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PART I

Bioventing Pilot Test Work Plan for Installation Restoration Program Site 3 Fire Training Area Battle Creek ANGB, Michigan

PART II

Draft Interim Pilot Test Results Report for Installation Restoration Program Site 3 Fire Training Area Battle Creek ANGB, Michigan

Prepared For

Air Force Center for Environmental Excellence
Brooks AFB, Texas

and

110th Tactical Fighter Group
Battle Creek ANGB, Michigan

ENGINEERING-SCIENCE

ES
Engineering-Science, Inc.

1700 BROADWAY, SUITE 900
DENVER, COLORADO 80290

November 1992

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PART I

BIOVENTING PILOT TEST WORK PLAN

FOR INSTALLATION RESTORATION PROGRAM SITE 3

FIRE TRAINING AREA

BATTLE CREEK ANGB, MICHIGAN

Prepared for:

Air Force Center for Environmental Excellence

Brooks AFB, Texas

and

110th Tactical Fighter Group

Battle Creek ANGB, Michigan

November 1992

Prepared by:

Engineering-Science, Inc.
1700 Broadway, Suite 900
Denver, Colorado 80290

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FIGURES

BIOVENTING TEST WORK PLAN FOR

INSTALLATION RESTORATION PROGRAM SITE 3
FIRE TRAINING AREA
BATTLE CREEK ANGB, MICHIGAN

1.0 INTRODUCTION

This work plan presents the scope of an *in situ* bioventing pilot test for treatment of fuel-contaminated soils at Installation Restoration Program (IRP) Site 3, Fire Training Area (Site 3), at the Battle Creek Air National Guard Base (ANGB), Michigan. Engineering-Science, Inc. (ES) will perform the testing. The pilot test has three primary objectives: 1) to assess the potential for supplying oxygen throughout the contaminated soil depth, 2) to determine the rate at which indigenous microorganisms will degrade fuel when supplied with oxygen-rich soil gas, and 3) to evaluate the potential for sustaining these rates of biodegradation until fuel contamination is remediated to concentrations below regulatory standards.

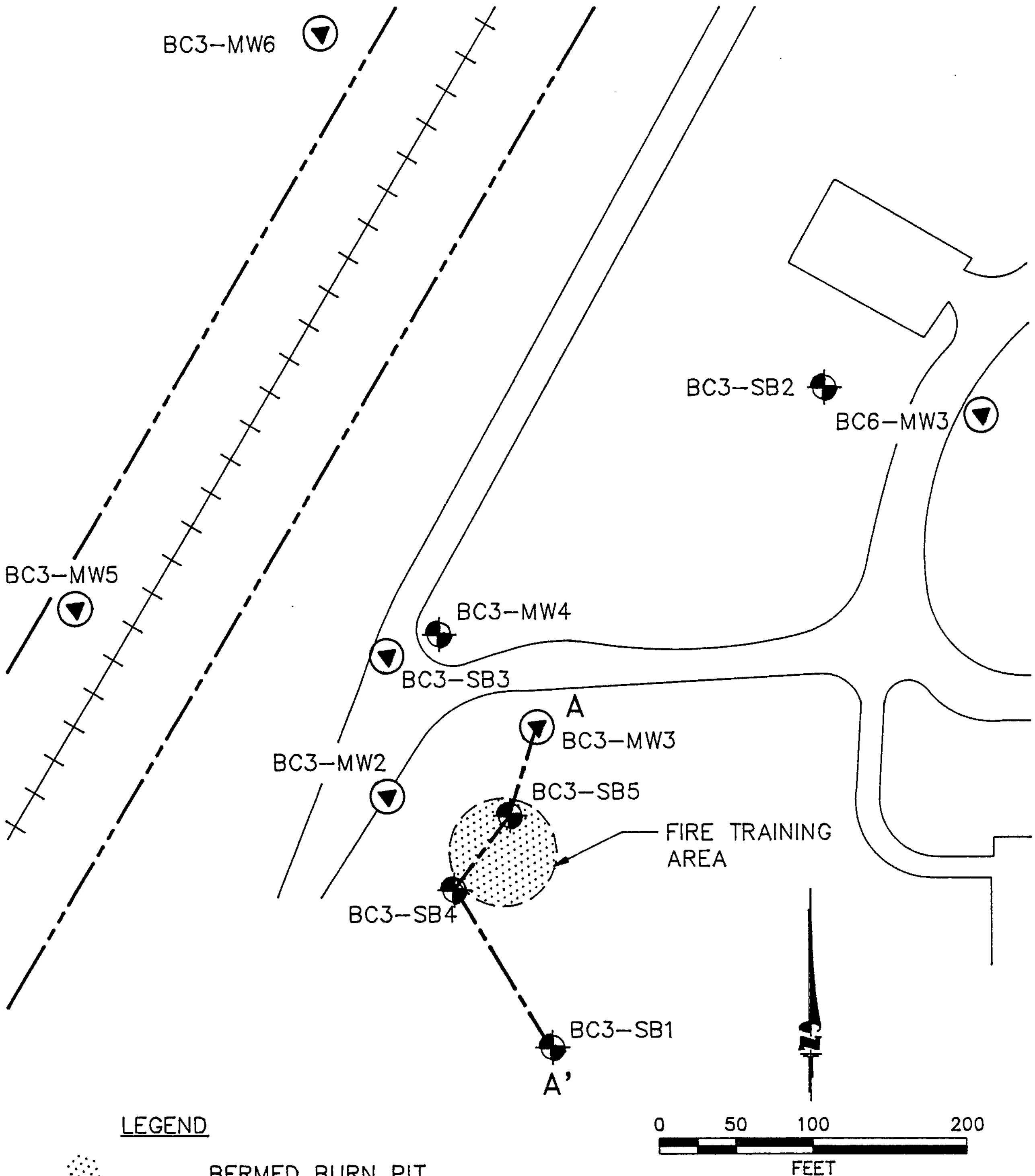
If bioventing proves to be an effective means of remediating soils at this site, pilot test data could be used to design a full-scale remediation system and to estimate the time required for site cleanup. An added benefit of the pilot testing at Site 3 is that a significant amount of the fuel contamination should be biodegraded during the 1-year pilot test, as the testing will take place within the most contaminated soils at the site.

Additional background information on the development and recent success of the bioventing technology is found in the document entitled *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing* (Hinchee et al., 1992). This protocol document provided earlier by the Air Force Center for Environmental Excellence will serve as the primary reference for pilot test well designs and detailed procedures to be used during the test.

2.0 SITE DESCRIPTION

2.1 Site Location and History

Site 3 is located in the western portion of the base, southwest of the Civil Engineering storage yard, and approximately 250 feet southeast of the railroad track (Figure 2.1). The fire training area is a circular area, approximately 70 feet in diameter, surrounded by an earthen berm.



LEGEND

- BERMED BURN PIT
- MONITORING WELL LOCATION
- SOIL BORING LOCATION
- CROSS-SECTION LOCATION
- BASE BOUNDARY
- RAILROAD

FIGURE 2.1

SITE MAP
IRP SITE 3
FIRE TRAINING AREA

BATTLE CREEK ANGB, MICHIGAN

ENGINEERING-SCIENCE, INC.
Denver, Colorado

26814-02, 07/28/92 at 13:21

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 jet fuel, 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 Site 3 (not shown on map). The hydrocarbon and minor solvent contamination that resulted from training activities at this site are the targets for bioventing treatment.

2.2 Site Geology

Because the bioventing technology is applied to the unsaturated soils, this section primarily discusses soils above the aquifer. Site 3 is underlain by fine to coarse silty sands interlayered with gravel and cobbles. Downgradient of the site, fine, loamy sand with some pebbles was encountered throughout the borings for monitoring wells BC3-MW5 and BC3-MW6. The lithology of Site 3 is illustrated on Figure 2.2, which is a hydrogeologic cross section extending across Site 3. The location of the cross section is shown on Figure 2.1.

Groundwater is encountered at a depth of approximately 30 feet and flows in a northwesterly direction across the site with a gradient of approximately 0.003 foot per foot.

The generally coarse-grained nature of the soils on this site appear to be well-suited to the bioventing treatment. Trilevel soil vapor monitoring points will be positioned in three locations to study the subsurface oxygen distribution during the pilot test.

2.3 Site Contaminants

The primary contaminants on this site are fuel residuals which have migrated to the groundwater surface at a depth of approximately 30 feet. Analytical data for soil samples collected at Site 3 in 1988 are not quantifiable due to poor data quality and lack of quality assurance/quality control (QA/QC) procedures in the laboratory. Although the data are not quantifiable, the results reported by the laboratory indicate the presence of fuel constituents at Site 3. Total benzene, toluene, ethylbenzene, and xylenes (BTEX) in the soils were detected at a maximum concentration of approximately 7,000 milligrams per kilogram (mg/kg) at soil boring BC3-SB4 (Figure 2.1).

Groundwater analyses in 1989 and 1991 also indicated the presence of volatile organic compounds (VOCs) and priority pollutant metals. Compounds found included 1,2-dichloroethene (1,2-DCE), benzene, ethylbenzene, xylenes, acetone, 2-butanone, trichloroethane (TCE), toluene, arsenic (dissolved), and lead.

3.0 PILOT TEST ACTIVITIES

This section describes the work that will be performed by ES at Site 3. Activities to be performed include siting and construction of a central vent well (VW) and vapor monitoring points (MPs), an *in situ* respiration test, an air permeability test, and the installation of a long-term bioventing system at Site 3. Soil and soil gas

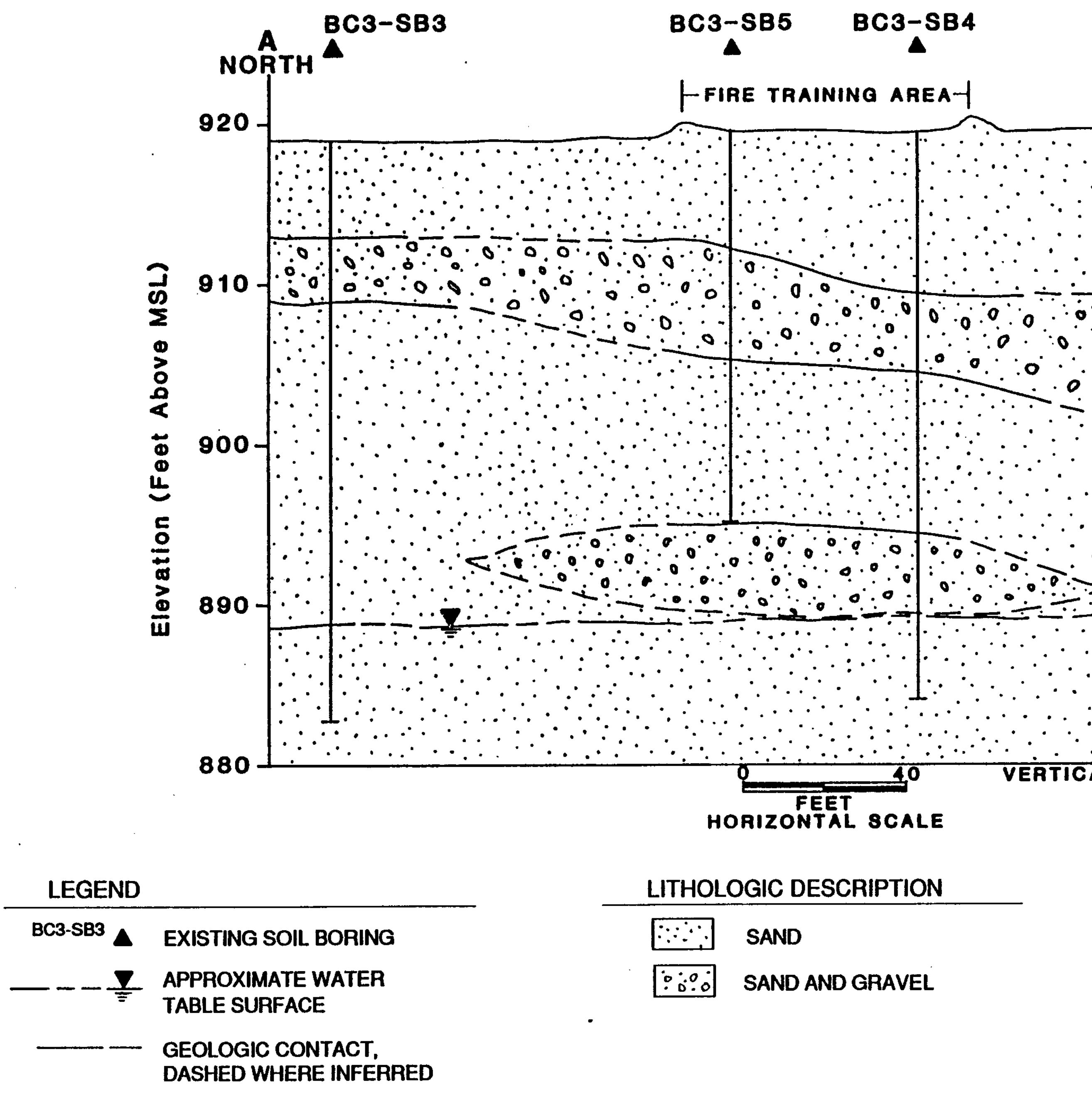


FIGURE 2.2

HYDROGEOLOGIC CROSS SECTION A-A'
IRP SITE 3
FIRE TRAINING AREA

BATTLE CREEK ANGB, MICHIGAN

ENGINEERING-SCIENCE, INC.
Denver, Colorado

ES

sampling procedures and the blower configuration that will be used to inject air (oxygen) into contaminated soils are also discussed in this section.

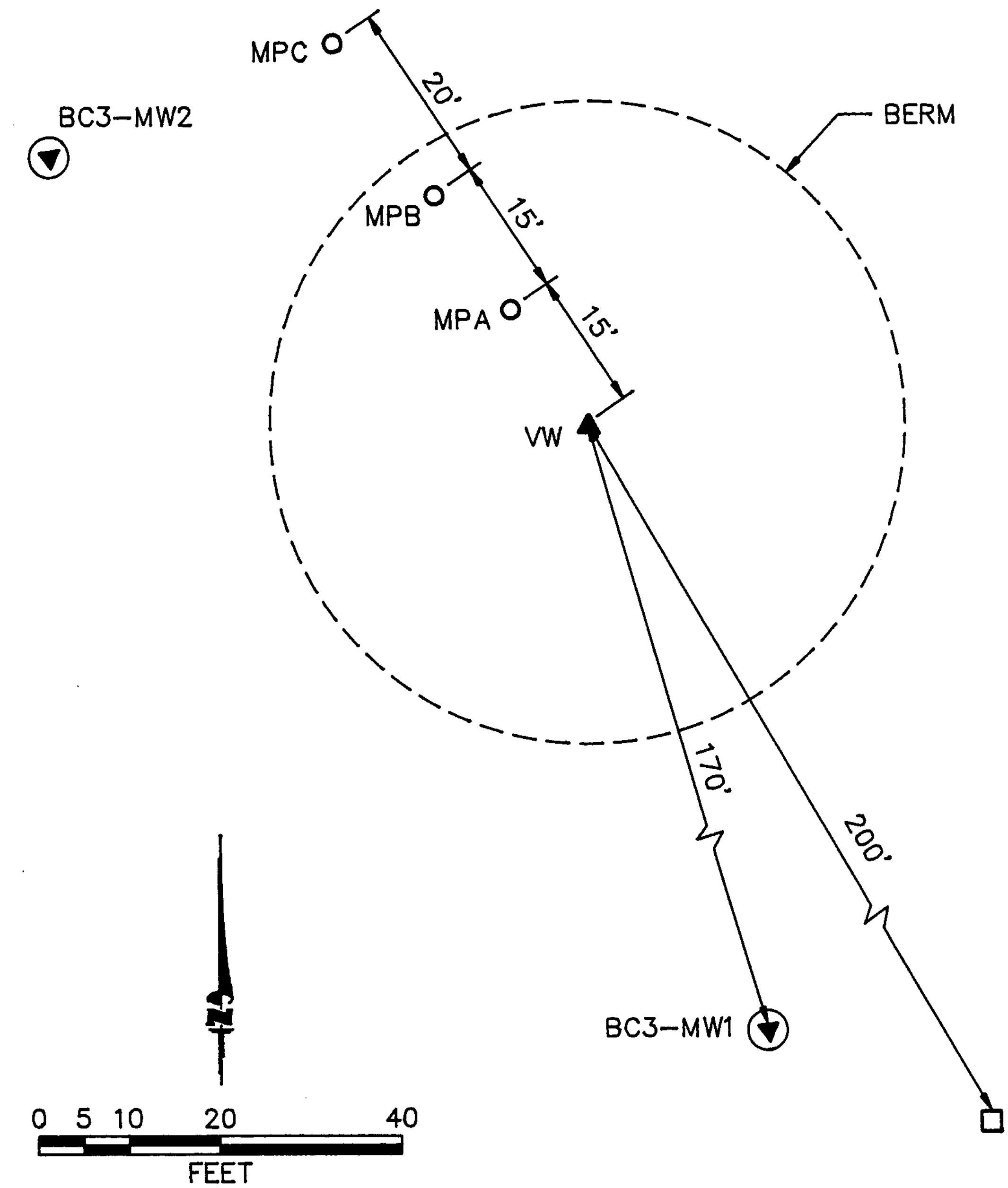
No dewatering will take place during the pilot test. Pilot test activities will be confined to unsaturated soils remediation. Existing monitoring wells will not be used as primary air injection wells. However, monitoring wells which have a portion of their screened interval above the water table may be used as vapor MPs or to measure the composition of background soil gas.

3.1 Location and Construction of Vent Well and Monitoring Points

A general description of criteria for siting a central VW and vapor MPs are included in the protocol document (Hinchee et al., 1992). Figure 3.1 indicates the proposed locations of the central VW and MPs at this site. The final location of these wells may vary slightly from the proposed location if significant fuel contamination is not observed in the boring for the central VW. Based on site investigation data, the central VW should be located in the center of the bermed fire training pit. Based on initial soil sampling this area is expected to have an average total petroleum hydrocarbon (TPH) concentration exceeding 5,000 mg/kg. Soils in this area are expected to be oxygen depleted (<2%), and increased biological activity should be stimulated by oxygen-rich soil gas ventilation during pilot test operations.

Due to the composition of the soils at this site, the radius of venting influence around the central air injection VW is expected to be 50 to 60 feet. Three vapor MPs (MPA, MPB, and MPC) will be located within a 50-foot radius of the central VW. A fourth vapor MP will be located approximately 200 feet southeast of the VW and will be used to measure background levels of oxygen and carbon dioxide and to determine if natural carbon sources are contributing to oxygen uptake during the in situ respiration test. Monitoring well BC3-MW1 may be used as a background MP if the screened intervals extend several feet above the water table, eliminating the need to install the fourth vapor MP. Additional details of the *in situ* respiration test procedures are presented in Section 5.7 of the protocol document.

The VW will be constructed of 4-inch inside-diameter (ID) Schedule 40 polyvinyl chloride (PVC), with a 20-foot interval of 0.04-inch slotted screen set from 10 feet bgs to the groundwater surface at 30 feet bgs. Flush-threaded PVC casing and screen with no organic solvents or glues will be used. The filter pack will be clean, well-rounded silica sand with a 6-9 grain size and will be placed in the annular space of the screened interval. A 2-foot layer of bentonite will be placed directly over the filter pack. The first 6 inches of bentonite will consist of bentonite pellets hydrated in place with potable water. This layer of pellets will prevent the addition of bentonite slurry from saturating the filter pack. The remaining 18 inches of bentonite will be fully hydrated and mixed aboveground, and the slurry will be tremied into the annular space to produce an air-tight seal above the screened interval. A complete seal is critical to prevent injected air from short-circuiting to the surface during the bioventing test. The remainder of the annular space will be filled with bentonite/cement grout. Figure 3.2 illustrates the proposed central vent well construction for this site.



LEGEND

MPA ○ MONITORING POINTS

VW ▲ CENTRAL VENT WELL (AIR INJECTION)

□ BACKGROUND MONITORING POINT

BC3-MW1 ▼ EXISTING GROUNDWATER MONITORING WELL

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FIGURE 3.1

PROPOSED VENT WELL/VAPOR MONITORING POINT LOCATIONS
IRP SITE 3
FIRE TRAINING AREA

BATTLE CREEK ANGB, MICHIGAN

ENGINEERING-SCIENCE, INC.
Denver, Colorado

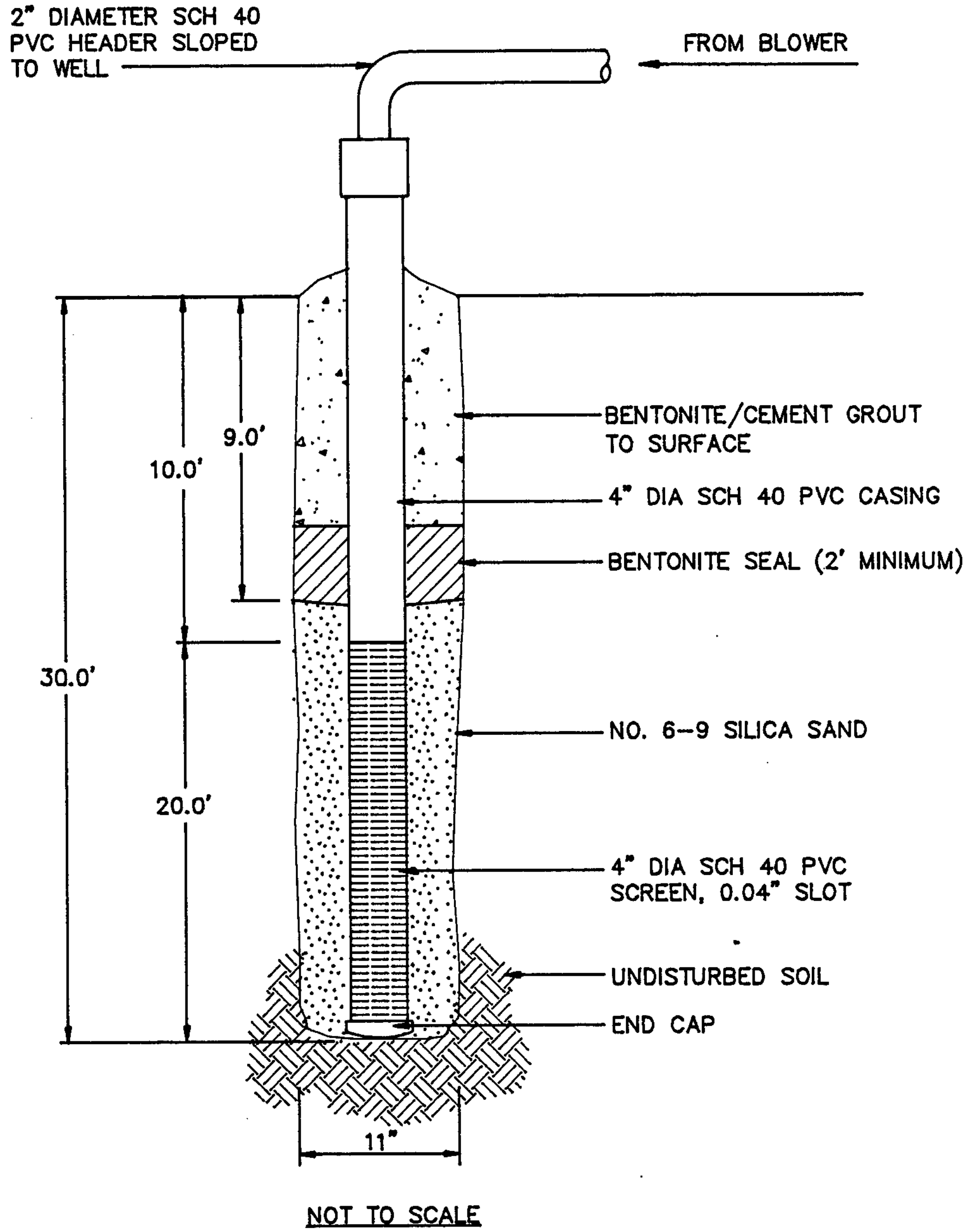

FIGURE 3.2

PROPOSED INJECTION VENT WELL CONSTRUCTION DETAIL
IRP SITE 3
FIRE TRAINING AREA

BATTLE CREEK ANGB, MICHIGAN

ENGINEERING-SCIENCE, INC.
Denver, Colorado

ES

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A typical multi-depth vapor MP installation for this site is shown in Figure 3.3. Soil gas oxygen and carbon dioxide concentrations will be monitored at depths of 8 feet, 18 feet, and 28 feet at each location. Multi-depth monitoring will confirm that the entire soil profile is receiving oxygen and be used to measure fuel biodegradation rates at these depths. The annular spaces between these three monitoring intervals will be sealed with bentonite to isolate the monitoring intervals. As for the central VW, several inches of bentonite pellets will be used to shield the filter pack from rapid infiltration of bentonite slurry additions. At the inner MP (MPA), thermocouples will also be installed at the same depths as the deepest and shallowest screens to measure soil temperatures. Additional details on VW and MP construction are presented in Section 4 of the protocol document (Hinchee et al., 1992).

3.2 Handling of Drill Cuttings

Drill cuttings from all borings will remain onsite. Cuttings will be temporarily placed on plastic then buried onsite within the bermed area.

3.3 Soil and Soil Gas Sampling

3.3.1 Soil Samples

Three soil samples will be collected from the pilot test area during the installation of the VW and MPs. One sample will be collected from the most contaminated interval of the central VW boring, and one sample will be collected from the interval of highest apparent contamination in each of the borings for the two inner MPs. Soil samples will be analyzed for total recoverable petroleum hydrocarbons (TRPH), BTEX, soil moisture, pH, particle sizing, alkalinity, total iron, and nutrients.

Samples collected for BTEX and TRPH analysis will be collected using a split-spoon sampler containing brass tube liners. Soil samples collected in the brass tubes will be immediately trimmed, and the ends will be sealed with aluminum foil or Teflon® fabric held in place by plastic caps. Soil samples collected for physical parameter analysis will be placed into appropriate sample containers. Soil samples will be labeled following the nomenclature specified in the protocol document (Section 5), wrapped in plastic, and placed in an ice chest for shipment. A chain-of-custody form will be filled out, and the ice chest will be shipped to the ES laboratory in Berkeley, California, for analysis. This laboratory has been audited by the U.S. Air Force and meets all QA/QC and certification requirements for the State of California.

3.3.2 Soil Gas Sampling

A total hydrocarbon vapor analyzer (see protocol document, Section 4.5.2) will be used during drilling to screen split-spoon samples for intervals of high fuel contamination. Initial and final soil gas samples will be collected in SUMMA® canisters from the central VW and the MPs closest to and furthest from the VW. These soil gas samples will be used to predict potential air emissions, to determine the reduction in BTEX and total volatile hydrocarbons (TVH) during the 1-year test, and to detect migration of these vapors from the source area.

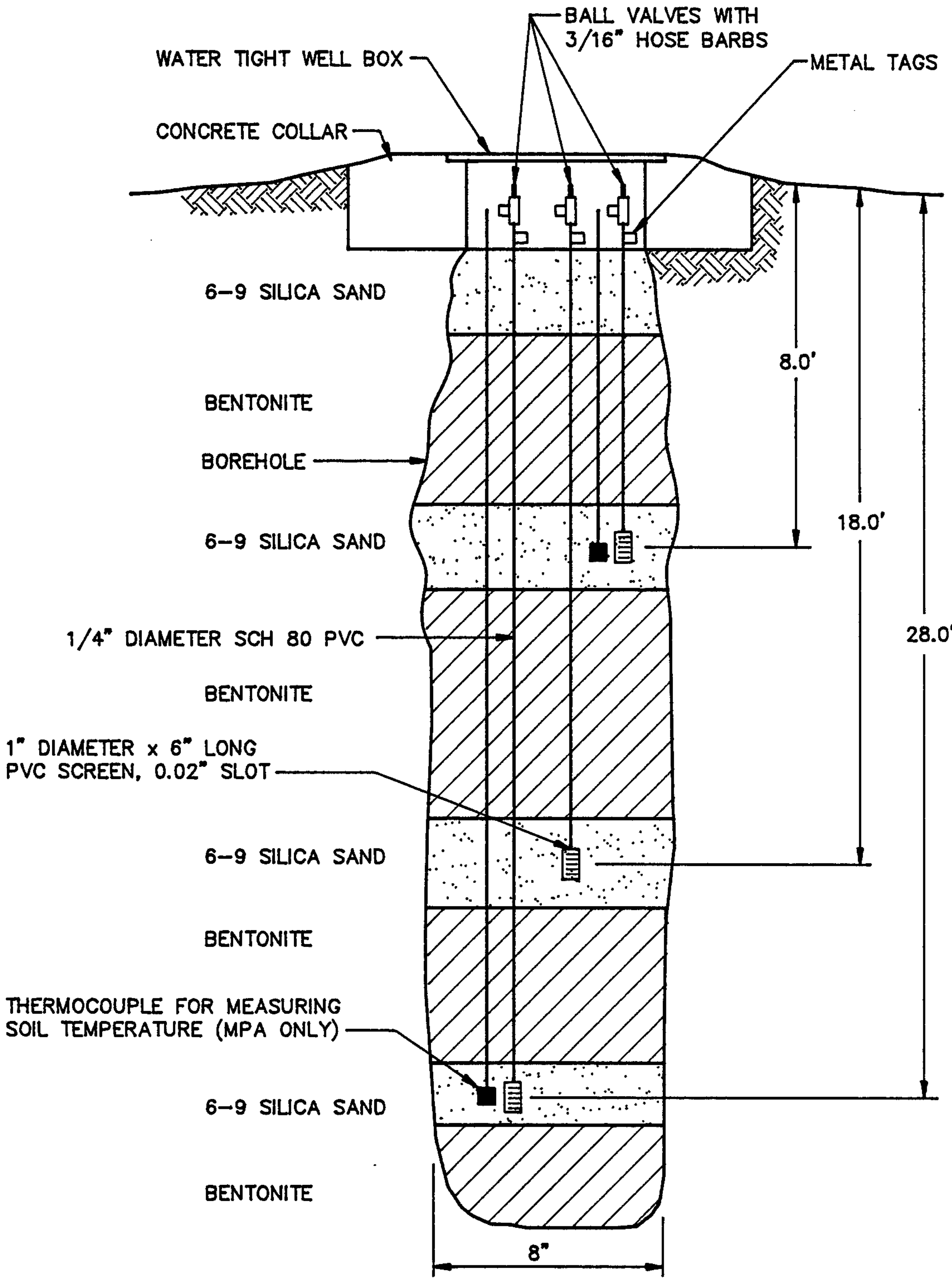


FIGURE 3.3

PROPOSED MONITORING POINT
CONSTRUCTION DETAIL
IRP SITE 3
FIRE TRAINING AREA

BATTLE CREEK ANGB, MICHIGAN

ENGINEERING-SCIENCE, INC.
Denver, Colorado

26814-04, 10/22/92 at 13:47

Soil gas samples will be placed in a small ice chest and packed with foam pellets to prevent excessive movement during shipment. Samples will not be sent on ice to prevent condensation of hydrocarbons. A chain-of-custody form will be filled out, and the ice chest will be shipped to the Air Toxics laboratory in Rancho Cordova, California for analysis.

3.4 Blower System

A 2.5-horsepower regenerative blower capable of injecting 50 standard cubic feet per minute (scfm) at 2 pounds per square inch will be used to conduct the initial air permeability test. Figure 3.4 is a schematic diagram of a typical air injection system used for pilot testing. The maximum power requirement anticipated for this pilot test is a 230-volt, single-phase, 30-amp service. Additional details on power supply requirements are described in Section 5.0, Base Support Requirements.

3.5 In Situ Respiration Test

The objective of the *in situ* respiration test is to determine the rate at which soil bacteria degrade petroleum hydrocarbons. Respiration tests will be performed at every vapor MP and VW interval where bacterial degradation of hydrocarbons is noted. These points are characterized by low oxygen levels and elevated carbon dioxide concentrations in the soil gas.

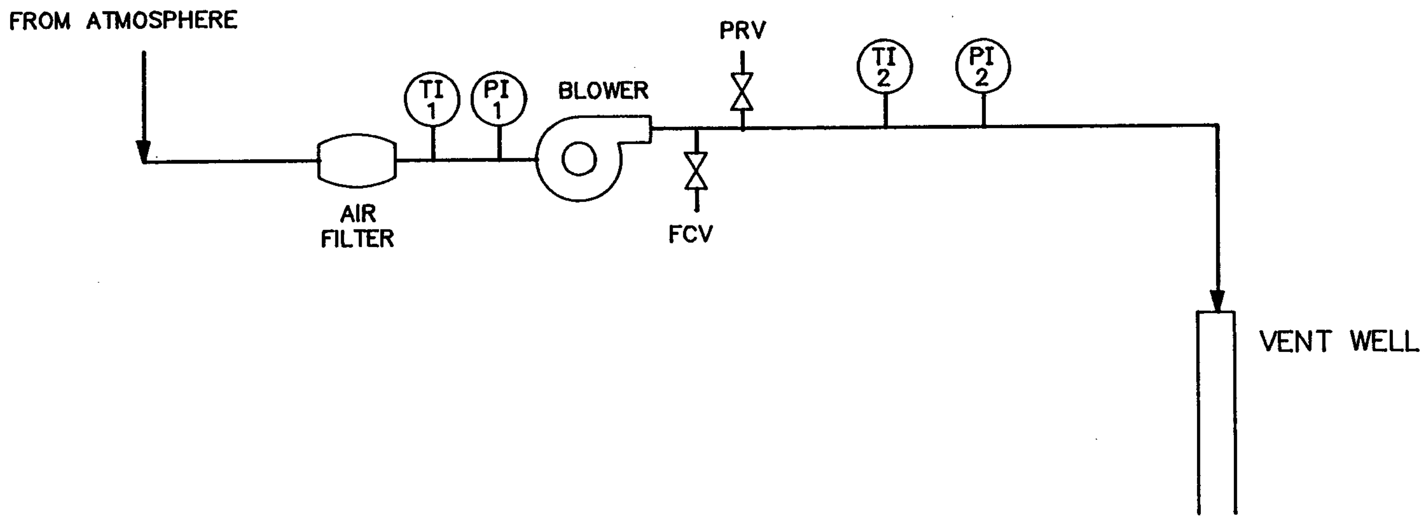
Air will be injected at each point containing low levels of oxygen (below 2%, approximately) for a 12-hour period to oxygenate local contaminated soils. The air injection equipment and methods to be used are described in detail in Section 5.2 of the protocol document (Hinchee et al., 1992). At the end of the 12-hour air injection period, the air supply will be cut off, and oxygen and carbon dioxide levels will be monitored for the following 48 hours. The decline in oxygen and increase in carbon dioxide concentrations over time will be used to estimate rates of bacterial degradation of fuel residuals. Helium will also be injected at one or two points to estimate oxygen diffusion rates in site soils.

3.6 Air Permeability Test

The objective of the air permeability test is to determine the extent of the subsurface that can be oxygenated using one air injection unit. Air will be injected into the 4-inch-diameter VW interval using the blower unit, and pressure responses will be measured at each MP with differential pressure gauges to determine the region influenced by the unit. Oxygen will also be monitored in the MPs to ascertain whether oxygen levels in the soil increase as the result of air injection. One air permeability test lasting 4 to 8 hours will be performed.

3.7 Extended Pilot Test Bioventing System

A long-term bioventing system will also be installed at Site 3. We request that the base electrician provide a power pole with a 230-volt, single phase, 30-amp breaker, one 230-volt receptacle, and two 110-volt receptacles. An electrician subcontracted to ES will be brought on base to assist in wiring the blowers to line power. The blower will be housed in a small, prefabricated shed to provide protection from the weather. The system will be operated for 1 year, and ES



LEGEND

PI 1	PRESSURE INDICATOR
TI 1	TEMPERATURE INDICATOR
FCV	FLOW CONTROL VALVE
PRV	PRESSURE RELIEF VALVE

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FIGURE 3.4

PROPOSED BLOWER SYSTEM INSTRUMENTATION DIAGRAM FOR AIR INJECTION IRP SITE 3 FIRE TRAINING AREA

BATTLE CREEK ANGB, MICHIGAN

ENGINEERING-SCIENCE, INC.
Denver, Colorado

personnel will be onsite in March and September 1993 to conduct *in situ* respiration tests to monitor the long-term performance of this bioventing system. Weekly system checks will be performed by Battle Creek ANGB personnel. If required, major maintenance of the blower unit will be performed by ES-Detroit personnel. Detailed blower system information and a maintenance schedule will be included in the operation and maintenance (O&M) manual provided to the base. More detailed information regarding the test procedures can be found in the protocol document.

4.0 EXCEPTIONS TO PROTOCOL PROCEDURES

The procedures that will be used to measure the air permeability of the soil and *in situ* respiration rates are described in Sections 4 and 5 of the protocol document (Hinchee et al., 1992). No exceptions to the protocol document procedures are anticipated.

5.0 BASE SUPPORT REQUIREMENTS

5.1 Test Preparation

The following base support is needed prior to the arrival of a driller and the ES test team:

- Confirmation of regulatory approval for the pilot test.
- Assistance in obtaining a digging permit.
- Installation of a new power line from the metal building northeast of Site 3 to a new power pole in the center of the Fire Training Area. The pole should include a 230-volt, single phase, 30-amp service, and a breaker box with one 230-volt receptacle and two 110-volt receptacles.
- Provision of any paperwork required to obtain gate passes and security badges for approximately three ES employees and two drillers. Vehicle passes will be needed for two trucks and a drill rig.

5.2 Initial Pilot Test

During the initial 3-week pilot test, the following base support is needed:

- Twelve square feet of desk space and a telephone in a building located as near to the site as practical.
- The use of a fax machine for transmitting 15 to 20 pages of test results.
- A decontamination pad where the driller can clean augers between borings.

5.3 Extended Pilot Test

During the 1-year extended pilot test, the following base support is needed:

- Check the blower system once a week to ensure that it is operating, change filters when required, and to record the air injection pressure. ES will provide a brief training session on this procedure.

- If the blower or motor stops working, notify Mr. Doug Downey or Ms. Gail Saxton, ES-Denver, (303) 831-8100, or Mr. Jim Williams, AFCEE, (800) 821-4528, ext. 246.
- Arrange site access for an ES technician to conduct *in situ* respiration tests at approximately 6 months and at 1 year after the initial pilot test.

6.0 PROJECT SCHEDULE

The following schedule is anticipated for this pilot test:

Event	**Date**
Test Work Plan to AFCEE/Battle Creek	4 August 1992
Approval to Proceed	13 August 1992
Begin Pilot Test	8 September 1992
Complete Initial Pilot Test	23 September 1992
Interim Results Report	3 November 1992
Respiration Test	March 1993
Final Respiration Test	September 1993

7.0 POINTS OF CONTACT

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Mr. Doug Downey
Engineering-Science, Inc.
1700 Broadway, Suite 900
Denver, CO 80290
(303) 831-8100
Fax (303) 831-8208

8.0 REFERENCES

Hinchee, R.E., S.K. Ong, R.N. Miller, D.C. Downey. 1992. *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing*. Prepared for USAF Center for Environmental Excellence. May.

HMTC, 1987.

SECTION 2

PART II

DRAFT

INTERIM PILOT TEST RESULTS REPORT FOR INSTALLATION RESTORATION PROGRAM SITE 3 FIRE TRAINING AREA BATTLE CREEK ANGB, MICHIGAN

Prepared for:

Air Force Center for Environmental Excellence

Brooks AFB, Texas

and

110th Tactical Fighter Group

Battle Creek ANGB, Michigan

November 1992

Prepared by:

Engineering-Science, Inc.
1700 Broadway, Suite 900
Denver, Colorado 80290

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PART II

DRAFT
INTERIM PILOT TEST RESULTS REPORT
FOR INSTALLATION RESTORATION PROGRAM SITE 3
FIRE TRAINING AREA
BATTLE CREEK ANGB, MICHIGAN

An initial bioventing pilot test was completed at the Installation Restoration Program (IRP) Fire Training Area Site 3 at Battle Creek Air National Guard Base (ANGB), Michigan during the period of 9 through 15 September 1992. The purpose of this Part II report is to describe the results of the initial pilot test at Site 3 and to make specific recommendations for extended testing to determine the long-term impact of bioventing on site contaminants. Descriptions of the history, geology, and contamination in the Fire Training Area are contained in Part I, the Bioventing Pilot Test Work Plan.

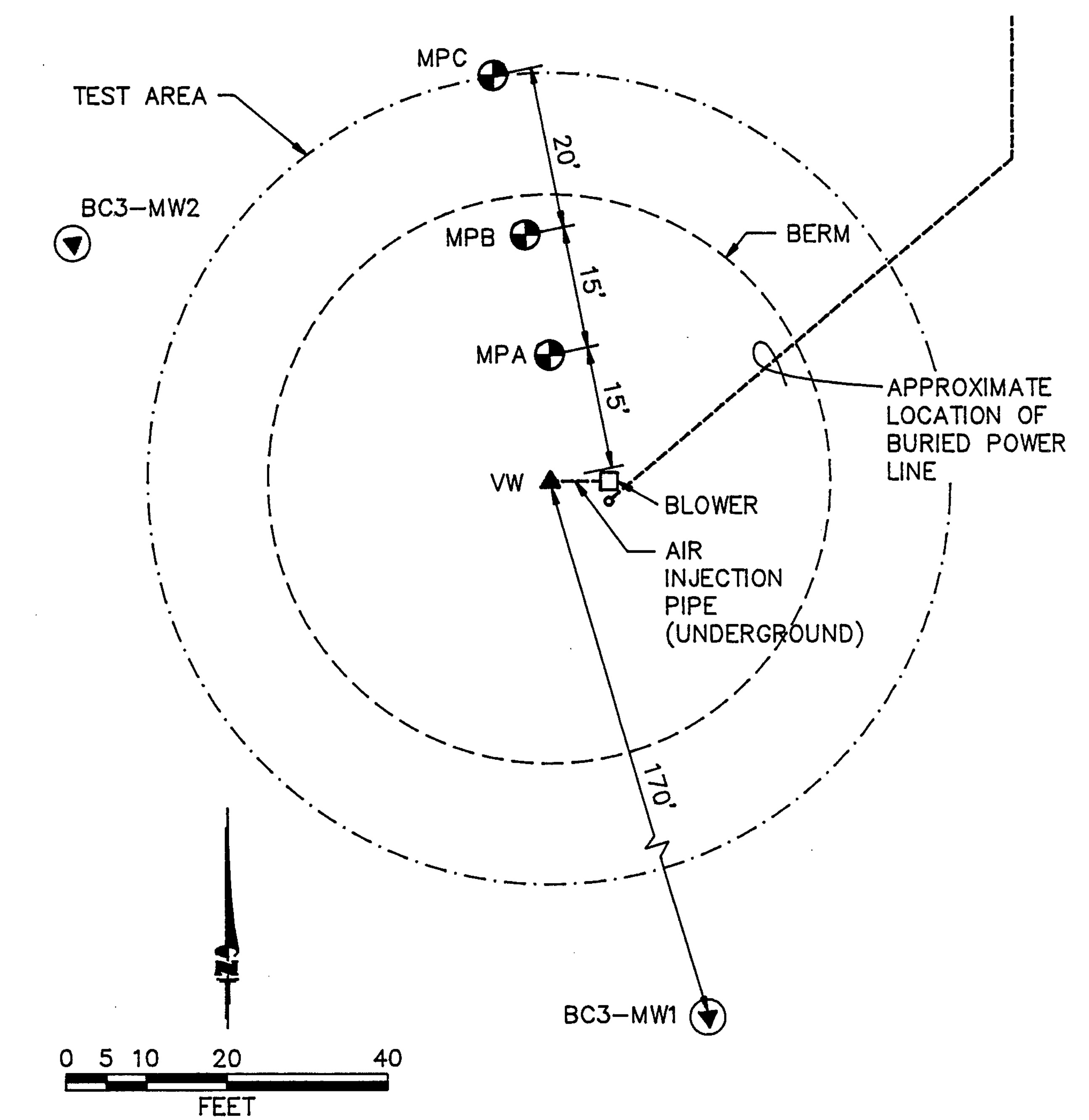
1.0 PILOT TEST DESIGN AND CONSTRUCTION

Installation of an air injection vent well (VW) and three vapor monitoring points (MPs) took place on 9 September 1992, and was completed on 10 September 1992. Drilling services were provided by CTI and Associates, Inc. of Farmington Hills, Michigan, and well installation and soil sampling was directed by Mr. John Hall, the Engineering-Science, Inc. (ES) site manager. The following sections describe the final design and installation of the bioventing system at this site.

One VW, three MPs, and a blower unit were installed at the Fire Training Area. The locations of the VW, MPs, and blower unit were changed slightly from those proposed in the work plan to avoid interference with adjacent road construction activity. Figures 1.1 and 1.2, respectively, depict the locations of and hydrogeologic cross sections for the VW and MPs completed at Site 3. The background MP for this site was existing groundwater monitoring well BC3-MW1, located approximately 170 feet southeast of the VW.

1.1 Air Injection Vent Well

The air injection VW was installed following procedures described in the Air Force Center for Environmental Excellence (AFCEE) bioventing protocol document (Hinchee et al., 1992). Figure 1.3 shows construction details for the VW. The VW was installed in highly contaminated soils with the screened interval



LEGEND

MPA — MONITORING POINTS

VW — CENTRAL VENT WELL (AIR INJECTION)

BC3–MW1 — EXISTING GROUNDWATER MONITORING WELL (USED FOR BACKGROUND MONITORING POINT)

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FIGURE 1.1

AS–BUILT
VENT WELL, VAPOR MONITORING POINT, AND BLOWER LOCATIONS
IRP SITE 3
FIRE TRAINING AREA

Battle Creek ANGB, Michigan

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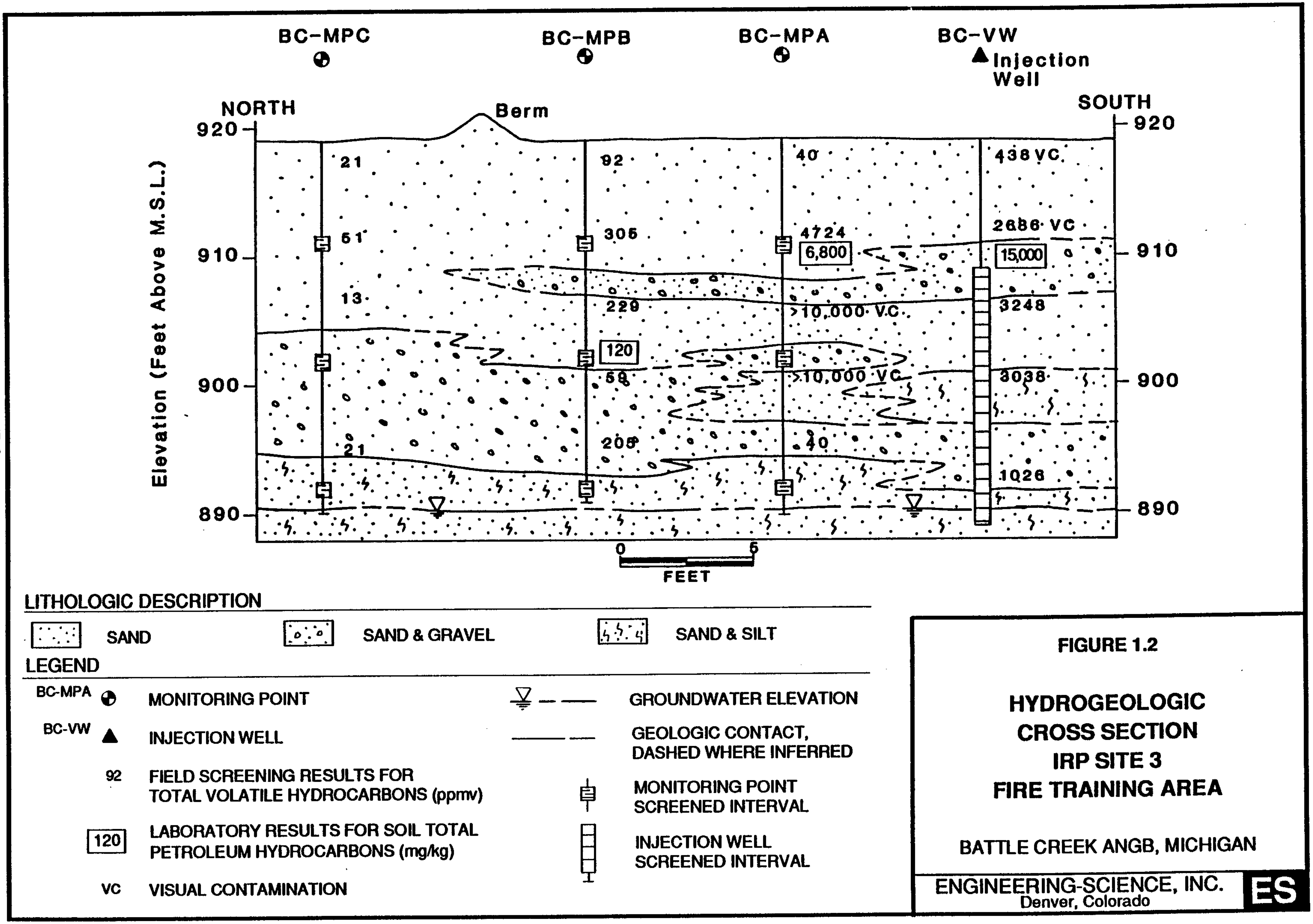

FIGURE 1.2

HYDROGEOLOGIC CROSS SECTION IRP SITE 3 FIRE TRAINING AREA

BATTLE CREEK ANGB, MICHIGAN

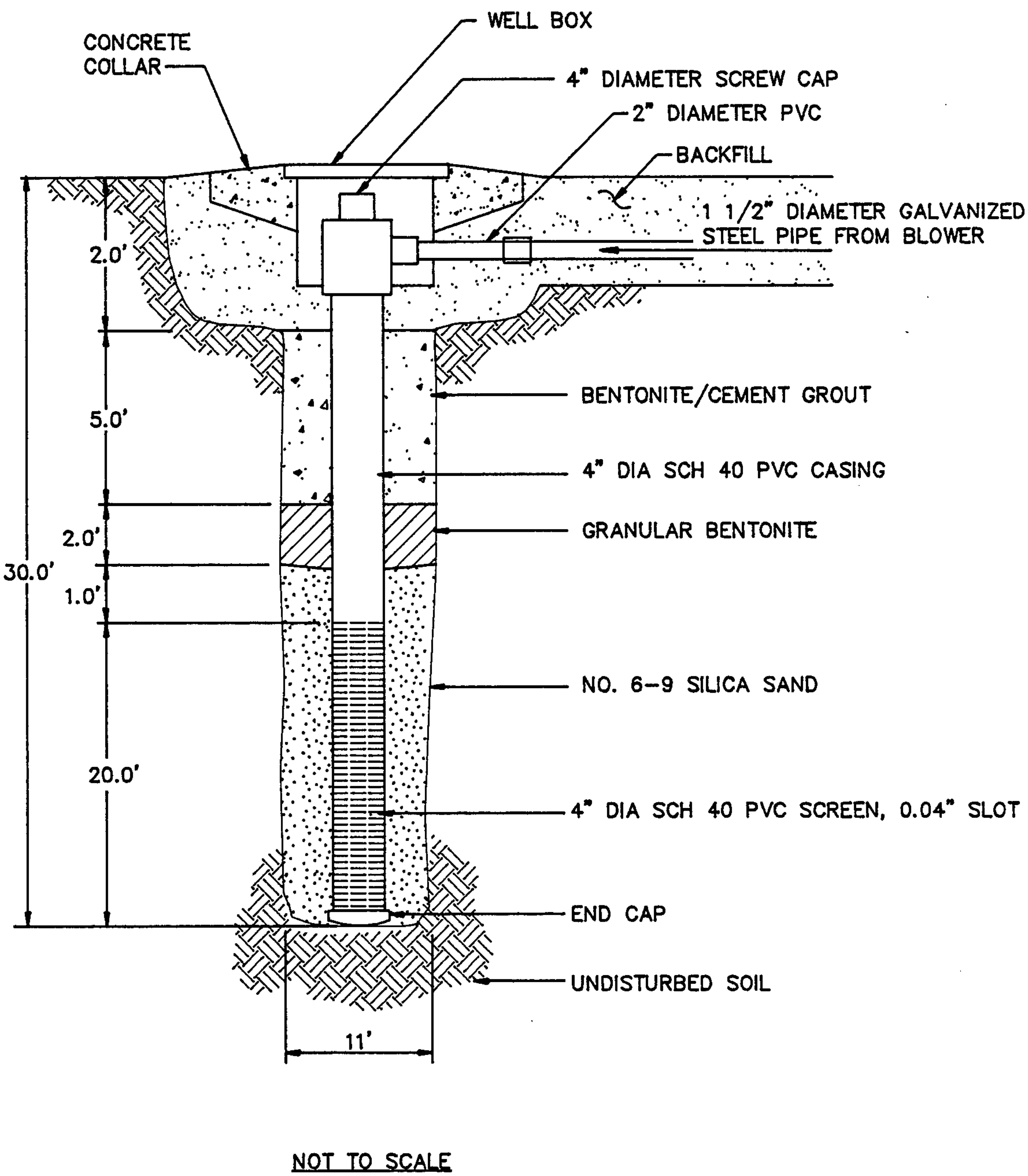

FIGURE 1.3
AS-BUILT
INJECTION VENT WELL
CONSTRUCTION DETAIL
IRP SITE 3
FIRE TRAINING AREA

BATTLE CREEK ANGB, MICHIGAN

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extending from 10 feet below ground surface (bgs) to the groundwater surface at 30 feet bgs. The VW was constructed using 4-inch-diameter, Schedule 40 polyvinyl chloride (PVC) casing, with 20 feet of 0.04-inch slotted PVC screen installed from 10 to 30 feet bgs. The annular space between the well casing and borehole was filled with 6-9 silica sand from the bottom of the borehole to approximately 1 foot above the well screen. Two feet of granular bentonite was placed above the sand, hydrated in place, and followed by a bentonite/cement grout to within 2 feet of the surface. The top of the well was completed with a 4-inch-diameter PVC tee with a screw cap in a 12-inch flush-mounted box to allow future access to the well.

1.2 Monitoring Points

The MP screens were installed at 8-, 17-, and 27-foot depths. The three MPs (MPA, MPB, and MPC) at this site were constructed as shown in Figures 1.2 and 1.4. Each was constructed using a 6-inch section of 1-inch-diameter PVC well screen and a 0.25-inch PVC riser pipe extending to the ground surface. At the top of each riser, a ball valve and a 3/16-inch hose barb were installed . The top of each MP was completed with a flush-mounted metal well protector set in a concrete base. Thermocouples were installed at the 8- and 27-foot depths at MPA to measure soil temperature variations.

The existing groundwater monitoring well BC3-MW1, also was utilized as a background MP. BC3-MW1 is located 170 feet southeast of the VW, is 4-inches in diameter, and the screened interval extends above the groundwater surface.

1.3 Blower Unit

A portable 1-horsepower Gast® R4110-2 regenerative blower unit was used at IRP Site 3 for both the initial pilot test and the extended pilot test. The fixed unit is energized by 230-volt, single-phase, 30-amp line power from a newly installed underground power line and aboveground breaker provided by the base. The blower is currently injecting approximately 40 standard cubic feet per minute (scfm) for the extended pilot test. The configuration, instrumentation, and specifications for this system are shown on Figure 1.5. Prior to departing from the site, ES engineers provided an operations and maintenance (O&M) briefing checklist and blower maintenance manual to base personnel. A copy of the checklist is provided in Appendix A.

2.0 PILOT TEST SOIL AND SOIL GAS SAMPLING RESULTS

2.1 Sampling Results

Soils at this site consist of sand in the upper 8 to 10 feet bgs, sand and gravel from approximately 10 to 26 feet bgs, and silty sand from 26 feet bgs to groundwater. Groundwater occurred at depths between 28 and 29.5 feet in the VW and MP boreholes and in nearby existing monitoring wells.

Hydrocarbon contamination at this site appears to be confined mainly within the bermed area. Contaminated soils were identified based on visual appearance, odor, and volatile organic compound (VOC) field screening results. Heavily contaminated soils were encountered in the VW and MPA boreholes. Soils at these

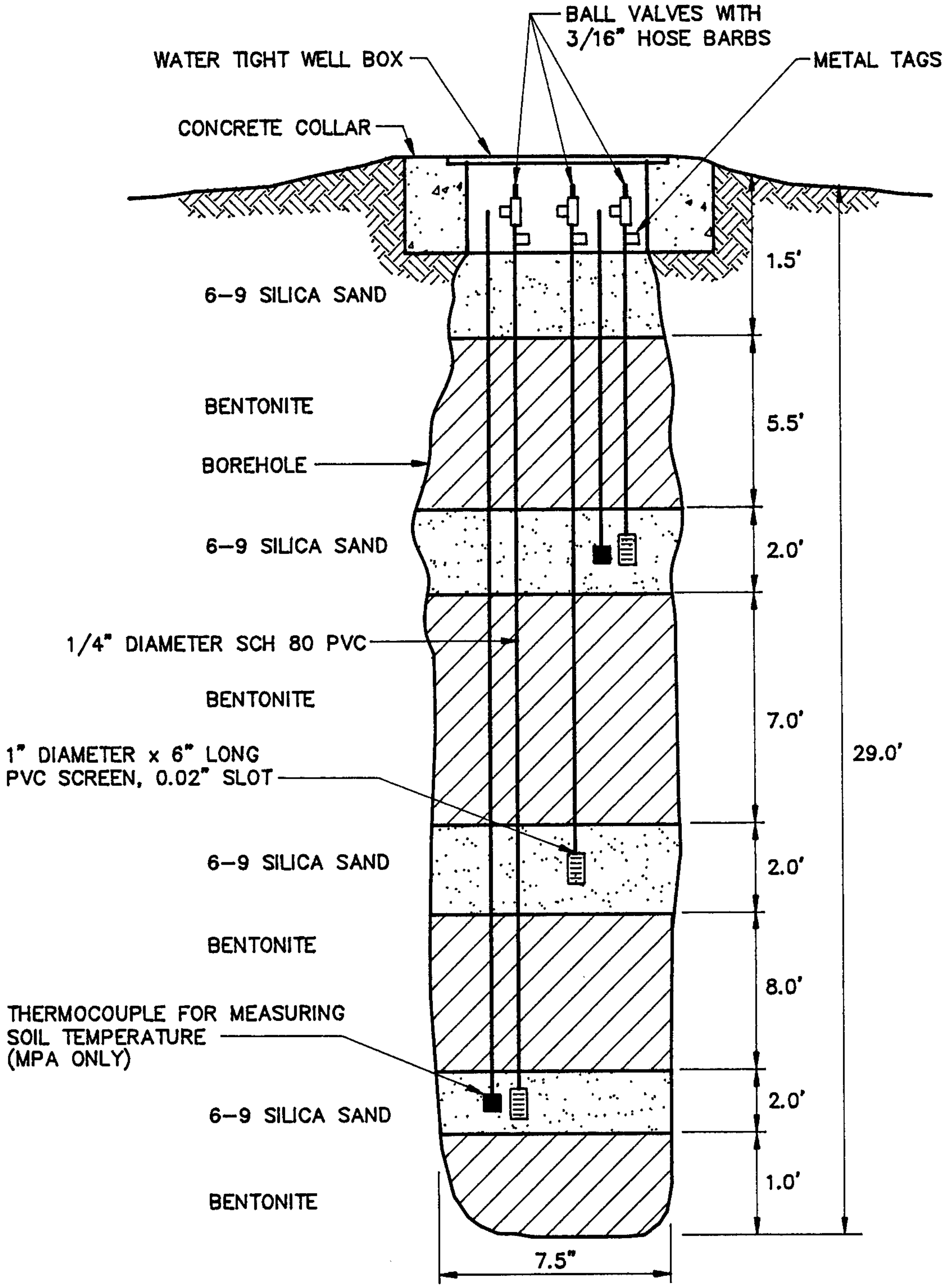


FIGURE 1.4

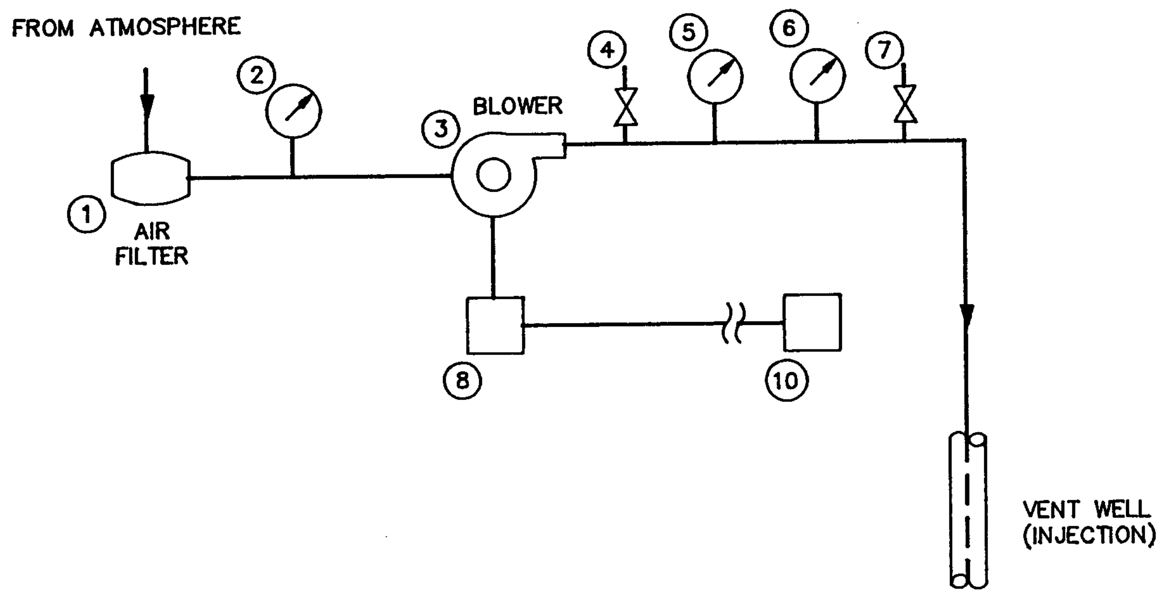
AS-BUILT MONITORING POINT CONSTRUCTION DETAIL IRP SITE 3 FIRE TRAINING AREA

BATTLE CREEK ANGB, MICHIGAN

ENGINEERING-SCIENCE, INC.
Denver, Colorado

ES

26814-08, 10/30/92 at 14:21



LEGEND

1. INLET AIR FILTER – SOLBERG F–18P–150
2. VACUUM GAUGE (in H_2O)
3. BLOWER – GAST R4110–2
4. AUTOMATIC PRESSURE RELIEF VALVE
5. PRESSURE GAUGE (in H_2O)
6. TEMPERATURE GAUGE (°F)
7. MANUAL PRESSURE RELIEF (BLEED) VALVE – 1 1/2" GATE
8. STARTER – FURNAS 14CSD33DA NEMA 3
9. BREAKER BOX – 230V/SINGLE PHASE/ 30 AMP

FIGURE 1.5

AS–BUILT BLOWER SYSTEM FOR AIR INJECTION IRP SITE 3 FIRE TRAINING AREA

BATTLE CREEK ANGB, MICHIGAN

ENGINEERING–SCIENCE, INC.
Denver, Colorado

26814–09, 10/30/92 at 14:24

two locations had a strong hydrocarbon odor and locally appeared to be almost saturated with oil or fuel. Contamination decreased noticeably about 20 feet bgs, and little contamination was detected outside the bermed area in the MPC borehole. No free product was detected on the groundwater surface.

Soil samples for laboratory analysis were collected from either drill cuttings or from split-spoon samplers, and were transferred to appropriate glass containers. Soil samples were screened for VOCs using a photoionization detector to determine the presence of contamination and to select soil samples for laboratory analysis. Soil samples for laboratory analysis were collected from MPA at a depth of 7 feet, from MPB at a depth of 18 feet, and from the VW at a depth of 8 feet. Soil gas samples were collected by extracting soil gas from the completed VW, at 8 feet from MPA, and at 17 feet from MPC.

Soil samples were shipped via Federal Express® to the ES Berkeley laboratory for chemical and physical analysis. Soil samples were analyzed for total recoverable petroleum hydrocarbons (TRPH); benzene, toluene, ethylbenzene and xylenes (BTEX); iron; alkalinity; total Kjeldahl nitrogen (TKN); and several physical parameters. Soil gas samples were shipped via Federal Express® to Air Toxics, Inc. in Rancho Cordova, California for total volatile hydrocarbon (TVH) and benzene, toluene, ethylbenzene, and xylenes (BTEX) analysis. The results of these analyses are provided in Table 2.1.

2.2 Exceptions To Test Protocol Document Procedures

Procedures described in the protocol document (Hinchee et al., 1992) were used to complete treatability tests at both sites. Soil sampling techniques were modified from those described in the protocol document because of poor sample recovery due to the presence of gravel and small cobbles. Instead of collecting soil samples in brass liners, samples for laboratory analyses were collected from fresh drill cuttings or, when possible from the split spoon, and immediately placed into glass sample jars. Additionally, a PID was used instead of a total hydrocarbon vapor analyzer to field screen soil samples.

2.3 Field QA/QC Results

To assess between-sample variability, a field duplicate was collected for one soil sample. The relative percent difference (RPD) between the duplicate and the primary sample were examined to determine the representativeness and precision of the samples. The advisory limit for RPD values of duplicate analyses on soil samples containing analyte concentrations greater than five times the detection limit is 70 percent. All RPD values of the soil duplicate were within the 70-percent advisory limit. This advisory limit reflects the heterogeneous nature of soils.

3.0 PILOT TEST RESULTS

3.1 Initial Soil Gas Chemistry

Prior to initiating any air injection, all MPs were purged until oxygen levels had stabilized, and initial oxygen, carbon dioxide, and TVH concentrations were

TABLE 2.1

IRP SITE 3 FIRE TRAINING AREA

SOIL AND SOIL GAS ANALYTICAL RESULTS

Analyte (Units)[a/]	Sample Location-Depth (feet below ground surface)		
Soil Hydrocarbons	VW-8	MPA-7	MPB-18
TRPH (mg/kg)	15,000	6,800[b/]	120
Benzene (mg/kg)	ND[c/]	ND	0.004
Toluene (mg/kg)	7.0	0.32	0.004
Ethylbenzene (mg/kg)	2.8	4.4	ND
Xylenes (mg/kg)	23.0	8.9[b/]	ND
Soil Gas Hydrocarbons	VW	MPA-8	MPC-17[b/]
TVH (ppmv)	29,000	3,600	88
Benzene (ppmv)	120	29	0.057
Toluene (ppmv)	50	3.3	0.036
Ethylbenzene (ppmv)	4.4	2.9	ND
Xylenes (ppmv)	22	11	0.010
Soil Inorganics	VW-8	MPA-7[b/]	MPB-17
Iron (mg/kg)	4,060	5,470	5,180
Alkalinity (mg/kg as $CaCO_3$)	150	160	210
pH (units)	8.2	8.0	8.6
TKN (mg/kg)	68	75	57
Phosphates (mg/kg)	210	150	150
Soil Physical Parameters	VW-8	MPA-7[b/]	MPB-17
Moisture (% wt.)	6.2	5.3	2.6
Gravel (%)	15	12	28.5
Sand (%)	68.5	69	56.5
Silt (%)	15	17	13
Clay (%)	1.5	2	2

a/ TRPH = total recoverable petroleum hydrocarbons; mg/kg = milligrams per kilogram; TVH = total volatile hydrocarbons; ppmv = parts per million, volume per volume; $CaCO_3$ = calcium carbonate; TKN = total Kjeldahl nitrogen.

b/ Results averaged with duplicate sample.

c/ ND = not detected.

sampled using portable gas analyzers, as described in the technical protocol document (Hinchee et al., 1992). MPB was not sampled at the 27-foot depth because water was drawn into the pump during initial purging and no air sample could be collected. The reduced pressure created by withdrawing air from the sampling point may have temporarily raised the groundwater surface near the MP, allowing water to be drawn into the riser at the top of the screen. However, during the permeability test, the water level had dropped sufficiently to allow pressure measurements to be taken at this point. In highly contaminated soils, microorganisms had depleted soil gas oxygen supplies. In contrast, the background monitoring point (BC3-MW1) outside the area of contamination, had 19.8 percent oxygen. Table 3.1 summarizes the initial soil gas chemistry at the Site 3. TRPH data are also provided to demonstrate the relationship between lower oxygen levels and more contaminated soils.

3.2 Soil Gas Permeability

A soil gas permeability test was conducted according to protocol document procedures. Air was injected into the VW for two hours at a rate of approximately 90 scfm and an average pressure of approximately 3 inches of water. The pressure response at each MP is listed in Table 3.2. The pressure measured at most MPs achieved steady-state conditions within 10 to 15 minutes, and therefore the test was discontinued earlier than specified in the Work Plan. Due to the rapid response and relatively short time to achieve steady-state conditions, the steady-state method of determining soil gas permeability was selected. As discussed in the technical protocol document (Hinchee et al., 1992), the dynamic method of determining soil gas permeability that is coded in the HyperVentilate® model is not appropriate for soils which reach steady state in less than about 10 minutes. Using the steady-state method, a soil gas permeability value of 227 darcys, typical for coarse sand soils, was calculated for this site. A radius of pressure influence of at least 50 feet was observed at the 8, 17 and 27-foot depths.

3.3 Oxygen Influence

The depth and radius of oxygen increase in the subsurface resulting from air injection into the central VW during pilot testing is the primary design parameter for full-scale bioventing systems. Optimization of full-scale and multiple VW systems requires pilot testing to determine the volume of soil that can be oxygenated at a given flow rate and VW screen configuration.

Table 3.3 describes the change in soil gas oxygen levels that occurred during a 2-hour air injection test at the site. This relatively brief air injection period at 90 scfm produced changes in soil gas oxygen levels at a distance of at least 50 feet from the central VW at all three monitored depth intervals in MPC. Oxygen level increases were measured at points near the VW (MPA-8, MPA-17, and MPB-17), while decreases were measured further from the VW (MPB-8, MPC-8, MPC-17, and MPC-27). Decreased oxygen levels measured at points that originally had significant oxygen were the result of oxygen-deficient air from the more highly contaminated central portion of the site being forced outward by the injected air. The decrease in oxygen levels indicates significant air movement through the soils,

TABLE 3.1
IRP SITE 3 FIRE TRAINING AREA
INITIAL SOIL GAS CHEMISTRY
BATTLE CREEK ANGB, MICHIGAN

MP	Depth (ft)	O_2 (%)	CO_2(%)	Field TVH (ppmv)	Lab TVH (ppmv)	TRPH (mg/kg)
A	8	0.0	13.2	4,000	3,600	6,800
B	8	9.2	8.7	300	NS[a/]	NS
C	8	15.5	3.9	440	NS	NS
A	17	0.0	13.5	4,200	NS	NS
B	17	3.5	12.0	300	NS	120
C	17	13.0	5.8	360	88	NS
A	27	0.0	12.5	1,600	NS	NS
B	27	NS	NS	NS	NS	NS
C	27	10.6	7.6	290	NS	NS
VW	8	0.0	12.0	7,200	29,000	15,000
Background	18	19.8	0.8	< 10	NS	NS

[a/]NS = not sampled

TABLE 3.2

IRP SITE 3 FIRE TRAINING AREA

PRESSURE RESPONSE

AIR PERMEABILITY TEST

BATTLE CREEK ANGB, MICHIGAN

	Pressure Response In MP (inches of water)								
	MPA			MPB			MPC		
Depth (ft)	8	17	27	8	17	27	8	17	27
Elapsed Time (min.)									
0.5	.15	.60	.50	.12	.54	.26	--	--	--
1.5	.24	.65	.60	--	--	--	--	--	--
2.0	.25	.67	.67	--	--	--	.16	.22	.19
3.5	.26	.72	.71	.18	.70	.50	--	--	--
4.5	.27	.72	.72	--	--	--	.18	.26	.20
6.0	--[a/]	--	--	.19	.72	.60	--	--	--
7.5	--	--	--	--	--	--	.19	.26	.21
9.5 Steady State	.30	.84	.85	.20	.74	.62	--	--	--
11.0	--	--	--	--	--	--	.21	.29	.24
14.0	.46	.82	.82	--	--	--	--	--	--
15.5	--	--	--	.20	.74	.64	--	--	--
17.0	--	--	--	--	--	--	.21	.30	.24
20.5	--	--	--	.20	.74	.66	--	--	--
21.0	.34	.82	.85	--	--	--	--	--	--
22.5	--	--	--	--	--	--	.22	.30	.26
30.5	--	--	--	.20	.76	.68	--	--	--
32.0	.40	.83	.86	--	--	--	--	--	--
32.5	--	--	--	--	--	--	.23	.31	.27
54.5	--	--	--	.20	.76	.66	--	--	--
55.0	.37	.88	.95	--	--	--	--	--	--

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TABLE 3.2 (Continued)

IRP SITE 3 FIRE TRAINING AREA

PRESSURE RESPONSE

AIR PERMEABILITY TEST

BATTLE CREEK ANGB, MICHIGAN

	Pressure Response In MP (inches of water)								
	MPA			MPB			MPC		
Depth (ft)	8	17	27	8	17	27	8	17	27
57.0	--	--	--	--	--	--	.21	.30	.24
75.0	.40	.95	.92	--	--	--	--	--	--
76.5	--	--	--	.20	.76	.68	--	--	--
79.0	--	--	--	--	--	--	.22	.30	.25
100.0	.37	.88	.92	--	--	--	--	--	--
102.5	--	--	--	.20	.77	.68	--	--	--
104.5	--	--	--	--	--	--	.22	.30	.25
120.0	.36	.87	.90	--	--	--	--	--	--
125.5	--	--	--	.20	.74	.64	--	--	--
127.5	--	--	--	--	--	--	.20	.29	.24

a/ - denotes no reading taken at this time.

TABLE 3.3

IRP SITE 3 FIRE TRAINING AREA
INFLUENCE OF AIR INJECTION AT VENT WELL
ON MONITORING POINT OXYGEN LEVELS
BATTLE CREEK ANGB, MICHIGAN

MP	Distance From VW (ft)	Depth(ft)	Initial O_2(%)	Final O_2(%)[a/]
A	15	8	0.0	19.5
B	30	8	9.2	6.3
C	50	8	15.5	13.2
A	15	17	0.0	15.0
B	30	17	3.5	20.0
C	50	17	13.0	12.7
A	15	27	0.0	0.0
B	30	27	NS [b/]	NS
C	50	27	10.6	9.6

a/ Test time = 2 hours
b/ NS = Not sampled

and it is likely that oxygenated air will reach MPC with continuous injection. The lack of change of the oxygen level measured at MPA at the 27 foot depth is probably the result of slower soil gas movement through the silty, wet sand at this depth. As explained in Section 3.1, it was not possible to collect samples from MPB at 27 feet due to groundwater mounding. Based on measured pressure response, which is an indicator of long-term oxygen transport, it is anticipated that the radius of influence for a long-term bioventing system at this site will exceed 50 feet at all depths. Monitoring during the extended pilot test at this site will better define the effective treatment radius.

3.4. In Situ Respiration Rates

The *in situ* respiration test was performed by injecting air (oxygen) into four MP screened intervals for a 20-hour period. The 12-hour period of air injection specified in the Work Plan was extended to 20 hours as per the Protocol Document. Oxygen loss and other changes in soil gas composition over time were then measured. Oxygen, TVH, and carbon dioxide were measured for a period of 48 hours following air injection. The estimated oxygen diffusion loss was then subtracted from the measured oxygen loss to obtain the biological oxygen utilization rate. The results of *in situ* respiration testing at this site are presented in Figures 3.1 through 3.4. Table 3.4 provides a summary of the observed and corrected oxygen utilization rates.

A 2-percent mixture of helium in air was injected into the MPA-17 screened interval, and then the loss of helium was measured for 2,800 minutes following air injection. Because helium is a conservative, inert gas, the change in helium concentrations over time can be useful in determining if oxygen diffusion is responsible for a portion of the oxygen lost from each MP. Figure 3.5 compares oxygen utilization and helium retention at MPA-17. During the respiration test, helium diffusion at MPA-17 resulted in a fractional loss of approximately 83 percent of the initial helium concentration (Figure 3.5). Due to oxygen's greater molecular weight, helium will diffuse approximately three times faster than oxygen. This means that at MPA-17, approximately 30 percent of the initial oxygen may have been lost due to diffusion. Based on initial oxygen levels in MPA-17, oxygen diffusion occurred at a rate of approximately 0.002 percent per minute. As these MPs were all completed in similar soils, oxygen diffusion rates at MPA-8, MPA-27, and MPB-17 were assumed to be the same as at MPA-17.

Results from this test indicate that only two of these points (MPA-8 and MPA-17) had significant soil hydrocarbon contamination. Both intervals had initial oxygen concentrations of 0 percent and a soil sample taken from MPA-8 had a TRPH concentration of 6,800 mg/kg. Oxygen loss at MPA-8 and MPA-17 occurred at rapid rates, and at MPA-8, the oxygen dropped to 0 percent in 1,430 minutes. Corrected oxygen utilization rates at MPA-8 and MPA-17 were 0.013 and 0.005 percent per minute, respectively (Table 3.4). In contrast, oxygen utilization at MPA-27 and MPB-17 occurred at very slow rates, indicating that little biological activity is occurring near these points. These low rates of biological activity appear to be the result of there being only slight soil contamination near these points. The soil sample taken from MPB at 17 feet bgs had a TRPH concentration of only 120

Figure 3.1
Respiration Test
Monitoring Point MPA-8
Battle Creek ANGB, MI

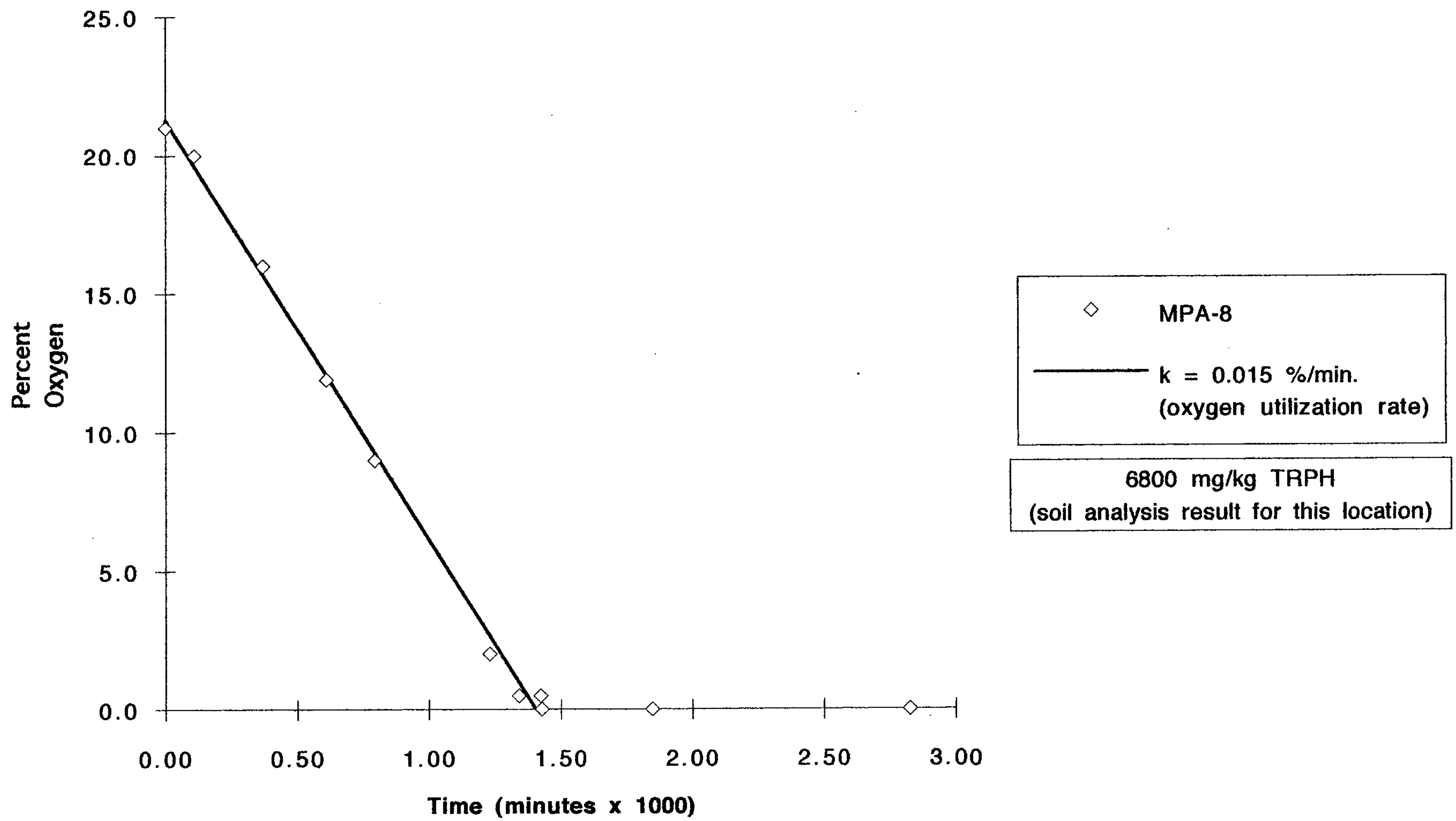

Figure 3.2
Respiration Test
Monitoring Point MPA-17
Battle Creek ANGB, MI

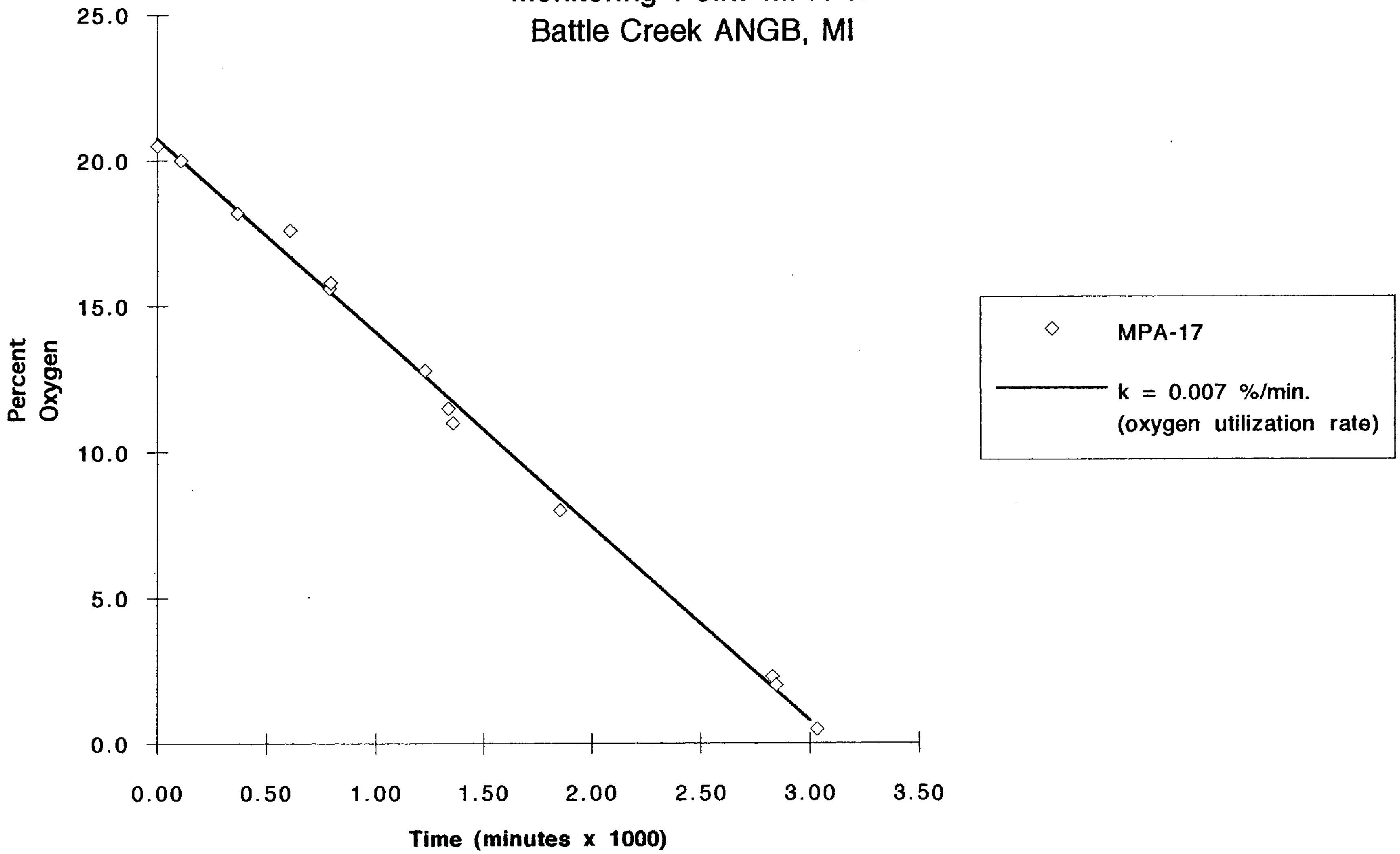

Figure 3.3
Respiration Test
Monitoring Point MPA-27
Battle Creek ANGB, MI

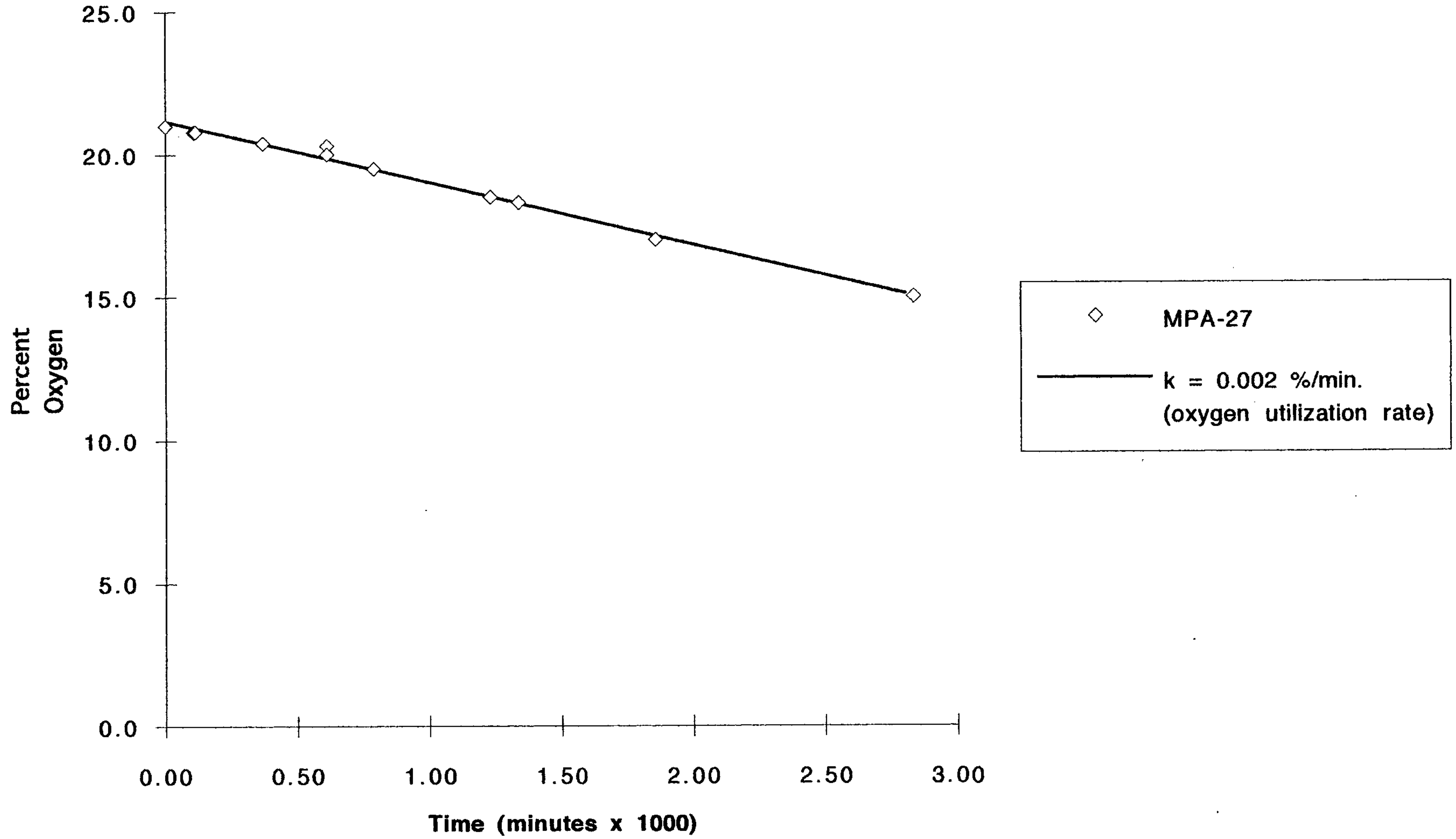

Figure 3.4
Respiration Test
Monitoring Point MPB-17
Battle Creek ANGB, MI

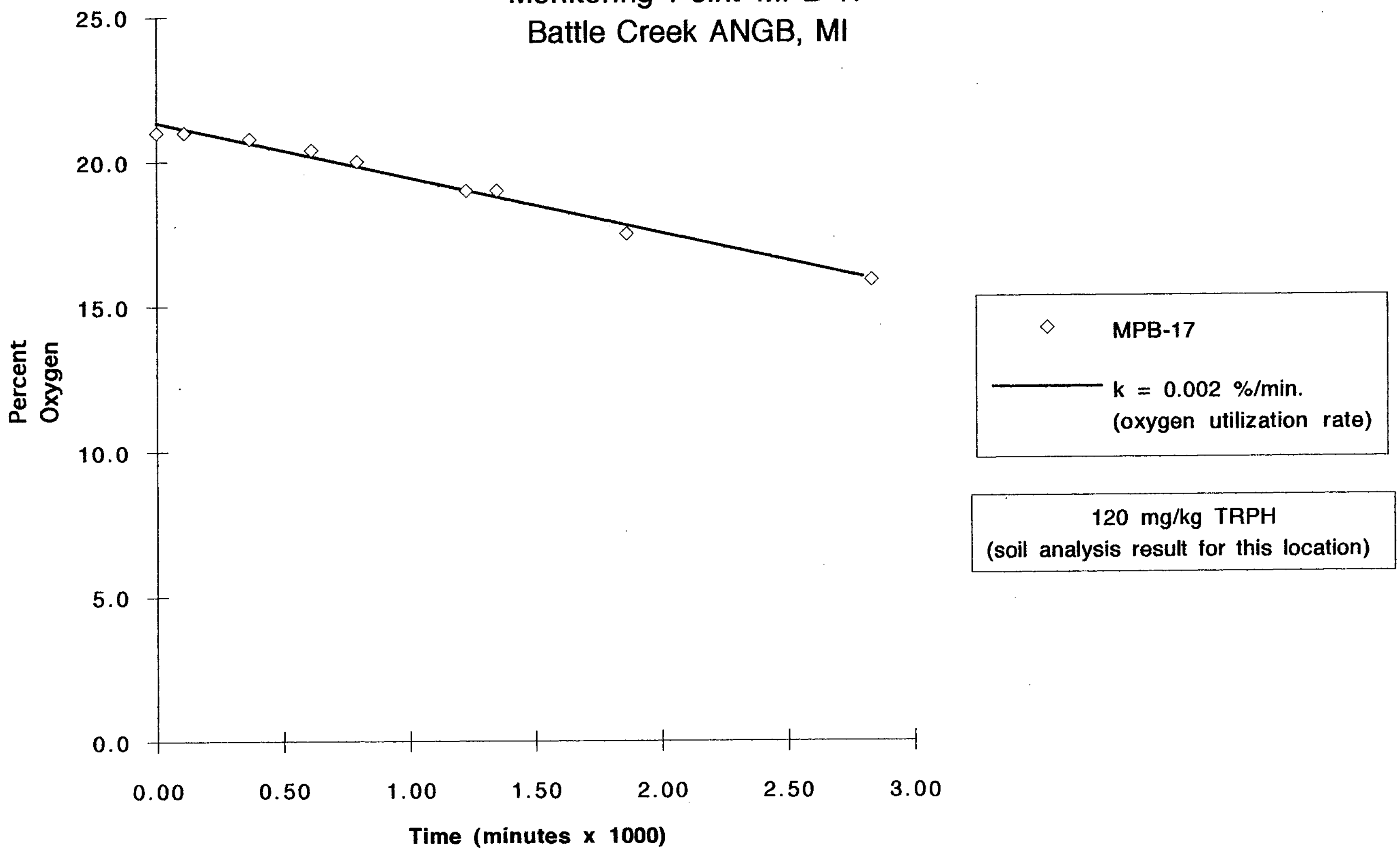

Figure 3.5
Respiration Test
Oxygen and Helium Concentrations
Monitoring Point MPA-17
Battle Creek ANGB, MI

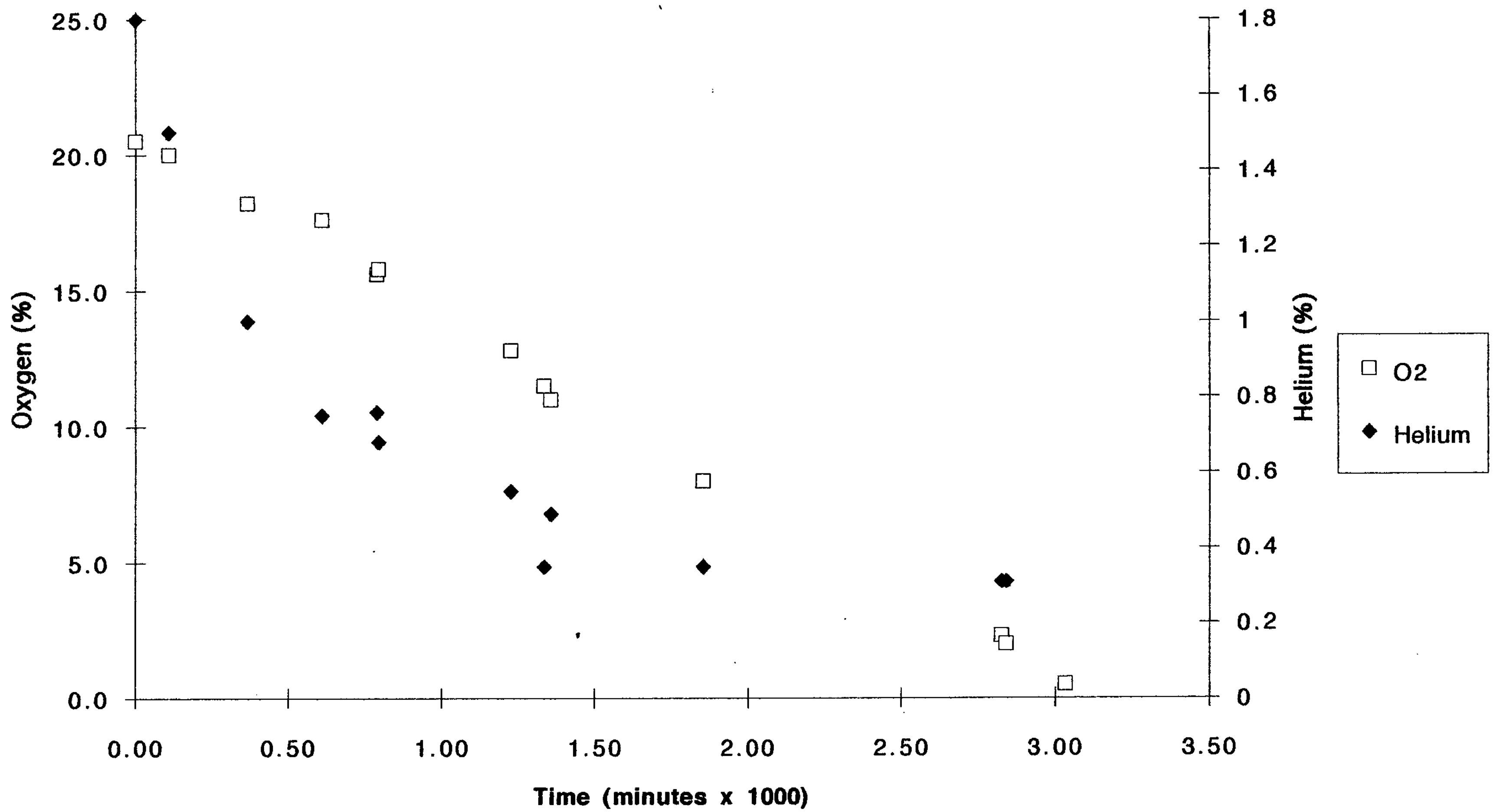

TABLE 3.4
IRP SITE 3
FIRE TRAINING AREA
APPARENT AND CORRECTED OXYGEN UTILIZATION RATES
BATTLE CREEK ANGB, MICHIGAN

MP	Test Duration (min)	Apparent O_2 loss (%/min)	Fractional Helium Loss (%)	Fractional O_2 Diffusion (%)	Estimated O_2 Diffusion (%/min)	Corrected O_2 Utilization a/ (%/min)
MPA-8	1430	0.015	42*	15*	.002*	0.013
MPA-17	2800	0.007	83	30	.002	.005
MPA-27	2800	0.002	83*	30*	.002*	0
MPB-17	2800	0.002	83*	30*	.002*	0

* Based on helium diffusion measured at MPA-17.

a/ Used to estimate fuel biodegradation rates.

A7-6-8

mg/kg. Relatively low levels of contamination are also indicated by the slow buildup of TVH concentrations measured in the soil gas at these two points following air injection, and the initial oxygen concentration of 3.5 percent at MPB-17. The majority of the measured oxygen loss at MPA-27 and MPB-17 during the respiration test appears to be due to diffusion.

Based on corrected oxygen utilization rates, an estimated 1,110 to 2,880 milligrams (mg) of fuel per kilogram (kg) of soil can be degraded each year at this site. This estimate is based on an average air-filled porosity of 0.11 liter per kg of soil, and a conservative ratio of 3.5 mg of oxygen consumed for every 1 mg of fuel biodegraded.

3.5 Potential Air Emissions

Soil concentrations of BTEX compounds detected were less than 35 mg/kg. Based on these BTEX concentrations, the long-term potential for air emissions from full-scale bioventing operations at this site is moderate. Initial emissions should be minimal because accumulated vapors will move slowly outward from the air injection point and will be biodegraded as they move horizontally through the soil. During the air permeability test air was injected at 90 scfm. Health and Safety monitoring on the site with a PID did not indicate hydrocarbon concentrations increased above 1 ppm during the test.

4.0 RECOMMENDATIONS

Initial bioventing tests at this site indicate that oxygen has been depleted in the contaminated soils, and that air injection is an effective method of increasing aerobic fuel biodegradation. The Air Force Center for Environmental Excellence (AFCEE) has recommended that air injection continue at this site to determine the long-term radius of oxygen influence and the effect of time, available nutrients, and changing temperatures on fuel biodegradation rates.

A small, 1-horsepower regenerative blower has been installed at the site to continue a rate of air injection of approximately 40 scfm. In March 1993, ES will return to the site to sample and analyze the soil gas and conduct a repeat respiration test. In September 1993, a final respiration test will be conducted, and soil and soil gas samples will be collected from the site to determine the degree of remediation achieved during the first year of *in situ* treatment.

Based on the results of the first year of pilot-scale bioventing, AFCEE will recommend one of three options:

1. Upgrade, if necessary, and continue operation of the bioventing system for full-scale remediation of the site. AFCEE can assist the base in obtaining regulatory approval for upgrading and continued operation.

2. If final soil sampling indicates significant contaminant removal has occurred, AFCEE may recommend additional sampling to confirm that cleanup criteria have been achieved.

3. If significant difficulties or poor results are encountered during bioventing at this site, AFCEE may recommend removal of the blower system and proper abandonment of the VW and MPs.

5.0 REFERENCES

Hinchee, R.E., S.K. Ong., R.N. Miller, D.C. Downey. 1992. *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing.* Prepared for USAF Center for Environmental Excellence. May.

APPENDIX A
O & M CHECKLIST

SYSTEM MAINTENANCE

1 BLOWER/MOTOR MAINTENANCE

The blower and motor are relatively maintenance free. There is no lubrication required because the blower and motor have sealed bearings. If a blower system is in need of repair, please contact John Hall at (303) 831-8100.

2 FILTER MAINTENANCE

To avoid damage caused by passing solids through the blower an air filter has been installed inline before the blower. By design, Gast regenerative blowers are able to ingest small quantities of particles without damage. However, continuous ingestion of solids will damage or imbalance the impellers. The inline air filter will prevent solids from entering the blower and is rated at 99 percent efficiency to 10 microns.

The filter element is a polyester cloth and is cleanable and replaceable. The filter should be checked weekly for the first two months of operation. The air filter should be cleaned or replaced when the pressure difference across the filter reaches 15 to 20 inches of water. It will be up to Battle Creek ANGB to determine the best schedule for filter cleaning and/or replacement depending on the results of the initial observations.

The filter can be checked after turning off the blower system. To remove the filter, loosen the clamps, lift the metal top off the air filter, and lift the air filter from the metal housing. When replacing the filter, be careful that the rubber seals remain in place. The filter is manufactured by Solberg Manufacturing, Inc. in Itasca, Illinois. Their phone number is (708) 773-1363. The filters can also be obtained through Fluid Technology, Inc. in Denver, Colorado. The contacts there are Mr. Bob Cook and Mr. Greg Sparks and they can be reached at (303) 233-7400. It is recommended that Battle Creek ANGB keep a spare air filter at the site.

3 BLOWER PERFORMANCE MONITORING

To monitor the blower performance, vacuum, pressure, and temperature will be measured. These data will be recorded on the data collection sheets provided. All measurements will be taken at the same time while the system is running.

3.1 Pressure/Vacuum

Open the shed roof and record the pressure and vacuum readings directly from the gauges in inches of water. Record the measurements on the data collection sheet provided.

3.2 Temperature

Open the shed roof and record the temperature readings directly from the gauges in degrees Fahrenheit. Record the measurements on the data collection sheet provided.

4 MONITORING SCHEDULE

The following monitoring schedule is recommended for this system. During the initial months of operation, more frequent monitoring is recommended to ensure that any start up problems are quickly corrected. Data collection sheets have been provided to assist your data collection.

Monitoring Item	Monitoring Frequency
Blower vacuum and temperature	Weekly for the first 2 months of operation. Battle Creek ANGB personnel may optimize the schedule depending on the results of initial observations.

REGENERATIVE BLOWER
INJECTION SYSTEM DATA COLLECTION SHEET

SITE:________

DATE	TIME	INLET VACUUM (IN. WATER)	OUTLET TEMP. (DEGREES F)	OUTLET PRESSURE (IN. WATER)	BLOWER FUNCTIONING UPON ARRIVAL (Y or N)	FILTER CHANGED (Y or N)	COMMENTS	CHECKED BY

APPENDIX B
GEOLOGIC BORING LOGS
AND
CHAIN-OF-CUSTODY FORMS

GEOLOGIC BORING LOG

BORING NO.:	BC-MPA	CONTRACTOR:	CTI	DATE SPUD:	9/10/92 07:40
CLIENT:	AFCEE	RIG TYPE:	CME-75	DATE CMPL:	9/10/92 09:40
JOB NO.:	DE268.14.04	DRLG METHOD:	HSA	ELEVATION:	APPROX. 918 MSL
LOCATION:	FIRE TRAINING AREA	BORING DIA.:	8"	TEMP.:	70 °F
GEOLOGIST:	JFH	DRLG FLUID	NONE	WEATHER:	SUNNY

COMMENTS: 15' from VW

Elev. (ft.)	Depth (ft.)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth(ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	1		SP-SW	SAND, f-vc, tr-sm f gravel, lt brn, v moist, oil odor					
						0-5	G		Tip=40
	5								
				SAA					
					BC-MPA-7	5-10	G		Tip=4724
	10								
			GW	SAND & GRAVEL					
			SW-SP	SAND, m-vc, tr gravel, lt brn, free product oil, 13' SAND, m, tan, v moist		12-14	D	4, 8 9, 7	Tip=>10,000
	15								
				Increasing gravel w/ depth					
			SW	SAND, f-m, tan, v moist, oil odor, no stain		18-20	D	4, 9	Tip=>10,000
	20							11, 11	
			GW	Increase gravel					
	25		SM	SAND & SILT, vf grained, tan-lt brn minor brn stain, oil/solvent odor, v moist		24-26	D	9, 18 15, 17	Tip=40
									@ 28.8'
	30								TD=30'

sl - slight	v - very	f - fine	
tr - trace	lt - light	m - medium	
sm - some	dk - dark	c - coarse	
& - and	bf - buff	BH - Bore Hole	
@ - at	brn - brown	SAA - Same As Above	
w - with	blk - black	veg - Vegetation	

SAMPLE TYPE
- D - DRIVE
- C - CORE
- G - GRAB

D Core recovery

Core lost

Water level drilled

GEOLOGIC BORING LOG

BORING NO.:	BC-MPB	CONTRACTOR:	CTI	DATE SPUD:	9/10/92
CLIENT:	AFCEE	RIG TYPE:	CME-75	DATE CMPL:	9/10/92
JOB NO.:	DE268.14.04	DRLG METHOD:	HSA	ELEVATION:	APPROX. 918 MSL
LOCATION:	FIRE TRAINING AREA	BORING DIA.:	8"	TEMP.:	70 °F
GEOLOGIST:	JFH	DRLG FLUID	NONE	WEATHER:	SUNNY
COMMENTS:	30' from VW				

Elev. (ft.)	Depth (ft.)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth(ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	1		SP	SAND, m, orange-brn, moist, sl odor					Tip=92
						0-5	G		
	5								
				SAA, becoming coarser, tr gravel					
						5-10	G		Tip=305
	10		GW	Increasing gravel - hard drilling					
			SW	SAND, f-m, tan-sl orange-brn stain, v moist, sl odor		12-14	D	4, 7	Tip=229
								9, 12	
	15								
			GW	SAND & GRAVEL, m-vc, orange-brn, gravel up to 3" dia.	BC-MPB	18-20	D	8, 11	Tip=58.9 Cuttings 13:45
	20				-18			14, 12	
	25								
			SP	SAND, vf, orange-tan, v moist, sl solvent odor, sat. @ 28'		26-28	D		Tip=205
								12, 15	
								16, 19	(water level symbol) @ 28'
	30								TD=29' 14:00

sl - slight
tr - trace
sm - some
& - and
@ - at
w - with

v - very
lt - light
dk - dark
bf - buff
brn - brown
blk - black

f - fine
m - medium
c - coarse
BH - Bore Hole
SAA - Same As Above
veg - Vegetation

SAMPLE TYPE
D - DRIVE
C - CORE
G - GRAB

D Core recovery
☒ Core lost

(water level symbol) Water level drilled

GEOLOGIC BORING LOG

BORING NO.:	BC-MPC	CONTRACTOR:	CTI	DATE SPUD:	9/10/92
CLIENT:	AFCEE	RIG TYPE:	CME-75	DATE CMPL:	9/10/92
JOB NO.:	DE268.14.04	DRLG METHOD:	HSA	ELEVATION:	APPROX. 918 MSL
LOCATION:	FIRE TRAINING AREA	BORING DIA.:	8"	TEMP.:	70 °F
GEOLOGIST:	JFH	DRLG FLUID	NONE	WEATHER:	SUNNY

COMMENTS: (Transcribed from field book)

Elev. (ft.)	Depth (ft.)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth(ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	1		SW-	SAND, m-c, dk brn					
			SP						
									Tip=20.5
	5								
				SAA					
	10								Tip=51
								14, 19	
			GW	SAND & GRAVEL, m-c		10-12	D	27,>50	
									Tip=13
	15								
				SAA		18-20	☒	>50	
	20								
									Tip=8
	25		SP	SAND, f, tan, Fe Stain, moist		24-26		6, 9	Tip=21.2
								12, 14	
									TD=28'
	30								

sl - slight	v - very	f - fine
tr - trace	lt - light	m - medium
sm - some	dk - dark	c - coarse
& - and	bf - buff	BH - Bore Hole
@ - at	brn - brown	SAA - Same As Above
w - with	blk - black	veg - Vegetation

SAMPLE TYPE
- D - DRIVE
- C - CORE
- G - GRAB

D Core recovery

☒ Core lost

Water level drilled

GEOLOGIC BORING LOG

BORING NO.:	BC-VW	CONTRACTOR:	CTI	DATE SPUD:	9/9/92 09:15
CLIENT:	AFCEE	RIG TYPE:	CME-75	DATE CMPL:	9/9/92 16:15
JOB NO.:	DE268.14.04	DRLG METHOD:	HSA	ELEVATION:	APPROX. 918 MSL
LOCATION:	FIRE TRAINING AREA	BORING DIA.:	11"	TEMP.:	70 °F
GEOLOGIST:	JFH	DRLG FLUID	NONE	WEATHER:	CLOUDY, WIND
COMMENTS:					

Elev. (ft.)	Depth (ft.)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth(ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	1		SW	0-5' SAND, f-vc, tan-brn w blk stain, v moist, oil odor					Tip=438 @ 4-5'
	5								
				SAA					
			GW	SAND & GRAVEL, m-c, tan w/blk & gray stain, grn @ 9.5',	BC-VW8	8-10	(Core lost)	11, 27,	Tip=2686
	10			possible free product @ 9', v moist			D	22, 15	
			SW-GW	SAND, m-vc, tr-sm gravel, brn-grn stain, oil odor		12-14	(Core lost)	6, 6	Tip=3248
							D	7, 7	
	15								
			SM	SAND & SILT, vf, tan, no staining, v moist, oil odor		18-20	D	5, 11	
	20							10, 12	Tip=3038
			GW	SAND & GRAVEL, lt brn, oil odor, gravel up to 2" diameter		22-24	D	5, 30	
								40	
	25								
			SM						
				SAND, vf-f, & SILT, tan, wet, oil odor		28-30	D	6, 15	(Water level) @ 28'
	30							17, 15	Tip=1026
									TD=30'

sl - slight	v - very	f - fine
tr - trace	lt - light	m - medium
sm - some	dk - dark	c - coarse
& - and	bf - buff	BH - Bore Hole
@ - at	brn - brown	SAA - Same As Above
w - with	blk - black	veg - Vegetation

SAMPLE TYPE
D - DRIVE
C - CORE
G - GRAB

D Core recovery
☒ Core lost

Water level drilled

CHAIN OF CUSTODY RECORD

ENGINEERING-SCIENCE, INC.
1700 BROADWAY, SUITE 900
DENVER, COLORADO 80290
303-831-8100

ES Job No. DE268. 14 .08

AFCEE BIOVENTING PILOT TESTS

Base: Battle Creek ANGB

Site: Fire Training Pit

Sampler(s): (Signature) [signature]

Preservative: NONE (SW 9045, A 403, SW 7380, SW 846) | HOLD AT 4C (SW 8020, E 418.1) | NONE (E 351.2, E 365.3, UCM)

Ship To:
ENGINEERING-SCIENCE LABORATORY
600 Bancroft Way
Berkeley, CA 94710

Attn: Tom Paulson
(510) 841-7353

Date	Time	Sample Description	Lab I.D.	No. of Contrs.	SW 9045 (PH)	A 403 (ALKA)	SW 7380 (IRON)	SW 846 (MOIST)	SW 8020 (BTEX)	E 418.1 (TRPH)	E 351.2 (TKN)	E 365.3 (PHOS)	UCM (CLASS)	Sample Type	Matrix	Remarks
9/8/92	09:40	BC-VW-8		3		/			/			/		G C	SOIL	
9/10/92	08:10	BC-MPA-7		3		/			/			/		G C	SOIL	
9/10/92	08:30	BC-MPA-18		3		/			/			/		G C	SOIL	
9/10/92	08:30	BC-MPA-18 (MS/MSD)		3		/			/			/		G C	SOIL	
9/10/92	13:45	BC-MPB-18		3		/			/			/		G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
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														G C	SOIL	
														G C	SOIL	

Relinquished by: (Signature)	Date / Time	Recieved for Laboratory by: (Signature)	Date / Time
[signature] to Fed EX	9/10/92 6:00		
Relinquished by: (Signature)	Date / Time	Recieved for Laboratory by: (Signature)	Date / Time
		[signature]	9/11/92 0915

Remarks:

G - Grab Sample, C - Composite Sample

Distribution: Original Accompanies Shipment. Copies to: Coordinator Field Files

Federal Express Number: ____

Airbill Number: ____

ENGINEERING-SCIENCE, INC.
1700 Broadway, Suite 900 • Denver, Colorado
(303) 831-8100

CCRSOIL

ENGINEERING-SCIENCE

CHAIN OF CUSTODY RECORD

ES JOB NO.

PROJECT NAME/LOCATION: WO# 4325.

FIELD CONTACT: TOM PAULSON

SAMPLERS NAMES & SIGNATURES: [signature] ESTELITO M. DELOS TRINOS

SHIP TO: SEQUDIA ANALYTICAL

PRESERVATIVES REQUIRED

ANALYSES REQUIRED

DATE	TIME	FIELD SAMPLE IDENTIFIER	TAL PHOSPHORUS PHOSPHATE BY 365.3	E 351.2 (TKN)	UCM (CLASS)		REMARKS
09/9/92	0940	BC-VW-8 (4325.01C)	✓	✓	✓	16-02 JAR 1857	REPORT RESULT ON DRY
09/10/92	0810	BC-MPA-7 (4325.02C)	✓	✓	✓	1858	SOIL BASIS. USE MDLS
9/10/92	0830	BC-MPA-18 (4325.03E)	✓	✓	✓	1859	FOR REPORTING UNITS.
9/10/92	0830	BC-MPA-18 (4325.03F)	✓	✓	✓	For MS/MSD 1860	REPORT METHOD BLANKS,
9/10/92	1345	BC-MPB-18 (4325.04C)	✓	✓	✓	1861	MS/MSD 10 DAY REPORT
						UCM is Particle size by	TAT. REPORT RESULT
						sieve and hydrometer	TO TOM PAULSON
						(per Tom Paulson, 9/14)	ESBL.

FIELD CUSTODY RELINQUISHED BY: [signature] DATE: 9/11/92 TIME: 1310

SHIPPED VIA: AIRBILL #

ON RECEIPT: CUSTODY SEALS? ______; TEMP: ______ °C

RECEIVED FOR LABORATORY BY: [signature] DATE: 9/11/92 TIME: 1:15pm

RELINQUISHED BY: [signature] 9/11/92 3:00 pm Jim [signature]