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Comparison of Three Field Screening Techniques for Delineating Petroleum Hydrocarbon Plumes in Groundwater at a Site in the Southern Carson Desert, Nevada

David R. Smuin

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Health and Safety Research Division

**Comparison of Three Field Screening Techniques
for Delineating Petroleum Hydrocarbon Plumes
in Groundwater at a Site in the Southern
Carson Desert, Nevada**

David R. Smuin

Date Published: January 1993

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
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MARTIN MARIETTA ENERGY SYSTEMS, INC.
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EXECUTIVE SUMMARY

Three types of field screening techniques used in the characterization of potentially contaminated sites at Naval Air Station Fallon, Nevada, are compared. The methods and results for each technique are presented. The three techniques include soil-gas surveys, electromagnetic geophysical surveys, and groundwater test hole screening.

Initial screening at the first study site included two soil-gas surveys and electromagnetic geophysical studies. These screening methods identified localized areas of contamination; however, results were inconclusive. Because of this, monitoring well placement was postponed, and groundwater test hole screening was performed.

Groundwater screening consisted of auger drilling down to the shallow alluvial aquifer. Groundwater samples were collected from the open drill hole with a bailer. On-site head-space analyses for volatile organic compounds (VOCs) were performed using a portable gas chromatograph (GC). Five areas of floating petroleum hydrocarbon product were identified along with the overall dissolved contaminant plume boundaries. Well placement was re-evaluated, and well sites were relocated based on the screening information. The monitoring wells were placed at the perimeter of the plume in locations expected to yield groundwater samples with no detectable VOCs. The program was successful as demonstrated by monitoring well sample results.

The most effective technique for identification of petroleum hydrocarbon-contaminant plumes was groundwater test hole screening. Groundwater screening was subsequently performed at 19 other sites. A total of 450 test holes were analyzed resulting in the delineation of six plumes. Comparisons of contaminated versus uncontaminated designations as determined by open hole photoionization detector (PID) measurements and field GC sample analysis revealed a 89% agreement between the PID readings and GC results. Field GC screening results were confirmed by sending 10 duplicate samples to an independent laboratory for overnight analysis of VOCs. Laboratory results were consistent with the field analyses on all 10 samples. Of the 66 monitoring wells installed based on the

groundwater screening results, only two did not fit the predicted status of either "clean" or "contaminated". Thus, the technique provided 97% confidence that a well could be located either within or outside of contaminant plume boundaries as desired.

The technique optimized the placement of and minimized the number of monitoring wells. Cost savings were realized because fewer wells were required for plume definition. In addition, a high degree of certainty about plume boundaries was achieved.

1. INTRODUCTION

A series of groundwater contaminant site-characterization studies were performed on a facility in the southern Carson Desert, Churchill County, Nevada (Fig. 1). Groundwater contamination at the first site studied was associated with the new fuel farm at the Naval Air Station (NAS) Fallon, 9.5 km (6 mi.) south-east of Fallon, Nevada (Fig. 2). Initial studies by the Navy and ERM-West included a soil-gas survey, fourteen recovery wells, eight monitoring wells, and seven soil borings. A groundwater contaminant plume was confirmed, but the plume limits were not fully defined (ERM West 1988). Additional monitoring wells were recommended in order to define the plume. Oak Ridge National Laboratory (ORNL) under the auspices of the Hazardous Waste Remedial Actions Program (HAZWRAP) was charged with completely characterizing the plume, recommending an appropriate remedial action, and investigating 20 other potentially contaminated sites on the facility. This report includes a comparison of the three field screening techniques used to detect and delineate petroleum hydrocarbons in groundwater at the facility.

1.1 PURPOSE AND SCOPE

The purpose of this study is to examine and compare the three types of field screening techniques used to detect and delineate petroleum hydrocarbon plumes in groundwater at NAS Fallon. The physical setting is described and includes a summary of the geology and hydrogeology. Background information for the facility and the new fuel farm are discussed. The results of two types of soil-gas surveys, a geophysical technique, and a groundwater test hole screening technique are also discussed. A comparison of the relative effectiveness of each technique is described and summarized. The results of electromagnetic geophysical surveys at three other sites (Appendix A) and groundwater test hole screening at several other sites (Appendix B) are also described.

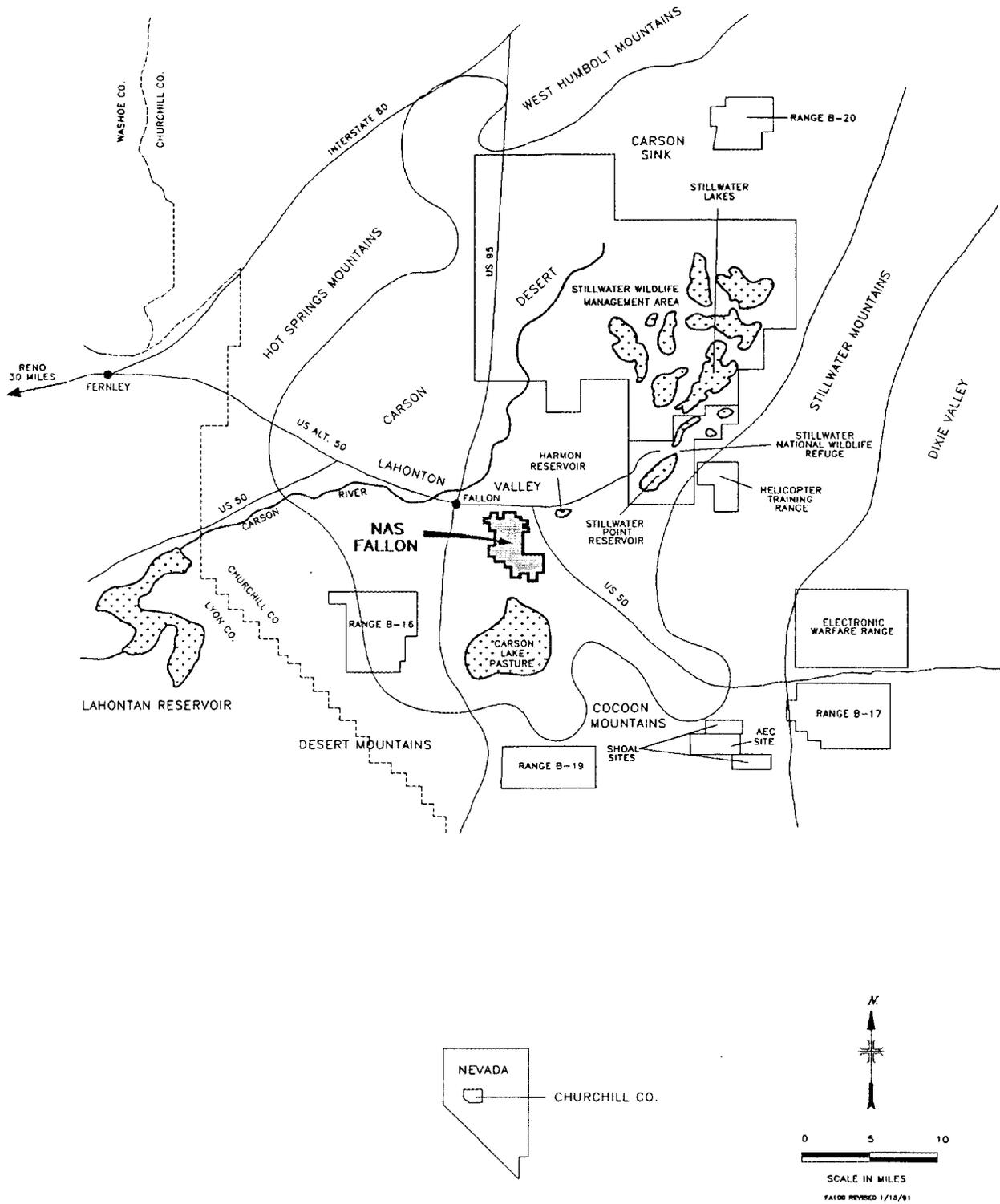


Fig. 1. Regional location map.

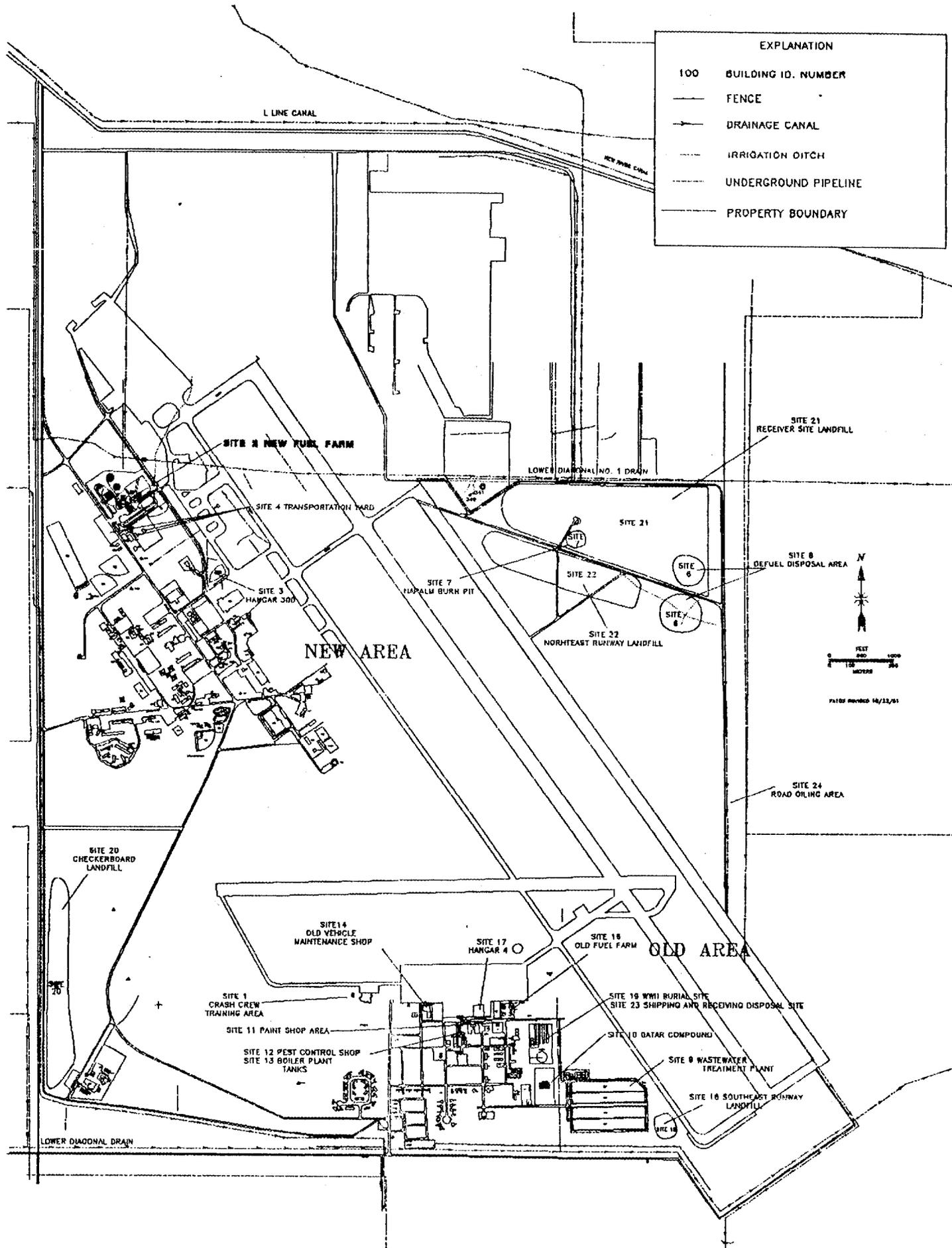


Fig. 2. NAS Fallon sites of investigation.

ORNL-DWG-92-15365

1.2 PHYSICAL SETTING

NAS Fallon lies on a broad, flat alluvial plain in the southern Carson Desert referred to as the Lahontan Valley. The area is part of the basin and range geological province. The valley is a sink for surface runoff from the surrounding mountains and the Carson River. Carson Lake is about 8 km (5 miles) south of the site, and the Stillwater National Wildlife Refuge is about 24 km (15 miles) northeast of the site. Surface water from the site flows to Stillwater while the shallow groundwater generally flows toward Carson Lake.

The Carson Desert is a hydrologically closed depression (Glancy 1986). The entire area is in the rain shadow of the Sierra Nevada Mountains; consequently, precipitation is about 13 cm (5 in.) a year. About 80% of the Carson Desert surface is the Carson River floodplain, and the rest is composed of playas and alluvial fans (Willden 1974). The Carson River, augmented by the Truckee River via the Truckee Canal (part of the Newlands Irrigation Project), provides more than 95% of all surface runoff received by the Carson Desert.

1.2.1 Geology

The Lahontan Valley contains up to 670 m (2,200 ft) of valley-fill sediments (Glancy 1986). The near-surface sediments comprise the shallow alluvial aquifer. They are composed of deltaic and fluvial unconsolidated sand, silt, and clay of Pleistocene to Holocene age (Fallon Formation). At NAS Fallon, the near-surface sediments [0 to 8 m (0 to 25 ft) deep] are related to deposition by former channels of the Carson River which occur in southeasterly trending bands across the facility (Fig. 3). The channels are surrounded by floodplain sediments grading into prehistoric, Lake Lahontan deltaic sediments. A 6- to 9-m (20 to 30 ft)-thick very impermeable clay layer called the Seho Formation underlies the Fallon Formation. This lacustrine clay layer separates the shallow alluvial aquifer from the underlying confined aquifer.

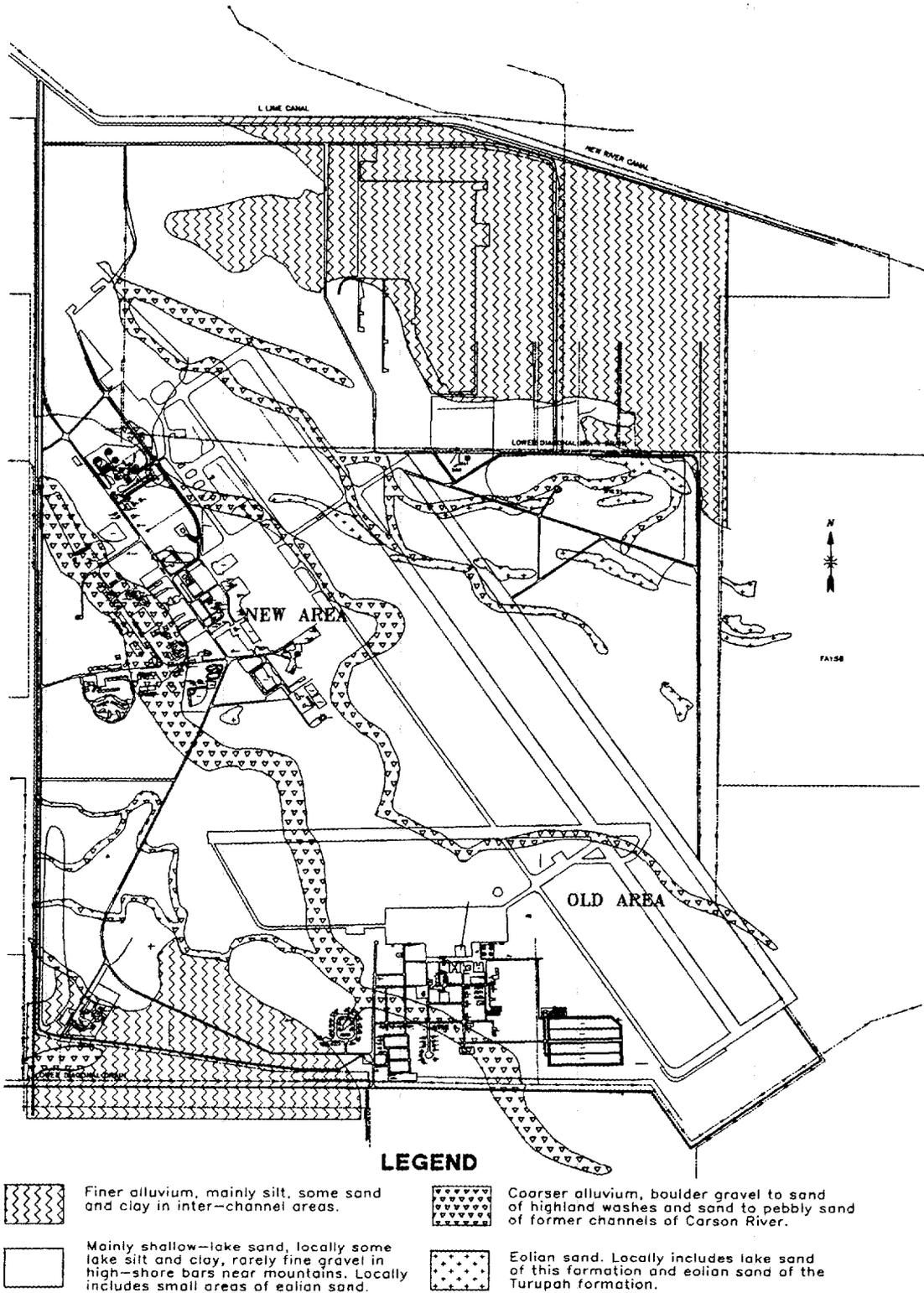


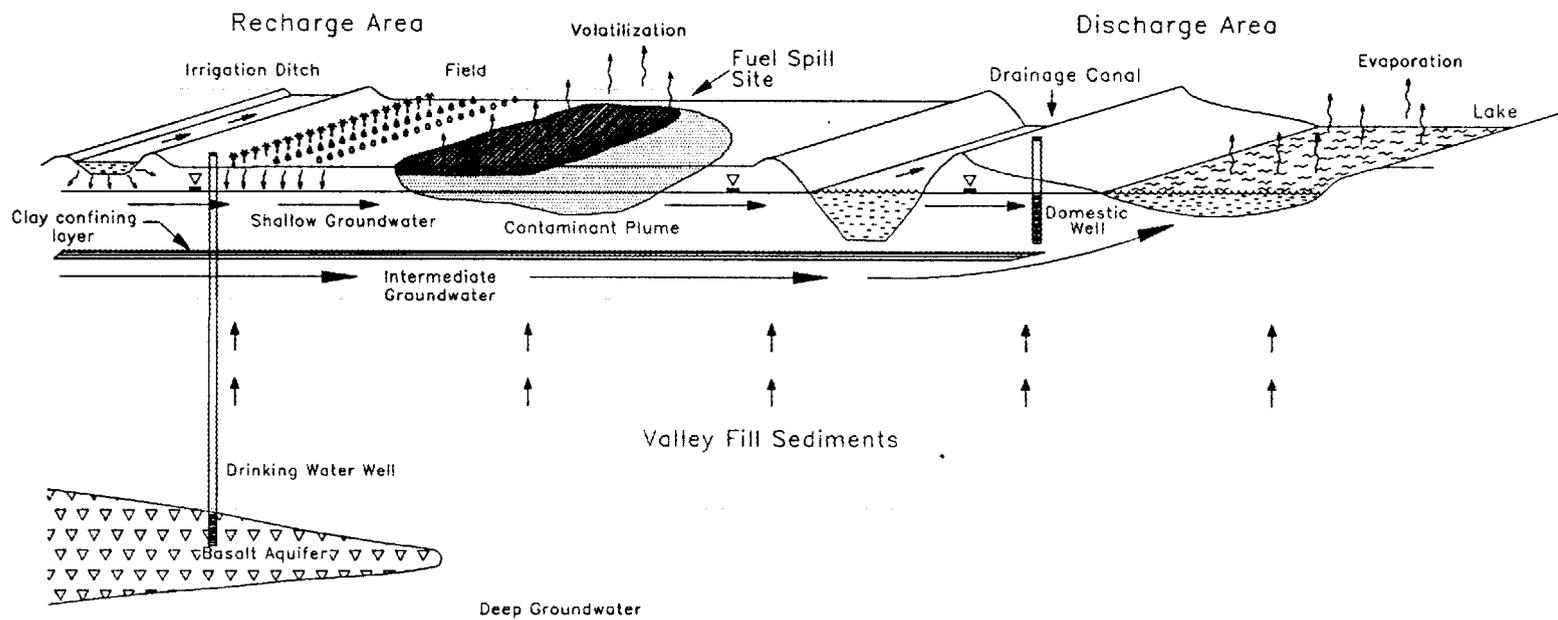
Fig. 3. Surficial geological map.

1.2.2 Conceptual Model of the Hydrologic System

Abundant groundwater is present in the valley-fill sediments and the underlying volcanic strata of the Carson Desert due to the closed nature of the hydrologic basin, which has been intermittently filled by Pleistocene Lake Lahontan (Morrison 1964). The dryer conditions associated with post-Pleistocene climate changes have resulted in the disappearance of Lake Lahontan. Remnants of the lake include the Stillwater marshes, Carson Lake, the saturated, valley-fill sediments, and nearby Pyramid Lake. Groundwater in the Lahontan Valley occurs in three principal valley-fill aquifer systems: 1) a shallow alluvial aquifer, 2) intermediate and deep alluvial aquifers, and 3) a basalt aquifer (Glancy 1986).

Figure 4 shows the conceptual cross-sectional model of the hydrologic system at the facility. The shallow aquifer at NAS Fallon varies in thickness from 6.5 to 7.5 m (21 to 25 ft) across the study area with the water level averaging 2 m (7 ft) below ground surface (bgs). The aquifer is composed of many interconnected zones of varying permeability ranging from highly transmissive channel sands to less-transmissive silty clay floodplain deposits. Water quality is generally poor because of abundant dissolved salts (Hoffman et.al. 1989). Regional groundwater flow direction is to the southeast toward Grimes Point with velocity estimated by Glancy to be 10 m (35 ft) per year (Glancy 1986). However, the ground-water flow velocity at NAS Fallon varies locally from 15 to 170 m (50 to 550 ft) per year as indicated by pumping-test and bail-test data from the facility. The gradient of the shallow groundwater at NAS Fallon is 0.0013 as calculated from the generalized potentiometric map for NAS Fallon (Fig. 5). This map was generated using water-level measurements from 66 wells, 4 staff gages, and 27 piezometers.

Wells penetrating the intermediate aquifer at NAS Fallon indicate a head difference of about 1.5 to 2.7 m (5 to 9 ft) between the shallow (unconfined) and intermediate (confined) aquifers. The head is higher in the deeper aquifer, precluding downward migration of shallow groundwater at the facility. Thus, there is little, if any, interaction between the shallow groundwater and the deeper, confined aquifer. In contrast, however, the shallow alluvial aquifer is alternately



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Fig. 4. Conceptual model of the hydrologic system.

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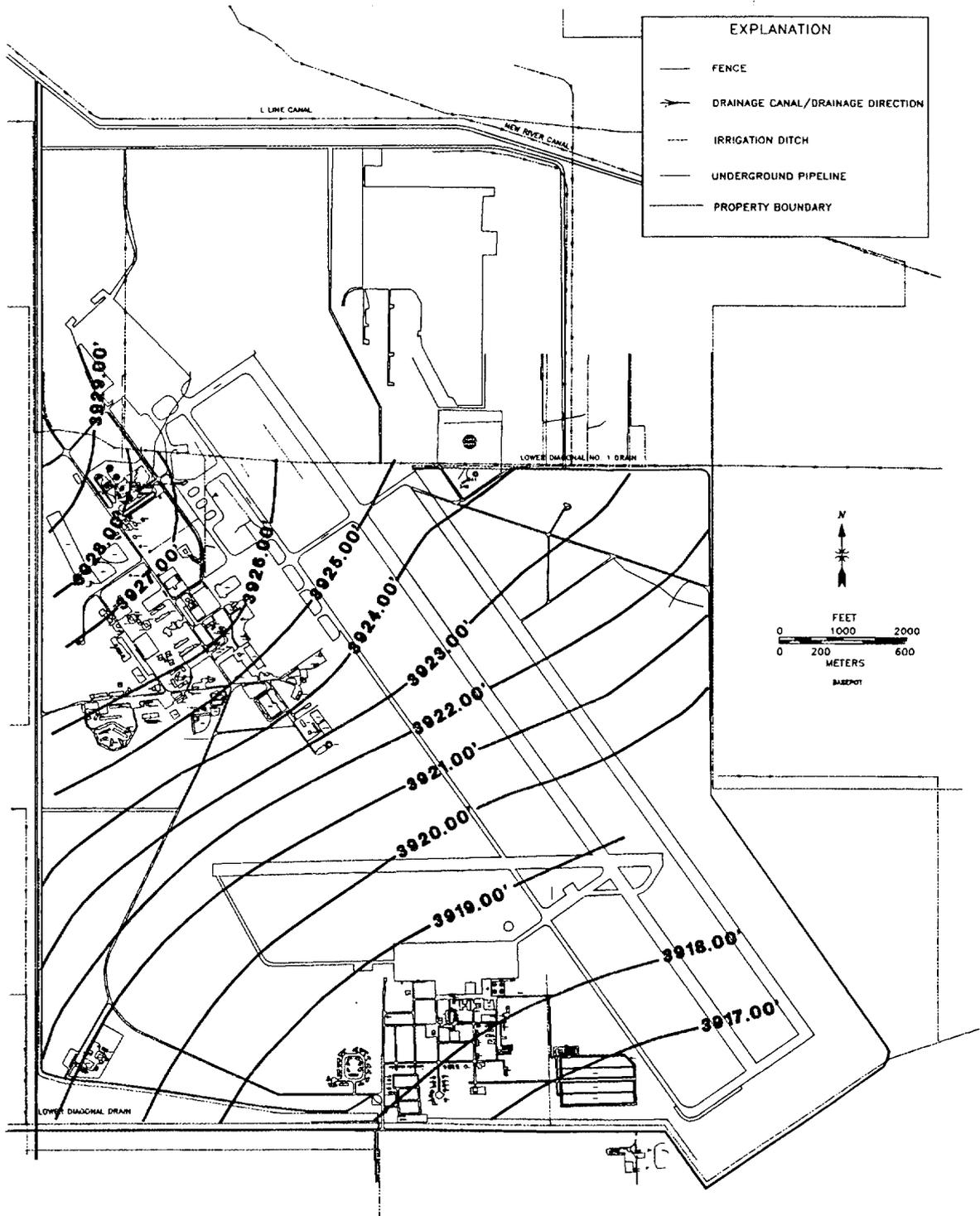


Fig. 5. Potentiometric map of the shallow alluvial aquifer.

recharged by or discharges to the surface water in the drainage canals, depending on the seasonal fluctuations in irrigation return flows to the drainage canals.

Intermediate and deep alluvial aquifers are present beneath the shallow alluvial aquifer. The boundary between the shallow and the intermediate aquifer is a relatively impermeable clay layer, approximately 6 to 9 m (20 to 30 ft) thick. The water in the intermediate and deep aquifers is generally of better quality than the water in the shallow aquifer. The boundary between the intermediate and deep aquifers is based more on water quality than the presence of a physical boundary, with water quality generally improving with depth. The base of the deep alluvial aquifer is about 670 m (2,200 ft) bgs in the center of the basin (Glancy 1986).

The basalt aquifer lies sandwiched in the alluvium about 180 m (600 ft) bgs in an area with a radius of about 6.5 km (4 miles) around a small volcanic cone, Rattlesnake Hill, which outcrops just north of the town of Fallon (Glancy 1986). It is the only source of municipal domestic water in the area and is recharged from the intermediate and deep alluvial aquifers. The basalt aquifer is not present beneath NAS Fallon except possibly in the extreme northeast corner of the facility; however, NAS Fallon derives all of its domestic water from this aquifer, utilizing deep wells northeast of the facility.

Much of the area upgradient from NAS Fallon is irrigated, and there is an irrigation ditch bordering the upgradient side of the facility and a drainage canal along the downgradient side. Thus, the shallow groundwater at NAS Fallon forms a groundwater cell bounded on the upgradient side by freshwater recharge from the irrigation ditch and on the downgradient side by discharge into the drainage canal. Fresh water recharge flows in the irrigation ditches an average of 10 times per irrigation season (Lico et al. 1987); however, no direct application of irrigation water is made to the land surface in the vicinity of investigative sites at NAS Fallon. Thus, most of the shallow alluvial aquifer recharge is from the irrigation ditch in the form of a line source. Lack of rainfall and irrigation causes vegetative cover to be very sparse to non-existent across the facility. Capillary pumping and evaporation of shallow groundwater causes the groundwater to become increasingly saline as it migrates across the cell from the recharge area (irrigation ditch)

to the discharge area (drainage canal). Groundwater seeps into the drainage canal because the canal intersects the shallow water-table aquifer across the down-gradient side of the facility. Flow rates in the drainage canal fluctuate with seasonal irrigation runoff; however, the canal flows year-round due to constant groundwater seepage. Thus, the canal constitutes wetland habitat for fish, water fowl and other fauna.

1.3 HISTORY OF NAVAL AIR STATION FALLON

The following section contains a brief history of operations at NAS Fallon. The history and nature of the environmental contaminants associated with the facility are also discussed.

NAS Fallon was originally established as a military facility in 1942 when the Civil Aviation Administration and Army Air Corps constructed four airfields in Nevada as part of the Western Defense Program. In 1943, the Navy assumed control of the still-uncompleted facility, and on June 10, 1944, Naval Air Auxiliary Station (NAAS) Fallon was commissioned. The newly commissioned facility provided training, servicing, and support to air groups sent to the base for combat training. From 1946 to 1951, NAAS Fallon experienced varying but reduced operational status and was eventually turned over to Churchill County and the Bureau of Indian Service.

In 1951, Fallon was used as an auxiliary landing field for NAS Alameda, California, and on October 1, 1953, NAAS Fallon was re-established. On January 1, 1972, NAAS Fallon was upgraded to its current status of Naval Air Station Fallon. NAS Fallon serves primarily as an aircraft weapons delivery and tactical air combat training facility.

Since its inception in 1942, various kinds of environmentally harmful materials have been routinely used and/or disposed of at NAS Fallon. These include jet fuel (JP-4 and JP-5), oil, avgas (aviation gasoline), gasoline, antifreeze, hydraulic fluid, solvents, paint, pesticides, and industrial and municipal garbage. These substances may have been introduced into the environment during aircraft

refueling, maintenance, and washing; vehicle maintenance; off-specification fuel disposal; fire training exercises; tank cleaning; sewage disposal; pest and weed control; landfilling; and accidental leaks and spills.

Environmental concerns associated with past activities at NAS Fallon have resulted in several environmental assessment initiatives. These include: 1) an investigation by ERM-West of fuel discovered floating on the water table underlying the new fuel farm facility (ERM-West 1988); 2) an investigation by the Nevada Division of Environmental Protection (NDEP) of an alleged fuel release at the new fuel farm facility (NDEP 1990); and 3) initiation of the current Installation Restoration (IR) Program. Portions of the IR Program initiative which have been completed to date include: Phase I, Preliminary Assessment/Site Inspection (PA/SI) (Dames and Moore 1988); preliminary portions of Phase II, Remedial Investigation (RI) for Site 2 (ORNL 1989a and ORNL 1990); the Engineering Evaluation and Cost Analysis for Site 2 (ORNL 1991a); Phase II, development of process options for the Feasibility Study (FS) on all sites (ORNL 1991b); and a Preliminary Site Characterization Summary for all sites (ORNL 1992).

1.3.1 History of the New Fuel Farm

Past spills, leaks, and disposal activities at the new fuel farm (Site 2) have resulted in public concern and several legal actions against NAS Fallon regarding environmental contamination issues. Numerous environmental investigations have been initiated to address these issues. Results from these investigations are presented in a recent report which outlines an interim removal action plan for recovering floating product (petroleum hydrocarbon liquids) from the site (ORNL 1991a). The results of the investigations are summarized below.

Of fourteen wells installed by the Navy after discovery of product at the site in 1986, thirteen wells contained free product. Recovery of free product from the Navy's wells was initiated in 1987. ERM-West, a private consulting firm, was also hired to investigate the extent of contamination. By June 1987, eight new monitoring wells had been installed by ERM-West, and three of these wells

contained from 5.08 cm (2 in.) to 43.18 cm (17 in.) of free product (Dames and Moore 1988). Due to improper well design, the Navy's product-recovery effort was discontinued when Phase II of the base-wide IR Program began in September 1988. One of the goals of the IR Program at Site 2 was to implement more effective remediation as an interim protective measure through a removal action (ORNL 1991a).

The Phase I PA/SI initiated shallow soil sampling efforts to address contamination of the tank bottom disposal area, the vehicle parking area and the outdoor vehicle maintenance area (Fig. 6) (Dames and Moore 1988). Soil samples were submitted for laboratory analysis of total petroleum hydrocarbons (TPH) using Environmental Protection Agency (EPA) method 418.1. Results indicated significant petroleum hydrocarbon contamination (260 mg/kg and 4200 mg/kg) from two surface soil samples collected in the tank bottom disposal area, minimal contamination (<54 mg/kg) in the vehicle parking area, and significant contamination in the outdoor vehicle maintenance area (17,000 mg/kg and 40 mg/kg). The contamination in the vehicle maintenance area attenuated rapidly with depth (Dames and Moore 1988).

Additional NDEP actions occurred in March 1989 when the NDEP notified NAS Fallon of an apparent malfunction of the oil/water separator (O/WS). The Navy subsequently discontinued use of the O/WS (ORNL 1991a). In February 1990, another NDEP action involved the investigation of an alleged fuel spill in February 1988 (ORNL 1991a). The investigation concluded that a release of JP-5 jet fuel had occurred on February 22, 1988, and recommended further investigation into the extent of subsurface contamination (NDEP 1990).

In response to NDEP actions and recommendations, the remedial investigation of the new fuel farm was expedited. During August and September 1989, two types of screening surveys were performed by ORNL at the new fuel farm. These surveys were performed to guide the selection of additional monitoring well locations. The intent was to locate wells around the periphery of the petroleum-hydrocarbon-contaminant plume to demonstrate that the boundaries of the plume were known. The initial screening survey was a geophysical method that used a Geonics EM-31 electromagnetometer (EM) coupled with an ultrasonic ranging and

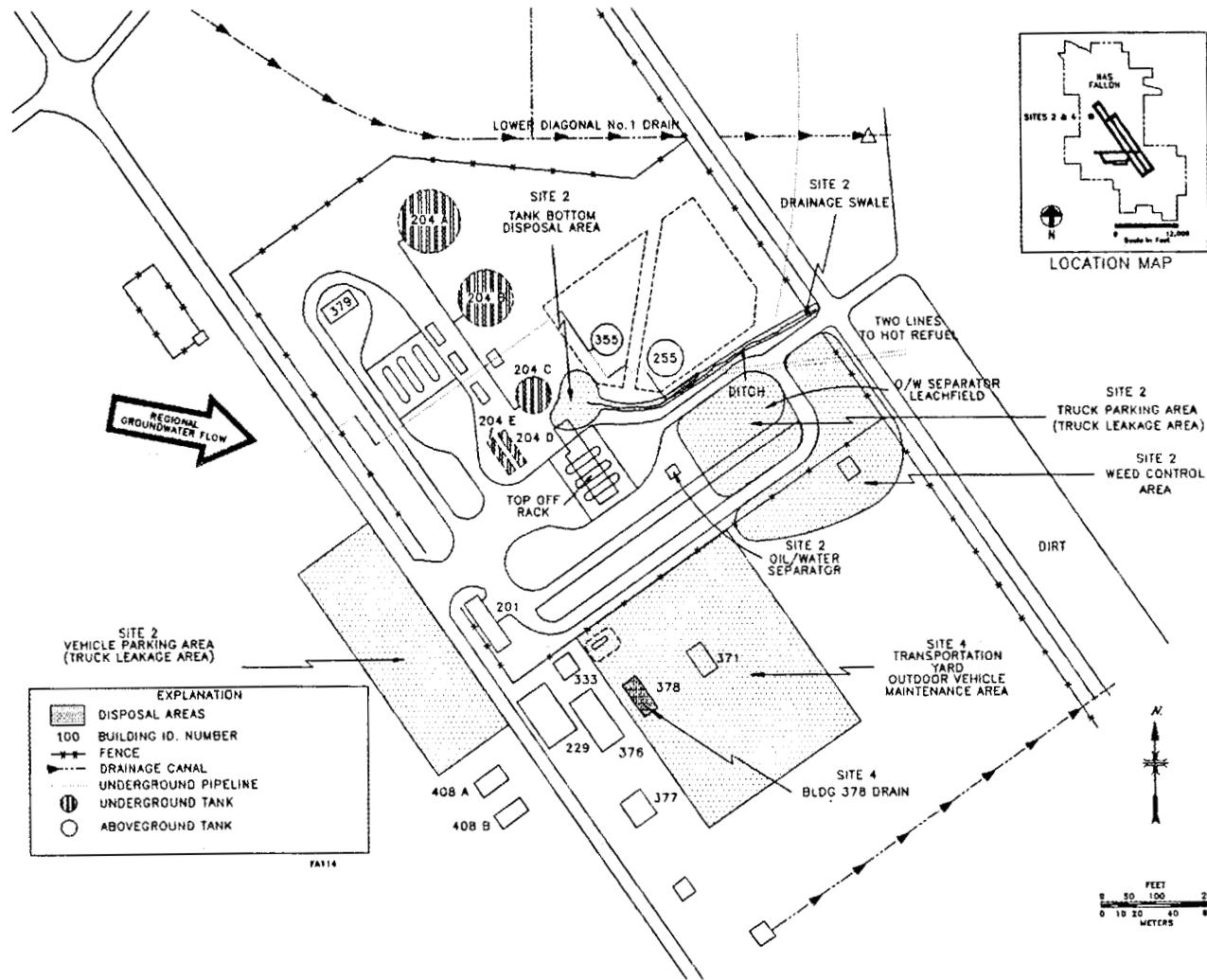


Fig. 6. Site 2 location map.

data collection system (USRADS). The EM was employed to map differences in the electrical conductivity of the shallow groundwater believed to be associated with floating jet fuel (JP-5) and/or fresh water recharge. USRADS is a patented, computerized data-acquisition system which relates the surveyor's precise physical location to the instantaneous data from the EM-31 instrument during walking surveys. It was developed by ORNL to facilitate field data collection (Dickerson et al. 1989).

The second screening survey tested soil gas using a Xitech™ soil-gas-collection system and a Photovac™ 10S50 portable gas chromatograph. After the data from these surveys was interpreted, tentative monitoring well locations were selected. These screening methods had identified localized areas of contamination; however, the results were inconclusive. Soil-gas and geophysical results were often conflicting, and the contaminant plume boundary appeared to be discontinuous. Monitoring well placement - as based on soil-gas and geophysical screening - was postponed, and groundwater screening was employed to provide additional insight into well placement.

Using a newly developed technique of groundwater screening, five areas of floating product were delineated, and the boundaries of the overall contiguous groundwater plume were identified. Results from this survey provided better plume boundary resolution and were also consistent with information obtained during the soil-gas and geophysical activities. After re-evaluation, well sites were relocated based on the screening information. The wells were placed at the perimeter of the plume in locations expected to yield groundwater samples at or below applicable or relevant and appropriate requirements (ARARs) for the site. Monitoring well sample results, which supported the screening-data definition of the edge of the plume, demonstrated the success of the program. Table 1 summarizes the environmental sampling completed at the new fuel farm. The method of assessment and party responsible for each method are also listed.

A detailed description of the various screening surveys is included in the following three sections.

Table 1. Site 2, summary of environmental sampling

ENVIRONMENTAL SAMPLING SUMMARY		
Responsible Party	Assessment Method	Number of Locations
ORNL/GJ	Soil gas	149
	EM geophysical survey	1
	Groundwater test holes	90
	Soil borings	4
	Groundwater wells	15
	Piezometers	7
	Staff gauges	4
Navy	Groundwater wells	14
ERM-West	Soil gas	85
	Soil borings	7
	Groundwater wells	8

Note: Multiple samples were often collected at each sample location.

2. SOIL-GAS SURVEYS

Two types of soil-gas surveys were performed at the new fuel farm. The purpose of these surveys was to delineate the lateral extent of VOCs related to various petroleum products spilled or released at the site (ERM-West 1988).

2.1 RATIONALE

There are a number of criteria to consider in the selection of a soil-gas survey method. These include: 1) physical and chemical properties of suspected contaminants, 2) depth to groundwater, 3) soil type, and 4) project schedule and budget. There are two basic types of soil-gas surveys: those that employ active collection of soil gas, and those that employ passive collectors. Passive techniques are generally less desirable because they do not provide real-time data (Korte et al. 1992). Soil-gas surveys are best employed as a reconnaissance tool to identify sources of contamination and delineate limits of contamination (Thompson and Marrin 1987). Data from soil-gas surveys are often utilized to select locations for monitoring wells that provide data for comparison to regulatory standards for maximum contaminant levels in groundwater.

Two types of active collection soil-gas surveys were performed at Site 2. The first type, used by ERM-West, employed a shallow PVC collection tube. The second type, used by ORNL, employed a steel probe driven to the capillary fringe. Both survey techniques are described below. The site was considered amenable to soil-gas techniques for the following reasons: 1) the suspected contaminant, liquid JP-5, contains about 13% VOCs, which would readily partition into soil gas (Hughes and Wiefling 1985); 2) the soils are relatively sandy with good connected porosity; 3) the groundwater is shallow; and 4) the area of investigation was relatively large. A large area can often be approached in the most cost-effective manner by using a reconnaissance-level technique to identify targets for more specific sampling systems such as groundwater monitoring wells. This approach to

site characterizations is considered state-of-the-art and is favored by the Environmental Protection Agency (Korte et al. 1989).

2.2 ERM-WEST SOIL-GAS METHODOLOGY

The ERM-West survey was accomplished by installing a 2.5-cm (1 in.)-diameter PVC probe to a shallow depth in the soil, withdrawing soil gas by suction, and analyzing the gas with an organic vapor analyzer (OVA). Sample points were located on a 15-m (50 ft) grid utilizing the perimeter fence and existing structures within the area as guides (Fig. 7). At each point, 2.5-cm (1 in.)-diameter borings were drilled to an approximate depth of 0.75 m (2.5 ft) using an electric roto-hammer. A soil-gas probe, depicted in Fig. 8, was then inserted into the boring and the annulus sealed with soil. The soil between the probe and the boring wall was tamped down to ensure that gas vapors from the soil only were entering the bottom of the probe. The presence of VOCs in the soil gas was tested with a Foxboro™ Century 128 flame ionization detector (FID), an OVA configured for survey mode. The instrument was connected to the soil-gas probe with Tygon™ tubing. The suction pump of the OVA was used to draw gas vapors from the probe. The OVA measures a VOC concentration by producing a response to an unknown sample that can be related to a methane gas standard of known concentration. The specific type and concentration of VOC is not identified by the instrument. The instrument must be periodically calibrated with the standard to ensure consistent readings. Both maximum and stabilized OVA readings were recorded from each probe location as parts per million (ppm) in moist air. OVA readings at each site were variable because the volume of VOCs occurring at each site varies depending on soil moisture, soil type, void ratio, porosity, and temperature. Thus, OVA readings can only be compared on a relative basis.

Prior to taking a field measurement, a background ambient VOC concentration was measured and recorded. Whenever field readings above the ambient

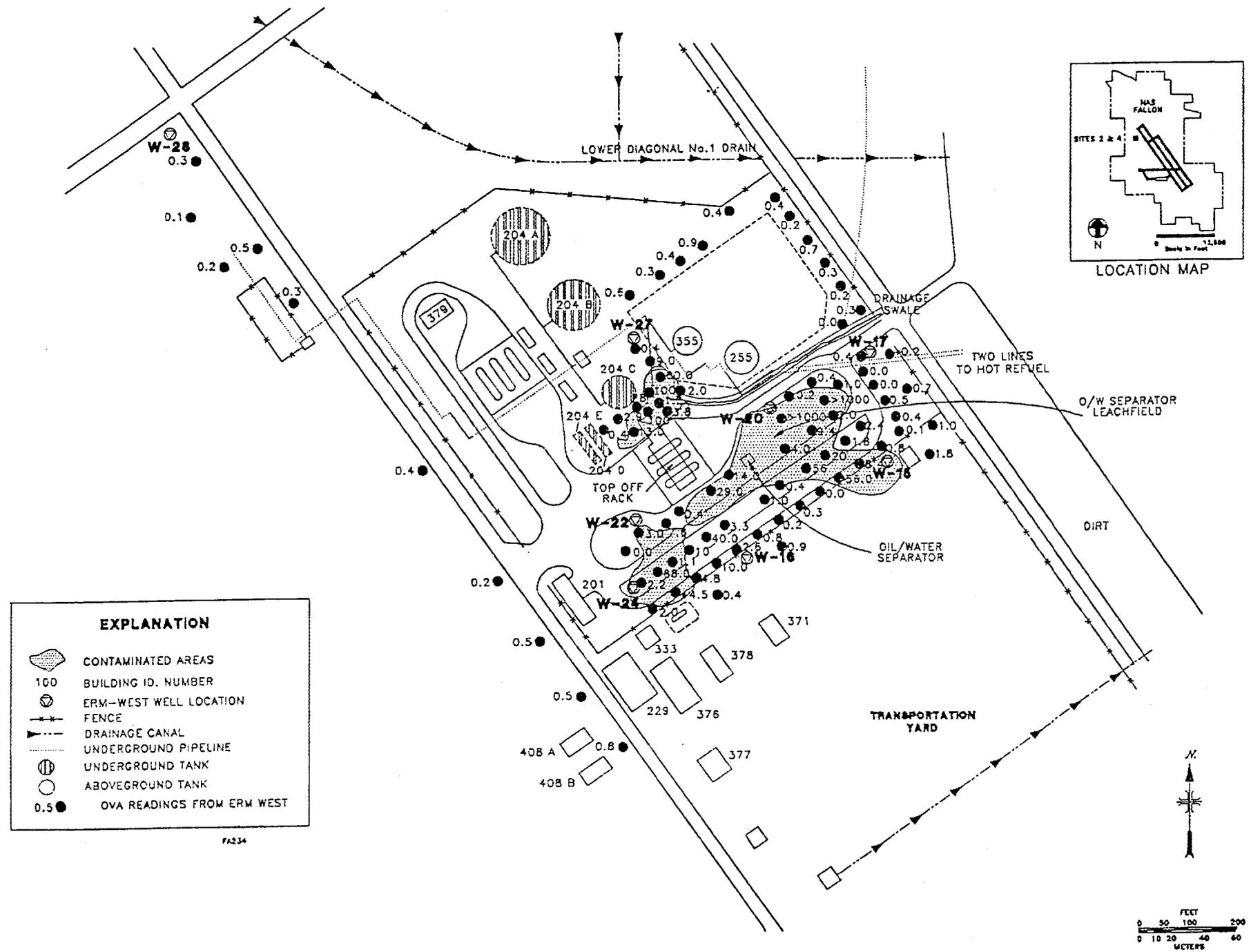


Fig. 7. ERM-West soil-gas map.

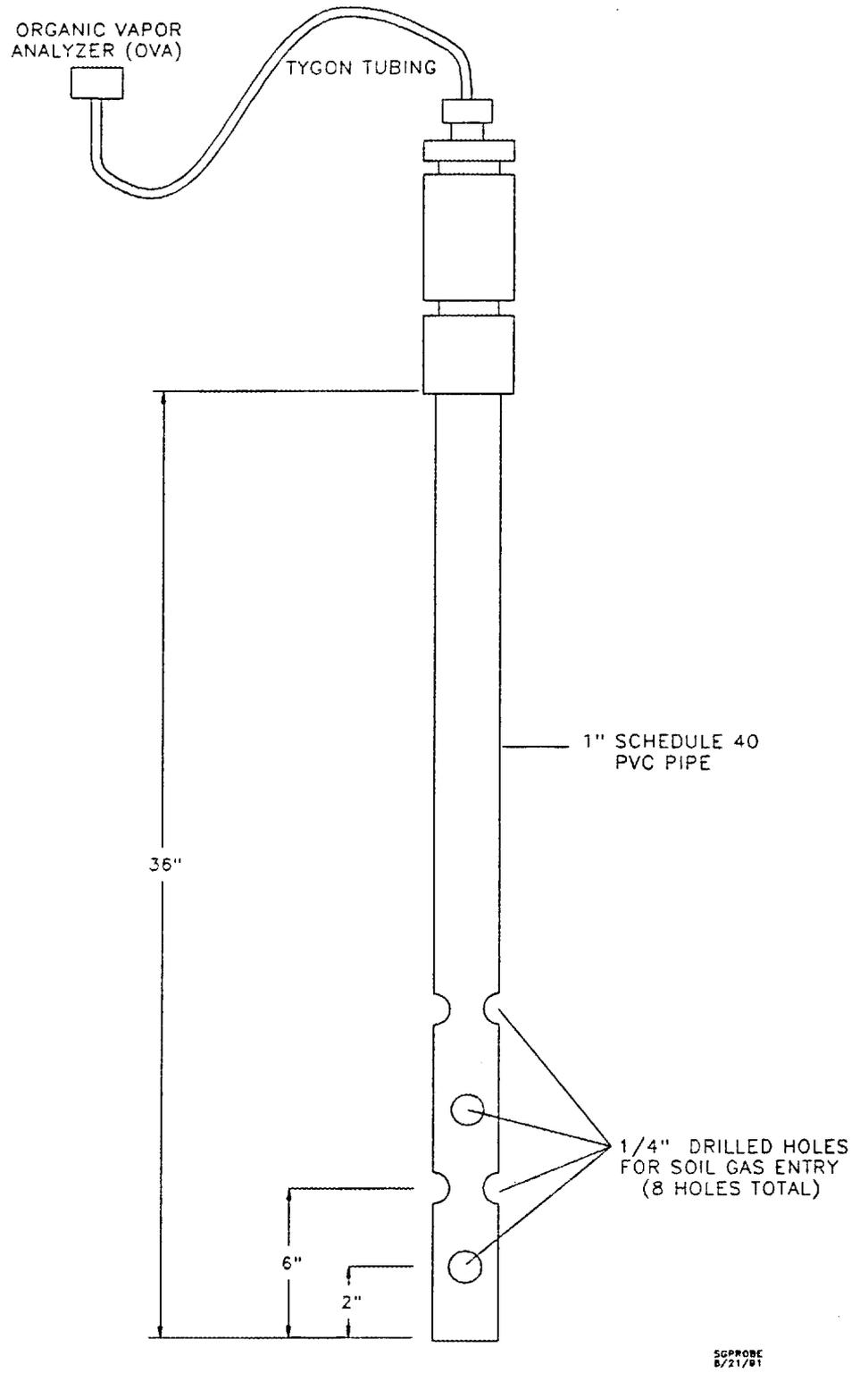


Fig. 8. ERM-West soil-gas system.

background were measured, they were checked with an HNU PID™ Model PI 101 to determine the presence or absence of any methane contribution to the reading. The PID equipped with a 10.2 electron volt (ev) ultraviolet lamp source does not detect methane; however, the PID does respond to many aromatic hydrocarbons that ionize at or below 10.2 ev. Thus, a positive response on the OVA coupled with no response on the PID was considered indicative of methane gas that could be attributed to the presence of natural organic matter rather than the presence of JP-5. Concurrent PID and OVA readings were also obtained at all locations with above-ambient OVA readings. Pure JP-5 jet fuel produced a reading of 300 ppm when tested under laboratory conditions with both the OVA and the PID. Concentration readings were found to decrease with the addition of water to pure JP-5 jet fuel in a controlled experiment (ERM-West 1988).

A total of 85 soil-gas locations were tested. Completion of the survey required three people for seven days. The results are discussed below.

2.3 ERM-WEST RESULTS

Stabilized soil-gas readings were collected from 85 locations at the fuel farm as shown on Fig. 7. The highest readings were obtained in the leachfield area near the O/WS. This area contained 5 of the 13 wells previously installed by the Navy that had revealed product floating on top of the groundwater. Readings of 1000 ppm were measured with the OVA within the leachfield area at the fuel farm. Comparison of these measurements to the measurements made in the pure product laboratory experiment, prompted the high readings to be attributed to the presence of petroleum hydrocarbon products other than JP-5 (possibly avgas or some other petroleum product with higher concentrations of VOCs). Water sample results from wells installed later neither supported nor refuted this assumption although the results did support a finding of JP-5. The level of VOCs in JP-5 is small; thus, a small amount of one of the other fuels such as avgas would give a high field reading for VOCs but still result in a finding of JP-5 when the floating product was analyzed in a laboratory.

The original purpose of the soil-gas survey was to provide data that could be contoured to indicate the areas of floating product at the fuel farm. The estimated product-plume areas drawn from the soil-gas survey are presented in Fig. 7. Three areas of anomalous readings were discovered within the fuel farm; however, significant variations in readings were found within the anomalous regions and two areas where floating product was later discovered went undetected by this method. Thus, the contoured gradient of organic vapors within the top 0.75 m (2.5 ft) of soil did not necessarily reflect the true areas of floating product. Even though the technique did not accomplish the original goal, the soil-gas survey provided some useful information for determining areas of high concentrations of JP-5 in the soil and groundwater. It was useful for locating several monitoring wells within the plume boundaries but failed to completely delineate either the product or the dissolved portions of the groundwater plume. In fact, soil-gas results from west of the fuel farm seemed to indicate the area was clean; however, later testing found a large plume of floating product there.

2.4 ORNL SOIL-GAS METHODOLOGY

The ORNL soil-gas survey was conducted to map the areal extent of the jet fuel contamination in the shallow groundwater. Potential sources of jet fuel contamination were identified prior to the survey as a faulty oil/water separator, runoff from spills on the asphalt surface, tank bottom disposal, and a 2000-gal fuel spill in February 1988.

The ORNL soil-gas survey was conducted in September 1989, one week after the completion of the EM-31 geophysical survey. The testing generally proceeded on a grid from areas of known contamination downgradient to the limits of detection of the sampling method. Contamination had been detected previously by the ERM-West soil-gas survey and confirmed by wells installed and sampled by ERM-West.

The ORNL soil-gas survey employed the Xitech™ system for collecting soil gas. This system included a set of hollow, 1.9-cm (3/4 in.)-diameter steel probes, a

drive hammer, well point filters, Tygon™ tubing, polyethylene tubing and a small vacuum pump (Fig. 9). The probe, with the point attached to polyethylene tubing (using Tygon™ tubing) inside the probe annulus, was driven into the soil. Unlike the ERM-West soil-gas method, which consisted of installing a PVC probe into a predrilled 0.75-m (2.5 ft) hole, the Xitech™ probe was driven to about 1.70 m (5.5 ft), a depth estimated to be near the capillary fringe of the shallow groundwater. The rationale for testing the deeper soil gas was that the closer the test was to the groundwater and possible floating or dissolved jet fuel, the more likely the chances of VOC detection by the method. After attaining the desired depth, the probe was withdrawn, leaving the slotted point in place attached to the polyethylene tubing. The surface of the remaining hole was tamped closed to seal the point off from ambient air. The vacuum pump was attached and at least three hole volumes of soil gas were purged prior to collecting a sample for testing. A sample was collected in a Tedlar™ bag and transported to the field GC for testing.

The field GC was regularly calibrated with benzene, toluene, ethylbenzene, and xylene (BTEX) standards and syringe blank samples were injected at frequent intervals as quality control (QC) samples. A continuous stream of carrier gas was run through the GC to purge the system between samples. The syringes were cleaned and baked between sample injections.

A 100- μ L syringe was used to transfer a sample of soil gas from the Tedlar™ bag to the field GC. The resulting chromatogram was inspected for anomalous peaks, and relative concentrations of volatile organic compounds were determined. Table 2 shows gross VOC values derived from the GC chromatograms by adding up total peak values for both identified and unknown compounds. Due to the limited accuracy of the field GC method and the lack of complete calibration, these measurements are considered strictly semiquantitative. Other semiquantitative designations, such as "clean", slightly contaminated, and highly contaminated were assigned to each soil-gas test hole. This data was used to define the limits of detectable contamination (plume boundaries) (Fig. 10). If the chromatogram for a soil-gas sample resembled the blank run, the sample was considered "clean". Designations such as slightly or highly contaminated were determined by comparing the relative number and intensity of peaks on the

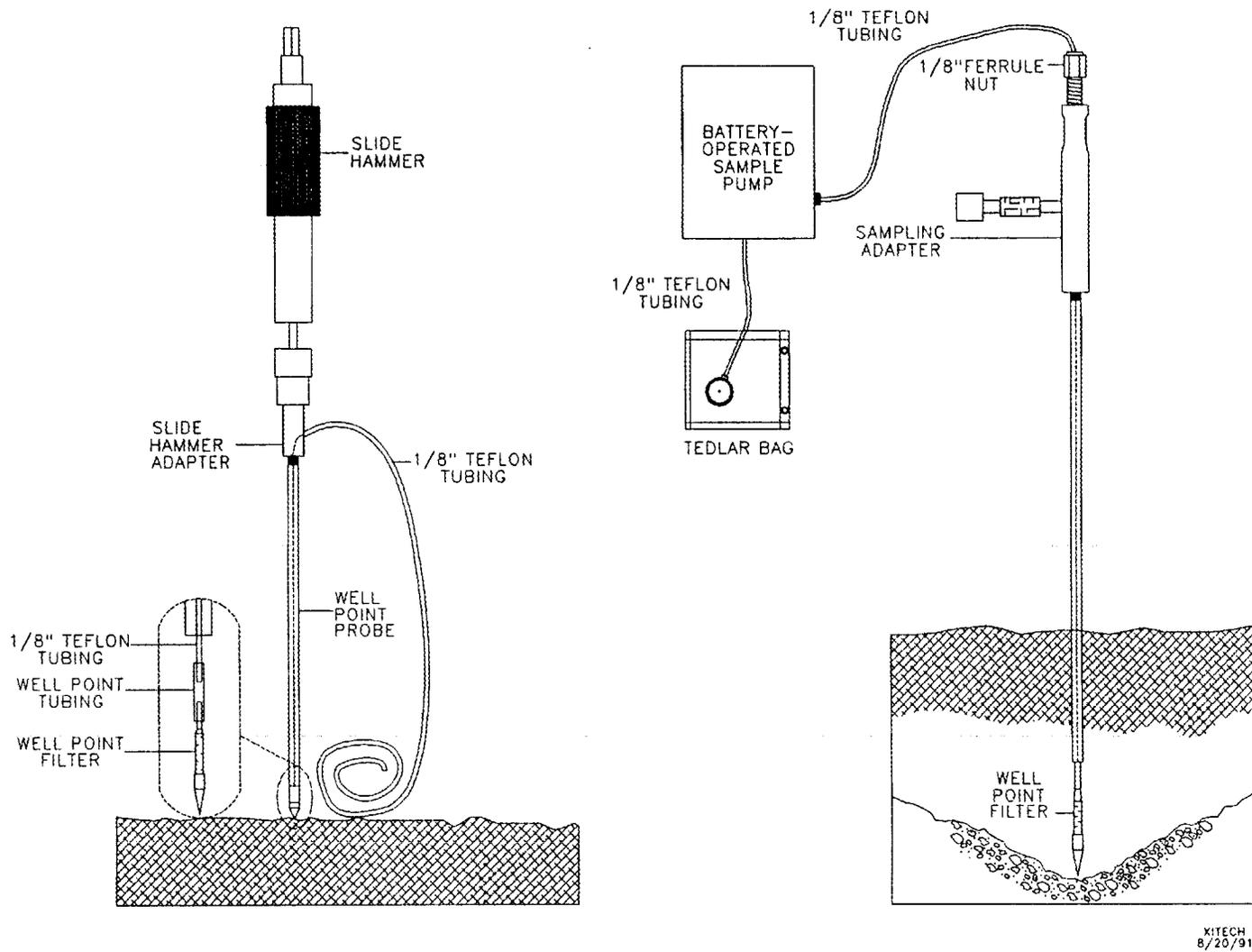


Fig. 9. XitechTM soil-gas system.

Table 2. Soil-gas results (ppm in air) from
survey conducted at IR-2, NAS Fallon, Nevada

	EAST	NORTH	SERIES 1 ^a	BTEX ^b	UNKNOWN ^c	TOTAL
1	0	0	0	0	0	0
2	0	100	0	0	0	0
3	0	150	0	150	0	150
4	0	250	250	175	150	575
5	0	300	0	99	150	249
6	0	400	0	100	0	100
7	0	500	0	0	150	150
8	40	100	0	37	0	37
9	50	150	250	1250	300	1800
10	50	200	0	0	300	300
11	50	250	3000	3000	150	6150
12	50	300	0	0	0	0
13	50	350	0	0	150	150
14	50	400	0	0	0	0
15	50	450	0	0	0	0
16	100	150	0	4000	0	4000
17	100	200	0	28	0	28
18	100	250	0	150	150	300
19	100	300	0	550	150	700
20	100	350	0	0	0	0
21	100	400	0	46	0	46
22	100	500	0	430	150	580
23	115	0	0	57	0	57
24	150	50	0	120	0	120
25	150	200	250	2000	0	2250
26	150	250	0	0	0	0
27	150	300	3000	2700	0	5700
28	150	350	3000	3000	0	6000
29	150	600	0	150	150	300
30	200	0	0	0	0	0
31	200	50	50	140	150	340
32	200	300	0	0	0	0
33	250	50	0	26	150	176
34	250	100	0	1600	500	2100
35	250	300	0	40	0	40
36	275	700	0	0	500	500
37	300	0	0	162	0	162
38	300	50	0	0	0	0
39	300	100	25	1500	500	2250
40	300	150	250	700	1000	1950

Table 2. (continued)

	EAST	NORTH	SERIES 1 ^a	BTEX ^b	UNKNOWN ^c	TOTAL
41	350	0	0	15	0	15
42	350	0	0	800	0	800
43	350	100	0	15	0	15
44	350	150	0	3000	500	3500
45	350	200	25	9500	0	9750
46	350	250	250	930	500	1680
47	400	-50	0	0	0	0
48	400	0	0	340	500	840
49	400	150	0	14	0	14
50	400	200	0	0	0	0
51	400	250	3000	3000	0	6000
52	400	300	0	100	150	250
53	400	350	0	0	0	0
54	450	0	0	0	0	0
55	450	50	0	190	300	490
56	450	150	0	0	150	150
57	450	250	0	0	0	0
58	450	300	3000	9400	0	12400
59	450	350	3000	3000	0	6000
60	450	400	0	0	150	150
61	450	450	0	0	0	0
62	500	-50	0	0	0	0
63	500	0	0	30	150	180
64	500	50	0	0	150	150
65	500	100	3000	3000	0	6000
66	500	150	250	2000	0	2250
67	500	200	0	0	0	0
68	500	250	250	600	0	850
69	500	300	0	0	0	0
70	500	350	3000	3000	0	6000
71	500	400	0	0	150	150
72	500	450	0	0	0	0
73	500	500	0	0	0	0
74	500	550	0	490	150	640
75	500	600	250	1680	300	2230
76	500	650	0	45	150	195
77	500	850	0	0	0	0
78	550	50	0	1500	1000	2500
79	550	100	0	0	0	0
80	550	150	250	100	500	850

Table 2. (continued)

	EAST	NORTH	SERIES 1 ^a	BTEX ^b	UNKNOWN ^c	TOTAL
81	550	200	0	0	0	0
82	550	300	0	0	0	0
83	550	350	3000	3000	0	6000
84	550	400	0	0	0	0
85	550	550	0	114	0	114
86	550	600	0	90	0	90
87	600	-50	0	0	0	0
88	600	0	0	600	300	900
89	600	50	0	1000	750	1750
90	600	100	0	0	0	0
91	600	150	0	0	0	0
92	600	200	0	4000	150	4150
93	600	250	0	60	0	60
94	600	350	0	0	0	0
95	600	400	0	60	150	210
96	600	450	0	43	0	43
97	600	500	0	0	0	0
98	650	50	0	590	1000	1590
99	650	100	0	0	300	300
100	650	150	0	2	1000	1002
101	650	200	0	0	500	500
102	650	250	0	210	150	360
103	650	300	0	20	300	320
104	650	350	0	0	150	150
105	650	400	0	70	0	70
106	700	-50	0	0	0	0
107	700	0	0	500	750	1250
108	700	50	0	0	150	150
109	700	100	0	0	0	0
110	700	150	3000	3000	0	6000
111	700	200	0	0	0	0
112	700	250	0	80	150	230
113	700	300	0	0	0	0
114	700	350	0	10	300	310
115	700	400	0	59	0	59
116	700	450	0	114	150	264
117	750	50	0	71	150	221
118	750	100	0	400	300	700
119	750	150	0	0	150	150
120	750	200	250	9000	0	9250

Table 2. (continued)

	EAST	NORTH	SERIES 1 ^a	BTEX ^b	UNKNOWN ^c	TOTAL
121	750	250	0	110	150	260
122	750	300	0	0	0	0
123	750	350	0	0	0	0
124	750	400	0	400	0	400
125	750	450	0	220	150	370
126	800	-50	0	0	0	0
127	800	0	0	0	0	0
128	800	50	0	0	0	0
129	800	100	0	0	0	0
130	800	150	0	0	150	150
131	800	200	0	48	0	48
132	800	250	0	100	1000	1100
133	800	300	0	0	0	0
134	850	50	0	0	500	500
135	850	100	0	110	300	410
136	850	150	0	0	0	0
137	850	200	0	0	0	0
138	900	-50	0	0	0	0
139	900	0	0	120	750	870
140	900	50	0	0	500	500
141	900	100	0	65	300	365
142	900	150	0	10	S	10
143	900	200	0	0	0	0
144	950	0	0	70	0	70
145	950	50	0	50	0	50
146	950	100	0	0	0	0
147	950	150	0	950	0	950
148	950	200	0	0	150	150
149	1000	50	0	0	150	150

^a Series 1 stands for JP-5; numbers are relative concentrations with 3000 representing the highest concentration and 0 the lowest.

^b BTEX is represented as the sum of the constituent concentrations.

^c Unknowns are relative concentrations with 1000 the highest and 0 the lowest.

Clean = 0

Slightly Contaminated = 1 - 1000

Highly Contaminated = 1000 or greater

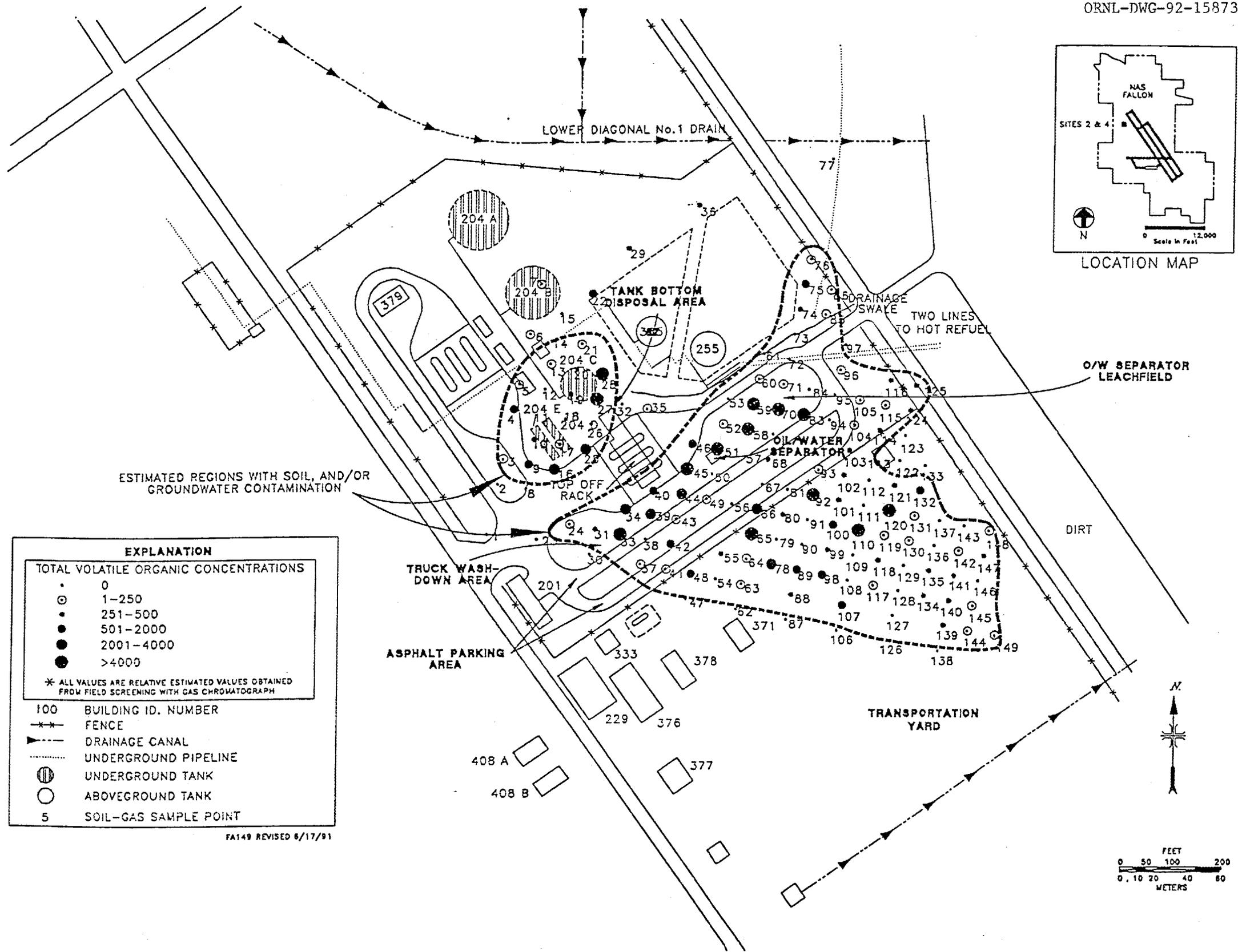


Fig. 10. ORNL soil-gas map.

chromatograms.

A total of 149 soil-gas locations were tested. Three people required 8 days to complete the survey. The results are discussed below.

2.5 ORNL RESULTS

The ORNL soil-gas results confirmed the presence of petroleum hydrocarbon contamination in the vadose zone at the fuel farm. There were, however, many samples on the grid within the overall plume that showed little or no detectable contamination using this method. These non-detect locations may have been the result of various factors, such as heterogeneous geology (e.g., permeability barriers such as clay stringers), preferred groundwater flow paths (e.g., buried channel sand deposits), varying volumetric water content of the vadose zone [Marrin (1988) has indicated little success in soil-gas monitoring studies when the vadose zone has low air-filled porosity], and varying depth to groundwater due to topography. All of the above factors can affect the detection of contaminated groundwater by soil-gas methods, which is why the method serves only as a reconnaissance tool (Devitt et al. 1987). Some of the grid points with detectable contamination outside of the known product areas were attributed to possible isolated spots of residual hydrocarbon contamination from past practices; however, later groundwater screening showed that the area contained one large contiguous groundwater plume encompassing several product plumes.

Two potential jet fuel plumes were identified by this soil-gas survey (Fig. 10). One plume area was in the vicinity of the underground storage tanks north of the topoff rack where concentrations of JP-5 indicating floating product were found by ERM-West. This area was historically used for tank bottom sludge disposal and was the site of a 2000-gal fuel spill in February 1988. Most of the fuel was cleaned up, and surface soil samples taken at the spill site by Navy personnel showed no detectable hydrocarbon contamination. This is, however, not conclusive evidence that some of the fuel did not infiltrate to the water table since

residual fuel in the surface soil may volatilize and degrade rapidly after the fuel wetting front has reached the water table. The contamination may also be the result of a leaking tank or associated underground piping.

The second soil-gas plume started at the O/WS leachfield and dissipated downgradient southeast into the transportation yard. It coincided roughly with the two plumes mapped by the ERM-West soil-gas survey except that the two plumes appeared as one and extended much farther downgradient. The extension of the plume to the west was explained by the surface runoff from the toff rack where numerous spills had reportedly occurred. Study of the chromatograms demonstrated that the concentrations of detectable VOCs diminished with distance from the source, and fewer compounds were detected at the distal edge of the plume. This was attributed to the assumed increase in age of the fuel with distance from the source, which would allow more time for the plume to be affected by dispersion, degradation, volatilization, and adsorption.

3. FIELD SCREENING WITH EM-31 AND USRADS

3.1 RATIONALE

During August 1989 and again during November 1990, electromagnetic geophysical surveys were performed at sites at NAS Fallon. The surveys involved the use of a Geonics™ EM-31 electromagnetometer coupled with an ultrasonic ranging and data collection system (USRADS). Specifically, the EM was employed to map differences in the electrical conductivity of the shallow groundwater and/or soil profile believed to be associated with floating jet fuel (JP-5), varying degrees of groundwater salinity, and/or buried metallic debris. The surveys were performed to help guide the selection of monitoring well locations at several sites.

3.2 METHODOLOGY

The EM-31 data provide a measure of the conductivity of the soil in the surveyed area. Underground conductivity contrasts often yield clues about the soil type, salinity, water content, and the location of buried metal.

USRADS is a patented, computerized data acquisition system developed by ORNL to collect and relate data from field portable instruments with the precise physical location of the data points (Fig. 11). The system incorporates three technologies: radio frequency (RF) communications, ultrasonics, and micro-computers (PC) (Dickerson et al. 1989). USRADS is adaptable to many field-portable instruments, including gamma-ray detectors, EM geophysical instruments, and x-ray fluorescence instruments. Any instrument that is field-portable and has a digital signal output can theoretically be adapted to the system.

RF is used for system timing, communications, and data transfer. The propagation time of an ultrasonic signal serves as a device to measure the distance travelled while scanning. The PC is used to: calculate the surveyor position; reduce, store, and display data; prepare reports; and transfer data into electronic data bases. The hardware included in the USRADS consists of a surveyor's backpack, 15 stationary receivers, a master receiver, a custom computer interface, and a PC.

3.3 FIELD WORK

Field work at the new fuel farm required three people for four days. Each setup with USRADS covered a block area of 60 m × 60 m (200 ft × 200 ft). The data were collected by: one person with the instrument and the backpack who walked over the block; a second person who monitored the PC as the data were transmitted and followed the system tracking on the screen to ensure that the block was adequately covered and that the data were transmitted correctly; and a third person who helped with setup and teardown of the system. The data consisted of many thousands of individual readings taken at one-second intervals

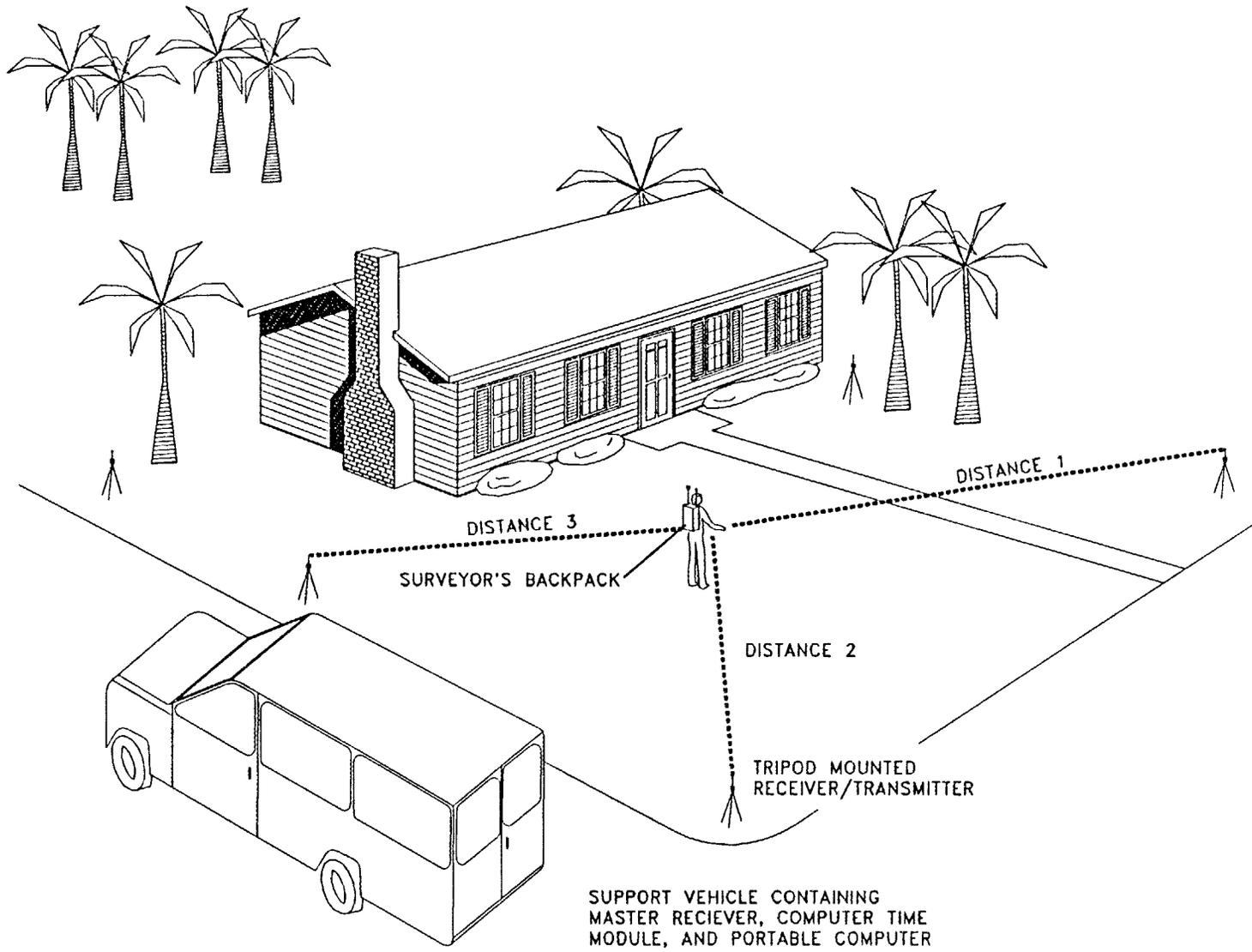


Fig. 11. USRAD System.

over the course of the surveys. This is far more data than acquired during the traditional survey technique of taking manual instrument readings at evenly spaced grid points. Thus, the data coverage is much better and the anomaly resolution more accurate.

3.4 RESULTS

The raw field data were contoured by inverse distance weighing using the Surfer™ program produced by Golden Software, Inc. (1989). The program was used to smooth the data and to remove some of the effects of cultural interferences, such as underground utilities, fences, aboveground tanks, etc. Smoothing can also be used to remove small scale anomalies (e.g., man-hole covers) and accent major trends. Contour maps of the data along with track maps of the survey blocks showing data collection points are also included. Only data for the new fuel farm are discussed in this section; the results for the other three sites surveyed are presented in Appendix A.

Two trends of low conductivity were revealed by the EM survey at the new fuel farm (Fig. 12). The two prominent, low-conductivity anomalies trend south 50° east and appear to be associated with changes in the electrical conductivity of the groundwater (Fig. 13). The conductivity of the groundwater tested in the monitoring wells at the site ranged from less than 1000 $\mu\text{hms/cm}$ to greater than 10,000 $\mu\text{hms/cm}$, indicating that the water quality ranges from fresh to brackish. The results also show anomalously high conductivities related to a chain link fence across the south side of the fuel farm and to two underground tanks (Fig. 12). The trends of low conductivity mapped by EM geophysics correlate with the wells exhibiting lower conductivity measurements. The trends do not necessarily correlate to areas with known floating product on the groundwater but do follow the same directional trends as the former Carson River channel mapped across the site (Fig. 3). Hence, the EM survey is probably mapping plumes of groundwater and soil with lower salinity and conductivity as opposed to mapping layers of floating hydrocarbons on the water table. Calculations performed by ORNL

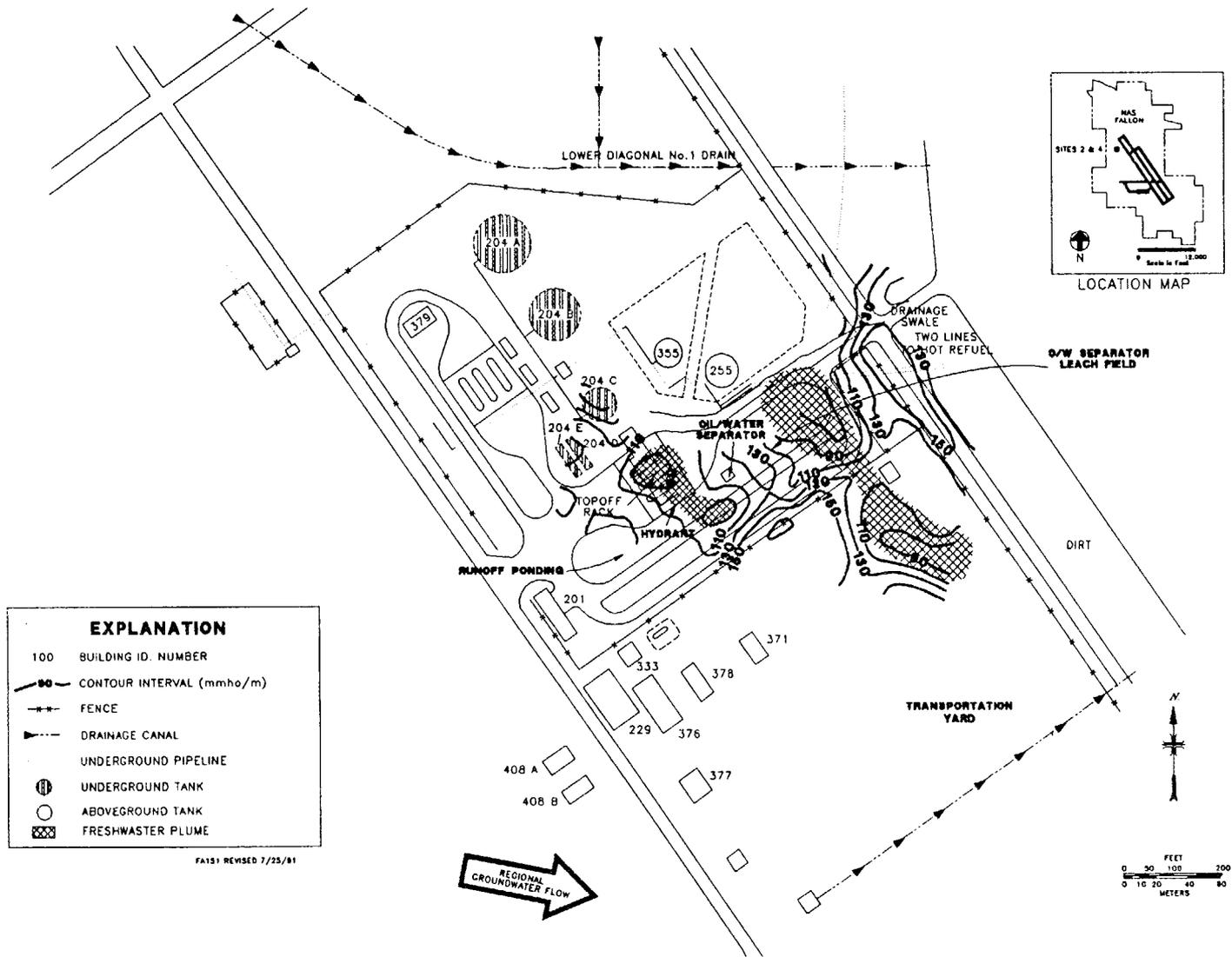


Fig. 12. Site 2 EM geophysical map.

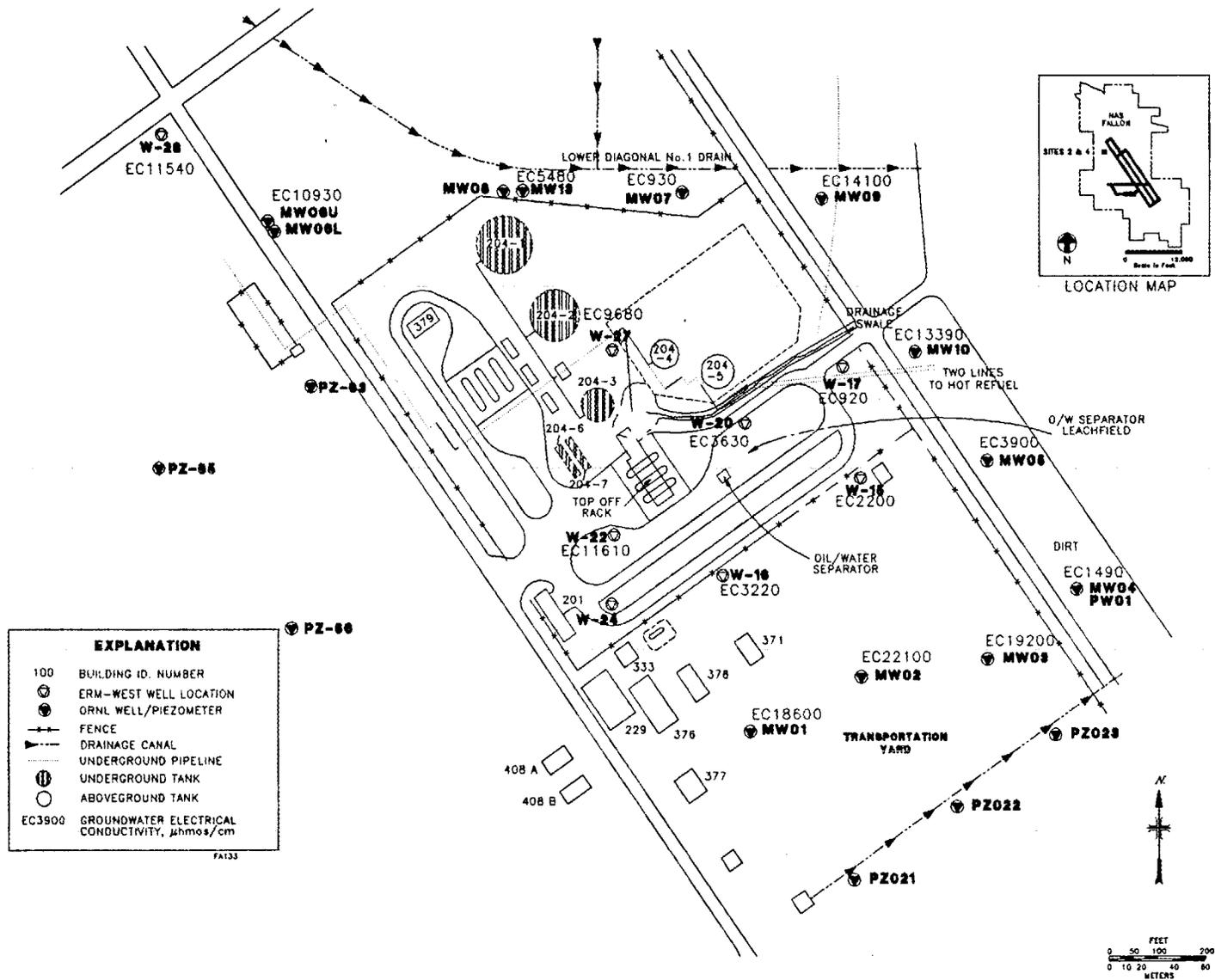


Fig. 13. Site 2 groundwater electrical conductivity in monitoring wells.

geophysicist Jon Nyquist support this conclusion. His evaluation indicated that the low-conductivity anomalies were too strong to be accounted for by floating hydrocarbons or by changing depth-to-water due to topography. This is not to say that the low-conductivity anomalies are not related to hydrocarbon plumes. In fact, the soil-gas survey and groundwater test hole data indicate that petroleum hydrocarbons are associated with both plumes of fresh water. However, the plume boundaries extend beyond the geophysical anomalies and were not completely described by the geophysical results.

The largest low-conductivity anomaly is associated with the O/WS leachfield (Fig. 12). Historical data indicate that this area is the major source of contamination in the area. The function of the O/WS, which was poorly designed and maintained, was to collect fuel spills and wash water from the toff rack. It collected both fuel and water from routine pavement washing at the toff rack but did not effectively separate the layer of fuel from the water layer prior to discharge into the leachfield. Thus, large amounts of fresh water and fuel were discharged through the leachfield into the shallow groundwater. Furthermore, the leachfield is occasionally inundated with surface runoff from rainfall. This water infiltrates and adds to the fresh water plume. Interpretation of the monitoring well water level data indicates that the groundwater flow gradient is approximately south 70° east (Fig. 14). Note that this is 20° different from the low-conductivity trend mapped by the EM geophysics. There are two possible explanations for the discrepancy: the fresh water plume may be following the trend of the buried channel (most likely), or mounding at the leachfield is causing errors in flow determination. (The surface of a mound is curved, and the solution to a three-point flow direction calculation assumes a planar surface.)

The geophysical contour map indicates that the extent of the fresh water plume associated with the leachfield has not been completely defined. The apparent end of the anomaly along the southeast boundary of the site is a distortion caused by high readings obtained along the chain link fence separating the fuel farm and the transportation yard. The anomaly resumes on the south side of the fence and appears to extend out of the surveyed area to the southeast.

A smaller, low-conductivity anomaly is located west of the O/WS just south

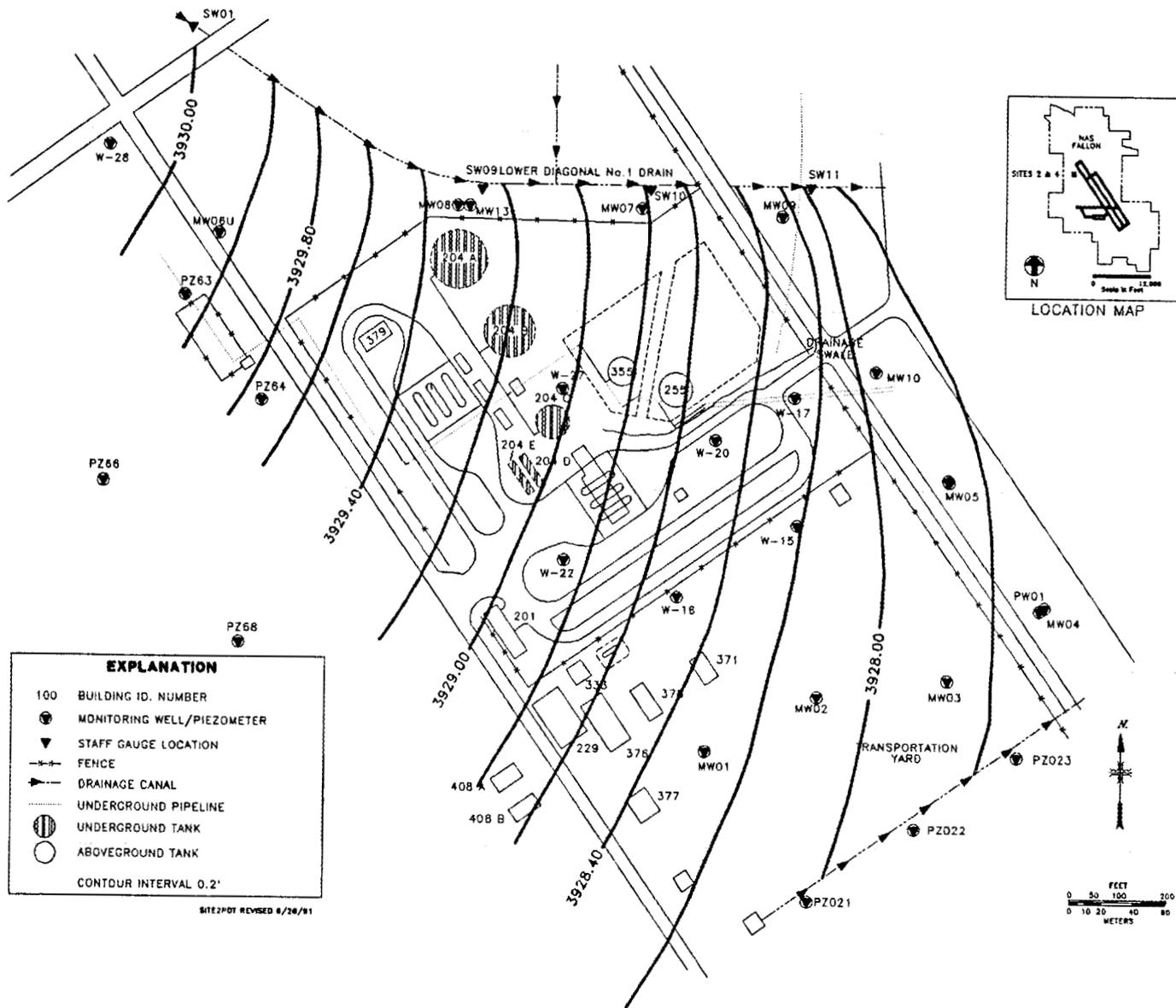


Fig. 14. Site 2 potentiometric surface map.

of the toff rack. A water hydrant located there was leaking fresh water at the time of the survey. It was still leaking several weeks later and probably represents a long-term source of fresh water recharge. This area also ponds water during rainfall, and facility personnel have noted hydrocarbons on the surface of the ponded water. The conclusion, therefore, is that the small southeasterly trending, low-conductivity anomaly in the area represents a second plume. The limits of this fresh water plume appear to be defined by the geophysical data; however, the associated soil gas and groundwater test hole plume of petroleum hydrocarbon contamination continues to the southeast. This may be an indication that the fresh water plume is younger than part of the fuel plume.

Recommendations for additional monitoring well locations at the fuel farm were made based on the geophysical and soil-gas survey results. There was little confidence, however, that these proposed locations were optimized by the existing data, and there was no assurance that once the wells were installed and tested that site characterization would be complete and the project could proceed to remedial design. It was anticipated that an additional set of wells might be needed to complete the characterization, a time-consuming and expensive prospect. Thus, monitoring well placement, as based on soil-gas and geophysical screening, was postponed, and groundwater test hole screening was employed to provide additional insight into well placement.

4. GROUNDWATER TEST HOLE FIELD SCREENING

4.1 RATIONALE

A method of direct groundwater screening was deemed desirable because results of soil-gas and geophysical surveys at the site were inconclusive. Two types of direct groundwater screening methods were considered. One type, involving the Xitech™ soil-gas system, had been tested successfully by ORNL at another site; however, it was very labor intensive, and acquisition of water samples was difficult.

The other type involved the use of a hydropunch sampler, new on the market at the time and relatively untested. However, it was adaptable for use with a small hydraulically powered drilling rig that promised to reduce the labor intensity. In practice, however, the hydropunch sampler proved to be slow, inconsistent, and subject to damage when used with a hydraulic hammer. Thus, a new method called groundwater test hole screening was developed for use at the site.

Similar to soil-gas and geophysical surveys, groundwater test hole screening was employed as a reconnaissance level investigative tool. Logically, if groundwater contamination is the concern at a site, a method of direct groundwater screening should be considered. A direct measurement method would be expected to yield the most consistent results and would also appear to be less sensitive to the variables affecting the results of soil-gas and geophysical methods. Criteria to consider when selecting a groundwater screening technique include: 1) depth to groundwater (is it feasible to obtain water samples quickly and easily?); 2) soil type (is the soil easily penetrated?); 3) site accessibility (can a small drill rig move easily around the site?); 4) data quality objectives (are reconnaissance-level data sufficient?); 5) size of the site (can the site be covered just as easily by one or two wells?); and 6) project budget and schedule (does the project require a rapid cost-effective screening approach?). Once the decision to use groundwater test hole screening was made, the next consideration was how best to proceed with the survey.

The approach to field screening at different sites varied depending on what was known about contamination at each site. Some sites, such as Site 1, the fire training area (Appendix B), and Site 2, the new fuel farm, were known to be or strongly suspected of being contaminated. In these cases, field screening started in areas of known groundwater contamination or surface soil staining and proceeded away and downgradient in the direction of regional groundwater flow to the detectable limits of contamination. The plume boundaries were then traced around the perimeter to the upgradient limits of detectable contamination. At other sites - such as Site 6, the defuel disposal area, and Site 20, the checkerboard landfill, where there was doubt about the potential for or location of contamination - screening was initially conducted by drilling fence patterns of groundwater test

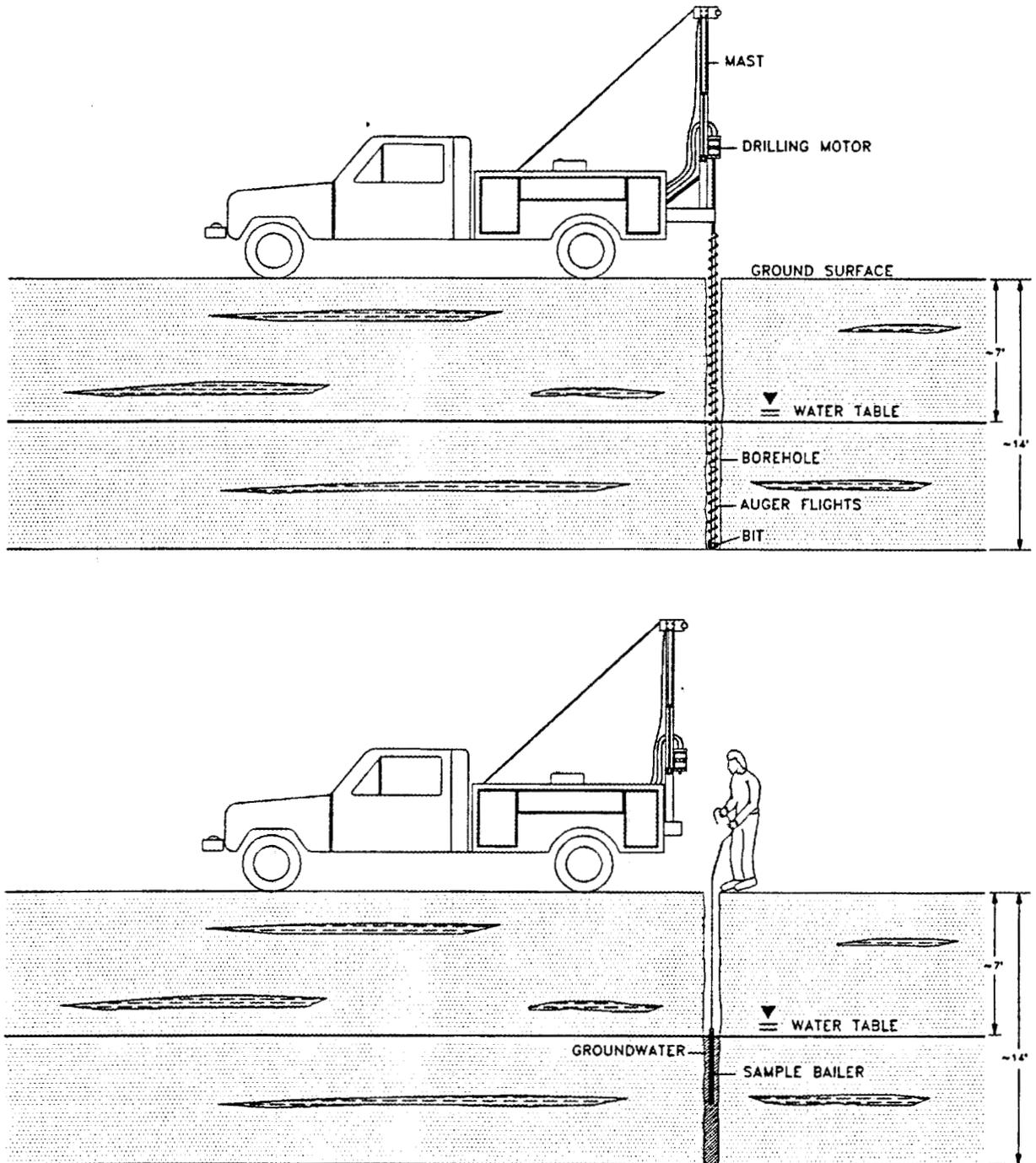
holes roughly perpendicular to regional groundwater flow lines downgradient from the suspected site (Appendix B). If contamination was detected, as at Site 6, the survey then proceeded as above. If, however, no contamination was detected, as at Site 20, the survey was completed around all sides of the site where it was reasonable to expect contaminants to be migrating from the site.

4.2 METHODOLOGY

Developed by ORNL/GJ field personnel after soil-gas and EM-31 geophysical techniques proved inconclusive or inadequate, this field-screening technique was an outgrowth of attempting to use a hydropunch sampler. After the third failed attempt at using the hydropunch to obtain a sample at one location, it was discovered that a bailer could be dropped into the open hole after removal of the hydropunch. It was much easier to obtain a water sample with the bailer than with the hydropunch, and since the purpose of the sampling was for field screening, it did not matter if the sample contained abundant suspended sediment.

The new technique, which proved to be quicker and simpler, involved drilling a 10-cm (4 in.)-diameter auger hole into the water table with a small, truck-mounted, hydraulically powered auger rig (Fig. 15). This was faster than driving the hydropunch with the same rig. Each hole was monitored continuously during drilling for VOCs with a PID (HNU model PI-101). The PID was calibrated daily with a known gas standard (isobutylene). Elevated readings obtained during drilling and in the open hole were noted in the field logbook. Occasionally, the PID would react to exhaust from the rig; however, this problem was eventually minimized by routing the exhaust away and downwind from the work area using a flexible metal pipe and by checking for repeatable readings with the PID.

Color and composition of the drill cuttings were also noted and recorded in the field logbook. This information was valuable because a correlation between gray, reduced cuttings and high readings on the PID was noted in the field. Thus, if all the cuttings were buff- or tan-colored, low VOC concentrations were indicated; if a gray soil zone was encountered, higher concentrations of VOCs



GWSCHM

Fig. 15. Groundwater test hole method.

were suspected.

After each hole was drilled at least 1 to 2 m (3 to 6 ft) into the shallow water table, a groundwater sample was collected from the open hole with a bailer or screened auger. The choice of which sampling device to use depended on whether or not the hole would stand open after the augers were removed. Where sandy soil was encountered, the holes tended to cave in up to the top of the water table, and a screened auger had to be drilled into the water-bearing sand to obtain a sample. Otherwise, a bailer was the quickest way to obtain a sample.

Once obtained, the water sample was poured from the bailer or screened auger into a 250-mL glass vial. Vials were purchased from I-Chem equipped with Teflon™ septum caps and were certified precleaned with respect to VOCs. A new vial was used for each sample. During the sample transfer, about 50 mL of headspace was left in the container. The sample was capped immediately and allowed to equilibrate in the container for at least 30 min to ensure that any dissolved VOCs in the water sample had sufficient time to partition into the headspace air of the vial. All augers, bailers, and other sampling tools were steam-cleaned between holes.

The capped samples were transported to the van containing the field-portable GC (Photovac™ Model 10S50) where an aliquot of headspace air was removed from each vial with a syringe (usually 100 μ L) and injected into the field GC. Sometimes a smaller sample aliquot was injected if there was evidence that the sample was highly contaminated. This subjective decision was made based on criteria such as: above-ambient PID readings in the open hole; visible product in the sample; noticeable hydrocarbon odor; and gray, reduced appearance of the drill cuttings. The appearance of visible product was considered ample evidence of contamination, and, generally, no test was run on such samples. If a sample did not contain visible product, a test was performed.

The resulting chromatogram was inspected for anomalous peaks, and a determination of relative concentrations of volatile organic compounds was made. Thus, semiquantitative designations, such as "clean", "slightly contaminated", and "highly contaminated", were assigned to each groundwater test hole for the purposes of creating a relative concentration map. The data tables in this section

and in Appendix B designate the holes as "pos" and "neg", indicating that the sample either tested positive or negative for VOCs with the PID and GC. In general, anomalous peaks on a chromatogram were confirmed by PID readings in the open drill hole. Specifically, for 89% of the 450 holes tested at various sites, field GC results were consistent with other field observations (Appendix B).

The field GC was regularly calibrated with BTEX standards. Syringe blank samples were injected at frequent intervals as QC samples. A continuous stream of carrier gas was run through the GC to purge the system between samples. Syringes were cleaned and baked between sample injections. If the chromatogram for the sample resembled the blank run and there were no elevated PID readings, the sample was considered "clean". Occasionally, samples were tested twice to check repeatability of the results. Ten split samples were sent to Alpha Analytical Laboratory in Reno, Nevada, for overnight analysis of VOCs by EPA method 624. The results confirmed the field designation of "clean" for all ten samples. This field screening method has proven very effective for detecting and delineating petroleum-hydrocarbon-contaminated groundwater plumes at NAS Fallon.

4.3 RESULTS

The results of groundwater screening at the new fuel farm are shown on a map in Fig. 16 and in Table 3. Similar maps and tables for other sites are included in Appendix B. A narrative summary of the results for the new fuel farm is presented below as well as the results of the subsequent monitoring well sampling. Discussions of results for other sites are included in Appendix B.

As shown in Fig. 16, five areas of floating product contamination have been delineated: 1) the area east of underground tank 204-1, 2) the area between the pumping station and the fuel farm, 3) the area near a former sump used for collecting fuel from leaking tanker trucks at the fuel farm, 4) the area just north of the toff rack, and 5) the O/WS and associated leachfield area. Groundwater test hole screening was accomplished in 6 days and required a crew of 4 people. Because data were available within an hour after obtaining a sample, the final

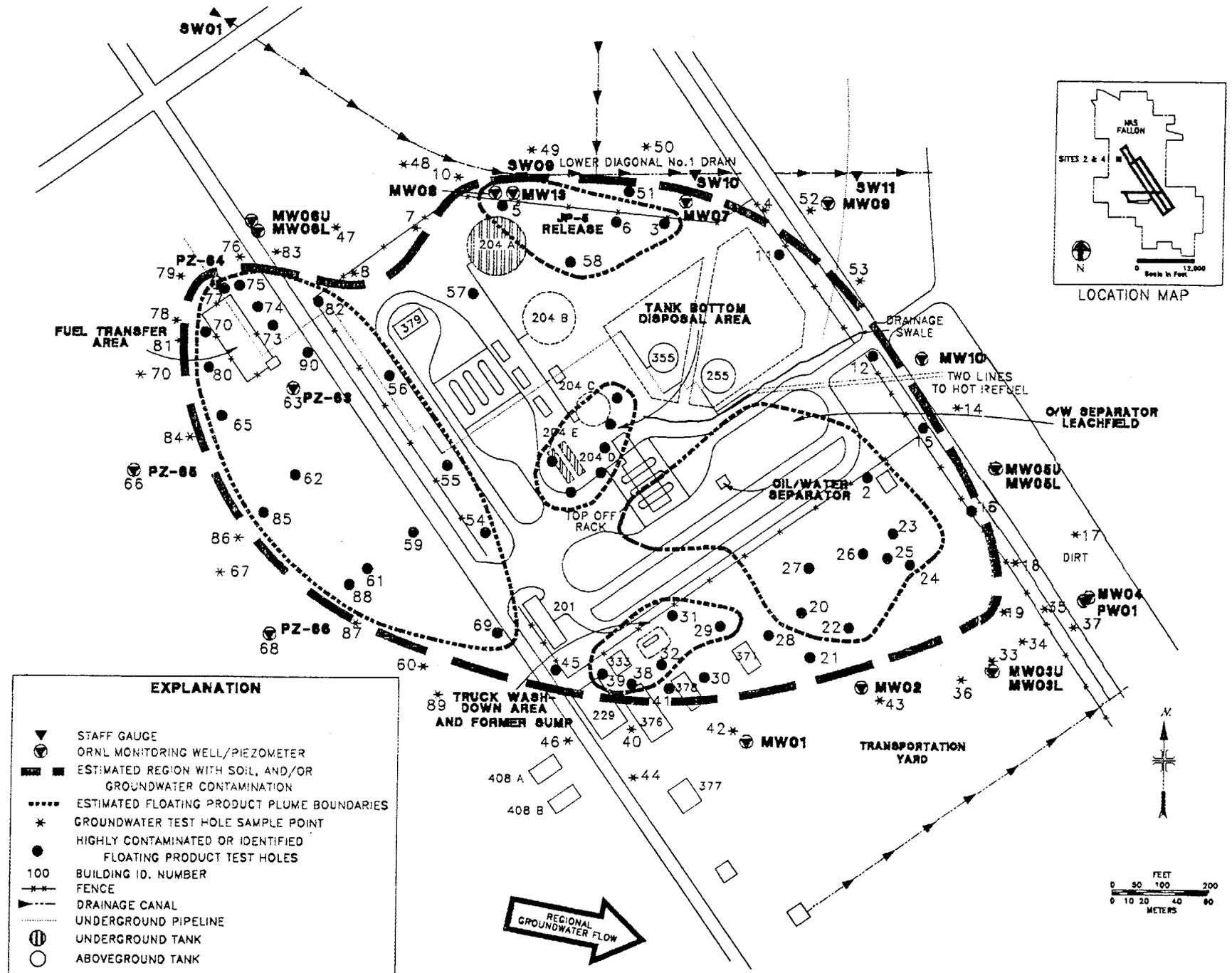


Fig. 16. Site 2 groundwater test hole results.

Table 3. Screening results for Site 2

Hole #	PID		Field GC		Final Decision	Comments
	Pos.	Neg.	Pos.	Neg.		
1	X		X		POS	Next to ERM15
2	X		X		POS	
3	X		X		POS	
4	X		X		POS	
5	X		X		POS	
6	X		X		POS	
7	X		X		POS	
8	X		X		POS	
9	X		X		POS	
10	X		X		POS	
11		X		X	NEG	
12		X		X	NEG	
13	X		X		POS	
14		X		X	NEG	
15		X		X	NEG	
16	X			X	NEG	PID reading exhaust
17		X		X	NEG	
18		X		X	NEG	
19	X		X		POS	
20	X		NA		POS	Product
21		X		X	NEG	
22		X		X	NEG	
23	X		NA		POS	Product
24		X	X		POS	Slight GC response, Neg deflection on PID
25		X	X		POS	Slight GC response
26		X	X		POS	Slight GC response
27	X		X		POS	
28		X		X	NEG	
29	X		X		POS	
30		X		X	NEG	
31	X		X		POS	Product
32	X		X		POS	Product
33		X		X	NEG	
34		X		X	NEG	
35	X			X	NEG	PID reading exhaust
36		X		X	NEG	
37		X		X	NEG	
38	X		X		POS	Product
39	X		X		POS	Product
40	X		X		POS	Slight GC response
41		X		X	NEG	
42	X		X		POS	
43		X		X	NEG	PID reading exhaust
44		X		X	NEG	PID reading exhaust
45	X			X	NEG	PID reading exhaust
46	X			X	NEG	PID reading exhaust
47		X		X	NEG	
48		X		X	NEG	
49		X		X	NEG	

Table 3. (continued)

Hole #	PID		Field GC		Final Decision	Comments
	Pos.	Neg.	Pos.	Neg.		
50						NO DATA
51		X		X	NEG	
52		X		X	NEG	
53		X		X	NEG	
54	X		ND		POS	Product
55	X		ND		POS	Product
56	X		ND		POS	Product
57	X		X		POS	
58	X		ND		POS	Product
59	X		ND		POS	Product
60	X			X	NEG	PID reading exhaust
61	X		ND		POS	Product
62	X		ND		POS	Product
63	X		ND		POS	Product
64	X			X	NEG	PID reading exhaust
65	X		ND		POS	Product
66		X		X	NEG	
67		X		X	NEG	
68		X		X	NEG	
69	X		X		POS	Product
70		X	X		POS	PID false negative
71		X		ND	NEG	Site 1
72		X		ND	NEG	Site 6
73	X		ND		POS	
74	X		ND		POS	Product
75	X		ND		POS	Product
76		X		ND	NEG	
77	X		ND		POS	Product
78		X		ND	NEG	
79	X		ND		NEG	
80	X		ND		POS	
81		X		ND	NEG	
82	X		ND		POS	Product
83		X		ND	NEG	
84		X		ND	NEG	
85	X		ND		POS	
86		X		ND	NEG	
87		X		ND	NEG	
88		X		ND	NEG	
89		X		ND	NEG	
90	X		ND		POS	Product

Total = 89

4 holes with negative PID and positive GC
6 holes with positive PID and negative GC
11% disagreement between PID and GC
89% agreement

ND = not detected
NA = not analyzed

decision about placement of monitoring wells was made immediately after completion of the survey. Well installations began the following week.

Phase II site characterization by ORNL included installing fourteen 5-cm (2 in.)-diameter monitoring wells and one pumping well at the new fuel farm (Fig. 17). Most of these wells were installed to confirm the limits of the dissolved product plume defined by groundwater test holes. Monitoring well MW06 was installed as a dual completion, "clean", upgradient well. Wells MW07 (single completion), MW08 (dual completion), and MW09 (single completion) were installed between the fuel farm and the Lower Diagonal No. 1 Drain. After purging, the upper completion of MW08 failed to recharge and was replaced with MW13. The remaining six wells were installed downgradient along the southern and eastern site boundaries. MW03 and MW05 are dual completions, and the other four wells are single completions. A 13-cm (5 in.)-diameter pumping well, PW01, was installed as an offset to MW04. This well was used for a pumping test to determine hydrological parameters for the underlying shallow alluvial aquifer.

Monitoring well placement resulted in collection of soil samples and groundwater samples. Soil samples were taken continuously with a split spoon or a California sampler during well installation. Sampling methodologies are described in the Phase II Remedial Investigation/Feasibility Study Work Plan (ORNL 1989b). Only selected samples were analyzed for organic contaminants. Additional sampling activities consisted of taking several surface soil samples, as well as surface water and sediment samples from the Lower Diagonal No.1 Drain (Fig. 17). Groundwater samples from all ORNL wells and from four ERM-West wells were also taken. Groundwater and soil sampling results for organic contaminants are given in Tables 4 and 5.

Major cation and anion analyses of groundwater indicate naturally high total dissolved solids (TDS) occurring in the upper aquifer of the region. These dissolved solids have rendered the groundwater in parts of Carson desert unfit for domestic use (Glancy 1986). Activities conducted at the new fuel farm have limited, if any, potential for introducing these contaminants into the environment, and their presence is apparently not a result of NAS Fallon activities (ORNL 1991a). Thus, the results are not included in this report.

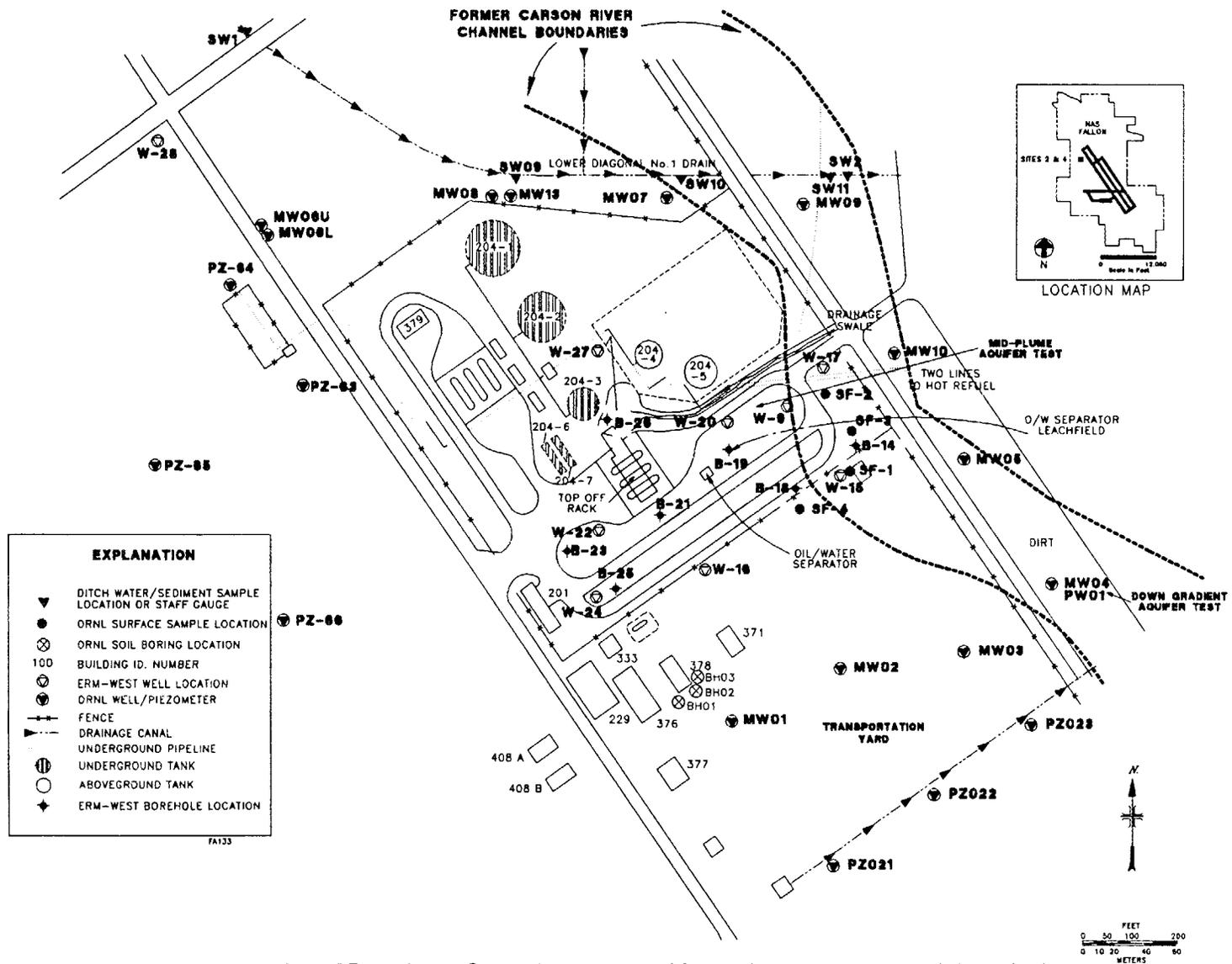


Fig. 17. Site 2 Monitoring wells, piezometers, and boreholes.

Table 4. Site 2 water analysis

WATER ANALYSIS µg/L			
Well Number	Volatile organic compounds Method 624 det. limit 5 µg/L	Low boiling point petroleum hydrocarbons Method 8015 modified det. limit 50 µg/L	High boiling point petroleum hydrocarbons Method 8015 modified det. limit 50 µg/L
MW04	ND	ND	ND
MW05L	ND	total: 84 toluene: 1 (dl:1) xylenes: 6 (dl:4)	ND
MW10	ND	ND	ND
MW09	ND	ND	ND
MW05U	ND	ND	ND
MW06L	ND	ND	ND
MW01	ND	ND	ND
MW02	ND	ND	ND
MW06U	ND	ND	ND
MW06U	ND	ND	ND
MW03L	ND	total: 140	ND
MW03U	ND	ND	ND
ERM17	xylenes: 14	ND	ND
ERM16	xylenes: 30	ND	ND
ERM22	xylenes: 8	ND	ND
ERM27	xylenes: 18	total: 520	ND
MW07	ND	ND	ND
MW07	ND	ND	ND
MW08	ND	ND	ND
MW13	3 TIC	total: 110 benzene: 0.9 (dl:0.5)	ND

Note: Wells listed more than once indicate the analysis of multiple samples.
 ND: not detected
 dl: detection limit
 TIC: tentatively identified compounds

ERM 15 & ERM 20 contained floating product.
 ERM 28 was a clean upgradient well, and ERM 24 contained 20 µg/L xylenes.

Table 5. Site 2 soil analysis

$\mu\text{g}/\text{kg}$ unless noted				
Sample Location	Depth, ft	Analysis		
		VOC	TPH, mg/kg	BNA, $\mu\text{g}/\text{kg}$
MW02	6.5-7.0	ND	ND	ND
MW04	8.5-9.0	ND	17	1600 bis(2-ethylhexyl) phthalate
MW05	6.5-7.0	ND	17	3900 bis(2-ethylhexyl) phthalate
MW05	8.5-9.0	ND	16	800 bis(2-ethylhexyl) phthalate
MW06	6.5-7.0	ND	13	ND
MW08	6.5-7.0	ND	16	ND
MW09	6.5-7.0	ND	ND	ND
SF1	0.0-1.0	ND	40	ND
SF1	3.0-4.0	ND	15	ND
SF2	0.0-1.0	ND	140	ND
SF2	3.0-4.0	ND	2	ND
SF3	0.0-1.0	ND	43	ND
SF4	0.0-1.0	ND	4	ND
SW1	sediment	ND	7	ND
SW2	sediment	ND	11	ND

VOC: Volatile organic compounds (Method 624, detection limit: 10 $\mu\text{g}/\text{kg}$).
 TPH: Total petroleum hydrocarbons (Method 418.1, detection limit: 10 mg/kg).
 BNA: Base neutral/acid extractable semivolatiles organics (Method 625, detection limit: 330 $\mu\text{g}/\text{kg}$).

Bis(2-ethylhexyl)phthalate at these levels is considered laboratory contamination.

Results support well placement using the groundwater test hole definition of the JP-5 plume boundaries. All wells placed inside the plume were "contaminated", and all wells placed outside the plume were "clean" by National Interim Primary Drinking Water Regulation (NIPDWR) standards with respect to contaminants associated with JP-5 (Table 6) (van der Leeden 1990). The results of the other groundwater test hole surveys are presented in Appendix B, and the relative merits of the method are discussed in the section on relative effectiveness of screening techniques.

JP-5 is made up of numerous compounds, and the relative composition varies depending on a number of factors. The compounds listed in Table 6, however, are the only constituents with regulatory standards and generally constitute less than 4.5% of the fuel mixture (Smith 1981).

NDEP standards for groundwater include the NIPDWR standards and also stipulate that floating petroleum product on groundwater greater than 1.2-cm (0.5 in.)-thick must be removed. TPH concentrations exceeding 100 mg/kg in soil also constitute cleanup criteria according to NDEP regulations.

5. RELATIVE EFFECTIVENESS OF SCREENING TECHNIQUES

The groundwater test hole results were utilized in selecting the final locations for monitoring wells at several sites. The number of monitoring wells, the duration of the field investigation, and the cost of the investigation were minimized by the use of groundwater test hole field screening. For instance, several wells from a previous investigation at Site 3 failed to fully delineate the plume, and the RI/FS Work Plan called for the installation of 8 additional wells (Fig 18). Approximate locations for the new wells were shown in the work plan according to the best available information at the time the plan was written. Re-evaluation of monitoring well placement after performance of EM geophysical and soil-gas surveys would have resulted in wells configured as shown on Fig. 19.

Table 6. NIPDWR standards for JP-5-related contaminants

Compound	Concentration	% of JP-5
Benzene	0.5 mg/L	0.5%
Toluene	2.0 mg/L	1.3%
Xylenes (Total)	10 mg/L	2.2%
Ethylbenzene	0.7 mg/L	0.5%

Source: van der Leeden 1990.

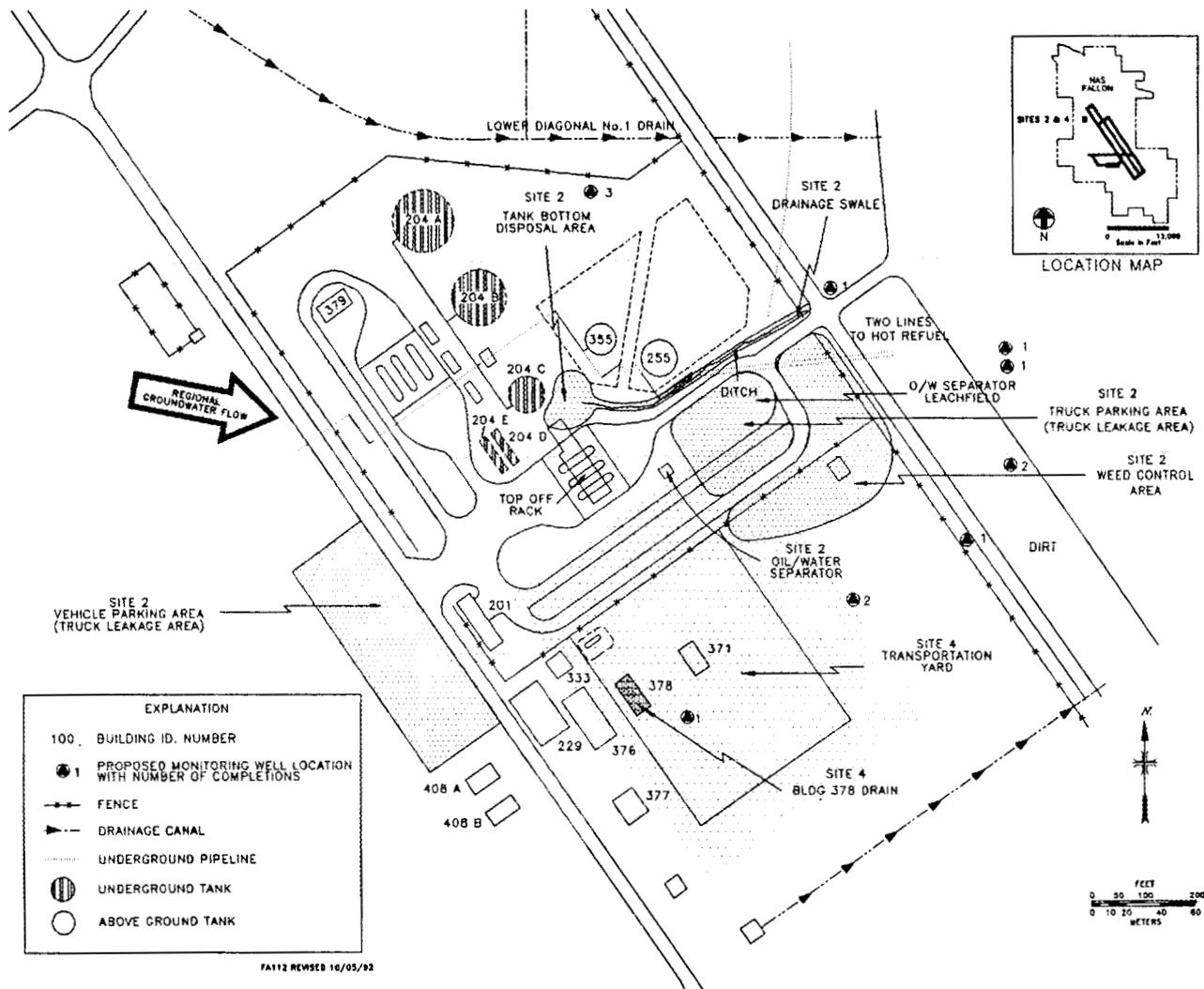


Fig. 18. Site 2 map of monitoring wells proposed in the work plan.

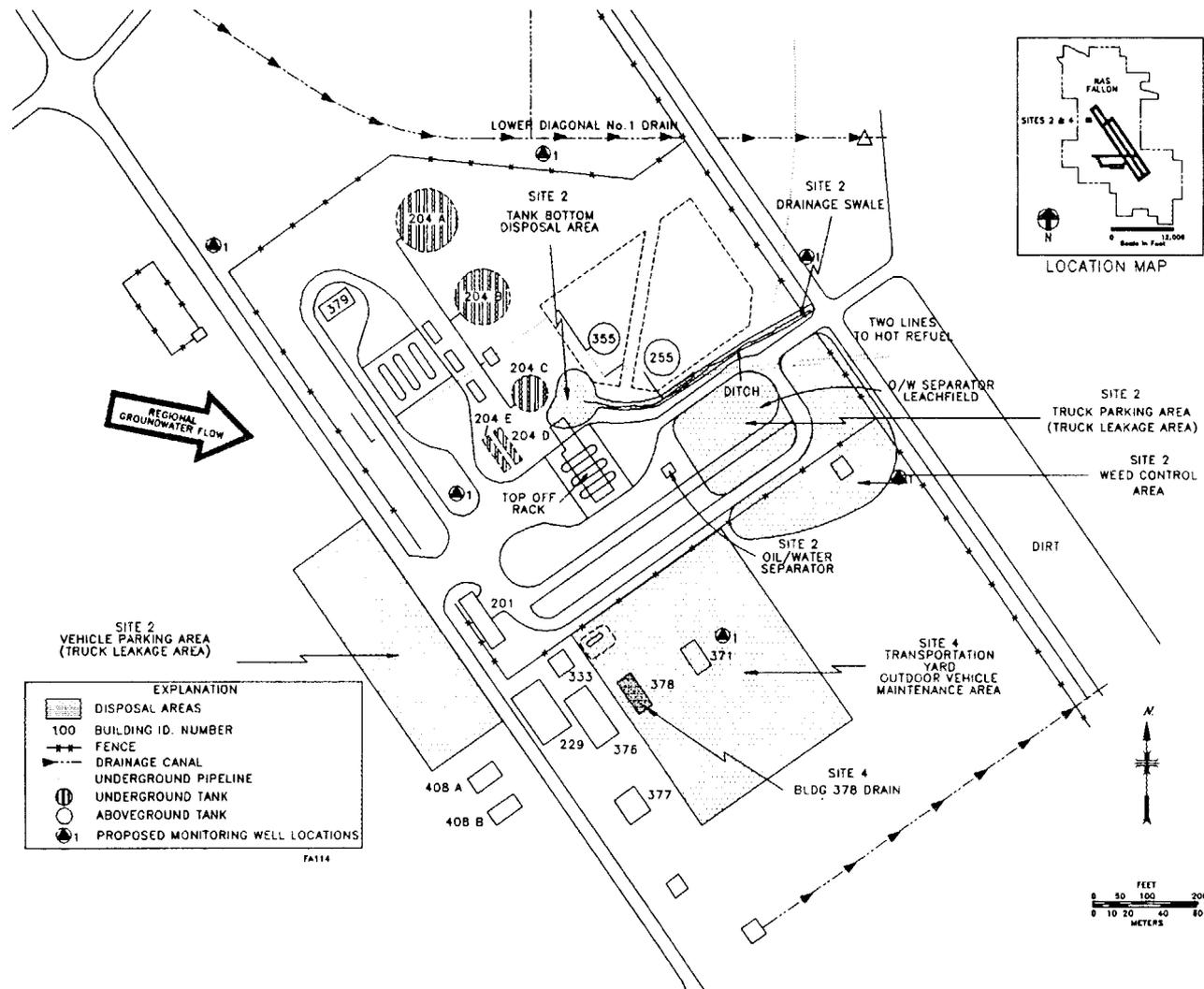


Fig. 19. Site 2 map of proposed monitoring wells based on soil-gas and geophysical data.

However, the actual positions of these wells were greatly modified after the groundwater screening was completed (Fig. 16). Comparison of well placement based on the results of various screening methods reveals that groundwater screening saved at least one additional round of well installation and sampling at Site 2 (a process that often takes 6 to 9 months and costs \$10,000 per well). Groundwater screening at the other sites was similarly successful.

A total of 66 wells were installed. Sixteen of these wells were purposely located within the limits of the plumes defined by groundwater screening. The remaining 50 wells were located along plume boundaries in order to confirm the limits of contamination. Only two of the wells located along plume boundaries contained concentrations of contaminants at levels that did not confirm the plume boundaries defined by groundwater test hole screening. Thus, a success level of 97% in monitoring well placement was achieved by following groundwater test hole plume delineation.

The only other information requested by the NDEP that required additional well installations was the gradient of contaminant concentrations within the plume boundaries. Several additional mid-plume wells were subsequently installed to determine the concentration gradients of contaminants within the plume boundaries.

It is interesting to note the effects of varying contaminant types on the correlation between PID and field GC measurements taken during groundwater test hole surveys performed at various sites. The average agreement between field GC and PID screening results was 89%, good agreement for a screening method. The range, however, was from 58% to 94% agreement (Table 7). The best agreement was achieved at sites with plumes related to gasoline and jet fuel, such as Site 2 (89%), Site 14 (92%), Site 16 (94%), and Site 6 (86%). The worst agreement was obtained at sites with solvents, such as Site 1 (81%) and Site 3 (58%). Site 13 was a mixed plume with both gasoline and fuel oil. It had a good agreement rate of 88%, probably due to the VOCs associated with the gasoline.

In general, it appears that contaminants with a variety and high concentrations of VOCs are more readily detected by the method. Fortunately,

Table 7. Rate of PID and GC results agreement

<u>Site Number</u>	<u>Principle Contaminants</u>	<u>Correlation PID to GC</u>
14	gasoline	92%
1	JP-5 and solvents	81%
2	JP-5	89%
6	JP-5	86%
3	solvents	58%
16	JP-5	94%
13	gasoline and fuel oil	88%

most of the sites with plumes had either jet fuel or some other petroleum hydrocarbon product which contained a significant percentage of VOCs. Thus, a field screening method effective at detecting these compounds in the groundwater was appropriate for most sites.

In the case of solvents, such as trichloroethene (TCE), environmental fate is more difficult to predict. TCE may behave differently depending on the amount of solvent present and other factors: TCE can sink as product, dissolve in the groundwater, or float as a thin layer (Schwille 1988). Thus, detection of solvent plumes is more difficult and yielded a poorer data correlation during this study.

5.1 DATA ANALYSIS AND CORRELATION

Evaluation of the correlation between PID readings and field GC results for the groundwater test hole survey at Site 2 revealed some interesting relationships. PID measurements and corresponding GC gross VOC measurements are shown on Table 8. Gross VOC values for the GC were derived by adding up the total peak values for both identified and unknown compounds shown on the chromatograms. Due to the limited accuracy of the field GC method and lack of complete calibration, these measurements are considered semiquantitative. PID and field GC values were paired by hole location, and a linear regression was performed (Fig. 20). It was found that a rough approximation of the gross GC VOC value could be estimated by multiplying the PID reading by 30. The analysis also revealed that for test holes with an open hole PID reading of <0.2 ppm, there was a 97% probability that the GC would show no detectable VOCs. Additionally, for PID readings between 0.2 and 8.0 ppm, there was a 43% chance that the GC would detect VOCs. For PID readings >8.0 ppm, there was a 97% chance of the GC detecting VOC contamination. Also, when the PID reading was >45 ppm, there was a 75% chance that floating product would be observed on the groundwater sample. These relationships were derived from the new fuel farm data where JP-5 was the source of the VOCs and proved useful for investigations at other sites where JP-5 was the principal contaminant. The presence of

Table 8. Screening results for New Fuel Farm

Hole #	PID			Field GC			Final Decision	Comments
	Reading PPM	Pos.	Neg.	Reading PPB	Pos.	Neg.		
1	110	X		4500	X		POS	Next to ERM15
2	60	X		2000	X		POS	
3	35	X		1000	X		POS	
4	100	X		4000	X		POS	
5	130	X		3000	X		POS	
6	15	X		300	X		POS	
7	45	X		1000	X		POS	
8	4	X		150	X		POS	
9	30	X		1500	X		POS	
10	8	X		500	X		POS	
11	1		X	10		X	NEG	
12	0		X	0	X	X	NEG	
13	20	X		800	X		POS	
14	0		X	0		X	NEG	
15	0		X	0		X	NEG	
16	7	X		110		X	NEG	
17	0		X	25		X	NEG	
18	0		X	15		X	NEG	
19	2	X		150	X		POS	
20	150	X		3000	X		POS	Product
21	0		X	0		X	POS	
22	0		X	12		X	NEG	
23	20	X		800	X		POS	Product
24	0.6		X	150		X	POS	Slight GC response
25	0		X	10		X	NEG	Slight GC response
26	0		X	0		X	NEG	Slight GC response
27	100	X		3100	X		POS	
28	0.1		X	8		X	NEG	
29	40	X		1500	X		POS	
30	0		X	0		X	NEG	
31	120	X		3800	X		POS	Product
32	50	X		2100	X		POS	Product
33	1		X	14		X	NEG	
34	0		X	0		X	NEG	
35	20	X		5		X	NEG	HNU reading exhaust?
36	0		X	0		X	NEG	
37	0		X	0		X	NEG	
38	30	X		1100	X		POS	Product
39	200	X		4800	X		POS	Product
40	0.3	X		15	X		POS	Slight GC response
41	0		X	0		X	NEG	
42	1.5	X		25	X		POS	
43	0.2		X	12		X	NEG	HNU reading exhaust?
44	0.2		X	8		X	NEG	HNU reading exhaust?
45	5	X		10		X	NEG	HNU reading exhaust?
46	2	X		8		X	NEG	HNU reading exhaust?
47	0		X	0		X	NEG	
48	0		X	0		X	NEG	
49	0		X	0		X	NEG	

Table B.1. (continued)

Hole #	PID			Field GC			Final Decision	Comments
	Reading PPM	Pos.	Neg.	Reading PPB	Pos.	Neg.		
50								NO DATA
51	0		X	0		X	NEG	
52	0		X	0		X	NEG	
53	0		X	0		X	NEG	
54	80	X		3200	X		POS	Product
55	90	X		4100	X		POS	Product
56	150	X		4800	X		POS	Product
57	140	X		4200	X		POS	
58	152	X		4500	X		POS	Product
59	150	X		4850	X		POS	Product
60	3	X		0		X	NEG	HNU reading exhaust?
61	60	X		1600	X		POS	Product
62	90	X		2800	X		POS	Product
63	75	X		3300	X		POS	Product
64	2	X		35		X	NEG	
65	50	X		2800	X		POS	Product
66	0		X	0		X	NEG	
67	0		X	0		X	NEG	
68	0		X	0		X	NEG	
69	100	X		3900	X		POS	Product
70	0		X	800	X		POS	HNU false negative
71	0		X	0		X	NEG	Site 1
72	0		X	0		X	NEG	Site 6
73	5	X		110	X		POS	
74	100	X		3700	X		POS	Product
75	100	X		3800	X		POS	Product
76	0		X	0		X	NEG	
77	40	X		2800	X		POS	Product
78	0		X	0		X	NEG	
79	1.5	X		15	X		NEG	
80	20	X		450	X		POS	
81	0		X	0		X	NEG	
82	50	X		2300	X		POS	Product
83	0		X	0		X	NEG	
84	0		X	0		X	NEG	
85	60	X		2700	X		POS	
86	0		X	0		X	NEG	
87	0		X	0		X	NEG	
88	0		X	0		X	NEG	
89	0		X	0		X	NEG	
90	120	X		4100	X		POS	Product

Regression Output:

Constant 100.4354
Std Err of Y Est 468.3124
R Squared 0.915804
No. of Observations 90
Degrees of Freedom 88

4 holes with negative HNU and positive GC
6 holes with positive HNU and negative GC
11% disagreement
89% agreement

X Coefficient(s) 31.00659
Std Err of Coef. 1.002205

HNU READINGS IN ppm ISOBTYLENE EQUIV.

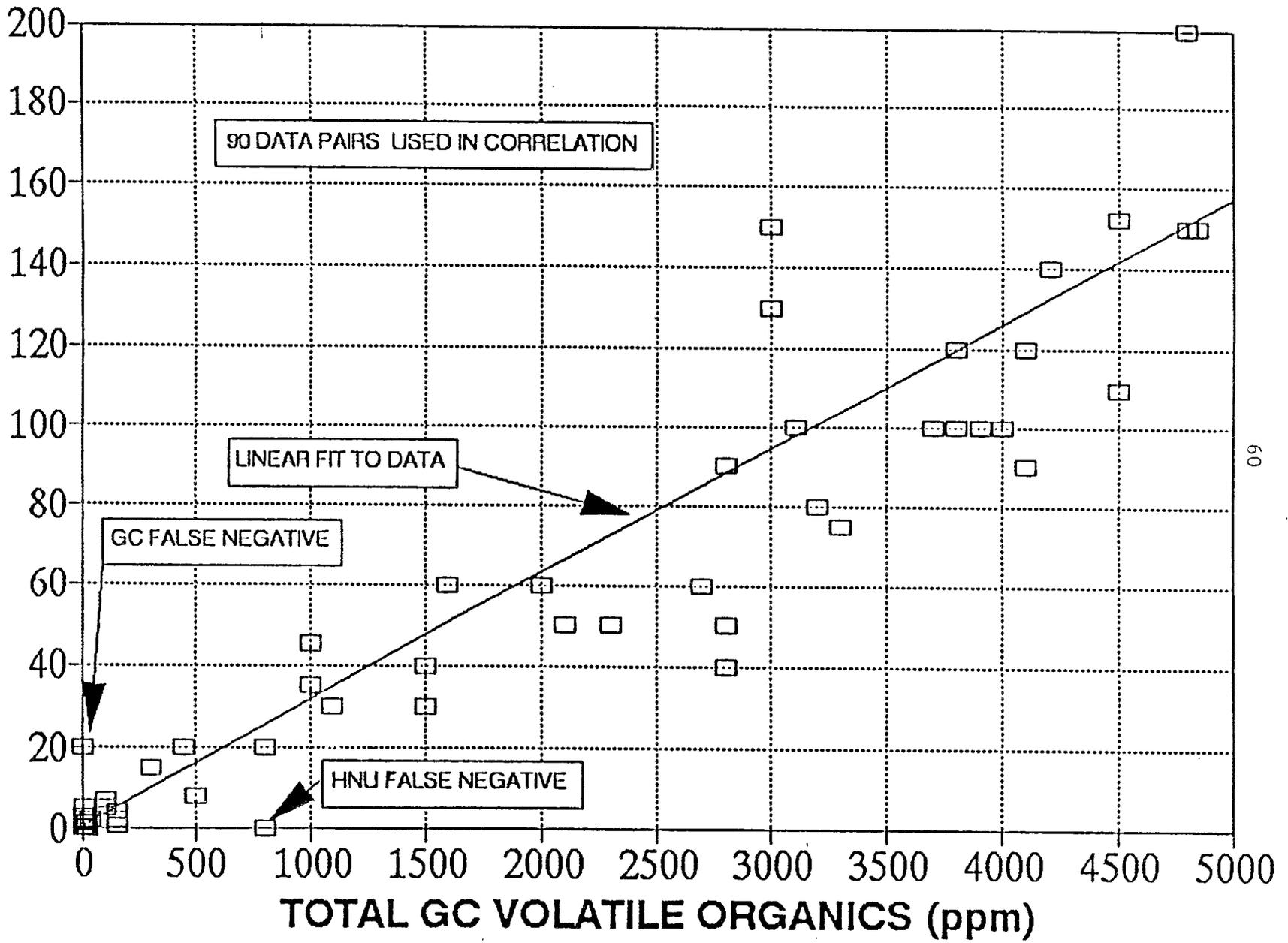


Fig. 20. Site 2 plot of PID vs GC values.

hydrocarbons with varying VOC concentrations, however, was found to change the relationship between PID and GC results.

5.2 COST COMPARISON

The relative costs of the three types of field screening techniques utilized at Site 2 were calculated based on the man hours of labor required to complete the field work and the time required to evaluate the data. A rate of \$65/man-hour was used in the calculation. Table 9 shows the cost breakdown for each method.

Comparison of the costs for the various surveys reveals that there is very little difference between them. Other miscellaneous costs are not included here, such as equipment costs, travel, per diem, etc.; however, because each of the methods has these additional attendant costs, it seems reasonable to compare the methods based solely on the cost of collecting and evaluating the data.

The other criterion for comparison is the relative success of the techniques. From the discussion of the results for each of the screening techniques, it is apparent that the groundwater test hole screening was more effective at delineating plume boundaries than either the soil-gas or the EM geophysical surveys. The soil-gas technique was, however, somewhat successful. The method involving extraction of soil gas from near the capillary fringe was more successful than the ERM-West method. The EM-31 survey technique was generally unsuccessful at detecting petroleum hydrocarbon plumes and seemed better suited to mapping features related to changing geology and buried metal.

6. CONCLUSIONS

Three types of field screening techniques used in the characterization of potentially contaminated sites at NAS Fallon have been presented and compared.

Table 9. Site 2 field screening surveys cost comparison

Screening Method	Cost of field work	Cost of data evaluation	Total cost
ERM-West Soil-Gas Survey	168 man hours × \$65 = \$10,920	20 man hours × \$65 = \$1,300	\$12,220
ORNL Soil-gas Survey	192 man hours × \$65 = \$12,480	20 man hours × \$65 = \$1,300	\$13,780
ORNL EM-31 survey	96 man hours × \$65 = \$6,240	80 man hours × \$65 = \$5,200	\$11,440
ORNL Groundwater Test Holes	192 man hours × \$65 = \$12,480	20 man hours × \$65 = \$1,300	\$13,780

The major conclusions from this comparison are:

- The most effective technique for identification of petroleum-hydrocarbon-contaminant plumes was groundwater test hole screening.
- This technique optimized the placement of and minimized the number of monitoring wells.
- Cost savings were realized because fewer wells were required to define a plume.
- A high degree of certainty about plume boundaries and overall data quality was maintained.
- The relationship between PID and field GC results proved useful for investigations at sites where JP-5 was the principal contaminant.
- The best correlation of PID/GC results was achieved at sites with plumes related to gasoline and jet fuel.

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ACRONYMS AND INITIALISMS

ARARs	Applicable or Relevant and Appropriate Requirements
avgas	aviation gasoline
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
cm	centimeter
EM	electromagnetometer
ev	electron volt
FID	flame ionization detector
FS	feasibility study
ft	feet
gal	gallons
GC	gas chromatograph
HAZWRAP	Hazardous Waste Remedial Actions Program
in.	inch
IR Program	Installation Restoration Program
km	kilometers
LD#1	Lower Diagonal No. 1 Drain
m	meters
mg/kg	milligrams per kilogram
μL	microliter
NAAS Fallon	Naval Air Auxiliary Station Fallon
NAS Fallon	Naval Air Station Fallon
NDEP	Nevada Division of Environmental Protection
NIPDWR	National Interim Primary Drinking Water Regulation
O/WS	oil/water separator
ORNL	Oak Ridge National Laboratory

OVA	organic vapor analyzer
PA/SI	preliminary assessment/site inspection
PC	personal computer
PID	photoionization detector
ppm	parts per million
QC	quality control
RF	radio frequency
RI	remedial investigation
TCE	trichloroethene
TDS	total dissolved solids
TPH	total petroleum hydrocarbons
USRADS	ultrasonic ranging and data collection system
VOC	volatile organic compound

APPENDIX A

ADDITIONAL GEOPHYSICAL SURVEY RESULTS

ADDITIONAL GEOPHYSICAL SURVEY RESULTS

Site 1, Crash Crew Training Area

Because groundwater contamination and possible floating product were suspected at Site 1, an EM-31 geophysical survey was performed. The data for the site were collected in 20 blocks covering about 60 m × 60 m (200 ft × 200 ft) each. Each block contains about 1,000 measurements, with the entire data set consisting of nearly 20,000 records. Each record has an x-y location for the measurement and the quadrature and in-phase readings from the EM-31.

After thorough examination, the data from the 20 blocks were pieced together to show the overall coverage (Fig A.1). A number of small flaws in the data set became apparent on the plot of the tracking map. The gap in coverage between several blocks is due to a fence that prevented data collection in that area. Other data gaps were caused by obstructions such as brush and aboveground tanks that prevented data collection. The quadrature data collected were rated as "good quality" by the interpreting geophysicist, Jon Nyquist. However, the in-phase data showed that the threshold was set too high; the EM-31 repeatedly went off scale, causing the data to be clipped. Because in-phase data are generally used only for detection of buried metal, which was not the objective at this site, the resultant loss of data was not critical. Only the quadrature data are discussed here.

Contouring the quadrature data (Fig A.2) shows that many small 6- to 9-m (20 to 30 ft)-diameter highs and lows exist. After buried metal, the strongest influences on terrain conductivity at the site are probably variation of water salinity and degree of soil saturation, most likely far stronger influences than the presence of jet fuel contamination. The strongest apparent trend is a high conductivity anomaly running northwest to southeast across the site. This trend may be related to several possible conditions including: increased soil moisture content, shallower depth to groundwater, presence of petroleum hydrocarbon contamination, or a

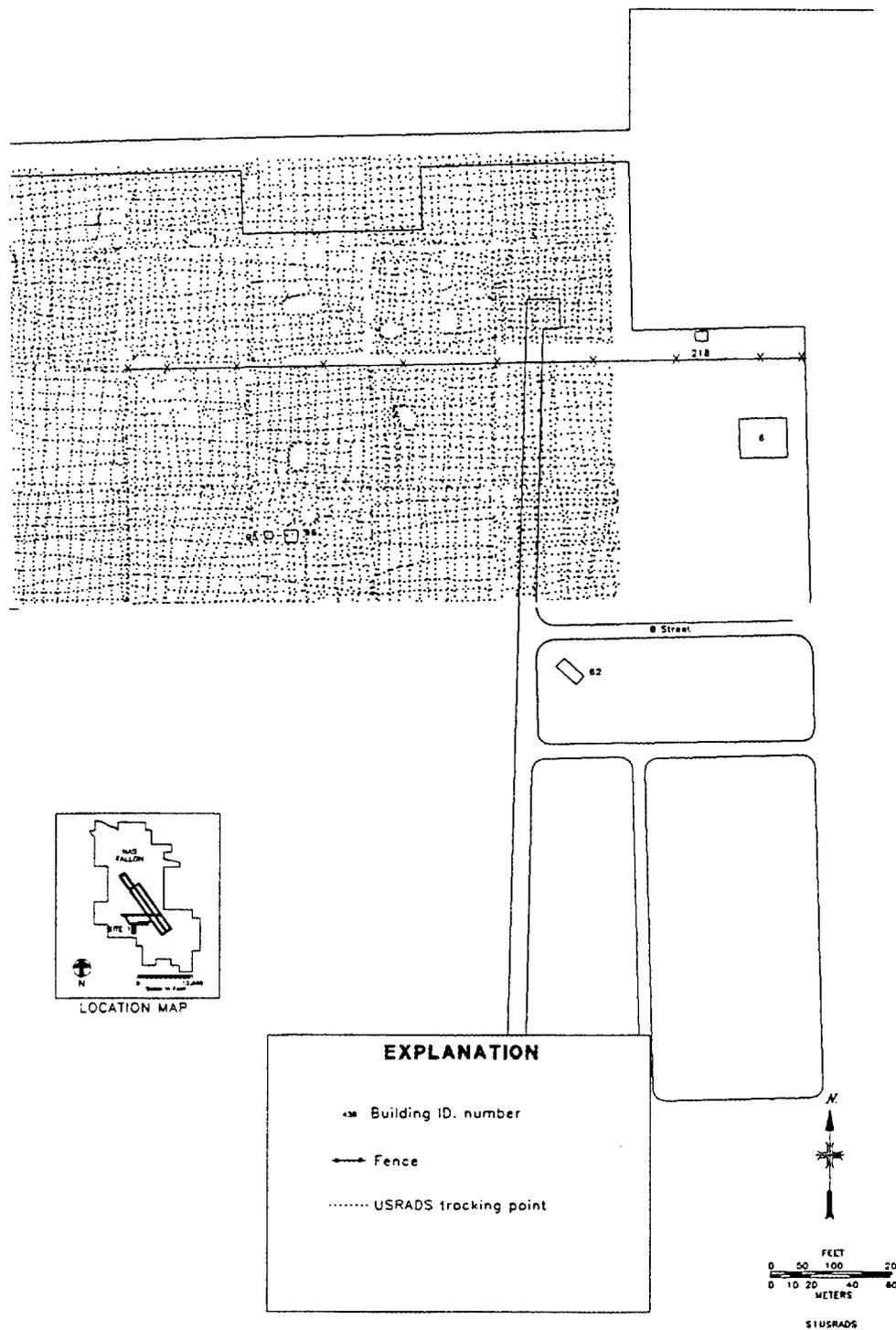


Fig. A.1. Track map for Site 1.

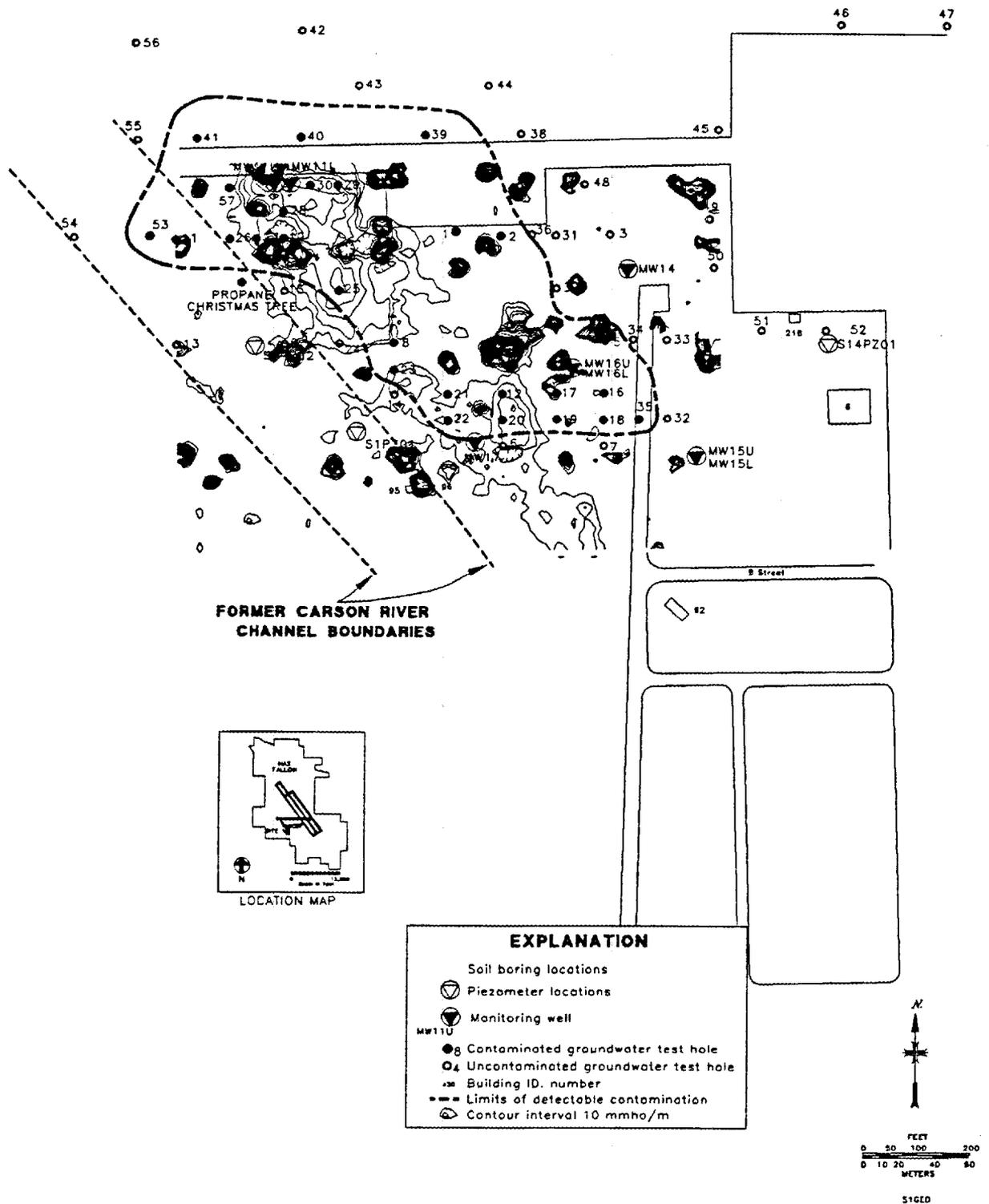


Fig. A.2. Quadrature map for Site 1.

combination of all three. The anomaly may also be attributable to the existence of a buried river channel that trends in the same direction across the southwest corner of the site. This channel was first noted on the geologic map (Fig. 3) and was later confirmed by groundwater test hole and monitoring well drilling data. Measurements of groundwater conductivity indicate an increase in conductivity from the northeast to southwest across the site, which is consistent with the EM geophysical anomaly. However, there are not enough groundwater conductivity data points to determine if there is a cause-and-effect relationship between the two. It is apparent that floating product mapped at the site is restricted to a small area around the former burn pit; there does not appear to be a correlation between floating product and the geophysical anomalies.

Site 19 and Site 23, Post-World War II Burial Site and Shipping and Receiving Disposal Site

Because these two sites are adjacent and nearly contiguous, the EM-31 survey covered the entire area. Ten USRADS setups were required to fully cover the area of 300 m × 120 m (1000 ft × 400 ft). Approximately 10,000 data points were generated. Site 19 was surveyed for trends possibly related to trenches containing buried scrap metal and engine cleaning solvent. The primary purpose of surveying Site 23 was to locate the aircraft reportedly buried there in 1984. The track map (Fig A.3) shows good coverage over the entire area with two exceptions: a rectangular segment in the southwest quarter where the GATAR compound fence prevented surveying, and a break in the north-south tracking in the north half of the area related to an east-west trending ditch.

Review of the quadrature data revealed numerous high and low conductivity anomalies, many of which can be related to scattered metallic debris on the ground surface. No obvious trends are shown by the contour plot of the quadrature data (Fig A.4). One slight low-conductivity anomaly appears to trend from northwest to southeast across the south half of the area in the vicinity of the contaminant plume discharge area delineated by the groundwater test hole mapping. It is difficult to say if this anomaly is related to the contaminant plume

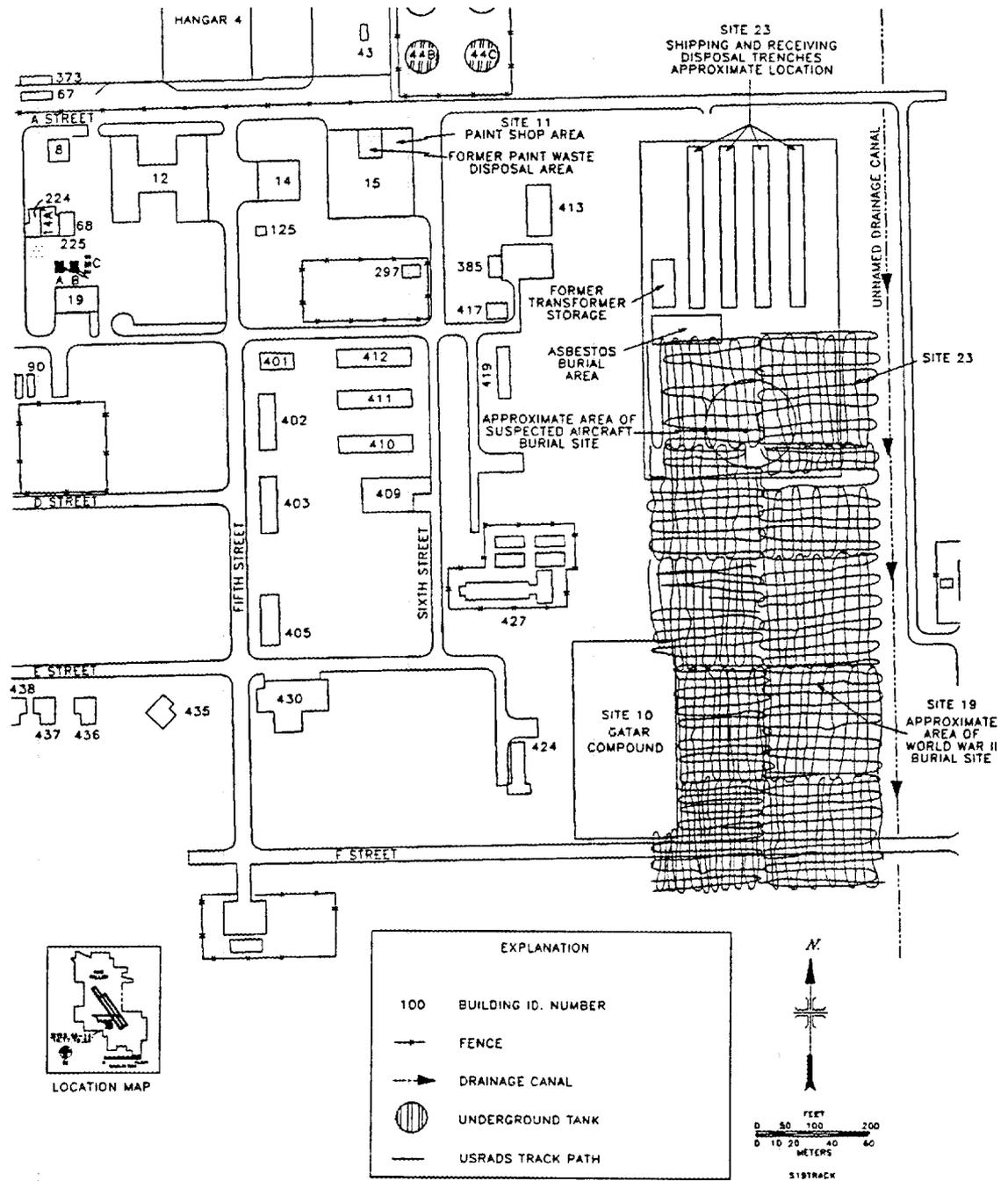


Fig. A.3. Track map for Sites 19 and 23.

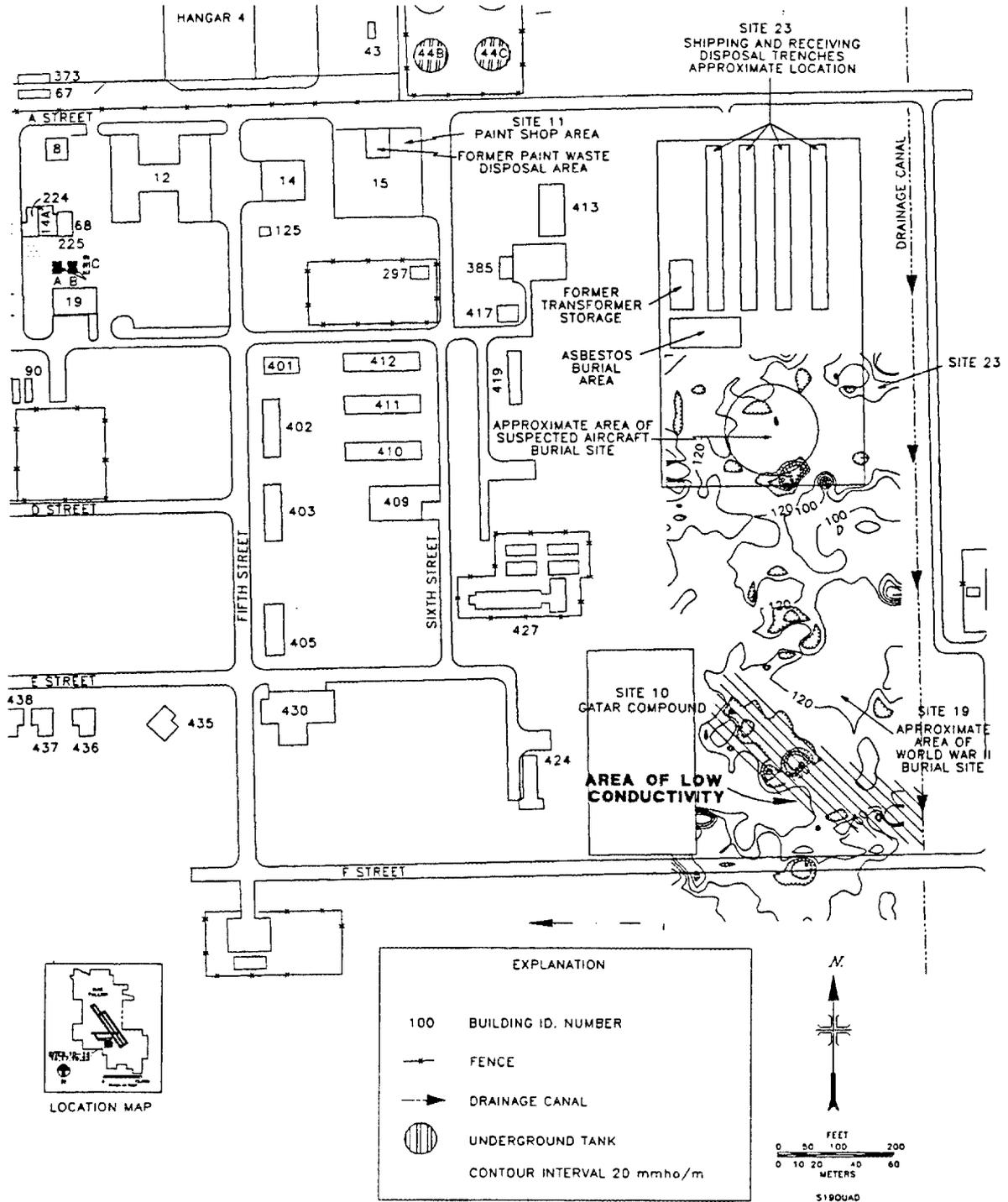


Fig. A.4. Quadrature map for Sites 19 and 23.

because there are no data on the conductivity of the groundwater in the vicinity of the anomaly. It is known, however, that there is no floating product on the groundwater in the vicinity of the anomaly; thus, the anomaly is not reflecting product concentrations of petroleum hydrocarbons.

The in-phase data similarly reflect anomalies, most of which can be related to piles of scrap metal and other debris containing metal such as rebar in concrete (Fig A.5). The road across the southern end of the area appears to be reflected by a slight low anomaly on the in-phase data. There does not appear to be a buried aircraft in any of the surveyed area unless it is buried underneath one of the surface scrap piles. There may be trenches containing some metallic debris in the southwest quarter of the region, 30 to 90 m (100 to 300 ft) north of the road. Otherwise, the area is devoid of in-phase anomalies.

Site 10, GATAR Compound

The purpose of the survey at this site was to locate possible cans or drums containing polychlorinated biphenyl (PCB)-laden oil that were possibly buried at the site. The containers were reportedly buried in the northeast quadrant of the compound. A metal-detector survey revealed several small pieces of shallowly buried metal in the region but no other anomalies. The groundwater test hole data indicate that there is no floating product on the groundwater at the site. Thus, there is no comparison to be made between the geophysical results and the groundwater test hole results.

The coverage shown on the track map is relatively regular with no gaps in the data (Fig. A.6). The area was covered by two USRADS setups, which produced approximately 2,000 data points. The area is enclosed by a chain link fence, but there were no other visible cultural interferences at the time of the survey.

The quadrature data show several high and low anomalies but no apparent trends (Fig. A.7). The EM-31 quadrature data, however, do show a possible concentration of more deeply buried metal about 24 m (80 ft) south and 6 m (20 ft) west of the northeast corner of the compound. Other anomalies appear in

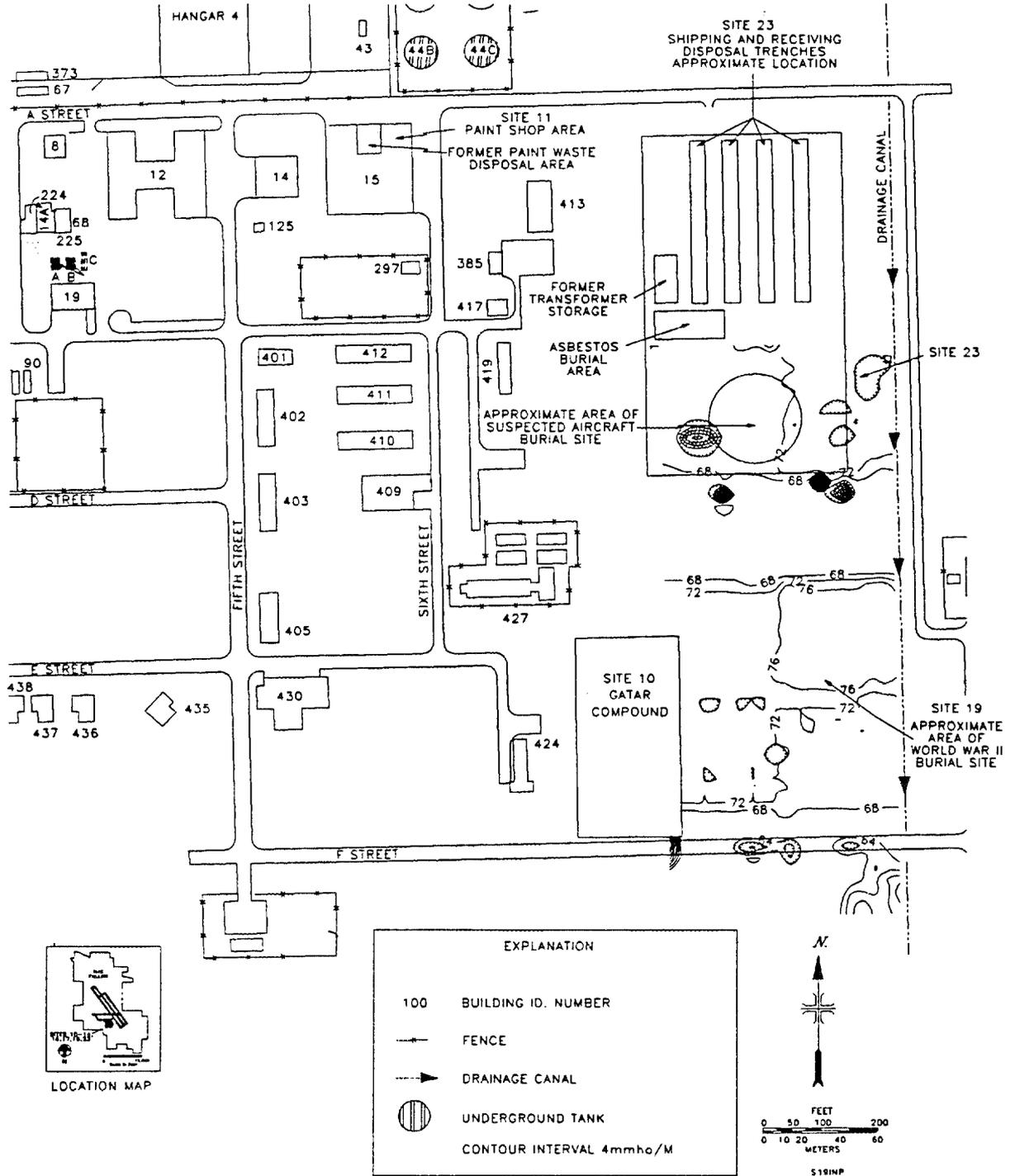


Fig. A.5. In-phase map for Sites 19 and 23.

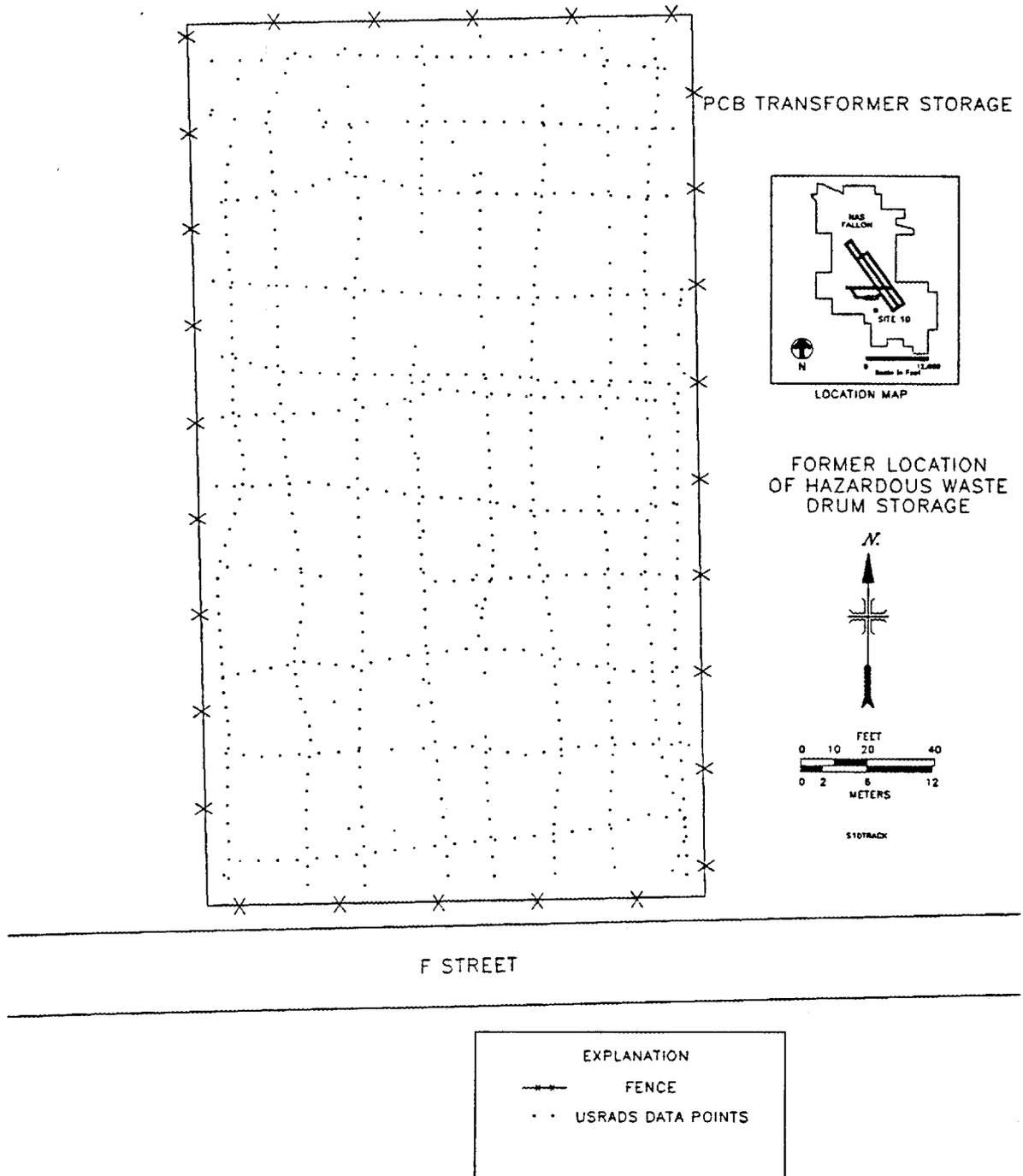
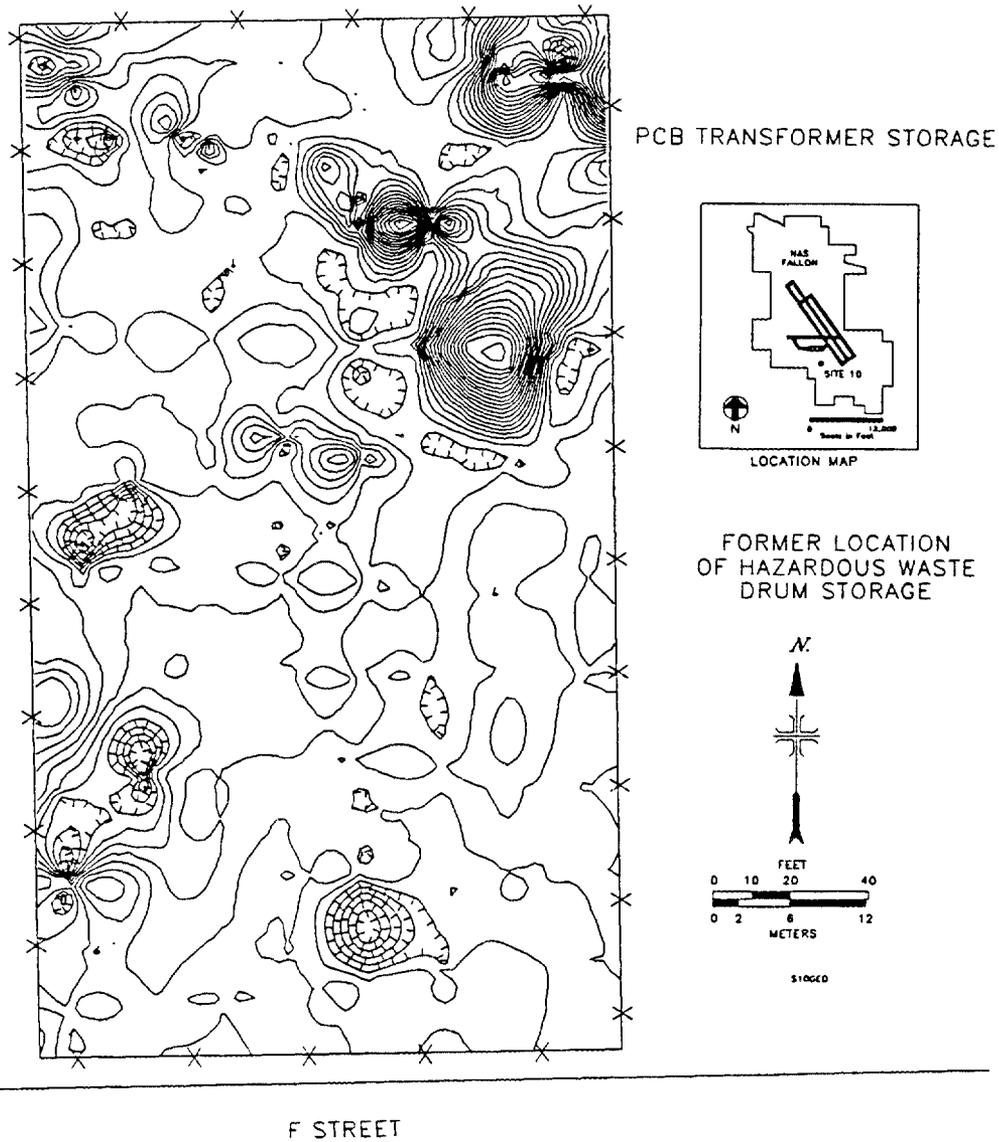


Fig. A.6. Track map for Site 10.



EXPLANATION	
	FENCE
CONTOUR INTERVAL 10 mmho/m	

Fig. A.7. Quadrature map for Site 10.

the region, but the large one would be the most likely place to continue the investigation for the containers of oil. Recommendations include excavating the site to see if buried drums are present and, if so, to remove them for appropriate disposal.

APPENDIX B

ADDITIONAL GROUNDWATER TEST HOLE RESULTS

ADDITIONAL GROUNDWATER TEST HOLE RESULTS

Site 1, Crash Crew Training Area:

Potential contaminants: jet fuel (JP-5), waste oil and other fuels, and solvents.

Screening: consisted of an EM-31 survey and 57 groundwater test holes (Table B.1). An area of floating product has been discovered near the old burn pit (Fig. B.1). A plume containing JP-5 and solvents was delineated. A former river channel was also located and partially mapped; it appears to trend southeast across the southwest part of the site.

Investigation: included drilling and sampling 6 soil borings, 8 monitoring wells, and 2 piezometers. Five wells were screened shallow to intersect the shallow alluvial water table (one of these is an upgradient well). Two wells were screened at the bottom of the shallow alluvial aquifer to detect any possible solvent product plume. One upgradient well was completed in the intermediate aquifer and is artesian. This precludes the migration of contaminants from the shallow alluvial aquifer through the clay-confining layer down into the other aquifers. Monitoring well results supported the groundwater test hole plume boundary delineation (Table B.2).

Site 3, Hangar 300 (renamed Hangar 1):

Potential contaminants: include JP-5, hydraulic fluid, lube oil, and solvents.

Screening: consisted of drilling 12 groundwater test holes (Table B.3). A solvent plume was detected in the southern part of the site (GSE area and south disposal area). However, the plume appeared to go under the apron,

Table B.1. Screening results for Site 1

Hole #	PID		Field GC		Final Decision	Comments
	Pos.	Neg.	Pos.	Neg.		
1	X		NA		POS	
2	X		NA		POS	
3	X			X	POS	GC false negative
4	X		X		POS	
5		X	X		POS	PID false negative
6		X	X		POS	PID false negative
7		X		X	NEG	
8	X		NA		POS	
9		X		X	NEG	
10	X		X		POS	
11	X		X		POS	
12	X		X		POS	
13		X		X	NEG	
14		X		X	NEG	
15		X		X	NEG	
16		X	X		POS	PID false negative
17		X	X		POS	PID false negative
18		X	X		POS	PID false negative
19	X		X		POS	
20	X		X		POS	
21	X		X		POS	
22		X	X		POS	PID false negative
23	X		X		POS	
24		X		X	NEG	
25		X	X		POS	PID false negative
26		X	X		POS	
27	X		X		POS	
28		X	X		POS	PID false negative
29	X		X		POS	
30	X		X		POS	
31		X		X	NEG	
32		X		X	NEG	
33		X		X	NEG	
34		X		X	NEG	
35		X	X		POS	PID false negative
36		X		X	NEG	
37		X		X	NEG	
38		X		X	NEG	
39	X		X		POS	
40	X		X		POS	
41		X	X		POS	PID false negative
42		X		X	NEG	
43		X		X	NEG	
44		X		X	NEG	
45		X		X	NEG	

Table B.1. (continued)

Hole #	PID		Field GC		Final Decision	Comments
	Pos.	Neg.	Pos.	Neg.		
46		X		X	NEG	
47		X		X	NEG	
48		X		X	NEG	
49		X		X	NEG	
50		X		X	NEG	
51		X		X	NEG	
52		X		X	NEG	
53	X		X		POS	
54		X		X	NEG	
55		X		X	NEG	
56		X		X	NEG	
57	X		X		POS	

Total = 57

10 holes with negative PID and positive GC
 1 hole with positive PID and negative GC
 19.3% disagreement between PID and GC
 80.7% agreement

NA = not analyzed

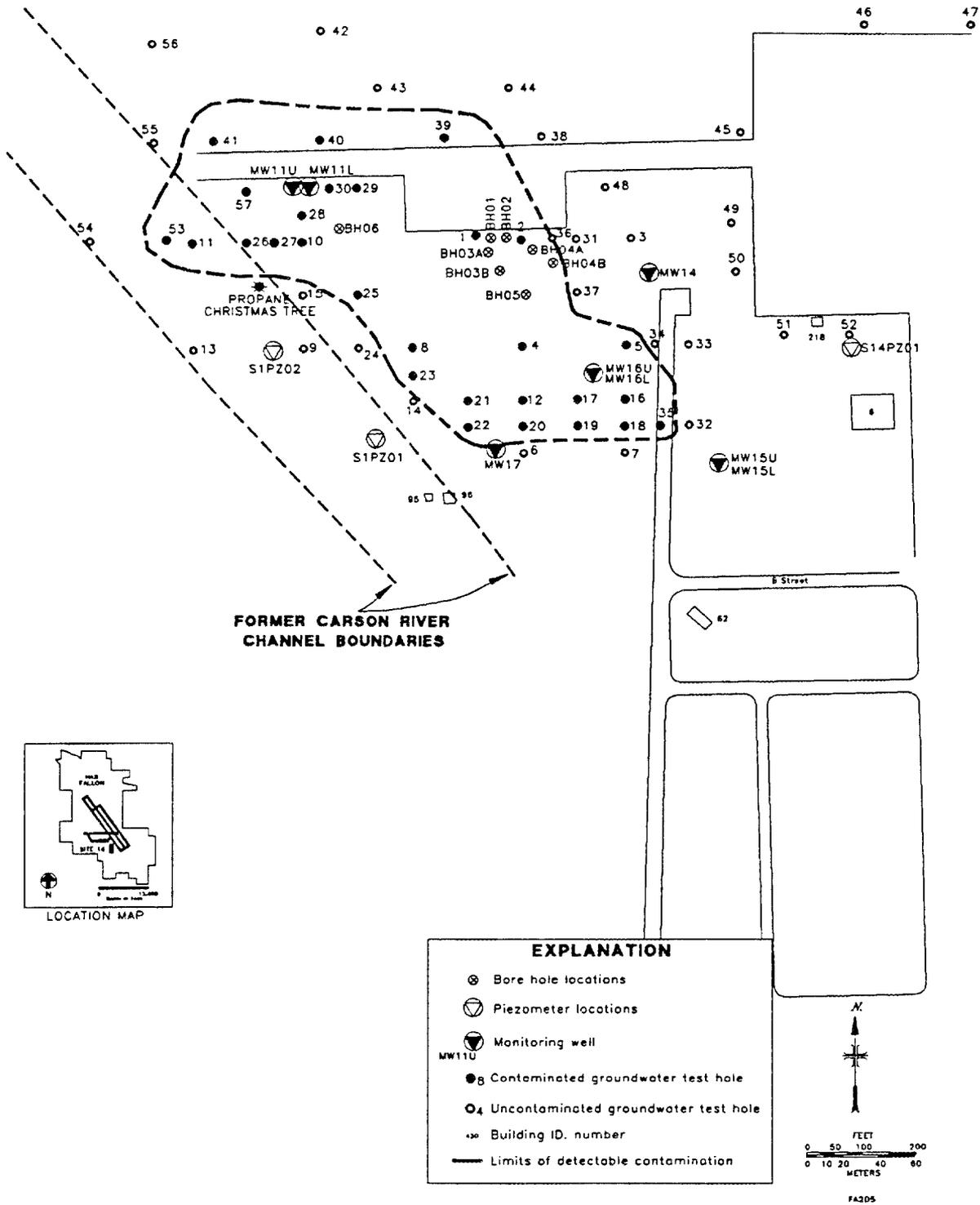


Fig. B.1. Groundwater test hole map for Site 1.

Table B.2. Water sample results for Site 1

Location Date	Sample Number	Total HBP PHC (*1) ug/L	Total LBP PHC (*2) ug/L	PCB/Pesticides (*3) ug/L	Semivolatiles Method 625, ug/L QL: 10 ug/L	Volatiles Method 624, ug/L QL: 5 ug/L	
MW011L 7/90	3468	NP	NP	U	TIC 1 1 Unknown	39.0 11.0	U
MW011U 7/90	3467	NP	NP	U	TIC 2 TIC 3 1 Unknown	10.0 11.0 65.0	U
MW011U 4/91	3778	U	U	U	TIC 4	10.0	U
MW014 4/91	3733	Die 50.0	U	U	TIC 5 TIC 3 1 Unknown	18.0 31.0 25.0	U
MW015L 4/91	3727	Die 290.0	65.0	U	U	1,2DCE 18.0 Tetra 1.0*J TCE 23.0	
MW015U 4/91	3730	U	U	U	TIC 6 2 Unknowns	14.0 8.1 8.7	1,2DCE 1.0*J TCE 5.0
MW016L 4/91	3729	U	U	U	1 Unknown	14.0	1,2DCE 7.0 TCE 2.0*J
MW016U 4/91	3728	Die 13000.0	95.0	U	TIC 7 TIC 8 TIC 9 17 Unknowns	15.0 180.0 65.0 15.0 88.0	1,1DCE 5.0 1,2DCE 110.0 B 3.0*J TCE 45.0
MW017 4/91	3731	Die 140.0	U	U	TIC 5 TIC 3 1 Unknown	24.0 23.0 18.0	TCE 5.0*J

*1 - Method 8015 Modified, quantitation limit: 50 ug/L

*2 - Method 8015/8020, quantitation limit: 50 ug/L

*3 - Method 608, quantitation limit: 0.05 ug/L

*J - concentration estimated

1,1DCE - 1,1-dichloroethene

1,2DCE - 1,2-dichloroethene (total)

B - benzene

Die - HBP PHC as compared to diesel fuel

HBP - high boiling point

LBP - low boiling point

NP - analysis not performed

PHC - petroleum hydrocarbons

QL - quantitation limit

TCE - trichloroethene

Tetra - tetrachloroethene

TIC - tentatively identified compound

U - no compounds detected

NOTE - concentrations are estimated for TICs and unknowns

TIC 1 - sulfur, mol. (s8)

TIC 2 - cyclohexanol, 1-bromo-2-chlor

TIC 3 - cyclohexanol, 2-bromo-

TIC 4 - hexanoic acid, 2-ethyl-

TIC 5 - cyclohexane, 1-bromo-2-chlor

TIC 6 - 2-pentanone, 4-hydroxy-4-met

TIC 7 - 1(2h)-naphthalenone isomer

TIC 8 - butane, 1-(2-methoxyethoxy)-

TIC 9 - oxirane, 2,2'-oxybis(methyl

Table B.3. Screening results for Site 3

Hole #	PID		Field GC		Final Decision	Comments
	Pos.	Neg.	Pos.	Neg.		
1		X	X		NEG	TCE?
2	X			X	NEG	Asphalt
3		X		X	NEG	
4		X	X		POS	TCE?
5		X	X		POS	TCE?
6		X	X		POS	TCE?
7	X		X		POS	TEC?
8		X		X	NEG	
9		X		X	NEG	
10		X		X	NEG	
11		X		X	NEG	
12		X		X	NEG	

Total = 12

4 holes with negative PID and positive GC

1 hole with positive PID and negative GC

42% disagreement between PID and GC

58% agreement

Note: TCE not detectable on PID at low concentrations

and no boundaries were delineated due to the difficulty of drilling through the thick concrete (Fig. B.2). No significant contamination was detected in the north disposal area or the bowser disposal area.

Investigation: consisted of drilling 8 soil borings, 12 monitoring wells, and taking 3 sediment samples from the ditch downstream of the O/WS. Monitoring well results supported the plume boundary definition (Table B.4).

Group II Sites: Site 6, Site 7, Site 21, and Site 22:

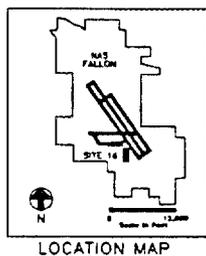
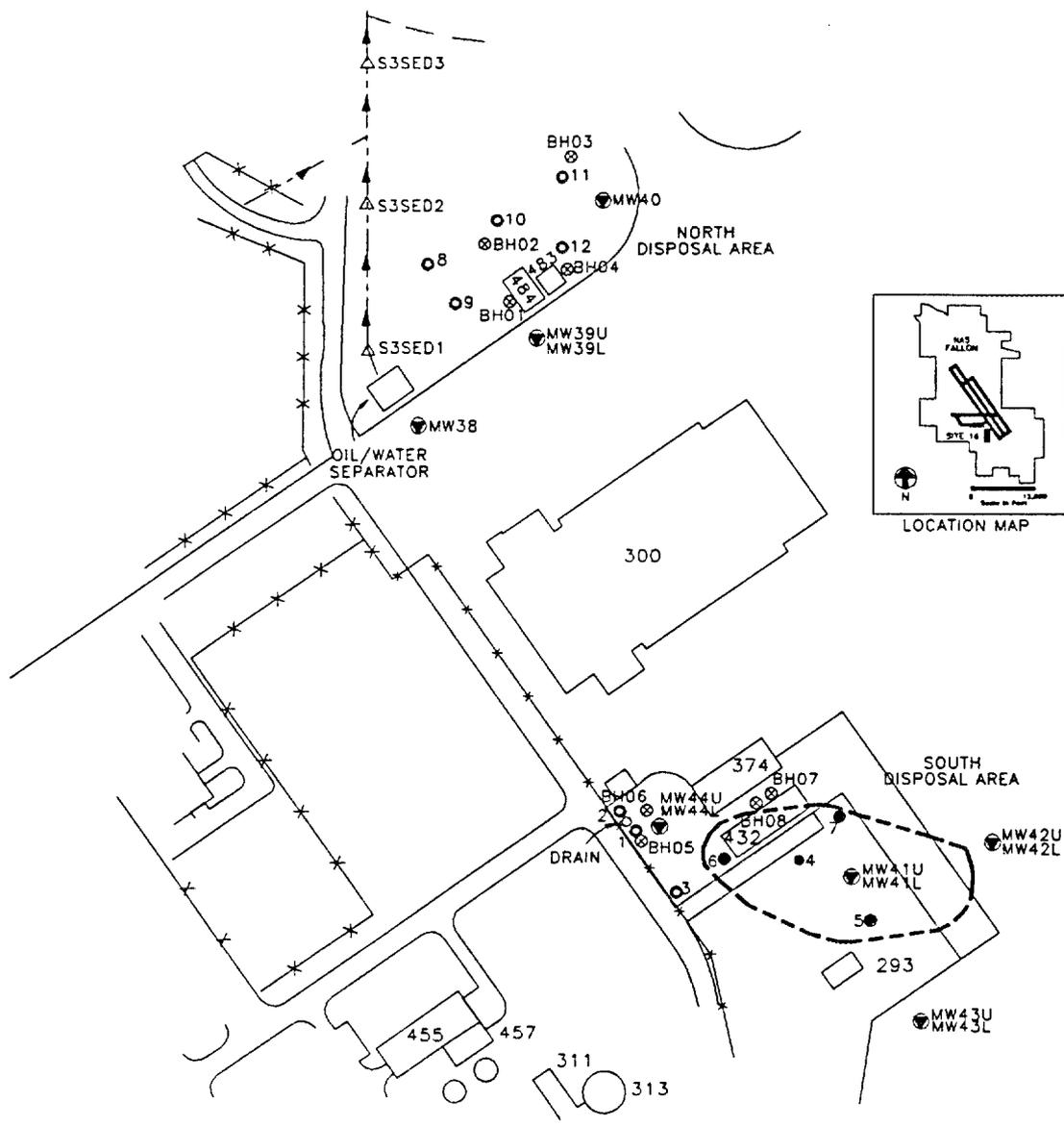
Potential contaminants Site 6: JP-4 and JP-5

Potential contaminants Site 7: napalm M-2 and napalm A&B

Potential contaminants Sites 21 and 22: JP-5, gasoline, diesel fuel, waste oils, hydraulic fluid, and wet garbage leachate.

Screening: consisted of drilling 95 groundwater test holes around the sites and includes the Lower Diagonal No. 1 Drain (LD#1) investigation (Table B.5). One large fuel plume was located and delineated emanating from Site 6 (Fig. B.3). A small area of floating product was discovered but may not be completely delineated.

No other significant contamination was detected from any other sites except along the road between Sites 21 and 22 near the intersection of the road leading to the receiver site. Attempts to trace this contamination south yielded no other contaminated test holes. Thus, the contamination appeared to be localized and inconsistent. Attempts to locate the napalm burn pit, Site 7, by drilling groundwater test holes failed due to the extensive landfill material buried in the area that prevented the drill from reaching the water table.



EXPLANATION	
	Monitoring well
	Soil boring locations
	Contaminated groundwater test hole
	Uncontaminated groundwater test hole
	Soil sediment sample location
	Building ID. number
	Ditch
	Fence
	Limits of detectable contamination

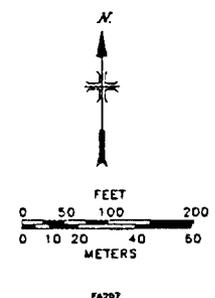


Fig. B.2. Groundwater test hole map for Site 3.

Table B.4. Water sample results for Site 3

Location Date	Sample Number	Total HBP PHC (*1) ug/L	Total LBP PHC (*2) ug/L	PCB/Pesticides (*3) ug/L	Semivolatiles Method 625, ug/L QL: 10 ug/L	Volatiles Method 624, ug/L QL: 5 ug/L
MW038 4/91	3806	Die 310.0	Gas 200.0	NP	TIC 1 10.0 TIC 2 19.0 TIC 3 28.0 2 Unknowns 9.6 15.0	E 5.0 TIC 4 32.0 TIC 5 16.0
MW039L 4/91	3807	U	U	NP	U	U
MW039U 4/91	3808	Die 60.0	U	NP	1 Unknown 17.0	U
MW040 4/91	3810	U	U	NP	1 Unknown 12.0	U
MW041L 4/91	3797	U	U	NP	U	Methcl 2.0** TCE 3.0*J
MW041L 4/91	3798	U	U	NP	TIC 6 10.0	Methcl 1.0** TCE 3.0*J
MW041U 4/91	3799	Die 90.0	Gas 160.0	NP	TIC 7 16.0 1 Unknown 9.0	1,1DCE 2.0*J 1,2DCE 33.0 Methcl 3.0** TCE 160.0 TIC 5 14.0 TIC 8 6.2 1 Unknown 7.3
MW042L 4/91	3796	U	U	NP	TIC 7 25.0	Methcl 1.0**
MW042U 4/91	3792	U	U	U	TIC 6 42.0 2 Unknowns 10.0 250.0	U
MW043L 4/91	3793	U	U	NP	U	U
MW043U 4/91	3794	Die 340.0	U	NP	TIC 7 13.0 1 Unknown 9.2	Methcl 1.0**
MW044L 4/91	3805	U	U	NP	TIC 7 93.0 1 Unknown 11.0	Methcl 2.0**
MW044U 4/91	3800	U	U	NP	TIC 7 32.0 TIC 9 11.0 1 Unknown 8.6	Methcl 2.0**

** - unusable data due to method blank contamination

*1 - Method 8015 Modified, quantitation limit: 50 ug/L

*2 - Method 8015/8020, quantitation limit: 50 ug/L

*3 - Method 608, quantitation limit: 0.05 ug/L

*J - concentration estimated

1,1DCE - 1,1-dichloroethene

1,2DCE - 1,2-dichloroethene (total)

Die - HBP PHC as compared to diesel fuel

E - ethylbenzene

Gas - LBP PHC as compared to gasoline

HBP - high boiling point

LBP - low boiling point

Methcl - methylene chloride

NP - analysis not performed

PHC - petroleum hydrocarbons

QL - quantitation limit

TCE - trichloroethene

TIC - tentatively identified compound

U - no compounds detected

NOTE - concentrations are estimated for TICs and unknowns

TIC 1 - 1-hexadecyne

TIC 2 - benzene, 2-ethyl-1,4-dimethy

TIC 3 - phenol, 4-(2,2,3,3-tetrameth

TIC 4 - ethane, 1,1,2-trichloro-1,2,2

TIC 5 - ethane, 1,2-dichloro-1,1,2-t

TIC 6 - 2-pentanone, 4-hydroxy-4-met

TIC 7 - 1,13-tetradecadiene

TIC 8 - pentane, 2,2,3-trimethyl-

TIC 9 - 2-heptenal, (z)-

Table B.5. Screening results for Sites 6, 7, 21, and 22

Hole #	PID		Field GC		Final Decision	Comments
	Pos.	Neg.	Pos.	Neg.		
1		X		X	NEG	
2		X		X	NEG	
3		X		X	NEG	
4		X		X	NEG	
5		X		X	NEG	
6		X		X	NEG	
7		X		X	NEG	
8		X		X	NEG	
9		X		X	NEG	
10		X		X	NEG	
11	X			X	NEG	PID slow response
12	X			X	NEG	PID slow response
13	X			X	NEG	PID slow response
14		X		X	NEG	
15	X		X		POS	PID slow response
16	X		X		POS	PID slow response
17	X			X	NEG	
18	X			X	NEG	
19		X		X	NEG	
20	X			X	NEG	PID slow response
21	X			X	NEG	PID slow response
22	X			X	NEG	PID slow response
23	X		X		POS	
24	X		X		POS	
25	X		X		POS	
26	X		X		POS	
27	X		X		POS	
28		X		X	NEG	
29	X			X	NEG	PID slow response
30		X		X	NEG	
31	X		X		POS	
32	X		X		POS	
33	X		X		POS	
34	X		X		POS	
35	X		X		POS	
36	X		X		POS	
37	X		X		POS	
38		X		X	NEG	
39		X		X	NEG	
40		X		X	NEG	
41		X		X	NEG	
42		X		X	NEG	
43		X		X	NEG	
44		X		X	NEG	
45		X		X	NEG	

Table B.5. (continued)

Hole #	PID		Field GC		Final Decision	Comments
	Pos.	Neg.	Pos.	Neg.		
46		X		X	NEG	
47		X		X	NEG	
48		X		X	NEG	
49		X		X	NEG	
50		X		X	NEG	
51		X		X	NEG	
52		X		X	NEG	
53	X		X		NEG	
54		X		X	POS	
55		X		X	NEG	
56		X		X	NEG	
57		X		X	NEG	
58		X		X	NEG	
59		X		X	NEG	
60		X		X	NEG	
61		X		X	NEG	
62		X		X	NEG	
63		X		X	NEG	
64		X		X	NEG	
65		X		X	NEG	
66		X		X	NEG	
67	X		X		POS	
68		X		X	NEG	
69		X		X	NEG	
70		X		X	NEG	
71		X		X	NEG	
72		X		X	NEG	
73		X	X		POS	PID false negative
74	X			X	NEG	PID slow response
75	X		NA		POS	Product
76		X		X	NEG	
PZ01	X		X		POS	
PZ02		X		X	NEG	
PZ03		X		X	NEG	

Total = 79

1 hole with negative PID and positive GC
 10 holes with positive PID and negative GC
 14% disagreement between PID and GC
 86% agreement

NA = not analyzed

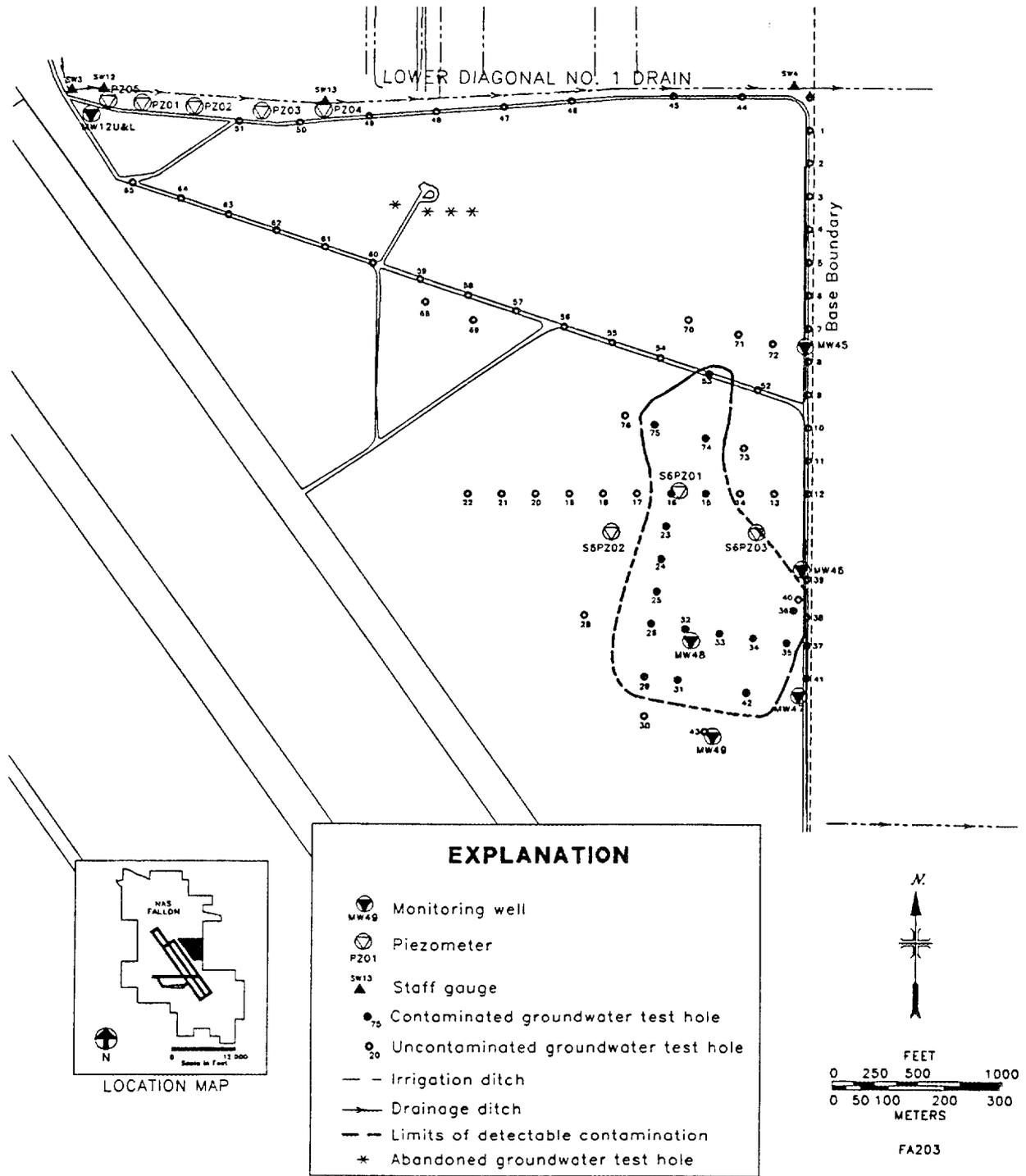


Fig. B.3. Groundwater test hole map for Sites 6, 7, 21, and 22.

Lower Diagonal No. 1 Drainage Ditch:

Site of a recent JP-5 cleanup, this is not an IR Program site but was investigated to determine the possibility of contaminant migration from nearby sites down the ditch. Part of this work was associated with an investigation of a fuel spill in the LD#1 in February 1991. No evidence of contribution to contamination in the ditch from any IR Program sites was found (Table B.6). The 19 groundwater test holes, 5 piezometers, and 2 staff gauges were all considered part of the Group II site investigation.

Investigation: consisted of drilling 7 wells. One upgradient well, drilled to the intermediate aquifer, was artesian with respect to the shallow aquifer. All other wells were completed across the water table in the shallow alluvial aquifer. Five piezometers were installed along the ditch on the north side of the area, and three were installed around the Site 6 plume (Fig. B.3). The monitoring well results supported the groundwater test hole delineation of the plume boundary as shown in Table B.7.

Group III Sites: Site 9 and Site 18:

Potential contaminants Site 9: oils, paint wastes, metals, and diesel fuel.

Potential contaminants Site 18: paints, metals, solvents, and hydrocarbons.

Screening: consisted of drilling 10 groundwater test holes between the sites and the Lower Diagonal Drain Ditch (Table B.8). No contamination was detected.

Investigation: consisted of drilling 2 single completion monitoring wells, two soil borings near the former diesel tank location (to water), three soil borings in the grit disposal area [to 1.2 m (4 ft)], two soil borings near the Imhoff tank sludge disposal pit [to 1.2 m (4 ft)], and one piezometer (Fig. B.4). Monitoring well sample results supported the finding of no

Table B.6. Screening results for LD#1

Hole #	PID		Field GC		Final Decision	Comments
	Pos.	Neg.	Pos.	Neg.		
1		X		X	NEG	
2		X		X	NEG	
3		X		X	NEG	
4		X		X	NEG	
5		X		X	NEG	
6		X		X	NEG	
7		X		X	NEG	
8		X		X	NEG	
9		X		X	NEG	
10		X		X	NEG	
11		X		X	NEG	
12		X		X	NEG	
13		X		X	NEG	
14		X		X	NEG	
15		X		X	NEG	
16		X		X	NEG	
17		X		X	NEG	
18		X		X	NEG	
19		X		X	NEG	

Total = 19

0 holes with negative PID and positive GC

0 holes with positive PID and negative GC

0% disagreement between PID and GC

100% agreement

Table B.7. Water sample results for Group II sites

Location Date	Sample Number	Total HBP PHC (*1) ug/L	Total LBP PHC (*2) ug/L	PCB/Pesticides (*3) ug/L	Semivolatiles Method 625, ug/L QL: 10 ug/L	Volatiles Method 624, ug/L QL: 5 ug/L
MW012L 7/90	3503	NP	NP	U	U	Acet 1.0
MW012U 7/90	3502	NP	NP	U	U	U
MW012U 4/91	3815	U	U	U	TIC 1 11.0 1 Unknown 34.0	U
MW045 4/91	3813	U	U	U	U	TIC 2 55.0
MW046 4/91	3812	U	U	U	U	U
MW047 4/91	3817	U	U	U		TIC 3 12.0
MW048 4/91	3819	Die 1100.0	Gas 350.0	U	TIC 4 8.6 4 Unknowns 9.0 16.0	TIC 5 9.1 TIC 5 14.0 TIC 6 7.8 TIC 7 5.6 1 Unknown 16.0
MW048 4/91	3820	Die 820.0	Gas 350.0	U	TIC 4 9.2 4 Unknowns 8.2 14.0	Clform 1.0*J Tetra 17.0 TIC 5 8.4 TIC 5 12.0 TIC 6 6.7 TIC 7 5.3 1 Unknown 21.0
MW049 4/91	3814	U	U	U	TIC 8 11.0 TIC 9 67.0** 2 Unknowns 11.0 14.0	TIC 10 5.2**

** - unusable data due to method blank contamination

*1 - Method 8015 Modified, quantitation limit: 50 ug/L

*2 - Method 8015/8020, quantitation limit: 50 ug/L

*3 - Method 608, quantitation limit: 0.05 ug/L

*J - concentration estimated

Acet - acetone

Clform - chloroform

Die - HBP PHC as compared to diesel fuel

Gas - LBP PHC as compared to gasoline

HBP - high boiling point

LBP - low boiling point

NP - analysis not performed

PHC - petroleum hydrocarbons

QL - quantitation limit

Tetra - tetrachloroethene

TIC - tentatively identified compound

U - no compounds detected

NOTE - concentrations are estimated for TICs and unknowns

TIC 1 - 2-heptenal, (z)-

TIC 2 - pentane, 3-methyl-

TIC 3 - cyclotetrasiloxane, (iodomet

TIC 4 - trimethyl benzene

TIC 5 - 1-pentene, 2-methyl-

TIC 6 - butane, 2-methyl-

TIC 7 - cyclobutane, methyl-

TIC 8 - 1h-indene, 1,1-dimethyl-

TIC 9 - 2-pentanone, 4-hydroxy-4-met

TIC 10 - cyclotetrasiloxane, octameht

Table B.8. Screening results for Sites 9 and 18

Hole #	PID		Field GC		Final Decision	Comments
	Pos.	Neg.	Pos.	Neg.		
1		X		X	NEG	
2		X		X	NEG	
3		X		X	NEG	
4		X		X	NEG	
5		X		X	NEG	
6		X		X	NEG	
7		X		X	NEG	
8		X		X	NEG	
9		X		X	NEG	
10		X		X	NEG	

Total = 10

0 holes with negative PID and positive GC

0 holes with positive PID and negative GC

0% disagreement between PID and GC

100% agreement

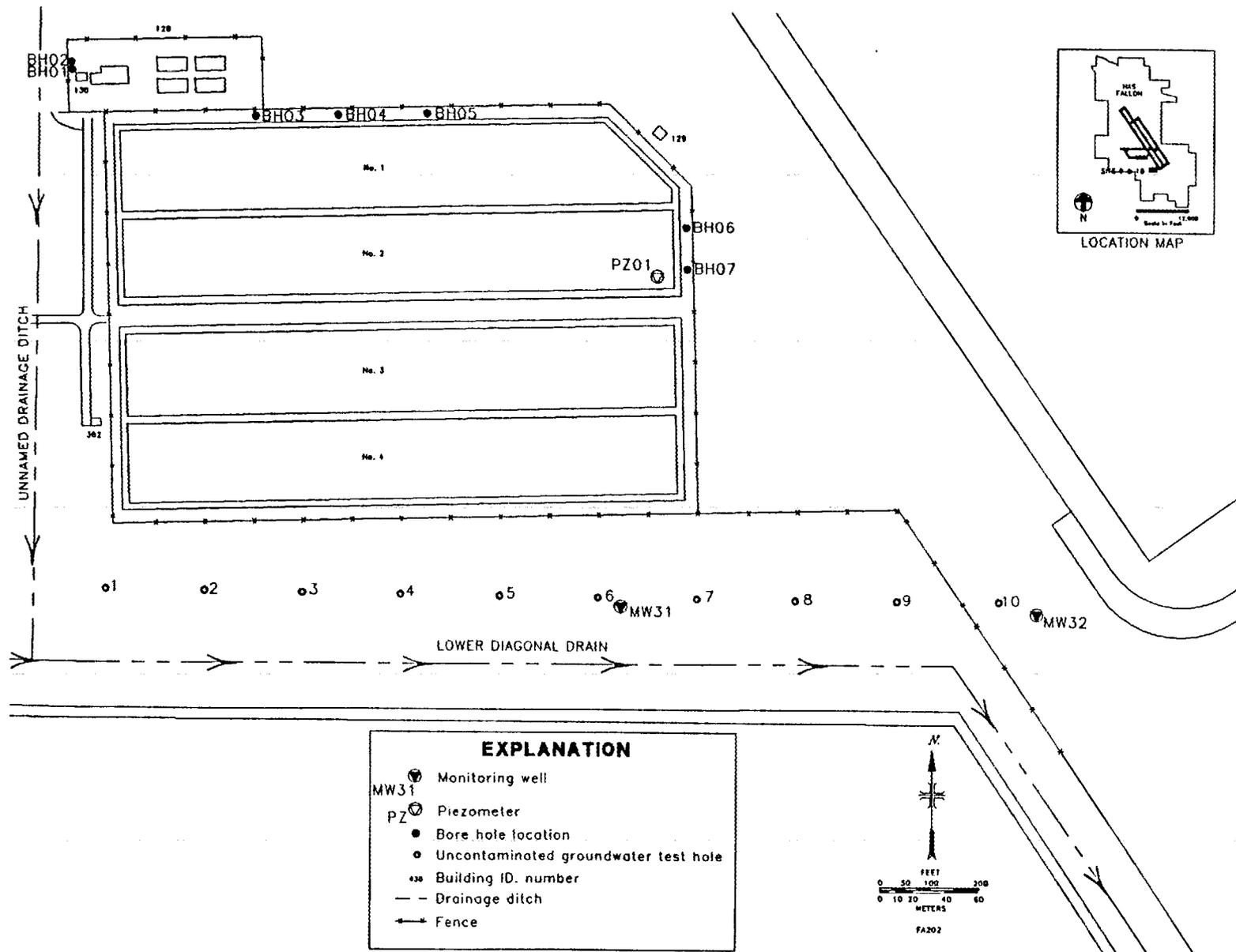


Fig. B.4. Groundwater test holes for Group III sites.

significant contamination as indicated by the groundwater test hole screening (Table B.9).

Group IV Sites: Site 10, Site 11, Site 12, Site 13, Site 14, Site 16, Site 17, Site 19, and Site 23:

Potential contaminants: fuel, paint wastes, pesticides, oil, grease, gasoline, diesel, fuel oil, and solvents.

Screening: consisted of drilling 162 groundwater test holes around the area (Fig. B.5) and performing an EM-31 survey over Sites 19, 23, and 10 (Tables B.10, B.11, and B.12). A large fuel plume was located which appeared to be emanating from the old fuel farm, Site 16, and flowing toward the unnamed lateral drain north of the Lower Diagonal Drain (Table B.10). Another gasoline/diesel plume was delineated emanating from the old vehicle maintenance shop area (Site 14) where two leaking tanks were removed (Table B.11). This plume appears to merge with a plume near the pesticide shop and boiler plant, Sites 12 and 13 (Table B.12). Monitoring well sample results (Table B.13) indicate that the groundwater contaminant plume emanating from Site 16 was successfully delineated with the groundwater test hole survey. The results from the wells drilled along the downgradient edge of the Site 14 plume, however, revealed that MW19 and MW20 which were supposed to be "clean" actually exceeded NIPDWR for several organic contaminants (Table B.14).

Investigations: consisted of the following site specific tasks:

Site 10, GATAR Compound

Field personnel tried to locate and excavate the reported cans of PCB oil using EM-31 surveys and a metal detector. None were found near the surface. However, the EM survey indicates some buried metal in the northeast part of the compound that will be further investigated. Five soil

**Table B.9. Water sample results for Group III sites
April 1991**

Location	Sample Number	Total HBP PHC (*1) ug/L	Total LBP PHC (*2) ug/L	PCB/Pesticides (*3) ug/L	Semivolatiles Method 625, ug/L QL: 10 ug/L	Volatiles Method 624, ug/L QL: 5 ug/L
MW031	3766	U	U	U	2 Unknowns 12.0 17.0	Methcl 1.0**
MW032	3764	U	T 2.0	U	TIC 1 2 Unknowns 12.0 44.0 52.0	Methcl 3.0**

** - unusable data due to method blank contamination

*1 - Method 8015 Modified, quantitation limit: 50 ug/L

*2 - Method 8015/8020, quantitation limit: 50 ug/L

*3 - Method 608, quantitation limit: 0.05 ug/L

HBP - high boiling point

LBP - low boiling point

TIC 1 - 2-pentanone, 4-hydroxy-4-met

Methcl - methylene chloride

PHC - petroleum hydrocarbons

QL - quantitation limit

T - toluene

TIC - tentatively identified compound

U - no compounds detected

NOTE - concentrations are estimated for TICs and unknowns

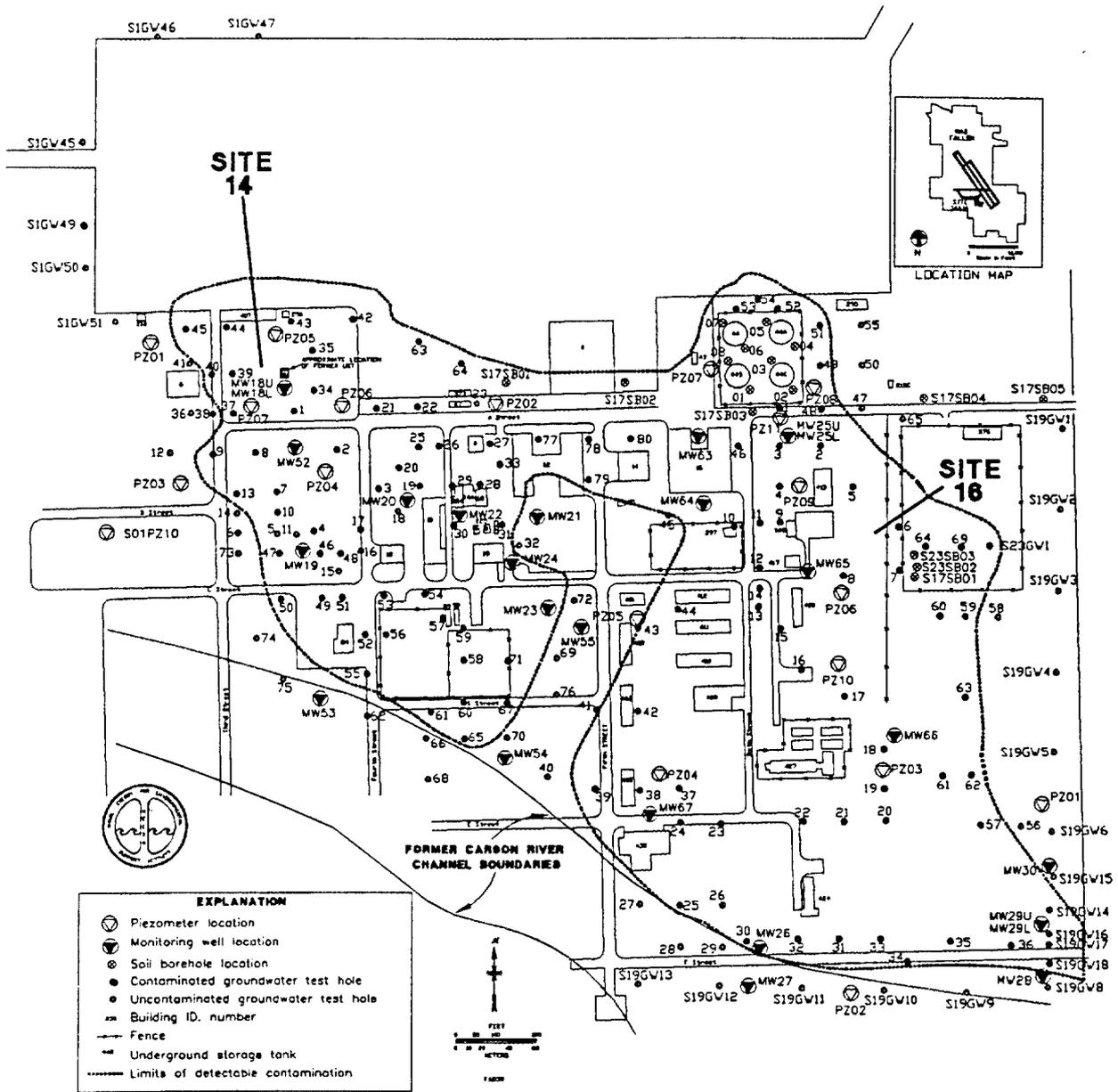


Fig. B.5. Groundwater test holes for Sites 12, 13, 14, 16, 19, and 23.

Table B.10. Screening results for Sites 16, 19, and 23

Site #	Hole #	PID		Field GC		Final Decision	Comments
		Pos.	Neg.	Pos.	Neg.		
16	1	X		X		POS	
16	2	X		X		POS	
16	3	X		X		POS	
16	4	X		X		POS	
16	5	X		X		POS	
16	6	X		X		POS	
16	7	X		X		POS	
16	8	X		X		POS	
16	9	X		X		POS	
16	10	X		X		POS	
16	11	X		X		POS	
16	12	X		X		POS	
16	13		X		X	NEG	
16	14	X		X		POS	
16	15	X		X		POS	
16	16	X		X		POS	
16	17	X		X		POS	
16	18	X		X		POS	
16	19	X		X		POS	
16	20	NA		X		POS	
16	21	X		X		POS	
16	22	X		X		POS	
16	23	X		X		POS	
16	24	X		X		POS	
16	25	X		X		POS	
16	26	X		X		POS	
16	27		X		X	NEG	
16	28		X		X	NEG	
16	29		X		X	NEG	
16	30		X		X	NEG	
16	31	X		X		POS	
16	32	X		X		POS	
16	33	X		X		POS	
16	34	X		X		POS	
16	35	NA		X		POS	
16	36	X		X		POS	
16	37	X		X		POS	
16	38	X		X		POS	
16	39	X		X		POS	
16	40	X		X		POS	

Table B.10. (continued)

Site #	Hole #	PID		Field GC		Final Decision	Comments
		Pos.	Neg.	Pos.	Neg.		
16	41		NA		X	NEG	
16	42	X		X		POS	
16	43	X		X		POS	
16	44	X		X		POS	
16	45		X		X	NEG	
16	46	X		NA		POS	
16	47		X		X	NEG	
16	48	X		X		POS	
16	49	X		X		POS	
16	50		X		X	NEG	
16	51		X	X		POS	PID false negative
16	52		X	X		POS	PID false negative
16	53	X		X		POS	
16	54		X	X		POS	PID false negative
16	55		X		X	NEG	
16	56		X		X	NEG	
16	57	X		X		POS	
16	58		X		X	NEG	
16	59		X		X	NEG	
16	60		X		X	NEG	
16	61	X		NA		POS	
16	62		X	X		POS	
16	63	X		X		POS	
16	64		X	X		POS	PID false negative
16	PZ01		X		NA	NEG	
16	PZ02		X		NA	NEG	
16	PZ03	X		NA		POS	
16	PZ04	X		NA		POS	
16	PZ05		X		NA	NEG	
16	PZ06	X		NA		POS	
16	PZ07	X		NA		POS	
16	PZ08	X		NA		POS	
19	1		X		X	NEG	
19	2		X		X	NEG	
19	3		X		X	NEG	
19	4		X		X	NEG	
19	5		X		X	NEG	
19	6		X		X	NEG	
19	7	X		X		POS	
19	8		X		X	NEG	
19	9		X		X	NEG	
19	10	X		X		POS	

Table B.10. (continued)

Site #	Hole #	PID		Field GC		Final Decision	Comments
		Pos.	Neg.	Pos.	Neg.		
19	11		X		X	NEG	
19	12		X		X	NEG	
19	13		X		X	NEG	
19	14	X		X		POS	
19	15		X		X	NEG	
19	16	X		X		POS	
19	17		X		X	NEG	
19	18		X		X	NEG	
23	1		X		X	NEG	
23	2		X		X	NEG	
23	3		X		X	NEG	
23	4	X			X	NEG	PID false positive
23	5		X		X	NEG	
23	6		X		NA	NEG	

Total = 96

5 holes with negative PID and positive GC
 1 hole with positive PID and negative GC
 6% disagreement between PID and GC
 94% agreement

NA = not analyzed

Table B.11. Screening results for Site 14

Hole #	PID		Field GC		Final Decision	Comments
	Pos.	Neg.	Pos.	Neg.		
1	X		X		POS	
2	X		X		POS	
3	X		X		POS	
4	X		X		POS	
5	X			X	NEG	PID false positive
6		X		X	NEG	
7	X		X		POS	
8	X		X		POS	
9	X		X		POS	
10	X		X		POS	
11		X		X	NEG	
12	X			X	NEG	PID false positive
13	X		X		POS	
14		X		X	NEG	
15		X		X	NEG	
16		X		X	NEG	
17	X		X		POS	
18	X			X	NEG	PID false positive
19		X		X	NEG	
20	X		X		POS	
21	X		X		POS	
22	X		X		POS	
23		X		X	NEG	
24		hit water line				
25	X		X		POS	
26	X		X		POS	
27	X		X		POS	
28	X		X		POS	
29	X		X		POS	
30	X		X		POS	
31	X		X		POS	
32		X		X	NEG	
33	X		X		POS	
34	X		X		POS	
35	X		X		POS	
36	X			X	NEG	PID false positive
37	X		X		POS	
38		X		X	NEG	
39	X		X		POS	
40	X		X		POS	

Table B.11. (continued)

Hole #	PID		Field GC		Final Decision	Comments
	Pos.	Neg.	Pos.	Neg.		
41		X		X	NEG	
42	X		X		POS	
43	X		X		POS	
44	X		X		POS	
45	X		X		POS	
PZ01		X		X	NEG	
PZ02		X		X	NEG	
PZ03	X		NA		POS	
PZ04	X		NA		POS	

Total = 49

4 holes with negative GC and positive PID
 8% disagreement between PID and GC
 92% agreement

NA = not analyzed

Table B.12. Screening results for Site 13

Hole #	PID		Field GC		Final Decision	Comments
	Pos.	Neg.	Pos.	Neg.		
1	X		X		POS	Slow PID response
2	X		X		POS	Slow PID response
3	X		X		POS	Slow PID response
4	X		X		POS	Slow PID response
5	X		X		POS	Slow PID response
6	X		X		POS	Slow PID response
7		X		X	NEG	
8		X		X	NEG	
9		X		X	NEG	
10	X			X	POS	False NEG GC
11	X			NA	POS	
12		X		X	NEG	
13		X		X	NEG	
14	X			X	POS	Petroleum odor
15		X		X	NEG	
16		X		X	NEG	
PZ01		NA	X		POS	

Total = 17

2 holes with negative GC and positive PID

Several holes had very weak GC and slow PID response

12% disagreement between PID and GC

88% agreement

NA = not analyzed

Table B.13. Water sample results for Site 16
April 1991

Location	Sample Number	Total HBP PHC (*1) ug/L	Total LBP PHC (*2) ug/L	PCB/Pesticides (*3) ug/L	Semivolatiles Method 625, ug/L QL: 10 ug/L	Volatiles Method 624, ug/L QL: 5 ug/L
MW025L	3786	JP5 60.0	Gas 200.0 B 22.0 E 14.0	U	TIC 1 8.6 TIC 2 12.0 TIC 3 15.0 TIC 4 81.0 TIC 5 9.0 2 Unknowns 22.0 32.0	1,2DCA 10.0 B 20.0 E 16.0 TIC 3 28.0 TIC 6 52.0 TIC 7 13.0 TIC 8 34.0 TIC 9 24.0
MW025L	3787	U	Gas 200.0 B 20.0 E 13.0 T 2.0	U	TIC 2 8.6 TIC 3 12.0 TIC 5 8.6 3 Unknowns 15.0 24.0	1,2DCA 9.0 B 15.0 E 12.0 TIC 10 9.7 TIC 3 23.0 TIC 6 42.0 TIC 8 28.0 TIC 9 19.0
MW025U	3781	JP5 8400.0	Gas 7800.0 B 300.0 E 1200.0 T 42.0 X 45.0	U	2,4Dim 59.0 2-Metp 5.0*J 4-Metp 16.0 Bis2 10.0** Naph 4.0*J Pent 34.0*J Phen 5.0*J TIC 1 81.0 TIC 2 190.0 TIC 3 320.0 TIC 11 77.0 TIC 12 64.0 TIC 13 110.0 TIC 14 170.0 TIC 15 69.0 12 Unknowns 63.0 1200.0	1,2DCA 80.0 B 410.0 E 990.0 T 40.0 X 50.0 TIC 16 200.0 TIC 17 140.0 TIC 18 460.0 TIC 6 1900.0 TIC 7 430.0 TIC 19 110.0 TIC 8 1200.0 TIC 9 1000.0 TIC 20 320.0 TIC 21 190.0
MW025U	3782	JP5 7200.0	Gas 5700.0 B 310.0 E 800.0 T 40.0 X 34.0	U	2,4Dim 69.0 2-Metp 7.0*J 4-Metp 17.0 Bis2 9.0** Pent 36.0*J TIC 1 84.0 TIC 2 200.0 TIC 3 330.0 TIC 11 78.0 TIC 12 68.0 TIC 13 120.0 TIC 22 110.0 TIC 14 210.0 TIC 15 83.0 11 Unknowns 63.0 1300.0	1,2DCA 56.0 B 150.0 E 850.0 T 17.0*J X 25.0*J TIC 16 300.0 TIC 3 310.0 TIC 6 1400.0 TIC 8 670.0 TIC 9 560.0 TIC 20 160.0 TIC 21 270.0 TIC 23 270.0

Table B.13. (continued)

Location	Sample Number	Total HBP PHC (*1) ug/L	Total LBP PHC (*2) ug/L	PCB/Pesticides (*3) ug/L	Semivolatiles Method 625, ug/L QL: 10 ug/L	Volatiles Method 624, ug/L QL: 5 ug/L
MW026	3780	Die 330.0	U	U	Dieth 9.0*J TIC 24 8.6 TIC 5 9.6 TIC 25 10.0 1 Unknown 17.0	U
MW027	3775	U	U	U	TIC 24 10.0 TIC 5 33.0	U
MW028	3772	U	U	U	U	U
MW029L	3770	U	U	U	TIC 26 11.0**	U
MW029U	3773	Die 320.0	U	U	TIC 26 14.0**	U
MW030	3771	U	U	U	U	U

** - unusable data due to method blank contamination

*1 - Method 8015 Modified, quantitation limit: 50 ug/L

*2 - Method 8015/8020, quantitation limit: 50 ug/L

*3 - Method 608, quantitation limit: 0.05 ug/L

*J - concentration estimated

1,2DCA - 1,2-dichloroethane

2,4Dim - 2,4-dimethylphenol

2-Metp - 2-methylphenol

4-Metp - 4-methylphenol

B - benzene

Bis2 - bis(2-Ethylhexyl) phthalate

Die - HBP PHC as compared to diesel fuel

Dieth - diethylphthalate

E - ethylbenzene

Gas - LBP PHC as compared to gasoline

HBP - high boiling point

JP5 - HBP PHC as compared to JP-5 jet fuel

LBP - low boiling point

Naph - naphthalene

Pent - pentachlorophenol

PHC - petroleum hydrocarbons

Phen - phenol

QL - quantitation limit

T - toluene

TIC - tentatively identified compound

U - no compounds detected

X - xylenes (total)

NOTE - concentrations are estimated for TICs and unknowns

TIC 1 - 2-pentanol, 2,3-dimethyl-

TIC 2 - 2-pentanol, 2,4-dimethyl-

TIC 3 - benzene, (1-methylethyl)-

TIC 4 - benzenemethanol, .alpha., .al

TIC 5 - cyclohexene, 3-bromo-

TIC 6 - butane, 2-methyl-

TIC 7 - cyclohexane (dot)

TIC 8 - cyclopentane (dot)

TIC 9 - cyclopentane, methyl-

TIC 10 - 1-pentene, 2-methyl-

TIC 11 - benzene, 1,3,5-trimethyl

TIC 12 - benzene, 1-ethenyl-2-methyl-

TIC 13 - benzene, 1-ethyl-2-methyl-

TIC 14 - diazene, bis(1,1-dimethyleth

TIC 15 - phenol, 2,3,5,6-tetrachloro-

TIC 16 - 3-pentanone, 2,2-dimethyl-

TIC 17 - benzene, 1,3,5-trimethyl-

TIC 18 - benzene, methylethyl-

TIC 19 - cyclohexane, methyl-

TIC 20 - pentane, 2,2,3-trimethyl-

TIC 21 - pentane, 2,3,3-trimethyl-

TIC 22 - benzeneacetic acid, .alpha.-

TIC 23 - pentane, 3-ethyl-2,2-dimethyl-

TIC 24 - 2-heptenal, (z)-

TIC 25 - furan, 2,5-diethyltetrahydro

TIC 26 - 1,13-tetradecadiene

Table B.14. Water sample results for Sites 13 and 14
April 1991

Location	Sample Number	Total HBP PHC (*1) ug/L	Total LBP PHC (*2) ug/L	PCB/Pesticides (*3) ug/L	Semivolatiles Method 625, ug/L QL: 10 ug/L	Volatiles Method 624, ug/L QL: 5 ug/L
MW018L	3762	U	Gas 260.0 B 65.0 T 6.0 X 14.0	U	Bis2 2.0*J Butyl 21.0 TIC 1 9.8 TIC 2 33.0 TIC 3 31.0 TIC 4 41.0 12 Unknowns 8.6 1400.0	1,2DCA 47.0 B 33.0 Methcl 2.0** T 2.0*J TIC 5 14.0 TIC 6 14.0 TIC 7 18.0 TIC 8 45.0 TIC 9 9.3 1 Unknown 7.5
MW018U	3753	U	Gas 850000000.0	U	2,4Dim 3600.0 2-Meth 3900.0 4-Metp 330.0*J Benzo 8500.0 Benzyl 2800.0 Bis2 4200.0 Naph 7900.0 TIC 10 4100.0 TIC 11 3400.0 TIC 12 8300.0 TIC 13 8300.0 TIC 14 2800.0 TIC 15 9200.0 TIC 16 7500.0 TIC 17 2800.0 TIC 18 9200.0 TIC 19 4900.0 TIC 20 12000.0 9 Unknowns 2300.0 14000.0	1,2DCA 2200.0 2-But 6100.0 Acet 16000.0 B 18000.0 E 2600.0 T 31000.0 X 15000.0 TIC 21 3100.0 TIC 8 1300.0 1 Unknown 1400.0
MW018U	3754	JP5 14000.0	Gas 100000.0 B 14000.0 E 2300.0 T 26000.0 X 13000.0	U	2,4Dim 1700.0 2-Meth 6000.0 4-Metp 160.0*J Benzo 4200.0 Benzyl 1500.0 Bis2 3400.0 Naph 7400.0 TIC 22 4900.0 TIC 11 8200.0 TIC 11 9200.0 TIC 12 7600.0 TIC 13 7400.0 TIC 23 11000.0 TIC 14 5600.0 TIC 15 8300.0 TIC 16 6500.0 TIC 17 6300.0 TIC 18 8000.0 TIC 24 10000.0 TIC 20 11000.0 7 Unknowns 6500.0 13000.0	1,2DCA 2000.0 2-But 7200.0 Acet 15000.0 B 15000.0 E 2400.0 T 29000.0 X 14000.0 TIC 21 1700.0

Table B.14. (continued)

Location	Sample Number	Total HBP PHC (*1) ug/L	Total LBP PHC (*2) ug/L	PCB/Pesticides (*3) ug/L	Semivolatiles Method 625, ug/L QL: 10 ug/L	Volatiles Method 624, ug/L QL: 5 ug/L
MW019	3752	JP5 5100.0	Gas 10000.0	U	2,4Dim 10.0 2-Metp 6.0*J 4-Metp 20.0 Bis2 35.0 Pent 2.0*J TIC 25 35.0 TIC 26 120.0 TIC 27 89.0 TIC 28 140.0 TIC 28 31.0 TIC 29 59.0 TIC 30 170.0 TIC 22 39.0 TIC 18 60.0 TIC 18 97.0 TIC 18 60.0 TIC 31 59.0 TIC 31 33.0 TIC 32 27.0 7 Unknowns 32.0 170.0	1,2DCA 550.0 B 2000.0 E 180.0 T 200.0 X 1100.0 TIC 33 62.0 TIC 34 240.0 TIC 35 110.0 TIC 36 160.0 TIC 5 140.0 TIC 37 250.0 TIC 38 69.0 TIC 39 390.0 TIC 40 310.0 TIC 41 70.0
MW020	3749	Die 270.0	U	U	TIC 42 8.6 3 Unknowns 8.0 51.00	1,2DCA 2.0*J 1,2DCE 3.0*J B 15.0 Clform 8.0 TCE 23.0
MW021	3743	U	U	U	TIC 42 12.0 2 Unknowns 26.0 85.0	U
MW023	3742	Die 70.0	U	U	TIC 42 8.2 3 Unknowns 8.0 72.0	X 2.0*J
MW024	3734	Die 50.0	B 0.9 T 18.0 X 14.0 210.0	U	Bis2 3.0*J Naph 3.0*J TIC 43 110.0 TIC 44 60.0 TIC 45 19.0 TIC 46 33.0 TIC 47 13.0 TIC 48 19.0 TIC 49 61.0 TIC 50 14.0 9 Unknowns 11.0 160.0	TIC 51 12.0 TIC 5 13.0 TIC 6 19.0 TIC 52 6.3 TIC 8 16.0

** - unusable data due to method blank contamination

*1 - Method 8015 Modified, quantitation limit: 50 ug/L

*2 - Method 8015/8020, quantitation limit: 50 ug/L

*3 - Method 608, quantitation limit: 0.05 ug/L

*J - concentration estimated

1,2DCA - 1,2-dichloroethane

1,2DCE - 1,2-dichloroethene (total)

Clform - chloroform

Die - HBP PHC as compared to diesel fuel

E - ethylbenzene

Gas - LBP PHC as compared to gasoline

HBP - high boiling point

JP5 - HBP PHC as compared to JP-5 jet fuel

LBP - low boiling point

Table B.14. (continued)

2,4Dim	- 2,4-dimethylphenol	Methcl	- methylene chloride
2-But	- 2-butanone	Naph	- naphthalene
2-Meth	- 2-methylnaphthalene	Pent	- pentachlorophenol
4-Metp	- 4-methylphenol	PHC	- petroleum hydrocarbons
Acet	- acetone	QL	- quantitation limit
B	- benzene	T	- toluene
Benzo	- benzoic acid	TCE	- trichloroethene
Benzyl	- benzyl alcohol	TIC	- tentatively identified compound
Bis2	- bis(2-Ethylhexyl) phthalate	U	- no compounds detected
Butyl	- butylbenzylphthalate	X	- xylenes (total)
NOTE	- concentrations are estimated for TICs and unknowns		
TIC 1	- 2-pentanone, 4-hydroxy-4-met	TIC 27	- 1h-inden, 3-methyl-
TIC 2	- 2-propanol, 1-(2-propenyloxy	TIC 28	- 1h-inden-1-one, 2,3-dihydro-
TIC 3	- 2-propanol, 1-[1-methyl-2-(2	TIC 29	- 2-cyclohexen-1-one, 3,5-dime
TIC 4	- cyclohexane, 1,1,3,5-tetrame	TIC 30	- 2-hexenoic acid, 3,4,4-trime
TIC 5	- cyclohexane (dot)	TIC 31	- benzeneacetaldehyde, .alpha.
TIC 6	- cyclohexane, methyl-	TIC 32	- ethanone, (methylphenyl)-
TIC 7	- cyclopentane (dot)	TIC 33	- 1,4-pentadiene, 3-methyl-
TIC 8	- cyclopentane, methyl-	TIC 34	- 1-pentene, 2-methyl-
TIC 9	- pentane, 3-methyl-	TIC 35	- 2-butene
TIC 10	- benzene, 1-ethenyl-3-ethyl-	TIC 36	- benzene, 1-ethyl-2-methyl-
TIC 11	- benzene, ethenyl-ethyl-	TIC 37	- cyclopentene
TIC 12	- benzene, ethenyl-methyl-	TIC 38	- cyclopentene, 1-methyl-
TIC 13	- benzene, ethyl-dimethyl-	TIC 39	- cyclopropane, 1,1-dimethyl-
TIC 14	- benzene, methyl-methylethyl-	TIC 40	- cyclopropane, ethyl-
TIC 15	- benzene, methyl-propyl-	TIC 41	- thiophene
TIC 16	- benzene, propyl-	TIC 42	- 2-heptenal, (z)-
TIC 17	- benzene, tetramethyl	TIC 43	- 1-hexanol, 2-ethyl-
TIC 18	- benzene, trimethyl-	TIC 44	- 2-butanol, 2,3-dimethyl-
TIC 19	- benzoic acid, 2,3-dimethyl-	TIC 45	- 2-pentanol, 2,4-dimethyl-
TIC 20	- undecane	TIC 46	- cyclohexane, 1-bromo-2-chlor
TIC 21	- benzene, ethylmethyl-	TIC 47	- cyclohexane, 1-methoxy-1-(1,
TIC 22	- benzene, dimethyl-methylethyl	TIC 48	- cyclohexanol, 2-bromo-
TIC 23	- benzene, ethyl-methyl-	TIC 49	- octane, 1-iodo-
TIC 24	- dodecane	TIC 50	- octane, 2-iodo-
TIC 25	- 1(2h)-naphthalenone, 3,4-dih	TIC 51	- 3-hexanol, 5-methyl-
TIC 26	- 1,4-hexadiene, 2,3-dimethyl-	TIC 52	- cyclopentane, 1,2-dimethyl-

borings were drilled in the former hazardous waste storage area [to 1.2 m (4 ft)].

Site 11, Paint Shop

This area is now paved over. However, the regional groundwater test hole program detected contamination downgradient from the site that may be related to past waste disposal.

Site 12, Pest Control Shop

Six soil borings were drilled to the water table in the vicinity of the suspected leachfields. One single completion monitoring well was drilled near suspected contamination.

Site 13, Boiler Plant Tanks (tanks still in place)

Two single completion monitoring wells were drilled downgradient from the tanks in the plume delineated by groundwater test hole drilling. One piezometer was installed.

Site 14, Old Vehicle Maintenance Shop

One dual and 3 single completion monitoring wells were installed and sampled. Four piezometers were installed.

Site 16, Old Fuel Farm

Eight soil borings were drilled around the tanks (to water). Four single and 2 dual completion wells were installed and sampled mostly to assess the extent of the plume. These wells also encompass landfills, Sites 19 and 23. Eight piezometers were also installed in the area.

Site 17, Hangar 4

Five soil borings were drilled to 1.2 m (4 ft) along the drainage swale leading to the unnamed lateral ditch.

Site 19 and 23, Post-WW II Burial Site and Shipping and Receiving.

Three soil borings were drilled in the transformer storage area to a depth of 1.2 m (4 ft).

Site 20, Checkerboard Landfill:

Potential contaminants: JP-5, gasoline, diesel fuel, waste oils, hydraulic fluid, and wet garbage leachate.

Screening: consisted of drilling 36 groundwater test holes around the site (Fig. B.6). No contamination was detected with the field GC (Table B.15). This finding was supported by the fact that all wells installed around the site were "clean" (Table B.16).

Investigation: consisted of drilling and sampling 4 single completion and 1 dual completion well.

Site 24, Road Oiling Area:

Potential contaminants: include waste oil, fuels, and solvents.

Screening: deemed unnecessary for this site since many of the groundwater test holes for the Group II sites were drilled in the road. No significant contamination was detected except that associated with the Site 6 plume.

Investigation: consisted of drilling and sampling 5 widely space soil borings to the water table along the road. Three of the wells were drilled adjacent to the road to assess the extent of the Site 6 plume and will also serve to assess the road oiling area.

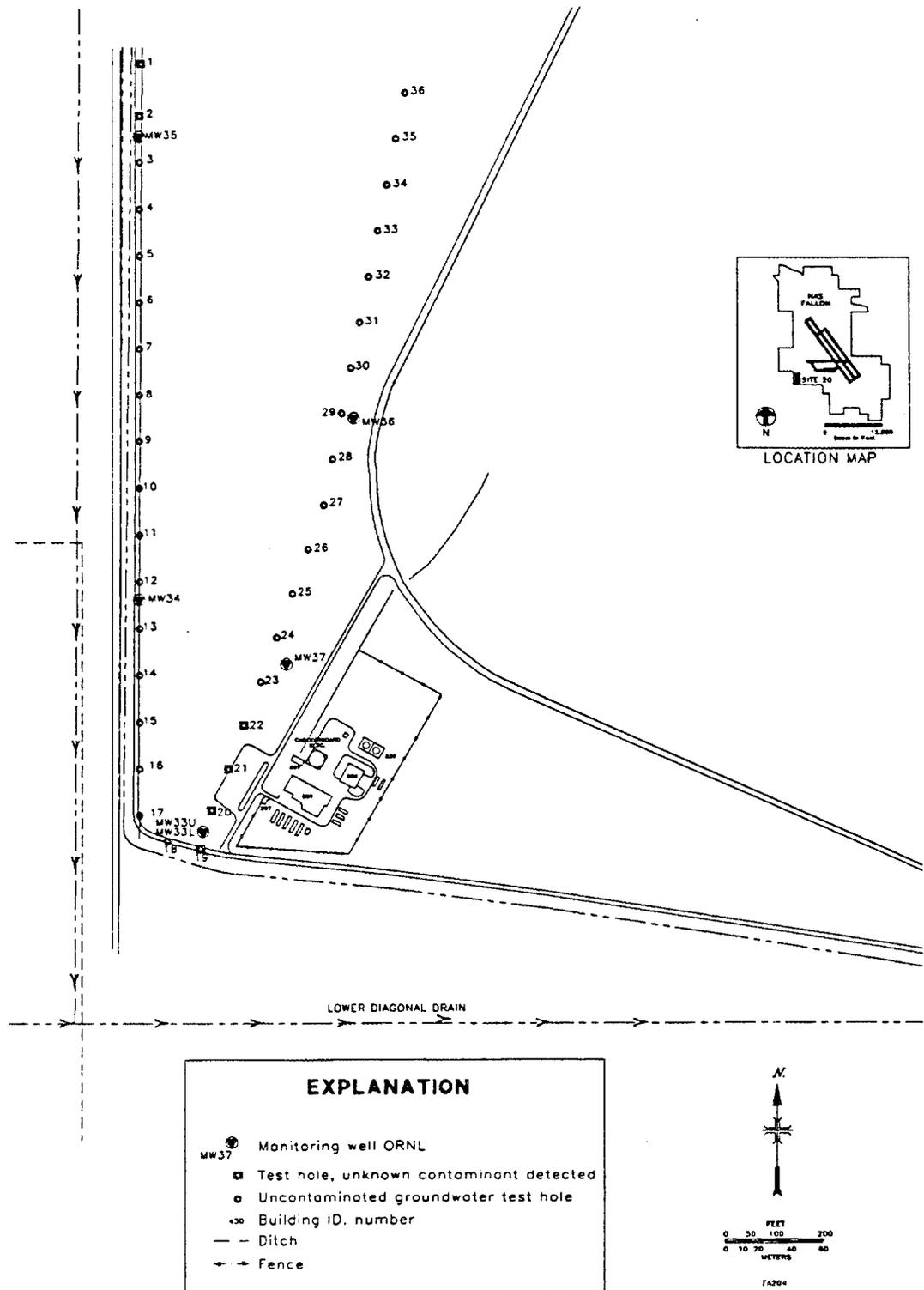


Fig. B.6. Groundwater test holes for Site 20.

Table B.15. Screening results for Site 20

Hole #	PID		Field GC		Final Decision	Comments
	Pos.	Neg.	Pos.	Neg.		
1	X			X	NEG	PID = 300 ppm slow PID = 60 ppm slow
2	X			X	NEG	
3		NA		X	NEG	
4		X		X	NEG	
5		X		X	NEG	
6		X		X	NEG	
7		X		X	NEG	
8		X		X	NEG	
9		X		X	NEG	
10		X		X	NEG	
11		X		X	NEG	
12		X		X	NEG	
13		X		X	NEG	
14		X		X	NEG	
15		X		X	NEG	
16		X		X	NEG	
17		X		X	NEG	
18		X		X	NEG	
19	X			X	NEG	PID = 28 ppm slow
20	X				NEG	PID = 62 ppm slow
21	X			X	NEG	PID = 52 ppm slow PID = 26 ppm slow
22	X			X	NEG	
23		X		X	NEG	
24		X		X	NEG	
25		X		X	NEG	
26		X		X	NEG	
27		X		X	NEG	
28		X		X	NEG	
29		X		X	NEG	
30		X		X	NEG	
31		X		X	NEG	
32		X		X	NEG	
33		X		X	NEG	
34		X		X	NEG	
35		X		X	NEG	
36		X		X	NEG	

Total = 36

0 holes with negative PID and positive GC
 6 holes with positive PID and negative GC
 16.6% disagreement between PID and GC
 83.4% agreement

NA = not analyzed

**Table B.16. Water sample results for Site 20
April 1991**

Location	Sample Number	Total HBP PHC (*1) ug/L	Total LBP PHC (*2) ug/L	PCB/Pesticides (*3) ug/L	Semivolatiles Method 625, ug/L QL: 10 ug/L	Volatiles Method 624, ug/L QL: 5 ug/L
MW033L	3777	U	U	U	U	U
MW033U	3784	U	U	U	TIC 1 12.0 TIC 2 13.0 TIC 3 20.0 3 Unknowns 18.0 280.0	U
MW034	3789	U	U	U	TIC 4 17.0	U
MW035	3791	U	U	U	Bis2 6.0**	U
MW036	3785	U	U	U	TIC 2 16.0 TIC 5 25.0 TIC 4 37.0	Bro 4.0*J
MW037	3788	U	U	U	Bis2 2.0** TIC 1 12.0 TIC 2 14.0 TIC 5 18.0 TIC 4 30.0 1 Unknown 9.8	TIC 6 130.0

** - unusable data due to method blank contamination
 *1 - Method 8015 Modified, quantitation limit: 50 ug/L
 *2 - Method 8015/8020, quantitation limit: 50 ug/L
 *3 - Method 608, quantitation limit: 0.05 ug/L
 *J - concentration estimated
 Bis2 - bis(2-Ethylhexyl) phthalate
 Bro - bromoform

HBP - high boiling point
 LBP - low boiling point
 PHC - petroleum hydrocarbons
 QL - quantitation limit
 TIC - tentatively identified compound
 U - no compounds detected

NOTE - concentrations are estimated for TICs and unknowns

TIC 1 - 2-heptenal, (z)-
 TIC 2 - 2-pentanone, 4-hydroxy-4-met
 TIC 3 - cyclohexanol, 2-bromo-, tran

TIC 4 - furan, 2,5-diethyltetrahydro
 TIC 5 - cyclohexene, 3-bromo-
 TIC 6 - furan, tetrahydro-

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