby wetlands Kalamazoo River	Base personnel, nearby residents	Dermal Ingestion	Low. Contaminants are found in low levels and the distance to other neaby surface water body is < 1 mile. Incidental contact with surface water would be infrequent and base access is restricted.
Soils	Affected soils, groundwater and site leaching, runoff	Surface soils	Base personnel, trespassers	Dermal Ingestion	Low - moderate. Concentrations are at moderate levels in the sediment. Incidental contact would be infrequent by workers. Access to the base is restricted. Soils and sediments are covered with vegetation.

TABLE 5.7
MATRIX OF POTENTIAL EXPOSURE PATHWAYS - FUTURE USE
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

SITE 2 - DRAINAGE SWALE

Transport Medium	Source and Release Mechanism	Primary Exposure Point	Potential Receptors	Primary Exposure Route	Probability of Pathway Completion
Future Use					
Air	Affected soils/fugitive dust generation, volatilization	Michigan ANGB & areas downwind	Base personnel, nearby workers and residents, hypothetical (future) construction workers, hypothetical (future) residents	Inhalation Dermal	Low - moderate. Concentrations in surface soils are at moderate levels. Drainage of the swale and construction work is not planned; however, if the sediments were disturbed, airborne contaminants could be released.
Groundwater	Affected soils, groundwater/site leaching	Wells used for drinking	Private well users	Ingestion Inhalation Dermal	Low - moderate. Concentraitons found in groundwater are relatively low; however, private wells are located downgradient of this site.
Surface water	Affected soils, groundwater or seepage to groundwater, surface runoff	Nearby wetlands Kalamazoo River	Base personnel, nearby residents, hypothetical (future) residents	Dermal Ingestion	Low. Concentrations in surface water are found in low levels. The distance to other surface water bodies limits potential effects of surface water runoff. Contact with surface water will remain low unless the base is sold.

TABLE 5.7–Continued
MATRIX OF POTENTIAL EXPOSURE PATHWAYS - FUTURE USE
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

SITE 2 - DRAINAGE SWALE

Transport Medium	Source and Release Mechanism	Primary Exposure Point	Potential Receptors	Primary Exposure Route	Probability of Pathway Completion
Soils	Affected soils, groundwater and site leaching, runoff	Surface soils	Base personnel, hypothetical (future) residents trespassers,	Dermal Ingestion	Low - moderate. Concentrations are found in moderate levels. Incidental contact is infrequent. Contact with soils is unlikely unless the base is sold.
			Hypothetical (future) construction workers	Dermal Ingestion	Moderate. Future construction and drainage of the swale is unlikely but possible.

TABLE 5.8
MATRIX OF POTENTIAL EXPOSURE PATHWAYS - CURRENT USE
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

SITE 3 - FIRE TRAINING AREA

Transport Medium	Source and Release Mechanism	Primary Exposure Point	Potential Receptors	Primary Exposure Route	Probability of Pathway Completion
Current Use					
Air	Affected soils/fugitive dust generation, volatilization	Michigan ANGB & areas downwind	Base personnel, nearby workers and residents	Inhalation Dermal	Unknown. Useable soil data is not available. Erosion of surface soils is likely to be retarded by vegetation in summer and snow in winter.
Groundwater	Affected soils, groundwater/site leaching	Wells used for drinking	Private well users	Ingestion Inhalation Dermal	Moderate. Contaminants in groundwater are found in moderate levels. Private wells are located downgradient of the base.
Surface water	Affected soils, groundwater or seepage to groundwater, surface runoff	Nearby wetlands Kalamazoo River	Base personnel, nearby residents	Dermal Ingestion	Unknown. Useable data is not available. Runoff is unlikely to reach any surface water body. Contact with surface water runoff would be infrequent.
Soils	Affected soils, groundwater and site leaching, runoff	Surface soils	Base personnel tresspassers	Dermal Ingestion	Unknown. Useable soil data is not available. Incidental contact would be infrequent. Base access is restricted so contact would be limited.

TABLE 5.9
MATRIX OF POTENTIAL EXPOSURE PATHWAYS - FUTURE USE
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

SITE 3 - FIRE TRAINING AREA

Transport Medium	Source and Release Mechanism	Primary Exposure Point	Potential Receptors	Primary Exposure Route	Probability of Pathway Completion
Future Use					
Air	Affected soils/fugitive dust generation, volatilization	Michigan ANGB & areas downwind	Base personnel, nearby workers and hypothetical (future) residents	Inhalation Dermal	Unknown. Useable soil data is not available. Erosion of soils would be retarded by vegetation and snow.
			Hypothetical (future) construction workers	Inhalation Dermal	Unknown. Useable soil data is not available. Construction is not planned and unlikely; however, if the soils are disturbed, airborne contaminants could be released.
Groundwater	Affected soils, groundwater/site leaching	Wells used for drinking	Private well users	Ingestion Inhalation Dermal	Moderate. Contaminants in groundwater are found in low to moderate levels. Private wells are located downgradient of the base.
Surface water	Affected soils, groundwater or seepage to groundwater, surface runoff	Nearby wetlands Kalamazoo River	Base personnel, nearby residents, hypothetical (future) residents	Dermal Ingestion	Unknown. Adequate data is not available. Runoff is unlikely to reach any surface water body. Probability of human contact with surface water is low unless the base is sold.

TABLE 5.9–Continued
MATRIX OF POTENTIAL EXPOSURE PATHWAYS - FUTURE USE
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

SITE 3 - FIRE TRAINING AREA

Transport Medium	Source and Release Mechanism	Primary Exposure Point	Potential Receptors	Primary Exposure Route	Probability of Pathway Completion
Soils	Affected soils, groundwater and site leaching, runoff	Surface Soils	Base personnel, tresspassers	Dermal Ingestion	Unknown. Useable data is not available. Probability of human contact is very low for workers. Access to the base is restricted.
			Hypothetical (future) construction worker	Dermal ingestion	Unknown. Useable data is not available. Future construction is not planned and unlikely but possible.
			Hypothetical (future) residents	Dermal Ingestion	Unknown. Useable data is not available. Human contact is unlikely unless the base is sold.

TABLE 5.10
MATRIX OF POTENTIAL EXPOSURE PATHWAYS - CURRENT USE
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

SITE 4 - ABANDONED LANDFILL

Transport Medium	Source and Release Mechanism	Primary Exposure Point	Potential Receptors	Primary Exposure Route	Probability of Pathway Completion
Current Use					
Air	Affected soils/fugitive dust generation, volatilization	Michigan ANGB & areas downwind	Base personnel, nearby workers and residents	Inhalation Dermal	Unknown. Soil data not available. Erosion of soil is limited by vegetation and snow. Landfill may be capped with clean fill.
Groundwater	Affected soils, groundwater/site leaching	Wells used for drinking	Private well users	Ingestion Inhalation Dermal	Low. No groundwater contamination is found; however, private drinking water wells are located downgradient.
Surface water	Affected soils, groundwater or seepage to groundwater, surface runoff	Nearby wetlands Kalamazoo River	Base personnel, nearby residents	Dermal Ingestion	Unknown. Soil data not available. Landfill may be capped with clean fill. Runoff unlikely to reach a surface water body due to distance.
Soils	Affected soils, groundwater and site leaching, runoff	Surface soils	Base personnel, trespassers	Dermal Ingestion	Unknown. Soil data not available. Worker contact would be infrequent. Access to the base is restricted.

TABLE 5.11
MATRIX OF POTENTIAL EXPOSURE PATHWAYS - FUTURE USE
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

SITE 4 - ABANDONED LANDFILL

Transport Medium	Source and Release Mechanism	Primary Exposure Point	Potential Receptors	Primary Exposure Route	Probability of Pathway Completion
Future Use					
Air	Affected soils/fugitive dust generation, volatilization	Michigan ANGB & areas downwind	Base personnel, nearby workers and residents, hypothetical (future) construction workers, hypothetical (future) residents	Inhalation Dermal	Unknown Soil data not available. Surface soils could release airborne contaminants.
Groundwater	Affected soils, groundwater/site leaching	Wel's used for drinking	Private well users	Ingestion Inhalation Dermal	Low. Groundwater contamination was not detected.
Surface water	Affected soils, groundwater or seepage to groundwater, surface runoff	Nearby wetlands Kalamazoo River	Base personnel, nearby residents, hypothetical (future) residents	Dermal Ingestion	Unknown. Soil data not available. Landfill may be capped with clean fill. Runoff to surface water body is unlikely due to distance.

TABLE 5.11–Continued
MATRIX OF POTENTIAL EXPOSURE PATHWAYS - FUTURE USE
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

SITE 4 - ABANDONED LANDFILL

Transport Medium	Source and Release Mechanism	Primary Exposure Point	Potential Receptors	Primary Exposure Route	Probability of Pathway Completion
Soils	Affected soils, groundwater and site leaching, runoff	Surface Soils	Base personnel, trespassers	Dermal Ingestion	Unknown. Soil data not available. Contact with soil unlikely since the site is inactive.
			Hypothetical (future) construction workers, hypothetical (future) residents	Dermal *Ingestion*	Unknown. Soil data not available. Disturbance of *soil could uncover contaminated soil.*

TABLE 5.12
MATRIX OF POTENTIAL EXPOSURE PATHWAYS - CURRENT USE
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

SITE 5 - FORMER COAL STORAGE AREA

Transport Medium	Source and Release Mechanism	Primary Exposure Point	Potential Receptors	Primary Exposure Route	Probability of Pathway Completion
Current Use					
Air	Affected soils/fugitive dust generation, volatilization	Michigan ANGB & areas downwind	Base personnel, nearby workers and residents	Inhalation Dermal	Unknown. Useable data is unavailable. Soil erosion is likely to be retarded by vegetation and snow.
Groundwater	Affected soils, groundwater/site leaching	Wells used for drinking	Private well users	Ingestion Inhalation Dermal	Low - moderate. Low concentrations of contaminants were found in groundwater. Private drinking water wells are located downgradient of the site.
Surface water	Affected soils, groundwater or seepage to groundwater, surface runoff	Nearby wetlands Kalamazoo River	Base personnel, nearby residents	Dermal Ingestion	Unknown. Useable data is unavailable. Runoff is unlikely to discharge into any surface water bodies.
Soils	Affected soils, groundwater and site leaching, runoff	Surface soils	Base personnel, trespassers	Dermal Ingestion	Unknown. Useable data is unavailable. Contact with surface soil is unlikely since the area is inactive. Base access is restricted.

TABLE 5.13
MATRIX OF POTENTIAL EXPOSURE PATHWAYS - FUTURE USE
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

SITE 5 - FORMER COAL STORAGE AREA

Transport Medium	Source and Release Mechanism	Primary Exposure Point	Potential Receptors	Primary Exposure Route	Probability of Pathway Completion
Future Use					
Air	Affected soils/fugitive dust generation, volatilization	Michigan ANGB & areas downwind	Base Personnel, nearby workers, and residents, hypothetical (future) construction workers, hypothetical (future) residents	Inhalation Dermal	Unknown. Useable data is unavailable. Construction is not planned and unlikely; however, if the soils are disturbed, airborne contaminants could be released.
Groundwater	Affected soils, groundwater/site leaching	Wells used for drinking	Private well users	Ingestion Inhalation Dermal	Low - moderate. Low concentration of contaminants were found in the groundwater. Private drinking water wells are located downgradient of the site.

TABLE 5.13–Continued
MATRIX OF POTENTIAL EXPOSURE PATHWAYS - FUTURE USE
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

SITE 5 - FORMER COAL STORAGE AREA

Transport Medium	Source and Release Mechanism	Primary Exposure Point	Potential Receptors	Primary Exposure Route	Probability of Pathway Completion
Surface water	Affected soils, groundwater or seepage to groundwater, surface runoff	Nearby wetlands Kalamazoo River	Base personnel, nearby residents, hypothetical (future) residents	Dermal Ingestion	Unknown. Useable data is unavailable. Runoff is unlikely to reach a surface water body. Human contact with surface water will be infrequent unless the base is sold.
Soils	Affected soils, groundwater and site leaching, runoff	Surface soils	Base personnel, trespassers	Dermal Ingestion	Unknown. Useable data is unavailable. Incidental contact would be infrequent.
			Hypothetical (future) construction workers, hypothetical (future) residents	Dermal Ingestion	Unknown. Useable data is unavailable. Future construction is *not planned and unlikely, but* possible. Contact with soils is unlikely unless the base is sold.

TABLE 5.14
MATRIX OF POTENTIAL EXPOSURE PATHWAYS - CURRENT USE
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

SITE 6 - UNDERGROUND FUEL STORAGE TANKS

Transport Medium	Source and Release Mechanism	Primary Exposure Point	Potential Receptors	Primary Exposure Route	Probability of Pathway Completion
Current Use					
Air	Affected soils/fugitive dust generation, volatilization	Michigan ANGB & areas downwind	Base personnel, nearby workers and residents	Inhalation Dermal	Low. Low concentrations in surface soils are unlikely to result in detectable concentrations in air *via* soil erosion or volatilization. Erosion of surface soils is likely to be retarded by vegetation and snow.
Groundwater	Affected soils, groundwater/site leaching	Wells used for drinking	Private well users	Ingestion Inhalation Dermal	Moderate. Contamination in groundwater was detected at low levels; however, private drinking water wells are located downgradient of the base.
Surface water	Affected soils, groundwater or seepage to groundwater, surface runoff	Nearby wetlands Kalamazoo River	Base personnel, nearby residents	Dermal Ingestion	Low. Runoff is unlikely to reach any surface water body. Incidental contact with surface water is infrequent and access to the base is restricted.
Soils	Affected soils, groundwater and site leaching, runoff	Surface soils	Base personnel, trespassers	Dermal Ingestion	Low. Low levels of contaminants are found in surface soil and incidental contact with the soils is infrequent. Access to the base is restricted.

TABLE 5.15
MATRIX OF POTENTIAL EXPOSURE PATHWAYS - FUTURE USE
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

SITE 6 - UNDERGROUND FUEL STORAGE TANKS

Transport Medium	Source and Release Mechanism	Primary Exposure Point	Potential Receptors	Primary Exposure Route	Probability of Pathway Completion
Future Use					
Air	Affected soils/fugitive dust generation, volatilization	Michigan ANGB & areas downwind	Base personnel, nearby workers, and residents, hypothetical (future) construction workers, hypothetical (future) residents	Inhalation Dermal	Low. Low concentrations in surface soils are unlikely to result in detectable concentrations in air *via* soil erosion or volatilization. Construction is not planned and unlikely; however, if the soils are disturbed, airborne contaminants could be released.
Groundwater	Affected soils, groundwater/site leaching	Wells used for drinking	Private well users	Ingestion Inhalation Dermal	Moderate. Contamination in groundwater is low; however, private drinking water wells are located downgradient of the base.
Surface water	Affected soils, groundwater or seepage to groundwater, surface runoff	Nearby wetlands Kalamazoo River	Base personnel, nearby residents, hypothetical (future) residents	Dermal Ingestion	Low. Low contaminant concentrations in the surface soils are unlikely to be transported by runoff. Runoff is unlikely to reach a surface water body. Contact with surface water will be infrequent unless the base is sold

TABLE 5.15–Continued
MATRIX OF POTENTIAL EXPOSURE PATHWAYS - FUTURE USE
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

SITE 6 - UNDERGROUND FUEL STORAGE TANKS

Transport Medium	Source and Release Mechanism	Primary Exposure Point	Potential Receptors	Primary Exposure Route	Probability of Pathway Completion
Soils	Affected soils, groundwater site leaching and runoff	Surface Soils	Base personnel, trespassers	Dermal Ingestion	Low. Contaminants are found in low levels in the surface soils. Incidental contact would be infrequent.
			Hypothetical (future) construction workers, hypothetical (future) residents	Dermal Ingestion	Moderate. Future construction is not planned and is unlikely (though possible). Contact with soils is unlikely unless base is sold.

TABLE 5.16
TOXICITY VALUE FOR THE ASSESSMENT OF POTENTIAL CARCINOGENIC EFFECTS
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

	Slope Factor 1/(mg/kg/day)		Weight of Evidence Classification		Tumor Site	
Chemical	Inhalation	Oral	Inhalation	Oral	Inhalation	Oral
Acetone	ND	ND	ND	ND	ND	ND
Benzene	2.9E-02	2.9E-02	A	A	leukemia	leukemia
Carbon disulfide	ND	ND	D	D	ND	ND
cis-1,2-Dichloroethene	ND	ND	D	D	ND	ND
trans 1,2 Dichloroethene	ND	ND	D	D	ND	ND
Ethylbenzene	ND	ND	D	D	ND	ND
1,1,2,2 Tetrachloroethane	2.0E-01	2.0E-01	C	C	liver	liver
Tetrachloroethene	NA	5.1E-02	B2	B2	leukemia, liver	leukemia, liver
1,1,1 Trichloroethane	NA	NA	D	D	ND	ND
Trichloroethene	1.7E-02	1.1E-02	B2	B2	lung	liver
Styrene	2.0E-03	3.0E-02	B2	B2	leukemia	lung, bronchi
Xylene (mixed)	ND	ND	D	D	ND	ND
4-Methylphenol (p-cresol)	ND	ND	C	C	NA	NA
Fluoranthene	ND	ND	D	D	ND	ND
Fluorene	ND	ND	D	D	ND	ND
Dimethylphthalate	ND	ND	D	D	ND	ND
Anthracene	ND	ND	D	D	ND	ND
Benzo(a)anthracene (a)	ND	ND	B2	B2	NA	NA
Benzo(b)fluoranthene(a)	ND	ND	B2	B2	NA	NA
Benzo(k)pyrene(a)	ND	ND	B2	B2	respiratory tract	stomach

TABLE 5.16–Continued
TOXICITY VALUE FOR THE ASSESSMENT OF POTENTIAL CARCINOGENIC EFFECTS
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Chemical	Slope Factor 1/(mg/kg/day)		Weight of Evidence Classification		Tumor Site	
	Inhalation	Oral	Inhalation	Oral	Inhalation	Oral
Benzo(k)fluoranthene[(a)]	ND	ND	B2	B2	NA	NA
Butylbenzylphthalate	ND	ND	NA	C	NA	NA
Bis(2-ethylhexyl)phthalate	ND	1.4E-02	B2	B2	NA	liver
2-Butanone	ND	ND	ND	ND	ND	ND
Toluene	ND	ND	ND	ND	ND	ND
Chrysene	ND	ND	B2	B2	NA	NA
Di-n-butyl phthalate	ND	ND	D	D	ND	ND
Indeno(1,2,3-cd)pyrene	ND	ND	B2	B2	NA	NA
Pyrene	ND	ND	D	D	ND	ND
Phenanthrene	ND	ND	D	D	ND	ND
Benzo(g,h,i)perylene	ND	ND	D	D	ND	ND
Chloroform	2.3E-05	1.7E-07	B2	B2	liver	kidney
Arsenic	5.0E+01	ND	A	A	respiratory tract	skin
Beryllium	8.4	4.3	B2	B2	lung	total tumors
Cadmium	6.1	ND	B1	ND	respiratory tract	NA
Chromium (III)	ND	ND	D	D	ND	ND
Chromium (IV)	4.1E+01	ND	A	ND	lung	NA
Copper	ND	ND	D	D	ND	ND
Nickel	1.7	ND	A	ND	respiratory tract	NA
Silver	ND	ND	D	D	ND	ND

TABLE 5.16–Continued
TOXICITY VALUE FOR THE ASSESSMENT OF POTENTIAL CARCINOGENIC EFFECTS
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Chemical	Slope Factor 1/(mg/kg/day)		Weight of Evidence Classification		Tumor Site	
	Inhalation	Oral	Inhalation	Oral	Inhalation	Oral
Zinc	NA	NA	D	D	NA	NA
Lead	NA	NA	B2	B2	NA	NA
Mercury	ND	ND	D	D	ND	ND
Thallium	ND	ND	ND	ND	ND	ND

(a) For RCRA sites only

(b) Nickel subsulfide

ND = No data, not determined

NA = Not applicable

Reference:

EPA Health Effects Assessment Summary Tables (HEAST), First Quarter FY-1991, NTIS PB91-921100, January 1991

TABLE 5.17
TOXICITY VALUE FOR THE EVALUATION OF POTENTIAL NONCARCINOGENIC EFFECTS
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Chemical	Chronic RfC (mg/kg/day)	Chronic RfD (mg/kg/day)	Critical Effect	
	Inhalation	Oral	Inhalation	Oral
Acetone	ND	1.01E-01	NA	liver & kidney effects
Benzene	ND	ND	ND	ND
Carbon Disulfide	1.0E-02	1.0E-01	NA	fetal toxicity
cis-1,2-Dichloroethene	ND	1.0E-02	NA	decreased hematocrit & hemoglobin
trans 1,2 Dichloroethene	ND	2.0E-02	NA	increased serum alkaline phosphate
Ethylbenzene	ND	1.0E-01	NA	hepatotoxicity & nephrotoxicity
1,1,2,2 Tetrachloroethane	ND	ND	ND	ND
Tetrachloroethene	ND	1.0E-02	NA	hepatotoxicity
1,1,1 Trichloroethane	1.0E+01	9.0E-01	hepatotoxicity	hepatotoxicity
Trichloroethene	ND	ND	ND	ND
Styrene	ND	2.0E-01	NA	affects RBC & liver
Xylene (mixed)	3.0E-01	2.0	CNS effects, nose & throat irritation	hyperactivity, body weight, mortality
4-Methylphenol (p-cresol)	ND	5.0E-02	NA	neurotoxicity, body weight
Fluoranthene	ND	4.0E-02	NA	nephropathy & hematological changes
Fluorene	ND	4.0E-01	NA	hematological changes
Dimethylphthalate	ND	1.0	BA	affects growth
2-Butanone	9.0E-02	5.0E-02	CNS	fetotoxicity
Chloroform	ND	1.0E-02	NA	liver lesions

TABLE 5.17–Continued
TOXICITY VALUE FOR THE EVALUATION OF POTENTIAL NONCARCINOGENIC EFFECTS
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Chemical	Chronic RfC (mg/kg/day)	Chronic RfD (mg/kg/day)	Critical Effect	
	Inhalation	Oral	Inhalation	Oral
Anthracene	ND	3.0E-01	NA	no effects
Benz(a)anthracene [(a)]	ND	ND	ND	ND
Benzo(b)fluoranthene[(a)]	ND	ND	ND	ND
Benzo(k)pyrene[(a)]	ND	ND	ND	ND
Benzo(k)fluoranthene[(a)]	ND	ND	ND	ND
Butylbenzylphthalate	ND	2.0E-01	NA	affects body weight, testes, liver & kidneys
Bis(2-ethylhexyl)phthalate	ND	2.0E-02	NA	affects liver
Toluene	2.0	2.0E-01	CNS effects, eye and nose irritation	changes in liver and kidney weights
Chrysene	ND	ND	ND	ND
Di-n-butyl phthalate	ND	1.0E-01	NA	mortality
Indeno(1,2,3-cd)pyrene	ND	ND	ND	ND
Pyrene	ND	3.0E-01	NA	renal effects
Phenanthrene	ND	ND	ND	ND
Benzo(g,h,i)perylene	ND	ND	ND	ND
Arsenic	ND	1.0E-03	NA	keratosis & hyperpigmentation
Beryllium	ND	5.0E-03	dNA	none observed
Cadmium	ND	1.0E-03 (food) 5.0E-04 (water)	cancer	renal damage

TABLE 5.17–Continued
TOXICITY VALUE FOR THE EVALUATION OF POTENTIAL NONCARCINOGENIC EFFECTS
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Chemical	Chronic RfC (mg/kg/day)	Chronic RfD (mg/kg/day)	Critical Effect	
	Inhalation	Oral	Inhalation	Oral
Chromium (III)	2.0E-06	1.0	nasal mucosa atrophy	hepatotoxicity
Chromium (IV)	2.0E-05	2.0E-02	nasal mucosa atrophy	not defined
Copper	ND	ND[(a)]	NA	local GI irritation
Nickel	ND	2.0E-02	cancer	body & organ weight
Silver	ND	3.0E-03	NA	argyria
Zinc	ND	2.0E-01	NA	anaemia
Lead	ND	ND	CNS effects	CNS effects
Mercury	3.0E-04	3.0E-04	neurotoxicity	kidney effects
Thallium (in soluble salts)	ND	7.0E-05	NA	increased SGOT and serum LDH levels, alopecia

(a) Data were inadequate for derivation of RfD

ND = No data, not determined

NA = Not applicable

Reference:

EPA, Health Effects Assessment Summary Tables (HEAST), First Quarter FY-1991 NTIS PB90-921100, January 1991

TABLE 5.18
COMPARISON OF CONCENTRATIONS WITH ARARs AND HEALTH-BASED CRITERIA
110TH FG, MICHIGAN AIR NATIONAL GUARD
BATTLECREEK, MICHIGAN

Site: 2
Medium: Sediment/Soil
Route: Oral

Chemical	Maximum Release Concentration µg/kg	Criterion Type Used	Criterion Value µg/kg	Release Concentration Exceeds Criterion
Acetone	13(b)	PA307S	14,000	No
Toluene	11J(b)	PA307S	800	No
Fluoranthene	30,000(b)(c)	PA307S	6,000	Yes
Fluorene	3,200J(b)	PA307S	6,000	No
Dimethylphthalate	2,700J(b)	RfD	0.08(d)	Yes
Anthracene	5,100(b)	PA307S	40,000	No
Benzo(a)anthracene	17,000(b)	PA307S	100	Yes
Benzo(b)flouranthene	25,000(b)(c)	PA307S	100	Yes
Benzo(a)pyrene	19,000(b)(c)	PA307S	100	Yes
Benzo(k)fluoranthene	18,000(b)(c)	PA307S	100	Yes
Butylbenzylphthalate	3,000J(b)	PA307S	28,000	No
Bis(2-ethylhexyl)phthalate	6,200(b)	SF	5.7E-06(d)	Yes
Chrysene	22,000(b)(c)	PA307S	100	Yes
Indeno(1,2,3-cd)pyrene	13,000(b)(c)	PA307S	100	Yes
Pyrene	27,000J(b)	PA307S	4,000	Yes
Cadmium	21,100(b)	RfD	8.0E-05(d)	Yes
Chromium	60,700(b)	RfD	0.08(d)	Yes
Copper	185,000(b)	ND	ND	ND
Nickel	28,200(b)	RfD	0.0016(d)	Yes
Silver	8,500(b)	RfD	2.4E-04(d)	Yes
Zinc	324,000J(b)	RfD	0.016(d)	Yes
Arsenic	68,000J(b)(c)	RfD	8.0E-05(d)	Yes
Lead	250,000(b)	ND	ND	ND
Mercury	210J(b)	RfD	2.4E-05(d)	Yes
Beryllium	740(b)(c)	SF	1.86E-08(d)	Yes
Carbon disulfide	0.8J(b)	RfD	8(d)	No
Tetrachloroethene	83J(b)	PA307S	14	Yes
Styrene	12J(b)	SF	4.0E-01(d)	Yes
Phenanthene	24,000(b)	ND	ND	ND
Di-n-butylphthalate	30,000(b)	PA307S	14,000	Yes
4-Methylphenol	630(b)	RfD	4(d)	Yes
Benzo(g,h,i)perylene	8,100	ND	ND	ND

(a) 1989 Sampling event.
(b) 1990 Sampling Event.
(c) Found in the Duplicate sample.
(d) Parameters in mg/kg/day

PA307S = State of Michigan PA 307 type B Criteria for Soils
RfD = Reference dose
SF = Slope Factor
ND = No data

TABLE 5.19
COMPARISON OF CONCENTRATIONS WITH ARARs AND HEALTH-BASED CRITERIA
110TH FG, MICHIGAN AIR NATIONAL GUARD
BATTLECREEK, MICHIGAN

Site: 2
Medium: Groundwater
Route: Oral

Chemical	Maximum Release Concentration μg/l	Criterion Type Used	Criterion Value mg/l/day	Release Concentration Exceeds Criterion
Zinc	13(a)	RfD	0.007	Yes

(a) 1990 Sampling Event.
RfD = Reference dose.

TABLE 5.20
COMPARISON OF CONCENTRATIONS WITH ARARs AND HEALTH-BASED CRITERIA
110TH FG, MICHIGAN AIR NATIONAL GUARD
BATTLECREEK, MICHIGAN

Site: 2
Medium: Surface water
Route: Oral

Chemical	Maximum Release Concentration µg/l	Criterion Type Used	Criterion Value µg/l	Release Concentration Exceeds Criterion
Toluene	0.49(a)	CWA	10,000	No
Fluoranthene	6J(a)	CWA	42	No
Chromium	13.9(a)	CWA	170	No
Copper	187(a)	CWA	1,300	No
Nickel	13.6(a)	CWA	510	No
Lead	96.9(a)	CWA	1,300	No
Mercury	0.2(a)	CWA	0.14	Yes
Thallium	56(a)	CWA	91	No
Zinc	200(a)	RfD	0.007(b)	Yes

(a) 1990 Sampling Event.
(b) Parameters in mg/l/day.
CWA = Clean Water Act.
RfD = Reference dose.

TABLE 5.21
COMPARISON OF CONCENTRATIONS WITH ARARs AND HEALTH-BASED CRITERIA
110TH FG, MICHIGAN AIR NATIONAL GUARD
BATTLECREEK, MICHIGAN

Site: 3
Medium: Groundwater
Route: Oral

Chemical	Maximum Release Concentration µg/l	Criterion Type Used	Criterion Value µg/l	Release Concentration Exceeds Criterion
Xylenes (total)	980(b)	PA307GW	20	Yes
Toluene	240J(b)	PA307GW	40	Yes
Benzene	200(b)	PA307GW	1.0	Yes
Trichloroethene	3J(b)	PA307GW	3.0	Yes
1,2-Dichloroethene	1200(b)	PA307GW	140	Yes
Ethylbenzene	100(b)	PA307GW	30	Yes
Acetone	480J(b)	PA307GW	14,000	No
Lead	9.4(a)	PA307GW	5	Yes
Arsenic	91.5J(b)	PA307GW	0.02	Yes
2-Butanone	100J(b)	PA307GW	350	No

(a) 1989 Sampling event.
(b) 1990 Sampling Event.
PA307GW = State of Michigan PA 307 Type B Criteria for groundwater.

TABLE 5.22
COMPARISON OF CONCENTRATIONS WITH ARARs AND HEALTH-BASED CRITERIA
110TH FG, MICHIGAN AIR NATIONAL GUARD
BATTLECREEK, MICHIGAN

Site: 5
Medium: Groundwater
Route: Oral

Chemical	Maximum Release Concentration μg/l	Criterion Type Used	Criterion Value μg/l	Release Concentration Exceeds Criterion
1,1,1-Trichloroethane	0.4J(a)	MCL	200	No
Xylenes	0.2J(a)	PA307GW	20	No

(a) 1990 Sampling Event.

MCL = Maximum Contaminant Level.

PA307GW = State of Michigan PA307 Type B Criteria for groundwater.

TABLE 5.23
COMPARISON OF CONCENTRATIONS WITH ARARs AND HEALTH BASED CRITERIA
110TH FG, MICHIGAN AIR NATIONAL GUARD
BATTLECREEK, MICHIGAN

Site: 6
Medium: Soil
Route: Oral

Chemical	Maximum Release Concentration µg/kg	Criterion Type Used	Criterion Value µg/kg	Release Concentration Exceeds Criterion
Toluene	52(a)	PA307S	40	Yes
Total Petroleum Hydrocarbons	21,000(a)	ND	ND	ND

(a) 1990 Sampling Event.

PA307S = State of Michigan PA 307 Type B Criteria for Soil.

TABLE 5.24
COMPARISON OF CONCENTRATIONS WITH ARARs AND HEALTH-BASED CRITERIA
110TH FG, MICHIGAN AIR NATIONAL GUARD
BATTLECREEK, MICHIGAN

Site: 6
Medium: Groundwater
Route: Oral

Chemical	Maximum Release Concentration µg/l	Criterion Type Used	Criterion Value µg/l	Release Concentration Exceeds Criterion
Benzene	0.36(b)	PA307GW	1.0	No
1,1,1-Trichloroethane	0.7J(b)	MCL	200	No
Trichloroethene	1.0(b)	PA307GW	3	No
Toluene	0.32J(b)	PA307GW	40	No
Tetrachloroethene	0.7J(b)	PA307GW	0.7	No
Xylene	0.3J(b)	PA307GW	20	No
Lead	0.005(a)	PA307GW	5	No
Zinc	11.4(b)	RfD	0.007(c)	Yes

(a) 1989 Sampling event.
(b) 1990 Sampling Event.
(c) Parameter in mg/l/day.
PA307GW = State of Michigan PA 307 Type B Criteria for soil.
MCL = Maximum Contaminant Level.
RfD = Reference Dose.

TABLE 5.25
COMPARISON OF CONCENTRATIONS WITH ARARs AND HEALTH-BASED CRITERIA
110TH FG, MICHIGAN AIR NATIONAL GUARD
BATTLE CREEK, MICHIGAN

Site: Base Boundary Wells
Medium: Groundwater
Route: Oral

Chemical	Maximum Release Concentration μg/l	Criterion Type Used	Criterion Value μg/l	Release Concentration Exceeds Criterion
Toluene	1J(b)	PA307GW	40	No
Trichloroethene	10(a)	PA307GW	3	Yes
1,2-Dichloroethene	92(b)	PA307GW	140	No
1,1,1-Trichloroethane	2.6(a)	PA307GW	200	No
Acetone	21(b)	PA307GW	700	No
Zinc	132(b)	RfD	0.007(c)	Yes
Lead	0.01(a)	PA307GW	5	No
1,1,2,2-Tetrachloroethane	2(b)	SF	1.75E-03(c)	Yes
Chloroform	0.6(b)	PA307GW	6	No
2-Butanone	54J(b)	PA307GW	350	No
Benzene	0.23J(b)	PA307GW	1.0	No

(a) 1989 Sampling Event

(b) 1990 Sampling Event

(c) Parameters in mg/l/day

PA307GW = State of Michigan PA 307 Type B Criteria for groundwater

RfD = Reference Dose

SF = Slope Factor

TABLE 5.26
MATRIX OF POTENTIAL EXPOSURE PATHWAYS FOR FLORA AND FAUNA - CURRENT USE
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Transport Medium	Source and Release Mechanism	Primary Exposure Point	Potential Receptors	Primary Exposure Route	Probability of Pathway Completion
Air	Affected soils/fugitive dust emissions, volatilization	Surrounding flora and fauna	Upland farming hardwood communities, marsh areas, and other ecological communities	Inhalation Adsorption	Low. Concentrations in surface soil are low enough that detectable airborne contamination is unlikely. Erosion of surface soils retarded by vegetative covering and gravel.
Groundwater	Affected soils, groundwater/site leaching	Suurounding flora and fauna, Kalamazoo River	Upland farming hardwood community, marsh area, and other ecological communities	Ingestion Inhalation Adsorption Transpiration	Low. Groundwater discharges to the Kalamazoo River located downgradient of the site.
Surface water	Affected soils, groundwater/seepage of groundwater, surface runoff	Immediately surrounding flora and fauna, Kalamzoo River	Upland farming hardwood community, marsh area, and other ecological communities	Ingestion, Adsorption, Transpiration	Moderate. Surface water is used by ecological communities and provides an habitat for aquatic species and water fowl.

TABLE 5.26–Continued
MATRIX OF POTENTIAL EXPOSURE PATHWAYS FOR FLORA AND FAUNA - CURRENT USE
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Transport Medium	Source and Release Mechanism	Primary Exposure Point	Potential Receptors	Primary Exposure Route	Probability of Pathway Completion
Soils/ Sediments	Affected soils, sediments, surface water and groundwater/site leaching, runoff, tracking	Immediately surrounding flora and fauna	Upland farming hardwood community, marsh area, and other ecological communities	Ingestion Adsorption Transpiration	Moderate. Soil nutrients are used by all ecological communities; sediments would effect aquatic communities and water fowl.

TABLE 5.27
MATRIX OF POTENTIAL EXPOSURE PATHWAYS FOR FLORA AND FAUNA - FUTURE USE
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Transport Medium	Source and Release Mechanism	Primary Exposure Point	Potential Receptors	Primary Exposure Route	Probability of Pathway Completion
Air	Affected soils/fugitive dust emissions, volatilization	Surrounding flora and fauna	Upland farming hardwood communities, marsh areas, and other ecological communities	Inhalation Adsorption	Low-Moderate. Concentrations in surface soil are low enough that detectable airborne contamination is unlikely. Erosion of surface soils retarded by vegetative covering and gravel. Construction or disturbance of soils would increase the potential of *fugitive dust emissions.*
Groundwater	Affected soils, groundwater/site leaching	Surrounding flora and fauna, Kalamazoo River	Upland farming hardwood community, marsh area, and other ecological communities	Ingestion Inhalation Adsorption Transpiration	Low. Groundwater discharges to the Kalamazoo River located downgradient of the site.
Surface water	Affected soils, groundwater/seepage of groundwater, surface runoff	Surrounding flora and fauna, Kalamzoo River	Upland farming hardwood community, marsh area, and other ecological communities	Ingestion, Adsorption, Transpiration	Moderate. Surface water is used by ecological communities and provides an habitat for aquatic species and water fowl.

TABLE 5.27–Continued
MATRIX OF POTENTIAL EXPOSURE PATHWAYS FOR FLORA AND FAUNA - FUTURE USE
110TH FG, MICHIGAN AIR NATIONAL GUARD
W. K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Transport Medium	Source and Release Mechanism	Primary Exposure Point	Potential Receptors	Primary Exposure Route	Probability of Pathway Completion
Soils/ Sediments	Affected soils, sediments, surface water and groundwater/site leaching, runoff, tracking	Immediately surrounding flora and fauna	Upland farming hardwood community, marsh area, and other ecological communities	Ingestion Adsorption Transpiration	Moderate. Soil nutrients are used by all ecological communities; sediments would effect aquatic communities and water fowl.

SECTION 6
CONCLUSIONS AND RECOMMENDATIONS

6.1 BASE BOUNDARY

The Base boundary wells were installed as part of an earlier investigation at the Base. The boundary itself is not a site under DOD's IRP, so no conclusions or recommendations will be made concerning the Base boundary.

6.2 SITE 1 - FUEL TANK FARM

6.2.1 Conclusions

The Site 2 background monitoring well also serves as a downgradient monitoring well for Site 1. No VOCs were detected in 1989 or 1991 in the groundwater samples from this well. Zinc was detected in 1991 at a concentration of 13 μg/L, above the reference dose of 7 μg/L/day. Zinc, however, was also detected in the Base background wells, along the southern boundary, at concentrations of 10.4 μg/L. Zinc is apparently a naturally occurring metal in the surficial aquifer. Groundwater contamination is determined to pose no significant threat at Site 1.

Soil contaminant levels cannot be quantified; however, laboratory results indicate the presence of TPH at Site 1. Also, visible staining and odors indicate the presence of fuel constituents in the soil.

6.2.2 Recommendations

No further action is recommended for the investigation of groundwater contamination.

An immediate removal of fuel-contaminated soil is recommended at Site 1. Although no valid data is available for Site 1 soils, the soil is visibly stained with fuel products and the soil emits an odor of fuel products, indicating the presence of fuel products. Resources would be utilized in the most efficient manner by removing the soils rather than conducting additional studies prior to removal. The immediate removal would be followed by sampling and analysis of soils underlying and surrounding the excavation in order to verify complete removal of contaminated soils.

6.3 SITE 2 - DRAINAGE SWALE

6.3.1 Conclusions

Toluene and fluoranthene were the only VOCs or semivolatiles detected in surface waters at and entering the drainage swale. Neither compound exceeded regulatory or risk-based ARARs. Mercury and zinc were both detected in concentrations that exceed ARARs. Mercury was detected in the drainage swale and in run-off from the motor pool parking lot at a concentration of 0.20 μg/L, exceeding the Clean Water Act water quality criteria of 0.14 μg/L. Zinc was detected in the same samples at concentrations of 134 to 200 μg/L, exceeding the reference dose of 7 μg/L/day. Run-off from the Base and from Dickman Road contained lesser concentrations of zinc, 54.7 to 60.7 μg/L, but still exceeded the ARAR by an order of magnitude.

Concentrations of many semivolatiles and metals in Site 2 sediments greatly exceeded the regulatory and risk-based ARARs. The greatest concentrations were found within the swale, but ARARs were also exceeded in samples from drainageways leading from the motor pool parking lot, from Site 1, and from Dickman Road. The greatest concentrations outside of the swale were detected in the sample in the culvert from the motor pool parking lot. Concentrations in this sample were similar to those within the swale, and were an order of magnitude greater than those from Dickman Road or site drainageways. The lack of contamination in the surface water samples indicates that sediment contamination may result from past activities and not from current practices.

Acetone, TCE, and 1,1,2,2-TCA were detected in groundwater samples from Base boundary wells located immediately downgradient of Site 2. The concentration of 1,1,2,2-TCA was 2 μg/L, which slightly exceeded the health-based criteria of 1.75 μg/L/day.

6.3.2 Recommendations

An FS is recommended for Site 2. The FS would evaluate the need for remedial action on sediments and groundwater and would develop remedial action alternatives, as appropriate. The FS should also evaluate the applicability of federal storm-water regulations on discharges to the swale.

6.4 SITE 3 - FIRE TRAINING AREA

6.4.1 Conclusions

Data is not available to quantify contaminant levels in Site 3 soils. However, the 1988 data does indicate extremely high concentrations of fuel constituents in the soil. BETX was reported in concentrations up to 7,000 mg/kg and the soils in the burn area were visibly contaminated and gave off fuel odors.

Several VOCs were detected in groundwater immediately downgradient of the FTA, in the upper portion of the surficial aquifer. Benzene, ethylbenzene, toluene, xylenes, and 1,2-dichloroethylene were detected at concentrations in excess of the State criteria. VOCs were also detected in the 1991 sample from the intermediate portion of the surficial aquifer, but concentrations were below ARARs.

6.4.2 Recommendations

An FS is recommended for Site 3. The FS would include sampling and analysis of soils to provide data for a baseline risk assessment, and aquifer pumping tests to provide data on the hydraulic characteristics of the aquifer.

6.5 SITE 4 - ABANDONED LANDFILL

6.5.1 Conclusions

No contaminants were detected in groundwater at Site 4. No evidence exists for the possibility of soil contamination.

6.5.2 Recommendations

A Decision Document should be prepared for no further action at Site 4.

6.6 SITE 5 - COAL STORAGE AREA

6.6.1 Conclusions

No useable data is available for the evaluation of soil contamination at Site 5. However, historical records indicate that this area was used only for the storage of coal in the past.

The downgradient groundwater sample contained 1,1,1-TCA and xylenes at concentrations below ARARs. Groundwater flow patterns indicate that the contaminants may originate from the Site 3 FTA, rather than Site 5.

6.6.2 Recommendations

The recommendation for Site 5 is removal of surface soils containing coal particles, followed by sampling and analysis of the underlying soil to verify removal of the coal. Clean backfill would then be placed in the excavation.

6.7 SITE 6 - FUEL SPILL

6.7.1 Conclusions

Toluene and TPH were detected in Site 6 soil samples. Toluene was detected in the background soil sample, indicating laboratory contamination or a contaminant source from outside the site. Only one sample contained toluene in excess of the state criteria. TPH concentrations were relatively low, with a maximum concentration of 21 ppm. Adverse threats are not likely because the area is well-vegetated and access is controlled, reducing the possibility of contact with the soils.

VOCs, lead, and zinc were detected in the groundwater at Site 6. However, no regulatory or risk-based ARARs were exceeded.

6.7.2 Recommendations

A Decision Document should be prepared for no further action at Site 6.

6.8 SUMMARY OF RECOMMENDATIONS

The following actions have been recommended:

- Remediate contaminated soils at Site 1, then sample and analyze soils to verify removal of contamination;
- Conduct an FS at Site 2 to evaluate the need for, and potential alternatives for, remediation of sediments and groundwater;
- Conduct an FS at Site 3 to evaluate the need for, and alternatives for, soil and groundwater remediation; the FS should include soil sampling and analysis, and aquifer pumping tests;
- Prepare a Decision Document for no further action at Site 4;
- Remove surface soils containing coal particles at Site 5, sample to verify removal, then prepare a Decision Document for no further action;
- Prepare a Decision Document for no further action at Site 6.

SECTION 7
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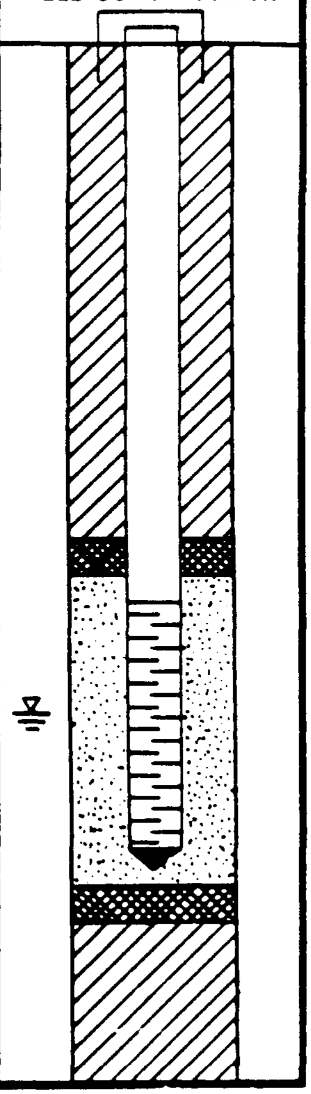
APPENDIX A
MONITORING WELL CONSTRUCTION RECORDS AND BORING LOGS

ENGINEERING-SCIENCE
DRILLING RECORD

PAGE 1 OF 2

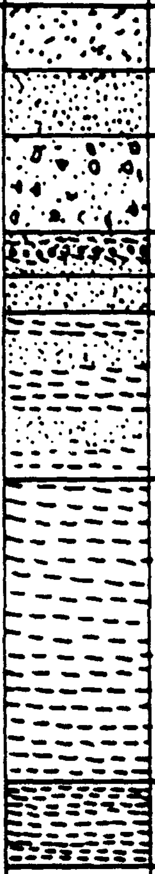
WELL/BORING ID: BC MW-1	DRILLING STARTED: 10/21/87
LOCATION: MICHIGAN ANGB BATTLE CREEK, MI	DRILLING COMPLETED: 10/23/87
PROJECT NO: AT103	DRILLING METHOD: 6.25 INCH I.D. HOLLOW-STEM AUGER
DRILLER: FOX DRILLING, INC	SAMPLING METHOD: SPLIT-SPOON
LOGGER:	STATIC WATER LEVEL: 888.46 ft
GEOLOGIST: J. M. STANGL	WATER LEVEL DATE: 11/6/87
SIGNATURE:	WATER LEVEL DATUM: MSL

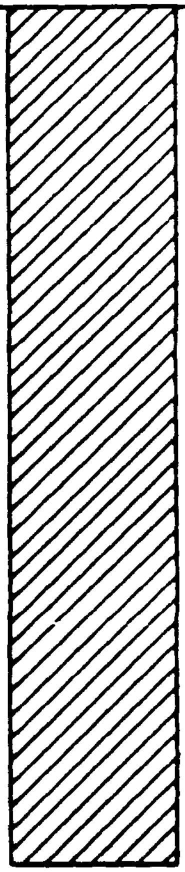
DEPTH IN FEET BELOW LS.	SAMPLER BLOWS	PERCENT RECOVERY	LITHOLOGY	SAMPLE DESCRIPTION	WELL CONSTRUCTION
0	2-4-7			SAND - MEDIUM TO COARSE WITH GRAVEL	
	4-9-19				
10	10-15-23				
				THIN ORGANIC LAYER	
	5-12-9			SAND - FINE TO MEDIUM	
20	6-7-20				
	4-12-16				
30	3-9-21				
	6-16-22				
40	3-6-7				
	4-9-15				
50	12-20-37			SAND - VERY COARSE WITH GRAVEL	
	13-26-39				
				SAND - MEDIUM	
60	19-25-27				

ENGINEERING-SCIENCE
DRILLING RECORD

PAGE 2 OF 2

BCMW-1



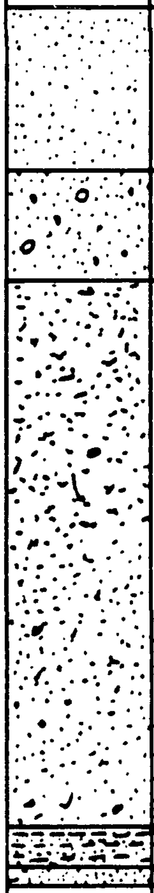
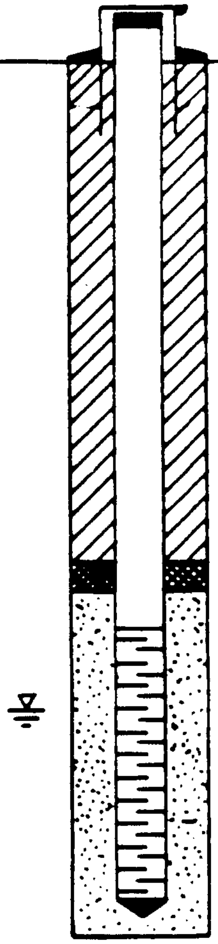


DEPTH IN FEET BELOW LS.	SAMPLER BLOWS	PERCENT RECOVERY	SAMPLE DESCRIPTION
			SAND - COARSE TO VERY COARSE
	20-27-35		SAND - VERY FINE
70	40-67-100/5		GRAVEL - WITH ROCK FRAGMENTS, AND SAND
	150/15"		CLAY - SANDY WITH GRAVEL
			SAND - VERY FINE, LAYERED
80	34-39-49		CLAY - BROWN - GREY WITH SAND AND GRAVEL LAYERS
	27-50-50/2"		
90	17-25-37		CLAY - SILTY, GREY
	20-37-38		
100	10-33-45		
	16-34-50		
110	100/7"		CLAY - BLUE - GREY, WITH SAND AND SILT
			BORING TERMINATED
120			

ENGINEERING-SCIENCE
DRILLING RECORD

PAGE 1 OF 1

WELL/BORING ID: BC MW-2	DRILLING STARTED: 10/27/87
LOCATION: MICHIGAN ANGB BATTLE CREEK, MI	DRILLING COMPLETED: 10/27/87
PROJECT NO: AT103	DRILLING METHOD: 6.25 INCH I.D. HOLLOW-STEM AUGER
DRILLER: FOX DRILLING, INC	SAMPLING METHOD: SPLIT-SPOON
LOGGER:	STATIC WATER LEVEL: 890.93
GEOLOGIST: J. M. STANGL	WATER LEVEL DATE: 11/6/87
SIGNATURE:	WATER LEVEL DATUM: MSL

DEPTH IN FEET BELOW LS.	SAMPLER BLOWS	PERCENT RECOVERY	LITHOLOGY	SAMPLE DESCRIPTION	WELL CONSTRUCTION
0	1-1-1			SAND - MEDIUM WITH SILT	
	1-1-2				
10	7-19-31			SAND - MEDIUM WITH SILT, COBBLES, GRAVEL	
	10-12-9			SAND - FINE TO MEDIUM WITH SOME COARSE LAYERS AND SOME GRAVEL	
20	3-4-5				
	7-12-15				
30	3-8-10				
	5-8-12				
40	1-19-23				
	7-13-27			CLAY - SANDY, GREY WITH GRAVEL SAND	
50				BORING TERMINATED	

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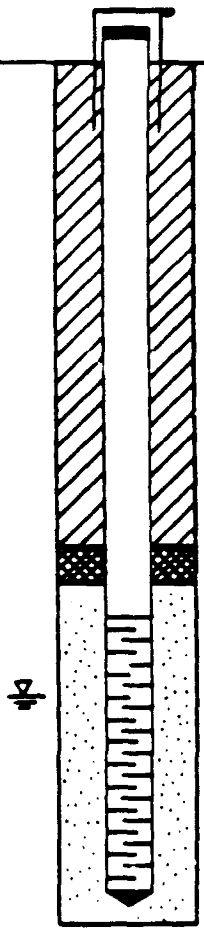
ENGINEERING-SCIENCE
DRILLING RECORD

PAGE 1 OF 1

WELL/BORING ID: BC MW-3	DRILLING STARTED: 10/16/87
LOCATION: MICHIGAN ANGB BATTLE CREEK, MI	DRILLING COMPLETED: 10/20/87
PROJECT NO: AT103	DRILLING METHOD: 6.25 INCH I.D. HOLLOW-STEM AUGER
DRILLER: FOX DRILLING, INC	SAMPLING METHOD: SPLIT-SPOON
LOGGER:	STATIC WATER LEVEL: 891.31
GEOLOGIST: J. M. STANGL	WATER LEVEL DATE: 11/6/87
SIGNATURE:	WATER LEVEL DATUM: MSL

DEPTH IN FEET BELOW LS.	SAMPLER BLOWS	PERCENT RECOVERY	LITHOLOGY	SAMPLE DESCRIPTION	WELL CONSTRUCTION
0	6-6-7			SAND, SILT, GRAVEL	
	2-8-12				
10	24-30-21				
	10-24-35			SAND - FINE TO MEDIUM	
20	4-8-10				
	7-10-9				
30	8-11-14				
	11-16-14			SAND - MEDIUM TO COARSE	
40	6-18-32				
50				BORING TERMINATED	

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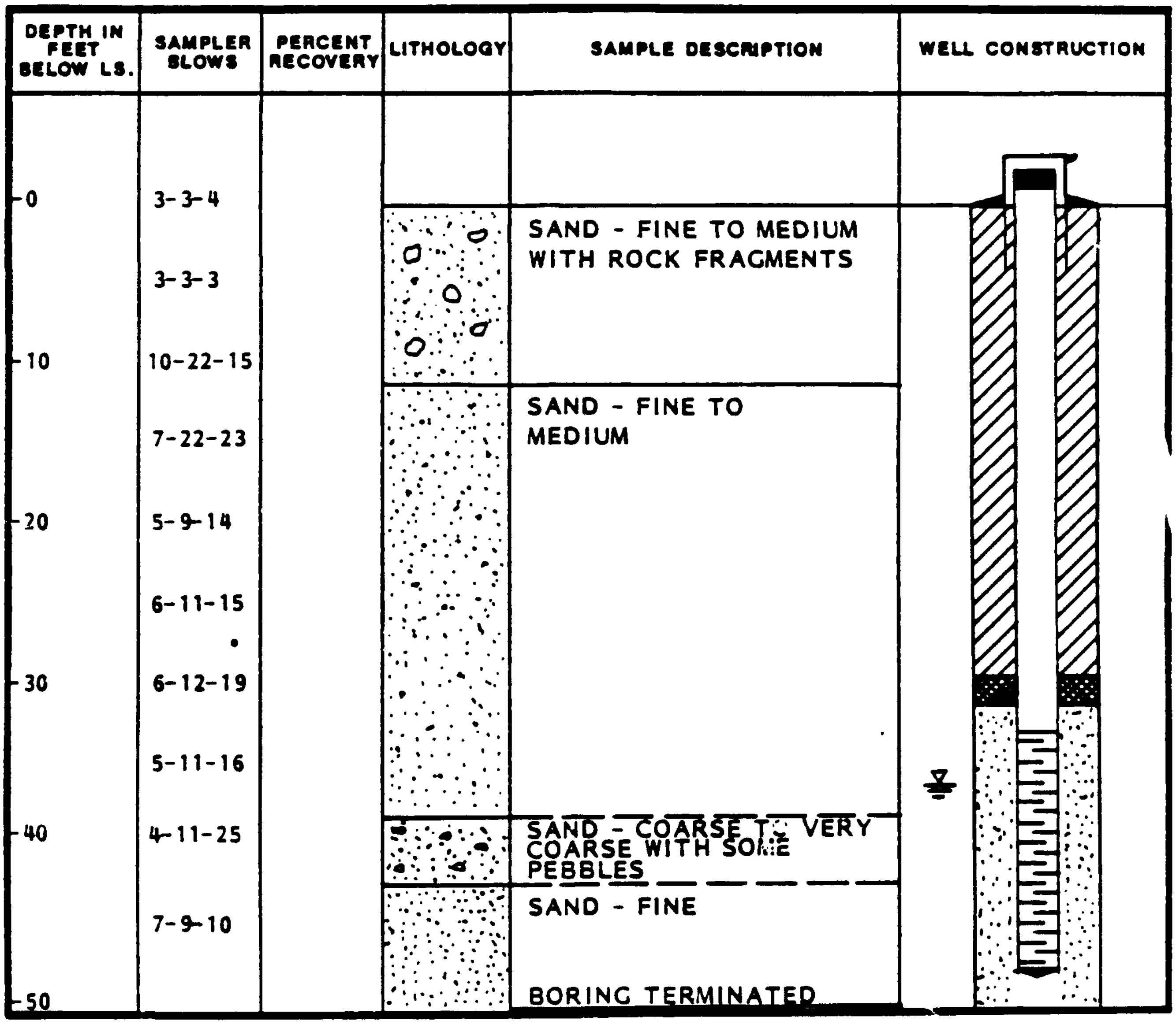
ENGINEERING-SCIENCE
DRILLING RECORD

PAGE 1 OF 1

WELL/BORING ID: BC MW-4	DRILLING STARTED: 10/10/87
LOCATION: MICHIGAN ANGB BATTLE CREEK, MI	DRILLING COMPLETED: 10/12/87
PROJECT NO: AT103	DRILLING METHOD: 6.25 INCH I.D. HOLLOW-STEM AUGER
DRILLER: FOX DRILLING, INC	SAMPLING METHOD: SPLIT-SPOON
LOGGER:	STATIC WATER LEVEL: 890.99
GEOLOGIST: J. M. STANGL	WATER LEVEL DATE: 11/6/87
SIGNATURE:	WATER LEVEL DATUM: MSL



DEPTH IN FEET BELOW LS.	SAMPLER BLOWS	PERCENT RECOVERY	LITHOLOGY	SAMPLE DESCRIPTION	WELL CONSTRUCTION
0	3-3-4				
	3-3-3			SAND - FINE TO MEDIUM WITH ROCK FRAGMENTS	
10	10-22-15				
	7-22-23			SAND - FINE TO MEDIUM	
20	5-9-14				
	6-11-15				
30	6-12-19				
	5-11-16				
40	4-11-25			SAND - COARSE TO VERY COARSE WITH SOME PEBBLES	
	7-9-10			SAND - FINE	
50				BORING TERMINATED	

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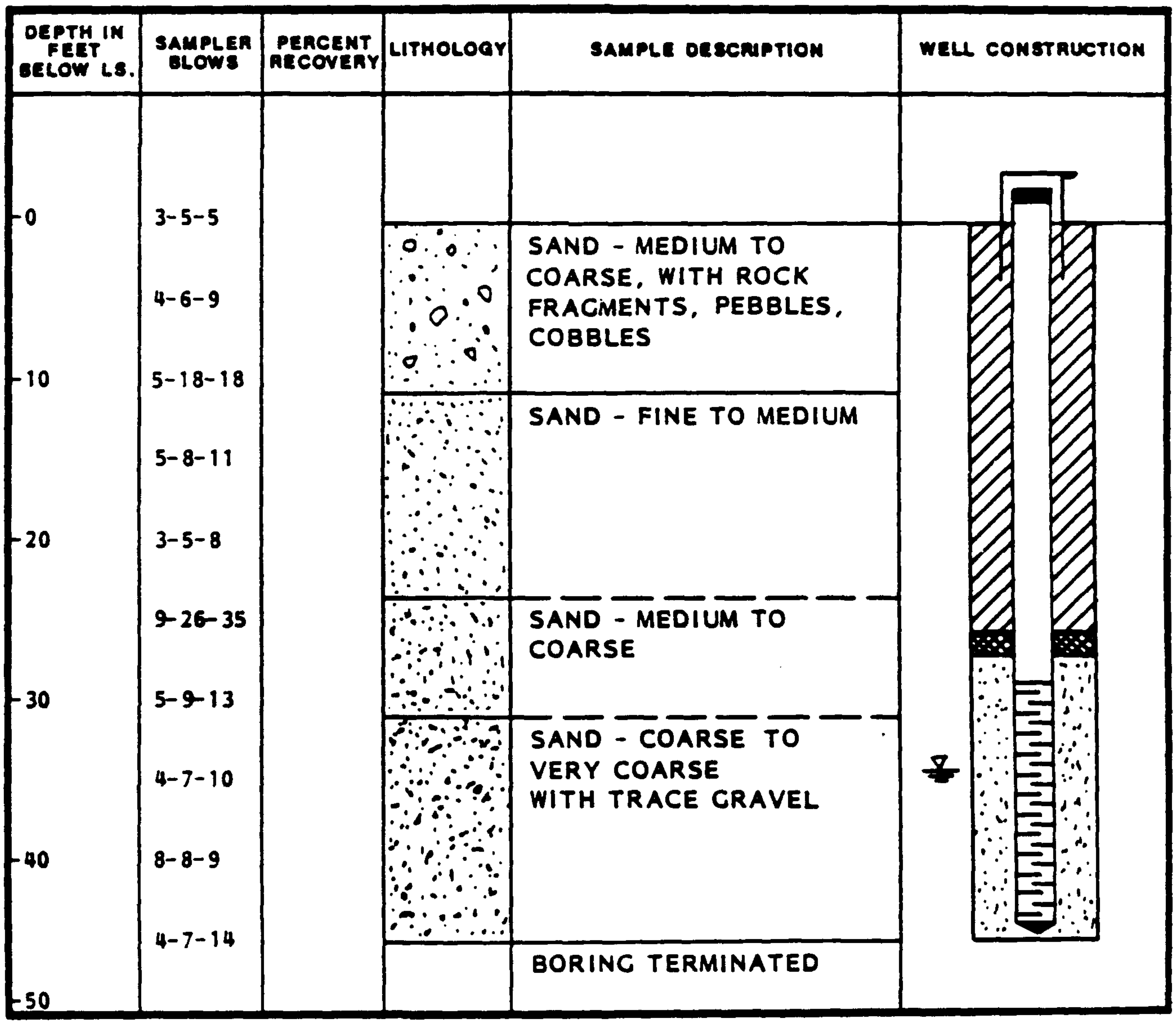
ENGINEERING-SCIENCE
DRILLING RECORD

PAGE 1 OF 1

WELL/BORING ID: BC MW-5	DRILLING STARTED: 10/7/87
LOCATION: MICHIGAN ANGB BATTLE CREEK, MI	DRILLING COMPLETED: 10/8/87
PROJECT NO: AT103	DRILLING METHOD: 6.25 INCH I.D. HOLLOW-STEM AUGER
DRILLER: FOX DRILLING, INC	SAMPLING METHOD: SPLIT-SPOON
LOGGER:	STATIC WATER LEVEL: 887.34
GEOLOGIST: J. M. STANGL	WATER LEVEL DATE: 11/6/87
SIGNATURE:	WATER LEVEL DATUM: MSL



DEPTH IN FEET BELOW LS.	SAMPLER BLOWS	PERCENT RECOVERY	LITHOLOGY	SAMPLE DESCRIPTION	WELL CONSTRUCTION
0	3-5-5			SAND - MEDIUM TO COARSE, WITH ROCK FRAGMENTS, PEBBLES, COBBLES	
	4-6-9				
10	5-18-18			SAND - FINE TO MEDIUM	
	5-8-11				
20	3-5-8				
	9-26-35			SAND - MEDIUM TO COARSE	
30	5-9-13			SAND - COARSE TO VERY COARSE WITH TRACE GRAVEL	
	4-7-10				
40	8-8-9				
	4-7-14			BORING TERMINATED	
50					

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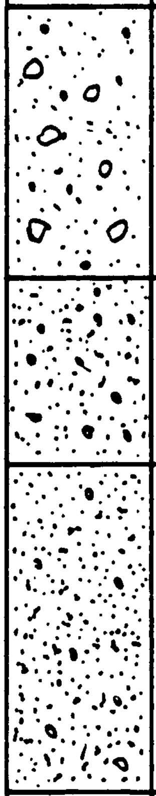
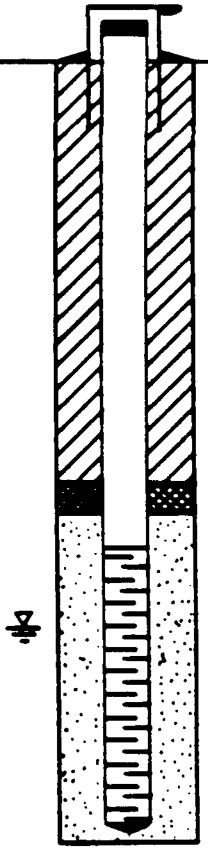
ENGINEERING-SCIENCE
DRILLING RECORD

PAGE 1 OF 1

WELL/BORING ID: BC MW-6	DRILLING STARTED: 10/6/87
LOCATION: MICHIGAN ANGB BATTLE CREEK, MI	DRILLING COMPLETED: 10/7/87
PROJECT NO: AT103	DRILLING METHOD: 6.25 INCH I.D. HOLLOW-STEM AUGER
DRILLER: FOX DRILLING, INC	SAMPLING METHOD: SPLIT-SPOON
LOGGER:	STATIC WATER LEVEL: 885.30
GEOLOGIST: J. M. STANGL	WATER LEVEL DATE: 11/6/87
SIGNATURE:	WATER LEVEL DATUM: MSL

DEPTH IN FEET BELOW LS.	SAMPLER BLOWS	PERCENT RECOVERY	LITHOLOGY	SAMPLE DESCRIPTION	WELL CONSTRUCTION
0	2-7-8			SAND - MEDIUM TO COARSE WITH ROCK FRAGMENTS AND GRAVEL	
	8-14-10				
10	10-8-11				
	5-12-7			SAND - VERY COARSE WITH GRAVEL	
20	6-10-13				
	4-6-9			SAND - MEDIUM TO COARSE WITH SOME GRAVEL	
30	3-4-6				
	5-12-21				
40	6-10-15				
				BORING TERMINATED	
50					





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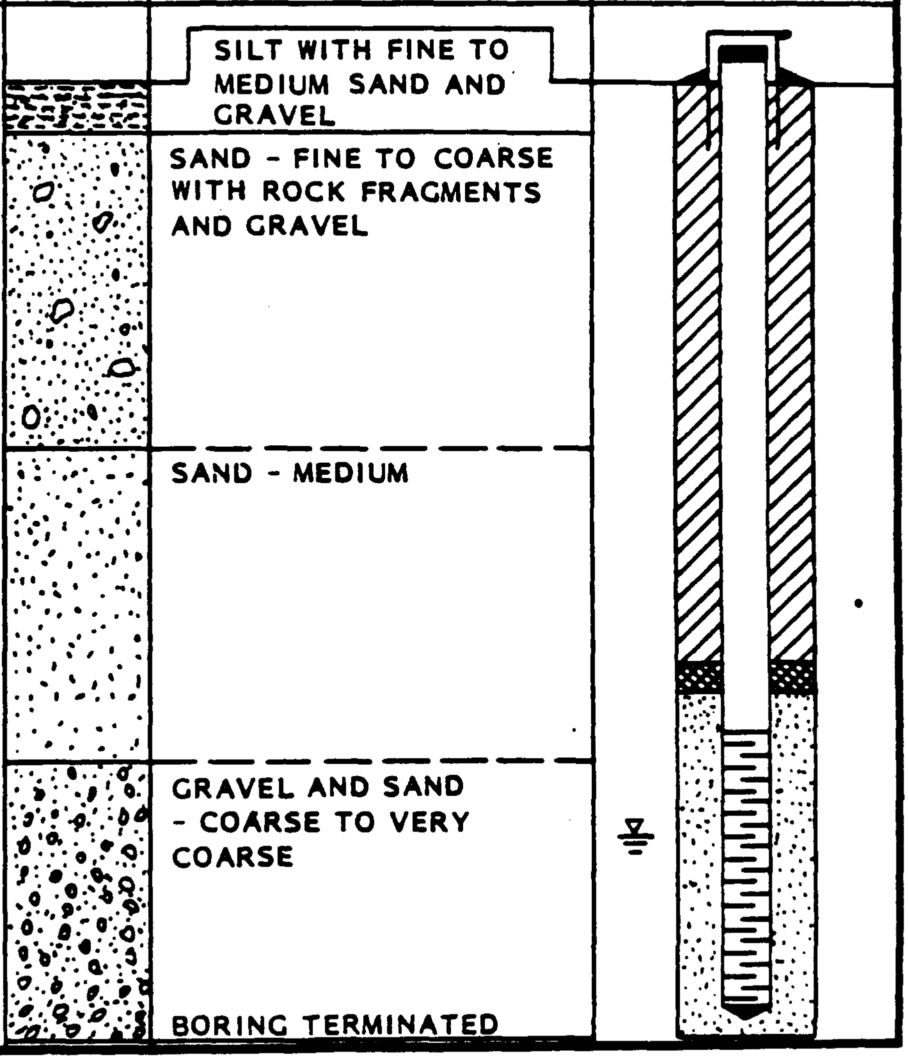
ENGINEERING-SCIENCE
DRILLING RECORD

PAGE 1 OF 1

WELL/BORING ID: BC MW-7	DRILLING STARTED: 10/15/87
LOCATION: MICHIGAN ANGB BATTLE CREEK, MI	DRILLING COMPLETED: 10/15/87
PROJECT NO: AT103	DRILLING METHOD: 6.25 INCH I.D. HOLLOW-STEM AUGER
DRILLER: FOX DRILLING, INC	SAMPLING METHOD: SPLIT-SPOON
LOGGER:	STATIC WATER LEVEL: 882.48
GEOLOGIST: J. M. STANGL	WATER LEVEL DATE: 11/6/87
SIGNATURE:	WATER LEVEL DATUM: MSL

DEPTH IN FEET BELOW LS.	SAMPLER BLOWS	PERCENT RECOVERY	SAMPLE DESCRIPTION
0	3-4-2		SILT WITH FINE TO MEDIUM SAND AND GRAVEL
	5-7-8		SAND - FINE TO COARSE WITH ROCK FRAGMENTS AND GRAVEL
10	3-12-20		
	10-14-15		
20	7-19-26		SAND - MEDIUM
	7-14-13		
30	4-9-19		
	4-10-16		
40	9-28-25		GRAVEL AND SAND - COARSE TO VERY COARSE
	9-16-15		
50	18-26-41		BORING TERMINATED



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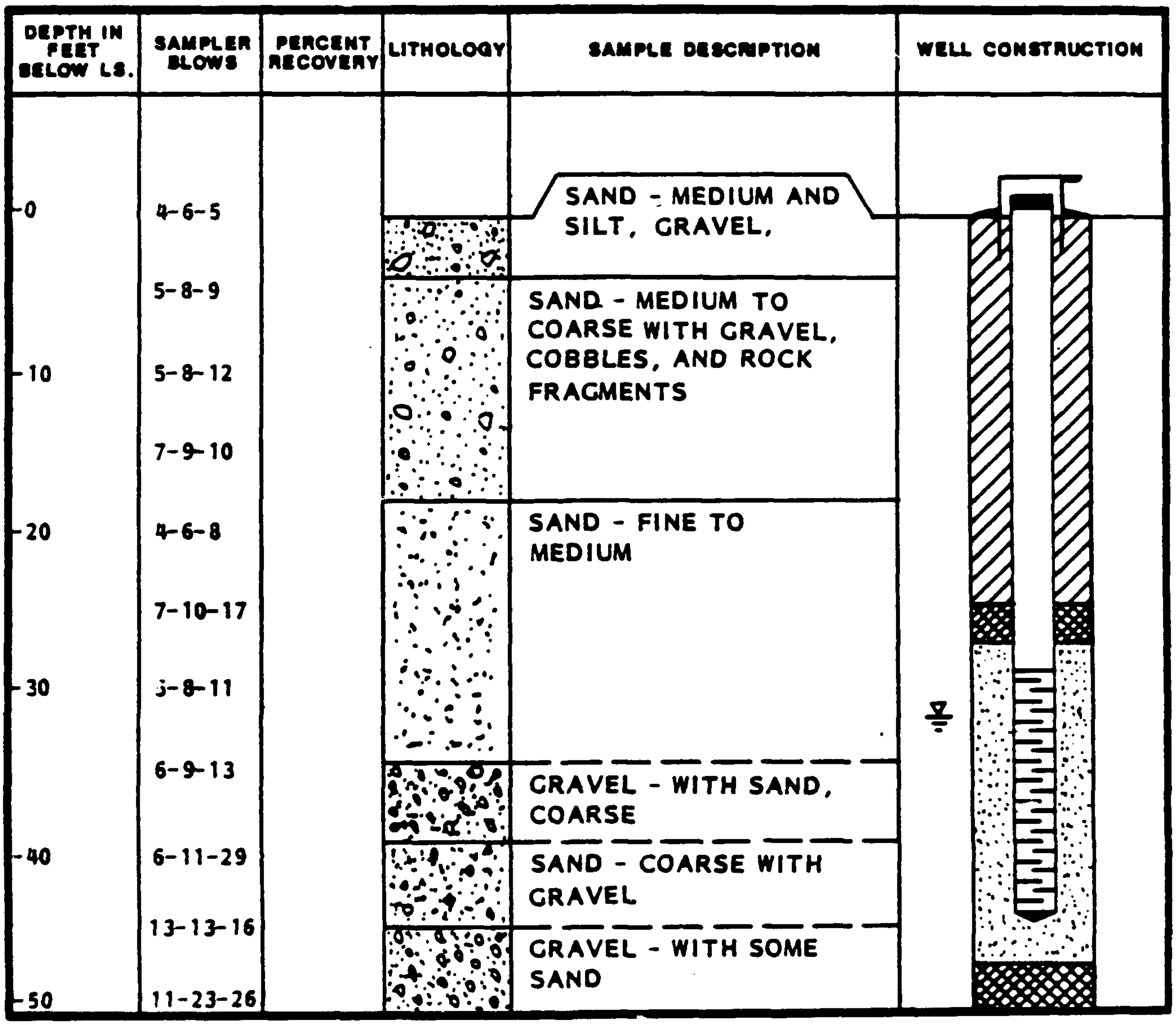
ENGINEERING-SCIENCE
DRILLING RECORD

PAGE 1 OF 2

WELL/BORING ID: BC MW-8	DRILLING STARTED: 10/28/87
LOCATION: MICHIGAN ANGB BATTLE CREEK, MI	DRILLING COMPLETED: 10/29/87
PROJECT NO: AT103	DRILLING METHOD: 6.25 INCH I.D. HOLLOW-STEM AUGER
DRILLER: FOX DRILLING, INC	SAMPLING METHOD: SPLIT-SPOON
LOGGER:	STATIC WATER LEVEL: 884.50
GEOLOGIST: J. M. STANGL	WATER LEVEL DATE: 11/6/87
SIGNATURE:	WATER LEVEL DATUM: MSL



DEPTH IN FEET BELOW LS.	SAMPLER BLOWS	PERCENT RECOVERY
0	4-6-5	
	5-8-9	
10	5-8-12	
	7-9-10	
20	4-6-8	
	7-10-17	
30	3-8-11	
	6-9-13	
40	6-11-29	
	13-13-16	
50	11-23-26	

LITHOLOGY

SAMPLE DESCRIPTION

- SAND - MEDIUM AND SILT, GRAVEL,
- SAND - MEDIUM TO COARSE WITH GRAVEL, COBBLES, AND ROCK FRAGMENTS
- SAND - FINE TO MEDIUM
- GRAVEL - WITH SAND, COARSE
- SAND - COARSE WITH GRAVEL
- GRAVEL - WITH SOME SAND

WELL CONSTRUCTION

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ENGINEERING-SCIENCE
DRILLING RECORD

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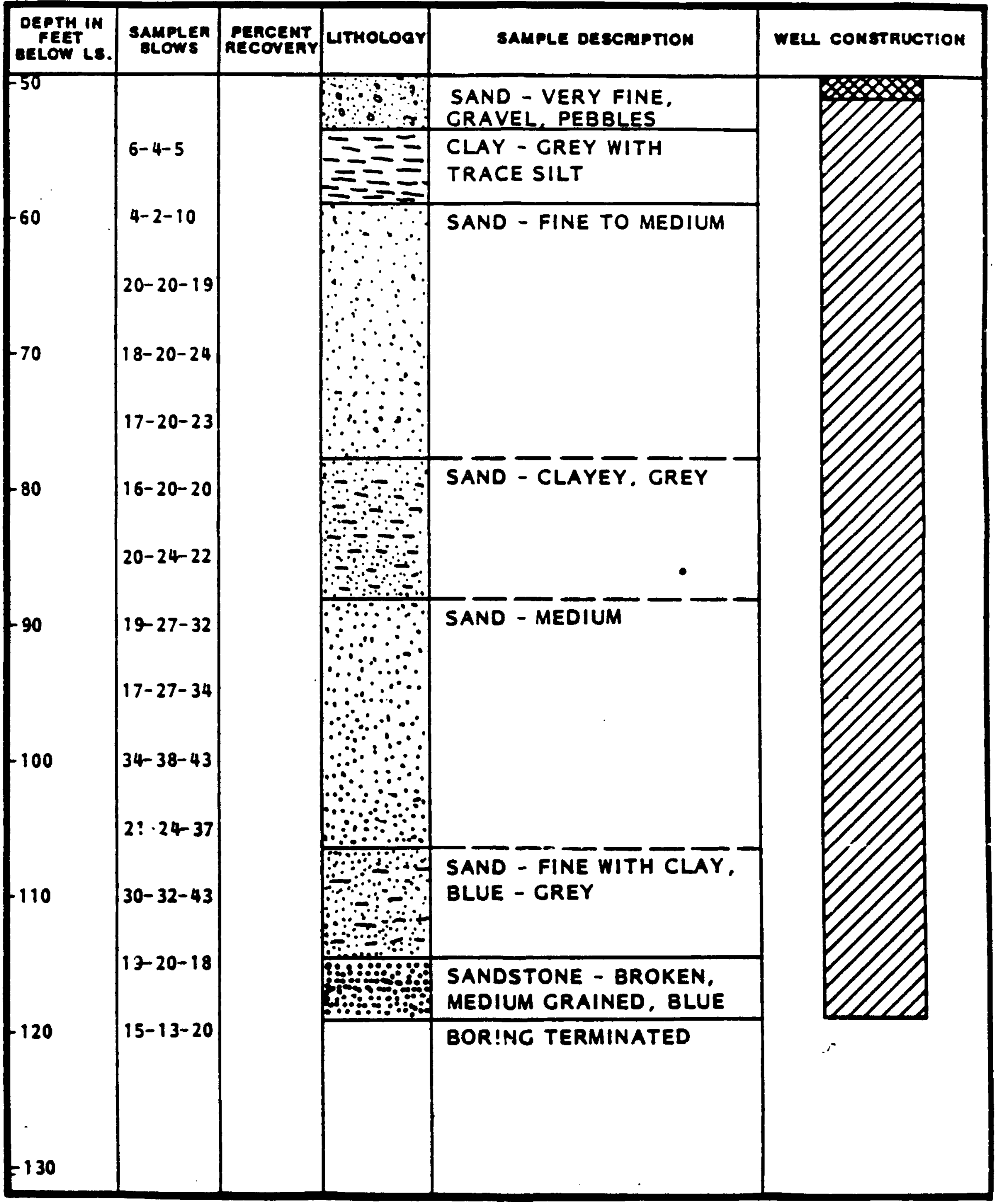
BCMW-8



DEPTH IN FEET BELOW LS.	SAMPLER BLOWS	PERCENT RECOVERY	LITHOLOGY	SAMPLE DESCRIPTION	WELL CONSTRUCTION
50				SAND - VERY FINE, GRAVEL, PEBBLES	
	6-4-5			CLAY - GREY WITH TRACE SILT	
60	4-2-10			SAND - FINE TO MEDIUM	
	20-20-19				
70	18-20-24				
	17-20-23				
80	16-20-20			SAND - CLAYEY, GREY	
	20-24-22				
90	19-27-32			SAND - MEDIUM	
	17-27-34				
100	34-38-43				
	21-24-37				
110	30-32-43			SAND - FINE WITH CLAY, BLUE - GREY	
	13-20-18			SANDSTONE - BROKEN, MEDIUM GRAINED, BLUE	
120	15-13-20			BORING TERMINATED	
130					

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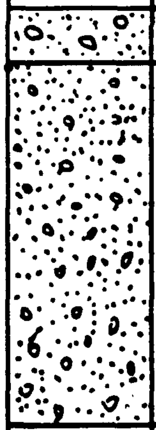
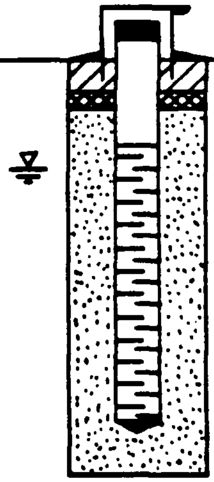
ENGINEERING-SCIENCE
DRILLING RECORD

PAGE 1 OF 1

WELL/BORING ID: BC MW-9	DRILLING STARTED: 10/14/87
LOCATION: MICHIGAN ANGB BATTLE CREEK, MI	DRILLING COMPLETED: 10/14/87
PROJECT NO: AT103	DRILLING METHOD: 6.25 INCH I.D. HOLLOW-STEM AUGER
DRILLER: FOX DRILLING, INC	SAMPLING METHOD: SPLIT-SPOON
LOGGER:	STATIC WATER LEVEL: 886.14
GEOLOGIST: J. M. STANGL	WATER LEVEL DATE: 11/6/87
SIGNATURE:	WATER LEVEL DATUM: MSL

DEPTH IN FEET BELOW LS.	SAMPLER BLOWS	PERCENT RECOVERY	LITHOLOGY	SAMPLE DESCRIPTION	WELL CONSTRUCTION
0	4-3-2			SAND - FINE TO MEDIUM WITH SILT AND ROCK FRAGMENTS	
	3-4-4			SAND - COARSE TO VERY COARSE WITH GRAVEL	
10	1-2-2				
	3-3-4				
20					
				BORING TERMINATED	
30					
40					
50					

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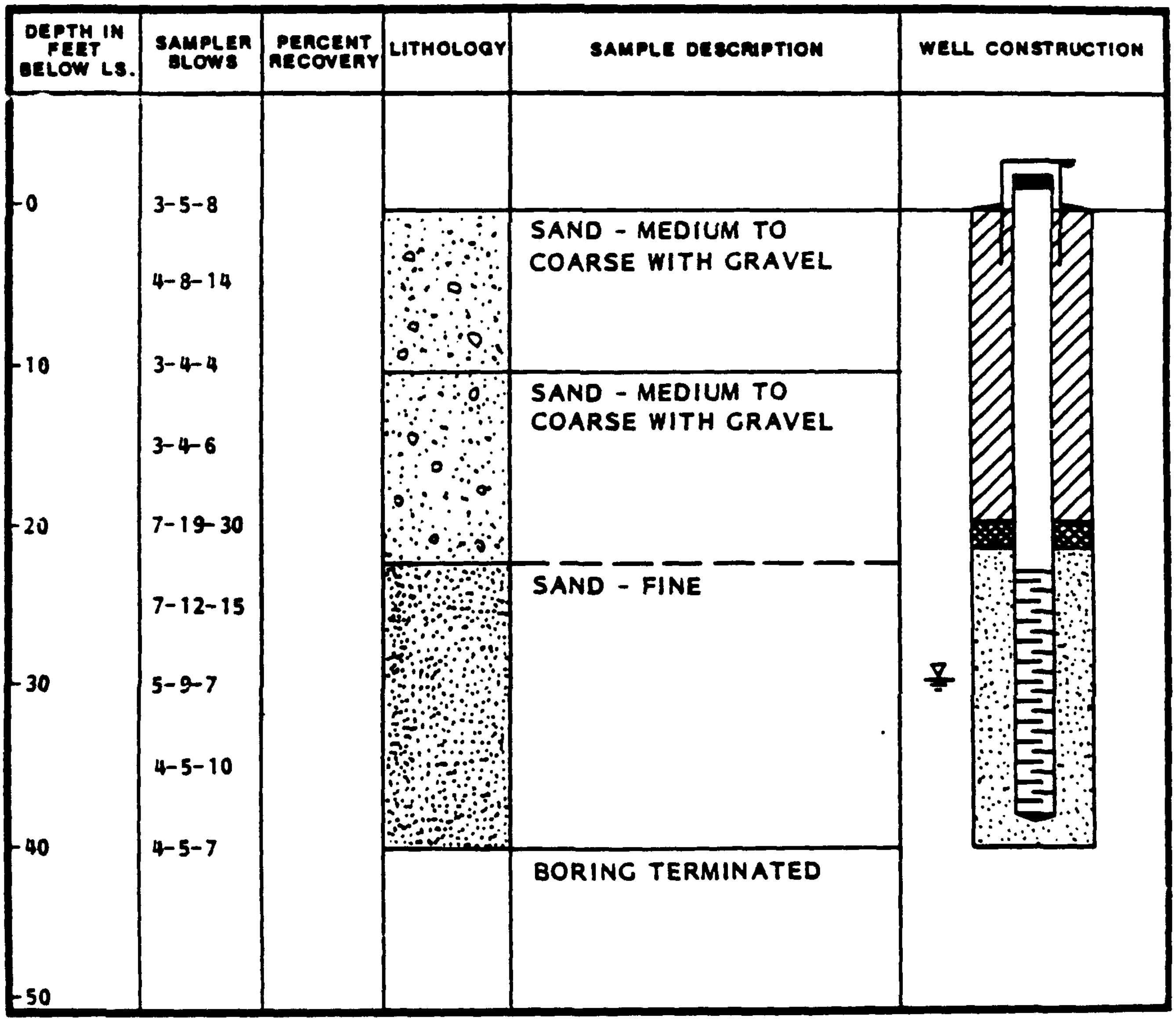
ENGINEERING-SCIENCE
DRILLING RECORD

PAGE 1 OF 1

WELL/BORING ID: BC MW-10	DRILLING STARTED: 10/13/87
LOCATION: MICHIGAN ANGB BATTLE CREEK, MI	DRILLING COMPLETED: 10/13/87
PROJECT NO: AT103	DRILLING METHOD: 6.25 INCH I.D. HOLLOW-STEM AUGER
DRILLER: FOX DRILLING, INC	SAMPLING METHOD: SPLIT-SPOON
LOGGER:	STATIC WATER LEVEL: 892.30
GEOLOGIST: J. M. STANGL	WATER LEVEL DATE: 11/6/87
SIGNATURE:	WATER LEVEL DATUM: MSL



DEPTH IN FEET BELOW LS.	SAMPLER BLOWS	PERCENT RECOVERY	LITHOLOGY	SAMPLE DESCRIPTION	WELL CONSTRUCTION
0	3-5-8			SAND - MEDIUM TO COARSE WITH GRAVEL	
	4-8-14				
10	3-4-4			SAND - MEDIUM TO COARSE WITH GRAVEL	
	3-4-6				
20	7-19-30				
				SAND - FINE	
	7-12-15				
30	5-9-7				
	4-5-10				
40	4-5-7			BORING TERMINATED	
50					

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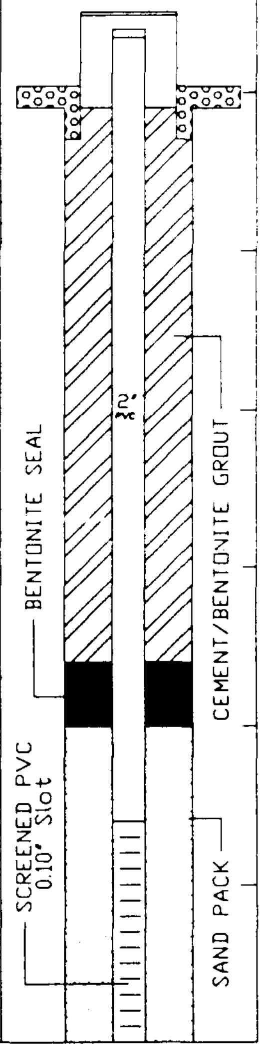
WELL COMPLETION RECORDS FOR MONITORING WELLS

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 1 OF 2
WELL/BORING LOCATION BC2-MW1 PROJECT I.D. AT103
COORDINATES 3878.9 E. 4712.8 N. DRILLING STARTED 11/14/88
ES GEOLOGIST/ENGINEER H.R. Vincent SIGNATURE
DRILLER FOX DRILLING, INC. DRILLING METHOD 6.25" HSA
DRILLING COMPLETED 11/14/88 WELL COMPLETED 11/14/88 TOTAL WELL DEPTH 38'
SCREENED INTERVALS 23-38' TOTAL BOREHOLE DEPTH 43'
SAMPLING METHOD Split-Spoon M.P. ELEV. 915.43 L.S. ELEV. 914.2
WATER LEVEL, FT. BELOW M.P. 26.82' ELEVATION 888.64 DATE 1/10/89

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0	SS1 0.2	100		SAND, medium, silty, brown.		
5	SS2 0.2	100	4,4,4	SAND, fine, tan		
10	SS3 1.2	100	5,7,8	SAND, medium, dark minerals, brown.		
15	SS4 0.1	100	8,10,11	SILT and SAND, fine, moist.		
20	SS5 1.6	100	7,7,10	SAND, fine, dark minerals.		
25	SS6 0.9	100	2,6,6	SAND, fine, dark minerals, wet.		
30	SS7 0.5	100	5,7,9	SAND, fine, dark minerals, wet.		



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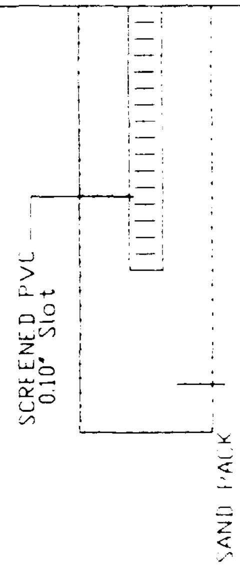
DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI   PAGE 2 OF 2
WELL/BORING LOCATION BC2-MW1   PROJECT ID AT103
COORDINATES 3978.9 E. 4712.8 N.   DRILLING STARTED 11/14/88
ES GEOLOGIST/ENGINEER HR Vincent   SIGNATURE

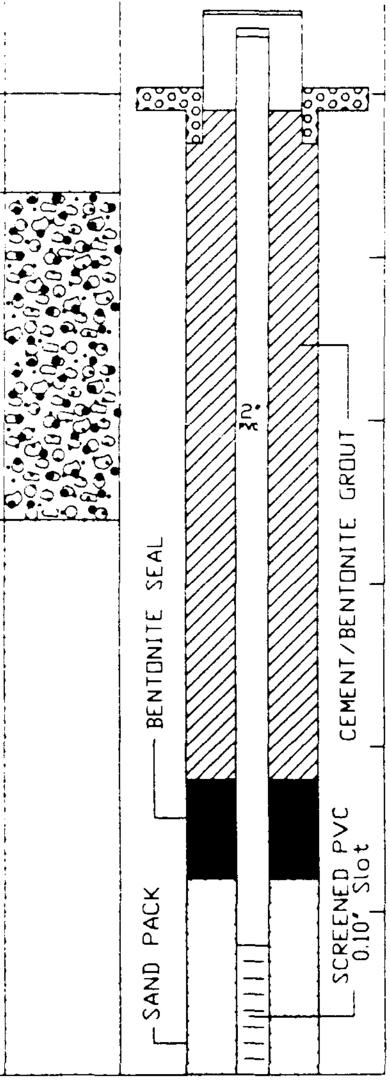
DEPTH BELOW LS	HNU/OVA	% REC	NO BLOWS	SAMPLE DESCRIPTION	LITHOLOGY	WELL CONSTRUCTION
				Same as above		
35						
40 SS9	0.1	100	2,3,3			
				B.T at 43'		
45						

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 2
WELL/BORING LOCATION BC3-MW1 PROJECT I.D. AT103
COORDINATES 3364.0 E. 3720.8 N. DRILLING STARTED 11/17/88
ES GEOLOGIST/ENGINEER H.R. Vincent SIGNATURE
DRILLER FOX DRILLING, INC. DRILLING METHOD 6.25" HSA
DRILLING COMPLETED 11/17/88 WELL COMPLETED 11/17/88 TOTAL WELL DEPTH 41'
SCREENED INTERVALS 26-41' TOTAL BOREHOLE DEPTH 41'
SAMPLING METHOD Split-Spoon M.P. ELEV. 923.16 L.S. ELEV. 921.9
WATER LEVEL, FT BELOW M.P. 32.08' ELEVATION 891.08 DATE 1/10/89

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION
0	SS1 0.8	100		SAND, fine to medium, some silt, light reddish-brown.
5	SS2 2.4	100	4,5,7	SAND and GRAVEL, medium to coarse.
10	SS3 0.4	100	6,9,11	As above with trace cobbles.
15	SS4 0.2	100	3,3,3	SAND, medium, light brown to tan, black oily appearance.
20	SS5 4.1	100	6,8,6	SAND, fine to medium, light brown to tan, some dark minerals.
25	SS6 0.9	100	6,9,14	SAND, fine, trace dark minerals.
30	SS7 1.1	100	9,9,14	SAND, medium with dark minerals, saturated at 31'.

LITHO-LOGY | WELL CONSTRUCTION

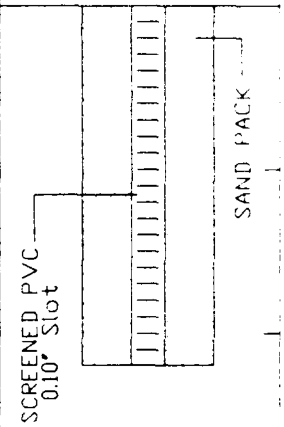


ENGINEERING-SCIENCE, INC

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 2 OF 2
WELL/BORING LOCATION BC3-MW1 PROJECT I.D. AT103
COORDINATES 3364.0 E. 3720.8 N. DRILLING STARTED 11/17/88
ES GEOLOGIST/ENGINEER H.R. Vincent SIGNATURE

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHOLOGY	WELL CONSTRUCTION
				Same as above.		
35	0.0			GRAVEL, some sand, coarse, saturated.	○○○	
40	SSB 0.4	100	13,16,17			
				B.T. at 41'		
45						



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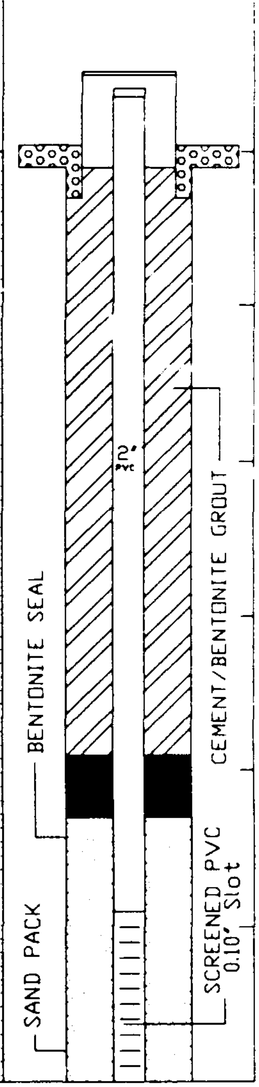
DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 1 OF 2
WELL/BORING LOCATION BC3-MW2 PROJECT I.D. AT103
COORDINATES 3261.3 E. 3932.4 N. DRILLING STARTED 11/17/88
ES GEOLOGIST/ENGINEER R.S. Bonner SIGNATURE
DRILLER FOX DRILLING, INC. DRILLING METHOD 6.25" HSA
DRILLING COMPLETED 11/17/88 WELL COMPLETED 11/17/88 TOTAL WELL DEPTH 39.5'
SCREENED INTERVALS 24.5-39.5' TOTAL BOREHOLE DEPTH 40'
SAMPLING METHOD Split-Spoon M.P. ELEV. 920.73 L.S. ELEV. 919.7
WATER LEVEL, FT. BELOW M.P. 30.24' ELEVATION 890.49 DATE 1/10/89

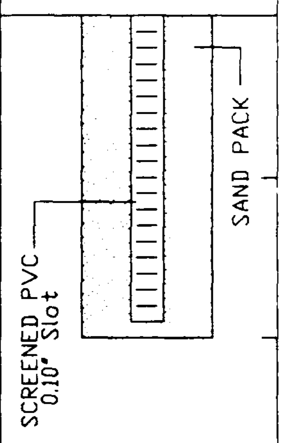
DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0	SS1 0.1			SAND, medium, trace silt, trace dark minerals, organic rich upper portion, moderate yellowish-brown.		
5	SS2 0.2	100	3,4,6	SAND, medium to coarse, little pebbles, trace silt, trace dark minerals, moderate yellowish-brown.		
10	SS3 0.4	100	7,10,10			
				Drilling cobbles at 12'.		
15	SS4 0.3	100	4,4,7	SAND, fine trace silt, grayish-orange, slightly moist.		
20	SS5 0.2	100	7,10,13			
25	SS6 0.2	100	6,11,11			
30	SS7 50.0	100	2,4,6	SAND, fine to medium, trace silt, trace gravel, fine, olive-gray, saturated, strong product odor.		

ENGINEERING-SCIENCE, INC.

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 2 OF 2
WELL/BORING LOCATION BC3-MW2 PROJECT I.D. AT103
COORDINATES 3261.3 E. 3932.4 N. DRILLING STARTED 11/17/88
ES GEOLOGIST/ENGINEER R.S. Bonner SIGNATURE

DEPTH BELOW L.S.	HNU/OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHOLOGY	WELL CONSTRUCTION
35						
40	SS8 0.2	100	2,2,2	SAND, fine, trace silt, grayish olive, wet.		
				B.T. at 40'		
45						

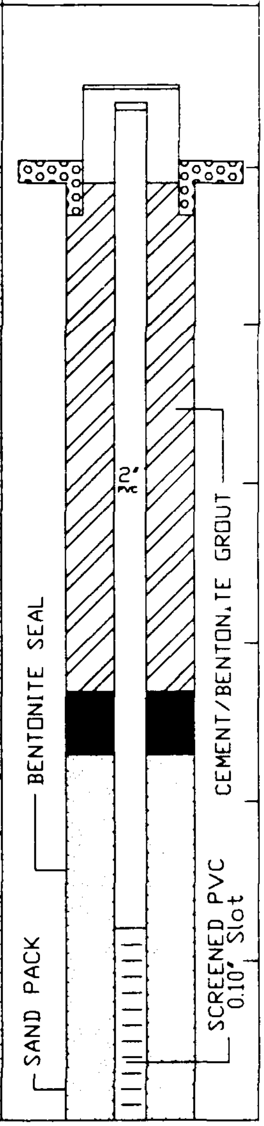


DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 1 OF 2
WELL/BORING LOCATION BC3-MW3 PROJECT I.D. AT103
COORDINATES 3352.4 E. 3976.3 N. DRILLING STARTED 11/18/88
ES GEOLOGIST/ENGINEER R.S. Bonner SIGNATURE
DRILLER FOX DRILLING, INC. DRILLING METHOD 6.25' HSA
DRILLING COMPLETED 11/18/88 WELL COMPLETED 11/18/88 TOTAL WELL DEPTH 39'
SCREENED INTERVALS 24-39' TOTAL BOREHOLE DEPTH 40'
SAMPLING METHOD Split-Spoon M.P. ELEV. 920.30 L.S. ELEV. 919.4
WATER LEVEL, FT. BELOW M.P. 29.86' ELEVATION 890.44 DATE 1/10/89

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY
0					
	SS1 0.8	100		SAND, fine to medium, little silt, organic rich layer in upper portion, moderate brown, cobbles.	
5	SS2 0.1	100	1,1,3	SAND, medium to coarse, little pebbles, trace silt, moderate brown.	
10	SS3 30.0	100	5,7,9	SAND, fine to medium, trace silt, moderate yellowish-brown.	
15	SS4 1.2	100	6,6,14	SAND, medium to coarse, moderate brown, (drilling cobbles at 15-18').	
20	SS5 0.8	10	8,10,13	SAND and GRAVEL, medium to coarse. (drilling cobbles at 21').	
25	SS6 1.0	85	8,8,8	SAND, fine, light brown to tan.	
30	SS7 0.5	100	3,8,8	SAND, fine, light brown to tan.	

WELL CONSTRUCTION



ENGINEERING-SCIENCE, INC.

DRILLING AND WELL COMPLETION RECORD

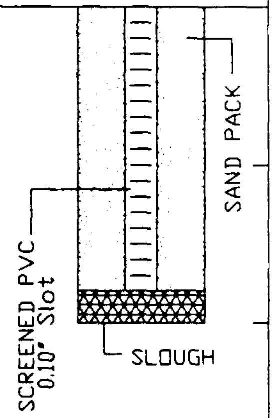
JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 2 OF 2

WELL/BORING LOCATION BC3-MW3 PROJECT I.D. AT103

COORDINATES 3352.4 E. 3976.3 N. DRILLING STARTED 11/18/88

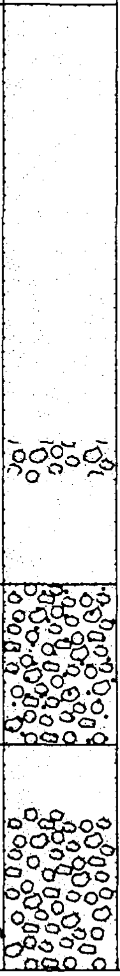
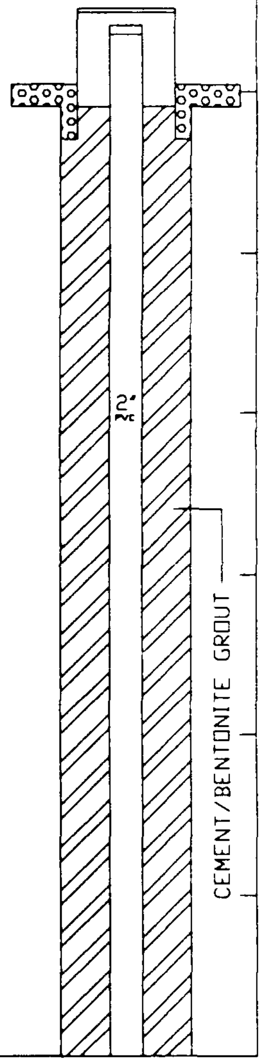
ES GEOLOGIST/ENGINEER R.S. Bonner SIGNATURE

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
35				Same as above.		
40	sse 0.1	100	4,6,11			
				B.T. at 40'		
45						



DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 1 OF 3
WELL/BORING LOCATION BC3-MW4 PROJECT I.D. AT103
COORDINATES 3301.3 E. 4029.5 N. DRILLING STARTED 11/20/88
ES GEOLOGIST/ENGINEER H.R. Vincent SIGNATURE
DRILLER FOX DRILLING, INC. DRILLING METHOD 6.0" HSA & Mud Rotary
DRILLING COMPLETED 11/22/88 WELL COMPLETED 11/22/88 TOTAL WELL DEPTH 65'
SCREENED INTERVALS 55-65' TOTAL BOREHOLE DEPTH 76' (68.5')
SAMPLING METHOD Split-Spoon M.P. ELEV. 920.42 L.S. ELEV. 918.6
WATER LEVEL, FT. BELOW M.P. 30.52' ELEVATION 889.90 DATE 1/10/89

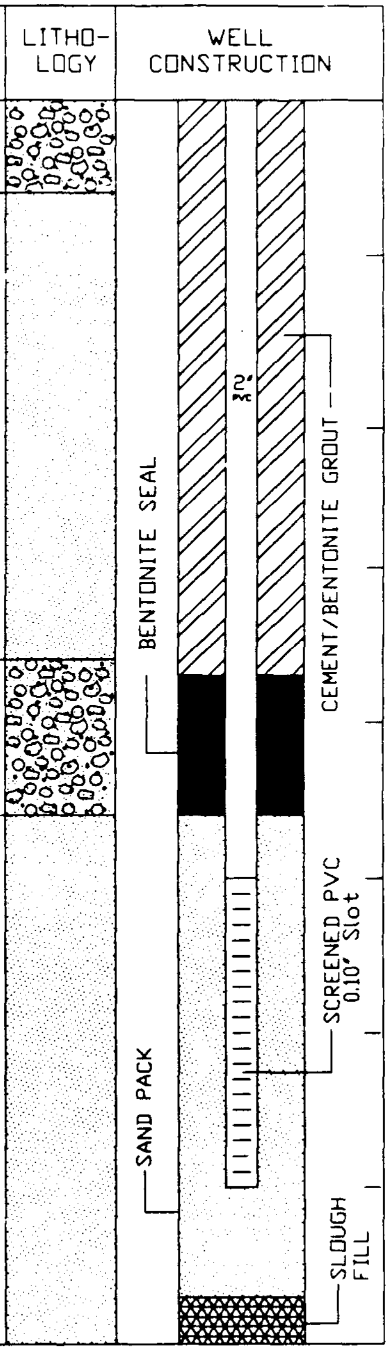
DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0	SS1 0.0	100		SAND, fine to medium, silty, reddish-brown.		
5	SS2 0.4	100	4,5,7	As above but dark brown.		
10	SS3 11.0	100	2,8,5	As above but light reddish-brown.		
15	SS4 13.8	100	8,11,15	SAND and GRAVEL layer at 13.5-14.5'.		
20	SS5 5.0	100	12,22,25	SAND and GRAVEL, light reddish-brown.		
25	SS6 0.2	100	8,11,11	SAND, medium to coarse, some gravel, light brown.		
	SS7 9.4	50	8,8,9	SAND and GRAVEL, light brown saturated, fuel odor.		

ENGINEERING-SCIENCE, INC.

DRILLING AND WELL COMPLETION RECORD

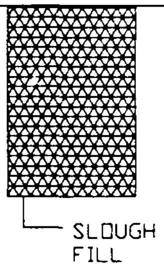
JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 2 OF 3
WELL/BORING LOCATION BC3-MW4 PROJECT I.D. AT103
COORDINATES 3301.3 E. 4029.5 N. DRILLING STARTED 11/20/88
ES GEOLOGIST/ENGINEER H.R. Vincent SIGNATURE

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION
				Same as above.
35	SS8 0.4	100	3,8,8	SAND, fine, dark minerals, light to moderate yellowish-brown
40	SS9 0.0	100	0,0,0	
45	SS10 0.2	100	8,12,14	
50	SS11 0.6	100	10,12,14	SAND and GRAVEL, dark yellowish-brown, cobbles.
55	SS12 0.3	100	9,17,17	SAND, medium, dark mineral present, olive gray.
60	SS13 0.3	100	11,11,13	As above with dark soft black rock fragments present.
65	SS14 0.4	100	8,10,7	SAND, fine to medium, some gravel, rock fragments of sandstone and shale. Drilling hard at 67'.
	SS15 0.4	100	14,30,23	



DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 3 OF 3
WELL/BORING LOCATION BC3-MW4 PROJECT I.D. AT103
COORDINATES 3301.3 E. 4029.5 N. DRILLING STARTED 11/20/88
ES GEOLOGIST/ENGINEER H.R. Vincent SIGNATURE

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
75	SS16 0.4	100	13,20,22	Same as above.		
				B.T. at 76'		
80						

ENGINEERING-SCIENCE, INC.

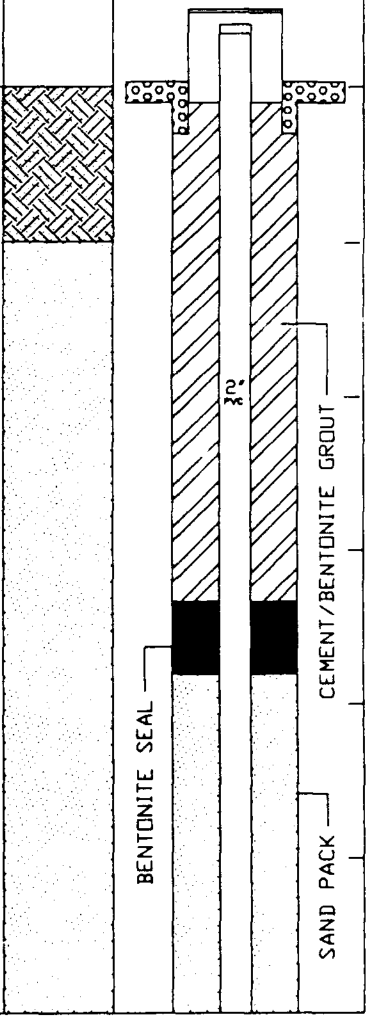
DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 1 OF 2
WELL/BORING LOCATION BC3-MW5 PROJECT I.D. AT103
COORDINATES 3070.1 E. 4047.0 N. DRILLING STARTED 8/27/89
ES GEOLOGIST/ENGINEER J. BURGIN SIGNATURE
DRILLER FOX DRILLING, INC. DRILLING METHOD 6.25' HSA
DRILLING COMPLETED 8/28/89 WELL COMPLETED 8/28/89 TOTAL WELL DEPTH 37'
SCREENED INTERVALS 22-37' TOTAL BOREHOLE DEPTH 40'
SAMPLING METHOD Split-Spoon M.P. ELEV. 920.28 L.S. ELEV 918.74
WATER LEVEL, FT. BELOW M.P. 30.63' ELEVATION 889.65 DATE 9/6/89

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION
0				
5	SS1 0.2	60	3,4,6	SAND and LOAM, fine, trace silt, light brown, damp, little dark staining.
10	SS2 0.1	20	35/5'	SAND, some gravel, fine to coarse, moderate to dark yellowish brown, damp.
15	SS3 0.05	80	5,7,7	SAND, fine, moderate yellowish-brown, damp.
20	SS4 0.05	70	10,10,10	SAND, fine, grayish-orange, moist, trace silt.
25	SS5 0.05	85	6,12,10	SAND, fine, yellowish-gray.
				WATER at 27 Ft.
	SS6 0	70	10,12,16	SAND, fine, yellowish-gray, wet.

LITHO-LOGY

WELL CONSTRUCTION

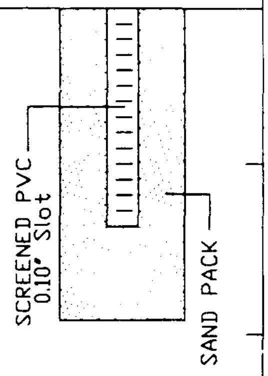


ENGINEERING-SCIENCE, INC.

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 2 OF 2
WELL/BORING LOCATION BC3-MW5 PROJECT I.D. AT103
COORDINATES 3070.1 E. 4047.0 N. DRILLING STARTED 8/27/89
ES GEOLOGIST/ENGINEER J. BURGIN SIGNATURE

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
35				SAND, fine, wet. Well completed at 37 feet.		
40			12,14,15			



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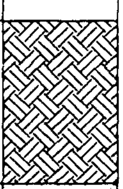
DRILLING AND WELL COMPLETION RECORD

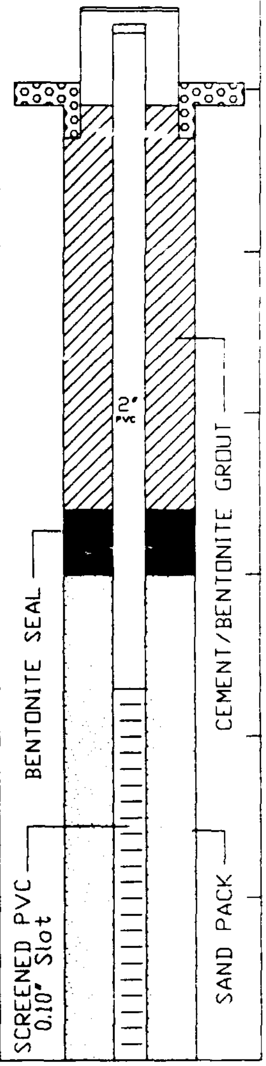
JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 1 OF 2
WELL/BORING LOCATION BC3-MW6 PROJECT I.D. AT103
COORDINATES 3223.2 E. 4400.0 N. DRILLING STARTED 8/27/89
ES GEOLOGIST/ENGINEER J. Burgin SIGNATURE
DRILLER FOX DRILLING, INC DRILLING METHOD 6.25" HSA
DRILLING COMPLETED 8/27/89 WELL COMPLETED 8/27/89 TOTAL WELL DEPTH 33.5'
SCREENED INTERVALS 18.5-33.5' TOTAL BOREHOLE DEPTH 33.5'
SAMPLING METHOD Split-Spoon M.P. ELEV. 913.42 L.S. ELEV. 911.92
WATER LEVEL, FT BELOW M.P. 24.98' ELEVATION 888.44 DATE 9/14/89

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION
0				
5	SS1 0.8	70	1,2,3	LOAM, trace sand, trace silt, fine, trace pebbles, loose, moderate brown.
10	SS2 0.0	70	3,4,7	SAND, medium to coarse, pale yellowish-brown at 6.5', moist some pebbles.
15	SS3 0.0	80	8,8,11	SAND, fine, yellowish-gray, trace silt, moist.
20	SS4 0.0	80	9,9,11	SAND, coarse to fine, moist, yellowish-gray, some pebbles, some cobbles.
25	SS5 0.1	70	12,7,6	WATER at 23.5'. SAND, medium to fine, wet, yellowish-gray, some pebbles, trace cobbles.

LITHOLOGY



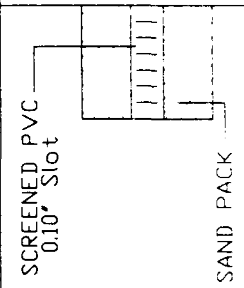
WELL CONSTRUCTION



ENGINEERING-SCIENCE, INC.

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 2 OF 2
WELL/BORING LOCATION BC3-MW6 PROJECT I.D. AT103
COORDINATES 3223.2 E. 4400.0 N. DRILLING STARTED 8/27/89
ES GEOLOGIST/ENGINEER J. Burgin SIGNATURE

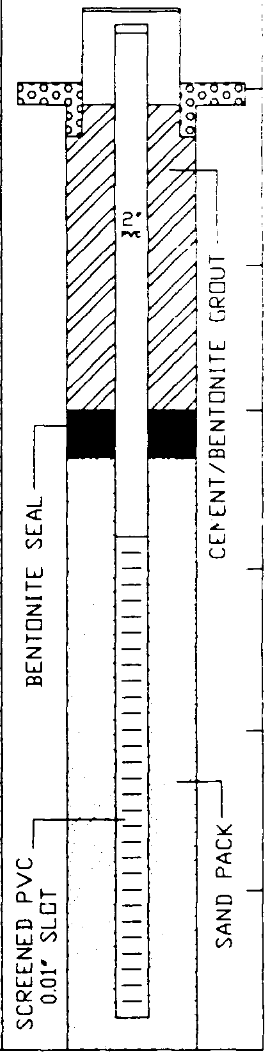
DEPTH BELOW LS	HNU/OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHOLOGY	WELL CONSTRUCTION
				Same as above.		
35	SS6 0.1	95	7,10,8	B.T. at 33′		
40						

ENGINEERING-SCIENCE, INC.

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 1 OF 1
WELL/BORING LOCATION BC4-MW1 PROJECT I.D. AT103
COORDINATES 2353.9 E. 1593.8 N. DRILLING STARTED 11/7/88
ES GEOLOGIST/ENGINEER M.E. HERRMANN SIGNATURE
DRILLER FOX DRILLING, INC. DRILLING METHOD 6.25" HSA
DRILLING COMPLETED 11/7/88 WELL COMPLETED 11/7/88 TOTAL WELL DEPTH 29'
SCREENED INTERVALS 14-29' TOTAL BOREHOLE DEPTH 30'
SAMPLING METHOD Split-Spoon M.P. ELEV. 917.12 L.S. ELEV. 915.3
WATER LEVEL, FT. BELOW M.P. 18.62' ELEVATION 898.45 DATE 1/10/89

DEPTH BELOW L.S.	HNU/OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHOLOGY	WELL CONSTRUCTION
0						
5	0	100	6,6,7	SAND, medium, tannish-brown, trace coarse, slightly moist.		
10	0	100	8,3,19	SAND, fine to medium, light brown.		
15	0	100	12,15,12			
				Saturated at 18'.		
20	0	100	10,10,8			
25	0	100	3,3,4			
	0	100	3,3,3	B.T. at 30'		

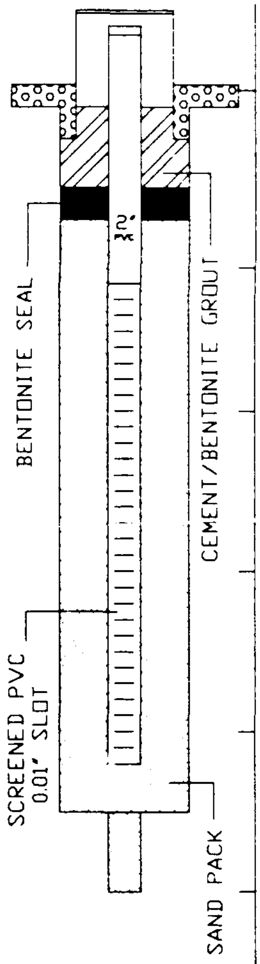


ENGINEERING-SCIENCE, INC.

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 1
WELL/BORING LOCATION BC4-MW2 PROJECT I.D. AT103
COORDINATES 1918.3 E. 1802.8 N. DRILLING STARTED 11/7/88
ES GEOLOGIST/ENGINEER M.E. HERRMANN SIGNATURE
DRILLER FOX DRILLING, INC. DRILLING METHOD 6.25" HSA
DRILLING COMPLETED 11/7/88 WELL COMPLETED 11/7/88 TOTAL WELL DEPTH 21'
SCREENED INTERVALS 6-21' TOTAL BOREHOLE DEPTH 25'
SAMPLING METHOD Split-Spoon M.P. ELEV. 906.39 L.S. ELEV. 904.4
WATER LEVEL, FT. BELOW M.P. 10.00' ELEVATION 895.99 DATE 1/10/89

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO- LOGY	WELL CONSTRUCTION
0				SAND, silty, dark brown, slightly moist.		
5	0	100	4,4,7	SAND, orange-brown, slightly moist.		
10	0	100	4,4,6	SAND, medium to fine, orange-brown, wet.		
15	0	100	0,0,0	Same as above.		
20	0	100	2,2,2			
25			4,6,8			
				B.T. at 25'		



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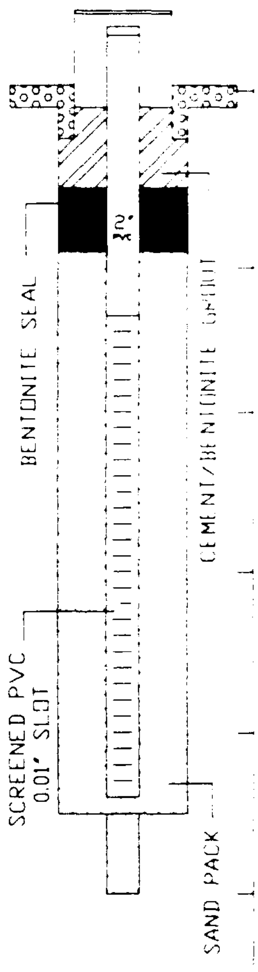
DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 1
WELL/BORING LOCATION BC4-MW3 PROJECT ID AT103
COORDINATES 2064.6 E. 2049.5 N. DRILLING STARTED 11/8/88
ES GEOLOGIST/ENGINEER M.E. HERRMANN SIGNATURE
DRILLER FOX DRILLING, INC. DRILLING METHOD 6.25" HSA
DRILLING COMPLETED 11/8/88 WELL COMPLETED 11/8/88 TOTAL WELL DEPTH 22'
SCREENED INTERVALS 7-22' TOTAL BOREHOLE DEPTH 23.5'
SAMPLING METHOD Split-Spoon M.P. ELEV. 907.02 L.S. ELEV. 905.4
WATER LEVEL, FT. BELOW M.P. 13.97' ELEVATION 893.05 DATE 1/10/89

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHOLOGY	WELL CONSTRUCTION
0				SAND, silty, dark brown 0 to 0.5'. SAND, medium, tannish brown slightly moist.		
5	0	80	3,4,4	SAND, grayish-orange.		
10	0	80	3,7,7	SAND, medium, brown.		
				Water encountered at 12'.		
15	0	100	8,10,20	SAND, medium, brown.		
20	0	100	2,2,2	As above, with black lamination.		
25		100	1,1,1			
				B.T. at 25'		

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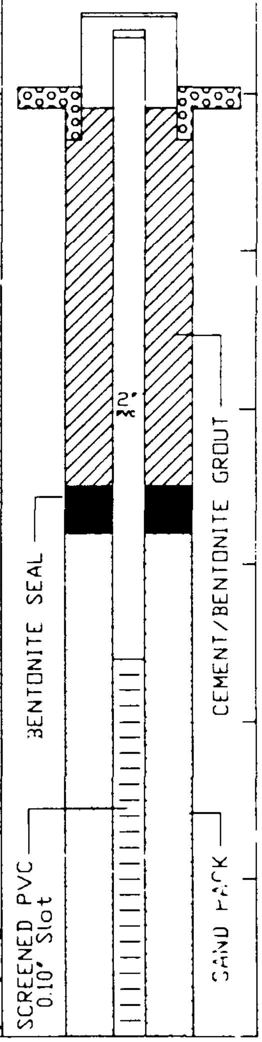
DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 1 OF 2
WELL/BORING LOCATION BC4-MW4 PROJECT I.D. AT103
COORDINATES 2266.3 E. 2314.2 N. DRILLING STARTED 11/8/88
ES GEOLOGIST/ENGINEER M.E. Herrmann SIGNATURE
DRILLER FOX DRILLING, INC. DRILLING METHOD 6.25' HSA
DRILLING COMPLETED 11/18/88 WELL COMPLETED 11/18/88 TOTAL WELL DEPTH 33'
SCREENED INTERVALS 18-33' TOTAL BOREHOLE DEPTH 35'
SAMPLING METHOD Split-Spoon M.P. ELEV. 915.69 L.S. ELEV. 914.2
WATER LEVEL, FT. BELOW M.P. 23.71' ELEVATION 891.98 DATE 1/10/89

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY
0					
5	SS1	90	2,3,5	SAND, silty, dark brown 0-0.5'. SAND, medium to coarse, trace gravel, moderate yellowish-brown.	
10	SS2	80	8,6,4	SAND, coarse, trace to some gravel, trace cobbles, grayish-brown, slightly moist.	
15	SS3	60	4,6,11	SAND, fine to medium, grayish-brown, slightly moist.	
20	SS4	60	8,11,13	As above with coarse sand and gravel interbeds.	
25	SS5	70	7,15,20	SAND and GRAVEL, trace silt, moderate brown.	○●○●
	SS6		4,9,10	SAND and GRAVEL, poorly sorted, orange-brown.	○●○●

WELL CONSTRUCTION



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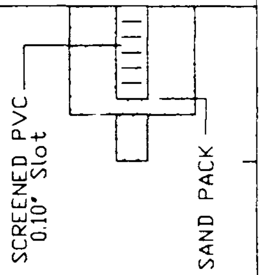
DRILLING AND WELL COMPLETION RECORD

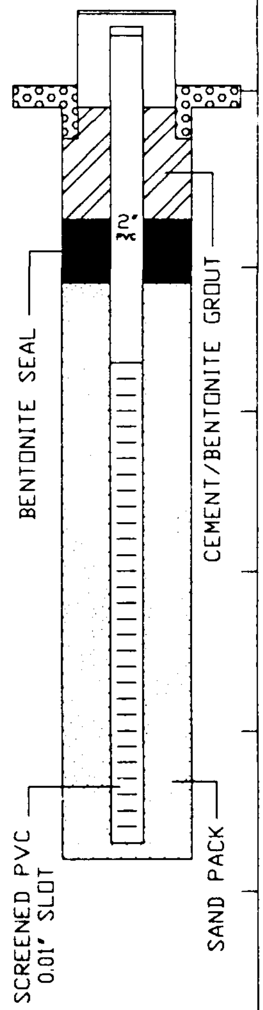
JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 2 OF 2
WELL/BORING LOCATION BC4-MW4 PROJECT I.D. AT103
COORDINATES 2266.3 E. 2314.2 N. DRILLING STARTED 11/8/88
ES GEOLOGIST/ENGINEER M.E. Herrmann SIGNATURE

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
				SAND and GRAVEL, poorly sorted, orange-brown.	○●○●	
35	SS7		4,10,25	SAND, coarse, trace silt, grayish-brown, wet.		
				B.T. at 33'		
40						

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 1 OF 1
WELL/BORING LOCATION BC5-MW1 PROJECT I.D. AT103
COORDINATES 3383.9 E. 4604.8 N. DRILLING STARTED 11/16/88
ES GEOLOGIST/ENGINEER H.R. Vincent SIGNATURE
DRILLER FOX DRILLING, INC. DRILLING METHOD 6.25" HSA
DRILLING COMPLETED 11/16/88 WELL COMPLETED 11/16/88 TOTAL WELL DEPTH 23.5'
SCREENED INTERVALS 8.5-23.5' TOTAL BOREHOLE DEPTH 24'
SAMPLING METHOD Split-Spoon M.P. ELEV. 901.81 L.S. ELEV. 900.5
WATER LEVEL, FT. BELOW M.P. 14.10' ELEVATION 887.71 DATE 1/10/89

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0	0	100		SAND, medium, silty, reddish-brown.		
5	110	10	7,8,14	SAND and GRAVEL, reddish-brown, fuel odor, cobbles at 6'.		
10	0	50	4,4,7	As above with some organics. Cobbles at 12'.		
15	0.2	5	5,7,9	Water encountered at 14'. SAND, fine, light brown.		
20		50		SAND, medium to coarse, brown.		
25			1,1,1	B.T. at 24'		

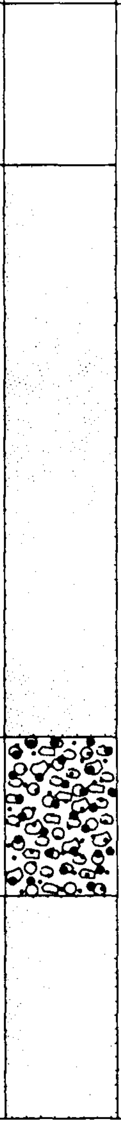


DRILLING AND WELL COMPLETION RECORD

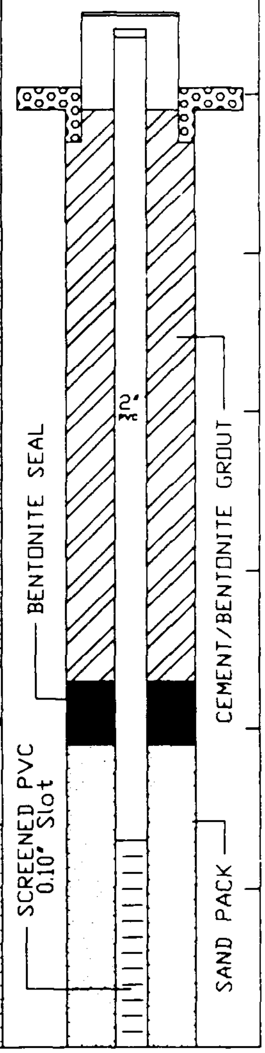
JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 1 OF 2
WELL/BORING LOCATION BC6-MW1 PROJECT I.D. AT103
COORDINATES 4039.9 E. 4317.2 N. DRILLING STARTED 11/16/88
ES GEOLOGIST/ENGINEER H.R. Vincent SIGNATURE
DRILLER FOX DRILLING, INC. DRILLING METHOD 6.25" HSA
DRILLING COMPLETED 11/16/88 WELL COMPLETED 11/16/88 TOTAL WELL DEPTH 38.5'
SCREENED INTERVALS 23.5-38.5' TOTAL BOREHOLE DEPTH 41'
SAMPLING METHOD Split-Spoon M.P. ELEV. 921.89 L.S. ELEV. 921.0
WATER LEVEL, FT. BELOW M.P. 31.82' ELEVATION 890.07 DATE 1/10/89

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION
0	SS1 0.1	100		SAND, silty, trace pebbles, light brown, moist.
5	SS2 1.8	100	3,3,3	SAND, medium, silty, reddish-brown.
10	SS3 0.3	100	3,3,4	SAND, fine to medium, some pebbles, reddish-brown, moist. Drilling hard at 13'.
15	SS4 2.6	100	3,4,7	SAND, medium to coarse with dark minerals, light reddish-brown, moist. Drilling hard at 17'.
20	SS5 0.4			SAND and GRAVEL.
25	SS6 0.7	100	6,6,7	SAND, fine, dark minerals, light brown to tan, slightly moist.
30	SS7 2.1	100	11,12,15	SAND, fine, dark minerals, light brown to tan. Water encountered at 30'.

LITHO-LOGY

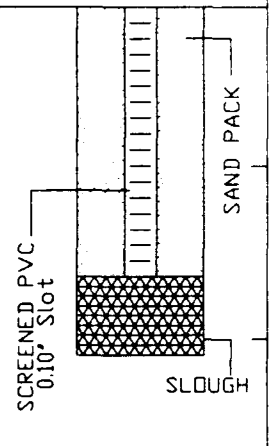


WELL CONSTRUCTION



DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 2 OF 2
WELL/BORING LOCATION BC6-MW1 PROJECT I.D. AT103
COORDINATES 4039.9 E. 4317.2 N. DRILLING STARTED 11/16/88
ES GEOLOGIST/ENGINEER H.R. Vincent SIGNATURE

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
35						
40	SS8 0.1	100	1,1,1	SAND, medium, heavy minerals, saturated.		
				B.T. at 41'		
45						

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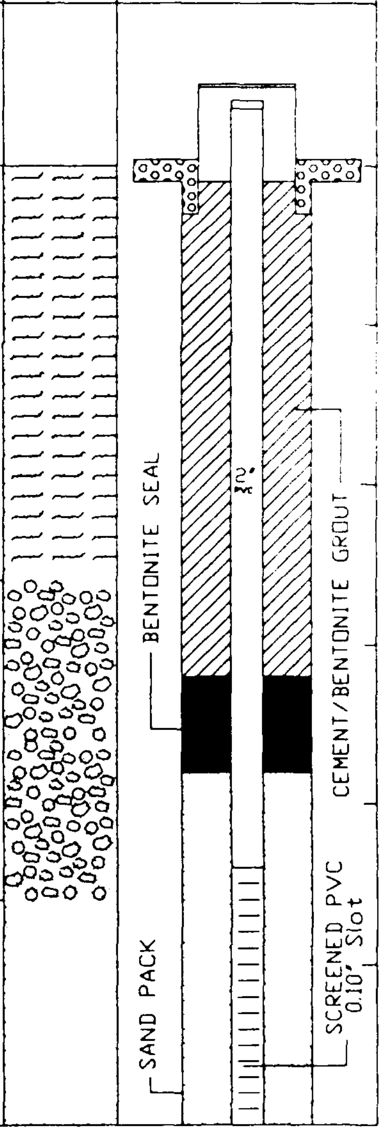
DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 1 OF 2
WELL/BORING LOCATION BC6-MW2 PROJECT I.D. AT103
COORDINATES 3793.1 E. 4319.4 N. DRILLING STARTED 11/15/88
ES GEOLOGIST/ENGINEER H.R. Vincent SIGNATURE
DRILLER FOX DRILLING, INC. DRILLING METHOD 6.25" HSA
DRILLING COMPLETED 11/15/88 WELL COMPLETED 11/15/88 TOTAL WELL DEPTH 37'
SCREENED INTERVALS 22-37' TOTAL BOREHOLE DEPTH 39'
SAMPLING METHOD Split-Spoon M.P. ELEV. 918.29 L.S. ELEV. 917.2
WATER LEVEL, FT. BELOW M.P. 28.42' ELEVATION 889.87 DATE 1/10/89

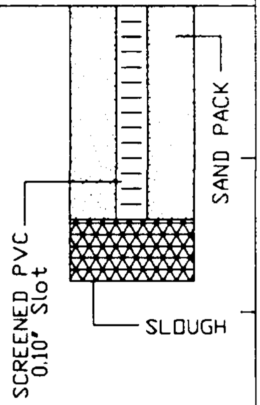
DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0	SS1 0.1	100		SAND, fine, silty, reddish-brown.		
5	SS2 0.0	100	3,3,3	As above and moist.		
10	SS3 0.0	100	7,6,5	SAND, fine to medium, silty, reddish-brown, moist.		
15	SS4 0.4	100	5,5,11	SAND, medium to coarse, and gravel, light brown, moist.		
20	SS5 4.0	100	11,11,12	As above with slight fuel(?) odor. Drilling hard at 21'.		
25	SS6 0.8	100	10,10,12	SAND, fine dark minerals, light tan, moist. Water encountered at 27.5'.		
30	SS7 0.0	100	4,5,5	SAND, fine dark minerals, light tan, moist.		



ENGINEERING-SCIENCE, INC.

DRILLING AND WELL COMPLETION RECORD

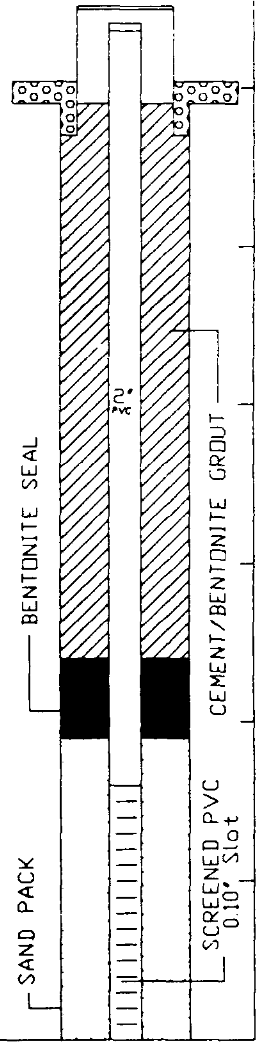
JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 2 OF 2
WELL/BORING LOCATION BC6-MW2 PROJECT I.D. AT103
COORDINATES 3793.1 E. 4319.4 N. DRILLING STARTED 11/15/88
ES GEOLOGIST/ENGINEER H.R. Vincent SIGNATURE

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
35	SS8 0.3	100	2,2,3	SAND, fine to medium, dark minerals, tan, moist.		
40				B.T. at 39'		
45						

ENGINEERING-SCIENCE, INC.

DRILLING AND WELL COMPLETION RECORD

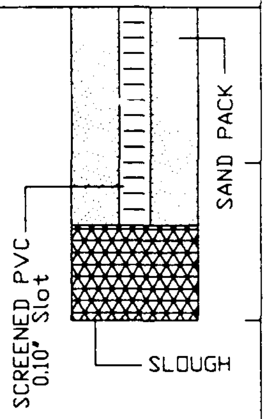
JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 1 OF 2
WELL/BORING LOCATION BC6-MW3 PROJECT I.D. AT103
COORDINATES 3620.5 E. 4171.4 N. DRILLING STARTED 11/14/88
ES GEOLOGIST/ENGINEER H.R. Vincent SIGNATURE
DRILLER FOX DRILLING, INC. DRILLING METHOD 6.25' HSA
DRILLING COMPLETED 11/15/88 WELL COMPLETED 11/15/88 TOTAL WELL DEPTH 37'
SCREENED INTERVALS 22-37' TOTAL BOREHOLE DEPTH 40'
SAMPLING METHOD Split-Spoon M.P. ELEV. 919.51 L.S. ELEV. 918.1
WATER LEVEL, FT. BELOW M.P. 29.40' ELEVATION 890.11 DATE 1/10/89

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO- LOGY	WELL CONSTRUCTION
0	SS1 0.2	100		SAND, fine to medium, silty, light brown to tan.		
5	SS2 0.2	100	3,4,6	SAND, medium to coarse, with pebbles, light brown.		
10	SS3 0.3	100	5,7,7	SAND, medium, with dark minerals, yellow-brown to tan. Drilling hard.		
15	SS4 0.0	100	7,7,19	SAND, medium to coarse, some pebbles, dark minerals, light brown to tan.		
20	SS5 0.1	100	6,9,7	SAND, medium to fine with dark minerals, tan.		
25	SS6 0.2	100	7,8,8	SAND, medium to coarse with dark minerals, light tan.		
30	SS7 0.1	100	6,7,20	SAND, medium to coarse with dark minerals, light tan.		

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 2 OF 2
WELL/BORING LOCATION BC6-MW3 PROJECT I.D. AT103
COORDINATES 3620.5 E. 4171.4 N. DRILLING STARTED 11/14/88
ES GEOLOGIST/ENGINEER H.P. Vincent SIGNATURE

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
35						
40	SS8 0.0	100	2,2,3	SAND, medium, dark minerals, saturated.	▒	
				B.T. at 40'		
45						



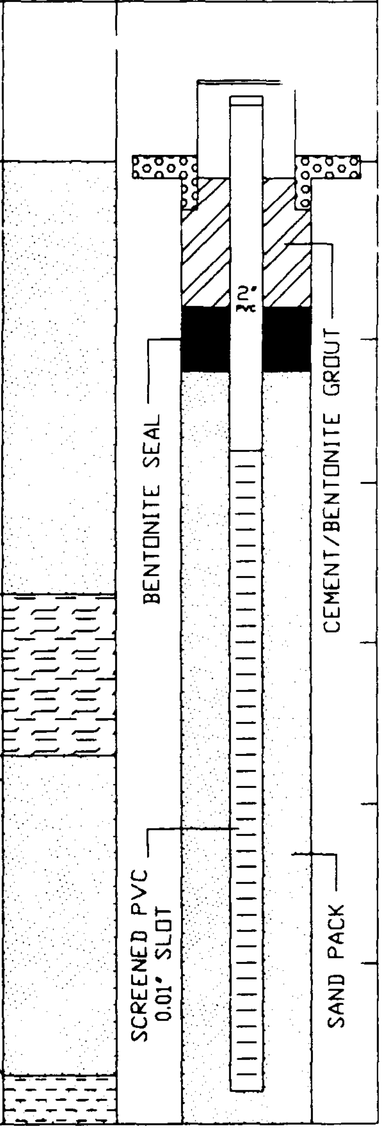
ENGINEERING-SCIENCE, INC.

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 1 OF 1
WELL/BORING LOCATION BC-MW11 PROJECT I.D. AT103
COORDINATES 4990.4 E. 3006.1 N. DRILLING STARTED 8/31/89
ES GEOLOGIST/ENGINEER J. BURGIN SIGNATURE
DRILLER FOX DRILLING, INC. DRILLING METHOD 6.25' HSA
DRILLING COMPLETED 8/31/89 WELL COMPLETED 8/31/89 TOTAL WELL DEPTH 29'
SCREENED INTERVALS 9-29' TOTAL BOREHOLE DEPTH 30'
SAMPLING METHOD Split-Spoon M.P. ELEV. 921.09 L.S. ELEV. 920.44
WATER LEVEL, FT. BELOW M.P. 25' ELEVATION 896.09 DATE 9/6/89

DEPTH BELOW L.S.	HNU/OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION
0				
5	SS1 0	80	7,10,7	SAND, medium, medium to dark yellowish-brown, some black staining (organics); some clay (thin layer from ~4-4.5'), light olive-gray.
10	SS2 0	80	13,14,13	SAND, medium to coarse, moderate yellowish-brown, with trace pebbles, (moderately sorted); some clay (from ~9-9.4'), light olive-gray, wet.
15	SS3 0	80	1,1,2	CLAY, some silt, trace sand, light olive-gray, wet.
20	SS4 0	70	9,12,12	SAND, medium to fine, moderate yellowish brown, moist.
25	SS5 0	60	6,8,8	SAND, medium to coarse, and pebbles, trace gravel, light olive-brown, little black staining, wet.
	SS6 0	70	9,9,19	CLAY, some sand and pebbles, coarse, trace silt, moderate yellowish-brown, saturated.

LITHOLOGY / WELL CONSTRUCTION



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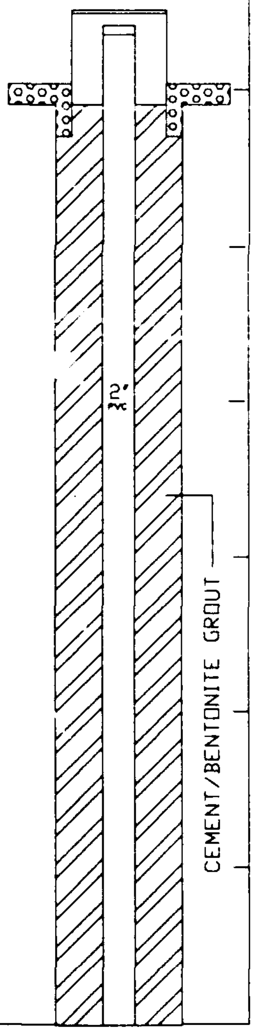
DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 1 OF 3
WELL/BORING LOCATION BC-MW12 PROJECT I.D. AT103
COORDINATES 5004.1 E. 3019.6 N. DRILLING STARTED 9/5/89
ES GEOLOGIST/ENGINEER J. BURGIN SIGNATURE
DRILLER FOX DRILLING, INC. DRILLING METHOD 6.25" HSA & Mud Rotary
DRILLING COMPLETED 9/6/89 WELL COMPLETED 9/6/89 TOTAL WELL DEPTH 83.5'
SCREENED INTERVALS 73.5-83.5' TOTAL BOREHOLE DEPTH 84.5' (90')
SAMPLING METHOD Split-Spoon M.P. ELEV. 922.32 L.S. ELEV. 920.74
WATER LEVEL, FT. BELOW M.P. 18' ELEVATION 904.32 DATE

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0				SAND, medium, medium to dark yellowish-brown, some black staining (organics); some clay (thin layer from ~4-4.5'), light olive gray.		
5						
10				SAND, medium to coarse, moderate yellowish-brown, with trace pebbles, (moderately sorted); some clay (from ~9-9.4'), light olive gray, wet.		
15				CLAY, some silt, trace sand, light olive gray, wet.		
20				SAND, medium to fine, moderate yellowish-brown, moist.		
25				SAND, medium to coarse, and pebbles, trace gravel, light olive brown, little black staining, wet.		
				CLAY, some sand and pebbles, coarse, trace silt, moderate yellowish-brown, saturated.		



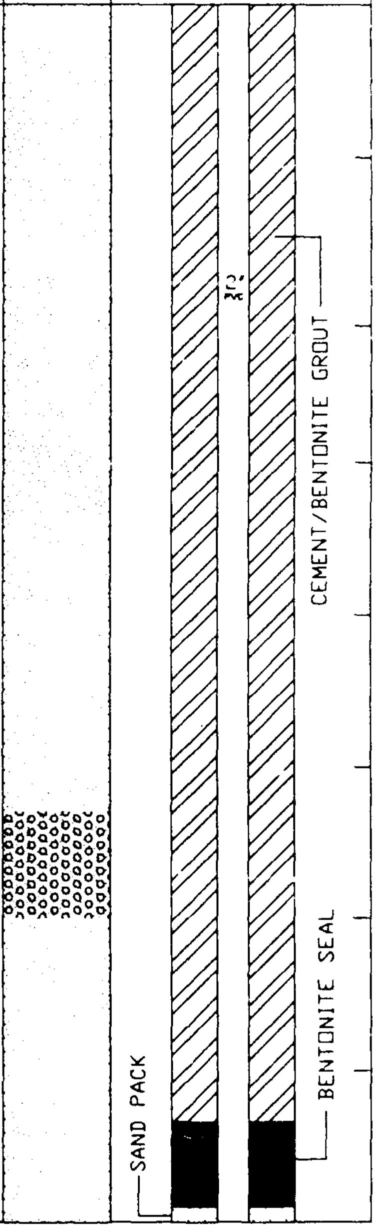
ENGINEERING-SCIENCE, INC.

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 2 OF 3
WELL/BORING LOCATION BC-MW12 PROJECT I.D. AT103
COORDINATES 5004.1 E. 3019.6 N. DRILLING STARTED 9/5/89
ES GEOLOGIST/ENGINEER J. BURGIN SIGNATURE

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION
35	SS1 0	85	17,26,17	SAND, moderate yellowish-brown, fine to medium, trace pebbles, trace clay, trace silt, trace black organics, wet.
40	SS2 0.1	85	14,18,20	SAND, moderate yellowish-brown, medium to coarse, trace gravel, some pebbles, moderately sorted, wet.
45	SS3 0	90	15,25,28	SAND, moderate yellowish-brown, medium grained, trace pebbles. Moderately sorted, wet.
50	SS4 0	70	18,23,17	Same as above.
55	SS5 0	65	21,22,31	SAND, moderate yellowish-brown, fine, trace silt, trace pebbles. Moderately sorted, wet.
60	SS6 0	80	17,26,42	SAND and PEBBLES, light olive-brown, medium to coarse, moderately sorted, wet.
65	SS7 0	70	16,27,47	SAND, light olive-gray, medium to coarse, some pebbles-subangular, well sorted.
	SS8 0	80	25,35,45	SAND, light olive-gray, medium; trace pebbles-subangular to rounded, well sorted, very moist.

LITHO-LOGY | WELL CONSTRUCTION



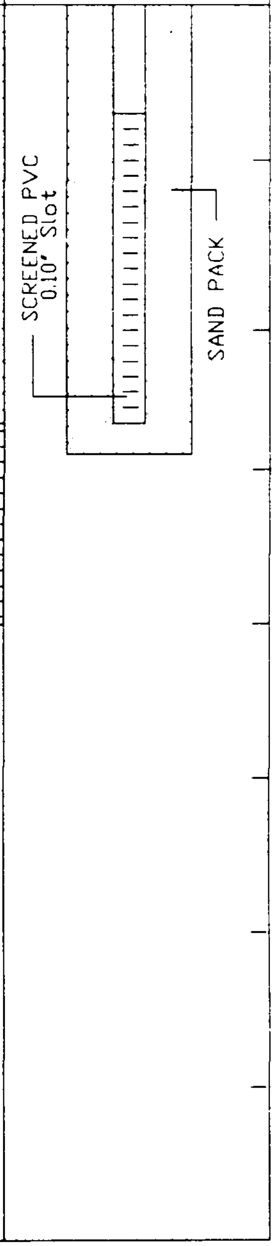
ENGINEERING-SCIENCE, INC.

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 3 OF 3
WELL/BORING LOCATION BC-MW12 PROJECT I.D. AT103
COORDINATES 5004.1 E. 3019.6 N. DRILLING STARTED 9/5/89
ES GEOLOGIST/ENGINEER J. BURGIN SIGNATURE

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO- LOGY
75	SS9 0	70	25,29,31	SAND, light olive-gray, medium; trace pebbles-subangular to rounded, well sorted, wet.	
80	SS10 0	80	17,46,50	SAND, light olive-gray, fine, trace pebbles-subangular to rounded, well sorted, wet.	
85	SS11 0	90	12,50,50	CLAY, some sand, trace silt, grayish-green, wet. Hard drilling at 83'-boulders.	
90	SS12 0	90	11,13,24	CLAY, trace sand, trace silt, grayish-green, wet.	
				B.T. at 90'	

WELL CONSTRUCTION



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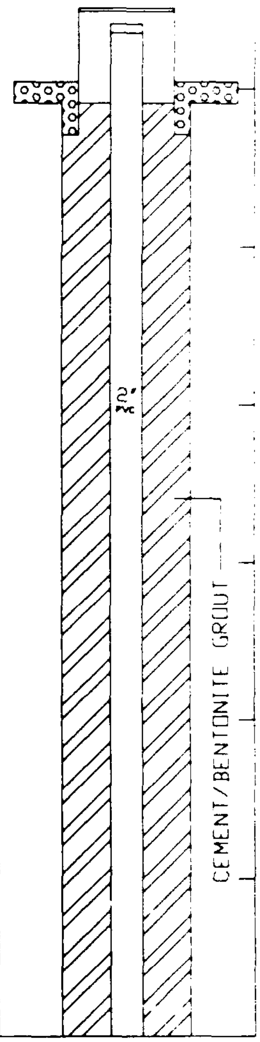
DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 1 OF 3
WELL/BORING LOCATION BC-MW13 PROJECT I.D. AT103
COORDINATES 5060.3 E. 4920.9 N. DRILLING STARTED 8/22/89
ES GEOLOGIST/ENGINEER M. Herrmann SIGNATURE
DRILLER FOX DRILLING, INC. DRILLING METHOD 6.25" HSA & Mud Rotary
DRILLING COMPLETED 8/23/89 WELL COMPLETED 8/23/89 TOTAL WELL DEPTH 93.5'
SCREENED INTERVALS 83.5-93.5' TOTAL BOREHOLE DEPTH 93.5'
SAMPLING METHOD Split-Spoon M.P. ELEV. 928.40 L.S. ELEV. 927.11
WATER LEVEL, FT. BELOW M.P. 38.68' ELEVATION 889.72 DATE 9/6/89

DEPTH BELOW L.S.	HNU/OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0						
5	SS1 0.1	70	7,8,16	SAND, medium, loose to firm, moderate yellowish-brown, dry, no odor, cobbles at ~6'-7.5', well rounded.		
10	SS2 0.0	80	12,34,28	SAND, medium, trace to some coarse, medium, yellowish-brown, firm to dense, trace cobble chips, very slightly moist.		
15		Auger Sample				
				SAND, 10-20', medium, trace to some coarse, trace cobbles.		
20		Auger Sample				
				SAND, 20-24', medium, dry to slightly moist, moderate yellowish-brown.		
25		Auger Sample		SAND, 24-30', fine, trace silt, slightly moist to moist, moderate yellowish-brown.		

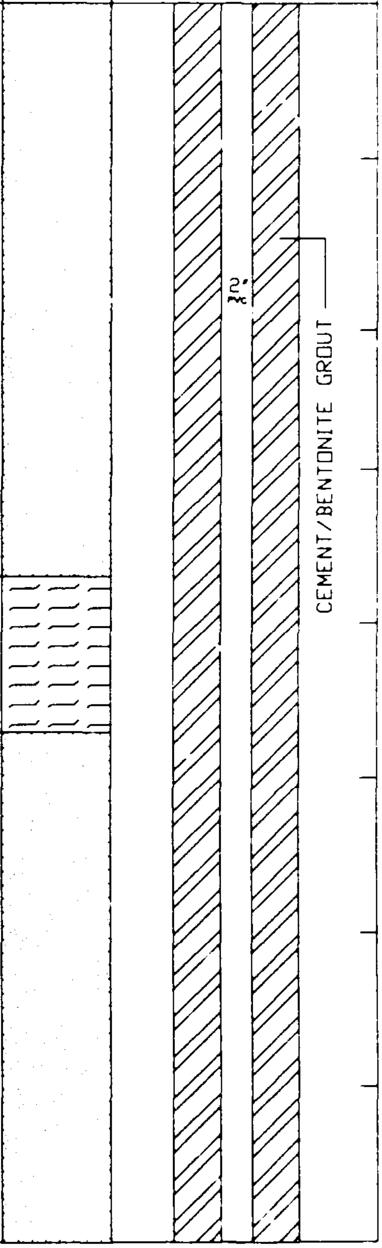


ENGINEERING-SCIENCE, INC.

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 2 OF 3
WELL/BORING LOCATION BC-MW13 PROJECT I.D. AT103
COORDINATES 5060.3 E. 4920.9 N. DRILLING STARTED 8/22/89
ES GEOLOGIST/ENGINEER M. Herrmann SIGNATURE

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION
				SAND, 30-37', Auger Samples
35				
40				
45	SS3 0.0	70	25,26,30	SAND, fine to very fine, very firm, grayish-orange, very moist to wet.
50	SS4 0.0	70	19,13,7	SILT, trace to some clay, trace very fine sand, stiff to firm, light olive-gray, wet.
55	SS5 0.0	80	6,7,5	SAND, medium, trace to some coarse, trace gravel, trace to some silt/clay fines, light olive-gray, loose, wet.
60	SS6 0.0	70	60,69/.25	Cobbles and Boulders 58-59'. SAND, trace to some boulders and cobbles, sand is medium to coarse, very dense and indurated, trace gravel, light olive-gray, very moist.
65	SS7 0.0	100	100/4"	SAND, some silt and clay, till texture, trace gravel, olive-gray, extremely dense, slightly moist.
	SS8 0.0	50	100/4"	



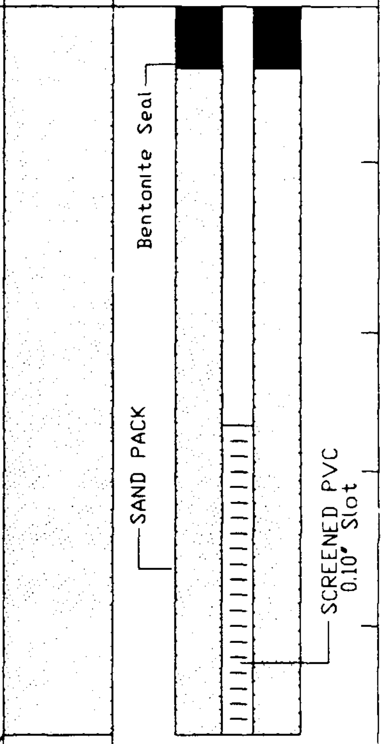
ENGINEERING-SCIENCE, INC.

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 3 OF 3
WELL/BORING LOCATION BC-MW13 PROJECT I.D. AT103
COORDINATES 5060.3 E. 4920.9 N. DRILLING STARTED 8/22/89
ES GEOLOGIST/ENGINEER M. Herrmann SIGNATURE

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION
				SAND, medium to coarse, chert chips, olive-gray.
75	SS9 0.0	50	100/4"	SAND, coarse, extremely dense wet, trace fines, olive-gray, trace gravel.
80	SS10 0.0	80	98/6"	SAND, fine, trace silt, olive-gray, wet, extremely dense.
85	SS11 1.0	90	100/4"	SAND, fine, trace silt, wet, olive-gray, extremely dense, very slight odor.
90	SS12 1.0	90	101/4"	SAND, fine, trace fines, wet, olive-gray, extremely dense, very slight odor, some blackish streaks.
95	SS13 0.0	95	100/4"	SAND, medium to fine, wet, olive-gray, extremely dense.
				B.T. at 93.5'
100				

LITHO-LOGY / WELL CONSTRUCTION



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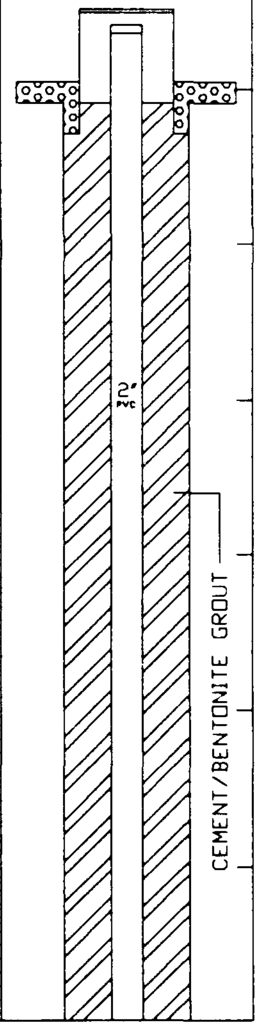
DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 1 OF 3
WELL/BORING LOCATION BC-MW14 PROJECT I.D. AT103
COORDINATES 3763.7 E. 4920.9 N. DRILLING STARTED 8/25/89
ES GEOLOGIST/ENGINEER M. Herrmann SIGNATURE
DRILLER FOX DRILLING, INC. DRILLING METHOD 6.25" HSA & Mud Rotary
DRILLING COMPLETED 8/25/89 WELL COMPLETED 8/25/89 TOTAL WELL DEPTH 87'
SCREENED INTERVALS 77-87' TOTAL BOREHOLE DEPTH 91'
SAMPLING METHOD Split-Spoon M.P. ELEV. 918.89 L.S. ELEV. 916.65
WATER LEVEL, FT. BELOW M.P. 32.46' ELEVATION 886.43 DATE 9/6/89

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO- LOGY
0					
				SAND, trace to some silt, medium, trace coarse, moderate brown, loose, trace cobbles.	
5	SS1 0.0	30	4,4,4	SAND, fine, pale yellowish-brown, moist. Loose cobbles cause refusal at ~7,5-8.0', offset.	
10	SS2 0.0	70	6,15,11	SAND, coarse, some gravel, moderate brown, slightly moist, firm.	
15	SS3 0.4	70	4,6,13	SAND, coarse, some gravel, slightly moist, slight odor, dark yellowish-orange, loose to firm.	
20	SS4 0.65	80	5,10,11	SAND, medium to coarse, trace gravel, slightly moist, loose to firm, moderate yellowish-brown.	
25	SS5	90	5,11,13	SAND, medium, slightly moist, firm, moderately yellowish-brown.	
	SS6 0.15	90	6,9,10	SAND, medium to coarse, wet, moderate brown, loose, 1st water at 29'.	

WELL CONSTRUCTION



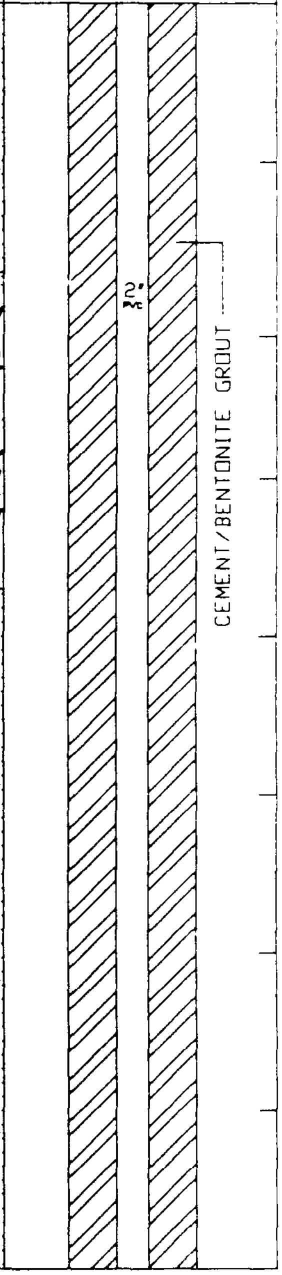
ENGINEERING-SCIENCE, INC.

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 2 OF 3
WELL/BORING LOCATION BC-MW14 PROJECT I.D. AT103
COORDINATES 3763.7 E. 4920.9 N. DRILLING STARTED 8/25/89
ES GEOLOGIST/ENGINEER M. Herrmann SIGNATURE

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY
35				Same as above.	
40	SS7 0.2	60	3,3,3	SAND and GRAVEL, medium to coarse, moderate yellowish-brown, wet, loose.	
45					
50	SS8 0.2	70	9,12,12	SAND, medium to coarse, trace gravel, wet, light olive gray, firm.	
55					
60	SS9 0.0	30	14,18,28	SAND, very fine, wet, olive gray, very firm, trace fines.	
65					
	SS10 0.1	85	28,42,33		

WELL CONSTRUCTION



ENGINEERING-SCIENCE, INC.

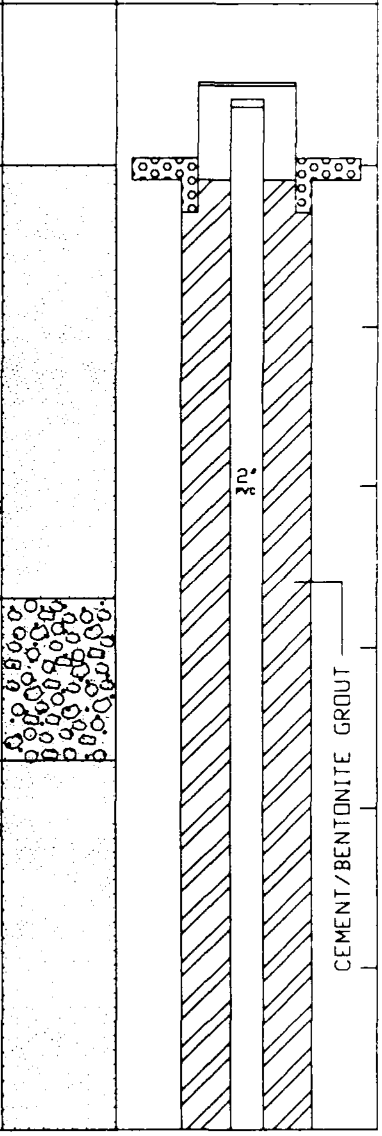
DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 1 OF 3
WELL/BORING LOCATION BC-MW15 PROJECT I.D. AT103
COORDINATES 2792.6 E. 5002.7 N. DRILLING STARTED 8/28/89
ES GEOLOGIST/ENGINEER J. Burgin SIGNATURE
DRILLER FOX DRILLING, INC. DRILLING METHOD 6.25" HSA & Mud Rotary
DRILLING COMPLETED 8/29/89 WELL COMPLETED 8/29/89 TOTAL WELL DEPTH 78'
SCREENED INTERVALS 68-78' TOTAL BOREHOLE DEPTH 80'
SAMPLING METHOD Split-Spoon M.P. ELEV. 926.68 L.S. ELEV. 925.10
WATER LEVEL, FT. BELOW M.P. 43.17' ELEVATION 883.51 DATE 9/6/89

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION
0				
5	SS1 0.0	90	6,7,8	SAND, moderate yellowish-brown, fine, trace pebbles, well sorted.
10	SS2 0.0	75	8,8,10	SAND, pale yellowish-brown, medium to fine, some pebbles moderately sorted.
15	SS3 0.1	70	18,27,14	SAND and GRAVEL, dark yellowish-brown, some very coarse gravel, medium sand.
20	SS4 0.2	75	12,17,8	SAND, pale yellowish-brown, medium to fine, some pebbles chert frgments, damp.
25	SS5	80	7,13,17	SAND, pale yellowish-brown, medium to fine, damp to moist.
	SS6		7,17,18	SAND, pale yellowish-brown, fine, trace black organics, moist.

LITHO-LOGY

WELL CONSTRUCTION



DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 3 OF 3

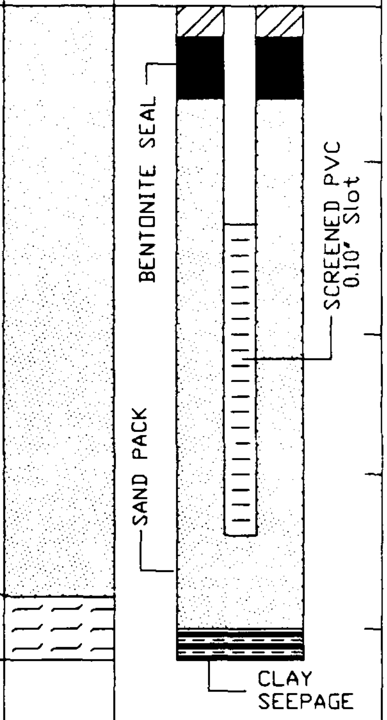
WELL/BORING LOCATION BC-MW14 PROJECT I.D. AT103

COORDINATES 3763.7 E. 4920.9 N. DRILLING STARTED 8/25/89

ES GEOLOGIST/ENGINEER M. Herrmann SIGNATURE

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION
				SAND, very fine, wet, olive gray, dense.
75				
80	SS11 0.0	90	27,37,49	SAND, very fine, wet, olive gray, very dense.
85				
90	SS12 0.0	80	28,75	SILT, trace to some clay, trace very fine sand, olive gray, extremly stiff.

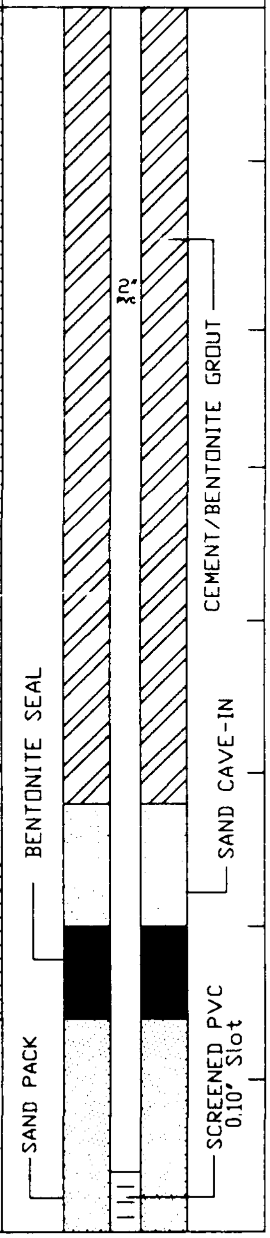
LITHO-LOGY / WELL CONSTRUCTION



ENGINEERING-SCIENCE, INC.

DRILLING AND WELL COMPLETION RECORD

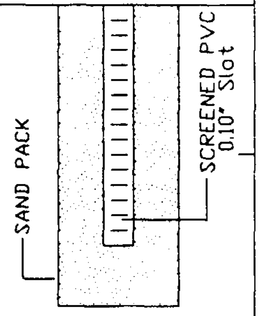
JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 2 OF 3
WELL/BORING LOCATION BC-MW15 PROJECT I.D. AT103
COORDINATES 2792.6 E. 5002.7 N. DRILLING STARTED 8/28/89
ES GEOLOGIST/ENGINEER J. Burgin SIGNATURE

DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHOLOGY	WELL CONSTRUCTION
35	SS7 0.4	75	8,14,23	SAND, pale yellowish-brown, fine damp, trace blavk organics.		
40	SS8 0.0	40	27,38,33	SAND, moderate yellowish-brown, very coarse and pebbles, (rock fragments) well rounded, poorly sorted, wet.		
45	SS9 0.2	50	27,28,25	Same as above.		
50	SS10 0.6	80	37,37,32	SAND, very loose to medium, and pebbles, wet, dark yellowish-brown.		
55	SS11 0.3	10	36,40,40	GRAVEL and PEBBLES, coarse, wet, dark yellowish-brown.		
60	SS12 0.3	90	7,27,30	SAND, medium to fine, wet, dark yellowish-brown.		
65			29,34,27	No sample - cobbles, wash material.	NO SAMPLE	
				No sample (to conserve mud).		

ENGINEERING-SCIENCE, INC.

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI. PAGE 3 OF 3
WELL/BORING LOCATION BC-MW15 PROJECT I.D. AT103
COORDINATES 2792.6 E. 5002.7 N. DRILLING STARTED 8/28/89
ES GEOLOGIST/ENGINEER J. Burgin SIGNATURE

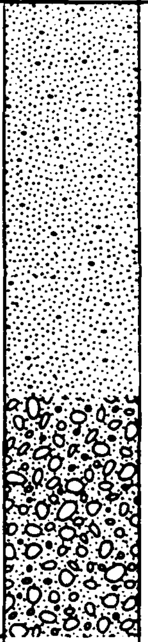
DEPTH BELOW L.S.	HNU/ OVA	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
				No Sample.	NO SAMPLE	
75	SS13 0.0	80	12,18,21	SAND, fine, trace clay, trace pebbles, gray, moderately to poorly sorted, wet.		
80	SS13 0.0	90	13,55,56	CLAY, trace sand, fine, trace pebbles, light olive-gray, wet.		
				B.T. at 80'		
85						
90						

ENGINEERING-SCIENCE, INC.

APPENDIX B
SOIL BORING LOGS

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 1
WELL/BORING LOCATION BC1 SB1 PROJECT I.D. AT103
COORDINATES 3,793.0' E 4,654.1' N DRILLING STARTED 11/2/88
ES GEOLOGIST/ENGINEER M. E. Herrmann
DRILLER Fox Drilling DRILLING METHOD H.S.A. 6-1/4" I.D., 11" O.D.
DRILLING COMPLETED 11/2/88 WELL COMPLETED N.A. TOTAL WELL DEPTH N.A.
SCREENED INTERVALS N.A. TOTAL BOREHOLE DEPTH 15'
SAMPLING METHOD 5' Continuous M.P. ELEV. N.A. L.S. ELEV. 914.4'
WATER LEVEL, Ft BELOW M.P. N.A. ELEVATION N.A. DATE N.A.

DEPTH BELOW L.S.	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0	0	100		SAND, medium, trace gravel, orange brown (slightly moist) (no odor).		
5	0	100				
10	0	100		SAND, medium to coarse, trace to some gravel, trace cobbles, tannish brown, (slightly moist) (petroleum odor).		
15	0	100		B.T. at 15'		

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 1
WELL/BORING LOCATION BC1 SB2 PROJECT I.D. AT103
COORDINATES 3,787.5' E 4,634.8' N DRILLING STARTED 11/2/88
ES GEOLOGIST/ENGINEER M. E. Herrmann
DRILLER Fox Drilling DRILLING METHOD H.S.A. 6-1/4" I.D., 11" O.D.
DRILLING COMPLETED 11/2/88 WELL COMPLETED N.A. TOTAL WELL DEPTH N.A.
SCREENED INTERVALS N.A. TOTAL BOREHOLE DEPTH 15'
SAMPLING METHOD 5' Continuous M.P. ELEV. N.A. L.S. ELEV. 914.6'
WATER LEVEL, Ft BELOW M.P. N.A. ELEVATION N.A. DATE N.A.

DEPTH BELOW L.S.	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0				SAND, medium, dark brown. SAND, medium, orange brown (slightly moist).		
5	0	100				
				SAND, medium, trace gravel.		
10	0	100		SAND, medium, trace to some gravel, trace cobbles, tannish brown, (slightly moist).		
15	3.5	100				
				B.T. at 15'		

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 1
WELL/BORING LOCATION BC1 SB3 PROJECT I.D. AT103
COORDINATES 3,787.5' E 4,634.8' N DRILLING STARTED 11/2/88
ES GEOLOGIST/ENGINEER M. E. Herrmann
DRILLER Fox Drilling DRILLING METHOD H.S.A. 6-1/4" I.D., 11" O.D.
DRILLING COMPLETED 11/2/88 WELL COMPLETED N.A. TOTAL WELL DEPTH N.A.
SCREENED INTERVALS N.A. TOTAL BOREHOLE DEPTH 15'
SAMPLING METHOD 5' Continuous M.P. ELEV. N.A. L.S. ELEV. 914.6'
WATER LEVEL, Ft BELOW M.P. N.A. ELEVATION N.A. DATE N.A.

DEPTH BELOW L.S.	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0				SAND, medium, trace gravel, trace cobbles, orange brown (slightly moist).	▨	
	0	50			▨	
5					▨	
	0	50		SAND, coarse, approximately 3" thick.	▨	
10					▨	
	0	50		SAND, medium.	▨	
15				B.T. at 15'		

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 1
WELL/BORING LOCATION BC1 SB4 PROJECT I.D. AT103
COORDINATES 3,829.9′ E 4,647.9′ N DRILLING STARTED 11/2/88
ES GEOLOGIST/ENGINEER M. E. Herrmann
DRILLER Fox Drilling DRILLING METHOD H.S.A. 6-1/4" I.D., 11" O.D.
DRILLING COMPLETED 11/2/88 WELL COMPLETED N.A. TOTAL WELL DEPTH N.A.
SCREENED INTERVALS N.A. TOTAL BOREHOLE DEPTH 12.5′
SAMPLING METHOD 5′ Continuous M.P. ELEV. N.A. L.S. ELEV. 914.8′
WATER LEVEL, Ft BELOW M.P. N.A. ELEVATION N.A. DATE N.A.

DEPTH BELOW L.S.	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0				SAND, silty, dark brown, (slightly moist).	░	
				CLAY, silty, trace gravel, reddish brown (slightly moist).	▓	
	0	50		SAND, medium, orange brown (slightly moist).	░	
5					░	
	0	50			○	
10				Cobbles--auger refusal.	○	
		0		A.R. at 12.5′		
15						

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 1
WELL/BORING LOCATION BC1 SB5 PROJECT I.D. AT103
COORDINATES 3,879.4' E 4,642.4' N DRILLING STARTED 11/2/88
ES GEOLOGIST/ENGINEER M. E. Herrmann
DRILLER Fox Drilling DRILLING METHOD H.S.A. 6-1/4" I.D., 11" O.D.
DRILLING COMPLETED 11/2/88 WELL COMPLETED N.A. TOTAL WELL DEPTH N.A.
SCREENED INTERVALS N.A. TOTAL BOREHOLE DEPTH 15'
SAMPLING METHOD 5' Continuous M.P. ELEV. N.A. L.S. ELEV. 914.0'
WATER LEVEL, Ft BELOW M.P. N.A. ELEVATION N.A. DATE N.A.

DEPTH BELOW L.S.	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0				SAND, medium, trace gravel, orange brown (mild odor).		
	70	50		SAND and GRAVEL, gray black (strong odor, obvious petroleum content) (moist).		
5						
	40	80				
				SILT and CLAY, trace gravel, orange, brown (moist).		
10	1			SAND and GRAVEL, orange brown (slightly moist).		
	35	65		SAND, medium, trace gravel, orange brown (slightly moist) (moderate petroleum odor). SAND, fine to medium, tannish brown, (slightly moist).		
15						
				B.T. at 15'		

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 1
WELL/BORING LOCATION BC1 SB6 PROJECT I.D. AT103
COORDINATES 3,876.3' E 4,655.8' N DRILLING STARTED 11/2/88
ES GEOLOGIST/ENGINEER M. E. Herrmann
DRILLER Fox Drilling DRILLING METHOD H.S.A. 6-1/4" I.D., 11" O.D.
DRILLING COMPLETED 11/2/88 WELL COMPLETED N.A. TOTAL WELL DEPTH N.A.
SCREENED INTERVALS N.A. TOTAL BOREHOLE DEPTH 15'
SAMPLING METHOD 5' Continuous M.P. ELEV. N.A. L.S. ELEV. 914.4'
WATER LEVEL, Ft BELOW M.P. N.A. ELEVATION N.A. DATE N.A.

DEPTH BELOW L.S.	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0				GRAVEL (very moist to wet) (strong petroleum odor).		
	160	25		SAND, medium, gray (very moist) (stronge odor).		
5						
	50	70		CLAY, sandy with some gravel, orange brown, (slightly moist) (slight odor).		
				SAND and GRAVEL, orange brown (slightly moist) (Moderate petroleum odor).		
10						
	6	25		SAND, fine to medium, orange brown to tannish brown.		
15						
				B.T. at 15'		

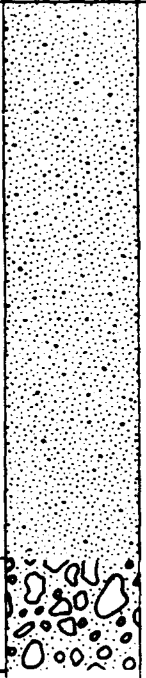
DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 1
WELL/BORING LOCATION BC1 SB7 PROJECT I.D. AT103
COORDINATES 3,912.7' E 4,668.4' N DRILLING STARTED 11/2/88
ES GEOLOGIST/ENGINEER M. E. Herrmann
DRILLER Fox Drilling DRILLING METHOD H.S.A. 6-1/4" I.D., 11" O.D.
DRILLING COMPLETED 11/2/88 WELL COMPLETED N.A. TOTAL WELL DEPTH N.A.
SCREENED INTERVALS N.A. TOTAL BOREHOLE DEPTH 15'
SAMPLING METHOD 5' Continuous M.P. ELEV. N.A. L.S. ELEV. 913.8'
WATER LEVEL, Ft BELOW M.P. N.A. ELEVATION N.A. DATE N.A.

DEPTH BELOW L.S.	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0				SAND, medium, orange brown (slightly moist).		
				CLAY, sandy, trace gravel, orange brown (slightly moist).		
5	0.4	50		SAND, medium, trace gravel, grey (slightly moist) (slight petroleum odor).		
	1.5	50		SAND and GRAVEL, orange brown (slightly moist) (slight petroleum odor).		
10				COBBLES.		
	2.0	50		SAND, medium to fine, tannish brown (slightly moist) (very slight odor).		
15				SAND and GRAVEL, tannish brown (slightly moist) (slight odor).		
				B.T. at 15'		

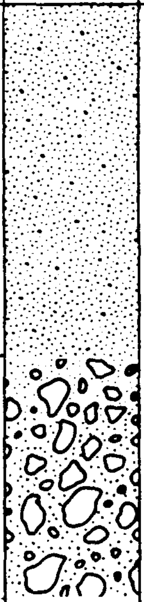
DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION **Michigan ANGB, Battle Creek, MI** PAGE **1** OF **1**
WELL/BORING LOCATION **BC1 SB8** PROJECT I.D. **AT103**
COORDINATES **3,957.1'** E **4,655.9'** N DRILLING STARTED **11/2/88**
ES GEOLOGIST/ENGINEER **M. E. Herrmann**
DRILLER **Fox Drilling** DRILLING METHOD **H.S.A. 6-1/4" I.D., 11" O.D.**
DRILLING COMPLETED **11/2/88** WELL COMPLETED **N.A.** TOTAL WELL DEPTH **N.A.**
SCREENED INTERVALS **N.A.** TOTAL BOREHOLE DEPTH **15'**
SAMPLING METHOD **5' Continuous** M.P. ELEV. **N.A.** L.S. ELEV. **914.2'**
WATER LEVEL, Ft BELOW M.P. **N.A.** ELEVATION **N.A.** DATE **N.A.**

DEPTH BELOW L.S.	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0				SAND, medium, trace gravel, gray (slightly moist) (slight odor).		
	60	40		As above with strong odor		
5						
	120	10		SAND, medium, trace gravel, trace cobbles, brown (slightly moist) (slight odor of petroleum).		
10						
	8	50				
15				SAND and GRAVEL, orange brown (slightly moist) (slight odor).		
				B.T. at 15'		

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 1
WELL/BORING LOCATION BC1 SB9 PROJECT I.D. AT103
COORDINATES 3,972.8' E 4,676.2' N DRILLING STARTED 11/2/88
ES GEOLOGIST/ENGINEER M. E. Herrmann
DRILLER Fox Drilling DRILLING METHOD H.S.A. 6-1/4" I.D., 11" O.D.
DRILLING COMPLETED 11/2/88 WELL COMPLETED N.A. TOTAL WELL DEPTH N.A.
SCREENED INTERVALS N.A. TOTAL BOREHOLE DEPTH 15'
SAMPLING METHOD 5' Continuous M.P. ELEV. N.A. L.S. ELEV. 914.4'
WATER LEVEL, Ft BELOW M.P. N.A. ELEVATION N.A. DATE N.A.

DEPTH BELOW L.S.	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0				SAND, medium, trace gravel, orange brown (slightly moist).		
	0.2	25				
5						
	60	70		SAND, medium, trace gravel, grayish brown (slightly moist to moist) (very strong petroleum odor).		
				SAND and GRAVEL, (slightly moist) (strong petroleum odor).		
10						
	60	50				
15				B.T. at 15'		

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 1
WELL/BORING LOCATION BC1 SB10 PROJECT I.D. AT103
COORDINATES 3,984.4' E 4,676.2' N DRILLING STARTED 11/2/88
ES GEOLOGIST/ENGINEER M. E. Herrmann
DRILLER Fox Drilling DRILLING METHOD H.S.A. 6-1/4" I.D., 11" O.D.
DRILLING COMPLETED 11/2/88 WELL COMPLETED N.A. TOTAL WELL DEPTH N.A.
SCREENED INTERVALS N.A. TOTAL BOREHOLE DEPTH 15'
SAMPLING METHOD 5' Continuous M.P. ELEV N.A. L.S. ELEV. 914.0'
WATER LEVEL, Ft BELOW M.P. N.A. ELEVATION N.A. DATE N.A.

DEPTH BELOW L.S.	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0				SAND, medium, orange brown (slightly moist) (slight odor).		
	190	50		SAND, medium, dark grey (slightly moist to moist).		
5				CLAY, sandy, trace gravel, olive grey (slightly moist) (moderate odor).		
				SAND, medium, dark brown (slightly moist) (slight odor).		
	3	80		SAND, medium, trace gravel (slightly moist).		
10						
	5	10				
15				B.T. at 15'		

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 1
WELL/BORING LOCATION BC1 SB11 PROJECT I.D. AT103
COORDINATES 4,024.3' E 4,687.2' N DRILLING STARTED 11/3/88
ES GEOLOGIST/ENGINEER M. E. Herrmann
DRILLER Fox Drilling DRILLING METHOD H.S.A. 6-1/4" I.D., 11" O.D.
DRILLING COMPLETED 11/3/88 WELL COMPLETED N.A. TOTAL WELL DEPTH N.A.
SCREENED INTERVALS N.A. TOTAL BOREHOLE DEPTH 15'
SAMPLING METHOD 5' Continuous M.P. ELEV. N.A. L.S. ELEV. 914.1'
WATER LEVEL, Ft BELOW M.P. N.A. ELEVATION N.A. DATE N.A.

DEPTH BELOW L.S.	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0	5	50		SAND, silty, trace gravel, orange brown (dry to slightly moist). SAND, silty, trace gravel, dark gray (dry to slightly moist).		
5				CLAY, sandy, trace to some gravel, orange brown (slightly moist)		
	0	75		SAND and GRAVEL, orange brown (slightly moist). SAND, medium, trace to some gravel orange brown.		
10	0	50		SAND and GRAVEL, trace cobbles, tannish brown (slightly moist).		
15				B.T. at 15'		

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 1
WELL/BORING LOCATION BC1 SB12 PROJECT I.D. AT103
COORDINATES 4,047.1' E 4,654.5' N DRILLING STARTED 11/3/88
ES GEOLOGIST/ENGINEER M. E. Herrmann
DRILLER Fox Drilling DRILLING METHOD H.S.A. 6-1/4" I.D., 11" O.D.
DRILLING COMPLETED 11/3/88 WELL COMPLETED N.A. TOTAL WELL DEPTH N.A.
SCREENED INTERVALS N.A. TOTAL BOREHOLE DEPTH 15'
SAMPLING METHOD 5' Continuous M.P. ELEV. N.A. L.S. ELEV. 914.4'
WATER LEVEL, Ft BELOW M.P. N.A. ELEVATION N.A. DATE N.A.

DEPTH BELOW L.S.	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0				SAND and GRAVEL, silty, medium brown.		
	0	45		SILT, clayey, trace sand, trace cobbles, orange brown.		
5				CLAY, sandy, trace to some gravel, trace cobbles.		
	0	50				
				SAND and GRAVEL, some clay, trace cobbles, orange brown.		
10				SAND, medium, tannish brown		
	0	50				
15				B.T. at 15'		

DRILLING AND WELL COMPLETION RECORD

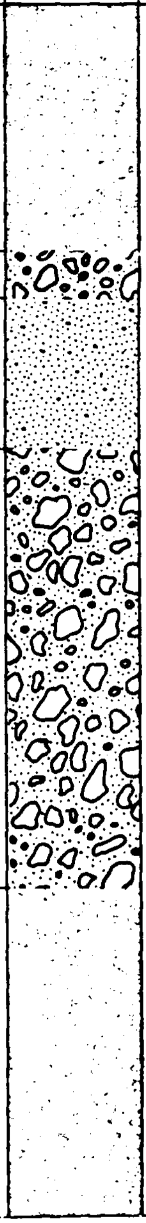
JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 1
WELL/BORING LOCATION BC1 SB13 PROJECT I.D. AT103
COORDINATES 4,075.8' E 4,632.3' N DRILLING STARTED 11/3/88
ES GEOLOGIST/ENGINEER M. E. Herrmann
DRILLER Fox Drilling DRILLING METHOD H.S.A. 6-1/4" I.D., 11" O.D.
DRILLING COMPLETED 11/3/88 WELL COMPLETED N.A. TOTAL WELL DEPTH N.A.
SCREENED INTERVALS N.A. TOTAL BOREHOLE DEPTH 15'
SAMPLING METHOD 5' Continuous M.P. ELEV. N.A. L.S. ELEV. 914.9'
WATER LEVEL, Ft BELOW M.P. N.A. ELEVATION N.A. DATE N.A.

DEPTH BELOW L.S.	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0	0	60		CLAY and SILT, sandy, trace gravel, dark brown to orange brown.	░	
5	0	27		SAND, medium, trace to some gravel, trace cobbles, orange brown.	◌	
10	0	70		SAND, medium to coarse, trace to some gravel, orange brown to tannish brown.	░	
15				B.T. at 15'		

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 2
WELL/BORING LOCATION BC3 SB1 PROJECT I.D. AT103
COORDINATES 3,360.3' E 3,783.8' N DRILLING STARTED 11/4/88
ES GEOLOGIST/ENGINEER M. E. Herrmann
DRILLER Fox Drilling DRILLING METHOD H.S.A. 6-1/4" I.D., 11" O.D.
DRILLING COMPLETED 11/4/88 WELL COMPLETED N.A. TOTAL WELL DEPTH N.A.
SCREENED INTERVALS N.A. TOTAL BOREHOLE DEPTH 35'
SAMPLING METHOD 5' Continuous M.P. ELEV. N.A. L.S. ELEV. 921.0'
WATER LEVEL, Ft BELOW M.P. N.A. ELEVATION N.A. DATE N.A.

DEPTH BELOW L.S.	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0				SAND, medium, orange brown.		
	0	50				
5						
				SAND and GRAVEL, orange brown.		
				SAND, medium, trace gravel, tannish brown.		
	0	50				
10						
				SAND and GRAVEL, some cobbles, trace boulders, greyish brown.		
	0.2	50				
15						
	0.2	60				
20						
				SAND, fine to medium, tannish brown.		
	0	80				
25						
	0.2	80				



DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 2 OF 2
WELL/BORING LOCATION BC3 SB1 PROJECT I.D. AT103
COORDINATES 3,360.3' E 3,783.8' N DRILLING STARTED 11/4/88
ES GEOLOGIST/ENGINEER M. E. Herrmann

DEPTH BELOW L.S.	HNU OVA PPM	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
30					░	
	1.0	75			░	
35				As above with slight petroleum odor.	░	
				B.T. at 35'.		

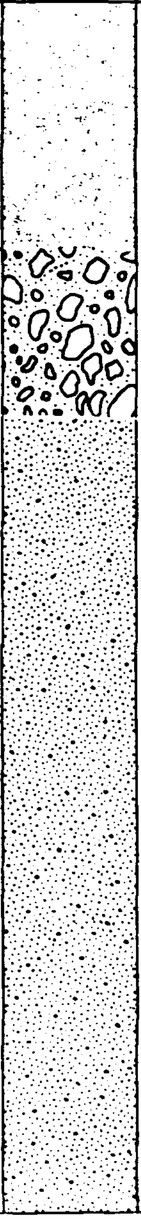
DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 1
WELL/BORING LOCATION BC3 SB2 PROJECT I.D. AT103
COORDINATES 3,401.8' E 4,049.1' N DRILLING STARTED 11/4/88
ES GEOLOGIST/ENGINEER M. E. Herrmann
DRILLER Fox Drilling DRILLING METHOD H.S.A. 6-1/4" I.D., 11" O.D.
DRILLING COMPLETED 11/4/88 WELL COMPLETED N.A. TOTAL WELL DEPTH N.A.
SCREENED INTERVALS N.A. TOTAL BOREHOLE DEPTH 24'
SAMPLING METHOD 5' Continuous M.P. ELEV. N.A. L.S. ELEV. 918.3'
WATER LEVEL, Ft BELOW M.P. N.A. ELEVATION N.A. DATE N.A.

DEPTH BELOW L.S.	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0				SAND, silty, trace coal, organics, medium brown.		
	0.4	50		SAND, medium, orange brown (laminated with thin dark brown layers).		
5				SAND, silty, trace gravel, dark brown (very moist to wet).		
	0	60		SAND, medium, trace gravel, trace cobbles, orange brown (slightly moist).		
10						
	0	50		SAND and GRAVEL, trace cobbles, orange brown.		
15				SAND, fine to medium, tan.		
	0.4	60				
20						
				COBBLES, gravel.		
25				A.R. at 24'.		

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 2
WELL/BORING LOCATION BC3 SB3 PROJECT I.D. AT103
COORDINATES 3,287.1' E 4,018.2' N DRILLING STARTED 11/4/88
ES GEOLOGIST/ENGINEER M. E. Herrmann
DRILLER Fox Drilling DRILLING METHOD H.S.A. 6-1/4" I.D., 11" O.D.
DRILLING COMPLETED 11/4/88 WELL COMPLETED N.A. TOTAL WELL DEPTH N.A.
SCREENED INTERVALS N.A. TOTAL BOREHOLE DEPTH 35'
SAMPLING METHOD 5' Continuous M.P. ELEV. N.A. L.S. ELEV. 918.7'
WATER LEVEL, Ft BELOW M.P. N.A. ELEVATION N.A. DATE N.A.

DEPTH BELOW L.S.	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0				SAND, silty, trace gravel, organics in upper 3 inches, medium brown.		
	0.2	50		SAND, silty, trace to some gravel, orange brown (black laminations at 6').		
5				SAND and GRAVEL, orange brown.		
	0.2	50				
10				SAND, medium, trace gravel, orange brown.		
		50				
15						
		50				
20				SAND, coarse, trace gravel, medium brown.		
		50				
25						
		50				

DRILLING AND WELL COMPLETION RECORD

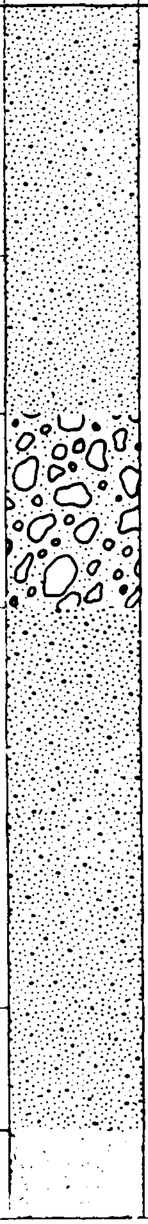
JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 2 OF 2
WELL/BORING LOCATION BC3 SB3 PROJECT I.D. AT103
COORDINATES 3,287.1' E 4,018.2' N DRILLING STARTED 11/4/88
ES GEOLOGIST/ENGINEER M. E. Herrmann

DEPTH BELOW L.S.	HNU OVA PPM	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHOLOGY	WELL CONSTRUCTION
30				SAND, very fine, tannish brown (wet).		
35				B.T. at 35'.		

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION **Michigan ANGB, Battle Creek, MI** PAGE **1** OF **2**
WELL/BORING LOCATION **BC3 SB4** PROJECT I.D. **AT103**
COORDINATES **3,301.7'** E **3,894.3'** N DRILLING STARTED **11/4/88**
ES GEOLOGIST/ENGINEER **M. E. Herrmann**
DRILLER **Fox Drilling** DRILLING METHOD **H.S.A. 6-1/4" I.D., 11" O.D.**
DRILLING COMPLETED **11/4/88** WELL COMPLETED **N.A.** TOTAL WELL DEPTH **N.A.**
SCREENED INTERVALS **N.A.** TOTAL BOREHOLE DEPTH **35'**
SAMPLING METHOD **5' Continuous** M.P. ELEV. **N.A.** L.S. ELEV. **919.6'**
WATER LEVEL, Ft BELOW M.P. **N.A.** ELEVATION **N.A.** DATE **N.A.**

DEPTH BELOW L.S.	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0				SAND, silty, black (oily with strong odor). SAND, coarse, trace gravel, grey (strong odor).		
		50				
5						
				SAND and GRAVEL, grey.		
	100	50				
10				GRAVEL and COBBLES, grey (strong odor).		
	95	25				
15				SAND, medium, trace gravel. SAND, medium to very fine, grey.		
	90	60				
20						
	110	75				
25				SAND and GRAVEL, grey (strong odor).		
	120	50		SAND, very fine, grey (strong odor).		



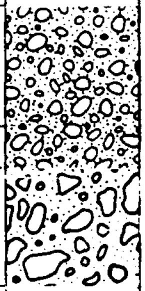
DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION **Michigan ANGB, Battle Creek, MI** PAGE **2** OF **2**
WELL/BORING LOCATION **BC3 SB4** PROJECT I.D. **AT103**
COORDINATES **3,301.7'** E **3,894.3'** N DRILLING STARTED **11/4/88**
ES GEOLOGIST/ENGINEER **M. E. Herrmann**

DEPTH BELOW L.S.	HNU OVA PPM	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
30						
	120			Black lamination and groundwater at 33'.		
35				B.T. at 35'.		

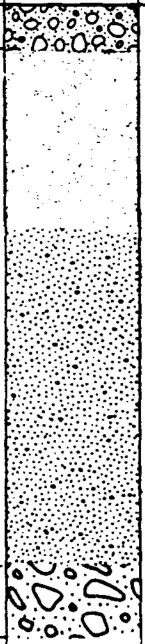
DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 1
WELL/BORING LOCATION BC3 SB5 PROJECT I.D. AT103
COORDINATES 3,335.6' E 3,920.1' N DRILLING STARTED 11/1/88
ES GEOLOGIST/ENGINEER M. E. Herrmann
DRILLER Fox Drilling DRILLING METHOD H.S.A. 6-1/4" I.D., 11" O.D.
DRILLING COMPLETED 11/1/88 WELL COMPLETED N.A. TOTAL WELL DEPTH N.A.
SCREENED INTERVALS N.A. TOTAL BOREHOLE DEPTH 24'
SAMPLING METHOD 5' Continuous M.P. ELEV. N.A. L.S. ELEV. 919.5'
WATER LEVEL, Ft BELOW M.P. N.A. ELEVATION N.A. DATE N.A.

DEPTH BELOW L.S.	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0				SAND, silty black, (oily). SAND, medium, grey (strong odor, obvious contamination).		
5						
				SAND and GRAVEL interbeds of medium sand, medium grey (oily).		
10				SAND, medium, trace gravel, grey (moist).		
				SAND and GRAVEL, cobbles, trace boulders (blue, sandstone, moist).		
				SAND, medium to fine, (dark tannish brown).		
15						
20						
25				B.T. at 24'		

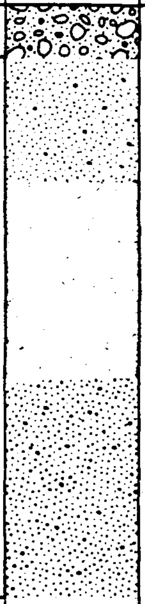
DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 1
WELL/BORING LOCATION BC5 SB1 PROJECT I.D. AT103
COORDINATES 3,786.5' E 4,351.8' N DRILLING STARTED 11/1/88
ES GEOLOGIST/ENGINEER M. E. Herrmann
DRILLER Fox Drilling DRILLING METHOD H.S.A. 6-1/4" I.D., 11" O.D.
DRILLING COMPLETED 11/1/88 WELL COMPLETED N.A. TOTAL WELL DEPTH N.A.
SCREENED INTERVALS N.A. TOTAL BOREHOLE DEPTH 15'
SAMPLING METHOD 5' Continuous M.P. ELEV. N.A. L.S. ELEV. 916.6'
WATER LEVEL, Ft BELOW M.P. N.A. ELEVATION N.A. DATE N.A.

DEPTH BELOW L.S.	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0				FILL, gravel, black, sand.		
	0	40		SAND, medium, organge brown.		
5						
	0	50		SAND, medium, trace gravel, grey, (cohesive).		
10						
	0	70				
				SAND and GRAVEL, grey brown		
15						
				B.T. at 15'		

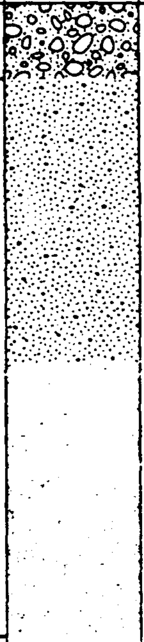
DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 1
WELL/BORING LOCATION BC5 SB2 PROJECT I.D. AT103
COORDINATES 3,730.8' E 4,439.0' N DRILLING STARTED 11/1/88
ES GEOLOGIST/ENGINEER M. E. Herrmann
DRILLER Fox Drilling DRILLING METHOD H.S.A. 6-1/4" I.D., 11" O.D.
DRILLING COMPLETED 11/1/88 WELL COMPLETED N.A. TOTAL WELL DEPTH N.A.
SCREENED INTERVALS N.A. TOTAL BOREHOLE DEPTH 15'
SAMPLING METHOD 5' Continuous M.P. ELEV. N.A. L.S. ELEV. 918.1'
WATER LEVEL, Ft BELOW M.P. N.A. ELEVATION N.A. DATE N.A.

DEPTH BELOW L.S.	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0				FILL, coal, gravel, sand, black (slightly moist).		
	0	50		SAND, coarse, trace to some gravel, trace silt, orange brown.		
5				SAND, medium, trace silt, orange brown.		
	0	70				
10				SAND, medium and cobbles, tan brown.		
	0	10				
15				B.T. at 15'		

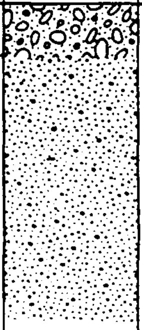
DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 1
WELL/BORING LOCATION BC5 SB3 PROJECT I.D. AT103
COORDINATES 3,517.2′ E 4,357.2′ N DRILLING STARTED 11/1/88
ES GEOLOGIST/ENGINEER M. E. Herrmann
DRILLER Fox Drilling DRILLING METHOD H.S.A. 6-1/4" I.D., 11" O.D.
DRILLING COMPLETED 11/1/88 WELL COMPLETED N.A. TOTAL WELL DEPTH N.A.
SCREENED INTERVALS N.A. TOTAL BOREHOLE DEPTH 15′
SAMPLING METHOD 5′ Continuous M.P. ELEV. N.A. L.S. ELEV. 919.0′
WATER LEVEL, Ft BELOW M.P. N.A. ELEVATION N.A. DATE N.A.

DEPTH BELOW LS	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0				SAND and GRAVEL, brown (possible fill).		
	0	50		SAND, medium, trace gravel, orange brown.		
5						
	0	75				
10				SAND, medium to coarse, orange brown.		
	0	75		SAND, medium, orange, brown.		
15						
				B.T. at 15′		

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 1
WELL/BORING LOCATION BC5 SB4 PROJECT I.D. AT103
COORDINATES 3,619.3' E 4,296.0' N DRILLING STARTED 11/1/88
ES GEOLOGIST/ENGINEER M. E. Herrmann
DRILLER Fox Drilling DRILLING METHOD H.S.A. 6-1/4" I.D., 11" O.D.
DRILLING COMPLETED 11/1/88 WELL COMPLETED N.A. TOTAL WELL DEPTH N.A.
SCREENED INTERVALS N.A. TOTAL BOREHOLE DEPTH 15'
SAMPLING METHOD 5' Continuous M.P. ELEV. N.A. L.S. ELEV. 917.5'
WATER LEVEL, Ft BELOW M.P. N.A. ELEVATION N.A. DATE N.A.



DEPTH BELOW L.S.	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0				FILL, coal, gravel, sand, black.		
	0	50		SAND, medium to coarse, gravel, orange brown.		
5						
	0	60				
				SAND, fine to medium, tannish brown.		
10				SAND, fine to medium tannish brown.		
	0	40				
15						
				B.T. at 15'		

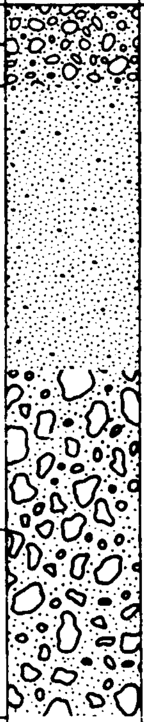
DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 1
WELL/BORING LOCATION BC5 SB5 PROJECT I.D. AT103
COORDINATES 3,430.7' E 4,207.4' N DRILLING STARTED 11/1/88
ES GEOLOGIST/ENGINEER M. E. Herrmann
DRILLER Fox Drilling DRILLING METHOD H.S.A. 6-1/4" I.D., 11" O.D.
DRILLING COMPLETED 11/1/88 WELL COMPLETED N.A. TOTAL WELL DEPTH N.A.
SCREENED INTERVALS N.A. TOTAL BOREHOLE DEPTH 13'
SAMPLING METHOD 5' Continuous M.P. ELEV. N.A. L.S. ELEV. 918.8'
WATER LEVEL, Ft BELOW M.P. N.A. ELEVATION N.A. DATE N.A.

DEPTH BELOW L.S.	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0				FILL, coal, gravel, black.		
	0	50		SAND, medium, trace silt, dark brown (cohesive).		
5						
	0	50				
				SAND, medium, and gravel, orange brown.		
10				COBBLES and BOULDERS		
		25				
				A.R. at 13'		
15						

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 1
WELL/BORING LOCATION BC5 SB6 PROJECT I.D. AT103
COORDINATES 3,532.2′ E 4,183.7′ N DRILLING STARTED 11/1/88
ES GEOLOGIST/ENGINEER M. E. Hermann
DRILLER Fox Drilling DRILLING METHOD H.S.A. 6-1/4" I.D., 11" O.D.
DRILLING COMPLETED 11/1/88 WELL COMPLETED N.A. TOTAL WELL DEPTH N.A.
SCREENED INTERVALS N.A. TOTAL BOREHOLE DEPTH 15′
SAMPLING METHOD 5′ Continuous M.P. ELEV. N.A. L.S. ELEV. 918.2′
WATER LEVEL, Ft BELOW M.P. N.A. ELEVATION N.A. DATE N.A.

DEPTH BELOW L.S.	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0				FILL, coal, gravel, black.		
				GRAVEL, trace sand, orange brown.		
	0	50		SAND, medium, trace to some gravel, orange brown.		
5						
	0	50				
10						
	0	50		SAND, coarse, gravel, cobbles, orange brown.		
				SAND and GRAVEL, orange brown with cobbles.		
15						
				B.T. at 15′		

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 1
WELL/BORING LOCATION BC6 SB1 PROJECT I.D. AT103
COORDINATES 3,725.1' E 4,090.8' N DRILLING STARTED 11/3/88
ES GEOLOGIST/ENGINEER M. E. Herrmann
DRILLER Fox Drilling DRILLING METHOD H.S.A. 6-1/4" I.D., 11" O.D.
DRILLING COMPLETED 11/3/88 WELL COMPLETED N.A. TOTAL WELL DEPTH N.A.
SCREENED INTERVALS N.A. TOTAL BOREHOLE DEPTH 15'
SAMPLING METHOD 5' Continuous M.P. ELEV. N.A. L.S. ELEV. 917.4'
WATER LEVEL, Ft BELOW M.P. N.A. ELEVATION N.A. DATE N.A.

DEPTH BELOW L.S.	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0				SAND, silty, trace gravel, trace coal chips (fill).		
	0	50		SAND, silty, trace gravel, orange brown.		
5				SAND, medium, orange brown to gray (slightly to very moist).		
	0	55		SAND, silty, trace gravel, dark brown to orange brown.		
10				SAND, medium, orange brown.		
	0	60				
15				B.T. at 15'		

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 1
WELL/BORING LOCATION BC6 SB2 PROJECT I.D. AT103
COORDINATES 3,714.1' E 4,034.8' N DRILLING STARTED 11/3/88
ES GEOLOGIST/ENGINEER M. E. Herrmann
DRILLER Fox Drilling DRILLING METHOD H.S.A. 6-1/4" I.D., 11" O.D.
DRILLING COMPLETED 11/3/88 WELL COMPLETED N.A. TOTAL WELL DEPTH N.A.
SCREENED INTERVALS N.A. TOTAL BOREHOLE DEPTH 15'
SAMPLING METHOD 5' Continuous M.P. ELEV. N.A. L.S. ELEV. 917.7'
WATER LEVEL, Ft BELOW M.P. N.A. ELEVATION N.A. DATE N.A.

DEPTH BELOW L.S.	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0				SAND, silty, trace gravel, trace coal, medium gray.	░	
	0	60		SAND, medium, trace gravel, orange brown.	░	
5					░	
	0	75		SAND, medium, interbedded sand and gravel, orange brown to dark brown	░	
10					░	
	0	75			░	
15				B.T. at 15'		

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 1
WELL/BORING LOCATION BC6 SB3 PROJECT I.D. AT103
COORDINATES 3,783.2' E 3,984.3' N DRILLING STARTED 11/3/88
ES GEOLOGIST/ENGINEER M. E. Herrmann
DRILLER Fox Drilling DRILLING METHOD H.S.A. 6-1/4" I.D., 11" O.D.
DRILLING COMPLETED 11/3/88 WELL COMPLETED N.A. TOTAL WELL DEPTH N.A.
SCREENED INTERVALS N.A. TOTAL BOREHOLE DEPTH 15'
SAMPLING METHOD 5' Continuous M.P. ELEV. N.A. L.S. ELEV. 917.9'
WATER LEVEL, Ft BELOW M.P. N.A. ELEVATION N.A. DATE N.A.

DEPTH BELOW L.S.	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0				SAND, silty, trace gravel, medium brown (slightly moist to moist).	▨	
	0	40			▨	
5					▨	
				CLAY, sandy, trace gravel, orange brown.	▨	
				SAND, medium trace gravel, orange brown to tan brown.	▨	
	0	70			▨	
10					▨	
	0	65			▨	
15					▨	
				B.T. at 15'		

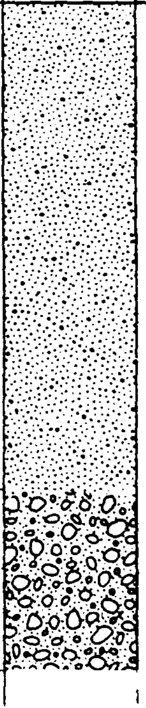
DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 1
WELL/BORING LOCATION BC6 SB4 PROJECT I.D. AT103
COORDINATES 3,863.3' E 4,097.0' N DRILLING STARTED 11/3/88
ES GEOLOGIST/ENGINEER M. E. Herrmann
DRILLER Fox Drilling DRILLING METHOD H.S.A. 6-1/4" I.D., 11" O.D.
DRILLING COMPLETED 11/3/88 WELL COMPLETED ______ TOTAL WELL DEPTH N.A.
SCREENED INTERVALS N.A. TOTAL BOREHOLE DEPTH 15'
SAMPLING METHOD 5' Continuous M.P. ELEV. N.A. L.S. ELEV. 918.3'
WATER LEVEL, Ft BELOW M.P. N.A. ELEVATION N.A. DATE N.A.

DEPTH BELOW L.S.	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0				SAND, silty, trace gravel, dark to medium brown.		
	0	60		SAND, medium to coarse, trace to some gravel, orange brown.		
5						
	0	60				
10						
15				B.T. at 15'		

DRILLING AND WELL COMPLETION RECORD

JOB NAME/LOCATION Michigan ANGB, Battle Creek, MI PAGE 1 OF 1
WELL/BORING LOCATION BC6 SB5 PROJECT I.D. AT103
COORDINATES 3,873.2' E 4,046.3' N DRILLING STARTED 11/3/88
ES GEOLOGIST/ENGINEER M. E. Herrmann
DRILLER Fox Drilling DRILLING METHOD H.S.A. 6-1/4" I.D., 11" O.D.
DRILLING COMPLETED 11/3/88 WELL COMPLETED N.A. TOTAL WELL DEPTH N.A.
SCREENED INTERVALS N.A. TOTAL BOREHOLE DEPTH 15'
SAMPLING METHOD 5' Continuous M.P. ELEV. N.A. L.S. ELEV. 919.2'
WATER LEVEL, Ft BELOW M.P. N.A. ELEVATION N.A. DATE N.A.

DEPTH BELOW L.S.	HNU OVA (PPM)	% REC	NO. BLOWS	SAMPLE DESCRIPTION	LITHO-LOGY	WELL CONSTRUCTION
0				SAND, silty, trace gravel, trace coal, dark brown.		
	0	50		SAND, medium, trace gravel, orange brown.		
5				SAND, fine to medium, trace gravel, tannish brown.		
	0	50				
10						
	0.2	50		SAND and GRAVEL.		
15						
				B.T. at 15'		

APPENDIX C
TOXICOLOGICAL PROFILES OF THE CHEMICALS OF CONCERN

APPENDIX C
TOXICOLOGICAL PROFILES OF THE CHEMICALS OF CONCERN

C.1 VOLATILE ORGANIC COMPOUNDS

C.1.1 Acetone

Acetone is a colorless liquid with a sweetish odor which boils at 56.5°C. It is used in the production of lubricating oils, solvents and as an intermediate in the manufacture of chloroform and various pharmaceutical products and pesticides [Sittig, 1985]. Acetone is also found in paints, varnishes, lacquers. The evaporation rate of acetone also makes it quite useful for cleaning and drying precision parts [ACGIH, 1990].

Acetone is expected to migrate freely in soil/groundwater systems. Volatilization may occur from surficial soils, however, vapor phase concentrations in soil are expected to be low whenever water is present. Therefore, inhalation may be an important exposure pathway in some situations. The primary pathway of migration from a soil/groundwater system is to groundwater drinking water supplies. Acetone can be biodegraded and hence bioaccumulation of acetone is not likely to be an important exposure pathway [Little, 1987].

No reports implicating acetone as a carcinogen or mutagen were found in the literature. Inhalation of acetone vapors in high concentrations produces dryness of throat and mouth, dizziness, nausea, uncoordinated movements, loss of coordinated speech, drowsiness, and in extreme cases, coma. The oral LD_{50} (i.e., the lethal dose in 50 percent of the test animals) in rats for acetone has been reported as 10.7 mL/kg [HEAST 1990]. The oral RfD has been reported to be 1E-1 mg/kg/day [ACGIH, 1990]. No injurious effects have been reported to result from occupational exposures other than skin irritation resulting from its defatting action, or headache from prolonged inhalation [Sax and Lewis, 1989].

C.1.2 Benzene

Benzene is a colorless aromatic hydrocarbon with a characteristic odor. Benzene was widely used in the past as a solvent and as an octane-raising additive in gasoline. Presently, benzene is used primarily in the chemical industry as a starting or intermediate material for the synthesis of many other organic compounds [Sittig, 1985].

Benzene has been shown to be mobile in the soil/groundwater system. It is relatively soluble in groundwater and may be transported through sandy soils and soils of low organic content. The amount of benzene sorbed to soil increases with increasing organic soil content. Benzene is highly volatile, and volatilization in surficial soils is probably an important transport mechanism. However, sorption of benzene vapors onto soil particles may slow vapor-phase transport. Data on the biodegradation of benzene are inconclusive. There is some evidence of gradual biodegradation at low concentrations by aquatic organisms, but the compound is considered fairly resistant to biodegradation. The rate of biodegradation may be enhanced in the presence of other hydrocarbons [Little, 1987], [Versar, 1979].

Benzene is readily absorbed following oral and inhalation exposure. The toxic effects of benzene in humans following exposure by inhalation is the same as that for laboratory animals, and includes central nervous system effects, hematological effects, and immune system depression. In humans, acute exposures to high concentrations of benzene vapors has been associated with dizziness, nausea, vomiting, headache, drowsiness, narcosis, coma, and death. Chronic exposure to benzene vapors can produce reduced leukocyte, platelet, and red blood cell levels. Chronic exposure to benzene is also associated with leukemia and bone marrow damage [Sittig, 1985] [ACGIH, 1990]. No data is available on the inhalation and oral reference doses in humans. Benzene has been classified a Group A human carcinogen by EPA. The inhalation and oral potency factors for Benzene are both 2.9E-2 $(mg/kg/d)^{-1}$ [HEAST, 1990].

C.1.3 Carbon Disulfide

Carbon disulfide is a highly refractive, flammable liquid which boils at 46°C. It has a sweet odor in pure form, however in commercial and reagent grades it has a foul smell [Sittig, 1985]. Carbon disulfide is a natural product of anaerobic biodegradation and is released to the atmosphere from oceans and land masses. It is also used in the manufacture of viscose rayon, cellophane, and carbon tetrachloride, and as a solvent and fumigant [Howard, 1990].

Due to carbon disulfides high vapor pressure and low adsorption to soil, it is expected to volatilize readily from soil or leach into the groundwater. There is some evidence that carbon disulfide will degrade in moist unsterilized soil [Howard, 1990].

Local exposure to carbon disulfide as a vapor can result in irritation to eyes, skin and mucous membranes. Contact with carbon disulfide as a liquid can result in blistering with second and third degree burns. Skin sensitivity can also occur. Systemic effects of exposure to carbon disulfide is primarily manifested by psychological, neurological, and cardiovascular disorders. Repeated exposures to this compound may cause behavioral disorders such as irritability, anger, suicidal tendencies, insomnia, defective memory, dizziness, and a toxic manic depressive psychosis. Neurological changes result in polyneuritis. Atherosclerosis and coronary heart disease have also been linked to exposure to carbon disulfide [Sittig, 1985]. The inhalation reference dose is 1.0E-02 mg/kg/d and the oral RfD is 1.0E-01 mg/kg/d, and it has been classified as a Group D carcinogen [HEAST, 1991].

C.1.4 Chloroform

Chloroform is a clear colorless liquid with a characteristic odor. It is widely used as a solvent, in the extraction and purification of penicillin and other pharmaceuticals. It is also widely used in the manufacture of artificial silk, plastics, floor polishes, and fluorocarbons. Chloroform is also widely found in the atmosphere and water due to the chlorination of drinking water, municipal sewage, and cooling water in electric power plants [Sittig, 1985] [Howard, 1990].

When chloroform is released to surface soil it is expected to evaporate rapidly into the atmosphere due to its high vapor pressure. It is poorly adsorbed to soil and can leach into the groundwater [Howard, 1990]. Transformation processes are not expected to be significant [Versar, 1985].

Chloroform vapor is a CNS depressant and may cause headache. drowsiness, vomiting, dizziness, irregular heartbeat and death. Chronic overexposure has been shown to cause enlargement of the liver and kidney damage. Dermal exposure may cause chronic skin irritation [Versar, 1985]. It has been classified as a B2 probable human carcinogen by the EPA and has an oral potency factor of 1.7E-07(1/mg/kg/d) [HEAST, 1991].

C.1.5 1,2-Dichloroethylene (1,2-DCE)

1,2-DCE is a halogenated organic compound which has two isomers (i.e., cis- and trans- 1,2-DCE), and is used as a solvent for fats, phenol, and camphor [Sittig, 1985].

Cis- and trans-1,2-DCE are expected to be highly mobile in soil/groundwater systems and therefore, the primary exposure pathway is ingestion of drinking water from wells containing DCE. Volatilization may be important for 1,2-DCE isomers near the surface or in the soil/air compartment. When released into the environment DCE gradually decomposes in the presence of air, light, and moisture to form hydrochloric acid. Transformation processes such as hydrolysis or biodegradation are not expected to be significant in natural soils [Little, 1987].

Inhalation or ingestion of 1,2-DCE produces nausea, vomiting, dizziness, and narcosis. The liquid can act as a primary irritant, producing dermatitis and irritation of mucous membranes. Long-term oral exposure to cis-1,2-DCE may result in anemia, whereas long-term oral exposure to trans-1,2-DCE may result in liver effects [ACGIH, 1990]. Neither the cis- nor the trans- isomers of 1,2-DCE can be classified as carcinogens. The oral RfD's for the cis and trans isomers are 1E-2 and 2E-2 mg/kg/d. respectively [HEAST, 1990].

C.1.6 Ethylbenzene

Ethylbenzene is a colorless aromatic liquid. It is used in industry as a resin solvent and as an intermediate in the manufacture of the styrene monomer.

Ethylbenzene is moderately adsorbed to soils but it will leach to groundwater, particularly in soils containing low levels of organic matter. Ethylbenzene will volatilize from surface soils and it is thought that it will biodegrade once microbial populations become acclimated [Howard et.al., 1989]. No empirical studies on the bioaccumulation of ethylbenzene are available. No information on the toxicity of ethylbenzene to terrestrial wildlife or birds are available [Sittig, 1985].

In humans, short-term inhalation exposure to ethylbenzene can result in sleepiness, fatigue, headache, mild eye and respiratory irritation. The liver and kidney appear to be the primary target organ following chronic oral exposure [Sittig, 1985]. The oral reference dose for ethylbenzene is 1 E-1 mg/kg/d [HEAST, 1990].

C.1.7 Methyl Ethyl Ketone (MEK)

MEK (2-butanone) is a clean, colorless liquid with a fragrant, mint like, moderately sharp odor boiling at 79° - 80°C. MEK is used as a solvent in nitrocellulose coating and vinyl film manufacture, in smokeless powder manufacture, in cements and adhesives and in the dewaxing of lubricating oils. It is also an intermediate in drug manufacturer [Sittig, 1985]. MEK is formed as a result of the natural photo-oxidation of olefinic hydrocarbons which get in the air from automobiles and other sources [Howard. 1990].

If MEK is released to soil, it will partially evaporate into the atmosphere from near-surface soil and many leach into the groundwater. If MEK is released into water, it will be lost by evaporation near surface or be slowly biodegraded. It will not hydrolyze in water or soil under natural environmental conditions. In the atmosphere it exists primarily in the gas phase. Potential human exposure is from occupational atmospheres or ambient air in the vicinity of industrial sources or during photochemical smog episodes. Although there is limited data, MEK has been found to be a natural component of some foods and therefore ingestion can also be a potential source of exposure [Howard, 1990].

MEK cannot be classified as a carcinogen. MEK is reported to be moderately toxic by ingestion, skin contact and intraperitoneal routes (Sax and Lewis, 1989). It has been reported that at levels approaching 100 ppm MEK causes slight nose and throat irritation and at 200 ppm it causes eye irritation in some subjects. The oral LD_{50} in rats is reported to be 6.86 mL/kg [ACGIH, 1990]. The inhalation and oral reference doses of MEK are 3E-1 and 5E-2 (mg/kg/d) respectively [HEAST, 1990].

C.1.8 Styrene

Styrene is the simplest member of the alkenylbenzenes. It is a colorless to yellow, refractive, oily liquid. Styrene has a sweet odor at low concentrations but a disagreeable odor at high concentration [Patty's, 1981].

Styrene is not known to occur as a natural product. Styrene is released into the environment by emissions and effluents from its production and its use in polymer manufacture. It has been found in exhausts from spark-ignition engines, oxyacetylene flames, cigarette smoke, and gases emitted by pyrolysis of brake linings. Styrene is also emitted in automobile exhaust. Likely consumer exposure sources are the use of products containing styrene, such as floor waxes and polishes, paints, adhesives, putty, metal cleaners, autobody fillers, fiberglass, boats, and varnishes [Howard et al., 1989].

Styrene released into the soils is subject to biodegradation of 87 to 95 percent in sandy loam or landfill soils. It can exhibit low to moderate soil mobility depending on soil conditions and it has been demonstrated to leach into underlying groundwater. Volatilization and biodegradation may be the dominant transport and transformation processes for styrene in environmental waters [Howard et al., 1989).

The adsorption of styrene in man and animals proceeds by all routes, but mainly through the respiratory tract. The major temporary effects of styrene is irritant to eyes, skin, mucous membranes, and respiratory system. High dose levels may cause anesthesia and some systemic effects [Patty's. 1989]. Styrene has been classified as a Group B2 probable human carcinogen by the EPA. It has an inhalation potency factor of 2.0E-03 (1/(mg/kg/d)) and an oral potency factor of 3.OE-02 (1/(mg/kg/d)) [HEAST, 1991].

C.1.9 Toluene

Toluene is a monocyclic, aromatic, colorless liquid. It is used in manufacturing benzoic acid, benzaldehyde, explosives, dyes, and many other organic compounds. Toluene functions as a solvent in products such as wood furniture cleaners.

Available data indicates that volatilization is the major route of removal from aquatic environments. Once volatilized, atmospheric photodestruction of toluene probably subordinates all other fates. Toluene will be adsorbed by sediments and suspended solids, but the degree to which this adsorption will interfere with volatilization is unknown. Toluene does not bioaccumulate in the environment [Little, 1987].

No data are available concerning the chronic toxicity of toluene to freshwater organisms. Toluene is a volatile compound that has been found to readily move from water to the atmosphere. Although its transport and persistence in the environment is not well understood, it is not expected to bioaccumulate to any great extent.

Toluene is absorbed in humans through all possible routes of exposure [EPA, 1985]. In humans, the primary acute effects of toluene vapors are central nervous system depression and narcosis. Also seen at low levels of exposure are irritation of the skin and eyes, and impairment of coordination and reaction time when inhaled. In humans, chronic exposure to toluene vapors has been associated with central and peripheral nervous system effects, hepatomegaly, and hepatic and renal function changes. Effects on the liver and central nervous system have also been observed in animals following oral exposure [EPA, 1987]. Toluene cannot be classified as a human carcinogen. Its inhalation RfC and oral RfD are 2 mg/m^3 and 2.0E-1 mg/kg/d, respectively [HEAST, 1990].

C.1.10 1,1,2,2-Tetrachloroethane

1,1,2,2-Tetrachloroethane is a heavy, volatile liquid which is nonflammable and has a sweetish odor. This compound is used as a dry cleaning agent, fumigant, and in cement and lacquers. It is also used in the manufacture of tetrachloroethene, artificial silk, artificial leather and artificial pearls [Sittig, 1985].

The primary pathway of concern for this compound is the migration to groundwater drinking supplies. A K_{oc} of 79 indicates that 1,1,2,2-tetrachloroethane is highly mobile in soil and therefore can leach into groundwater. This compound also has a high Henry's Law constant, indicating that volatization from surface soils and surface water will occur. There is evidence that this compound may slowly degrade [Howard, 1990] [Versar, 1985].

Short term ingestion and inhalation exposure cause irritation of nose and throat, fatigue, nausea, headaches, loss of reflexes, and loss of appetite. Acute exposure could occur in liver dysfunction. Liver and kidney damage are expected from long term exposure [Versar, 1985]. It has been classified as a C possible human carcinogen by the EPA and it has an oral potency factors of 2.0E-01 (1/(mg/kg/d)) [HEAST, 1991].

C.1.11 Tetrachloroethylene (PCE)

Tetrachloroethylene is a clear, colorless, nonflammable liquid with a characteristic odor noticeable at 50 ppm. Tetrachloroethylene is widely used as a solvent and has been used as a dry cleaning agent, a degreaser, a chemical intermediate, a fumigant and an anthelmintic. By far the most significant exposure to PCE can occur in industrial environments through inhalation and dermal exposure [Sittig, 1985].

PCE is relatively mobile in soil-water systems. It can be transported through air filled pores as well as in solution. PCE is resistant to hydrolysis and to biodegradation. The primary migration pathways for PCE involve release to and transport by groundwater and air [Little, 1987].

PCE has been classified as a Group B2 carcinogen by the EPA. The inhalation and oral potency factors in humans are 5.2E-7 and 5.1E-2 $(mg/kg/d)^{-1}$ respectively.

Its oral RfD is 1E-2 mg/kg/d [HEAST, 1990]. Excessive exposure to PCE results in systemic effects on the central nervous system, mucous membranes, eyes and skin, and, to a lesser extent, the lungs, liver, and kidneys [ACGIH, 1990]. PCE can cause dermatitis particularly after prolonged contact with the skin, and it irritates the gastrointestinal tract upon ingestion [Sax and Lewis, 1989].

C.1.12 1,1,1-Trichloroethane

1,1,1-Trichloroethane is a colorless, nonflammable liquid, which has a odor similar to chloroform. It is used as a degreaser and for cleaning metals in liquid form. Other industrial applications of 1,1,1-trichloroethane solvent properties include its use as a dry-cleaning agent, a vapor degreasing agent and a propellant. It is also commonly substituted for carbon tetrachloride [Sittig, 1985].

The primary pathway of concern is the migration of this compound to groundwater drinking water supplies. 1,1,1-Trichloroethane is not adsorbed well by soils containing low levels or organic matter such as subsurface soils, allowing it to pass rapidly through soil into groundwater. This compound also rapidly volatiles from water and soil. Biodegradation in natural soils is not expected to be significant [Howard, 1990].

Local exposure to this compound may result in irritation to eyes, conjunctivitis and dermatitis [Sittig, 1985]. It also acts as a narcotic and depresses the central nervous system. Acute exposure may lead to dizziness, incoordination, drowsiness, increased reaction time and irregular heart beat. The long term effects of exposure to 1,1,1-trichloroethane is hepatotoxicity [Versar, 1985]. It has been classified as a Group D carcinogen [HEAST, 1991].

C.1.13 Trichloroethylene (TCE)

TCE is a halogenated organic compound widely used in industry as a solvent. Industries that use TCE include dry cleaning, fumigation, paint dilution, aerospace operations, and textile processing [Sittig, 1985].

TCE is relatively mobile in the soil/groundwater system, particularly if soils have a low organic content. It is moderately soluble in water, but can be sorbed on soils which have a high organic content. Transport mechanisms include volatilization from surficial soils and migration in groundwater. Most TCE released onto surface soils will volatilize. The persistence of TCE in soil/groundwater systems is not known, but in most cases it is assumed that TCE can persist for months to years. TCE can be biodegraded into cis-1,2-dichloroethene, trans-1,2-dichloroethene, 1,1-DCE, and vinyl chloride. TCE may bioaccumulate in organisms, but it does not appear to biomagnify in the food chain [Little, 1987].

TCE has been classified as a probable human carcinogen (EPA Group B2). The inhalation and oral potency factors are 1.7E-2 and 1.1E-2 $(mg/kg/d)^{-1}$, respectively. No data is available on the reference doses [HEAST, 1990]. Chronic exposure to TCE may affect the central nervous system and cause minor liver function impairments. Short-term high-level concentrations of TCE may cause depression of the central nervous system, kidney and liver damage, cardiovascular damage, and death due to ventricular fibrillation. Short-term, low-level exposure may cause irritation of the eyes, nose, throat, and skin [Sittig, 1985].

There was only limited data on the toxicity of trichloroethylene to aquatic organisms. The lowest level at which an adverse effect in freshwater aquatic life may occur was 45 mg/L [Little, 1987].

No information on the toxicity of trichloroethylene to domestic animals or terrestrial wildlife was available in the literature reviewed.

C.1.14 o-, m-, and p-Xylenes

Xylene exists in three isomer forms: ortho-, meta-, and para-xylene. Commercial xylene is a mixture of these three isomers. Meta-xylene is predominant in commercial xylene and shares physical properties with o-xylene in that both are mobile, colorless, flammable liquids. Para-xylene forms colorless plates or prisms at low temperature (13°C to 14°C). Xylene is used as a solvent, as a constituent of paint, lacquers, varnishes, inks, dyes, adhesives, cements, cleaning fluids, and aviation fuels. It is also used as a chemical feedstock for raw materials which go into the manufacture of plastic materials and synthetic textile fabrics. Xylenes are also used in the manufacture of quartz crystal oscillators, hydrogen peroxide, perfumes, insect repellants, epoxy resins, pharmaceuticals, and leather products [Sittig, 1985].

Xylene is relatively mobile in soil-water systems, especially in the aqueous phase. Volatilization through air filled pores is also possible. The chemical is resistant to hydrolysis but is probably biodegradable. The primary exposure pathway for soil-water systems involves the migration of xylene to drinking water supplies, however, xylene can also be inhaled as a result of volatilization from surface soils [Little, 1987].

None of the xylene isomers have been classified as carcinogens. The inhalation and oral RfD of o-xylene are 7E-1 and 2 mg/kg/d, respectively. The inhalation and oral RfD's for m,p-xylene are 3E-1 and 2 mg/kg/d, respectively [HEAST, 1990]. Xylene is moderately toxic by intraperitoneal and subcutaneous routes. However, it is only mildly toxic by ingestion and inhalation. Xylene is an eye irritant with irritation starting at 200 ppm [Sax and Lewis, 1989].

C.2 SEMI-VOLATILE ORGANIC COMPOUNDS

C.2.1 Bis(2-ethylhexyl)phthalate

Bis(2-ethylhexyl)phthalate, also known as di-ethylhexylphthalate, is a common laboratory contaminant. It is used in vacuum pumps and, when heated to decomposition, emits acrid smoke. As a group, phthalate esters are widely distributed in the environment by anthropogenic and perhaps natural sources. They have been found in well and drinking waters, oil, soil, air, plants, fish, food, animals, and humans. Phthalate ester contamination in surface water residues has been correlated with drainage from industrial or heavily polluted areas [Versar, 1979].

A variety of organisms can accumulate phthalate esters and they have become concentrated in animal and human tissues and organs. Under aerobic conditions, microbial systems can degrade phthalate esters, but under anaerobic conditions, bis(2-ethylhexyl)phthalate ceases to degrade. In determining the environmental fate of phthalate esters, bioaccumulation, biotransformation, and biodegradation are probably the most important processes [Versar, 1979].

Bis(2-ethylhexyl)phthalate is a probable human carcinogen (EPA Group B2). The oral potency factor of the compound is 1.4E-2 $(mg/kg/d)^{-1}$. Its oral RfD is 2E-2 mg/kg/d [HEAST, 1990]. Exposure to bis(2-ethylhexyl)phthalate has also been associated with developmental toxicity as well as with adverse effects upon the liver, kidneys in laboratory animals [EPA, 1980]. This compound causes irritation of the eyes and mucous membranes and may also cause nausea and diarrhea [Sittig, 1985].

C.2.2 Butylbenzylphthalate

Butylbenzylphthalate is a phthalate ester. As a group, phthalate esters are widely distributed in the environment by anthropogenic and perhaps natural sources [Versar, 1979].

Butylbenzylphthalate probably does not undergo direct photolysis in surface waters. It will hydrolyze very slowly under most conditions. Sorption onto suspended particulates and biota, and complexation with humic substances are probably the most important transport mechanisms. Phthalate esters can be accumulated and metabolized by organisms [Versar, 1979].

Ingestion by laboratory animals causes body weight gain and may also affect reproductive organs, liver, and kidneys. Butylbenzylphthalate has been classified as a Group C human carcinogen by the EPA, and as a Group 3 agent not classifiable as to its carcinogenicity to humans by the International Agency for Research on Cancer (IARC) [Sittig, 1985]. Its oral RfD for humans is 2E-1 mg/kg/d [HEAST, 1990].

C.2.3 Dimethyl Phthalate (DMP)

DMP is a colorless, oily liquid with a sugar ester odor which boils at 285°C and is used as an insect repellant, as a plasticizer for cellulose ester plastics [Sittig, 1985], and as a solvent [ACGIH, 1990]. DMP may be released as an air emission (most probably in the form of aerosols), as a component of wastewaters generated during manufacturing, or as a leachate from plastic tubing and other containers [Howard et. al., 1989].

The soil adsorption coefficient of DMP has been estimated to be 160, which indicates low adsorption to soil and sediment. If spilled on land, DMP should weakly sorb to most soils unless the soil has a very high organic content. Therefore, leaching through most soils to groundwater is expected. If released into water, DMP tends to remain in the water column since it absorbs weakly to soils and sediments. The half life of DMP is 13-27 hours suggesting that biodegradation is significant in lakes and ponds. Humans are exposed to DMP principally in occupational settings [Howard et. al., 1989].

DMP has not been classified as a carcinogen. The acute toxicity of DMP by inhalation is extremely low. The oral RfD is 1E-1 mg/kg/d [HEAST, 1990]. Intraperitoneally in the mouse, the LD_{50} was 3.6 g/kg [ACGIH, 1990].

C.2.4 Di-n-butylphthalate (DBP)

DBP is a colorless, oily liquid with a very weak, aromatic odor, which boils at 340°C. It is used in plasticizing vinyl acetate emulsion systems and cellulose esters. It is also used as an insect repellant [Sittig, 1985]. It is an environmental pollutant which is widely distributed. DBP may be released into the environment as air emissions and in wastewater during its production and use, incineration of plastics, and migration of the plasticizer from materials containing it [Howard et. al., 1989].

When spilled on soil, DBP will be adsorbed to a moderate extent, will slowly biodegrade, and if present in high concentrations can also leach into groundwater. In water, DBP will absorb moderately to sediment, complex with humic material, and can be significantly biodegraded. DBP has a low vapor pressure and therefore volatilization from soil is not a significant loss process. If released to the atmosphere, DBP will absorb on particulate matter and be subject to gravitational settling. Vapor phase DBP will photodegrade by reaction with hydroxyl radicals. Humans may be exposed to DBP in the workplaces where it is manufactured and used. Other human exposures may occur due to DBP present in drinking water, food and particulate matter and vapor in the ambient air [Howard et. al., 1989].

There is no evidence that indicates DBP is carcinogenic. The acute oral LD_{50} in the rat is 8-16 g/kg. The oral RfD is 1E-1 mg/kg/d [HEAST, 1990]. It is moderately toxic by intraperitoneal and intravenous routes and mildly toxic by ingestion.

C.2.5 Cresols

Cresol is a colorless, yellowish or pinkish liquid with a pungent odor. Cresol is a mixture of three isomers, o-, m-, and p-cresol (4-methylphenol). Cresol is soluble in alcohol, glycol and dilute alkalis, and is used as a disinfectant, as an ore flotation agent, and as an intermediate in the manufacture of chemicals, dyes, plastics, and antioxidants [Sittig, 1985]. Cresol is released to the atmosphere in auto and diesel exhaust, during coal and coal tar refining, wood pulping, and during its use in manufacturing and metal refining [Howard et. al., 1989].

Cresol is relatively mobile in some soils and therefore may leach into the groundwater. It biodegrades rapidly in soil. with complete degradation in seven days. In water, biodegradation and dilution are the significant removal processes. Cresol has a low Henry's law constant and hence does not volatilize readily. Humans can be exposed to cresol by inhalation and dermal contact, especially in source areas or occupational settings [Howard et. al., 1989].

Evidence suggests that all isomers of cresol are Group C human carcinogens. Cresol is poisonous by ingestion, skin contact, subcutaneous, intravenous, and intraperitoneal routes, and is also a severe skin and eye irritant [Sax and Lewis, 1989]. The oral RfD is 5E-2 mg/kg/d [HEAST, 1990]. The oral LD_{50} value is 1.8 g/kg.

C.2.6 Polycyclic Aromatic Hydrocarbons

C.2.6.1 Acenapthalene; Anthracene; Benz(a)anthracene; Benzo(k)fluoranthene; Benzo(g,h,i)perylene; Benzo(a)pyrene; Chrysene; Dibenz(a,h)anthracene; Fluoranthene; Fluorene; Indeno(1,2,3-cd)pyrene; Napthalene; Phenanthrene; Pyrene

Polycyclic aromatic hydrocarbons (PAHs) are a class of chemical compounds characterized by a basic structure of two or more fused aromatic (benzene) rings. The compounds are fused by pairs of carbon atoms, resulting in a molecule with a carbon atom lying in a single plane with hydrogen atoms. The lowest molecular weight member of this group is naphthalene, with two fused rings. The highest *molecular weight member is graphite.* PAH compounds can be divided into two groups based on their chemical, physical and biological properties. These two groups are the lower molecular weight (two- to three-ring) compounds and the higher molecular weight (four- to seven-ring) compounds.

The physical properties of PAHs typically vary with increasing molecular weight. Vapor pressure and solubility decrease almost logarithmically with increasing molecular weight. Resistance to reduction and oxidation typically decreases with increasing molecular weight. These trends help to explain why the lower-ring-numbered and higher-ring numbered compounds differ substantially in their behavior and distribution in the environment.

The lower-ring-numbered compounds have K_{oc} values in the 10^3 to 10^4 range. The higher-ring-numbered compounds have K_{oc} values from 10^5 to 10^6. Relative to other classes of chemical compounds, the K_{oc} values for PAHs are very high, indicating little tendency for mobility [Versar, 1979].

PAHs have been noted to be ubiquitous in the environment. In the past, PAH compounds were typically thought to result only from high-temperature pyrolysis of organic materials. Although this is the principal means of PAH generation, it has more recently been shown that low-temperature transformation of sedimentary organic material to form fossil fuels, as well as direct biosynthesis by microbes and plants, are additional sources of PAHs. Anthropogenic sources also increase the loading of PAHs into the environment. These include industrial activities such as coke and coal gas production, gas production from petroleum, oil refining, and preparation of acetylene from natural gas. Other sources include incineration of domestic and industrial wastes, power generation from fossil fuels, and automobile exhaust. Due to contributions of these generation processes, PAHs are widespread in the environment.

PAH compounds vary substantially in their acute toxicity to aquatic animals. In general, toxicity to species will increase with increasing molecular weight. However, the higher-ring-numbered PAHs have low acute toxicity, apparently due to their low solubilities. In most cases, crustaceans are the most sensitive species, polychaete worms are intermediate in sensitivity, and fish are the most resistant. Acute toxicity levels in water are several orders of magnitude higher than levels found in even the most polluted marine and freshwaters. Sediment levels typically approach concentrations similar to the acutely toxic level, however, being bound to the sediment renders PAHs considerably less toxic.

Biodegradation is thought to be the primary fate of PAHs in the environment. Some PAH compounds have been noted to be highly toxic, carcinogenic, mutagenic, and/or teratogenic to many species. PAHs have demonstrated toxicity via the oral and dermal routes, indicating that they are capable of passage across epithelial membranes. Additionally, research indicates that they are easily absorbed through the lungs. They tend to concentrate initially in the liver and kidneys until they are excreted. They eventually move to organs containing or surrounded by fat (e.g., mammary glands, adrenals) [Versar, 1979].

C.3 METALS

C.3.1 Arsenic

Arsenic is a naturally-occurring metalloid which may be present in the environment in a number of different valence states. It may be a constituent of both organic and inorganic compounds. Arsenic is widely used by industry as an alloying agent, in ore concentrating processes, and as a pesticide.

Arsenic is generally extremely mobile in aquatic environments, and cycles through air, water, and soils. Its precise fate in a particular environment depends upon the complex interactions of a number of factors, including oxidation potential (Eh), pH, the presence and concentrations of metal sulfide and sulfide ions.

Arsenic has been classified as a Group A carcinogen by the EPA. Its inhalation potency factor is 5E+1 $(mg/kg/d)^{-1}$ and the oral RfD is 1E-3 mg/kg/d [HEAST, 1990].

C.3.2 Beryllium

Beryllium is a naturally occurring metal which is present in the earth's crust. Beryllium metals and alloys are used in the aerospace industry, electronics, and nuclear reactors.

Given the pH range of most natural waters, salts of beryllium in water are hydrolyzed to form insoluble beryllium hydroxide. Beryllium is expected to adsorb tightly to soils. Beryllium may also adsorb to clay surfaces at low pH and become complexed into insoluble compounds at high pH. There is no evidence that beryllium volatilizes to the air from water or soil. There are no data regarding biotransformation of beryllium compounds in water or soils. Bioconcentration factors of 100 have been reported for freshwater and marine plants, invertebrates, and fish [Versar, 1979].

Chronic inhalation exposure to beryllium can produce a pulmonary fibrosis known as "berylliosis," a condition that is often fatal. There is also limited evidence in humans and sufficient evidence from animal studies that inhaled beryllium causes lung cancer (EPA Group B Carcinogen) [EPA, 1990]. The potency factors for inhalation and ingestion of beryllium are 8.4 and 4.3 mg/kg/d^{-1} and the oral RfD is 5E-3 mg/kg/d [HEAST, 1990].

C.3.3 Cadmium

Cadmium is a transitional metal which occurs widely in nature, generally in association with lead or zinc ores. Elemental cadmium is insoluble in water, but many cadmium compounds are fairly soluble in water. The general population is widely exposed to low levels of cadmium in drinking water, food, and in industrial settings [Sittig, 1985].

Cadmium is relatively mobile in the environment compared to most other heavy metals. Cadmium is less mobile in alkaline than in acidic waters. Sorption processes affect cadmium less than most other heavy metals. However, the mobility of cadmium can be reduced by sorption onto clays, hydrous iron, aluminum and manganese oxides, and organic materials. Volatilization is not an important process in aqueous environments [Versar, 1979].

In aquatic systems, hardness affects the toxicity of cadmium. Species also exhibit different sensitivities to cadmium. There is no evidence that cadmium is an essential mineral [Eisler, 1985]. Mammals have no effective mechanism for the elimination of ingested cadmium; therefore, with time, cadmium tends to accumulate in the liver and kidneys. It tends to be very persistent in the kidney and can cause renal tubular damage. Toxic effects include decreased growth rates, anemia, infertility, fetus abnormalities, abortions, kidney disease, intestinal disease, and hypertension [NAS, 1980].

Cadmium compounds, when inhaled, have been associated with pulmonary cancer. The inhalation of cadmium dust or fumes affects the respiratory tract and kidneys [EPA, 1985]. Exposure to high concentrations may result in pulmonary edema and death. Cadmium is a suspected human carcinogen via inhalation (EPA Group B1) [EPA, 1990]. The potency factor for inhalation of cadmium is 6.1

mg/kg/d^{-1} and oral RfDs of 1E-3 mg/kg/d and 5E-4 mg/kg/d have been established for food and water, respectively [HEAST, 1990].

C.3.4 Chromium (Elemental Chromium)

Chromium may exist in one of three valence states: +2, +3 and +6. Chromium trioxide is produced from chromite ore. Chromic acid, along with chromates, is in the hexavalent form. Chromium trioxide is used in chrome plating, photography, copper stripping, aluminum anodizing, and in organic syntheses [Sittig, 1985].

Chemical specification plays a dominant role in the fate of chromium in the aquatic environment. Conditions favorable for hexavalent chromium, Cr(VI), will keep chromium in a soluble form in the water. While conditions favorable for trivalent chromium Cr(III), will lead to precipitation and adsorption of chromium in the sediments. Volatilization and adsorption do not play an important role in determining aquatic fate. Both Cr(III) and Cr(VI) are only weakly adsorbed onto inorganic solids and clays. As an essential nutrient, chromium is bioaccumulated by a variety of aquatic organisms and may therefore be transferred via the food chain [Versar, 1979].

There is evidence that chromium is a carcinogen via inhalation and it has been classified by the EPA as a Group A carcinogen. Increased incidence of lung cancer among workers in the chromate-producing industry and possibly among chromium platers and chromium alloy workers served as the primary evidence for this classification. The potency factor assigned for inhalation of Cr(VI) is 4.1E+1 (mg/kg/d)$^{-1}$ [HEAST, 1990]. Acute exposures to dust or mist may cause coughing and wheezing, headache, dysphea, pain or deep inspiration, fever and loss of weight [Sittig, 1985]. The oral RfDs for Cr(III) and Cr(VI) are 1E+1 and 5E-3 mg/kg/d, respectively [HEAST, 1990].

C.3.5 Copper

Copper is a reddish brown metal which occurs freely or in ores such as malachite, cuprite, and chalcopyrite. It may form both mono and divalent compounds. Copper is insoluble in water but is soluble in nitric acid and hot sulfuric acid. Metallic copper is an excellent conductor of electricity and is widely used in the electrical industry. Copper compounds are also used as insecticides, algicides, molluscicides, plant fungicides, mordants, pigments, catalysts, and as a copper supplement for pastures and in the manufacture of powdered bronze paint and percussion caps. Additionally, copper compounds are utilized as analytical reagents, in paints for bottoms of ships, in electroplating and as a solvent for cellulose in rayon manufacture [Sittig, 1985].

Several processes determine the fate of copper in the aquatic environment: complex formation, sorption, and bioaccumulation. The formation of complexes with organic liquids modifies the solubility and precipitation behavior of copper such that solid copper species probably do not precipitate under normal circumstances. Furthermore, complexed copper is more easily adsorbed by clay and other surfaces than the free cation. Copper is also strongly bioaccumulated [Versar, 1979].

There is no evidence suggesting that copper is carcinogenic. Humans are most commonly exposed to copper through inhalation and/or ingestion in the workplace. Industrial exposure to copper occurs chiefly from fumes and dusts generated in welding copper containing metals. Copper fumes and dust cause irritation of the upper respiratory tract, a metallic taste in the mouth, nausea, metal fume fever, and in some instances, discoloration of skin and hair [Sittig, 1985] The recommended drinking water standard in humans is 1.3 mg/L, however, an oral RfD has not been established for this compound [HEAST, 1990].

C.3.6 Lead

Elemental lead is heavy, ductile, and bluish-white in color. It is widely used in industry because of its softness, resistance to corrosion and radiation, and high density. Lead is also used in solders, in storage batteries, and as a paint pigment.

The concentration and mobility of lead is controlled primarily by sorption. The tendency for lead to form complexes with naturally-occurring organic materials increases its adsorptive affinity for clays and other mineral surfaces. At low pH values, sorption and precipitation are not nearly as effective in removing lead from solution; therefore, lead has greater mobility in acidic waters than at higher pH values. In alkaline and circumneutral waters, removal of lead by sorption and precipitation may occur relatively quickly. Bioaccumulation may also be an important fate process [Versar, 1979].

Lead is generally considered a highly toxic contaminant because it is not an essential nutrient to either plants or animals. Lead bioaccumulates in animal tissues, but has a low potential for biomagnification in the food chain. The solubility of lead is dependent on water hardness; furthermore, lead is considered 20 to 100 times more toxic in soft water. In aquatic environments, most lead is found in bottom sediments. It is, therefore, a greater concern in benthic organisms than in planktonic or pelagic organisms. Toxicity of lead in water is dependent on pH, organic materials, and the presence/absence of other metals [Versar, 1979, Davies et al., 1976].

The primary mechanism of acute toxicity of lead to freshwater organisms is unknown. Invertebrate species appear more sensitive than vertebrate species [Spehar et al., 1978]. Lead inhibits plant growth, and reduces photosynthesis, mitosis, and water absorption [Eisler, 1988].

Lead is stored in humans in bone, kidneys, and liver. The major adverse effects in humans caused by lead include alterations in the hematopoietic and nervous systems. The toxic effects are generally related to the concentration of this metal in blood. Toxic blood concentration in children and in sensitive adults can cause severe, irreversible brain damage, encephalopathy, and possible death [EPA, 1984a]. Physiological and biochemical effects that occur even at low levels include enzyme inhibition, elevated erythrocyte protoporphyrin, interference with vitamin D metabolism, cognitive dysfunction in infants, electrophysiological dysfunction, and reduced childhood growth [ATSDR, 1988].

C.3.7 Mercury

Mercury is a silvery, liquid, metallic element. It is used in barometers, thermometers, hydrometers, pyrometers, mercury arc lamps producing ultraviolet rays, switches, fluorescent lamps, mercury boilers, as well as the extraction of gold and silver ores, making amalgams, and dentistry [Sittig, 1985; ACGIH, 1990].

In the environment, mercury readily bioaccumulates. It is strongly sorbed to both inorganic and organic particulates. Precipitation of mercury sulfide can result when mercury-laden sediments are deposited in reducing zones. Mercury in sediments can be remobilized through biomethylation. Volatilization of dimethyl mercury may occur in the environment [Little, 1987; Versar, 1979].

In birds and mammals mercury can adversely affect reproduction, growth and development, behavior, blood chemistry, coordination, vision, hearing, and metabolism. Symptoms of mercury poisoning in birds include muscular incoordination, hyperactivity, and withdrawal. Mercury toxicity in birds depends on the form of the element, route of exposure, and age of the animal. Organic forms of mercury, such as methylmercury, are more toxic than inorganic mercury. In mammals, organomercury compounds are more toxic than the inorganic form. Larger mammals such as the mule, deer appear to be more resistant than smaller animals such as cats, dogs, pigs, monkeys, and river otters. This may be related to differences in metabolism and detoxification rates. Mercury is not known to be readily taken up by plants. Symptoms of toxicity to plants include stunting of seedling growth and root development, and an inhibition of photosynthesis, which causes yield reductions.

In humans, elemental and inorganic mercury are adsorbed following inhalation exposure or contact with skin and the gastrointestinal tract. Spilled and heated elemental mercury is particularly hazardous. Occupational exposure of workers to elemental mercury vapors has been associated with mental disturbances, tremors, and gingivitis. The central nervous system is a major target for organic mercury compounds. Adverse effects in humans from exposure to organic mercury compounds have included destruction of cortical cerebral neurons, damage to Purkinje cells, and lesions of the cerebellum. Clinical symptoms following exposure to organic mercury compounds have included paresthesia, loss of sensation in extremities, ataxia, and hearing and visual impairment. A primary target organ for inorganic compounds is the kidney. Human exposure to inorganic mercury compounds has been associated with anuria, polyuria, proteinuria, and renal lesions [Sax and Lewis, 1989] [ACGIH, 1990]. There is no evidence to suggest that mercury is carcinogenic. The inhalation RfC and oral RfD values are 3E-4 mg/m^3 3E-4 mg/kg/d [HEAST, 1990].

C.3.8 Nickel

Nickel is a naturally occurring metal which constitutes approximately 0.008% of the earth's crust. Nickel is used in making stainless steel and other alloys. It is also used as a catalyst, in electroplating, in coin production, in Ni-Cd batteries and in ceramics.

Nickel appears to be a relatively mobile heavy metal due to the solubility of many of its salts. Sorption and precipitation are not as effective in immobilizing nickel as they are with other heavy metals. Nickel has an affinity for organic materials, hydrous iron, and manganese oxygen. Although nickel is bioaccumulated, the concentrations, found in most freshwater organisms indicate that partitioning into biota is not a dominant fate process.

In freshwater, toxicity depends on hardness; nickel tends to be more toxic in soft water [EPA, 1986]. Acute values for exposure to a variety of nickel salts, expressed as nickel, range from 510 μg/L for *Daphnia magna* to 46,200 μg/L for banded killfish at comparable hardness levels. Chronic values range from 14.8 μg/L for *Daphnia magna* in soft water to 530 μg/L for the fathead minnow in hard water. Acute-chronic ratios for *Daphnia magna* range from 14 in hard water to 83 in soft water, and are approximately 50 in both hard and soft water for the fathead minnow. Residue data for the fathead minnow indicate a bioconcentration factor of 61. Freshwater algae experience reduced growth at nickel concentrations as low as 100 μg/L.

Acute values for saltwater species range from 152 μg/L for mysid shrimp to 350,000 μg/L for the mummichog. A chronic value of 92.7 μg/L is reported for the mysid shrimp, which gives an acute-chronic ratio of 5.5 for the species. Reduced growth has been seen in saltwater algae at concentrations as low as 1,000 μg/L. Bioconcentration factors ranging from 299 to 416 have been reported for oysters and mussels.

The major source of nickel uptake by humans is food (up to 900 μg/day). Airborne nickel has been detected at rural and urban sites at concentrations ranging from 1 to 60 ng/m^3. Higher levels have been detected in industrial settings [ATSDR, 1987].

Extensive epidemiological evidence indicates that inhalation of certain nickel compounds (nickel oxide and nickel subsulfide dusts, nickel carbonyl vapor, and soluble aerosols of nickel sulfate, nickel chloride, and nickel sulfate) causes cancer of the lung and nasal cavities in humans. Contact dermatitis has also been reported in humans exposed dermally to nickel compounds. Nickel carbonyl has been shown to cause birth defects in rats [ATSDR, 1987]. EPA has classified nickel via inhalation as a Group A carcinogen. The unit risk for nickel by inhalation is 8.4E-1

$\mu g/m^3$ and an oral RfD of 2E-2 mg/kg/d has been assigned to nickel [HEAST, 1990].

C.3.9 Silver

Silver is a white metal which is extremely ductile and malleable. Silver compounds find use in photography, silver plating, inks, dyes, coloring of glass and porcelain, ivory etching and as analytical chemical reagents and catalysts. Some silver compounds are also of medical importance. Silver is alloyed with copper, aluminum, cadmium, lead, or antimony, and used in the manufacture of silverware, jewelry, coins, automobile bearings, and grids in storage batteries [Sittig, 1985].

The main removal mechanism for silver in soil-water systems is sorption by organic and inorganic materials. Bioaccumulation also removes silver from solution and is strongly related to habitat and distribution of biota. Numerous plants and primary consumer organisms accumulate silver, however, there is little evidence to suggest biomagnification [Versar, 1979]. Volatilization of silver compounds is probably not an important process in determining fate in solution.

Silver is not classified as a carcinogenic substance. Argyria, a cosmetic defect which consists of an unsightly blue-gray discoloration of the skin, mucous membranes and eyes is the main pathologic effect resulting from accumulation of silver in the body. Inhalation of fumes or dust, ingestion of solutions or dust, eye and skin contact are the potential human exposure routes. The recommended oral RfD is 3E-3 mg/kg/d [HEAST, 1990; Sax and Lewis, 1989; and ACGIH, 1990].

C.3.10 Thallium

Thallium is a soft, heavy metal insoluble in water and organic solvents. It is usually generated as a by-product in flue-dust during the roasting of pyrite ores, in the smelting and refining of lead and zinc. Thallium sulfate is used as a poison for rats and other rodents. Thallium is also used in semi-conductor research and is alloyed with mercury in some switches. In addition, it is used in mineralogical solutions, optical systems, photoelectric cells and low range glass thermometers [ACGIH, 1990].

In soil/water/systems thallium is adsorbed to clay minerals and hydrous metal oxides. Thallium is bioaccumulated by aquatic organisms. In aerobic waters, adsorption and bioaccumulation are the primary removal mechanisms from solution; volatilization is not significant [Versar, 1979].

Thallium compounds can affect eyes, central nervous system, lungs, liver, kidneys, gastrointestinal tract and body hair. Locally, thallium salts act as skin irritants and sensitizers. Thallium is not classified as carcinogenic but is an extremely toxic and cumulative poison. Early symptoms include fatigue, limb pain, metallic taste in the mouth, and loss of hair. Long term exposure may produce optic atrophy and paresthesia. Acute poisoning rarely occurs in industry [Sittig, 1985]. The oral RfD is 7E-5 mg/kg/d [HEAST, 1990].

C.3.11 Zinc

Zinc is a common trace metal generally associated with base metal and precious metal deposits. Zinc is used commercially in the manufacture of batteries, for galvanizing, and as an alloying agent. Zinc is an essential trace nutrient. Zinc compounds are commonly used in such products as antidandruff shampoos and astringents.

Zinc is one of the most mobile of the heavy metals in natural surface water systems, but is only moderately mobile in natural soil/water systems. In soil/groundwater systems zinc can be sorbed onto hydrous iron and manganese oxides, clay minerals, and organic material, thereby reducing its mobility. Volatilization of zinc is not an important process in the transportation of zinc [Versar, 1979].

Zinc bioaccumulates and is moderately toxic to aquatic life and vegetation. Zinc is an essential element for plants and animals. The toxicity of zinc is strongly influenced by water hardness, pH, temperature, and dissolved oxygen. Zinc toxicity increases with soft water, increase in temperature, reduction in dissolved oxygen, and an increase in pH [EPA, 1986].

The toxicity of zinc is considered to be very low. There is no known association between zinc and cancer. Small amounts of zinc are necessary for normal human growth and development; however, ingestion of zinc salts can cause fevers, nausea, vomiting, stomach cramps, and diarrhea [EPA, 1984]. Exposure to zinc chloride fumes can cause damage to the respiratory tract and nasal tract. [Sax and Lewis, 1989]. The oral RfD for zinc is 2E-1 mg/kg/d [HEAST, 1990].

C.4 PETROLEUM HYDROCARBONS

Petroleum hydrocarbons are a group of compounds that are thick, dark yellow to brown, or green-black liquids which consist of a mixture of hydrocarbons from C_2H_2 and up. They are used as a source of gasoline, petro ether, petrolatum, fuel and lubricating oils, butane, and isopropyl alcohol. Gasoline, jet fuel, and mineral spirits are the petroleum hydrocarbons of primary concern in this risk evaluation.

Hydrocarbon-containing petroleum residues are decomposed in soil systems. Hydrocarbons degrade to carbon dioxide and water via several intermediates (organic acids, ketones, aldehydes, alcohols, and other hydrocarbon derivatives). Nonvolatile components of oils tend to stay tightly bound in soil, while volatile fractions may escape into the atmosphere. No significant movement of oil through surface runoff from rainfall or downward leaching occurs.

Gasoline is an aspiration hazard, defats the skin, and has been shown to cause kidney tumors in laboratory animals. It contains benzene and toluene which may be absorbed through the skin. Benzene is a cancer hazard that affects the blood. Primary routes of exposure are inhalation and skin contact. Eye contact with liquid gasoline may cause burning, tearing, redness, and transient corneal damage. Prolonged or repeated dermal contact may cause burning, redness, drying and cracking of the skin, and dermatitis. Exposure to mist or excessive vapor concentration may cause irritation of the nose, throat, and upper respiratory tract. Severe exposures may result in unconsciousness, coma, and death. Ingestion of gasoline may cause signs of central nervous system depression, headache, nausea, drowsiness, and dizziness.

Fuel oil is a combustible liquid and a skin irritant. Breathing oil mists may irritate the nose and throat. Chronic exposure to oil mists may lead to the development of lipoid pneumonia. Similarly refined and processed residual petroleum materials have been shown to cause skin cancer and liver damage in laboratory animals through prolonged skin contact. There is no direct evidence that fuel oil causes skin cancer or liver damage in humans.

APPENDIX D
AQUIFER CHARACTERISTICS

APPENDIX D.1
BACKGROUND

APPENDIX D
AQUIFER CHARACTERISTICS

Fourteen slug tests were conducted at the Michigan Air National Guard Base (ANGB), to estimate aquifer parameters (hydraulic conductivity, transmissivity, and velocity). Slug testing is a rapid means of estimating aquifer characteristics, but its effectiveness is limited to measuring these characteristics only in the immediate vicinity of a particular well. Slug tests were performed in wells BC-MW1, BC-MW3, BC-MW6, BC-MW7, BC-MW9, BC3-MW1, BC3-MW2, BC3-MW3, BC4-MW2, BC4-MW4, BC5-MW1, BC6-MW1, BC6-MW2, and BC6-MW3. However, data collected at wells BC-MW7, BC-MW9, BC3-MW1, BC4-MW4, and BC5-MW1 were not useful in evaluating aquifer characteristics.

Slug testing was performed by rapidly lowering a stainless-steel or PVC slug into each well and monitoring changes in water level using an In-Situ Model SB-1000 *Hermit recorder and electronic* pressure transducer which measures and records rapid changes. Upon introduction of the slug, the water level rose to a level above the static water level. After the water level had dropped back to the static water level, the slug was quickly withdrawn and the water level again monitored until it returned to static water level. The rate at which the water level returned to the static level after introduction or removal of the slug is related to the hydraulic conductivity of the media surrounding the well.

Water level data collected during slug tests are given in Appendix D.2. The slug test data were analyzed using the procedures developed by Bouwer and Rice (Bouwer, 1978) for slug tests in unconfined aquifers. Using this method, positive values of injection or removal of the slug are plotted on a log axis while the time since injection or removal of the slug is plotted on an arithmetic axis. A straight-line portion of the resulting curve is identified and projected back to time zero. The equation used to determine hydraulic conductivity is then:

$$K = \frac{rc^2 \ln(Re/rw)}{2\,Le} \quad \frac{1}{t} \quad \ln \frac{yo}{yt} \qquad \text{(Equation D.1)}$$

where:

K = hydraulic conductivity, in feet per minute (ft/min)

rc = radius of the well casings, in feet (ft.)

Re = effective radial distance over which the change in water level is dissipated, in feet (ft.)

rw = radius of the borehole, in feet (ft.)

yo = change in water level at time zero projected back from straight-line portion of curve, in feet (ft.)

yt = change in water level, in feet, on straight-line portion of curve at time t, in minutes (min.); and

Le = height of screened, saturated section of well, in feet (ft.)

The distance over which the change in water level is dissipated (Re) is related to the well and aquifer geometry by the empirical equation:

$$\ln \frac{Re}{rw} = \frac{1}{\dfrac{1.1}{\ln(Lw/rw)} + \dfrac{A+B\ln[(H-Lw)/rw]}{(Le/rw)}} \qquad \text{(Equation D.2)}$$

where A and B are dimensionless parameters that can be found using a figure given by Bouwer (1978, Figure 5.11); Lw is the height of the static water table above the bottom of the screened interval, in feet. For these wells, H is estimated as the height of the water table above the impermeable clay which overlies the Marshall Formation.

Values of Le, Lw, rc, rw, A, B, H, and Ln (Re/rw), used for each well are presented in Table D.1 along with values of yo, yt, t, and K determined from both injection and removal analyses. Plots of log y versus t used to determine yo, yt, and t are shown in Figures D.1 through D.28.

The estimated hydraulic conductivity ranges from 2.88 ft/day at well BC4-MW2 to 60.29 ft/day at BC3-MW2, with an average value of about 27 ft/day. The variations in conductivities over the area are due to the presence or absence of clay lenses.

Transmissivity values were estimated using the hydraulic conductivity values and the saturated thickness of the aquifer (b), which is equal to "H" in the slug analysis procedure described above, in the formula:

$$T = Kb$$

TABLE D.1
MICHIGAN AIR NATIONAL GUARD BASE
SLUG TEST ANALYSES SUMMARY

Well I.D.	Depth to Water Table[(1)] (ft)	Screened Interval[(1)] (ft)	Le = Lw (ft)	H (ft)	Screen Radius (rc) (ft)	Borehole Radius (rw) (ft)	A	B	ln (Re/rw)	Injection Analysis yo (ft)	yt (ft)	t (min)	K (ft/day)	Removal Analysis yo (ft)	yt (ft)	t (min)	K (ft/day)
BC MW1	39.39	32-47	7.61	75	0.083	0.417	1.9	0.25	1.86	2.00	0.130	0.10	32.25	5.50	0.040	0.30	19.30
BC MW3	37.18	31-46	8.82	75	0.083	0.417	2.1	0.30	1.94	8.00	0.023	0.20	30.95	3.75	0.028	0.30	17.27
BC 3 MW2	30.23	24-39	8.77	100	0.083	0.417	2.1	0.30	1.91	3.00	0.190	0.05	58.03	4.50	0.230	0.05	62.54
BC 3 MW3	29.84	24-39	9.16	100	0.083	0.417	2.1	0.30	1.96	0.90	0.074	0.20	12.89	7.00	0.095	0.20	22.18
BC 4 MW2	10.00	6-21	11.00	100	0.083	0.417	2.3	0.40	2.05	0.40	0.20	1.00	0.62	4.50	0.450	0.40	5.14
BC 6 MW1	31.82	23-38	6.18	100	0.083	0.417	1.9	0.28	1.61	0.25	0.060	0.10	18.00	1.40	0.037	0.30	15.22
BC 6 MW2	28.40	22-37	8.60	100	0.083	0.417	2.0	0.30	1.91	0.38	0.056	0.10	20.45	1.10	0.090	0.05	53.57
BC 6 MW3	29.10	22-37	7.60	100	0.083	0.417	1.9	0.25	1.84	4.10	0.023	0.10	60.77	0.18	0.015	0.10	7.27

(1) Measured from top of casing

This yielded an average transmissivity of about 19,000 gpd/ft. All transmissivity and hydraulic conductivity values estimated from the slug test data are given in Table D.2.

Generally, groundwater flow at the Base is to the north with an average hydraulic gradient of .005 ft/ft. The estimated velocity (V) of groundwater flow at each site was estimated using the formula:

$$V = \frac{KI}{\emptyset} \qquad \text{(Lohman, 1972)}$$

where:

K = the average estimated hydraulic conductivity at the site, based on slug test data (ft/day)

I = hydraulic gradient between two wells, (h1-h2)/L

h1 = water level in one well (ft)

h2 = water level in second well (ft)

L = distance between the two wells (ft)

Ø = aquifer porosity (assumed = 0.20; dimensionless)

The estimated flow velocities range from about 0.05 to 0.9 ft/day, and are presented in Table D.3.

Calculations for all aquifer parameters can be found in Appendix D.3.

TABLE D.2
MICHIGAN ANGB, BATTLE CREEK, MICHIGAN
SLUG TEST RESULTS

Monitoring Well	Average* Transmissivity (T) gpd/ft	Average* Hydraulic Conductivity (K) gpd/ft^2	ft/day
BC-MW1	14,400	193	25.8
BC-MW3	13,500	180	24.1
BC-MW6	**	**	**
BC-MW7	**	**	**
BC-MW9	**	**	**
BC3-MW1	**	**	**
BC3-MW2	45,100	451	60.3
BC3-MW3	13,100	131	17.5
BC4-MW2	2,200	21.6	2.88
BC4-MW4	**	**	**
BC5-MW1	**	**	**
BC6-MW1	12,400	124	16.56
BC6-MW2	28,700	277	37.0
BC6-MW3	25,400	254	34.0

* K and T for slug introduction and withdrawal were averaged.

** Slug test data were inconclusive.

TABLE D.3
MICHIGAN ANGB, BATTLE CREEK, MICHIGAN
ESTIMATED AQUIFER POROSITY AND SEEPAGE VELOCITY

Wells between which seepage velocity is calculated	K* ft/day	h_1 (feet)	h_2 (feet)	L (feet)	I $(h_1-h_2)/L$ (ft/ft)	Ø (EST)	V (ft/day) (KI/Ø)
BC3-MW1, BC3-MW2	39	891.07	890.45	238	0.0026	0.20	0.51
BC3-MW2, BC3-MW5	39	890.45	889.50	225	0.0042	0.20	0.82
BC3-MW5, BC3-MW6	39	889.50	888.44	381	0.0028	0.20	0.55
BC4-MW1, BC4-MW4	2.9	898.40	891.92	488	0.0133	0.20	0.19
BC4-MW1, BC4-MW3	2.9	898.40	893.00	619	0.0087	0.20	0.13
BC4-MW1, BC4-MW2	2.9	898.40	895.99	738	0.0033	0.20	0.05
BC4MW4, BC4-MW3	2.9	891.92	893.00	281	0.0038	0.20	0.05
BC6-MW1, BC6-MW2	29	890.14	889.94	238	0.0008	0.20	0.12
BC6-MW3, BC6-MW2	29	890.17	889.94	231	0.0010	0.20	0.14
BC-MW5, BC-MW4	25	888.28	890.99	388	0.0070	0.20	0.88
BC-MW13, BC-MW2	25	889.64	891.75	644	0.0033	0.20	0.41
BC-MW2, BC-MW1	25	891.75	889.30	631	0.0039	0.20	0.49

* Average of hydraulic conductivities estimated from slug test data for wells in vicinity of respective sites.

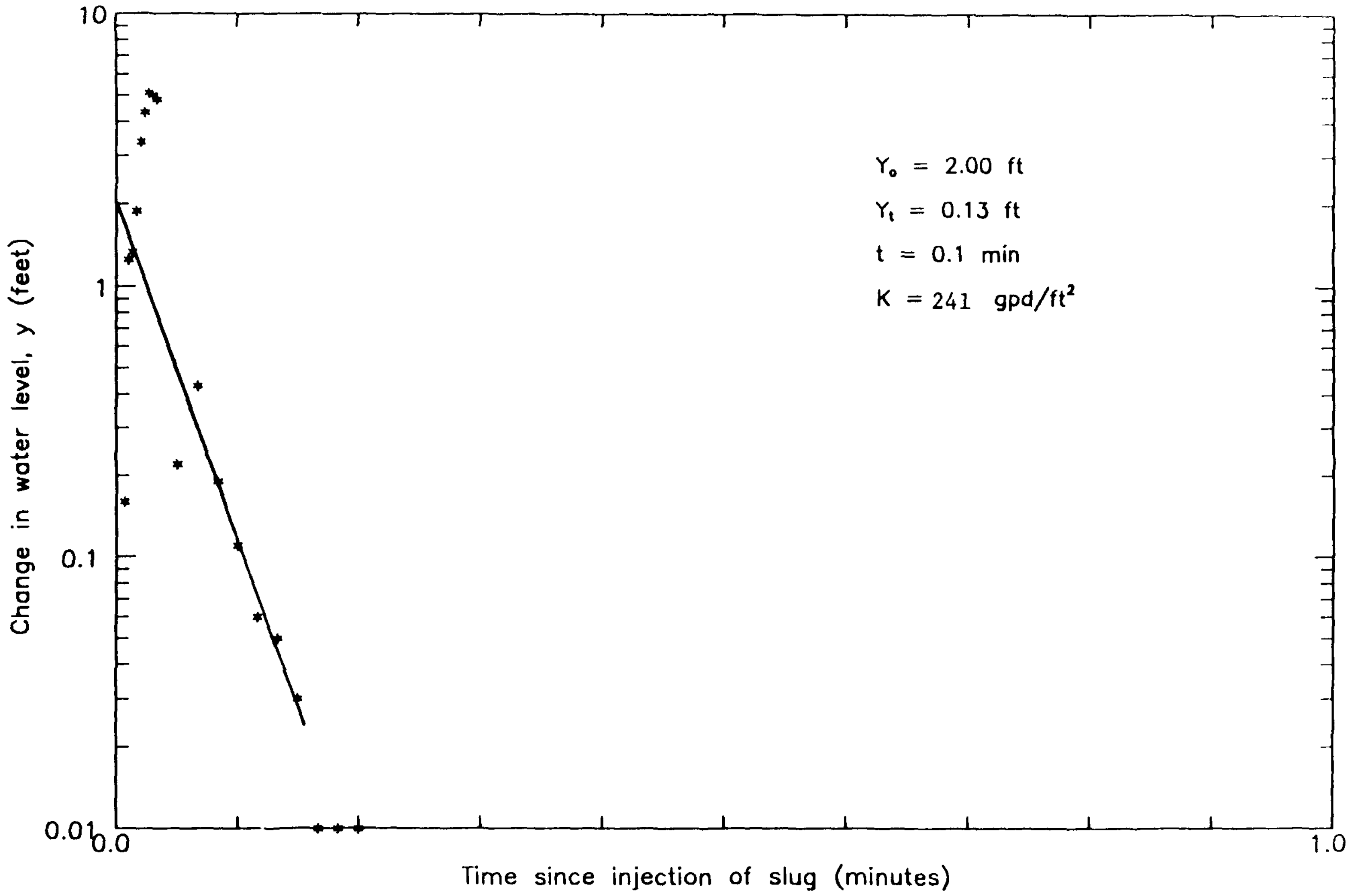


FIGURE D.1 Slug Injection Test Analysis Using Data from Well BC MW1

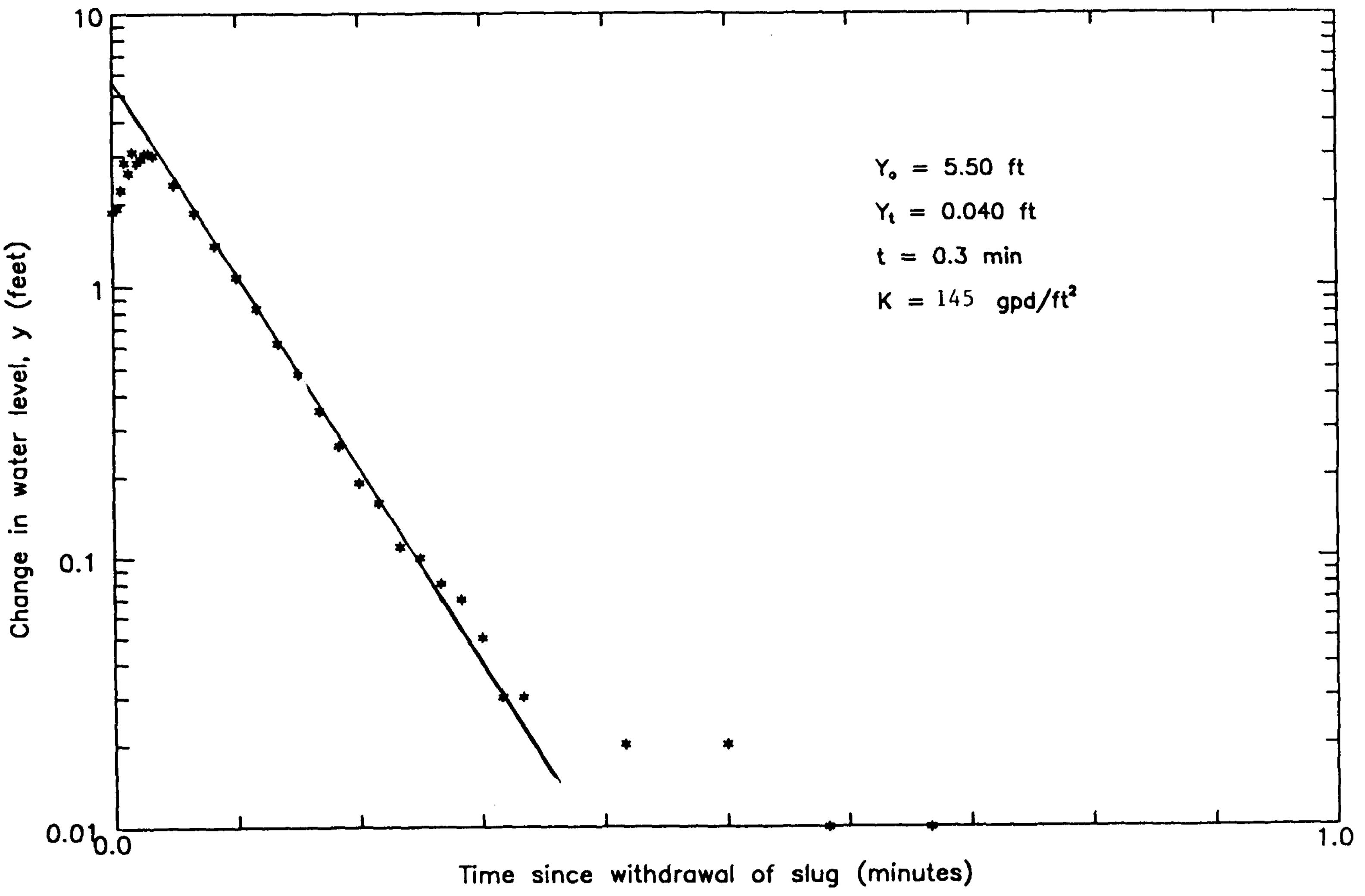


FIGURE D.2 Slug Withdrawal Test Analysis Using Data from Well BC MW1

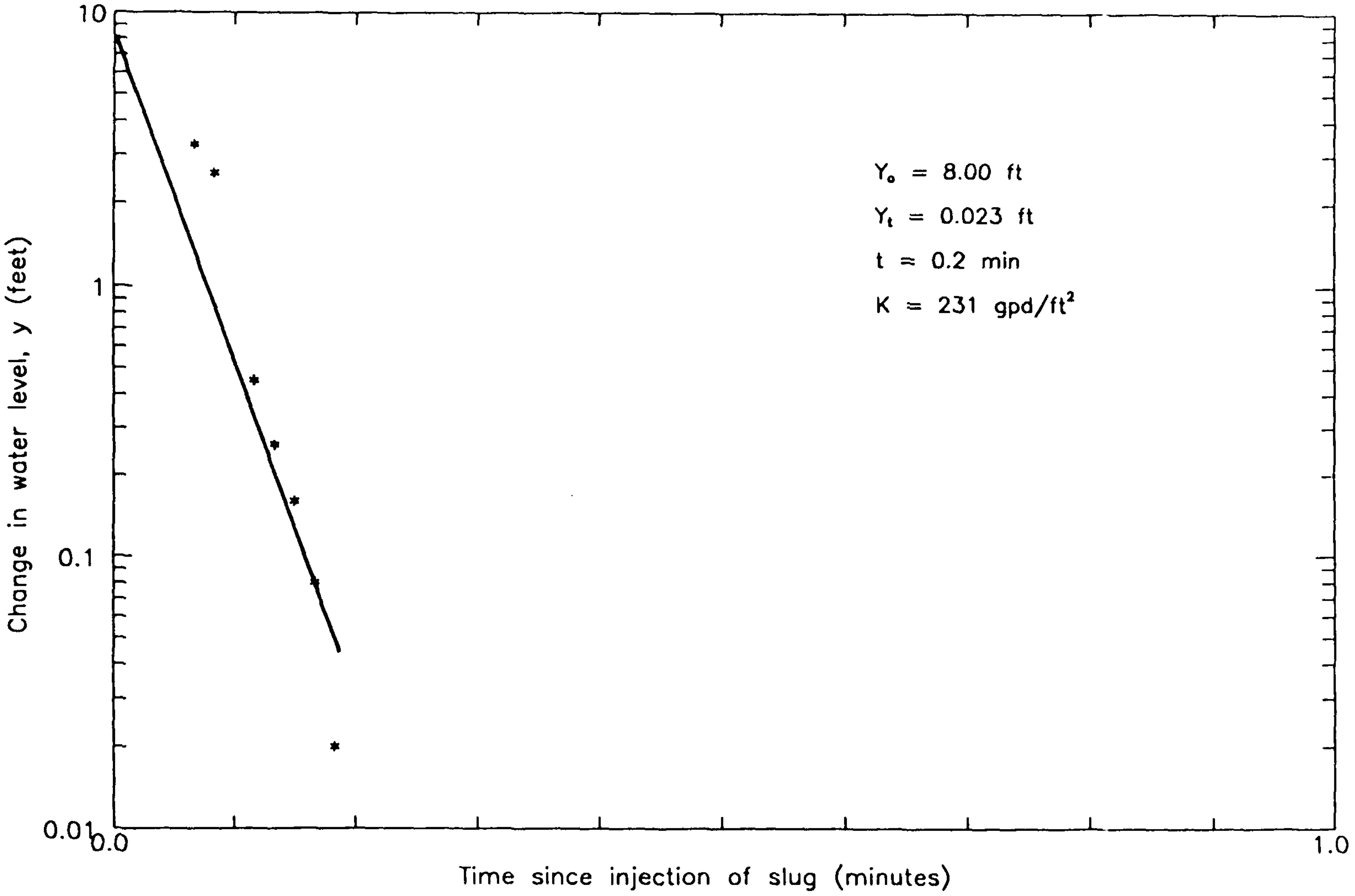


FIGURE D.3 Slug Injection Test Analysis Using Data from Well BC MW3

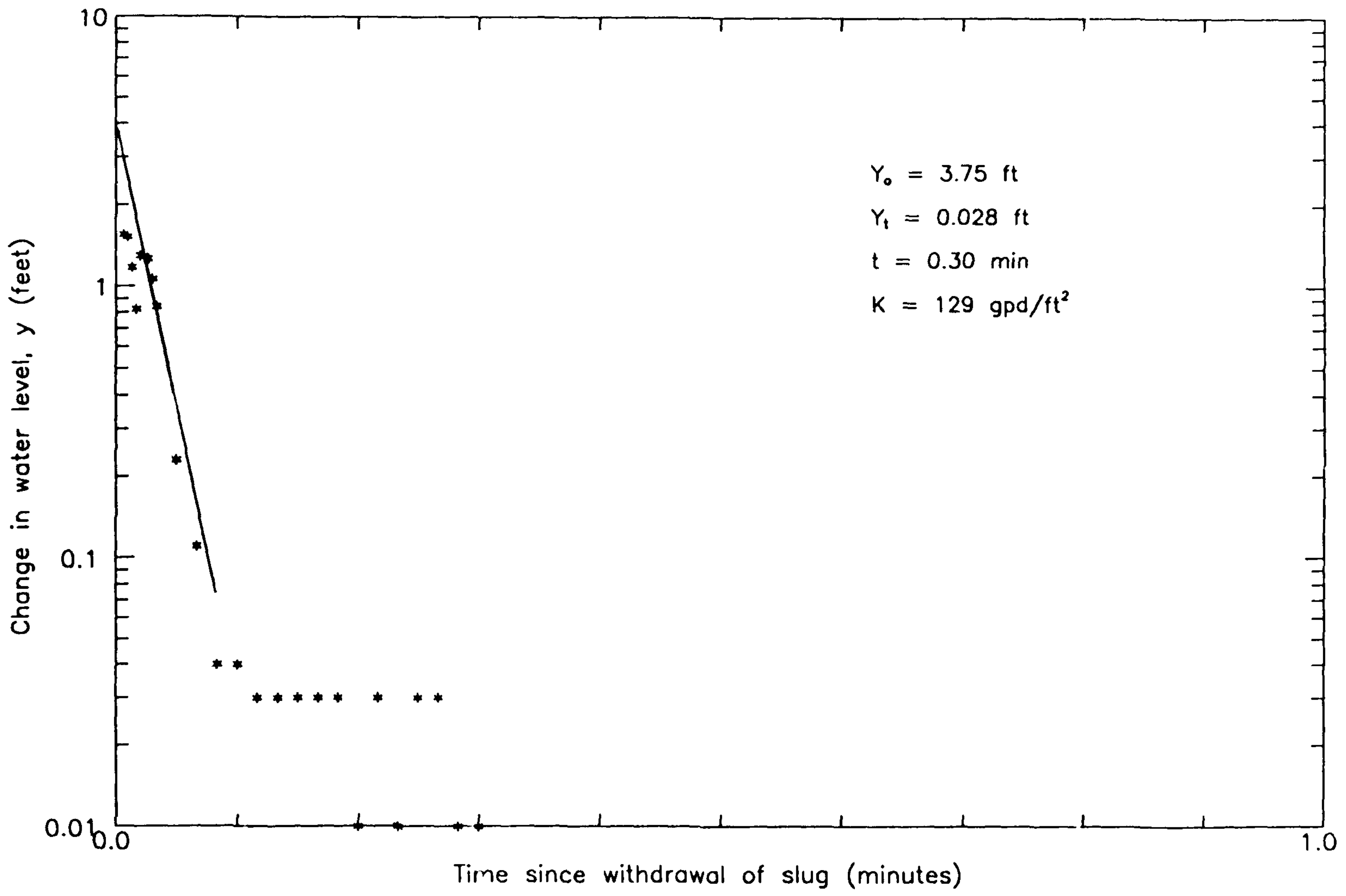


FIGURE D.4 Slug Withdrawal Test Analysis Using Data from Well BC MW3

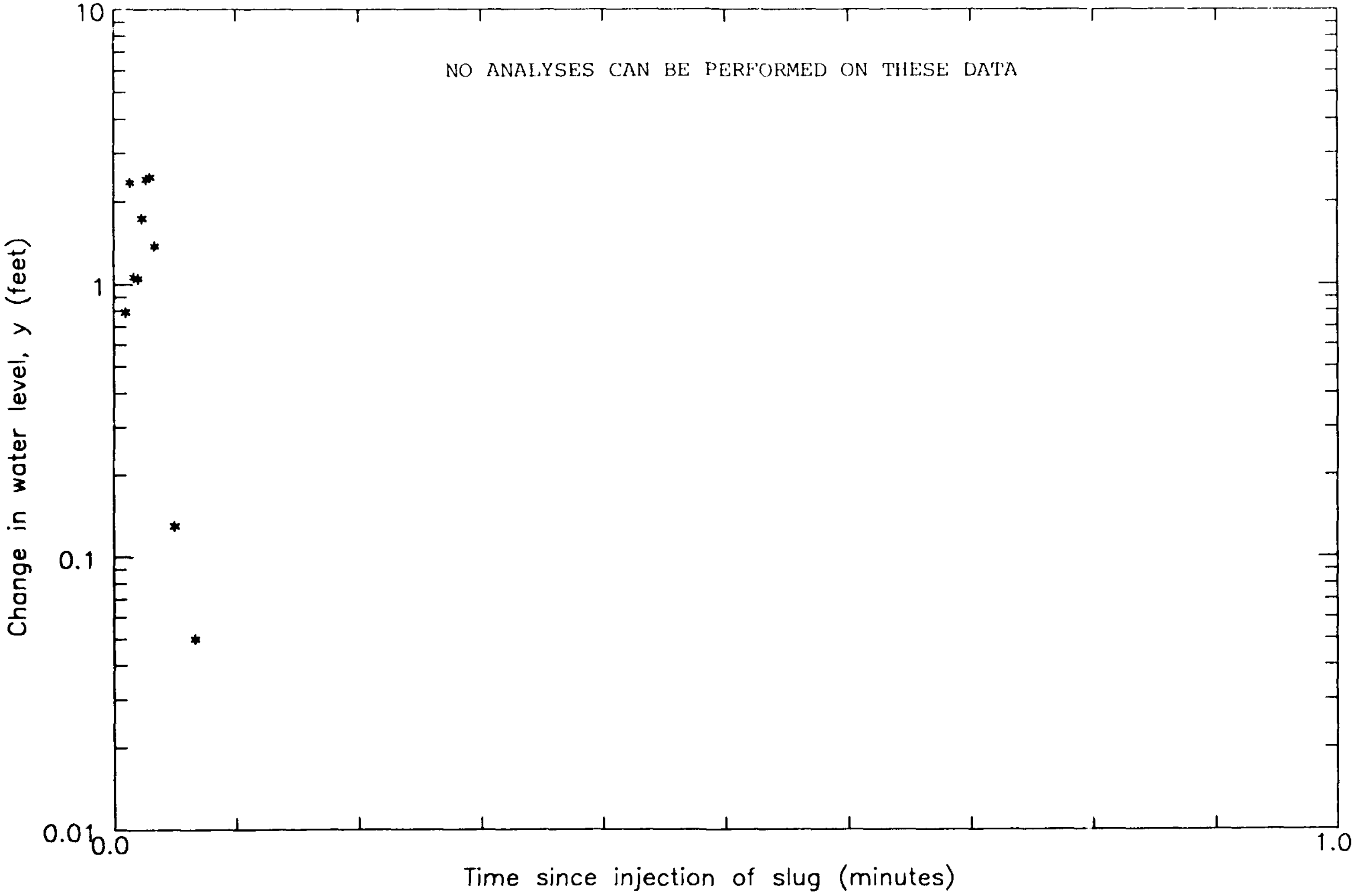


FIGURE D.5 Slug Injection Test Analysis Using Data from Well BC MW6

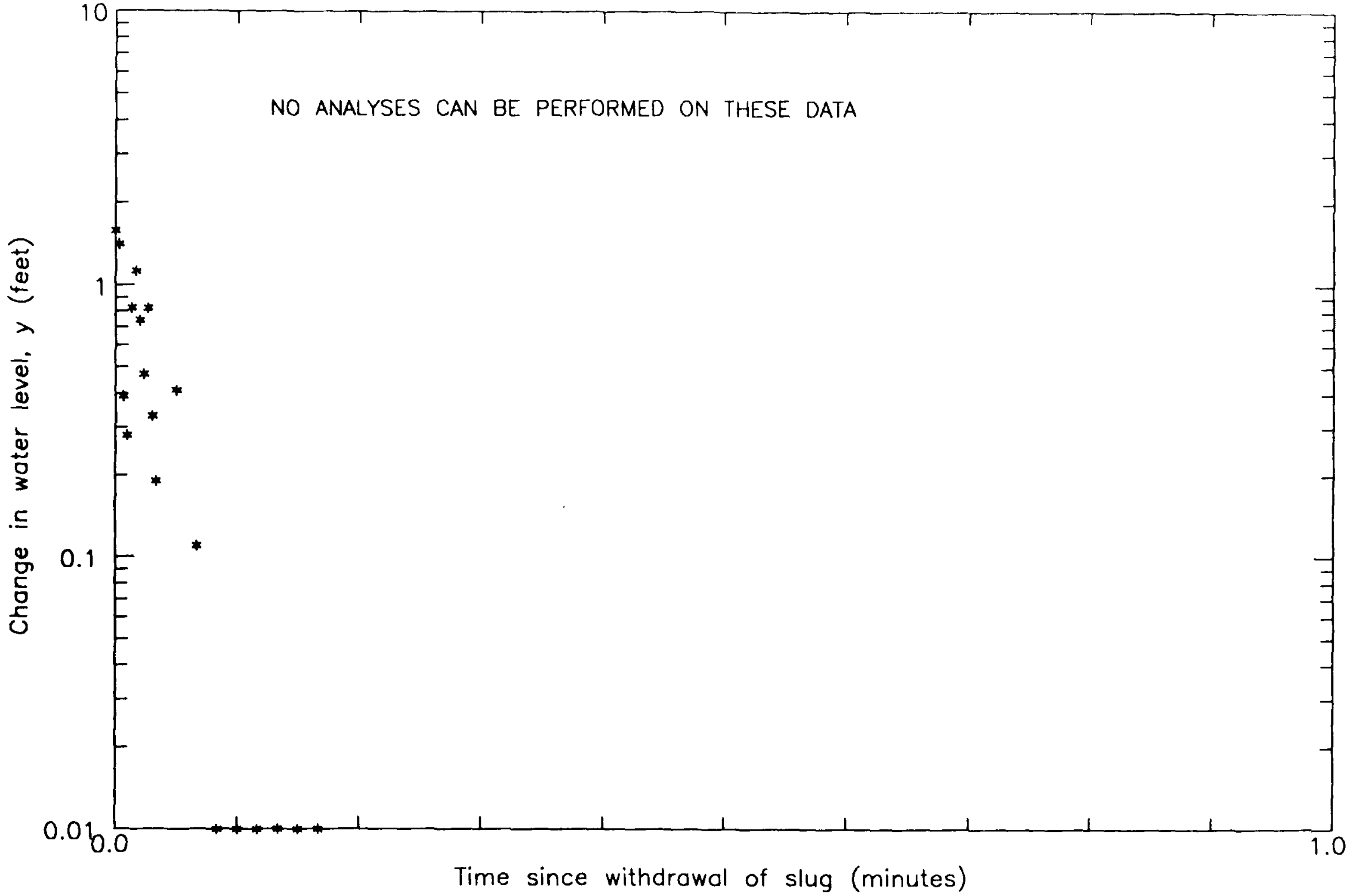


FIGURE D.6 Slug Withdrawal Test Analysis Using Data from Well BC MW6

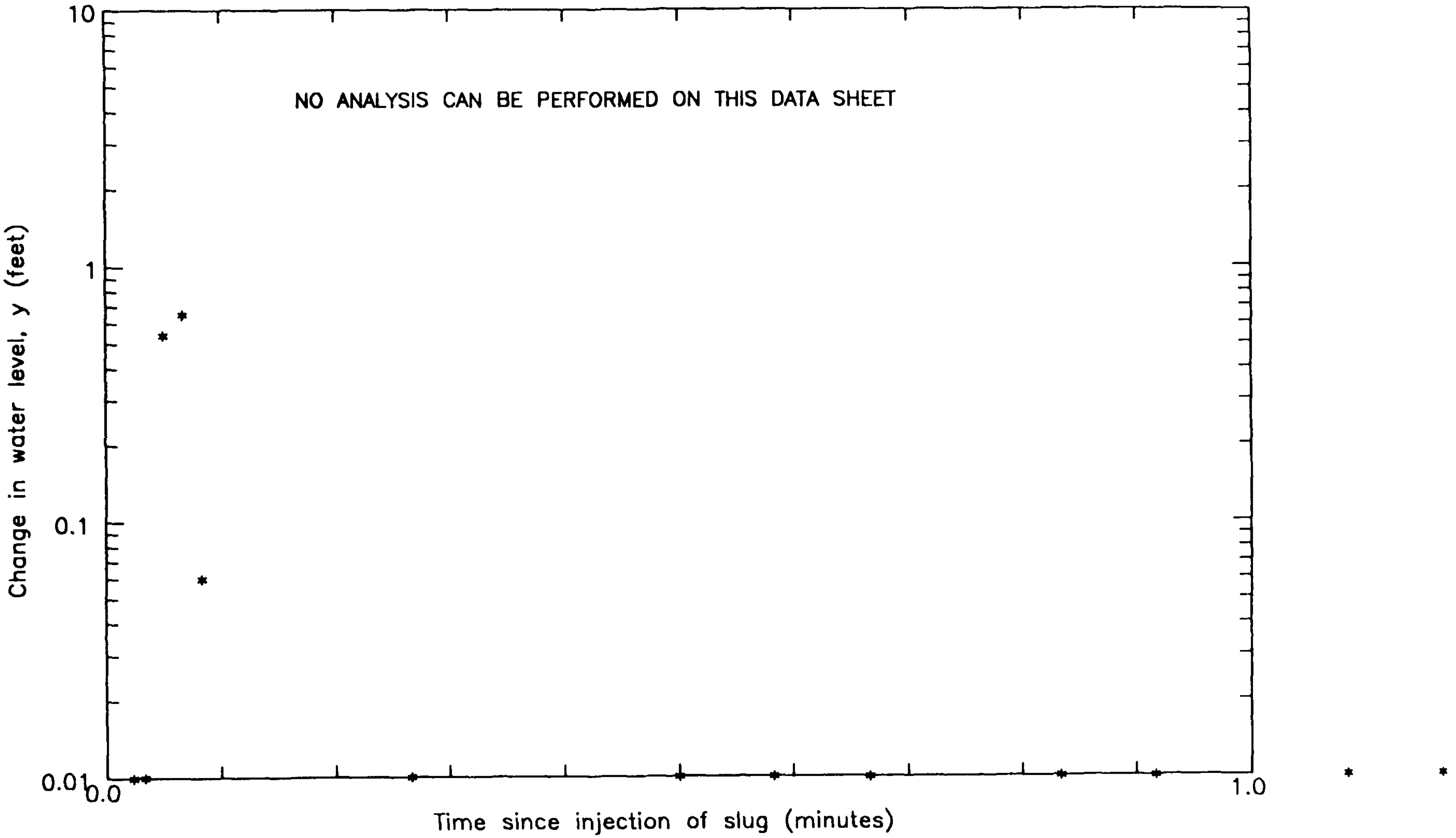


FIGURE D.7 Slug Injection Test Analysis Using Data from Well BC MW7

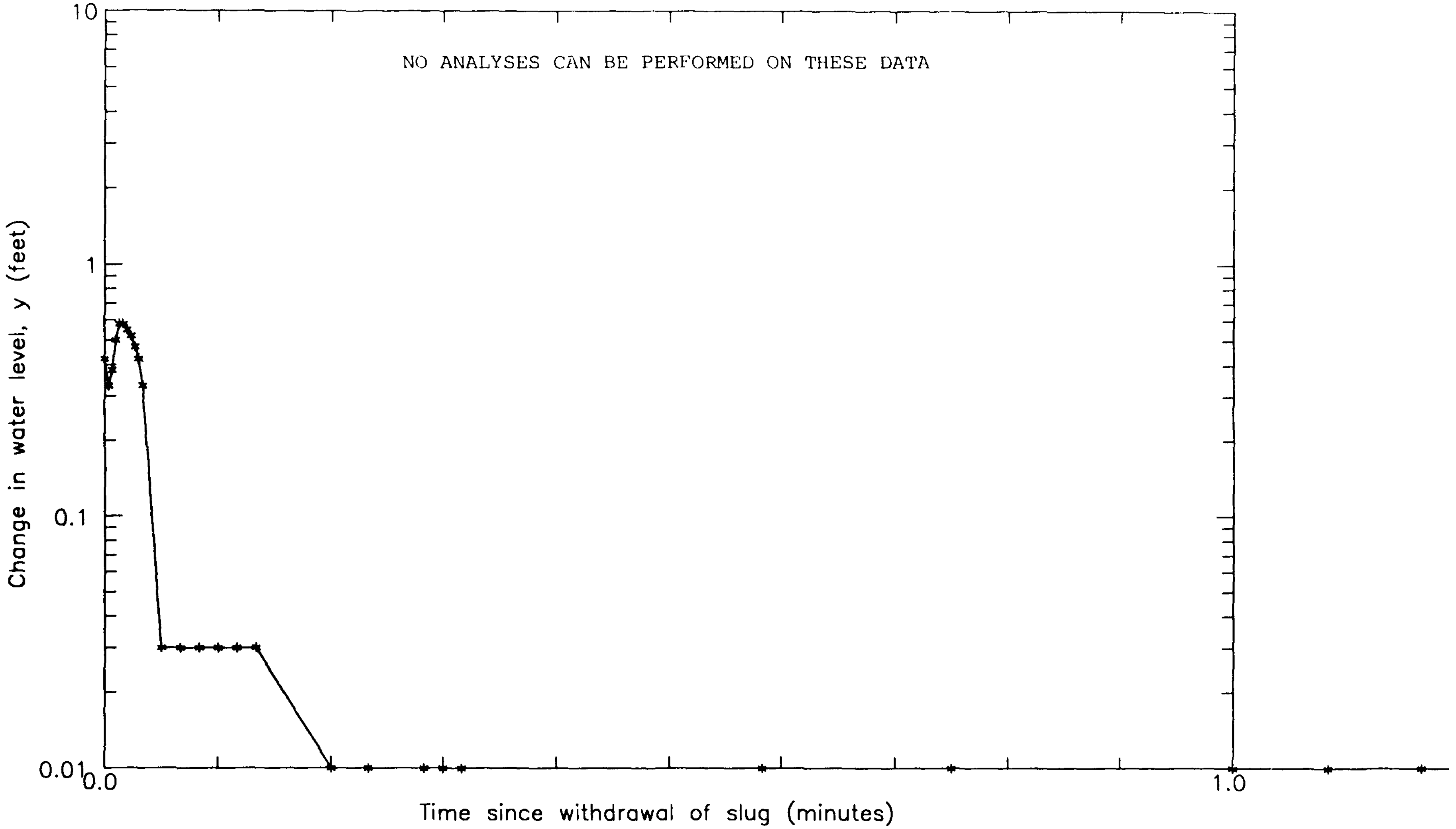


FIGURE D.8 Slug Withdrawal Test Analysis Using Data from Well BC MW7

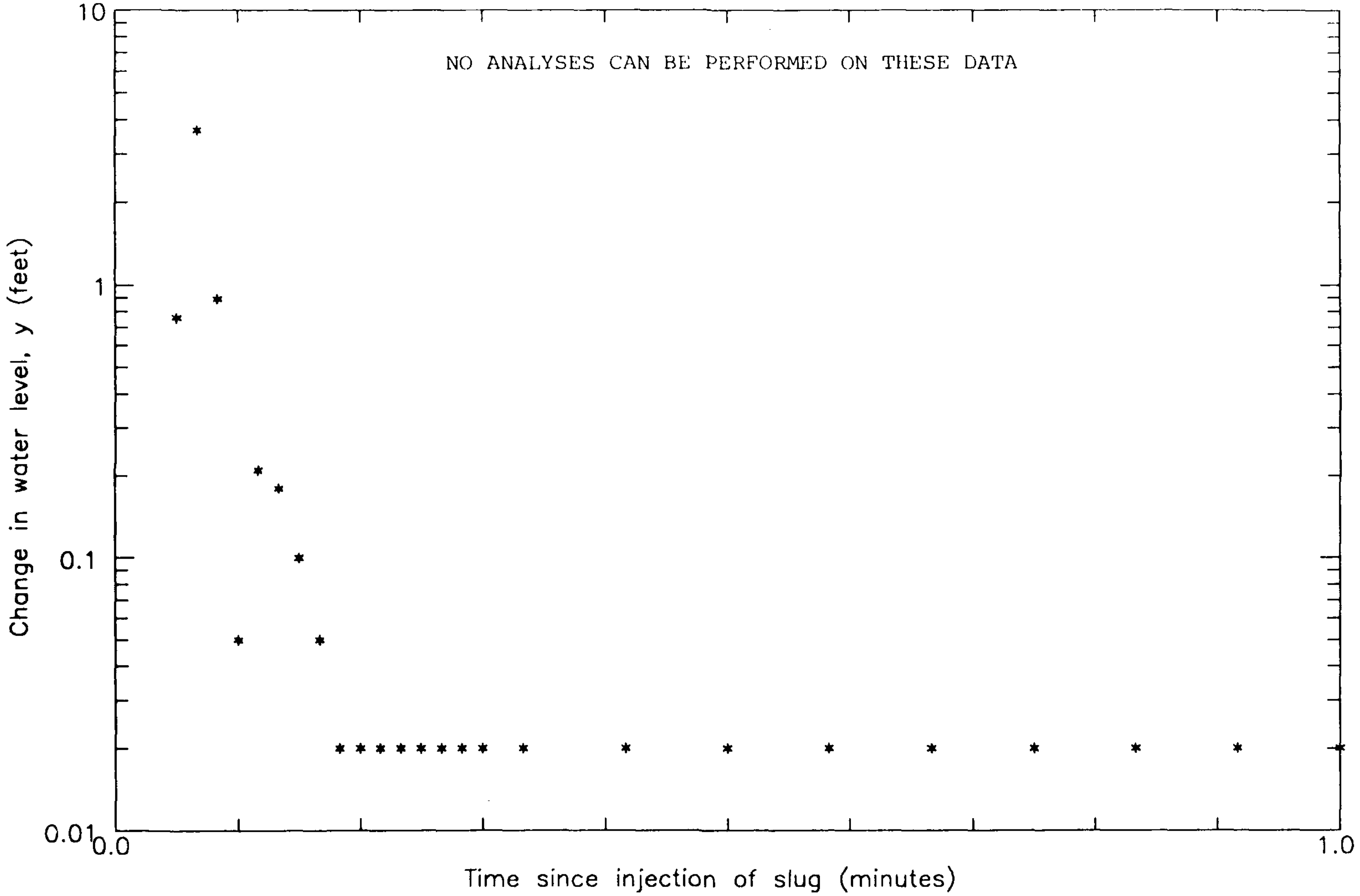


FIGURE D.9 Slug Injection Test Analysis Using Data from Well BC MW9

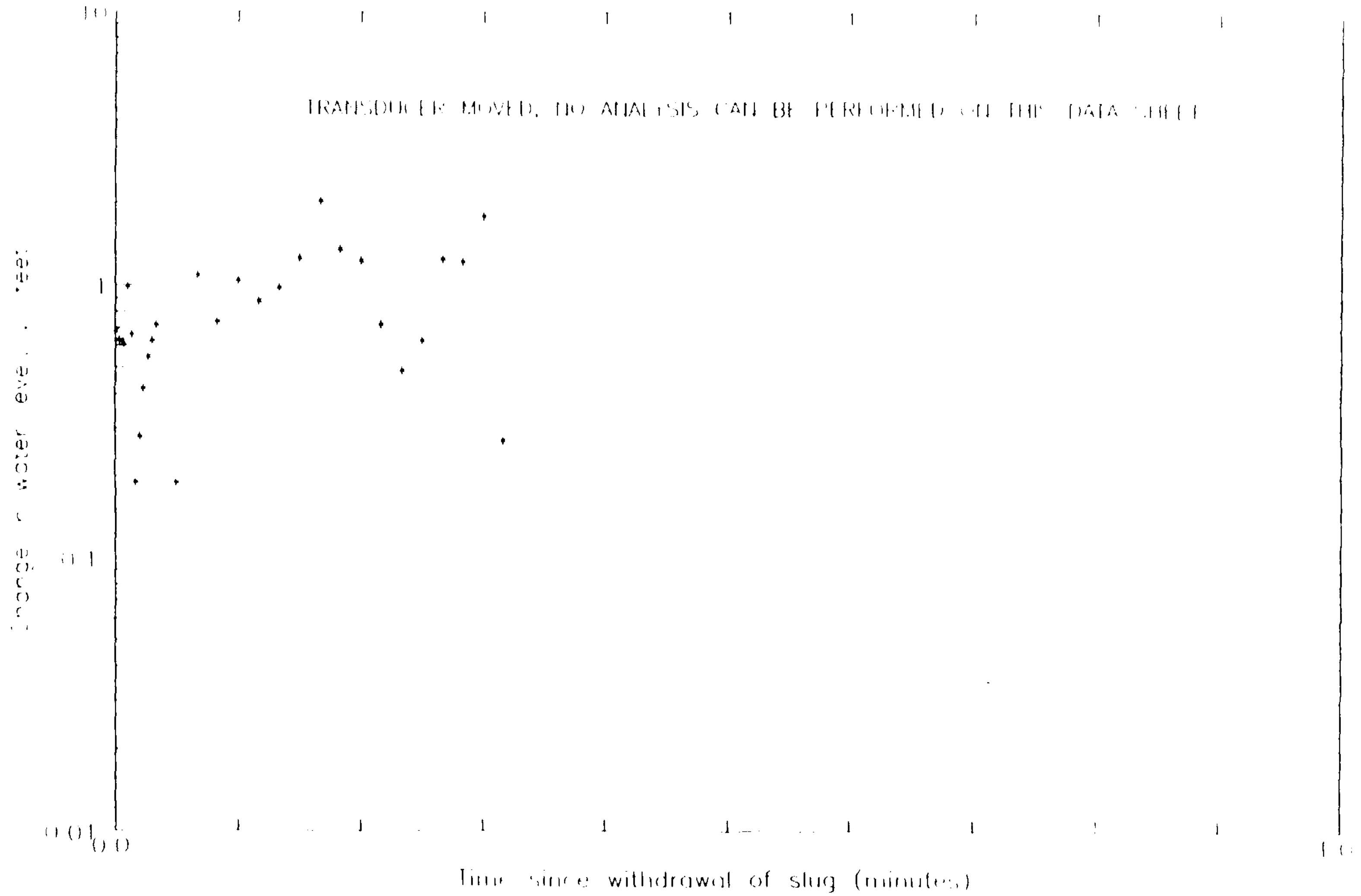


FIGURE D.10 Slug Withdrawal Test Analysis Using Data from Well [illegible]

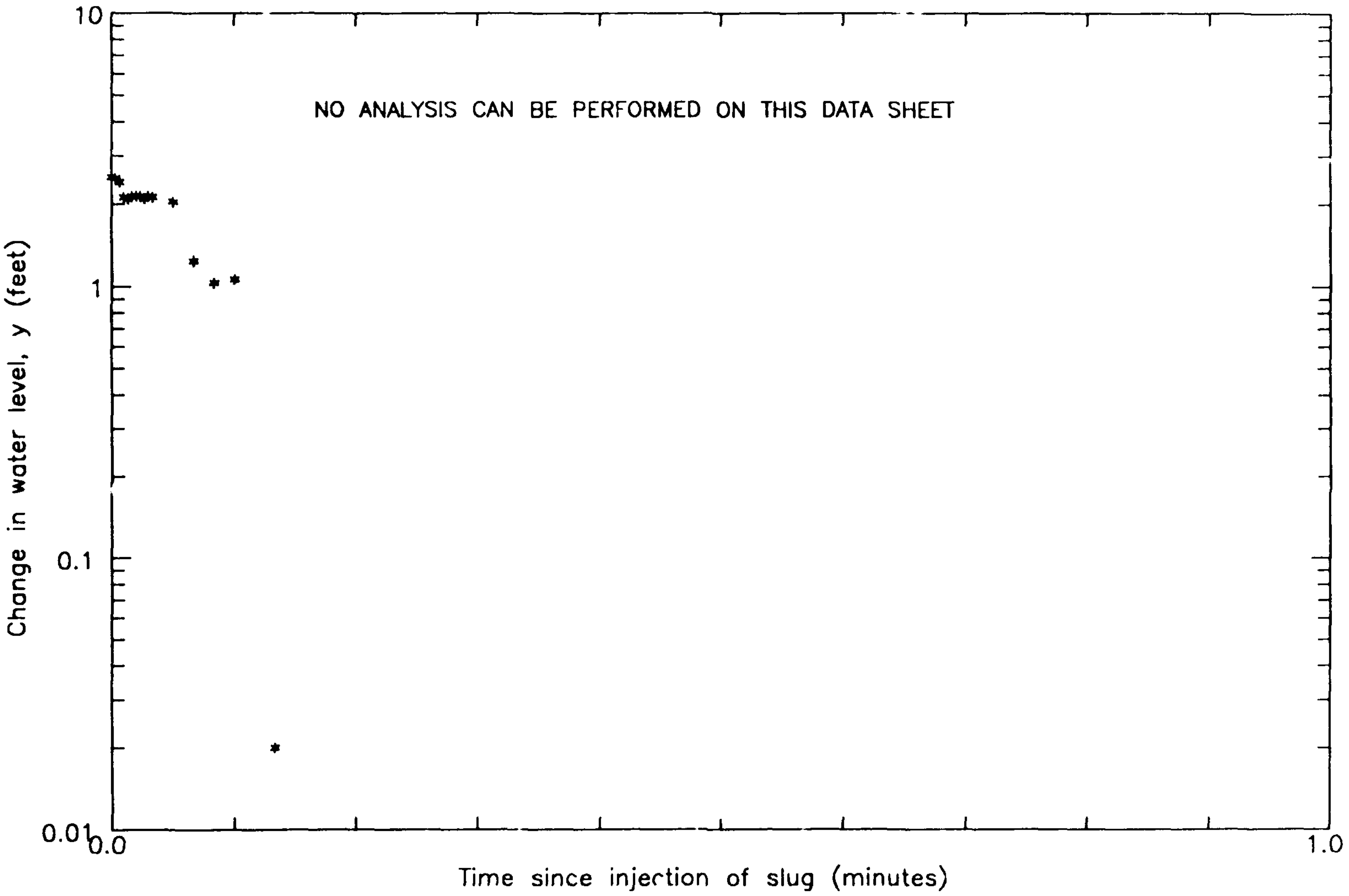


FIGURE D.11 Slug Injection Test Analysis Using Data from Well BC3 MW1

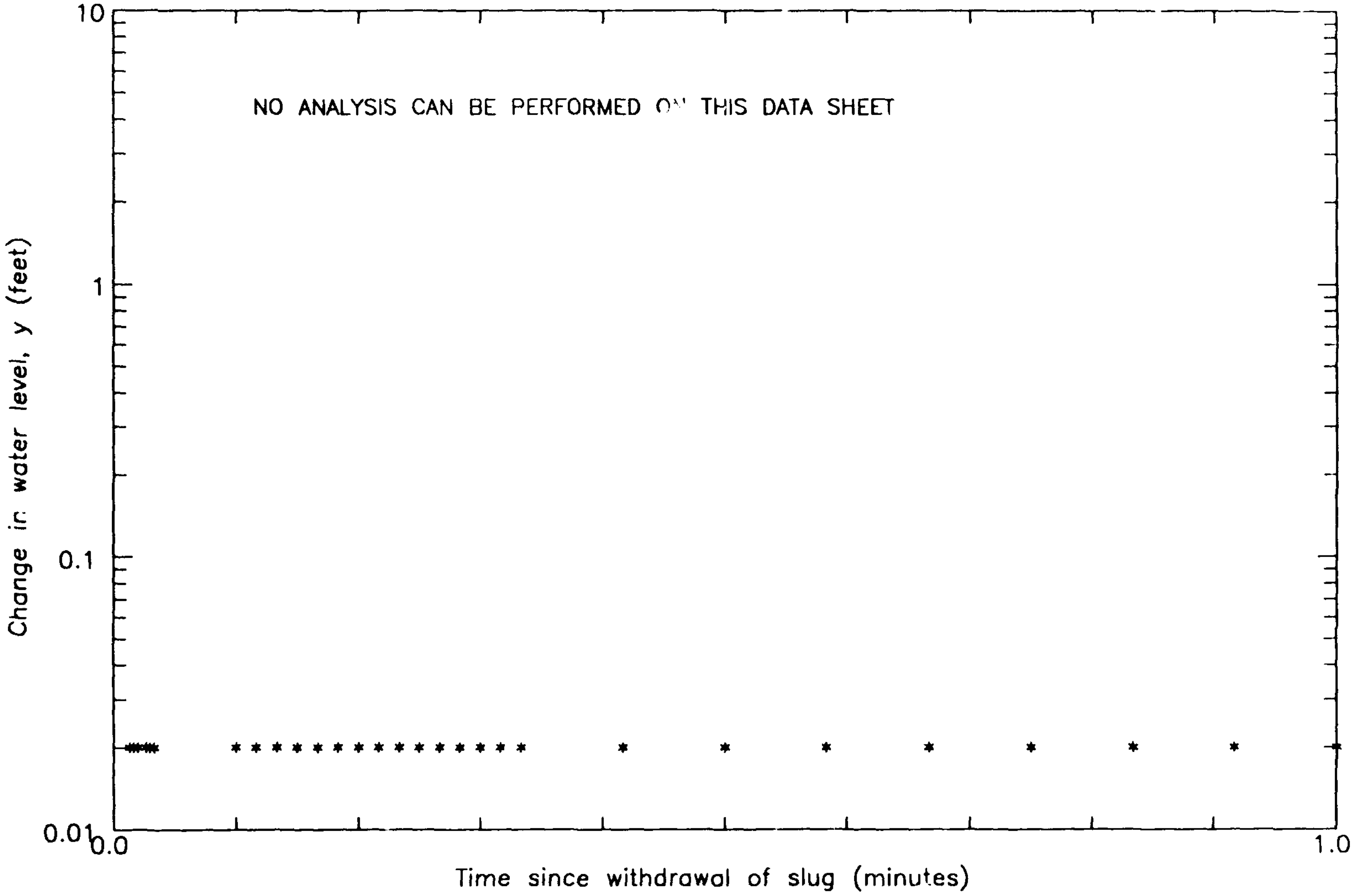


FIGURE D.12 Slug Withdrawal Test Analysis Using Data from Well BC3 MW1

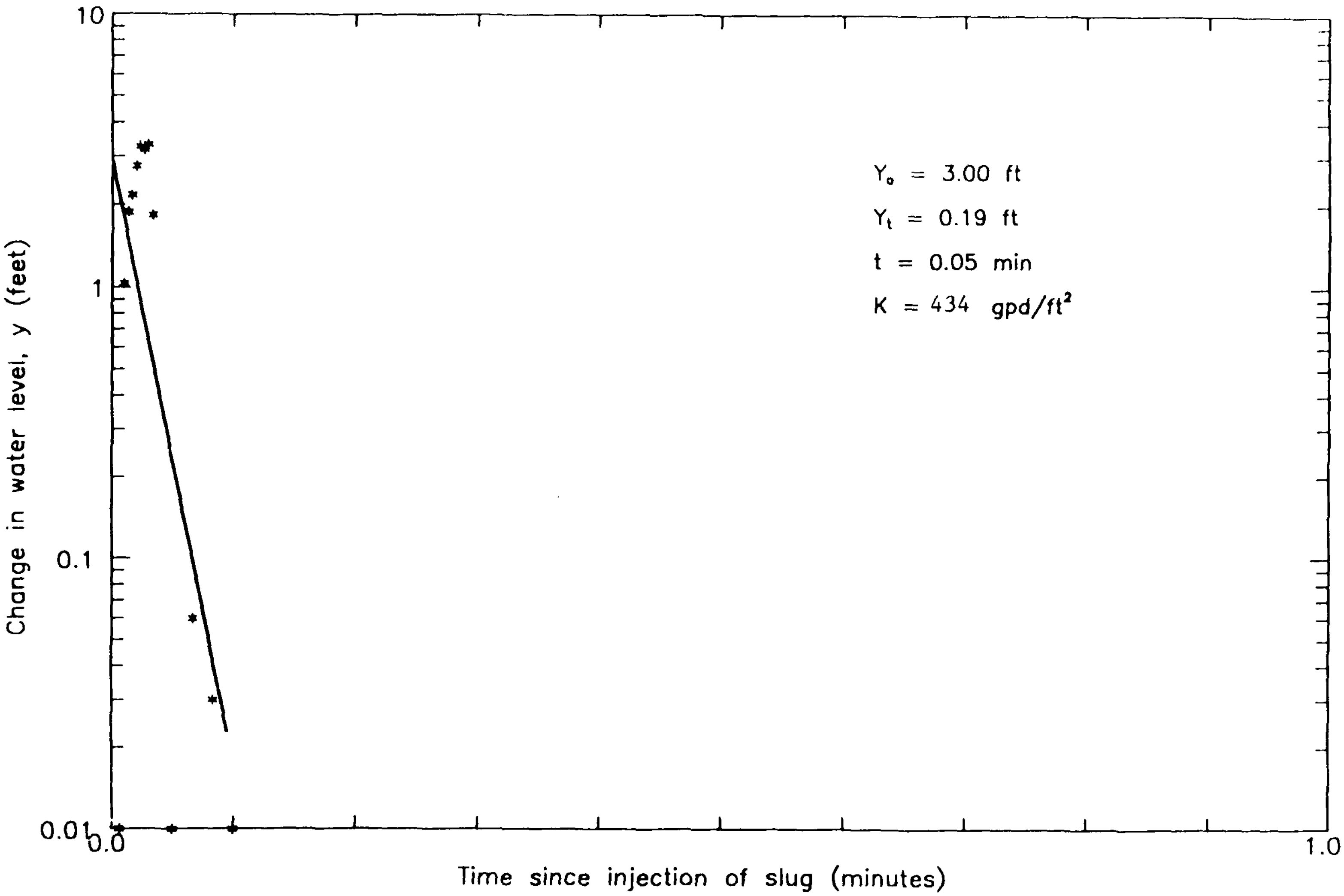


FIGURE D.13 Slug Injection Test Analysis Using Data from Well BC3 MW2

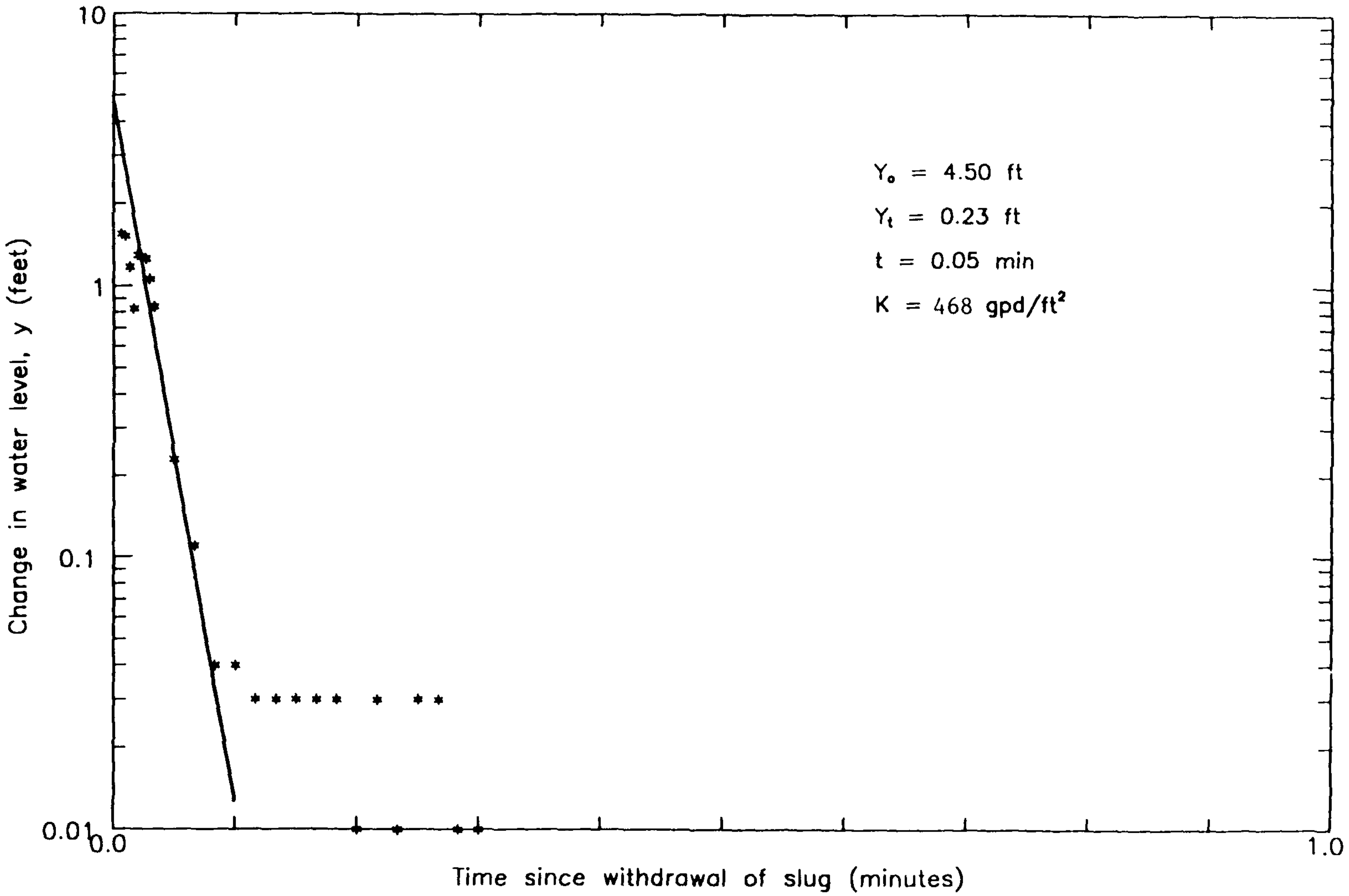


FIGURE D.14 Slug Withdrawal Test Analysis Using *Data from* Well BC3 MW2

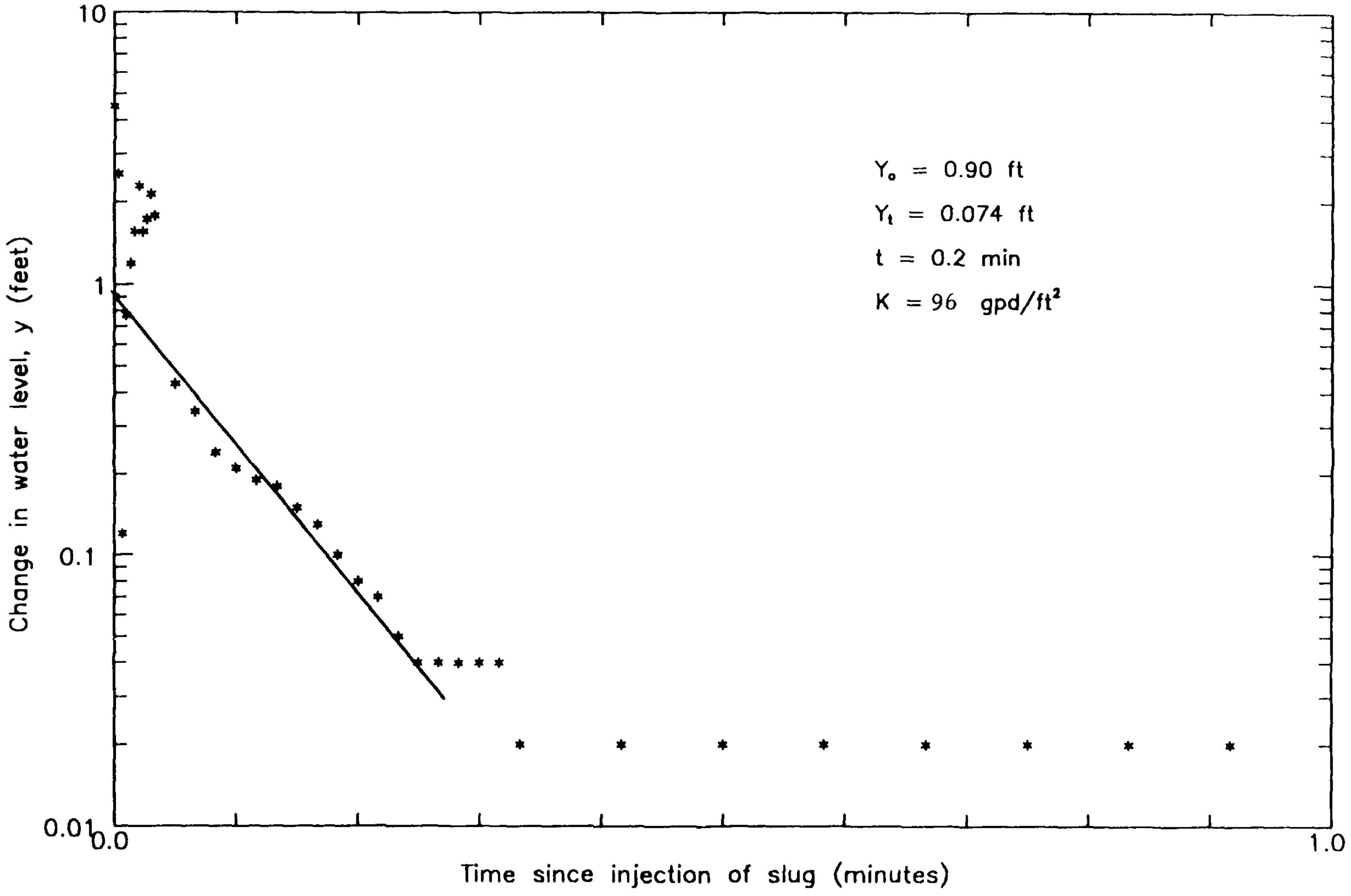


FIGURE D.15 Slug Injection Test Analysis Using Data from Well BC3 MW3

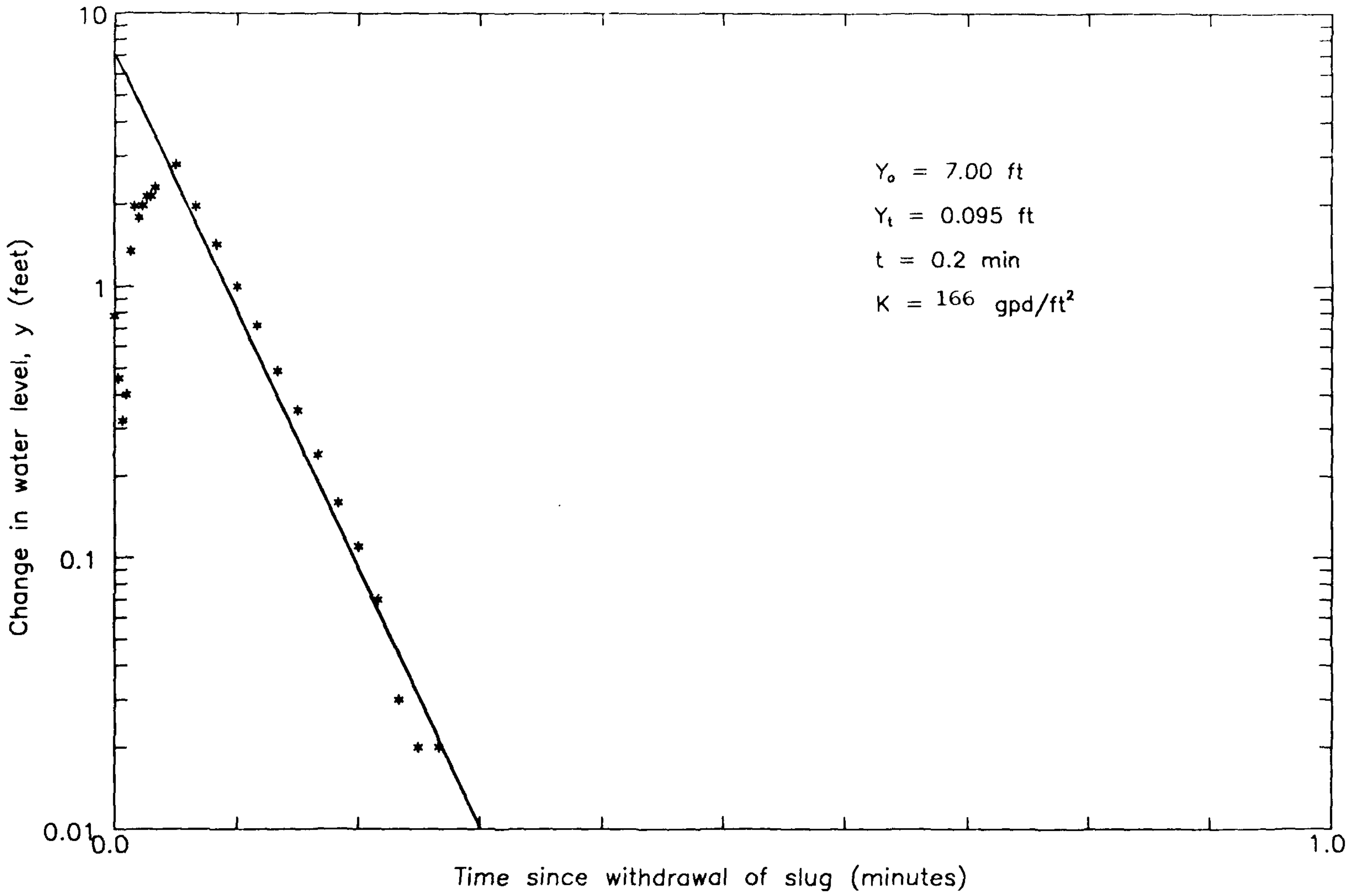


FIGURE D.16 Slug Withdrawal Test Analysis Using Data from Well BC3 MW3

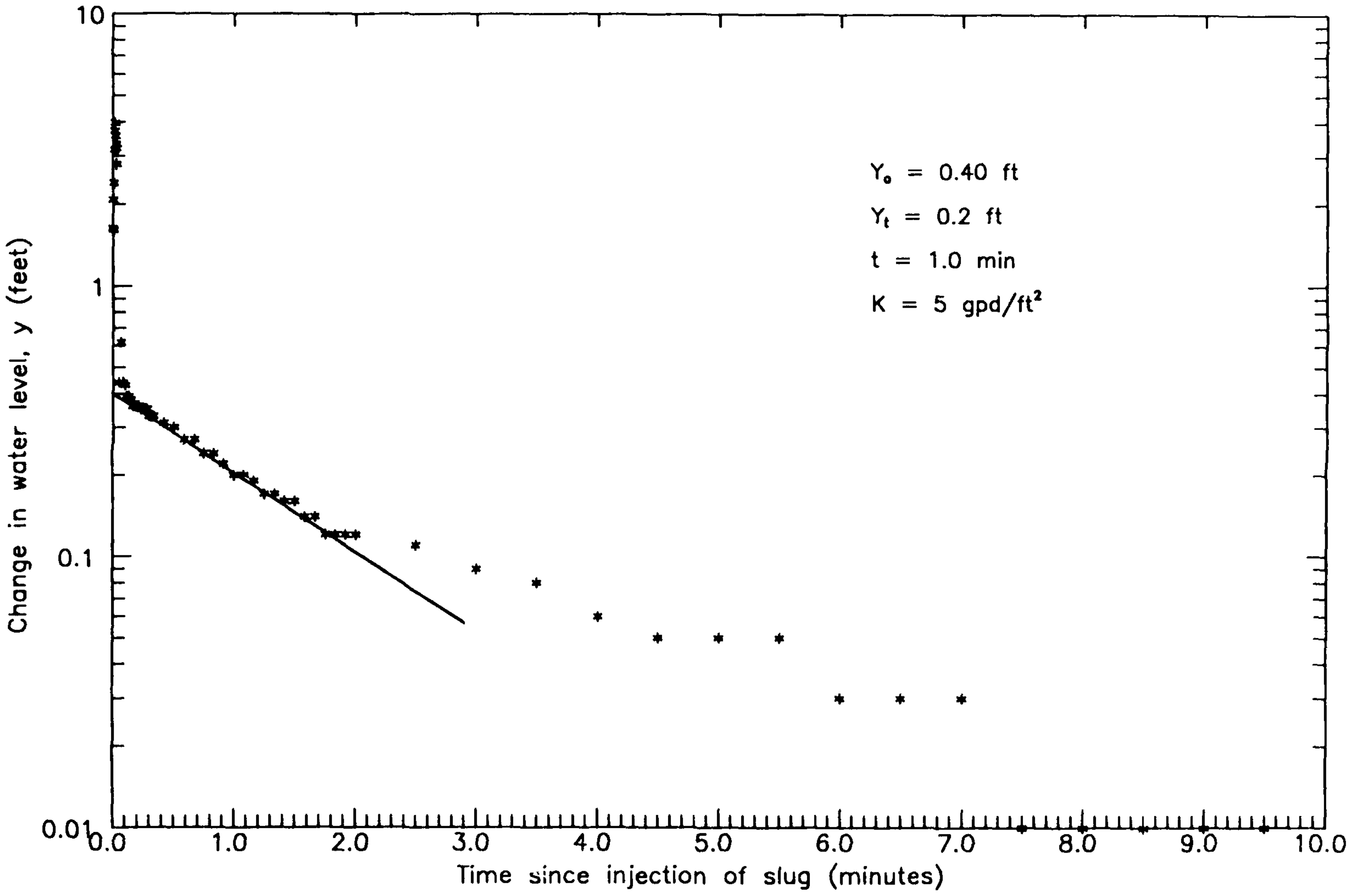


FIGURE D.17 Slug Injection Test Analysis Using Data from Well BC4 MW2

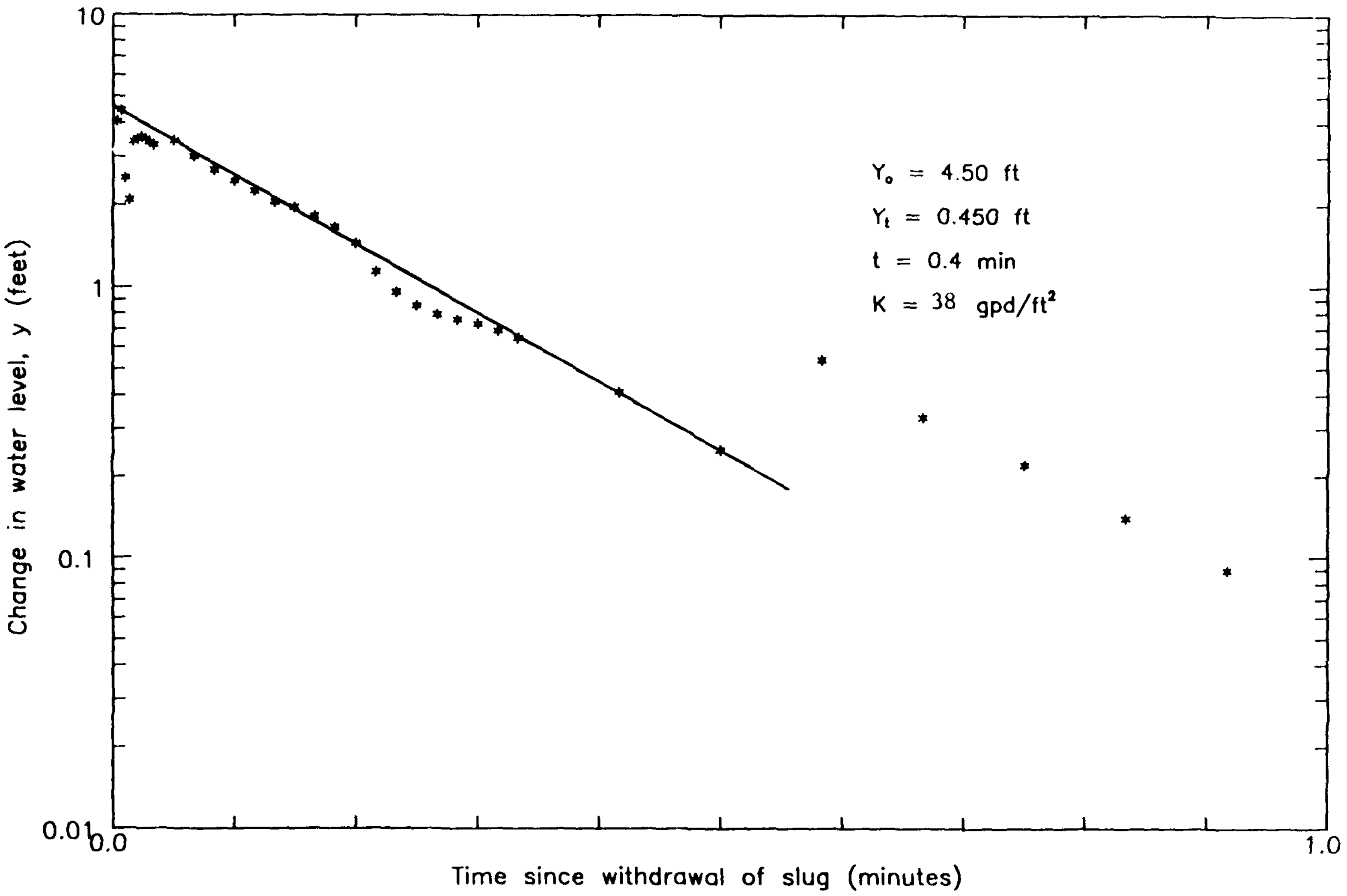


FIGURE D.18 Slug Withdrawal Test Analysis Using Data from Well BC4 MW2

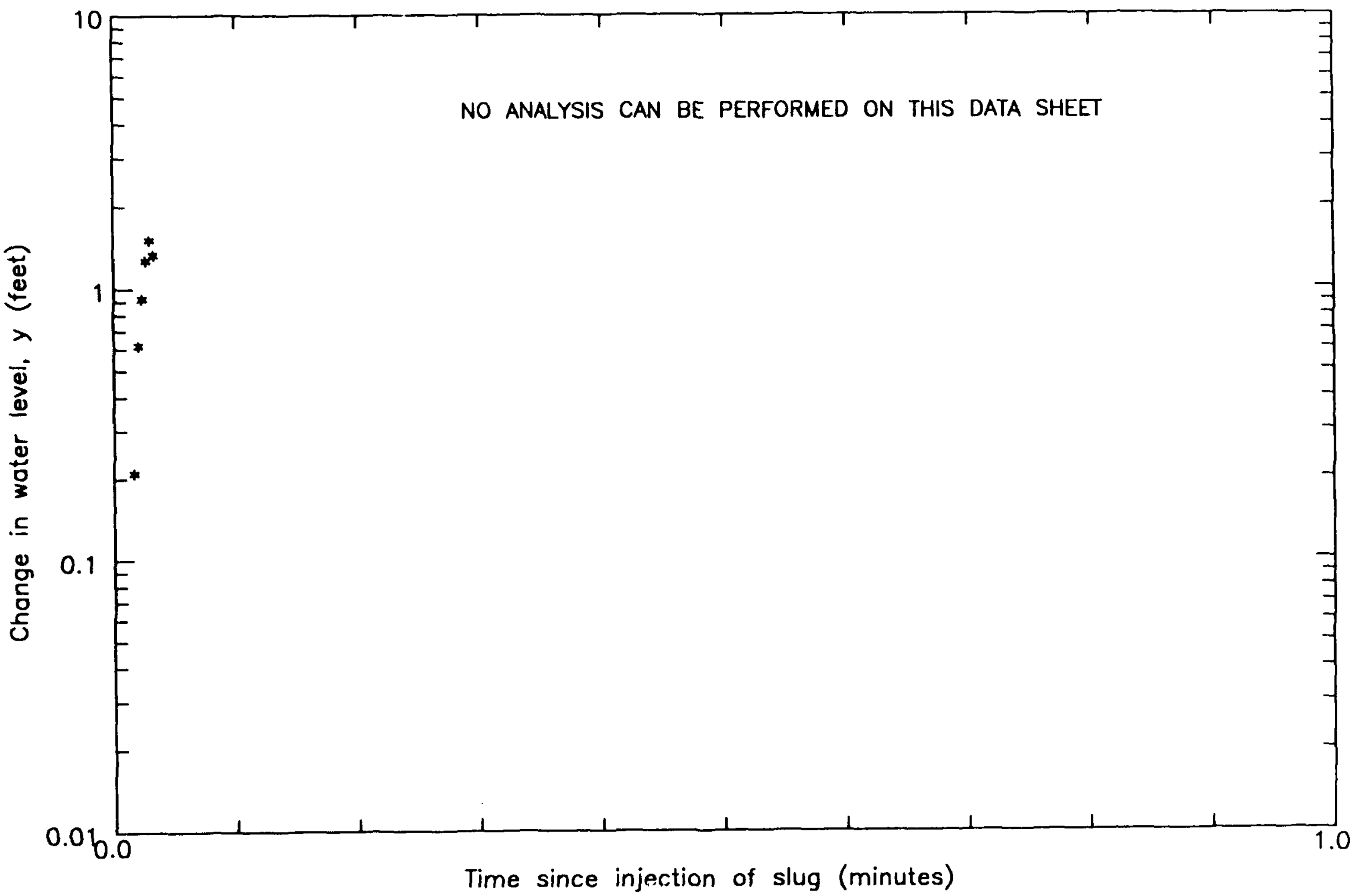


FIGURE D.19 Slug Injection Test Analysis Using Data from Well BC4 MW4

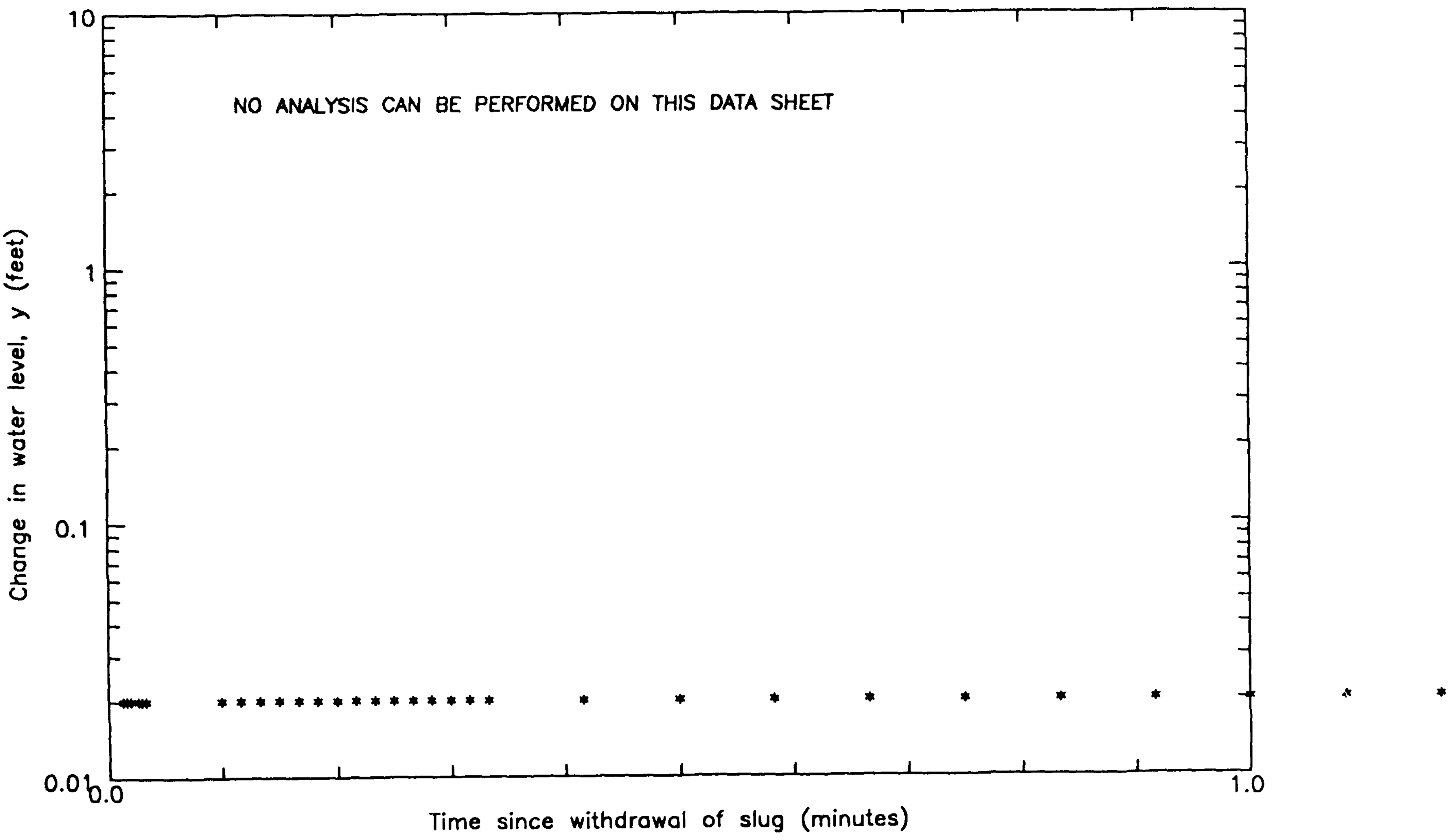


FIGURE D.20 Slug Withdrawal Test Analysis Using Data from Well BC4 MW4

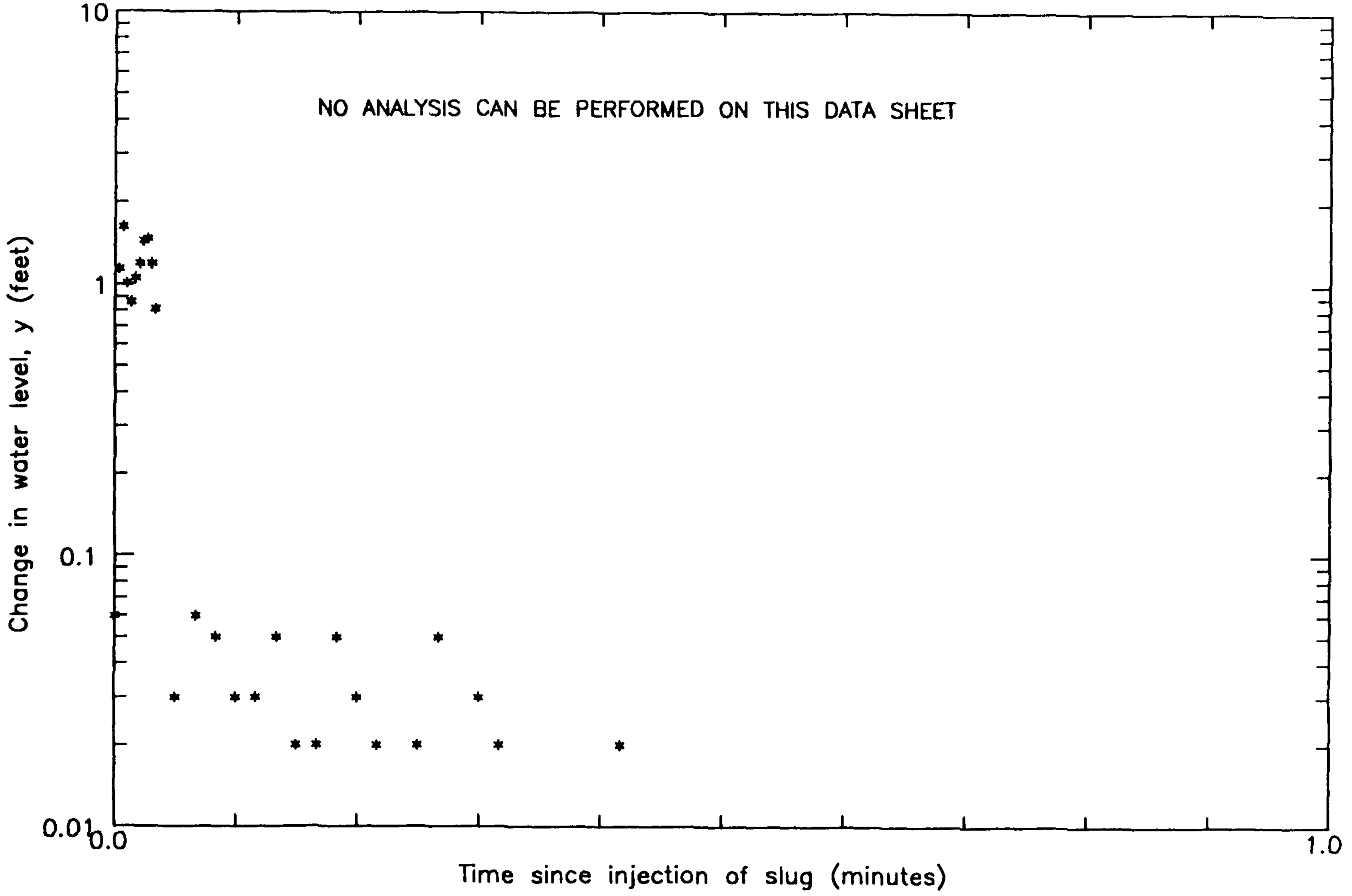
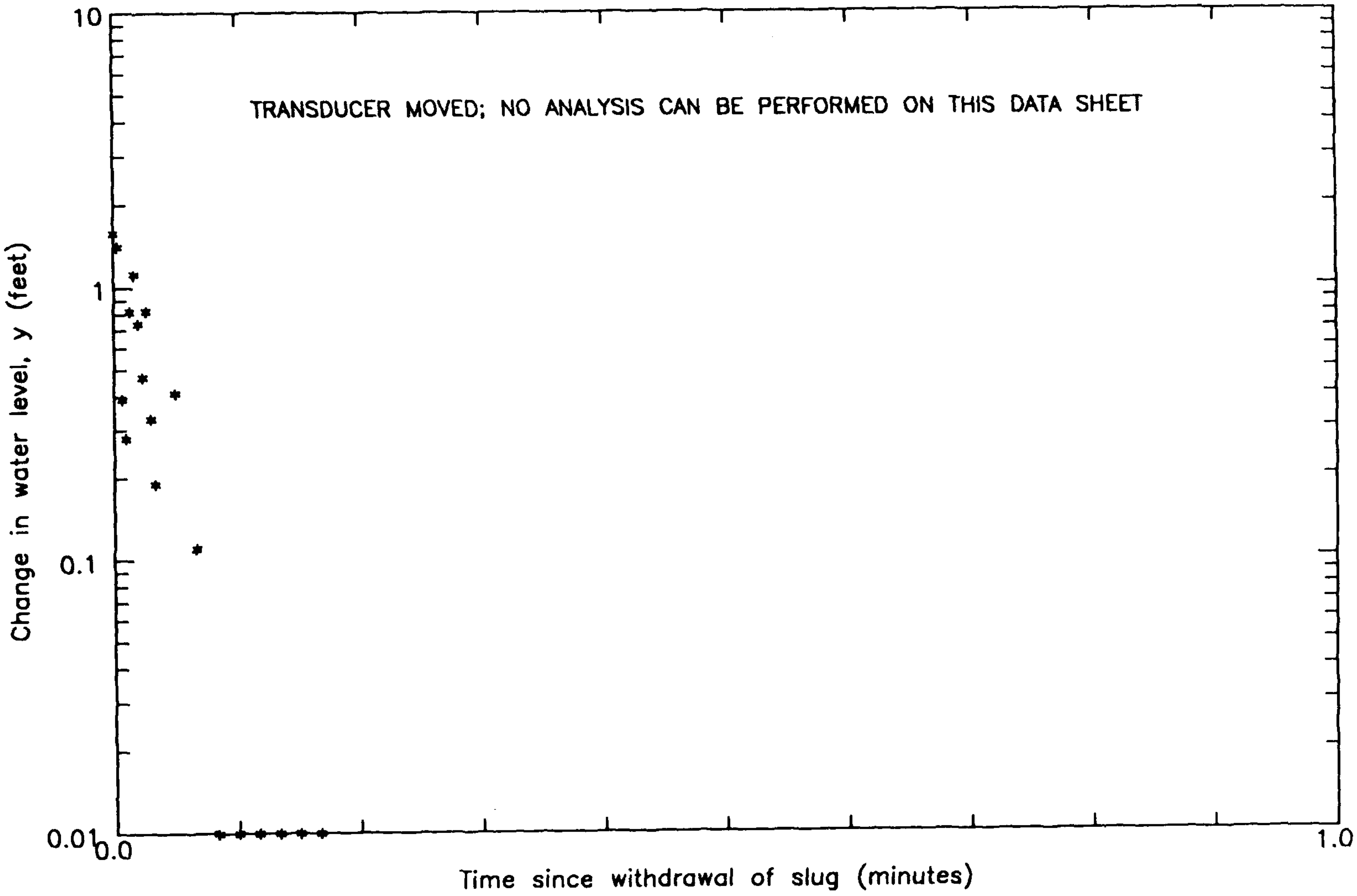


FIGURE D.21 Slug Injection Test Analysis Using Data from Well BC5 MW1



TRANSDUCER MOVED; NO ANALYSIS CAN BE PERFORMED ON THIS DATA SHEET

FIGURE D.22 Slug Withdrawal Test Analysis Using Data from Well BC5 MW1

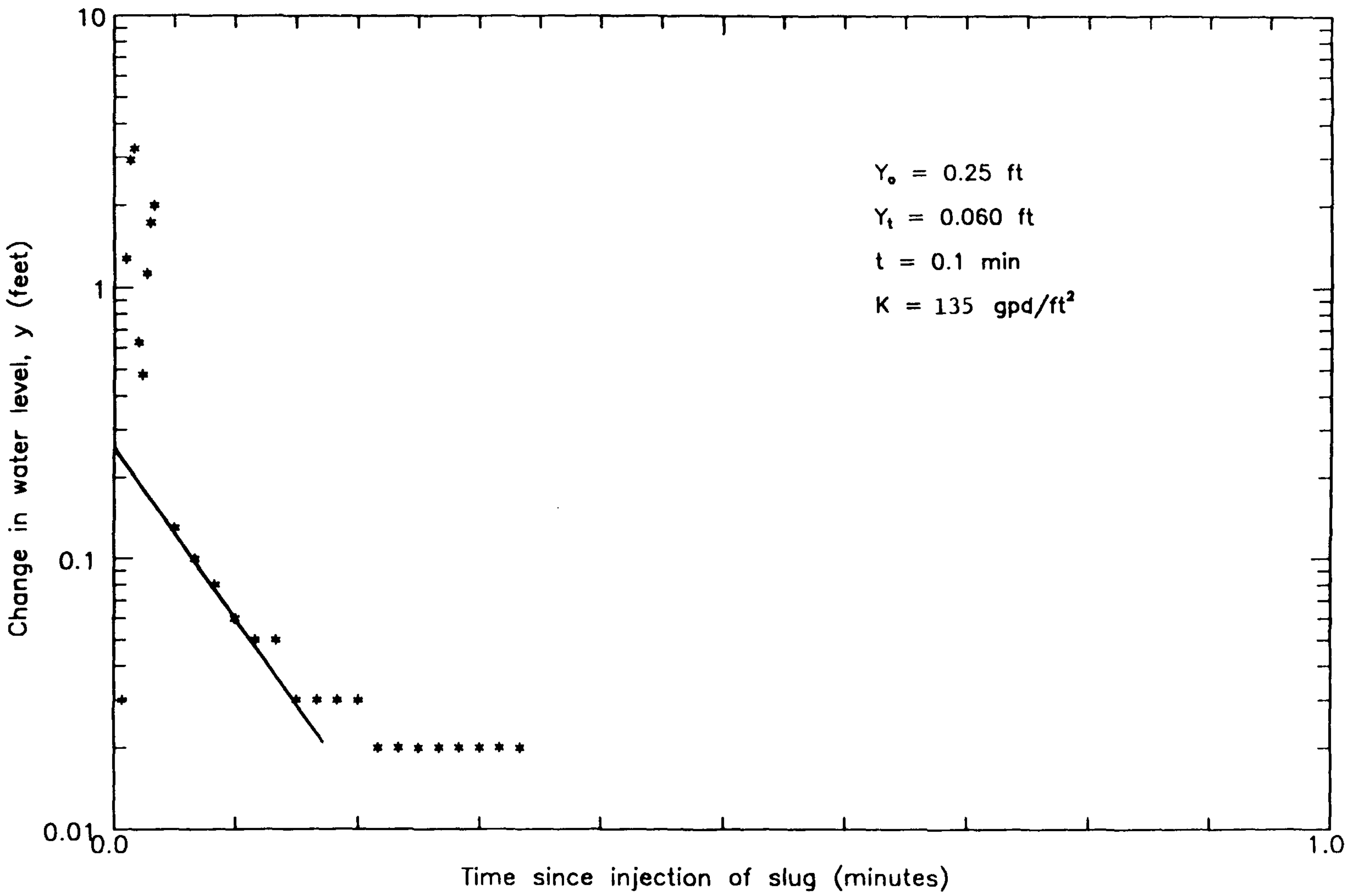


FIGURE D.23 Slug Injection Test Analysis Using Data from Well BC6 MW1

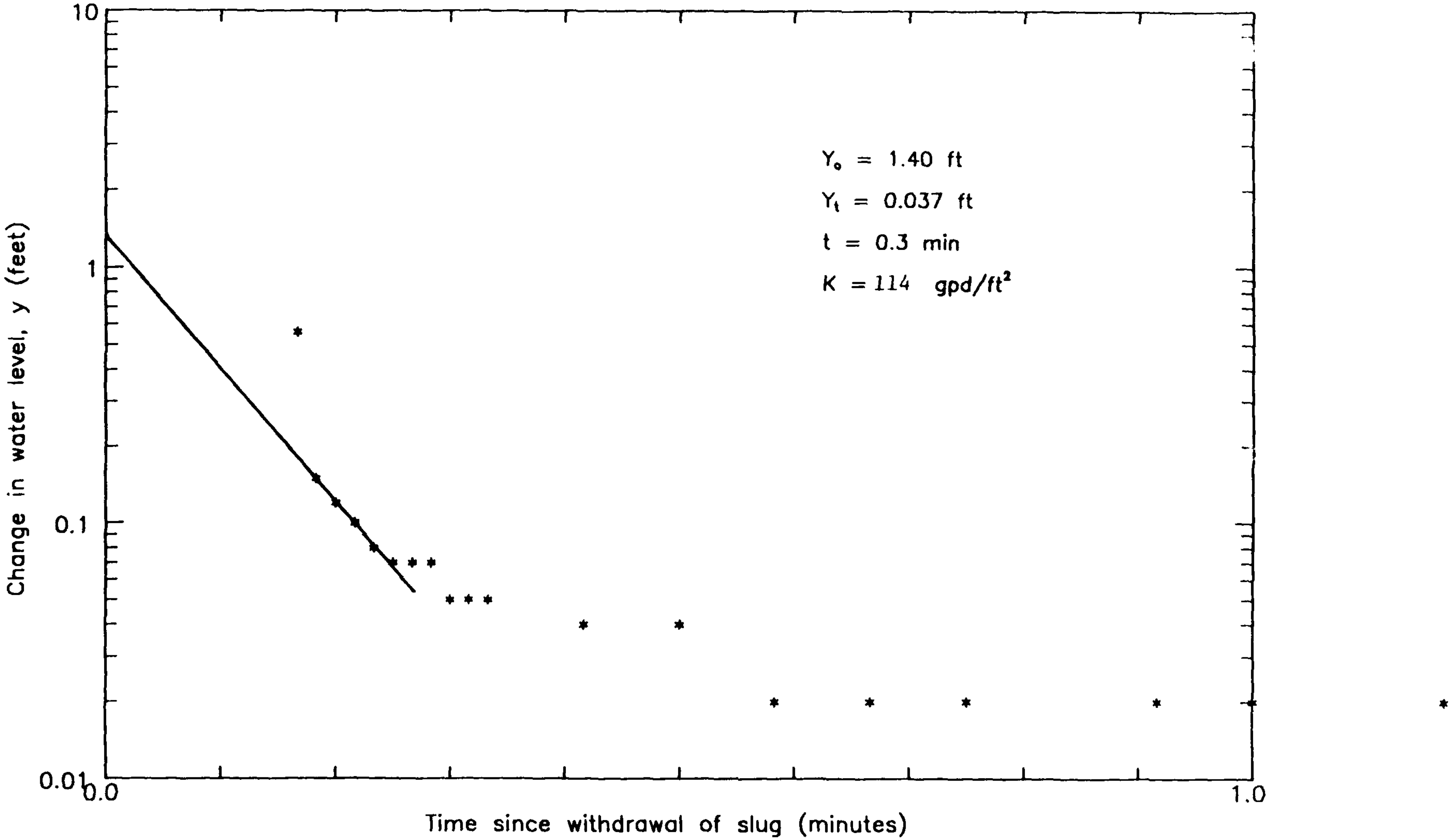


FIGURE D.24 Slug Withdrawal Test Analysis Using Data from Well BC6 MW1

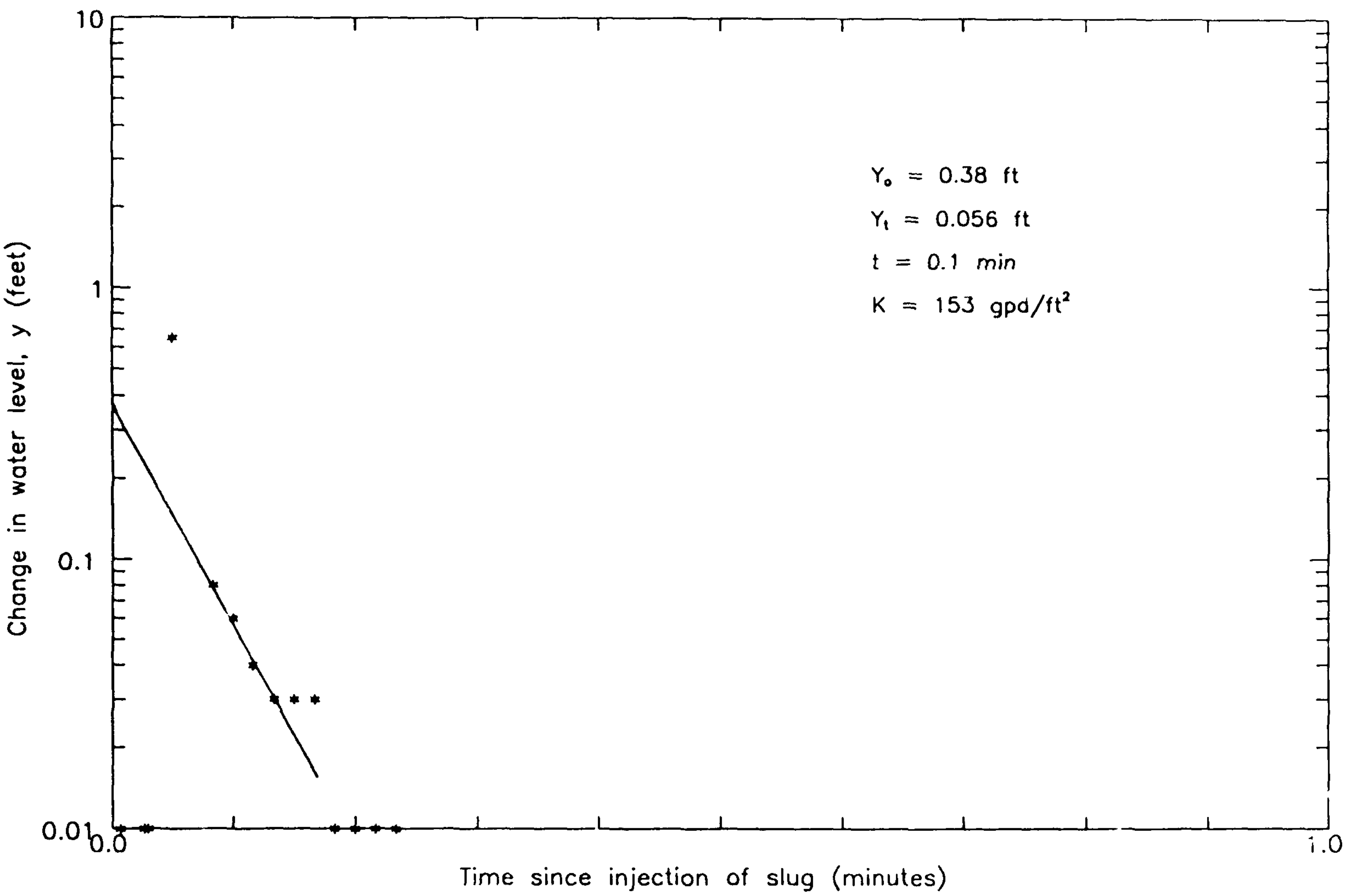


FIGURE D.25 Slug Injection Test Analysis Using Data from Well BC6 MW2

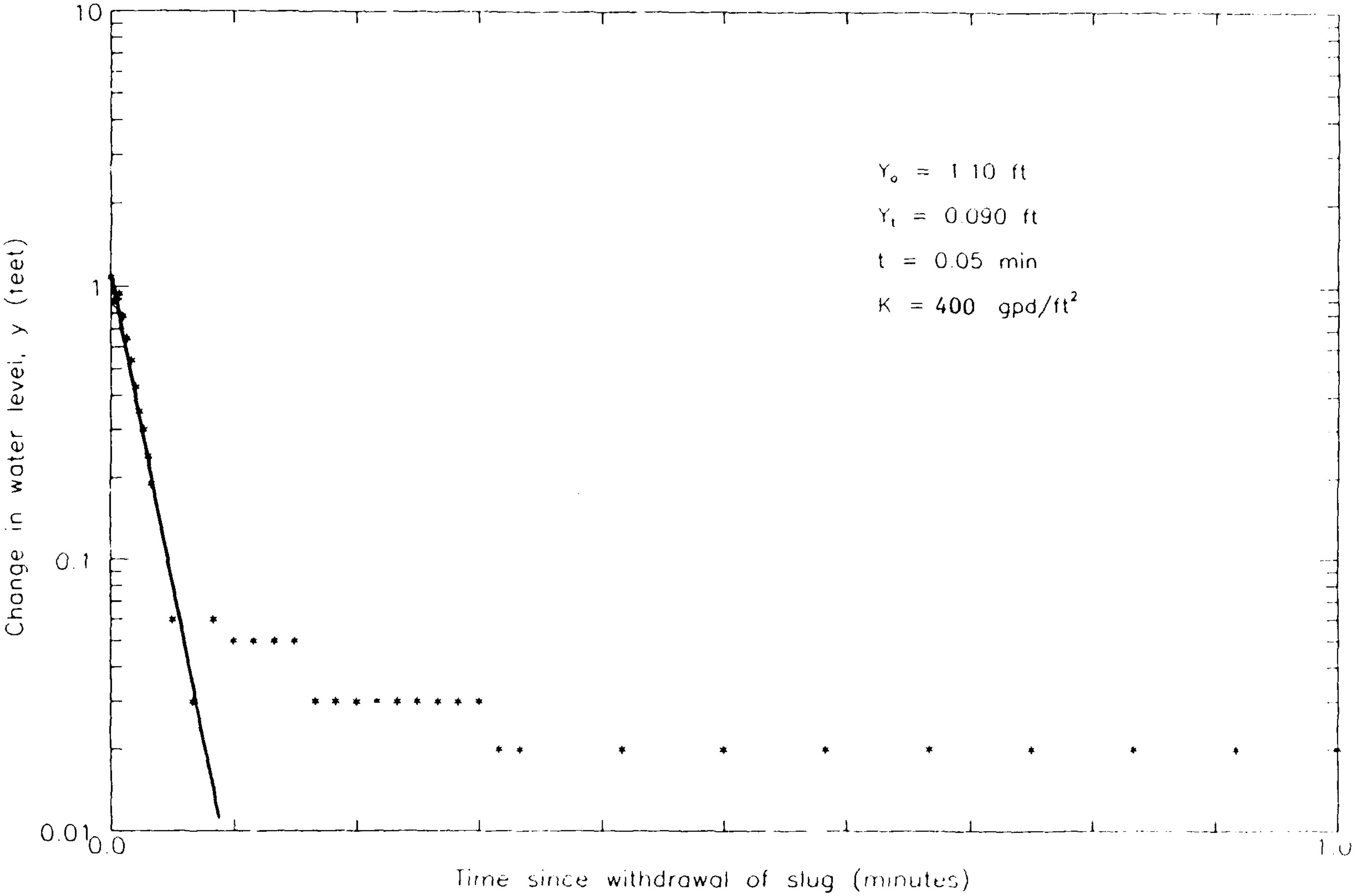


FIGURE D.26 Slug Withdrawal Test Analysis Using Data from Well BC6 MW2

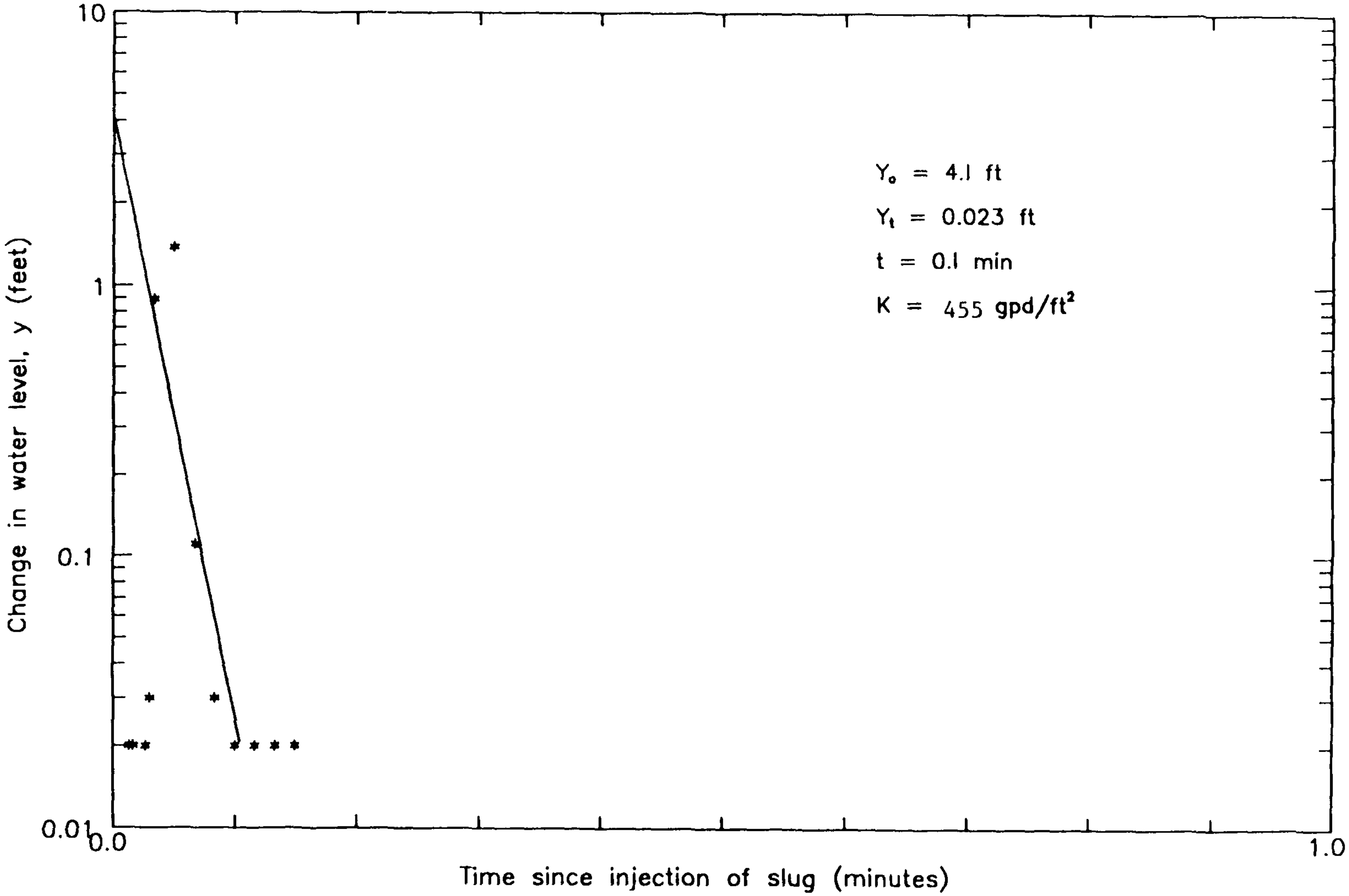


FIGURE D.27 Slug Injection Test Analysis Using Data from Well BC6 MW3

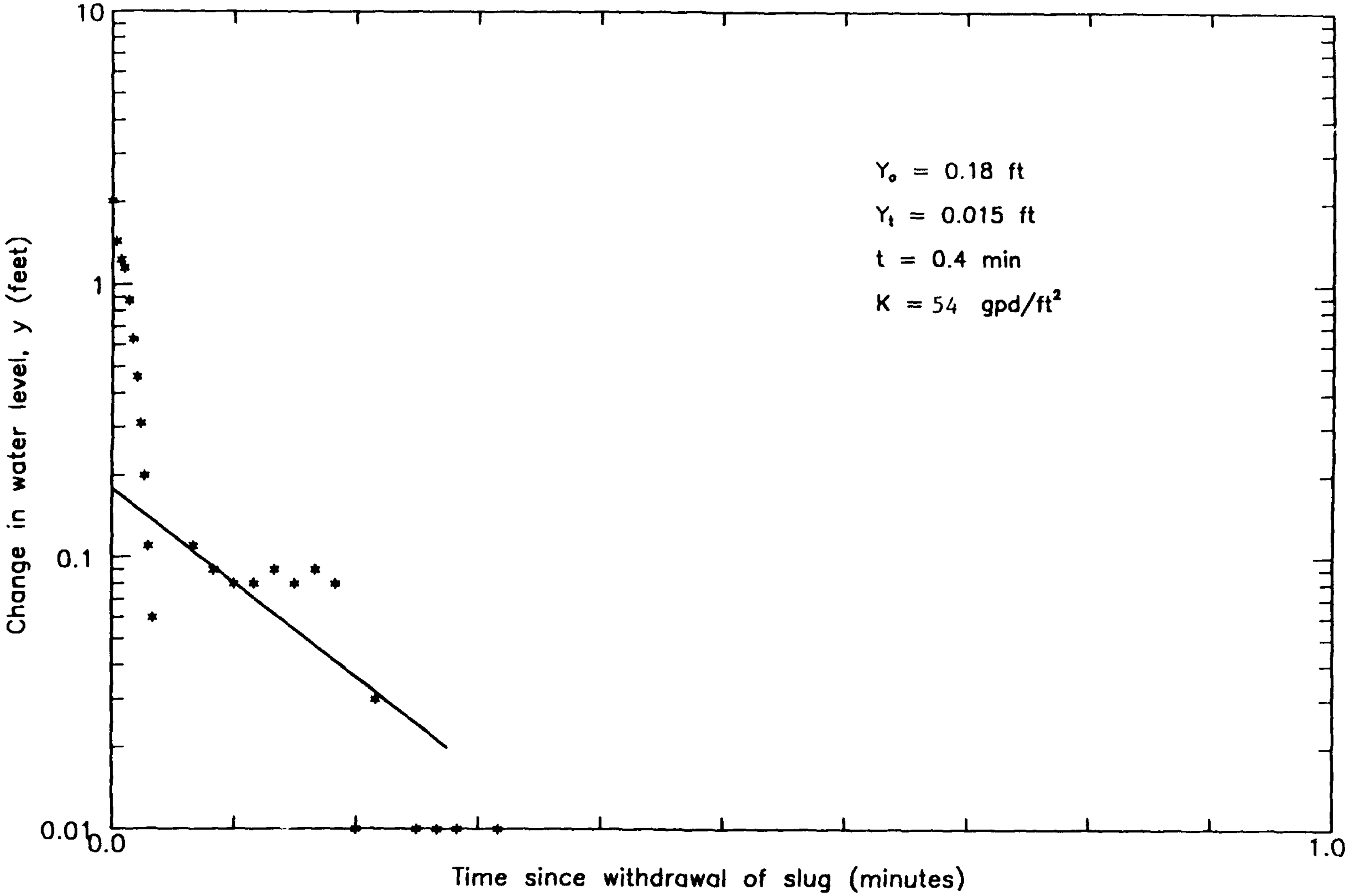


FIGURE D.28 Slug Withdrawal Test Analysis Using Data from Well BC6 MW3

APPENDIX D.2
WATER LEVEL DATA

TABLE D.4

MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SLUG TEST DATA FOR WELL
BC MW1

INITIAL WATER LEVEL: 39.39 FEET BELOW TOP OF CASING

	WATER LEVEL CHANGE	
	INJECTION TEST	REMOVAL TEST
DATE:	1/12/89	1/12/89
TIME:	0920	0930
t (min)	y1 (ft)	y2 (ft)
0.0000	-0.02	1.87
0.0033	-0.03	1.92
0.0066	0.16	2.25
0.0099	1.25	2.85
0.0133	1.33	2.61
0.0166	1.88	3.11
0.0200	3.36	2.84
0.0233	4.32	2.93
0.0266	5.10	3.06
0.0300	5.02	3.07
0.0333	4.83	3.01
0.0500	0.22	2.35
0.0666	0.43	1.85
0.0833	0.19	1.41
0.1000	0.11	1.08
0.1166	0.06	0.83
0.1333	0.05	0.62
0.1500	0.03	0.48
0.1666	0.01	0.35
0.1833	0.01	0.26
0.2000	0.01	0.19
0.2166	0.00	0.16
0.2333	0.00	0.11
0.2500	0.00	0.10
0.2666	0.00	0.08
0.2833	0.00	0.07
0.3000	-0.02	0.05
0.3166	0.00	0.03
0.3333	-0.02	0.03
0.4167	-0.02	0.02
0.5000	-0.02	0.02
0.5833	-0.02	0.00
0.6667	-0.02	0.00
0.7500	-0.02	0.00
0.8333	-0.02	0.00
0.9167	-0.02	0.00
1.0000	-0.02	0.00

TABLE D.4
(CONTINUED)
MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SLUG TEST DATA FOR WELL
BC MW1

INITIAL WATER LEVEL: 39.39 FEET BELOW TOP OF CASING

	WATER LEVEL CHANGE INJECTION TEST	 REMOVAL TEST
DATE:	1/12/89	1/12/89
TIME:	0920	0930
t (min)	y1 (ft)	y2 (ft)
1.0833	-0.02	0.00
1.1667	-0.02	0.00
1.2500	-0.02	0.00
1.3333	-0.02	0.00
1.4166	0.00	0.00
1.5000	0.00	0.00
1.5833	0.00	0.00
1.6667	0.00	-0.01
1.7500	0.00	-0.01
1.8333	0.00	0.00
1.9167	0.00	0.00
2.0000	-0.02	0.00
2.5000	0.00	0.00
3.0000	0.00	0.00
3.5000	0.00	0.00
4.0000	0.00	0.00
4.5000	0.00	0.00
5.0000	0.00	0.00
5.5000	0.00	0.00
6.0000	0.00	0.00
6.5000	0.00	0.00
7.0000	0.00	0.00
7.5000	0.00	0.00
8.0000	0.00	0.00
8.5000	0.00	0.00
9.0000	0.00	0.02
9.5000	0.00	0.00
10.0000	0.00	0.00

TABLE D.5

MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SLUG TEST DATA FOR WELL
BC MW3

INITIAL WATER LEVEL: 37.18 FEET BELOW TOP OF CASING

	WATER LEVEL CHANGE	
	INJECTION TEST	REMOVAL TEST
DATE:	1/12/89	1/12/89
TIME:	0947	0957
t (min)	y1 (ft)	y2 (ft)
0.0000	-0.05	1.74
0.0033	-0.05	2.09
0.0066	-0.05	1.85
0.0099	-0.05	1.28
0.0133	-0.05	1.25
0.0166	-0.05	1.79
0.0200	-0.05	2.23
0.0233	-0.05	2.63
0.0266	-0.05	2.47
0.0300	-0.05	2.67
0.0333	-0.03	2.42
0.0500	-0.05	1.80
0.0666	3.28	1.25
0.0833	2.57	1.04
0.1000	-0.20	0.74
0.1166	0.45	0.28
0.1333	0.26	0.09
0.1500	0.16	0.03
0.1666	0.08	0.00
0.1833	0.02	0.00
0.2000	-0.01	0.00
0.2166	-0.05	0.00
0.2333	-0.06	0.00
0.2500	-0.06	0.00
0.2666	-0.06	0.00
0.2833	-0.06	0.00
0.3000	-0.06	-0.02
0.3166	-0.06	-0.02
0.3333	-0.06	0.00
0.4167	-0.05	-0.02
0.5000	-0.05	-0.02
0.5833	-0.05	-0.02
0.6667	-0.05	-0.02
0.7500	-0.05	-0.02
0.8333	-0.03	-0.02
0.9167	-0.03	-0.02
1.0000	-0.03	-0.02

TABLE D.5
(CONTINUED)
MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SLUG TEST DATA FOR WELL
BC MW3

INITIAL WATER LEVEL: 37.18 FEET BELOW TOP OF CASING

	WATER LEVEL CHANGE	
	INJECTION TEST	REMOVAL TEST
DATE:	1/12/89	1/12/89
TIME:	0947	0957
t (min)	y1 (ft)	y2 (ft)
1.0833	-0.03	-0.02
1.1667	-0.03	-0.02
1.2500	-0.03	-0.02
1.3333	-0.03	-0.02
1.4166	-0.03	-0.02
1.5000	-0.01	-0.02
1.5833	-0.01	-0.02
1.6667	-0.01	-0.02
1.7500	-0.01	-0.02
1.8333	-0.01	-0.02
1.9167	-0.01	-0.02
2.0000	-0.01	0.00
2.5000	-0.01	-0.02
3.0000	0.00	-0.02
3.5000	0.00	0.00
4.0000	0.00	0.00
4.5000	0.00	-0.02
5.0000	-0.01	0.00
5.5000	0.00	0.00
6.0000	0.00	0.00
6.5000	0.00	0.00
7.0000	0.00	0.00
7.5000	0.00	0.00
8.0000	0.00	0.00
8.5000	0.00	0.00
9.0000	0.00	0.00
9.5000	0.00	0.00
10.0000	0.02	0.00

TABLE D.6

MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SLUG TEST DATA FOR WELL
BC MW6

INITIAL WATER LEVEL: 32.10 FEET BELOW TOP OF CASING

	WATER LEVEL CHANGE	
	INJECTION TEST	REMOVAL TEST
DATE:	1/11/89	1/11/89
TIME:	1613	1624
t (min)	y1 (ft)	y2 (ft)
0.0000	0.00	1.58
0.0033	-0.01	1.41
0.0066	-0.03	0.39
0.0099	0.79	0.28
0.0133	2.35	0.82
0.0166	1.06	1.12
0.0200	1.05	0.74
0.0233	1.74	0.47
0.0266	2.41	0.82
0.0300	2.46	0.33
0.0333	1.38	0.19
0.0500	0.13	0.41
0.0666	0.05	0.11
0.0833	-0.01	0.01
0.1000	0.00	0.01
0.1166	0.00	0.01
0.1333	-0.01	0.01
0.1500	-0.01	0.01
0.1666	-0.01	0.01
0.1833	0.00	0.00
0.2000	-0.01	0.00
0.2166	-0.01	0.00
0.2333	-0.01	0.00
0.2500	-0.01	0.00
0.2666	0.00	0.01
0.2833	0.00	0.00
0.3000	-0.01	0.00
0.3166	-0.01	0.00
0.3333	0.00	0.00
0.4167	-0.01	0.00
0.5000	0.00	0.00
0.5833	0.00	0.00
0.6667	0.00	0.00
0.7500	0.00	0.00
0.8333	0.00	0.00
0.9167	0.00	0.00
1.0000	0.00	0.00

TABLE D.6
(CONTINUED)
MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SLUG TEST DATA FOR WELL
BC MW6

INITIAL WATER LEVEL: 32.10 FEET BELOW TOP OF CASING

	WATER LEVEL CHANGE INJECTION TEST	REMOVAL TEST
DATE:	1/11/89	1/11/89
TIME:	1613	1624
t (min)	y1 (ft)	y2 (ft)
1.0833	0.00	0.00
1.1667	0.00	0.00
1.2500	0.00	0.01
1.3333	0.00	0.00
1.4166	0.00	0.00
1.5000	0.00	0.00
1.5833	0.00	0.00
1.6667	0.00	0.00
1.7500	0.00	0.00
1.8333	0.00	0.00
1.9167	0.00	0.00
2.0000	0.00	0.00
2.5000	0.00	0.00
3.0000	0.00	0.00
3.5000	0.02	0.00
4.0000	0.02	0.00
4.5000	0.02	0.01
5.0000	0.02	0.00
5.5000	0.02	0.00
6.0000	0.02	0.00
6.5000	0.02	0.00
7.0000	0.02	0.00
7.5000	0.02	0.00
8.0000	0.02	0.00
8.5000	0.02	0.00
9.0000	0.02	0.00
9.5000	0.02	0.00
10.0000	0.02	0.00

TABLE D.7

MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SLUG TEST DATA FOR WELL
BC MW7

INITIAL WATER LEVEL: 42.11 FEET BELOW TOP OF CASING

	WATER LEVEL CHANGE INJECTION TEST	REMOVAL TEST
DATE:	1/12/89	1/12/89
TIME:	0727	0738
t (min)	y1 (ft)	y2 (ft)
0.0000	0.00	0.42
0.0033	0.00	0.33
0.0066	-0.02	0.38
0.0099	0.00	0.50
0.0133	0.00	0.58
0.0166	0.00	0.58
0.0200	0.00	0.55
0.0233	0.01	0.52
0.0266	0.00	0.47
0.0300	0.00	0.42
0.0333	0.01	0.33
0.0500	0.54	0.03
0.0666	0.65	0.03
0.0833	0.06	0.03
0.1000	0.00	0.03
0.1166	0.00	0.03
0.1333	0.00	0.03
0.1500	0.00	0.00
0.1666	0.00	0.00
0.1833	0.00	0.00
0.2000	0.00	0.01
0.2166	0.00	0.00
0.2333	0.00	0.01
0.2500	0.00	0.00
0.2666	0.01	0.00
0.2833	0.00	0.01
0.3000	0.00	0.01
0.3166	0.00	0.01
0.3333	0.00	0.00
0.4167	0.00	0.00
0.5000	0.01	0.00
0.5833	0.01	0.01
0.6667	0.01	0.00
0.7500	0.00	0.01
0.8333	0.01	0.00
0.9167	0.01	0.00
1.0000	0.00	0.01

TABLE D.7
(CONTINUED)
MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SLUG TEST DATA FOR WELL
BC MW7

INITIAL WATER LEVEL: 42.11 FEET BELOW TOP OF CASING

	WATER LEVEL CHANGE INJECTION TEST	 REMOVAL TEST
DATE:	1/12/89	1/12/89
TIME:	0727	0738
t (min)	y1 (ft)	y2 (ft)
1.0833	0.01	0.01
1.1667	0.01	0.01
1.2500	0.01	0.01
1.3333	0.01	0.01
1.4166	0.01	0.00
1.5000	0.01	0.01
1.5833	0.01	0.01
1.6667	0.01	0.00
1.7500	0.01	0.00
1.8333	0.01	0.00
1.9167	0.01	0.01
2.0000	0.03	0.00
2.5000	0.03	0.00
3.0000	0.01	0.00
3.5000	0.01	0.00
4.0000	0.01	0.00
4.5000	0.01	0.00
5.0000	0.01	0.00
5.5000	0.01	0.00
6.0000	0.01	0.00
6.5000	0.01	0.00
7.0000	0.01	0.00
7.5000	0.01	0.00
8.0000	0.01	0.00
8.5000	0.01	0.00
9.0000	0.01	0.00
9.5000	0.01	0.00
10.0000	0.01	0.00

TABLE D.8

MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SLUG TEST DATA FOR WELL
BC MW9

INITIAL WATER LEVEL: 6.85 FEET BELOW TOP OF CASING

	WATER LEVEL CHANGE INJECTION TEST	WATER LEVEL CHANGE REMOVAL TEST
DATE:	1/12/89	1/12/89
TIME:	0831	0843
t (min)	y1 (ft)	y2 (ft)
0.0000	0.00	0.68
0.0033	0.00	0.63
0.0066	-0.02	0.61
0.0099	0.00	0.99
0.0133	0.00	0.66
0.0166	-0.02	0.19
0.0200	-0.03	0.28
0.0233	-0.02	0.42
0.0266	-0.02	0.55
0.0300	-0.02	0.63
0.0333	-0.03	0.72
0.0500	0.76	0.19
0.0666	3.67	1.09
0.0833	0.89	0.74
0.1000	0.05	1.04
0.1166	0.21	0.88
0.1333	0.18	0.98
0.1500	0.10	1.26
0.1666	0.05	2.04
0.1833	0.02	1.36
0.2000	0.02	1.23
0.2166	0.02	0.72
0.2333	0.02	0.49
0.2500	0.02	0.63
0.2666	0.02	1.25
0.2833	0.02	1.22
0.3000	0.02	1.79
0.3166	0.00	0.27
0.3333	0.02	-0.05
0.4167	0.02	-0.05
0.5000	0.02	-0.05
0.5833	0.02	-0.04
0.6667	0.02	-0.04
0.7500	0.02	-0.04
0.8333	0.02	-0.04
0.9167	0.02	-0.04
1.0000	0.02	-0.04

TABLE D.8
(CONTINUED)
MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SLUG TEST DATA FOR WELL
BC MW9

INITIAL WATER LEVEL: 6.85 FEET BELOW TOP OF CASING

	WATER LEVEL CHANGE	
	INJECTION TEST	REMOVAL TEST
DATE:	1/12/89	1/12/89
TIME:	0831	0843
t (min)	y1 (ft)	y2 (ft)
1.0833	0.02	-0.05
1.1667	0.02	-0.04
1.2500	0.02	-0.05
1.3333	0.02	-0.05
1.4166	0.02	-0.05
1.5000	0.02	0.01
1.5833	0.02	0.01
1.6667	0.02	0.01
1.7500	0.02	0.01
1.8333	0.00	0.01
1.9167	0.02	0.01
2.0000	0.00	0.01
2.5000	0.02	0.01
3.0000	0.02	0.01
3.5000	0.02	0.00
4.0000	0.02	0.00
4.5000	0.02	0.00
5.0000	0.02	0.00
5.5000	0.00	0.01
6.0000	0.00	0.00
6.5000	0.00	0.00
7.0000	0.00	0.00
7.5000	0.00	0.00
8.0000	0.00	0.00
8.5000	0.00	0.00
9.0000	0.00	0.00
9.5000	0.00	0.00
10.0000	0.00	0.00

TABLE D.9

MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SLUG TEST DATA FOR WELL
BC3 MW1

INITIAL WATER LEVEL: 32.08 FEET BELOW TOP OF CASING

	WATER LEVEL CHANGE INJECTION TEST	REMOVAL TEST
DATE:	1/11/89	1/11/89
TIME:	1438	1450
t (min)	y1 (ft)	y2 (ft)
0.0000	2.50	0.00
0.0033	2.49	0.00
0.0066	2.41	0.00
0.0099	2.12	0.00
0.0133	2.09	0.02
0.0166	2.14	0.02
0.0200	2.14	0.02
0.0233	2.14	0.00
0.0266	2.09	0.02
0.0300	2.14	0.02
0.0333	2.12	0.02
0.0500	2.04	-0.68
0.0666	1.24	-0.11
0.0833	1.03	0.00
0.1000	1.06	0.02
0.1166	-0.09	0.02
0.1333	0.02	0.02
0.1500	-0.03	0.02
0.1666	-0.01	0.02
0.1833	-0.01	0.02
0.2000	0.00	0.02
0.2166	-0.01	0.02
0.2333	-0.01	0.02
0.2500	0.00	0.02
0.2666	0.00	0.02
0.2833	0.00	0.02
0.3000	0.00	0.02
0.3166	0.00	0.02
0.3333	0.00	0.02
0.4167	0.00	0.02
0.5000	0.00	0.02
0.5833	0.00	0.02
0.6667	0.00	0.02
0.7500	0.00	0.02
0.8333	0.00	0.02
0.9167	0.00	0.02
1.0000	0.00	0.02

TABLE D.9
(CONTINUED)
ICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SLUG TEST DATA FOR WELL
BC3 MW1

INITIAL WATER LEVEL: 32.08 FEET BELOW TOP OF CASING

	WATER LEVEL CHANGE INJECTION TEST	REMOVAL TEST
DATE:	1/11/89	1/11/89
TIME:	1438	1450
t (min)	y1 (ft)	y2 (ft)
1.0833	0.00	0.02
1.1667	0.00	0.02
1.2500	0.00	0.02
1.3333	0.00	0.02
1.4166	0.00	0.02
1.5000	0.00	0.02
1.5833	0.00	0.02
1.6667	0.00	0.02
1.7500	0.00	0.02
1.8333	0.00	0.02
1.9167	0.00	0.00
2.0000	0.00	0.00
2.5000	0.00	0.00
3.0000	0.00	0.00
3.5000	0.00	0.00
4.0000	0.00	0.00
4.5000	0.00	0.00
5.0000	0.00	0.00
5.5000	0.00	0.00
6.0000	0.00	0.00
6.5000	0.00	0.00
7.0000	-0.01	0.00
7.5000	0.00	0.02
8.0000	0.00	0.00
8.5000	0.00	0.00
9.0000	0.00	0.00
9.5000	0.00	0.00
10.0000	0.00	0.00

TABLE D.10

MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SLUG TEST DATA FOR WELL
BC3 MW2

INITIAL WATER LEVEL: 30.23 FEET BELOW TOP OF CASING

	WATER LEVEL CHANGE	
	INJECTION TEST	REMOVAL TEST
DATE:	1/12/89	1/12/89
TIME:	1120	1130
t (min)	y1 (ft)	y2 (ft)
0.0000	0.00	1.36
0.0033	0.00	1.44
0.0066	0.01	1.55
0.0099	1.03	1.52
0.0133	1.88	1.17
0.0166	2.17	0.82
0.0200	2.77	1.29
0.0233	3.26	1.29
0.0266	3.18	1.26
0.0300	3.31	1.06
0.0333	1.83	0.84
0.0500	0.01	0.23
0.0666	0.06	0.11
0.0833	0.03	0.04
0.1000	0.01	0.04
0.1166	0.00	0.03
0.1333	0.00	0.03
0.1500	0.00	0.03
0.1666	0.00	0.03
0.1833	0.00	0.03
0.2000	0.00	0.01
0.2166	0.00	0.03
0.2333	0.00	0.01
0.2500	0.00	0.03
0.2666	0.00	0.03
0.2833	0.00	0.01
0.3000	0.00	0.01
0.3166	0.00	0.01
0.3333	0.00	0.01
0.4167	0.00	0.01
0.5000	0.00	0.01
0.5833	0.00	0.01
0.6667	0.00	0.01
0.7500	0.00	0.00
0.8333	0.00	0.01
0.9167	0.00	0.01
1.0000	0.00	0.01

TABLE D.10
(CONTINUED)
MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SLUG TEST DATA FOR WELL
BC3 MW2

INITIAL WATER LEVEL: 30.23 FEET BELOW TOP OF CASING

	WATER LEVEL CHANGE	
	INJECTION TEST	REMOVAL TEST
DATE:	1/12/89	1/12/89
TIME:	1120	1130
t (min)	y1 (ft)	y2 (ft)
1.0833	0.01	0.01
1.1667	0.00	0.01
1.2500	0.00	0.01
1.3333	0.00	0.01
1.4166	0.01	0.01
1.5000	0.01	0.01
1.5833	0.00	0.01
1.6667	0.01	0.01
1.7500	0.01	0.01
1.8333	0.01	0.01
1.9167	0.01	0.01
2.0000	0.01	0.01
2.5000	0.01	0.01
3.0000	0.01	0.01
3.5000	0.03	0.01
4.0000	0.01	0.01
4.5000	0.01	0.01
5.0000	0.01	0.03
5.5000	0.03	0.01
6.0000	0.03	0.01
6.5000	0.01	0.01
7.0000	0.01	0.00
7.5000	0.01	0.01
8.0000	0.03	0.01
8.5000	0.03	0.00
9.0000	0.03	0.00
9.5000	0.03	0.00
10.0000	0.03	0.00

TABLE D.11

MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SLUG TEST DATA FOR WELL
BC3 MW3

INITIAL WATER LEVEL: 29.84 FEET BELOW TOP OF CASING

	WATER LEVEL CHANGE	
	INJECTION TEST	REMOVAL TEST
DATE:	1/12/89	1/12/89
TIME:	1052	1103
t (min)	y1 (ft)	y2 (ft)
0.0000	4.49	0.78
0.0033	2.54	0.46
0.0066	0.12	0.32
0.0099	0.77	0.40
0.0133	1.19	1.35
0.0166	1.56	1.97
0.0200	2.29	1.79
0.0233	1.56	1.98
0.0266	1.73	2.14
0.0300	2.14	2.14
0.0333	1.78	2.30
0.0500	0.43	2.79
0.0666	0.34	1.97
0.0833	0.24	1.43
0.1000	0.21	1.00
0.1166	0.19	0.72
0.1333	0.18	0.49
0.1500	0.15	0.35
0.1666	0.13	0.24
0.1833	0.10	0.16
0.2000	0.08	0.11
0.2166	0.07	0.07
0.2333	0.05	0.03
0.2500	0.04	0.02
0.2666	0.04	0.00
0.2833	0.04	0.00
0.3000	0.04	-0.01
0.3166	0.04	-0.01
0.3333	0.02	-0.01
0.4167	0.02	-0.03
0.5000	0.02	-0.03
0.5833	0.02	-0.03
0.6667	0.02	-0.03
0.7500	0.02	-0.03
0.8333	0.02	-0.03
0.9167	0.02	-0.03
1.0000	0.02	-0.03

TABLE D.11
(CONTINUED)
MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SLUG TEST DATA FOR WELL
BC3 MW3

INITIAL WATER LEVEL: 29.84 FEET BELOW TOP OF CASING

	WATER LEVEL CHANGE	
	INJECTION TEST	REMOVAL TEST
DATE:	1/12/89	1/12/89
TIME:	1052	1103
t (min)	y1 (ft)	y2 (ft)
1.0833	0.02	-0.03
1.1667	0.02	-0.03
1.2500	0.02	-0.03
1.3333	0.02	-0.03
1.4166	0.02	-0.03
1.5000	0.02	-0.03
1.5833	0.02	-0.03
1.6667	0.02	-0.03
1.7500	0.02	-0.03
1.8333	0.00	-0.03
1.9167	0.00	-0.03
2.0000	0.00	-0.03
2.5000	0.00	-0.03
3.0000	0.02	-0.01
3.5000	0.02	-0.01
4.0000	0.02	-0.01
4.5000	0.00	-0.01
5.0000	0.02	-0.01
5.5000	0.02	-0.01
6.0000	0.02	-0.01
6.5000	0.02	-0.01
7.0000	0.02	-0.01
7.5000	0.00	-0.01
8.0000	0.00	-0.01
8.5000	0.00	-0.01
9.0000	0.00	0.00
9.5000	0.00	0.00
10.0000	0.02	7.82

TABLE D.12

MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SLUG TEST DATA FOR WELL
BC4 MW2

INITIAL WATER LEVEL: 10.00 FEET BELOW TOP OF CASING

	WATER LEVEL CHANGE	
	INJECTION TEST	REMOVAL TEST
DATE:	1/11/89	1/11/89
TIME:	1340	1351
t (min)	y1 (ft)	y2 (ft)
0.0000	1.63	-0.08
0.0033	2.07	4.05
0.0066	1.61	4.45
0.0099	2.39	2.52
0.0133	3.15	2.09
0.0166	3.70	3.42
0.0200	3.97	3.48
0.0233	3.55	3.56
0.0266	3.31	3.48
0.0300	3.21	3.39
0.0333	2.80	3.32
0.0500	0.44	3.42
0.0666	0.62	3.02
0.0833	0.44	2.69
0.1000	0.43	2.45
0.1166	0.39	2.25
0.1333	0.39	2.06
0.1500	0.38	1.96
0.1666	0.36	1.82
0.1833	0.36	1.66
0.2000	0.36	1.45
0.2166	0.36	1.14
0.2333	0.35	0.96
0.2500	0.35	0.85
0.2666	0.35	0.79
0.2833	0.35	0.76
0.3000	0.33	0.73
0.3166	0.33	0.69
0.3333	0.33	0.65
0.4167	0.31	0.41
0.5000	0.30	0.25
0.5833	0.27	0.54
0.6667	0.27	0.33
0.7500	0.24	0.22
0.8333	0.24	0.14
0.9167	0.22	0.09
1.0000	0.20	-0.02

TABLE D.12
(CONTINUED)
MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SLUG TEST DATA FOR WELL
BC4 MW2

INITIAL WATER LEVEL: 10.00 FEET BELOW TOP OF CASING

	WATER LEVEL CHANGE	
	INJECTION TEST	REMOVAL TEST
DATE:	1/11/89	1/11/89
TIME:	1340	1351
t (min)	y1 (ft)	y2 (ft)
1.0833	0.20	-0.05
1.1667	0.19	0.00
1.2500	0.17	0.06
1.3333	0.17	-0.05
1.4166	0.16	0.00
1.5000	0.16	-0.03
1.5833	0.14	-0.02
1.6667	0.14	-0.03
1.7500	0.12	0.00
1.8333	0.12	-0.03
1.9167	0.12	-0.05
2.0000	0.12	-0.05
2.5000	0.11	-0.02
3.0000	0.09	0.00
3.5000	0.08	0.00
4.0000	0.06	0.01
4.5000	0.05	0.01
5.0000	0.05	0.01
5.5000	0.05	0.01
6.0000	0.03	0.01
6.5000	0.03	0.01
7.0000	0.03	0.01
7.5000	0.01	0.01
8.0000	0.01	0.01
8.5000	0.01	0.01
9.0000	0.01	0.00
9.5000	0.01	0.00
10.0000	0.00	0.00

TABLE D.13

MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SLUG TEST DATA FOR WELL
BC4 MW4

INITIAL WATER LEVEL: 23.70 FEET BELOW TOP OF CASING

	WATER LEVEL CHANGE INJECTION TEST	 REMOVAL TEST
DATE:	1/11/89	1/11/89
TIME:	1247	1257
t (min)	y1 (ft)	y2 (ft)
0.0000	-0.01	0.62
0.0033	-0.01	0.62
0.0066	-0.01	0.54
0.0099	-0.01	0.53
0.0133	-0.01	0.38
0.0166	0.21	0.32
0.0200	0.62	0.37
0.0233	0.92	0.38
0.0266	1.27	0.37
0.0300	1.51	0.35
0.0333	1.33	0.34
0.0500	-0.03	0.04
0.0666	-0.01	0.04
0.0833	-0.01	0.04
0.1000	-0.01	0.04
0.1166	-0.01	0.04
0.1333	-0.01	0.04
0.1500	-0.01	0.04
0.1666	-0.01	0.04
0.1833	-0.01	0.04
0.2000	-0.01	0.04
0.2166	0.00	0.04
0.2333	0.00	0.04
0.2500	-0.01	0.02
0.2666	0.00	0.00
0.2833	0.00	0.00
0.3000	-0.01	0.00
0.3166	0.00	0.00
0.3333	-0.01	0.00
0.4167	0.00	0.00
0.5000	0.00	0.00
0.5833	0.00	0.00
0.6667	0.00	0.00
0.7500	0.00	0.00
0.8333	0.00	0.00
0.9167	0.00	0.00
1.0000	-0.01	0.00

TABLE D.13
(CONTINUED)
MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SLUG TEST DATA FOR WELL
BC4 MW4

INITIAL WATER LEVEL: 23.70 FEET BELOW TOP OF CASING

	WATER LEVEL CHANGE INJECTION TEST	 REMOVAL TEST
DATE:	1/11/89	1/11/89
TIME:	1247	1257
t (min)	y1 (ft)	y2 (ft)
1.0833	-0.01	0.00
1.1667	0.00	0.00
1.2500	0.00	0.00
1.3333	0.00	0.00
1.4166	0.00	0.00
1.5000	0.00	0.00
1.5833	0.00	0.00
1.6667	0.00	0.00
1.7500	0.00	0.00
1.8333	0.00	0.00
1.9167	0.00	0.00
2.0000	0.00	0.00
2.5000	0.00	0.00
3.0000	0.00	-0.01
3.5000	0.00	0.00
4.0000	0.00	0.00
4.5000	0.00	0.00
5.0000	0.00	0.00
5.5000	0.00	0.00
6.0000	0.00	0.00
6.5000	0.00	0.00
7.0000	0.00	0.00
7.5000	0.00	-0.01
8.0000	0.00	0.00
8.5000	0.00	0.00
9.0000	0.00	0.00
9.5000	0.00	0.00
10.0000	0.00	-0.01

TABLE D.14

MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SLUG TEST DATA FOR WELL
BC5 MW1

INITIAL WATER LEVEL: 14.08 FEET BELOW TOP OF CASING

	WATER LEVEL CHANGE	
	INJECTION TEST	REMOVAL TEST
DATE:	1/12/89	1/12/89
TIME:	0758	0808
t (min)	y1 (ft)	y2 (ft)
0.0000	0.06	0.33
0.0033	1.14	0.27
0.0066	1.62	0.25
0.0099	1.01	0.44
0.0133	0.86	0.36
0.0166	1.05	0.25
0.0200	1.19	0.51
0.0233	1.44	0.82
0.0266	1.47	0.71
0.0300	1.19	0.57
0.0333	0.81	0.68
0.0500	0.03	0.46
0.0666	0.06	0.54
0.0833	0.05	0.24
0.1000	0.03	0.03
0.1166	0.03	0.00
0.1333	0.05	-0.06
0.1500	0.02	-0.06
0.1666	0.02	-0.05
0.1833	0.05	0.08
0.2000	0.03	0.03
0.2166	0.02	0.03
0.2333	0.00	0.03
0.2500	0.02	0.03
0.2666	0.05	0.03
0.2833	0.00	0.03
0.3000	0.03	0.01
0.3166	0.02	0.01
0.3333	0.00	0.03
0.4167	0.02	0.01
0.5000	-0.02	0.01
0.5833	-0.02	0.01
0.6667	-0.02	0.01
0.7500	-0.02	0.01
0.8333	-0.02	0.01
0.9167	-0.02	0.01
1.0000	-0.02	0.01

TABLE D.14
(CONTINUED)
MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SLUG TEST DATA FOR WELL
BC5 MW1

INITIAL WATER LEVEL: 14.08 FEET BELOW TOP OF CASING

	WATER LEVEL CHANGE	
	INJECTION TEST	REMOVAL TEST
DATE:	1/12/89	1/12/89
TIME:	0758	0808
t (min)	y1 (ft)	y2 (ft)
1.0833	-0.02	0.00
1.1667	0.00	0.01
1.2500	0.00	0.01
1.3333	0.00	0.01
1.4166	0.00	0.00
1.5000	0.00	0.00
1.5833	0.00	0.01
1.6667	-0.02	0.01
1.7500	0.00	0.01
1.8333	0.00	0.01
1.9167	0.00	0.01
2.0000	0.00	0.01
2.5000	0.00	0.00
3.0000	0.00	0.00
3.5000	-0.02	0.00
4.0000	0.00	0.00
4.5000	0.00	0.00
5.0000	0.00	0.00
5.5000	0.00	0.00
6.0000	0.00	0.00
6.5000	0.00	0.00
7.0000	0.00	0.00
7.5000	0.00	0.00
8.0000	0.00	0.00
8.5000	0.00	0.00
9.0000	0.00	0.00
9.5000	0.00	0.00
10.0000	0.00	0.00

TABLE D.15

MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SLUG TEST DATA FOR WELL
BC6 MW1

INITIAL WATER LEVEL: 31.82 FEET BELOW TOP OF CASING

	WATER LEVEL CHANGE INJECTION TEST	 REMOVAL TEST
DATE:	1/11/89	1/11/89
TIME:	1542	1552
t (min)	y1 (ft)	y2 (ft)
0.0000	-0.20	-4.10
0.0033	-0.05	-4.60
0.0066	0.03	-4.27
0.0099	1.28	-4.03
0.0133	2.93	-3.00
0.0166	3.22	-2.24
0.0200	0.63	-3.83
0.0233	0.48	-3.54
0.0266	1.13	-3.42
0.0300	1.73	-3.42
0.0333	2.00	-3.45
0.0500	0.13	-3.53
0.0666	0.10	-3.53
0.0833	0.08	-3.54
0.1000	0.06	-3.54
0.1166	0.05	-2.99
0.1333	0.05	-0.47
0.1500	0.03	-0.95
0.1666	0.03	0.56
0.1833	0.03	0.15
0.2000	0.03	0.12
0.2166	0.02	0.10
0.2333	0.02	0.08
0.2500	0.02	0.07
0.2666	0.02	0.07
0.2833	0.02	0.07
0.3000	0.02	0.05
0.3166	0.02	0.05
0.3333	0.02	0.05
0.4167	0.00	0.04
0.5000	0.00	0.04
0.5833	0.00	0.02
0.6667	0.00	0.02
0.7500	-0.01	0.02
0.8333	-0.01	0.00
0.9167	-0.01	0.02
1.0000	-0.01	0.02

TABLE D.15
(CONTINUED)
MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SLUG TEST DATA FOR WELL
BC6 MW1

INITIAL WATER LEVEL: 31.82 FEET BELOW TOP OF CASING

	WATER LEVEL CHANGE	
	INJECTION TEST	REMOVAL TEST
DATE:	1/11/89	1/11/89
TIME:	1542	1552
t (min)	y1 (ft)	y2 (ft)
1.0833	-0.01	0.00
1.1667	-0.01	0.02
1.2500	-0.01	0.00
1.3333	-0.01	0.00
1.4166	-0.01	0.02
1.5000	-0.01	0.00
1.5833	-0.01	0.02
1.6667	-0.01	0.02
1.7500	-0.01	0.00
1.8333	-0.01	0.02
1.9167	-0.01	0.02
2.0000	-0.01	0.02
2.5000	-0.01	0.00
3.0000	0.00	0.02
3.5000	0.00	0.00
4.0000	0.00	0.02
4.5000	0.00	0.02
5.0000	0.00	0.02
5.5000	0.00	0.02
6.0000	0.00	0.02
6.5000	0.00	0.02
7.0000	0.00	0.02
7.5000	0.00	0.00
8.0000	0.00	0.02
8.5000	0.00	0.02
9.0000	0.00	0.02
9.5000	0.00	0.02
10.0000	0.00	0.02

TABLE D.16

MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SLUG TEST DATA FOR WELL
BC6 MW2

INITIAL WATER LEVEL: 28.40 FEET BELOW TOP OF CASING

	WATER LEVEL CHANGE	
	INJECTION TEST	REMOVAL TEST
DATE:	1/11/89	1/11/89
TIME:	1511	1521
t (min)	y1 (ft)	y2 (ft)
0.0000	0.00	1.08
0.0033	0.00	0.87
0.0066	0.01	0.94
0.0099	0.00	0.78
0.0133	0.00	0.65
0.0166	0.00	0.54
0.0200	0.00	0.43
0.0233	0.00	0.35
0.0266	0.01	0.30
0.0300	0.01	0.24
0.0333	0.00	0.19
0.0500	0.65	0.06
0.0666	-0.15	0.03
0.0833	0.08	0.06
0.1000	0.06	0.05
0.1166	0.04	0.05
0.1333	0.03	0.05
0.1500	0.03	0.05
0.1666	0.03	0.03
0.1833	0.01	0.03
0.2000	0.01	0.03
0.2166	0.01	0.03
0.2333	0.01	0.03
0.2500	0.00	0.03
0.2666	0.00	0.03
0.2833	0.00	0.03
0.3000	0.00	0.03
0.3166	0.00	0.02
0.3333	0.00	0.02
0.4167	0.00	0.02
0.5000	0.00	0.02
0.5833	0.00	0.02
0.6667	0.00	0.02
0.7500	0.00	0.02
0.8333	0.00	0.02
0.9167	0.00	0.02
1.0000	0.00	0.02

TABLE D.16
(CONTINUED)
MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SLUG TEST DATA FOR WELL
BC6 MW2

INITIAL WATER LEVEL: 28.40 FEET BELOW TOP OF CASING

	WATER LEVEL CHANGE	
	INJECTION TEST	REMOVAL TEST
DATE:	1/11/89	1/11/89
TIME:	1511	1521
t (min)	y1 (ft)	y2 (ft)
1.0833	0.00	0.02
1.1667	0.00	0.02
1.2500	0.00	0.02
1.3333	0.00	0.02
1.4166	0.00	0.02
1.5000	0.00	0.02
1.5833	0.00	0.02
1.6667	0.00	0.02
1.7500	0.00	0.02
1.8333	0.00	0.02
1.9167	0.00	0.02
2.0000	0.01	0.02
2.5000	0.01	0.02
3.0000	0.01	0.02
3.5000	0.01	0.02
4.0000	0.01	0.02
4.5000	0.01	0.00
5.0000	0.01	0.00
5.5000	0.01	0.00
6.0000	0.03	0.00
6.5000	0.03	0.00
7.0000	0.03	0.02
7.5000	0.03	0.00
8.0000	0.03	0.00
8.5000	0.03	0.00
9.0000	0.03	0.02
9.5000	0.03	0.00
10.0000	0.03	0.00

TABLE D.17

MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SLUG TEST DATA FOR WELL
BC6 MW3

INITIAL WATER LEVEL: 29.40 FEET BELOW TOP OF CASING

	WATER LEVEL CHANGE	
	INJECTION TEST	REMOVAL TEST
DATE	1/11/89	1/11/89
TIME	1125	1135
t (min)	y1 (ft)	y2 (ft)
0.0000	0.00	2.02
0.0033	-0.01	1.44
0.0066	0.00	1.23
0.0099	0.00	1.15
0.0133	0.02	0.87
0.0166	0.02	0.63
0.0200	0.00	0.46
0.0233	0.00	0.31
0.0266	0.02	0.20
0.0300	0.03	0.11
0.0333	0.89	0.06
0.0500	1.38	-0.05
0.0666	0.11	0.11
0.0833	0.03	0.09
0.1000	0.02	0.08
0.1166	0.02	0.08
0.1333	0.02	0.09
0.1500	0.02	0.08
0.1666	0.00	0.09
0.1833	0.02	0.08
0.2000	0.00	0.01
0.2166	0.00	0.03
0.2333	0.00	0.00
0.2500	0.00	0.01
0.2666	0.00	0.01
0.2833	0.00	0.01
0.3000	0.00	0.00
0.3166	0.00	0.01
0.3333	0.00	0.00
0.4167	0.00	0.00
0.5000	0.00	0.00
0.5833	0.00	0.00
0.6667	0.00	0.00
0.7500	0.00	0.00
0.8333	0.00	0.00
0.9167	0.00	0.00
1.0000	0.00	0.00

TABLE D.17
(CONTINUED)
MICHIGAN AIR NATIONAL GUARD BASE
BATTLE CREEK, MICHIGAN
SLUG TEST DATA FOR WELL
BC6 MW3

INITIAL WATER LEVEL: 29.40 FEET BELOW TOP OF CASING

	WATER LEVEL CHANGE	
	INJECTION TEST	REMOVAL TEST
DATE	1/11/89	1/11/89
TIME	1125	1135
t (min)	y1 (ft)	y2 (ft)
1.0833	0.00	0.00
1.1667	0.00	0.00
1.2500	0.00	0.00
1.3333	0.00	0.00
1.4166	0.02	0.00
1.5000	0.00	0.00
1.5833	0.00	0.00
1.6667	0.02	0.00
1.7500	0.02	0.00
1.8333	0.00	0.00
1.9167	0.02	0.00
2.0000	0.02	0.00
2.5000	0.02	0.00
3.0000	0.02	0.00
3.5000	0.02	0.00
4.0000	0.02	0.00
4.5000	0.02	0.00
5.0000	0.02	0.00
5.5000	0.02	0.00
6.0000	0.02	0.00
6.5000	0.02	0.00
7.0000	0.02	0.00
7.5000	0.02	0.00
8.0000	0.02	0.00
8.5000	0.02	0.00
9.0000	0.02	0.00
9.5000	0.02	0.00
10.0000	0.02	0.00

APPENDIX D.3
CALCULATIONS OF AQUIFER PARAMETERS

ENGINEERING-SCIENCE

Client Battle Creek ANGB Job No. [illegible]63 Sheet 1 of 1

Subject Slug test analysis By MCB Date 1/15/90

Estimating hydraulic conductivity Checked Rev. VM 2/16/90

BC-MW1

$$\ln \frac{R_e}{R_w} = \frac{1}{\frac{1.1}{\ln(L_w/r_w)} + \frac{A + B \ln[(H-L_w)/r_w]}{L_e/r_w}}$$

$L_e = L_w = 7.61$ ft.
$r_w = 5$ in. $= 0.417$ ft.
$H = 75$ ft.
$L_e/r_w = 18.25$
$A = 1.9$
$B = 0.25$

$$\ln \frac{R_e}{R_w} = \frac{1}{0.379 + 0.174} = 1.81$$

$$K = \frac{r_c^2 \ln(R_e/r_w)}{2 L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

$r_c = 1$ in. $= 0.083$ ft.

$$\frac{(0.083)^2(1.81)}{2(7.61)} \quad 3\,.33$$

Injection:
$t = 0.1$ min.
$y_0 = 2.0$ ft.
$y_t = 0.13$ ft.

$K = .0224$ ft/min.

$K = \boxed{3.73 \times 10^{-4} \text{ ft/s}}$

$$K = \frac{(.083)^2(1.81)}{2(7.61)} \cdot \frac{1}{.3} \ln\left(\frac{5.5}{.040}\right)$$

Withdrawal:
$t = 0.3$ min.
$y_0 = 5.5$ ft.
$y_t = 0.040$ ft.

16.413

$= 0.0134$ ft/min.

$= \boxed{2.24 \times 10^{-4} \text{ ft/s}}$

$\overline{K} = 2.98 \times 10^{-4}$ ft/s $= 25.77$ ft/day $\cdot$ 7.48 g/ft³ $= 193$ gpd/ft²

ENGINEERING-SCIENCE

Client ______ Job No. ______ Sheet 2
Subject ______ By ______ Date ______
Checked ______ Rev. ______

EC-MW3:

$$\ln\frac{R_e}{r_w} = \cfrac{1}{\cfrac{1.1}{\ln(L_w/r_w)} + \cfrac{A + B\ln\left[(H - L_w)/r_w\right]}{L_e/r_w}}$$

$$= \cfrac{1}{\cfrac{1.1}{\ln(21.15)} + \cfrac{2.1 + .3\ln 158.7}{21.15}}$$

$$= 1.88$$

$L_e = L_w = 8.82$ ft.
$r_w = 0.417$ ft.
$H = 75$ ft
$L_e/R_w = 21.15$ ft.
$A = 2.1$
$B = 0.3$

$$K = \frac{r_c^2 \ln(R_e/r_w)}{2L_e}\,\frac{1}{t}\ln\frac{y_0}{y_t}$$

$$= \frac{(0.083)^2(1.88)}{2(8.82)}\,\frac{1}{.2}\ln(347.83)$$

$$29.25$$

$= .02149$ ft/min

$$\boxed{= 3.58\times10^{-4}\text{ ft/sec}}$$

$r_c = 0.083$ ft.

Injection:
$t = 0.2$ min
$y_0 = 8.0$ ft.
$y_t = 0.023$ ft.

$$K = \frac{(.083)^2(1.88)}{2(8.82)}\,\frac{1}{.3}\ln(133.93)$$

$$16.[illegible]$$

$= .01199$ ft/min

$$\boxed{= 2.00\times10^{-4}\text{ ft/s}}$$

Withdrawal:
$t = 0.3$ min.
$y_0 = 3.75$ ft.
$y_t = 0.028$ ft.

$\bar{K} = 2.79\times10^{-4}$ ft/s $= 24.11$ ft/day [illegible] $= 190$ [illegible]

ENGINEERING-SCIENCE

Client ______ Job No. ______ Sheet ______

Subject ______ By ______ Date ______

______ Checked ______ Rev. ______

EC = MW 2;

$$\ln \frac{Re}{Rw} = \frac{1}{\frac{1.1}{\ln(Lw/rw)} + \frac{A+B\ln[(H-Lw)/rw]}{Le/rw}}$$

$$= \frac{1}{0.361 + 0.177} = 1.86$$

$Le = Lw =$ [illegible] ft.

$rw = 0.41$[illegible] ft.

$H = 100$ ft.

$Le/rw = 21.03$

$A = 2.1$

$B = 0.3$

$$K = \frac{rc^2 \ln(Re/rw)}{2Le} \frac{1}{t} \ln \frac{y_0}{y_t}$$

$$= \frac{(0.083)^2(1.86)}{2(8.77)} \quad 55.187$$

.00073

$= .040279$ ft/min.

$rc = 0.083$ ft.

Injection:

$t = 0.05$ min.

$y_0 = 3.0$ ft.

$y_t = 0.19$ ft.

$$K = \frac{(0.083)^2(1.86)}{2(8.77)} \quad 51.475$$

$= .04343$ ft/min

Withdrawal

$t = 0.05$ min

$y_0 = 4.5$ ft

$y_t = 0.23$ ft.

$\overline{K} = .0419$ ft/min [illegible] $= 60.29$ ft/day $= \boxed{451}$ [illegible]

ENGINEERING-SCIENCE

Client ______ Job No. ______ Sheet 4 of 8
Subject ______ By ______ Date ______
______ Checked ______ Rev. ______

ol 3-MW3:

$$\ln \frac{R_e}{r_w} = \cfrac{1}{\cfrac{1.1}{\ln(L_w/r_w)} + \cfrac{A + B \ln[(H-L_w)/r_w]}{(L_e/r_w)}}$$

$L_e = L_w = 9.16$ ft.
$r_w = 0.417$ ft.
$H = 00$ ft.
$L_e/r_w = 21.97$
$A = 2.1$
$B = 0.3$

$$\ln \frac{R_e}{R_w} = \frac{1}{0.356 + 0.169} = 1.90$$

$$K = \frac{r_c^2 \ln(R_e/r_w)}{2 L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

$r_c = 0.083$ ft.

$.000716 \quad 2.00$

$= .00595$ ft/min

Injection:
$t = 0.2$ min.
$y_0 = 0.9$ ft.
$y_t = 0.074$ ft.

$K = .000737 \quad \frac{1}{t} \ln \frac{y_0}{y_t}$

21.499

$= .01540$ ft/min.

Withdrawal:
$t = 0.2$ min.
$y_0 = 7.00$ ft.
$y_t = 0.095$ ft.

$\overline{K} = .0122$ ft/min × $\frac{1440 \text{ min.}}{\text{day}}$ = 17.52 ft/day × 7.48 g/ft^3 = 131 $\frac{\text{gpd}}{\text{ft}^2}$

ENGINEERING-SCIENCE

Client ______ Job No. ______ Sheet 5 : 7

Subject ______ By ______ Date ______

______ Checked ______ Rev. ______

BC4-MW2:

$$\ln\frac{R_e}{R_w} = \frac{1}{\frac{1.1}{\ln(L_w/r_w)} + \frac{A + B\ln[(H-L_w)/r_w]}{(L_e/r_w)}}$$

$$\ln\frac{R_e}{R_w} = \frac{1}{0.336 + 0.169} = 1.98$$

$L_e = L_w = 11.0$ ft.
$r_w = 0.417$ ft
$H = 100$ ft.
$L_e/r_w = 26.38$
$A = 2.3$
$B = 0.4$

$$K = \frac{r_c^2 \ln(R_e/r_w)}{2L_e} \frac{1}{t} \ln\frac{y_0}{y_t}$$

$r_c = 0.083$ ft.

.000621 .693

$= 0.000430$ ft./min.

Injection:
$t = 1.0$ min.
$y_0 = 0.4$ ft.
$y_t = 0.2$ ft.

$$K = (.000642)\frac{1}{.4}\ln\frac{4.5}{.45}$$

5.756

$= 0.00357$ ft/min.

Withdrawal:
$t = 0.4$ min.
$y_0 = 4.5$ ft.
$y_t = 0.45$ ft.

$\overline{K} = 0.00200$ ft/min × 1440 $\frac{\text{min}}{\text{day}}$ = 2.88 ft/day

× 7.48 g/ft³ = 21.6 gpd/ft²

ENGINEERING-SCIENCE

Client ______ Job No. ______ Sheet 6 of 8

Subject ______ By ______ Date ______

______ Checked ______ Rev. ______

BC6-MW1.

$L_e = L_w = 6.18'$

$r_w = 0.417'$

$H = 100'$

$L_e/r_w = 14.82$

$A = 1.9$

$B = 0.28$

$$\ln \frac{R_e}{R_w} = \cfrac{1}{\cfrac{1.1}{\ln(L_w/r_w)} + \cfrac{A + B \ln[(H-L_w)/r_w]}{L_e/r_w}}$$

$$\ln \frac{R_e}{R_w} = \frac{1}{0.408 + .231} = 1.57$$

$$K = \frac{r_c^2 \ln(R_e/r_w)}{2 L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

$$= (.000873)\ (14.27)$$

$$= 0.0125 \text{ ft/min.}$$

$r_c = 0.083$ ft.

Injection:

$t = 0.1$ min.

$y_0 = 0.25$ ft.

$y_t = 0.06$ ft.

$$K = (.000873) \frac{1}{.3} \ln\left(\frac{1.40}{.037}\right)$$

$$= .01057 \text{ ft/min}$$

Withdrawal:

$t = 0.3$ min.

$y_0 = 1.40$ ft.

$y_t = 0.037$ ft.

$$\overline{K} = .01151 \text{ ft/min} \times \frac{1440 \text{ min}}{\text{day}} = 16.58 \text{ ft/day}$$

$$\times\ 7.48 \text{ g/f}^3 = 124 \text{ gpd/ft}^2$$

ENGINEERING-SCIENCE

Client ____________ Job No. ____________ Sheet 7 of ____

Subject ____________ By ____________ Date ____________

____________ Checked ____________ Rev. ____________

BCG-MW2:

$$\ln\frac{R_e}{R_w} = \cfrac{1}{\cfrac{1.1}{\ln(L_w/r_w)} + \cfrac{A + B\ln[(H-L_w)/r_w]}{(L_e/r_w)}}$$

$$\ln\frac{R_e}{R_w} = \frac{1}{0.363 + 0.175} = 1.86$$

$$K = \frac{r_c^2 \ln(R_e/r_w)}{2L_e}\,\frac{1}{t}\,\ln\frac{y_0}{y_t}$$

0.000743 19.148

$= .0142$ ft/min.

$L_e = L_w = 8.6'$

$r_w = 0.417'$

$H = 100'$

$L_e/r_w = 20.62$

$A = 2.0$

$B = 0.3$

$r_c = 0.083$ ft.

Injection:

$t = 0.1$ min.

$y_0 = 0.38$ ft.

$y_t = 0.056$ ft.

$$K = (.000743)\,\underbrace{\frac{1}{.05}\ln\left(\frac{1.10}{.090}\right)}_{50.065}$$

$= .0372$ ft/min.

Withdrawal:

$t = 0.05$ min.

$y_0 = 1.10$ ft.

$y_t = 0.090$ ft.

$\overline{K} = .0257$ ft/min $\times 1440 \frac{\text{min}}{\text{day}} = 37.04$ ft/day

$\times\ 7.48$ g/f^3 $= 277$ gpd/ft^2

Client ______ Job No. ______ Sheet 8 of 8
Subject ______ By ______ Date ______
______ Checked ______ Rev. ______

BC6-11W3:

$$\ln \frac{R_e}{R_w} = \frac{1}{\frac{1.1}{\ln(L_w/r_w)} + \frac{A + B\ln[(H-L_w)/r_w]}{(L_e/r_w)}}$$

$L_e = L_w = 7.6'$
$r_w = 0.417'$
$H = 100'$
$L_e/r_w = 18.23$
$A = 1.9$
$B = .25$

$$\ln \frac{R_e}{R_w} = \frac{1}{0.379 + 0.178} = 1.79$$

$$K = \frac{r_c^2 \ln(R_e/r_w)}{2L_e} \frac{1}{t} \ln \frac{y_0}{y_t}$$

$$= 0.000813 \quad 51.8$$

$$= .0422 \text{ ft/min.}$$

$r_c = 0.083$ ft.

Injection:
$t = 0.1$ min.
$y_0 = 4.1$ ft.
$y_t = 0.023$ ft.

$$K = (.000834) \frac{1}{.1} \ln\left(\frac{4.1}{.023}\right)$$

$$= .00505 \text{ ft/min.}$$

Withdrawal:
$t = 0.4$ min.
$y_0 = 0.18$ ft.
$y_t = 0.015$ ft.

$$\bar{K} = .0236 \text{ ft/min} \times 1440 \text{ min/day} = 33.99 \text{ ft/day}$$

$$\times 7.48 \text{ g/ft}^3 = 254 \text{ gpd/ft}^2$$

ENGINEERING-SCIENCE

Client Battle Creek M-B Job No. T-103 Sheet ___ of ___
Subject Calculation of Transmissivity By M. Bunn Date 1/8/90
Checked ______ Rev. CM 2/16/90

Transmissivity (T) will be calculated using gen. formula $T=Kb$; in this case $b=H$ used in slug test analyses = saturated aquifer thickness. Value of K used will be $\bar{K}$ determined for each well from slug test analyses.

BC-MW1:

$H = 75$ ft
$\bar{K} = 2.98 \times 10^{-4}$ ft/s

$$T = KH$$

$$= (2.98 \times 10^{-4})(75) = .0224 \text{ ft}^2/\text{s}$$

$$.0224 \text{ ft}^2/\text{s} \times 6.46 \times 10^{5} = 14{,}438 \text{ gpd/ft}$$

BC-MW3:

$H = 75$ ft.
$\bar{K} = 2.79 \times 10^{-4}$ ft/s

$$T = (2.79 \times 10^{-4})(75) = .0209 \text{ ft}^2/\text{s}$$

$$.0209 \text{ ft}^2/\text{s} \times 6.46 \times 10^{5} = 13{,}518 \text{ gpd/ft}$$

CONVERSION FACTOR:

$$\left(\frac{7.48 \text{ gal}}{\text{ft}^3}\right)\left(60 \frac{\text{sec}}{\text{min}}\right)\left(1440 \frac{\text{min}}{\text{day}}\right) = 6.46 \times 10^{5}$$

ENGINEERING-SCIENCE

Client Battle Creek ANGB
Job No. AT-103
Sheet 2 of 3
Subject Transmissivity, etc.
By MG Burgin
Date
Checked ✓
Rev

BC3-MW2:

$H = 100$ ~~30~~.

$\bar{K} = 6.98 \times 10^{-4} f/s$

$T = (6.98 \times 10^{-4})(100) = .0698\ f^2/s$

$\times 6.46 \times 10^{5} = 45,112$ gpd/f

BC3-MW3:

$H = 100$ ft

$\bar{K} = 2.03 \times 10^{-4} f/s$

$T = (2.03 \times 10^{-4})(100) = .0203\ f^2/s$

$\times 6.46 \times 10^{5} = 13,135$ gpd/f

BC4-MW2:

$H = 100$ ft

$K = 3.33 \times 10^{-5} f/s$

$T = (3.33 \times 10^{-5})(100) = .00333\ f^2/s$

$\times 6.46 \times 10^{5} = 2,153$ gpd/f

ENGINEERING-SCIENCE

Client Battle Creek ANGB
Job No. AT-103
Sheet 3 of 3
Subject Transmissivity Est.
By M.J. [illegible]
Date 1-17-90
Checked
Rev.

BC6-MW1

$H = 100$ ft
$\bar{K} = 1.$ [illegible] $\times 10^{-4}$ ft/s

$T = (1.92 \times 10^{-4})(100) = .0192$ ft²/s

$\times 6.46 \times 10^{5} = 12{,}392$ gpd/ft

BC6-MW2

$H = 100$ ft.
$\bar{K} = 4.28 \times 10^{-4}$ ft/s

$T = (4.28 \times 10^{-4})(100) = .0428$ ft²/s

$\times 6.46 \times 10^{5} = 27{,}670$ gpd/ft

BC6-MW3

$H = 100$ ft.
$\bar{K} = 3.93 \times 10^{-4}$ ft/s

$T = (3.93 \times 10^{-4})(100) = .0393$ ft²/s

$\times 6.46 \times 10^{5} = 25{,}409$ gpd/ft

APPENDIX E
QA/QC REPORT AND DATA VALIDATION SUMMARY FOR 1988 SAMPLING EVENT

APPENDIX E
QA/QC REPORT AND DATA VALIDATION SUMMARY FOR 1988 SAMPLING EVENT

E.1 INTRODUCTION

During the 1988 sampling event, 104 field samples consisting of 76 soil and sediment samples and 28 groundwater and surface water samples were collected in November and December at the W.K. Kellogg Regional Airport in Battle Creek, Michigan. Samples were packed in ice and shipped via overnight courier to metaTRACE Laboratories, Inc. for analysis. Samples were selectively analyzed for volatile organics (SW8240, SW8010 and SW8020), semi-volatile organics (SW8270), total petroleum hydrocarbons (E418.1), priority pollutant metals, and polynuclear aromatic hydrocarbons (SW8100). The validation was done in accordance with the HAZWRAP (1988) guidelines for data validation (DOE/HWP-65, Requirements for Quality Control of Analytical Data. Laboratory data reports are contained in Appendix H.

E.2 CRITERIA USED TO ASSESS LABORATORY DATA QUALITY

The following criteria were used to evaluate the data where applicable to the particular analysis:

- Sample holding times;
- Gas chromatograph/mass spectrometry (GC/MS) tuning and mass calibration;
- Initial and continuing calibrations;
- Surrogate spike results;
- Matrix spike and matrix spike duplicate results;
- Laboratory blank results;
- Field blank results;
- Completeness; and
- Field duplicates.

E.2.1 Criteria for Holding Time Compliance

For all the analyses conducted, specific holding times apply. Analyses performed after holding times have been exceeded are estimated.

E.2.2 Criteria for Instrument Tuning and Calibration

Tuning and calibration criteria evaluate the ability of the analytical instrument to identify and quantify the target compounds of concern. The tuning and calibration criteria are method specific.

The GC/MS used for volatile organics must be tuned every 12 hours of operation using a BFB tune. These chromatographs or mass spectra must be filed in the lab and available if problems arise in reviewing/validating the data. If the chromatographs or mass spectra are unavailable, the data is flagged (J) for positive results and (R) for negative results.

For volatiles, GC data, the response factors and their percent differences from the initial calibration must be reported. If response factors are less than 0.05, the associated compounds are flagged (R) as rejected for negative results and (J) as estimated for positive results. If the percent differences from the initial calibration is greater than 25%, the associated compounds are flagged (J) as estimated for positive results. In the initial calibration, the percent relative standard deviation (RSD%) cannot exceed 30%, or the positive results of the associated compound(s) will have to be flagged (J) as estimated.

Internal standard areas for GC/MS analyses shall be supplied and a second-column confirmation is conducted for all GC work when compounds are detected above reporting limit. If internal standard area criteria is not met, all compounds in the associated sample are flagged as estimated -(J) if positive, (UJ), if negative.

The GC/MS for semi-volatile organic analyses must be tuned each 12 hours using a decafluorotriphenylphosphine tune. If these tunes do not meet set criteria, all data is flagged as rejected.

The calibration of the GC for the SW8010 and SW8020 was evaluated using the following criteria:

- For initial calibration the % RSD for all target compounds must be less than or equal to 20%.
- For continuing calibration, all % D must be less than 15% D.

If this criteria is not met, associated compounds are flagged (J) as estimated.

For ICP analyses for metals a blank and at least one standard must be used while calibration for AA analyses must consist of a blank and at least three standards, one of which must be at the CRDL. In mercury analyses four standards are used. The correlation coefficient for the calibration-curve must equal or exceed 0.995 in all cases. If this does not occur, the results are flagged as estimated (J).

For petroleum hydrocarbons, calibrations using a 3-5 point curve bracketing the sample concentration are performed daily. If this criteria is not met, positive data is flagged (J) as estimated and the negative data is flagged (R) as rejected.

E.2.3 Criteria for Laboratory Quality Control Data

Laboratory quality control data consist of the results obtained from the analysis of laboratory blanks, surrogate spikes, spiked samples, and laboratory duplicate samples.

The assessment of results on blank analyses is for the purpose of determining the existence and magnitude of contamination problems. The criteria for evaluation of both laboratory and field blanks is described below. When more than one type of blank is associated with a given sample, qualification is based on the blank having the highest concentration of the contaminant.

Two rules are used for evaluating laboratory blank contamination, the 10x rule and the 5x rule. For the common laboratory contaminants methylene chloride, acetone, toluene, 2-butanone, and phthalate esters, if the concentration of the compound is greater than the CRQL but less than ten times the highest concentration found in a blank, the result is reported as non-detect. When the concentration is less than the CRQL it is reported as non-detect. When the concentration of the compound is greater than ten times the highest concentration found in any blank, the result is considered positive and no flags are used.

The 5x rule applies to all compounds other than the common laboratory contaminants. This rule is applied the same as the 10x rule except that a level of five times the blank contaminant level is used.

The criteria used to evaluate the field blanks was dependent on the type of blank. The results of the potable water blanks were not used to qualify the data because this was the initial rinse used in decontamination and the equipment was rinsed with solvent and HPLC water prior to contact with the samples. For the HPLC water blanks and the equipment rinseate blank, if the concentration of the contaminant in the sample did not exceed five times the level in the associated HPLC or rinseate blank the sample concentration was flagged as estimated (J).

Surrogate spike compounds are analytes added to each sample at a known concentration. The recovery of these compounds is determined to indicate laboratory performance on individual samples. The use of surrogate spikes is required for some but not all methods published by EPA.

The analytical methods for the analysis of volatile and semi-volatile organics require surrogate analyses to be performed. According to the methods, corrective action is required when any surrogate compound in the volatile fraction or any two surrogates within a base neutral (BN) or acid (A) fraction are out of specification. Corrective action is also required if any surrogate in a fraction has a recovery of less than 10 percent. If the reanalysis results are still out of specification, the compounds in the fraction corresponding to the problem surrogates are all qualified for the sample involved. The positive and negative results are estimated (J) unless the surrogate recovery is less than 10% in which case the negative results are unusable (R).

Matrix spike samples and laboratory duplicates are used to assess analytical accuracy and precision, respectively. The accuracy of the analytical results is evaluated upon the basis of percent recovery (PR) of matrix spiking compounds in matrix spike (MS) and matrix spike duplicates (MSD) at a minimum of one sample per 20 samples of similar matrix. The acceptance range for the percent recovery for each matrix spiking compound is either presented in the QAPP or in the analytical method used. The recovery of spiking compounds is an indication of the effect of the sample matrix upon the accuracy of the analysis results.

If the results of the MS or MSD analyses are not within the QC acceptance range for PR, the sample and its spikes are reextracted and reanalyzed. If the results are still out of compliance, positive results are considered estimated (J). If sample results for a compound are less than the detection limit and spike recovery is low, the result in the unspiked sample is unusable (R).

Precision is evaluated for a set of samples of similar matrix by the analysis and comparison of MS and MSD samples. The relative percent difference (RPD) of the values obtained for the MS and MSD samples should be less than the values specified as the upper limit in the QAPP or in the analytical method. When the RPD values obtained do not meet the acceptance criteria, either a blank spike or laboratory control sample (LCS) is analyzed as done for the accuracy corrective action. Also, if surrogate recovery values are within the acceptance criteria, no further corrective action is required and the QC data are considered to be of good quality.

For the metals analyses, the LCS is designed to serve as a monitor of the efficiency of the digestion procedure. If the control windows are exceeded, all data associated with the LCS should be reanalyzed.

E.2.4 Criteria for Field Quality Control Data

Field quality control samples include rinseate blanks, source water blanks, and trip blanks. Rinseate blanks are a water rinse using deionized, analyte-free water following the decontamination of the field sampling equipment. Rinseate blanks were collected at a frequency of 10% per matrix per sampling event and analyzed for the parameters determined in the samples during that event. Source water blanks consist of samples of the potable water and high pressure liquid chromatography (HPLC) water used in decontamination. A blank from each source was collected for each sampling event.

The QAPP also requires the collection of one trip blank for every shipment of samples requiring volatile organics analysis (VOA). The trip blank is filled at the laboratory with deionized, analyte-free water, sealed and accompanies the VOA sample vials at all times. Trip blanks were not opened in the field.

To assess representativeness of the sample collection procedures, the QAPP required that coded field duplicates were collected at a frequency of 5% per matrix per event.

If the data collected during the SI did not meet the criterion contained in the QAPP and discussed above, it was flagged to indicate the limitations associated with the data. The various flags used to qualify the data are discussed in the following paragraph.

E.2.5 Summary of Data Flags

Flags used to qualify the data are an effort to describe the circumstances surrounding and quality of that piece of data. They are based on all the information available to the data reviewer. Flags and symbols used are defined as follows:

U - The compound was not present in the sample above the detection limit.

J - The number preceding is estimated. The qualitative analysis is acceptable but the value cannot be considered as accurate.

N - Presumptive evidence of presence of material (tentative identification). There is evidence that the material is present, but for some reason or combination of reasons, it has not been confirmed.

R - Data is rejected and is totally unusable. The only way to obtain useful data is to resample and reanalyze.

It is possible that a result may contain more than one qualifying flag. For instance a result may be reported as UJ. This indicates that the target compound was not detected in the sample; however, the detection limit is estimated.

E.2.6 Completeness

The completeness of the data was evaluated by reviewing the data collected and determining if any data gaps exist for completing the SI. For this field event, 90% of the data needed to be considered valid for the data package to be considered complete. If excessive data gaps were identified (>10%) the data was judged to be incomplete.

E.3 FINDINGS OF DATA VALIDATION

Laboratory services were provided by metaTRACE Inc. of Earth City, Missouri for the 1988 sampling event at the Base. A laboratory audit was conducted by Engineering-Science due to numerous quality control problems. The audit included review of various portions of the analytical methods documentation, instrument tuning/calibration verifications, internal standards, blanks preparations and analysis, integrations, chromatograms, serial dilution results, and quality control (QC) criteria.

During the audit, it was discovered that organic analyses conducted with GC/MS instrumentation contained improper documentation of the internal QC and analytical results. The basis for these conclusions was poor chromatography and improper integrations.

In addition to poor chromatography and improper integration, volatiles and inorganic analyses suffered from cross contamination. No matrix spike/matrix spike duplicates were run with the exception of the SW8010/8020 analyses. As a result of the extensive QA/QC problems, all data has been rejected.

Due to all data being rejected, precision, accuracy, representativeness, completeness, and comparability cannot be evaluated.

APPENDIX F
QA/QC REPORT AND DATA VALIDATION SUMMARY FOR THE 1989 SAMPLE EVENT

APPENDIX F
QA/QC REPORT AND DATA VALIDATION SUMMARY FOR THE 1989 SAMPLING EVENT

F.1 INTRODUCTION

A total of 44 field samples were collected in the August-September 1989 field event at Michigan Air National Guard Base in Battle Creek, Michigan. Samples were packed in ice and shipped via overnight courier to Savannah Laboratories for analysis. Samples were selectively analyzed for chromium (SW7190), lead, (SW7421), purgeable halogenated volatile organics (SW 8010), and purgeable aromatic volatile organics (SW 8020).

F.2 CRITERIA USED TO ASSESS LABORATORY DATA QUALITY

The analytical data collected during the SI were evaluated in accordance with the HAZWRAP document "Requirements for Quality Control of Analytical Data" (DOE/HWP-65/R1) and the procedures contained in the Quality Assurance Project Plan contained in Section 3 of the Sampling and Analysis Plan (Engineering-Science, 1990). The following criteria were used to evaluate the data where applicable to the particular analysis:

- Sample holding times
- Gas chromatograph/mass spectrometry (GC/MS) tuning and mass calibrations
- Initial and continuing calibrations
- Surrogate spike results
- Matrix spike and matrix spike duplicate results
- Detection limit compliance
- Laboratory blank results
- Field blank results
- Completeness

F.2.1 Criteria for Holding Time Compliance

For all of the analyses conducted, specific holding times apply. Table F.1 presents the holding times for each analysis performed during the SI. Table F.2 presents holding times for field quality control samples.

F.2.2 Criteria for Instrument Tuning and Calibration

Tuning and calibration criteria are used to evaluate the ability of the analytical instrument to identify and quantify the target compounds of concern. The tuning and calibration criteria are method specific.

The GC/MS used for volatile organics must be tuned each twelve hours of operation using a BFB tune. CLP criteria are used to evaluate the tune. If the tune does not meet the CLP functional guidelines, the associated data are considered unusable and are flagged with R's.

The initial calibration of the instrument is evaluated by reviewing the average relative response factors (RRF) and the Percent Relative Standard Deviations (% RSD) for each target compound. If any compounds have a RRF of less than 0.05 all positive results are flagged as estimated (J) and all negative data are flagged as unusable (R). This is also true for evaluation of the continuing calibration. If any compound has a % RSD of greater than 30% for the initial calibration or greater than 25% for the continuing calibration, then the positive data are flagged as estimated (J). The negative data are evaluated on a case-by-case basis by reviewing all the appropriate QC data available.

The GC/MS for semi-volatile organic analysis must be tuned each 12 hours using a decafluorotriphenylphosphine tune that meets CLP criteria. If tuning criteria are not met, the associated data are rejected and flagged with R's. The initial and continuing calibration are evaluated using the same criteria as described previously for the volatile organics by GC/MS.

The calibration of the GC for the SW8010 and SW8020 was evaluated using the following criteria:

- For initial calibration the % RSD for all target compound must be less than or equal to 20%.
- For continuing calibration, all % D must be less than 15% D.

If criteria are not met, all quantitative data are estimated (J).

For ICP analyses for metals a blank and at least one standard must be used while calibration for AA analyses must consist of a blank and at least three standards, one of which must be at the CRDL. In mercury analyses four standards are used. The correlation coeffluent for the calibration-curve must equal or exceed 0.995 in all cases. If the minimum number of standards are not used the data is unusable and is flagged with an R. If the correlation coefficient is less than 0.995 the results are flagged as estimated (J).

F.2.3 Criteria for Laboratory Quality Control Data

Laboratory Quality Control Data consist of the results obtained from the analysis of laboratory blanks, surrogate spikes, spiked samples, and laboratory duplicate samples.

The assessment of results on blank analyses is for the purpose of determining the existence and magnitude of contamination problems. The criteria for evaluation of both laboratory and field blanks is described below. When more than one type of blank is associated with a given sample, qualification is based on the blank having the highest concentration of the contaminant.

Two rules are used for evaluating laboratory blank contamination, the 10x rule and the 5x rule. For the common laboratory contaminants methylene chloride, acetone, toluene, 2-butanone, and phthalate esters, if the concentration of the compound is greater than the CRQL but less than ten times the highest concentration found in a blank, the result is reported as non-detect. When the concentration is less than the CRQL it is reported as non-detect. When the concentration of the compound is greater than ten times the highest concentration found in any blank, the result is considered positive and no flags are used.

The 5x rule applies to all compounds other than the common laboratory contaminants. This rule is applied the same as the 10x rule except that a level of five times the blank contaminant level is used.

The criteria used to evaluate the field blanks was dependent on the type of blank. The results of the potable water blanks were not used to qualify the data because this was the initial rinse used in decontamination and the equipment was rinsed with solvent and HPLC water prior to contact with the samples. For the HPLC water blanks and the equipment rinseate blank, if the concentration of the contaminant in the sample did not exceed five times the level in the associated HPLC or rinseate blank the sample concentration was flagged as estimated (J).

Surrogate spike compounds are analytes added to each sample at a known concentration. The recovery of these compounds is determined to indicate laboratory performance on individual samples. The use of surrogate spikes is required for some but not all methods published by EPA.

The analytical methods for the analysis of volatile and semi-volatile organics require surrogate analyses to be performed. According to the methods, corrective action is required when any surrogate compound in the volatile fraction or any two surrogates within a base neutral (BN) or acid (A) fraction are out of specification. Corrective action is also required if any surrogate in a fraction has a recovery of less than 10 percent. If the reanalysis results are still out of specification, the compounds in the fraction corresponding to the problem surrogates are all qualified for the sample involved. The positive and negative results are estimated (J) unless the surrogate recovery is less than 10% in which case the negative results are unusable (R).

Matrix spike samples and laboratory duplicates are used to assess analytical accuracy and precision, respectively. The accuracy of the analytical results is evaluated upon the basis of percent recovery (PR) of matrix spiking compounds in matrix spike (MS) and matrix spike duplicates (MSD) at a minimum of one sample per 20 samples of similar matrix. The acceptance range for the percent recovery for each matrix spiking compound is either presented in the QAPP or in the analytical method used. The recovery of spiking compounds is an indication of the effect of the sample matrix upon the accuracy of the analysis results.

If the results of the MS or MSD analyses are not within the QC acceptance range for PR, the sample and its spikes are reextracted and reanalyzed. If the results are still out of compliance, positive results are considered estimated (J). If sample results for a compound are less than the detection limit and spike recovery is low, the result in the unspiked sample is unusable (R).

Precision is evaluated for a set of samples of similar matrix by the analysis and comparison of MS and MSD samples. The relative percent difference (RPD) of the values obtained for the MS and MSD samples should be less than the values specified as the upper limit in the QAPP or in the analytical method. When the RPD values obtained do not meet the acceptance criteria, either a blank spike or laboratory control sample (LCS) is analyzed as done for the accuracy corrective action. Also, if surrogate recovery values are within the acceptance criteria, no further corrective action is required and the QC data are considered to be of good quality.

For the metals analyses, the LCS is designed to serve as a monitor of the efficiency of the digestion procedure. If the control windows are exceeded, all data associated with the LCS should be reanalyzed.

F.2.4 Criteria for Detection Limit Compliance

Adherence to the target compound detection limits listed in the QAPP was the primary objective for compliance. For quantitation of certain compounds or analytes, the detection limit is increased according to the dilution and the increased detection limit is reported by the laboratory with the analytical results. In many cases, when dilution is required for the quantitation of only a few compounds on a target list, the normal detection limits are reported for all compounds except those quantitated from the diluted sample.

F.2.5 Criteria for Field Quality Control Data

Field quality control samples include rinseate blanks, source water blanks, and trip blanks. Rinseate blanks are a water rinse using deionized, analyte-free water following the decontamination of the field sampling equipment. Rinseate blanks were collected at a frequency of 10% per matrix per sampling event and analyzed for the parameters determined in the samples during that event. Source water blanks consist of samples of the potable water and high pressure liquid chromatography (HPLC) water used in decontamination. A blank from each source was collected for each sampling event.

The QAPP also requires the collection of one trip blank for every shipment of samples requiring volatile organics analysis (VOA). The trip blank is filled at the laboratory with deionized, analyte-free water, sealed and accompanies the VOA sample vials at all times. Trip blanks were not opened in the field.

To assess representativeness of the sample collection procedures, the QAPP required that coded field duplicates were collected at a frequency of 10% per matrix per event.

If the data collected during the SI did not meet the criterion contained in the QAPP and discussed above, it was flagged to indicate the limitations associated with it. The various flags used to qualify the data are discussed in the following paragraph.

F.2.6 Summary of Data Flags

Flags used to qualify the data are an effort to describe the circumstances surrounding and quality of that piece of data. They are based on all the information available to the data reviewer. Flags and symbols used are defined as follows:

U - The compound was not present in the sample above the detection limit.

J - The number preceding is estimated. The qualitative analysis is acceptable but the value cannot be considered as accurate.

N - Presumptive evidence of presence of material (tentative identification). There is evidence that the material is present, but for some reason or combination of reasons, it has not been confirmed.

R - Data is <u>rejected</u> and is <u>totally unusable</u>. The only way to obtain useful data is to resample and reanalyze.

It is possible that a result may contain more than one qualifying flag. For instance a result may be reported as UJ. This indicates that the target compound was not detected in the sample; however, uncertainty exists over the detection limit.

F.2.7 Completeness

The completeness of the data will be evaluated by reviewing the data collected and determining if any data gaps exist for completing the SI. If data gaps are identified the data will be judged to be incomplete. The completeness of individual sampling rounds will not be assessed. Completeness will be determined by evaluating all the data collected during the SI.

F.3 EVALUATION OF LABORATORY QA/QC

F.3.1 Volatile Organics (SW8010/8020)

As shown on Tables F.1 and F.2, all samples collected during the SI were analyzed for volatile organics within the required holding time. All surrogate and spike recoveries were within criteria.

F.3.2 Metals Analyses (SW7421/7191)

The lead and chromium analyses met holding time requirements, as shown in Table F.1, as well as blank and spiking criteria.

F.4 PRECISION ACCURACY, REPRESENTATIVENESS, AND COMPARABILITY

Laboratory precision is calculated through the comparison of duplicate samples. Matrix spike duplicates are used to assess the precision of the laboratory analysis. The laboratory results are all within criteria.

Accuracy involves the analysis of spiked samples and an evaluation of the recovery of the spiked compound. Laboratory accuracy was calculated through the review of the recoveries of blank spikes, surrogate spikes, and matrix spikes. All spike recoveries are within the required limits.

Representativeness was achieved by having all the samples collected according to accepted procedures. In addition, sample location selection and sample handling procedures were used to ensure that the most representative samples were obtained. The QAPP states that representativeness of specific samples are elevated through the analysis of coded field duplicate samples. The objective for representativeness was satisfied. Therefore, all date presented for this sampling event is considered representative of the actual conditions Michigan ANGB, Battle Creek, Michigan.

Comparability by definition is the ability to combine analytical results acquired from various sources using different methods for samples taken over the period of investigation. When precision and accuracy are known, the data sets can be compared with confidence. Since precision and accuracy are within criteria, the data sets can be compared with confidence.

F.5 FIELD QC RESULTS

As part of the field effort, trip blanks, source water blanks and equipment rinseate blanks were collected to assess the potential for the introduction of contaminants to the samples during sample collection. The results of the analysis of the field blanks showed no contamination present. Table F-3 summarizes the results of the analysis of the field QA samples. Contaminants were not detected in any of the field QA/QC samples.

As part of the field investigation, duplicate samples were collected to assess the precision of the field data. Table F-4 present the results of the duplicate analyses as well as the calculated RPDs. All RPDs were less than 50%. This data is considered precise.

F.6 COMPLETENESS

Completeness is defined as acquiring enough valid data in order that the objective of the event may be satisfied. Since all samples met quality control criteria, this data set satisfies the completeness objective.

F.7 CONCLUSIONS

The analytical data generated during the 1991 field effort are believed to be accurate, precise, and complete. The valid data available were sufficient to satisfy the project objectives.

TABLE F.1

SUMMARY OF HOLDING TIMES FOR GROUNDWATER AT ALL SITES
SAMPLED DURING THE AUGUST-SEPTEMBER 1989 SAMPLING EVENT
MICHIGAN AIR NATIONAL GUARD BASE, BATTLE CREEK, MICHIGAN

Sample Identification	Lab I.D.	Date Sample Collected	Date Sample Received By Laboratory	SW8010 Date Analyzed	SW8020 Date Analyzed	SW7421 Date Analyzed	SW7191 Date Analyzed
Base Boundary							
BC-MW1	7651-1	9/10/89	9/12/89	9/20/89(10)	9/20/89(10)	10/02/89(22)	--
BC-MW2	7651-3	9/10/89	9/12/89	9/20/89(10)	9/20/89(10)	10/02/89(22)	--
BC-MW3	7651-7	9/11/89	9/12/89	9/20/89(9)	9/20/89(9)	10/02/89(21)	--
BC-MW4	7651-4	9/10/89	9/12/89	9/20/89(10)	9/20/89(10)	10/02/89(22)	--
BC-MW5	7651-8	9/11/89	9/12/89	9/20/89(9)	9/20/89(9)	10/02/89(21)	--
BC-MW6	7714-3	9/13/89	9/14/89	9/26/89(13)	9/26/89(13)	10/04/89(21)	--
BC-MW7	7617-5	9/8/89	9/9/89	9/19/89(11)	9 [illegible]'89(11)	9/30/89(22)	--
BC-MW8	7651-2	9/10/89	9/12/89	9/20/89(10)	9/20/89(10)	10/02/89(22)	--
BC-MW9	7651-5	9/11/89	9/12/89	9/20/89(9)	9/20/89(9)	10/02/89(21)	--
BC-MW10	7651-12	9/11/89	9/12/89	9/20/89(9)	9/20/89(9)	10/02/89(21)	--
BC-MW11	7714-5	9/13/89	9/14/89	9/26/89(13)	9/26/89(13)	10/04/89(21)	--
BC-MW12	7714-4	9/13/89	9/14/89	9/26/89(13)	9/26/89(13)	10/04/89(21)	--
BC-MW13	7651-6	9/10-11/89	9/12/89	9/20/89(9)	9/20/89(9)	10/02/89(22)	--
BC-MW14	7714-1	9/13/89	9/14/89	9/26/89(13)	9/26/89(13)	10/04/89(21)	--
BC-MW15	7626-2	9/9/89	9/11/89	9/19/89(10)	9/19/89(10)	10/05/89(26)	--
Site 2							
BC2-MW1	7487-5	9/7/89	9/8/89	9/20/89(13)	9/20/89(13)	9/26/89(19)	--
Site 3							
BC3-MW1	7681-6	9/12/89	9/13/89	9/21/89(9)	9/21/89(9)	10/04/89(22)	--
BC3-MW2	7714-6	9/13/89	9/14/89	9/26/89(13)	9/26/89(13)	10/04/89(21)	
BC3-MW3	7681-7	9/12/89	9/13/89	9/21/89(9)	9/21/89(9)	10/04/89(22)	
BC3-MW4	7681-8	9/12/89	9/13/89	9/21/89(9)	9/21/89(9)	10/04/89(22)	
BC3-MW5	7617-3	9/8/89	9/9/89	9/19/89(11)	9/19/89(11)	9/30/89(22)	
BC3-MW6	7617-2	9/8/89	9/9/89	9/19/89(11)	9/19/89(11)	9/30/89(22)	

TABLE F.1 (cont'd.)

SUMMARY OF HOLDING TIMES FOR GROUNDWATER AT ALL SITES
SAMPLED DURING THE AUGUST-SEPTEMBER 1989 SAMPLING EVENT
MICHIGAN AIR NATIONAL GUARD BASE, BATTLE CREEK, MICHIGAN

Sample Identification	Lab I.D.	Date Sample Collected	Date Sample Received By Laboratory	SW8010 Date Analyzed	SW8020 Date Analyzed	SW7421 Date Analyzed	SW7191 Date Analyzed
Site 4							
BC4-MW1	7681-2	9/12/89	9/13/89	9/21/89(9)	9/21/89(9)	10/04/89(22)	9/27/89(15)
BC4-MW2	7681-3	9/12/89	9/13/89	9/21/89(9)	9/21/89(9)	10/04/89(22)	9/27/89(15)
BC4-MW3	7681-4	9/12/89	9/13/89	9/21/89(9)	9/21/89(9)	10/04/89(22)	9/27/89(15)
BC4-MW4	7681-5	9/12/89	9/13/89	9/21/89(9)	9/21/89(9)	10/04/89(22)	9/27/89(15)
Site 5							
BC5-MW1	7617-1	9/8/89	9/9/89	9/19/89(11)	9/19/89(11)	9/30/89(22)	--
Site 6							
BC6-MW1	7651-9	9/11/89	9/12/89	9/20/89(9)	9/20/89(9)	10/02/89(21)	--
BC6-MW2	7651-10	9/11/89	9/12/89	9/20/89(9)	9/20/89(9)	10/02/89(21)	--
BC6-MW3	7651-11	9/11/89	9/12/89	9/20/89(9)	9/20/89(9)	10/02/89(21)	--

-- Sample not collected for this analysis.

TABLE F.2

SUMMARY OF HOLDING TIMES FOR FIELD QUALITY CONTROL SAMPLES
GROUNDWATER-COLLECTED DURING THE AUGUST-SEPTEMBER 1989 SAMPLING EVENT
MICHIGAN AIR NATIONAL GUARD BASE, BATTLE CREEK, MICHIGAN

Sample Identification	Lab I.D.	Date Sample Collected	Date Sample Received By Laboratory	SW8010 Date Analzyed	SW8020 Date Analzyed	SW7421 Date Analzyed	SW7191 Date Analzyed
Trip Blanks							
BC-TB1	7487-6	9/7/89	9/8/89	9/20/89(13)	9/20/89(13)	--	--
BC-TB2	7617-6	9/8/89	9/9/89	9/19/89(11)	9/19/89(11)		
BC-TB3	7626-3	9/9/89	9/11/89	9/19/89(10)	9/19/89(10)		
BC-TB4	7651-13	9/10/89	9/12/89	9/19/89(9)	9/19/89(9)		
BC-TB5	7681-9	9/12/89	9/13/89	9/21/89(9)	9/21/89(9)		
BC-TB6	7714-8	9/13/89	9/14/89	9/23/89(10)	9/23/89(10)		
Bailer Rinseates							
BC-BR1	7487-4	9/7/89	9/8/89	9/20/89(13)	9/20/89(13)	9/26/89(19)	--
BC-BR2	7626-1	9/9/89	9/11/89	9/19/89(10)	9/19/89(10)	10/05/89(26)	--
BC-BR3	7681-1	9/12/89	9/13/89	9/21/89(9)	9/21/89(9)	10/04/89(22)	9/27/89(15)
Reagent Blanks (a)							
BC-HPLC	7487-1	9/7/89	9/8/89	9/20/89(13)	9/20/89(13)	9/26/89(19)	9/20/89(13)
BC-DDI	7487-2	9/7/89	9/8/89	9/20/89(13)	9/20/89(13)	9/26/89(19)	9/20/89(13)
BC-TAP	7487-3	9/7/89	9/8/89	9/20/89(13)	9/20/89(13)	9/26/89(19)	9/20/89(13)

-- Sample not collected for this analysis.

(a) HPLC Used for decontamination of sampling equipment and for rinsate samples.

DDI Deionized water used during the drilling effort.

TAP Base supplied potable water.

TABLE F.3

SUMMARY OF ANALYTICAL RESULTS FOR FIELD QUALITY CONTROL SAMPLES
GROUNDWATER-COLLECTED DURING THE AUGUST-SEPTEMBER 1989 SAMPLING EVENT
MICHIGAN AIR NATIONAL GUARD BASE, BATTLE CREEK, MICHIGAN

Sample Identification	Date Sample Collected	Volatile Organics SW8010/SW8020 (ug/L)	Lead SW7421 (mg/L)	Chromium SW7191 (mg/L)
Trip Blanks				
BC-TB1	9/7/89	ND	--	--
BC-TB2	9/8/89	ND	--	--
BC-TB3	9/9/89	ND	--	--
BC-TB4	9/10/89	ND	--	--
BC-TB5	9/12/89	ND	--	--
BC-TB6	9/13/89	ND	--	--
Bailer Rinseates				
BC-BR1	9/7/89	ND	ND	
BC-BR2	9/9/89	ND	ND	
BC-BR3	9/12/89	ND	ND	ND
Reagent Blanks (a)				
BC-HPLC	9/7/89	ND	ND	ND
BC-DDI	9/7/89	ND	ND	ND
BC-TAP	9/7/89	ND	ND	ND

ND None detected.

Sample not collected for this analysis.

(a) HPLC Used for decontamination of sampling equipment and for rinsate samples.

DDI Deionized water used during the drilling effort.

TAP Base supplied potable water.

TABLE F.4
SUMMARY OF RESULTS FOR QUALITY CONTROL DUPLICATE GROUNDWATER SAMPLES COLLECTED DURING THE AUGUST-SEPTEMBER 1989 SAMPLING EVENT MICHIGAN AIR NATIONAL GUARD BASE, BATTLE CREEK, MICHIGAN

Duplicate Field Sample					
Identifier Number One (Actual Sample ID)	Identifier Number Two	Units	Result One	Result Two	Relative Percent Difference (RPD)
Volatile Organics (SW8010/SW8020)					
BC-MW14	BC-MW16	µg/L	ND	ND	NA
BC3-MW2	BC3-MW7	µg/L	1,2-Dichloroethene-180J Benzene-39 Ethylbenzene-21 Xylenes-91	1,2-Dichloroethene-240J Benzene-56 Ethylbenzene-26 Xylenes-110	29 35 21 19
BC3-MW5	BC3-MW7	µg/L	ND	ND	NA
Lead (SW7421)					
BC-MW14	BC-MW16	mg/L	ND	ND	NA
BC3-MW2	BC3-MW7	mg/L	ND	ND	NA
BC3-MW5	BC3-MW7	mg/L	0.0093	0.0094	1

ND - None detected
NA - Not applicable

APPENDIX G
QA/QC REPORT AND DATA VALIDATION SUMMARY FOR MARCH 1991 SAMPLING EVENT

APPENDIX G
QA/QC REPORT AND DATA VALIDATION SUMMARY FOR 1991 SAMPLING EVENT

G.1 INTRODUCTION

A total of 52 field samples consisting of 10 soil samples, 35 water samples, and 7 sediment samples were collected between March 14 and March 27, 1991 at the Michigan Air National Guard Base in Battle Creek, Michigan. Samples were packed in ice and shipped via overnight courier to Savannah Laboratories for analysis. Samples were selectively analyzed for volatile organics (CLP), semi-volatile organics (CLP), total petroleum hydrocarbons (E 418.1), priority pollutant metals, and purgeable aromatic volatile organics (SW 8020).

The CLP method for volatile organic analysis of water was modified to reduce the detection limit of selected compounds. The CLP SOW was modified in order to achieve the detection limits required for the Michigan Air National Guard Base (Battle Creek, Michigan) HAZWRAP project.

G.2 ANALYTICAL METHOD MODIFICATION

The detection limits for the volatile TCLs (target compound list) have been determined for 5 ml sample volumes. Savannah Laboratories used the following basis for the interpretation of the ability to achieve this project's required detection limit: using a five fold increase in sample volume analyzed (25 ml) and correlating this to a five fold decrease in Savannah Laboratories' MDLs. In order that detection limits might be lowered, the following analytical method were used.

MODIFICATIONS:

1. Five point calibration levels: 1; 4; 10; 20; 30 (μg/L)
2. Continuing calibration check: 10 μg/L
3. Internal standards concentration: 10 μg/L
4. Surrogate standards concentration: 10 μg/L
5. Matrix spike concentration: 10 μg/L
6. Sample/standard purge volumes: 25 ml

The appropriate CLP 2/88 SOW forms will be modified to reflect the above changes. In the event that the CLP form can not be modified, a Savannah Laboratories or HP computer generated form will be substituted.

G.3 CRITERIA USED TO ASSESS LABORATORY DATA QUALITY

The analytical data collected during the SI/RI were evaluated in accordance with the HAZWRAP document "Requirements for Quality Control of Analytical Data" (DOE/HWP-65/R1). The following criteria were used to evaluate the data where applicable to the particular analysis:

- Sample holding times
- Gas chromatograph/mass spectrometry (GC/MS) tuning and mass calibrations
- Initial and continuing calibrations
- Surrogate spike results
- Matrix spike and matrix spike duplicate results
- Detection limit compliance
- Laboratory blank results
- Field blank results
- Completeness

G.3.1 Criteria for Holding Time Compliance

For all of the analyses conducted, specific holding times apply. Tables G.1 through G.5 present the holding times for each analysis performed during the SI/RI.

G.3.2 Criteria for Instrument Tuning and Calibration

Tuning and calibration criteria evaluate the ability of the analytical instrument to identify and quantify the target compounds of concern. The tuning and calibration criteria are method specific.

The GC/MS used for volatile organics must be tuned each twelve hours of operation using a BFB tune. CLP criteria are used to evaluate the tune. If the tune does not meet the CLP functional guidelines, the associated data are considered unusable and are flagged with R's.

The initial calibration of the instrument is evaluated by reviewing the average relative response factors (RRF) and the Percent Relative Standard Deviations (% RSD) for each target compound. If any compounds have a RRF of less than 0.05 all positive results are flagged as estimated (J) and all negative data are flagged as unusable (R). This is also true for evaluation of the continuing calibration. If any compound has a % RSD of greater than 30% for the initial calibration or greater than 25% for the continuing calibration, then the positive data are flagged as estimated (J). The negative data are evaluated on a case-by-case basis by reviewing all the appropriate QC data available.

The GC/MS for semi-volatile organic analysis must be tuned each 12 hours using a decafluorotriphenylphosphine tune that meets CLP criteria. If tuning criteria are not met, the associated data are rejected and flagged with R's. The initial and continuing calibration are evaluated using the same criteria as described previously for the volatile organics by GC/MS.

The calibration of the GC for the SW8010 and SW8020 was evaluated using the following criteria:

- For initial calibration the % RSD for all target compound must be less than or equal to 20%.
- For continuing calibration, all % D must be less than 15% D.

If criteria are not met, all quantitative data are estimated (J).

For ICP analyses for metals a blank and at least one standard must be used while calibration for AA analyses must consist of a blank and at least three standards, one of which must be at the CRDL. In mercury analyses four standards are used. The correlation coefficient for the calibration-curve must equal or exceed 0.995 in all cases. If the minimum number of standards are not used the data is unusable and is flagged with an R. If the correlation coefficient is less than 0.995 the results are flagged as estimated (J) for positive results and (UJ) for negative results.

G.3.3 Criteria for Laboratory Quality Control Data

Laboratory Quality Control Data consist of the results obtained from the analysis of laboratory blanks, surrogate spikes, spiked samples, and laboratory duplicate samples.

The assessment of results on blank analyses is for the purpose of determining the existence and magnitude of contamination problems. The criteria for evaluation of both laboratory and field blanks is described below. When more than one type of blank is associated with a given sample, qualification is based on the blank having the highest concentration of the contaminant.

Two rules are used for evaluating laboratory blank contamination, the 10x rule and the 5x rule. For the common laboratory contaminants methylene chloride, acetone, toluene, 2-butanone, and phthalate esters, if the concentration of the compound is greater than the CRQL but less than ten times the highest concentration found in a blank, the result is reported as non-detect. When the concentration is less than the CRQL it is reported as non-detect. When the concentration of the compound is greater than ten times the highest concentration found in any blank, the result is considered positive and no flags are used.

The 5x rule applies to all compounds other than the common laboratory contaminants. This rule is applied the same as the 10x rule except that a level of five times the blank contaminant level is used.

The criteria used to evaluate the field blanks was dependent on the type of blank. The results of the potable water blanks were not used to qualify the data because this was the initial rinse used in decontamination and the equipment was rinsed with pesticide grade methanol and HPLC-grade water prior to contact with the samples. For the HPLC water blanks and the equipment rinseate blank, if the concentration of the contaminant in the sample did not exceed five times the level in the associated HPLC or rinseate blank the sample concentration was flagged as estimated (J).

Surrogate spike compounds are analytes added to each sample at a known concentration. The recovery of these compounds is determined to indicate laboratory performance on individual samples. The use of surrogate spikes is required for some but not all methods published by EPA.

The analytical methods for the analysis of volatile and semi-volatile organics require surrogate analyses to be performed. According to the methods, corrective action is required when any surrogate compound in the volatile fraction or any two surrogates within a base neutral (BN) or acid (A) fraction are out of specification. Corrective action is also required if any surrogate in a fraction has a recovery of less than 10 percent. If the reanalysis results are still out of specification, the compounds in the fraction corresponding to the problem surrogates are all qualified for the sample involved. The positive and negative results are estimated (+J/UJ-) unless the surrogate recovery is less than 10% in which case the negative results are unusable (R).

Matrix spike samples and laboratory duplicates are used to assess analytical accuracy and precision, respectively. The accuracy of the analytical results is evaluated upon the basis of percent recovery (PR) of matrix spiking compounds in matrix spike (MS) and matrix spike duplicates (MSD) at a minimum of one sample per 20 samples of similar matrix. The acceptance range for the percent recovery for each matrix spiking compound is presented in the analytical method used. The recovery of spiking compounds is an indication of the effect of the sample matrix upon the accuracy of the analysis results.

If the results of the MS or MSD analyses are not within the QC acceptance range for PR, the sample and its spikes are re-extracted and reanalyzed. If the results are still out of compliance, positive results are considered estimated (J). If sample results for a compound are less than the detection limit and spike recovery is low, the result in the unspiked sample is unusable (R).

Precision is evaluated for a set of samples of similar matrix by the analysis and comparison of MS and MSD samples. The relative percent difference (RPD) of the values obtained for the MS and MSD samples should be less than the values specified as the upper limit in the QAPP or in the analytical method. When the RPD values obtained do not meet the acceptance criteria, either a blank spike or laboratory control sample (LCS) is analyzed as done for the accuracy corrective action. Also, if surrogate recovery values are within the acceptance criteria, no further corrective action is required and the QC data are considered to be of good quality.

For the metals analyses, the LCS is designed to serve as a monitor of the efficiency of the digestion procedure. If the control windows are exceeded, all data associated with the LCS should be reanalyzed.

G.3.4 Criteria for Detection Limit Compliance

Adherence to the target compound detection limits listed in the laboratory contract was the primary objective for compliance. For quantitation of certain compounds or analytes, the detection limit is increased according to the dilution and the increased detection limit is reported by the laboratory with the analytical results. In many cases, when dilution is required for the quantitation of only a few compounds on a target list, the normal detection limits are reported for all compounds except those quantitated from the diluted sample. Due to the need for low detection limits compliance, a modified CLP method outlined in Section G.2 was used.

G.3.5 Criteria for Field Quality Control Data

Field quality control samples include rinseate blanks, source water blanks, and trip blanks. Rinseate blanks are a water rinse using deionized, analyte-free water following the decontamination of the field sampling equipment. Rinseate blanks were collected at a frequency of 10% per matrix per sampling event and analyzed for the parameters determined in the samples during that event. Source water blanks consist of samples of the potable water and high performance liquid chromatography (HPLC) water used in decontamination. A blank from each source was collected for each sampling event.

HAZWRAP's document "HWP/DOE-69/RI, Quality Control Requirements for Field Methods" also requires the collection of one trip blank for every shipment of samples requiring volatile organics analysis (VOA). The trip blank is filled at the laboratory with deionized, analyte-free water, sealed and accompanies the VOA sample vials at all times. Trip blanks were not opened in the field.

To assess representativeness of the sample collection procedures, HAZWRAP's Requirements for Quality Control of Analytical Data required that coded field duplicates were collected at a frequency of 10% per matrix per event.

If the data collected during the SI did not meet the criterion contained in the HAZWRAP's Requirements for Quality Control of Analytical Data and discussed above, it was flagged to indicate the limitations associated with it. The various flags used to qualify the data are discussed in the following paragraph.

G.3.6 Summary of Data Flags

Flags used to qualify the data are an effort to describe the circumstances surrounding and quality of that piece of data. They are based on all the information available to the data reviewer. Flags and symbols used are defined as follows:

U - The compound was not present in the sample above the detection limit.

J - The number preceding is estimated. The qualitative analysis is acceptable but the value cannot be considered as accurate.

N - Presumptive evidence of presence of material (tentative identification). There is evidence that the material is present, but for some reason or combination of reasons, it has not been confirmed.

R - Data is rejected and is totally unusable. The only way to obtain useful data is to resample and reanalyze.

It is possible that a result may contain more than one qualifying flag. For instance, a result may be reported as UJ. This indicates that the target compound was not detected in the sample; however, the detection limit is estimated.

G.3.7 Completeness

The completeness of the data was be evaluated by reviewing the data collected and determining if any data gaps exist for completing the SI. If data gaps were identified the data was be judged to be incomplete. The completeness of individual sampling rounds was assessed.

G.4 EVALUATION OF LABORATORY QA/QC

G.4.1 Soil Samples

Soil samples were collected only from Site 6, and were analyzed with laboratory batch B00005. Table G.6 identifies the samples associated with each batch analyzed by the laboratory.

G.4.1.1 Volatile Organics (SW8020)

As shown on Table G.4 all soil samples collected during the SI were analyzed for purgeable aromatic volatile organics (SW8020) within the required holding time. The method blank associated with this batch was free of contaminants. All calibrations were considered of good quality. The matrix spike/matrix spike duplicate analyses were within the required limits, and surrogate recoveries were within guidelines. All soil analytical data is of good quality and no volatile organic data has been flagged.

G.4.1.2 Total Petroleum Hydrocarbons

Batch B00005 met all QC criteria for total petroleum hydrocarbons. All samples were analyzed within holding times. No contamination was detected in rinseate, field, or method blanks associated with these samples. Calibration were considered to be of good quality, and spiking recoveries were within guidelines. All soil analytical data is of good quality; and no TPH has been flagged..

G.4.2 Sediment Samples

Sediment samples were collected only from Site 2 and were analyzed with laboratory batch B00001 and B00005. Table G.6 identifies the samples associated with each batch analyzed by the laboratory.

G.4.2.1 Volatile Organics (CLP SOW)

As shown on Table G.3 all sediment samples collected during the SI were analyzed for VOC, (CLP) within the required holding times.

Acetone was detected in associated sediment samples at concentrations less that 10x the concentration in the method blank and is not reported in the data summary tables. Methylene chloride was not detected in associated sediment samples. The following compounds had calibration difficulty: bromomethane; chloroethane; chloromethane; acetone; 2-butanone; vinyl acetate; 4-methyl-2-pentanone; 2-hexanone; 1,1,2,2-tetrachloroethane; and methylene chloride. Only 2-butanone's negative results were flagged (R) for rejection because its response factor was less than 0.05. The other compounds had high percent differences in the continuing calibrations. This problem effected only positive results of the above-mentioned compounds, of which none were detected in the sediment samples.

Samples BC2-SED2-3 (S132129-2), BC2-SED5-3 (S132129-4), BC2-SED10-3 (S132129-5) and BC2-SED6-3 (S132129-6) had internal standard areas which did not meet criteria. Re-extractions performed on BC2-SED5-3 and BC2-SED6-3 also had internal standard areas which did not meet criteria. The positive data is flagged (J) and the negative data is flagged (UJ). Sample BC2-SED3-3 (32129-1) had a high surrogate recovery of bromofluorobenzene. This sample was flagged (J) for positive results and (UJ) for negative results.

The matrix spike/matrix spike duplicate had high relative percentage differences for benzene, toluene, and chlorobenzene and high percent recovery for benzene and toluene. Both of these problems required no flagging activity because the LCS was within criteria.

G.4.2.2 Semivolatile Organics (CLP SOW)

Batch B00001 had no method blank contamination.

The following compounds had calibration difficulties: benzoic acid; 4-chlorophenyl-phenylether; 2,4-dinitrotoluene; 3-nitroaniline; 4,6-dinitro-2-methylphenol; bis(2-chloroisopropyl)ether; 2,4-dinitrophenol; 3,3-dichlorobenzidine; diethylphthalate; 4-nitroaniline; and pyrene. These compounds had either a high relative standard deviation in the initial calibrations or a high percent difference in the continuing calibration. Flagging of data was not required. Samples BC2-SED6-3, BC2-SED1-3, and BC2-SED1-3 (re-extraction) had blown internal standard areas. As a result, the positive data was flagged (J) and the negative data was flagged (UJ).

The matrix spike/matrix spike duplicate had a zero recovery for pyrene and high relative percentage differences for 2-chlorophenol, N-nitroso-di-n-propylamine, 4-chloro-3-methylphenol, and pentachlorophenol. Pyrene and pentachlorophenol results were flagged (J) if positive, (UJ) if negative, and all the other mentioned compounds required no flagging because the LCS was within criteria.

Samples BC2-SED6-3 (32129-6) and BC2-SED1-3 (3219-8) had high surrogate recoveries for Terphenyl-d14; however, no flagging was required. Holding time criteria was met.

G.4.2.3 Metals

The QC criteria for inorganics included holding times, calibration checks, blank contamination, spiking recoveries, and duplicates.

The following are flags the laboratory placed on metal analytical results for sediment samples:

"E" - serial dilution exceeded the 10 percent difference limit.

"W" - Post-digestion spike for furnace AA analysis is out of control limits, while sample absorbance is less than 50% of spike absorbance.

"N" - spike sample recovery is not within control limits.

For batch B00001, antimony and mercury results were flagged "N", zinc results were flagged "E", and selenium results were flagged "WN". All flags were replaced with a (J) to demonstrate them to be estimated.

Zinc was found in the method blank; however, this required no flagging because zinc was detected in sediment samples at concentrations less that 5x the concentration in the associated method blank. Holding time criteria was met.

G.4.3 Water Samples

Water samples were collected from all sites and the boundary wells. Batch numbers and associated samples are identified in Table G.6.

G.4.3.1 Volatile Organic Compounds (CLP)

Batch B00001 - The following compounds had calibration problems: bromomethane; chloroethane; chloromethane; acetone; 2-butanone; vinyl acetate; 4-methyl-2-pentanone; 2-hexanone; 1,1,2,2-tetrachloroethane; and methylene chloride. These compounds had high percent differences in the continuing calibration. Only 2-butanone required its negatives to be flagged (R) as rejected because of a relative response factor RRF of less than 0.05.

The laboratory control sample had a low surrogate recovery of bromoflurorobenzene, and the matrix spike/matrix spike duplicate had a high surrogate recovery of toluene-d8, but no field samples required no flagging activity.

The matrix spike/matrix spike duplicate had high relative percentage differences for 4-nitrophenol and pentachlorophenol, but the 4-nitrophenol required no flagging because the LCS was within criteria. The pentachlorophenol results were flagged (J) as estimated if positive and (UJ) if negative. The method blank contained acetone and methylene chloride, (benzene, chloroform, bromoform, bromodichloromethane, and dibromochloromethane). These compounds did not affect the data because of the 10x rule and were not flagged. All holding time requirements were met.

Batch B00002 met all holding time requirements. The compounds 2-butanone, 2-hexanone, acetone, and dibromochloromethane had calibration difficulties. All the compounds had high percent differences in the continuing calibration, but only 2-butanone and 2-hexanone required the flagging of negative results with an (R) as rejected because their RRF was less than 0.05. The method, trip field, and rinseate blank contained chloroform, benzene, bromoform, bromodichloromethane, dibromochloromethane, and methylene chloride contamination. This compound did not affect the data because of the 10x rules and required no flagging. The matrix spike/matrix spike duplicate met criteria.

Batch B00003 met all holding time requirements. The compounds 2-butanone; 2-hexanone; chloromethane; chloroethane; acetone; vinyl acetate; bromodichloromethane; dibromochloromethane; 1,1,2-trichloroethane; trans-1,3-dichloropropene; bromoform; and 1,1,2,2-tetrachloroethane had calibration difficulties. All the compounds had high percent differences in the continuing calibration, but only 2-butanone and 2-hexanone required their results be flagged (J) as estimated if positive and (R) as rejected if negative because their RRF was less than 0.05. The method blanks contained (chloroform, bromoform, bromodichloromethane), dibromochloromethane, xylenes, acetone, and 2-butanone contamination. These compounds did not effect the data because of the 5X/10X rule and required no flagging. The matrix spike/matrix spike duplicate met criteria.

Batch B00004 met all holding time requirements. The compounds 2-butanone, 2-hexanone, acetone, dibromochloromethane, bromoform, vinyl acetate, bromodichloromethane, 1,1,2-trichloroethane, trans-1,3-dichloropropene, and 1,1,2,2-tetrachloroethane had calibration difficulties. All the compounds had high percent differences in the continuing calibration, but only 2-hexanone required its results be flagged (J) if positive and (R) if negative because its RRF was less than 0.05. The method blanks contained chloroform, bromoform, bromodichloromethane, dibromochloromethane, xylenes, acetone, and 2-butanone contamination. These compounds did not effect the data and required no flagging. The matrix spike duplicate had two surrogate recoveries out of range and low internal standard areas. These problems did not affect the sample data and required no flagging because the matrix spike met criteria.

G.4.3.2 Semivolatile Organics (CLP SOW)

Batch B00002 met holding time requirements. The compounds benzoic acid; 2,4-dinitrophenol; 4-chlorophenyl-phenylether; 4,6-dinitro-2-methylphenol; hexachloroethane; 4-methylphenol; 4-chloroaniline; 3-nitroaniline; 4-nitrophenol; fluorene; and indeno(1,2,3-cd)pyrene had calibration difficulties. These compounds had high percent differences in continuing calibrations or high relative standard deviations in the initial calibration. However, no flagging was required because none of these compounds was detected. The method blank's re-extractions did not meet internal standard area criteria. This problem did not effect the data because initially the blank met the criteria. The method blank contained bis(2-ethylhexyl)phthalate contamination. This common contamination required no flagging because of the 10x rule. The matrix spike/matrix spike duplicate had high relative percentage difference of 4-nitrophenol and pentachlorophenol. The 4-nitrophenol required no flagging because the LCS met criteria, but the pentachlorophenol results were flagged (J) as estimated if positive and (UJ) if negative.

G.4.3.3 Metals

The QC criteria for inorganics included holding times calibration checks, blank contamination, duplicates, and surrogate recoveries.

The following are flags the laboratory placed on metal analyses:

"E" - serial dilution exceeded the 10 percent difference limit.

"W" - Post-digestion spike for furnace AA analysis is out of control limits, while sample absorbance is less than 50% of spike absorbance.

"N" - spike sample recovery is not within control limits.

Batch B00001, had the arsenic (W) and selenium (N) analyses flagged. These flags were replaced with a (J) to demonstrate the values to be estimated. The holding times, blank contamination, duplicates and calibrations met criteria for all samples.

Batch B00002 had arsenic and selenium analyses flagged with "W". These "W" flags were replaced with a (J) to demonstrate the values to be estimated. The method blank contained copper and zinc, but this did not effect the data. The holding times, spike recoveries, blank contamination, duplicates and calibrations met criteria for all samples.

Batch B00003 had arsenic ("N" and/or "W"), selenium ("W" and/or "N"), and lead (W) analyses flagged. These flags were replaced with (J) to demonstrate the values to be estimated. The holding time, blank contamination, duplicate and calibration criteria were met by all samples.

Batch B-00004 had arsenic (W), selenium (W), and thallium (W) analyses flagged. These flags were replaced with (J) to demonstrate the values to be estimated. The holding time, spike recovery, blank contamination, duplicate and calibration criteria were met by all samples.

G.4.4 Accuracy, Precision, Completeness, Representativeness, and Comparability

Accuracy, as previously discussed, involves the analysis of spiked samples and an evaluation of the recovery of the spiked compound. Laboratory accuracy was calculated through the review of the recoveries of blank spikes, surrogate spikes and matrix spikes. In some instances spike recoveries were outside the required limits as described in the previous sections. However, the laboratory analyses for this project are considered accurate except as noted by data flags.

Laboratory precision is calculated through the comparison of duplicate samples. Matrix spike duplicates are used to assess the precision of the laboratory analysis. Except for the few instances described in the previous sections, the laboratory results are considered to be precise.

Representativeness was achieved by having all the samples collected according to accepted procedures. In addition, sample location selection and sample handling procedures were used to ensure that the most representative samples were obtained. Representativeness of specific samples are elevated through the analysis of coded field duplicate samples. The objective for representativeness was satisfied. Therefore, all data presented for this sampling event is considered representative of the actual conditions at Michigan ANGB, Battle Creek, Michigan.

Comparability by definition is the ability to combine analytical results acquired from various sources using different methods for samples taken over the period of investigation. When precision and accuracy are known, the data sets can be compared with confidence. Since precision and accuracy are within criteria, the data sets can be compared with confidence.

The completeness of the data is evaluated by determining if the data is sufficient to meet the project objectives. The data are considered to be complete.

G.5 FIELD QC RESULTS

As part of the field effort, trip blanks, source water blanks and equipment rinseate blanks are collected to assess the potential for the introduction of contamination to the samples during collection. The results of the analysis of the field blanks are summarized in Table G.7. Table G.8 shows which investigation samples are associated with which field QC samples. Chloroform, bromoform, bromodichloromethane, and dibromochloromethane were detected in the trip blanks. These compounds were found in laboratory blanks. According to Savannah Laboratory, the laboratory and trip blanks use the same source water. Therefore, these compounds are believed to be indicative of laboratory contamination and not introduced into the samples in the field. These compounds were not detected in any of the environmental samples.

The field and rinseate blanks contained chloroform, bromodichloromethane, dibromochloromethane, bromoform, 2-butanone, toluene, and bis(2-ethylhexyl)phthalate. These compounds are commonly found in chlorinated water and/or are common laboratory contaminants. The presence of these compounds in the blank does not affect the data quality because of the 5X/10X rule.

A field and rinseate blank contained zinc and copper. The results of the data were not altered by this contamination because of the 5x rule.

As part of the field investigation, duplicate samples were collected to assess the precision of the field data. Table G.9 presents the results of the duplicate analyses as well as the calculated RPDs. The RPDs for several soil samples were very high, greater than 25%. These high RPDs are believed to be due to heterogeneity of the soil samples and to the high dilution factors required.

The RPDs for the water samples were much lower than the soil samples. However, water samples had zinc, acetone, *trans*-1,2-dichloroethene and trichloroethene with high RPDs and/or were present in a sample, but not the duplicate. Variation in sampling procedures or surges in contamination could be the cause of these problems. However, due to these problems, the high RPDs and non-detection of compounds in a duplicate that were detected in a sample do not affect data quality.

G.6 CONCLUSIONS

The analytical data generated during the 1991 field effort are believed to be accurate, precise, and complete. Isolated problems were encountered relating to calibration and spike recoveries. Results for 2-butanone and 2-hexanone analyses in soil, sediment and water samples were rejected due to low response factors. The analytical method followed is responsible for this. For the most part the low spike recoveries were indicative of matrix interferences. Problems were encountered in the analyses of sediment for volatile organics. However, the valid data available were sufficient to satisfy the project objectives.

TABLE G.1
WATER SAMPLES HOLDING TIMES
110TH TASG MICHIGAN AIR NATIONAL GUARD
W.K.KELLOGG AIRPORT
BATTLE CREEK, MICHIGAN

Sample	Date Sample Collected	Volatiles (SW8240) (14 days)	ICP Metals (SW6010) (6 months)	Arsenic (SW7060) (6 months)	Lead (SW7421) (6 months)	Mercury (SW7470/7471) (28 days)	Selenium (SW7740) (6 months)	Thallium (SW7841) (6 months)
BC-MW1-1	3-19-91	3-27-91 (08)	3-25-91 (06)	4-10-91 (22)	4-13-91 (25)	3-30-91 (11)	4-15-91 (27)	4-13-91 (25)
BC-MW2-3	3-20-91	3-27-91 (07)	3-25-91 (05)	4-10-91 (21)	4-13-91 (24)	3-30-91 (10)	4-15-91 (26)	4-13-91 (24)
BC-MW3-3	3-20-91	3-27-91 (07)	3-25-91 (05)	4-10-91 (21)	4-13-91 (24)	3-30-91 (10)	4-15-91 (26)	4-13-91 (24)
BC-MW4-3	3-19-91	3-27-91 (08)	3-25-91 (06)	4-10-91 (22)	4-13-91 (25)	3-30-91 (11)	4-15-91 (27)	4-13-91 (25)
BC7-MW3-3	3-19-91	3-27-91 (08)	3-25-91 (06)	4-10-91 (22)	4-13-91 (25)	3-30-91 (11)	4-15-91 (27)	4-13-91 (25)
BC-MW5-3	3-19-91	3-27-91 (08)	3-25-91 (06)	4-10-91 (22)	4-13-91 (25)	3-30-91 (11)	4-15-91 (27)	4-13-91 (25)
BC7-MW2-3	3-19-91	3-27-91 (08)	3-25-91 (06)	4-10-91 (22)	4-13-91 (25)	3-30-91 (11)	4-15-91 (27)	4-13-91 (25)
BC-MW6-3	3-19-91	3-27-91 (08)	3-25-91 (06)	4-10-91 (22)	4-13-91 (25)	3-30-91 (11)	4-15-91 (27)	4-13-91 (25)
BC-MW7-3	3-21-91	3-30-91 (09)	3-27-91 (06)	4-10-91 (20)	4-13-91 (23)	3-30-91 (09)	4-15-91 (25)	4-13-91 (23)
BC-MW8-3	3-20-91	3-28-91 (08)	3-25-91 (05)	4-10-91 (21)	4-13-91 (24)	3-30-91 (10)	4-15-91 (26)	4-13-91 (24)
BC-MW9-3	3-18-91	3-30-91 (12)	3-22-91 (04)	3-21-91 (03)	3-23-91 (05)	3-27-91 (09)	3-28-91 (10)	4-16-91 (29)
BC-MW10-3	3-17-91	3-30-91 (13)	3-22-91 (05)	3-21-91 (04)	3-23-91 (06)	3-27-91 (10)	3-28-91 (11)	3-24-91 (07)
BC-MW11-3	3-17-91	3-30-91 (13)	3-22-91 (05)	3-21-91 (04)	3-23-91 (06)	3-27-91 (10)	3-28-91 (11)	3-24-91 (07)
BC-MW12-3	3-17-91	3-30-91 (13)	3-22-91 (05)	3-21-91 (04)	3-23-91 (06)	3-27-91 (10)	3-28-91 (11)	3-24-91 (07)
BC-MW13-3	3-20-91	3-27-91 (07)	3-25-91 (05)	4-10-91 (21)	4-13-91 (24)	3-30-91 (10)	4-15-91 (26)	4-13-91 (24)
BC-MW14-3	3-19-91	3-27-91 (08)	3-25-91 (06)	4-10-91 (22)	4-13-91 (25)	3-30-91 (11)	4-15-91 (27)	4-13-91 (25)
BC-MW15-3	3-21-91	3-28-91 (07)	3-27-91 (06)	4-10-91 (20)	4-13-91 (23)	3-30-91 (09)	4-15-91 (25)	4-13-91 (23)
BC2-MW1-3	3-18-91	3-29-91 (11)	3-22-91 (04)	3-21-91 (03)	3-23-91 (05)	3-27-91 (09)	3-28-91 (10)	4-16-91 (29)
BC3-MW1-3	3-16-91	3-29-91 (13)	3-22-91 (06)	3-21-91 (05)	3-23-91 (07)	3-27-91 (11)	3-28-91 (12)	3-24-91 (08)
BC3-MW2-3	3-16-91	3-29-91 (13)	3-22-91 (06)	3-21-91 (05)	3-23-91 (07)	3-27-91 (11)	3-28-91 (12)	3-24-91 (08)
BC7-MW1-3	3-16-91	3-29-91 (13) 3-30-91 (14)	3-22-91 (06)	4-18-91 (33)	3-23-91 (07)	3-27-91 (11)	3-28-91 (12)	3-24-91 (08)
BC3-MW3-3	3-16-91	3-29-91 (13)	3-22-91 (06)	3-21-91 (05)	3-23-91 (07)	3-27-91 (11)	3-28-91 (12)	3-24-91 (08)
BC3-MW4-3	3-16-91	3-30-91 (14)	3-22-91 (06)	3-21-91 (05)	3-23-91 (07)	3-27-91 (11)	3-28-91 (12)	3-24-91 (08)
BC3-MW5-3	3-20-91	3-28-91 (08)	3-25-91 (05)	4-10-91 (21)	4-13-91 (24)	3-30-91 (10)	4-15-91 (26)	4-13-91 (24)

TABLE G.1- - Continued
WATER SAMPLES HOLDING TIMES
110TH TASG MICHIGAN AIR NATIONAL GUARD
W.K.KELLOGG AIRPORT
BATTLE CREEK, MICHIGAN

Sample	Date Sample Collected	Volatiles (SW8240) (14 days)	ICP Metals (SW6010) (6 months)	Arsenic (SW7060) (6 months)	Lead (SW7421) (6 months)	Mercury (SW7470/7471) (28 days)	Selenium (SW7740) (6 months)	Thallium (SW7841) (6 months)
BC3-MW6-3	3-21-91	3-28-91 (07)	3-27-91 (06)	4-10-91 (20)	4-13-91 (23)	3-30-91 (09)	4-15-91 (25)	4-13-91 (23)
BC4-MW1-3	3-14-91	3-25-91 (11)	3-21-91 (07)	3-21-91 (07)	3-23-91 (09)	3-26-91 (12)	3-29-91 (15)	3-23-91 (09)
BC4-MW2-3	3-15-91	3-26-91 (11)	3-21-91 (06)	3-21-91 (06)	3-25-91 (10)	3-26-91 (11)	3-28-91 (13)	3-23-91 (08)
BC4-MW3-3	3-15-91	3-26-91 (11)	3-21-91 (06)	3-21-91 (06)	3-25-91 (10)	3-26-91 (11)	3-28-91 (13)	3-23-91 (08)
BC4-MW4-3	3-15-91	3-26-91 (11)	3-21-91 (06)	3-21-91 (06)	3-25-91 (10)	3-26-91 (11)	3-28-91 (13)	3-23-91 (08)
BC5-MW1-3	3-21-91	3-28-91 (07)	3-27-91 (06)	4-10-91 (20)	4-13-91 (23)	3-30-91 (09)	4-15-91 (25)	4-13-91 (23)
BC6-MW1-3	3-18-91	3-29-91 (11)	3-22-91 (04)	3-21-91 (03)	3-23-91 (05)	3-27-91 (09)	3-28-91 (10)	4-16-91 (29)
BC6-MW2-3	3-16-91	3-29-91 (13)	3-22-91 (06)	3-21-91 (05)	3-23-91 (07)	3-27-91 (11)	3-28-91 (12)	3-24-91 (08)
BC6-MW3-3	3-16-91	3-30-91 (14)	3-22-91 (06)	3-21-91 (05)	3-23-91 (07)	3-27-91 (11)	3-28-91 (12)	3-24-91 (08)

TABLE G.2
SURFACE WATER SAMPLES HOLDING TIMES
110TH TASG MICHIGAN AIR NATIONAL GUARD
W.K. KELLOGG AIRPORT
BATTLE CREEK, MICHIGAN

Sample	Date Sample Collected	Volatiles by GC/MS (SW8240) (14 days)	ICP Metals (SW6010) (6 months)	Arsenic (SW7060) (6 months)	Lead (SW7421) (6 months)	Mercury (SW7470/7471) (28 days)	Selenium (SW7740) (6 months)	Thallium (SW7841) (6 months)
BC2-SW1-3	3-18-91	3-26-91 (08)	3-21-91 (03)	3-21-91 (03)	3-25-91 (07)	3-27-91 (09)	3-28-91 (10)	3-24-91 (06)
BC2-SW2-3	3-18-91	3-26-91 (08)	3-21-91 (03)	3-21-91 (03)	3-25-91 (07)	3-27-91 (09)	3-28-91 (10)	3-24-91 (06)
BC2-SW3-3	3-18-91	3-26-91 (08)	3-21-91 (03)	3-21-91 (03)	3-25-91 (07)	3-27-91 (09)	3-28-91 (10)	3-24-91 (06)
BC2-SW4-3	3-18-91	3-26-91 (08)	3-21-91 (03)	3-21-91 (03)	3-25-91 (07)	3-27-91 (09)	3-28-91 (10)	3-24-91 (06)
BC7-SW1-3	3-18-91	3-26-91 (08)	3-21-91 (03)	3-21-91 (03)	3-25-91 (07)	3-27-91 (09)	3-28-91 (10)	3-24-91 (06)

TABLE G.3
SEDIMENT SAMPLES HOLDING TIMES
110TH TASG MICHIGAN AIR NATIONAL GUARD
W.K. KELLOGG AIRPORT
BATTLE CREEK, MICHIGAN

Sample	Date Sample Collected	Arsenic (SW7060) (6 months)	Lead (SW7421) (6 months)	Mercury (SW7470/7471) (28 days)	Selenium (SW7740) (6 months)	Thallium (SW7841) (6 months)	Volatiles by GC/MS (SW8240) (14 days)	Semi-Volatile Organics (SW8270) Date Extracted (14 days)	Semi-Volatile Organics (SW8270) Date Analyzed (40 days)	ICP Metals (SW6010) (6 months)
BC2-SED1-3	3-14-91	4-12-91 (29)	3-21-91 (07)	3-27-91 (13)	4-12-91 (29)	4-12-91 (29)	3-21-91 (07)	3-20-91 (06)	4-06-91 (17)	3-21-91 (07)
BC2-SED2-3	3-14-91	4-12-91 (29)	3-21-91 (07)	3-27-91 (13)	4-12-91 (29)	4-12-91 (29)	3-22-91 (08)	3-20-91 (06)	3-23-91 (03)	3-21-91 (07)
BC2-SED3-3	3-14-91	4-12-91 (29)	3-21-91 (07)	3-27-91 (13)	4-12-91 (29)	4-12-91 (29)	3-20-91 (06)	3-20-91 (06)	3-23-91 (03)	3-21-91 (07)
BC2-SED4-3	3-14-91	4-12-91 (29)	3-21-91 (07)	3-27-91 (13)	4-12-91 (29)	4-12-91 (29)	3-22-91 (08)	3-20-91 (06)	3-23-91 (03)	3-21-91 (07)
BC2-SED5-3	3-14-91	4-12-91 (29)	3-21-91 (07)	3-27-91 (13)	4-12-91 (29)	4-12-91 (29)	3-21-91 (07)	3-20-91 (06)	3-23-91 (03)	3-21-91 (07)
BC2-SED6-3	3-14-91	4-12-91 (29)	3-21-91 (07)	3-27-91 (13)	4-12-91 (29)	4-12-91 (29)	3-21-91 (07)	3-20-91 (06)	3-23-91 (03)	3-21-91 (07)
BC2-SED7-3	3-14-91	4-12-91 (29)	3-21-91 (07)	3-27-91 (13)	4-12-91 (29)	4-12-91 (29)	3-22-91 (08)	3-20-91 (06)	3-22-91 (02)	3-21-91 (07)
BC2-SED10-3	3-14-91	4-12-91 (29)	3-21-91 (07)	3-27-91 (13)	4-12-91 (29)	4-12-91 (29)	3-22-91 (08)	3-20-91 (06)	3-23-91 (03)	3-21-91 (07)

TABLE G.4
SOIL SAMPLES HOLDING TIMES
110TH TASG MICHIGAN AIR NATIONAL GUARD
W.K. KELLOGG AIRPORT
BATTLE CREEK, MICHIGAN

Sample	Date Sampled Collected	Purgeable Aromatic Organics (SW8020)/(14 days)	Total Petroleum Hydrocarbons (E418.1) (28 days)
BC6-BKG	3-25-91	4-08-91 (14)	4-09-91 (15)
BC6-SB1-0	3-25-91	4-05-91 (11)	4-09-91 (15)
BC6-SB1-2	3-25-91	4-08-91 (14)	4-09-91 (15)
BC6-SB2-0	3-25-91	4-08-91 (14)	4-09-91 (15)
BC6-SB2-2	3-25-91	4-08-91 (14)	4-09-91 (15)
BC6-SB3-0	3-25-91	4-05-91 (11)	4-09-91 (15)
BC6-SB3-2	3-25-91	4-05-91 (11)	4-09-91 (15)
BC6-SB6-0	3-25-91	4-05-91 (11)	4-09-91 (15)
BC6-SB6-4	3-25-91	4-05-91 (11)	4-09-91 (15)
BC6-SB7-0	3-25-91	4-05-91 (11)	4-09-91 (15)
BC6-SB7-4	3-25-91	4-08-91 (14)	4-09-91 (15)
BC7-SB1-0	3-25-91	4-08-91 (14)	4-09-91 (15)

TABLE G.5
QA SAMPLES HOLDING TIMES
MARCH/APRIL 1991
110TH TASG MICHIGAN AIR NATIONAL GUARD
W.K. KELLOGG AIRPORT
BATTLE CREEK, MICHIGAN

Sample	Date Sample Collected	Volatiles By GC/MS (SW8240) (14 days)	Semivolatile Organics (SW8270) Extracted (14 days)	Semivolatile Organics (SW8270) Analyzed (40 days)	ICP Metals (SW6010) (6 months)	Purgeable Aromatic Organics (SW8020)/ (14 days)	Total Petroleum Hydrocarbon (E418.1) (28 days)	Arsenic (SW7060) (6 months)	Lead (SW7421) (6 months)	Mercury (SW7470/ 7471) (28 days)	Selenium (SW7740) (6 months)	Thallium (SW7841) (6 months)
BC-TB1-3	3-15	3-25 (10)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BC-TB2-3	3-15	3-26 (11)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BC-TB3-3	3-16	3-26 (10)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BC-TB4-3	3-19	3-27 (08)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BC-TB5-3	3-20	3-30 (10)	NA	NA	3-25 (05)	NA	NA	NA	NA	NA	NA	NA
BC-TB6-3	3-21	3-28 (07)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BC-TB7-3	3-25	NA	NA	NA	NA	3-31 (06)	NA	NA	NA	NA	NA	NA
BC-FB1-3	3-15	3-26 (11)	3-20 (05)	3-26 (06)	3-21 (06)	NA	NA	3-21 (06)	3-25 (10)	3-26 (11)	3-28 (13)	3-23 (08)
BC-FB2-3	3-15	3-26 (11)	3-20 (05)	4-14 (26)	NA	NA	NA	3-21 (06)	3-25 (10)	3-26 (11)	3-28 (13)	3-23 (08)
BC-FB3-3	3-25	NA	NA	NA	NA	3-31 (06)	4-10 (16)	NA	NA	NA	NA	NA
BC-FB4-3	3-25	NA	NA	NA	NA	3-31 (06)	4-10 (16)	NA	NA	NA	NA	NA
BC-RB1-3	3-14	3-25 (11)	3-20 (05)	3-26 (06)	3-21 (07)	NA	NA	3-21 (07)	3-26 (12)	3-26 (12)	3-29 (13)	3-23 (09)
BC-RB2-3	3-15	3-26 (11)	NA	NA	3-21 (06)	NA	NA	3-21 (06)	3-26 (11)	3-26 (11)	3-28 (13)	3-23 (08)
BC-RB3-3	3-18	3-30 (12)	NA	NA	3-22 (04)	NA	NA	3-21 (03)	3-27 (09)	3-27 (09)	3-28 (10)	4-16 (29)
BC-RB4-3	3-21	3-30 (09)	NA	NA	3-27 (06)	NA	NA	NA	NA	NA	NA	NA
BC-RB5-3	3-25	NA	NA	NA	NA	3-31 (06)	4-10 (16)	NA	NA	NA	NA	NA

TABLE G.6
110TH TASG, MICHIGAN AIR NATIONAL GUARD
W.K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Batch Number	Sample	Batch Number	Sample
32129	BC2-SED1-3	32353	BC-FB3-3
(B00001)	BC2-SED2-3	(B00005)	BC-RB4-3
	BC2-SED3-3		BC-RB5-3
	BC2-SED4-3		BC-TB7-3
	BC2-SED5-3		
	BC2-SED6-3		
	BC2-SED7-3		
	BC2-SED10-3		
			BC6-BKG
32129	BC-FB1-3		BC6-SB1-0
(B00002)	BC-FB2-3		BC6-SB1-2
	BC-RB1-3		BC6-SB2-0
	BC-RB2-3		BC6-SB2-2
	BC-TB1-3		BC6-SB3-0
	BC-TB2-3		BC6-SB3-2
	BC-MW1-3		BC6-SB6-0
	BC-SW1-3		BC6-SB6-4
	BC2-SW2-3		
	BC2-SW3-3		
	BC2-SW4-3		
	BC4-MW2-3		
	BC4-MW3-3		
	BC4-MW4-3		
	BC7-SW1-3		
			BC6-SB7-0
32180	BC-RB3-3		BC6-SB7-4
(B00003)	BC-TB3-3		BC7-SB1-0
	BC-MW10-3		
	BC-MW11-3		
	BC-MW12-3		
	BC-MW9-3		
	BC2-MW1-3		
	BC3-MW1-3		
	BC3-MW2-3		
	BC3-MW3-3		
	BC3-MW4-3		
	BC6-MW1-3		
	BC6-MW2-3		
	BC6-MW3-3		
	BC7-MW1-3		

TABLE G.6--Continued
110TH TASG, MICHIGAN AIR NATIONAL GUARD
W.K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Batch Number	Sample	Batch Number	Sample
32202	BC-TB4-3		
(B00004)	BC-MW1-3		
	BC-MW14-3		
	BC-MW4-3		
	BC-MW5-3		
	BC-MW6-3		
	BC7-MW2-3		
	BC7-MW3-3		
32229	BC-TB5-3		
(B00004)	BC-MW13-3		
	BC-MW2-3		
	BC-MW3-3		
	BC-MW8-3		
	BC3-MW5-3		
32285	BC-RB4-3		
(B00004)	BC-TB6-3		
	BC-MW15-3		
	BC-MW7-3		
	BC3-MW6-3		
	BC5-MW1-3		

TABLE G.7
FIELD AND RINSEATE BLANK ANALYTICAL DATA - MARCH 1991
110TH TASG, MICHIGAN AIR NATIONAL GUARD
W.K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Parameter	BC-RB1-3	BC-RB2-3	BC-RB3-3	BC-RB4-3	BC-RB5-3	BC-FB1-3	BC-FB2-3	BC-FB3-3	BC-FB4-3
Volatiles (SW8240) (ug/l)									
Chloroform	26	38	56	U	NA	44	1	NA	NA
Bromodichloromethane	U	U	U	U	NA	U	3	NA	NA
Dibromochloromethane	U	U	U	U	NA	U	8	NA	NA
Bromoform	U	U	U	U	NA	U	5	NA	NA
2-Butanone	U	U	R	20JB	NA	U	U	NA	NA
Toluene	U	U	U	1J	NA	U	U	NA	NA
Purgeable Aromatic Organics (SW8020)									
All analyses	NA	NA	NA	NA	U	NA	NA	U	U
Total Petroleum Hydrocarbons(418.1)									
All analyses	NA	NA	NA	NA	U	NA	NA	U	U
Semivolatiles(SW8270) (ug/l)									
bis(2-Ethylhexyl)phthalate	89	NA	NA	NA	NA	17JB	270JB	NA	NA
Priority Pollutant Metals (mg/l)									
Copper	U	U	U	U	NA	U	80.3	NA	NA
Zinc	U	38	U	U	NA	U	71	NA	NA

B - Compound found in the method blank

NA - Not Analyzed

TABLE G.8
QA SAMPLE IDENTIFICATION
110TH TASG MICHIGAN AIR NATIONAL GUARD
W.K. KELLOGG AIRPORT
BATTLE CREEK, MICHIGAN

QA Identification			QA Identification			QA Identification		
Trip Blank	Date Sampled	Associated Sample Identification	Field Blank	Date Sampled	Associated Sample Identification	Rinsate Blank	Date Sampled	Associated Sample Identification
BC-TB1-3	3-15-91	BC2-SED1-3	BC-FB1-3	3-15-91	BC2-SED1-3	BC-RB1-3	3-14-91	BC2-SED1-3
BC-TB1-3	3-15-91	BC2-SED1-3	BC-FB1-3	3-15-91	BC2-SED1-3	BC-RB1-3	3-14-91	BC2-SED1-3
		BC2-SED2-3	BC-FB2-3	3-15-91	BC2-SED2-3			BC2-SED2-3
		BC2-SED3-3			BC2-SED3-3			BC2-SED3-3
		BC2-SED4-3			BC2-SED4-3			BC2-SED4-3
		BC2-SED5-3			BC2-SED5-3			BC2-SED5-3
(BC2-SED10-3)		BC2-SED5-3 DUP			BC2-SED6-3			BC2-SED6-3
		BC2-SED6-3			BC2-SED7-3			BC2-SED7-3
		BC2-SED7-3	(BC2-SED10-3)		BC2-SED5-3 DUP			BC2-SED10-3
		BC-MW1-3			BC-MW2-3			BC4-MW1-3
		BC-RB1-3			BC-MW3-3			
					BC-MW8-3	BC-RB2-3	3-15-91	BC3-MW1-3
BC-TB2-3	3-16-91	BC4-MW2-3			BC-MW9-3			BC3-MW2-3
		BC4-MW3-3			BC-MW10-3			BC3-MW3-3
		BC4-MW4-3			BC-MW11-3			BC3-MW4-3
					BC-MW12-3			BC4-MW2-3
BC-TB3-3	3-16-91	BC-MW9-3			BC-MW13-3			BC4-MW3-3
		BC-MW10-3			BC2-MW1-3			BC4-MW4-3
		BC-MW11-3			BC3-MW1-3			BC6-MW2-3
		BC-MW12-3			BC3-MW2-3			BC6-MW3-3
		BC2-MW1-3	(BC7-MW1-3)		BC3-MW2-3 DUP	(BC7-MW1-3)		BC3-MW2-3 DU
		BC3-MW1-3			BC3-MW3-3			
		BC3-MW2-3			BC3-MW4-3	BC-RB3-3	3-18-91	BC-MW9-3

TABLE G.8--Continued
QA SAMPLE IDENTIFICATION
110TH TASG MICHIGAN AIR NATIONAL GUARD
W.K. KELLOGG AIRPORT
BATTLE CREEK, MICHIGAN

QA Identification			QA Identification			QA Identification		
Trip Blank	Date Sampled	Associated Sample Identification	Field Blank	Date Sampled	Associated Sample Identification	Rinsate Blank	Date Sampled	Associated Sample Identification
BC-TB1-3	3-15-91	BC2-SED1-3	BC-FB1-3	3-15-91	BC2-SED1-3	BC-RB1-3	3-14-91	BC2-SED1-3
(BC3-MW2-3 DUP)		BC7-MW1-3			BC3-MW5-3			BC-MW10-3
		BC3-MW3-3			BC4-MW2-3			BC-MW11-3
		BC3-MW4-3			BC4-MW3-3			BC-MW12-3
		BC6-MW1-3			BC4-MW4-3			BC2-MW1-3
		BC6-MW2-3			BC6-MW1-3			BC6-MW1-3
		BC6-MW3-3			BC6-MW2-3			
		BC2-SW1-3			BC6-MW3-3	BC-RB4-3	3-21-91	BC-MW7-3
		BC2-SW2-3			BC-SW1-3			BC-MW15-3
(BC7-SW1-3)		BC2-SW2-3 DUP			BC2-SW2-3			BC3-MW6-3
		BC2-SW3-3	(BC7-SW1-3)		BC2-SW2-3 DUP			BC5-MW1-3
		BC2-SW4-3			BC2-SW3-3			
					BC2-SW4-3			
BC-TB4-3	3-20-91	BC-MW6-3	BC-FB4-3	3-25-91	BC6-BKG	BC-RB5-3	3-25-91	BC6-BKG
		BC-MW14-3	BC-FB3-3	3-25-91	BC6-SB1-0			BC6-SB1-0
		BC-MW5-3			BC6-SB1-2			BC6-SB1-2
(BC7-MW2-3)		BC-MW5-3 DUP			BC6-SB2-0			BC6-SB2-0
		BC-MW4-3			BC6-SB2-2			BC6-SB2-2
(BC7-MW3-3)		BC-MW4-3 DUP			BC6-SB3-0			BC6-SB3-0
		BC-MW1-3			BC6-SB3-2			BC6-SB3-2
					BC6-SB6-0			BC6-SB6-0

TABLE G.8--Continued
QA SAMPLE IDENTIFICATION
110TH TASG MICHIGAN AIR NATIONAL GUARD
W.K. KELLOGG AIRPORT
BATTLE CREEK, MICHIGAN

QA Identification			QA Identification			QA Identification		
Trip Blank	Date Sampled	Associated Sample Identification	Field Blank	Date Sampled	Associated Sample Identification	Rinsate Blank	Date Sampled	Associated Sample Identification
BC-TB1-3	3-15-91	BC2-SED1-3	BC-FB1-3	3-15-91	BC2-SED1-3	BC-RB1-3	3-14-91	BC2-SED1-3
BC-TB5-3	3-20-91	BC-MW2-3			BC6-SB6-4			BC6-SB6-4
		BC-MW3-3			BC6-SB7-0			BC6-SB7-0
		BC-MW8-3			BC6-SB7-4			BC6-SB7-4
		BC-MW13-3	(BC7-SB1-0)		BC6-SB7-4 DUP	(BC7-SB1-0)		BC6-SB7-4 DUP
		BC3-MW5-3						
BC-TB6-3	3-21-91	BC-MW7-3						
		BC-MW15-3						
		BC3-MW6-3						
		BC5-MW1-3						
BC-TB7-3	3-25-91	BC6-BKG						
		BC6-SB1-0						
		BC6-SB1-2						
		BC6-SB2-0						
		BC6-SB2-2						
		BC6-SB6-0						
		BC6-SB6-4						
		BC6-SB7-0						
		BC6-SB7-4						
		BC6-SB3-0						
		BC6-SB3-2						
(BC7-SB1-0)		BC6-SB3-2 DUP						

TABLE G.9
FIELD DUPLICATE ANALYTICAL DATA - MARCH 1991
110TH TASG, MICHIGAN AIR NATIONAL GUARD
W.K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Parameter	BC-MW4-3	Duplicate BC7-MW3-3	RPD	BC-MW5-3	Duplicate BC7-MW2-3	RPD	BC3-MW2-3	Duplicate BC3-MW1-3	RPD
Volatiles (ug/l)									
Acetone	ND	ND		ND	ND		ND	480J	
Trans-1,2-Dichloroethene	ND	ND		ND	ND		ND	1200	
1,1,1-Trichloroethane	.9J	.9J	0%	.5J	.6J	18%	ND	ND	
Trichloroethene	4	4	0%	5	6	18%	ND	3J	
Benzene	ND	ND		ND	ND		200	190	5%
Toluene	ND	ND		ND	ND		200	240	18%
Ethylbenzene	ND	ND		ND	ND		100	82	20%
Xylenes	ND	ND		ND	ND		980	770	24%
Priority Pollutant Metals (mg/l)									
Zinc	ND	ND		132	99.2	28%	ND	ND	
Arsenic	ND	ND		ND	ND		91.5J	65.35J	33%

TABLE G.9--Continued
FIELD DUPLICATE ANALYTICAL DATA - MARCH 1991
110TH TASG, MICHIGAN AIR NATIONAL GUARD
W.K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Parameter	BC2-SW2-3	Duplicate BC7-SW1-3	RPD	BC2-SED5-3	Duplicate BC7-SED10-3	RPD	BC6-SB7-4	Duplicate BC7-SB1-0	RPD
Semivolatiles									
Fluoranthene	6J	ND		19000	30000	45%	NA	NA	
Phenanthrene	ND	ND		8000	17000	72%	NA	NA	
Di-n-butylphthalate	ND	ND		ND	32000	---	NA	NA	
Pyrene	ND	ND		17000J	ND	---	NA	NA	
Benzo(a)anthracene	ND	ND		7100	17000	82%	NA	NA	
bis(2-ethylhexyl)phthalate	ND	ND		3300J	ND	---	NA	NA	
Chrysene	ND	ND		12000	22000	59%	NA	NA	
Benzo(b)fluoranthene	ND	ND		14000	25000	56%	NA	NA	
Benzo(k)fluoranthene	ND	ND		12000	18000	40%	NA	NA	
Benzo(a)pyrene	ND	ND		9800	19000	64%	NA	NA	
Indeno(1,2,3-cd)pyrene	ND	ND		7200	13000	57%	NA	NA	
Benzo(g, h, i)perylene	ND	ND		7000	13000	60%	NA	NA	
Anthracene	ND	ND		U	2700J	---	NA	NA	
Metals									
Beryllium	ND	ND		ND	0.74		NA	NA	
Cadmium	ND	ND		14.4	4.5	'105%	NA	NA	
Chromium	11.6	13.9	18%	39.6	31.2	24%	NA	NA	
Copper	64.5	77.3	18%	161	45.6	'112%	NA	NA	
Nickel	11.5	13.6	17%	28.2	24	16%	NA	NA	
Silver	ND	ND		8.5	7.8	9%	NA	NA	
Zinc	54.7	200	'114%	324J	211J	42%	NA	NA	

TABLE G.9--Continued
FIELD DUPLICATE ANALYTICAL DATA - MARCH 1991
110TH TASG, MICHIGAN AIR NATIONAL GUARD
W.K. KELLOGG MEMORIAL AIRPORT
BATTLE CREEK, MICHIGAN

Parameter	BC2-SW2-3	Duplicate BC7-SW1-3	RPD	BC2-SED5-3	Duplicate BC2-SED10-3	RPD	BC6-SB7-4	Duplicate BC7-SB1-0	RPD
Arsenic	ND	ND		28.3	68J	82%	NA	NA	
Lead	87.7	96.9	10%	250	169	39%	NA	NA	
Mercury	0.2	0.2	0%	.21J	0.12J	55%	NA	NA	
Thallium	56	ND		ND	ND		NA	NA	
Total Petroleum Hydrocarbons (mg/kg) Results	NA	NA		NA	NA		17	13	27%