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V-0202-01

# Geophysics Survey
# 2,4-D Site
# Hanford-North Slope

April 1994

**Cascade Earth Sciences, Ltd.**
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Portland, Oregon 97220

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GEOPHYSICS SURVEY
2,4-D SITE
HANFORD - NORTH SLOPE

APRIL 1994

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA, WASHINGTON
CONTRACT NO. DACW 68-93-D-0002
DELIVERY ORDER 4

# 1.0 PROJECT DESCRIPTION

## 1.1 Introduction

This report summarizes the results of a geophysics survey conducted by Shannon & Wilson, Inc. at the 2,4-D disposal site located at Hanford - North Slope. The work was performed for the U.S. Army Corps of Engineers, Walla Walla District (COE), under contract #DACW 68-93-D-0002, Delivery Order No. 4. A magnetometer survey was performed on February 17 and 18, and a search using electromagnetic methods was performed on March 13, 1994. Shannon & Wilson performed this work as a subconsultant to Cascade Engineering Services, Portland, Oregon.

## 1.2 Site Background and Description

The North Slope consists of approximately 140 square miles of land north and east of the Columbia River across from the active area of the Hanford Site. The 2,4-D site is located on the North Slope approximately 25 miles north of the city of Richland, Washington. The location is shown on the Vicinity Map (Figure 1).

The 2,4-D site is located at the base of an approximately 60-foot-high sand dune to the west and approximately one quarter mile west of a gravel road. The dimensions of the site are approximately 440 by 60 feet with the long dimension approximately north-south parallel to the large sand dune. Signs marking the site are posted at the north and south ends. The site is vegetated with cheatgrass and sage.

According to documents supplied by the COE, soil contaminated with between 150 to 900 gallons of 2,4-D (2,4-Dichlorophenoxyacetic acid, a commercial herbicide) was buried at the site in 1966. The contaminated soil was generated from leaking, U.S. Bureau of Reclamation storage tanks in Eltopia, Washington. In 1967, the 2,4-D storage tanks were crushed and buried at the site as well. Documentation differs as to whether 6 or 10 storage tanks were buried at the site.

### 1.3 Purpose and Scope

As part of a previous study by others, a magnetometer was used to crudely locate the buried tanks, and 8 borings were advanced across the site but away from the tanks to obtain soil samples for contamination testing. The purpose of our work was to more precisely locate the tanks so that angle borings can be drilled close to the edges of the tanks to obtain soil samples from beneath the tanks. For our work, a magnetometer and a shallow electromagnetic (EM) device was used to locate the tanks.

## 2.0 GEOPHYSICS SURVEY

### 2.1 Theory and Application

#### 2.1.1 Magnetometer

Ferromagnetic objects, such as iron and steel, have an induced magnetic field when subject to the earth's magnetic field (primary field). This magnetization causes a secondary magnetic field in the vicinity of the object. The magnetometer measures total field, which is the magnitude of the resultant of the primary and secondary magnetic field vectors measured in the direction of the earth's magnetic field. The secondary magnetic field may add to or subtract from the earth's magnetic field, resulting in a local detectable magnetic anomaly. The magnetic anomaly may be symmetrical or asymmetrical and may have both positive and negative peaks depending on the shape, orientation, and the polarization of an object.

To conduct a magnetometer survey, numerous measurements of the total field are made over an area, generally with a fixed offset between measuring points. Anomalous readings, both positive and negative, indicate the presence of nearby ferromagnetic objects. Because

## APPENDIX
## GEOPHYSICAL METHODS AND EQUIPMENT

This section discusses the geophysical techniques used for this survey and the parameters measured by those techniques.

### Electromagnetics - EM31-D

The EM methods employs a portable power source, transmitter, and receiver coils to induce and measure an electromagnetic current in the ground. Current flowing in the transmitter coil generates a magnetic field that induces small electrical currents in the ground beneath the instrument. These currents generate secondary magnetic fields that are detected by the receiver coil. The ratio of primary to secondary field strengths is proportional to terrain conductivity and can be read directly on the EM instrument meter, which is calibrated in units of conductivity. Decaying refuse and buried metal area electrically conductive compared to native soil, and therefore produce anomalous adings in measured conductivity values.

Two components of the EM field were measured: terrain conductivity (sometimes referred to as the quadrature phase component) as expressed in millimhos per meter (mmhos/m), and the in-phase component of the EM field expressed in millivolts (a measure of signal strength). Terrain conductivity data can be used to locate backfilled trenches or pits, provided the conductivity of the backfill material contrasts with the surrounding native material. The in-phase mode of the EM field is particularly sensitive to metal objects and was used to locate buried metallic debris.

A Geonics Limited Model EM31-D terrain conductivity meter, which can measure subsurface conditions to a depth of approximately 20 feet, was used in this investigation. The EM31-D was connected to a Molytek Model 221/222 portable two-channel chart recorder, and an Omnidata Polycorder Model 516 digital data logger for ntinuous data acquisition along the survey ansects.

### Electromagnetics - M-Scope

The Fisher Research Laboratory Model TW-6 M-Scope is similar in principle to the EM31-D. The unit comprises a mobile transmitter and receiver which are connected by a handle. The transmitter radiates an electromagnetic field which is detected by the receiver. Nearby metal objects cause distortions in the field. The receiver, which has been previously tuned in an area free of metal, detects the distortions and produces an audible signal when held within approximately 4 feet of metal objects. The M-Scope has the advantage of being sensitive to smaller pieces of buried metal than the EM31-D.

### Magnetics

The magnetic technique measures the total intensity of the earth's magnetic field in units of magnetic intensity called gammas. Ferrous metal debris in a landfill will create variations (anomalies) in the field intensity which are recorded by the MAG instrument. The magnetic sensor is a vessel filled with a proton-rich source such as kerosene. The protons behave as small spinning magnets which orient themselves to the earth's magnetic field. A reading is initiated when an electrical current is passed through a wire coil around the sensor vessel. The current generates its own magnetic field and the protons readily align themselves to the new field. When the applied field is removed, the protons return to their original orientation. The returning motion (or precession) generates a small electrical signal that is related to the intensity of the earth's magnetic field at the sensor location. The intensity is a scalar measurement of the magnetic field vector independent of its orientation.

A pair of EG&G Geometrics, Inc., Model G-856X proton precession magnetometers were used for this survey. One was used for a base station, and the other was deployed as a gradient magnetometer. The base station uses a single magnetic sensor; it was placed in a remote location and programmed to

automatically record the earth's magnetic field intensity every thirty seconds.

The gradient magnetometer uses two magnetic sensors spaced two feet apart on a staff and was carried along the survey transects. This arrangement allows for the simultaneous measurement of the magnetic field at the two sensor locations. The difference between the two values divided by 2 is the vertical magnetic gradient in gammas per foot. As the effect of localized ferrous metal on the earth's magnetic field diminishes rapidly with distance, the gradient measurement is more sensitive to buried metal than single sensor magnetic field measurements. Moreover, the effects of diurnal magnetic drift and any regional magnetic gradient are removed by the gradient measurement approach.

**DISTRIBUTION**

Results of Geophysical Survey
H-06-L Landfill
Hanford North Slope
Richland, Washington(Title)

July 26, 1994

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RWS/DWG/ld/RS043-geo

# Results of Geophysical Survey
# H-83-L Landfill
# Hanford North Slope
# Richland, Washington

DRAFT

Prepared for

CDM Federal Programs Corporation
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### APPENDIX


GEOPHYSICAL METHODS AND EQUIPMENT


### DISTRIBUTION

## 1.0 INTRODUCTION

This report presents the results of Harding Lawson Associates' (HLA) surface geophysical investigation at the H-83-L landfill site on the North Slope of the Hanford Reservation near Richland, Washington. The purpose of the investigation was to locate areas of buried metal and delineate possible landfill cells in support of CDM Federal Programs Corporation (CDM) site characterization activities.

HLA's field investigation comprised the two work tasks described in the statement of work (SOW) telecopied by CDM to HLA on June 2, 1994:

- A survey to verify the locations of 7 geophysical anomalies identified during a geophysical investigation conducted by the Westinghouse Hanford Company (WHC) in 1991.

- A survey of adjacent previously uninvestigated areas to locate additional landfill cells, if present.

The field work was performed June 15 through 19, 1994, by HLA geophysicist Roark W. Smith of HLA's Novato, California, office, and Scott R. Yancey of HLA's Seattle, Washington, office. Guidance and logistical support were provided by Paul A. Karas and Jim Moore of CDM.

This document was prepared for the sole use of CDM Federal Programs Corporation and its authorized subcontractors. No other party should rely on the information contained herein without the prior written consent of HLA.

## 2.0 GEOPHYSICAL METHODS

HLA used two geophysical methods during this investigation: electromagnetics (EM) and magnetics (MAG). The EM instruments used were a Geonics Model EM31-D terrain conductivity meter and a Fisher Model TW-6 M-Scope. The EM31-D was used to locate landfill cells by detecting conductivity changes associated with landfill materials. The M-Scope was used to detect shallowly buried metal typically found in landfills. The MAG instrument was a GEM Model GSM-19 magnetometer, which was used to detect ferrous metal debris. Because of vehicle access restrictions due to loose sandy soil, the presence of sensitive vegetation and the fire danger associated with the vehicles' catalytic converters, ground penetrating radar was not used. A more detailed description of the methods and equipment used is presented in the Appendix.

## 3.0 SITE CHARACTERISTICS

The H-83-L landfill investigation area, which includes both the HLA and WHC survey areas, is rectangular and measures approximately 600 feet east-west by 500 feet north-south (Plates 1 and 2). The site is vegetated along its perimeter, and the terrain is generally flat except for a low ridge along the southern boundary. Small amounts of localized debris, including crushed ammo crates and steel cable, were observed on the ground surface.

In 1991 WHC surveyed a 300- by 300-foot area and identified 7 geophysical anomalies. At the direction of U.S. Army Corps of Engineers representative Randy Chong, HLA extended the survey area an additional 100 feet to the north, south, and east and an additional 200 feet to the west (Plate 2). The enlarged survey area boundaries were determined based on the distribution of surface debris around the original WHC survey area.

## 4.0 FIELD PROCEDURES

Before each day's field work, a safety briefing was given by Mr. Karas or Mr. Moore, and operational checks were made on all functional components of the two geophysical systems. Each system was tuned to local conditions according to the manufacturers' operations manuals. A calibration point for the EM system and a base station location for the MAG system were established in an area of native soil identified during a walkaround survey. These points were occupied at the beginning and end of each day's surveying for instrument calibration and tuning. The background calibration values and tuning signal strengths were recorded in the geophysicist's field logbook.

The field work was conducted in four stages:

- WHC Anomaly Verification Survey
- HLA Horizontal Control Installation
- HLA Geophysical Survey
- HLA Site Map Preparation.

### 4.1 WHC Anomaly Verification Survey

The HLA geophysicist hand-carried the EM31-D and M-Scope instruments to each anomaly location shown on a map provided by CDM. In general, the 7 anomalies previously identified by WHC were marked in the field by wooden stakes, although many stakes had fallen and were not in their original position.

At each anomaly location, the HLA geophysicist first used the M-Scope to delineate areas of shallowly buried metal. The EM31-D was then used to delineate areas of anomalous conductivity indicative of more deeply buried metallic and nonmetallic landfill materials. Geophysical responses were monitored by observing the instruments' meters; no data were recorded for this survey. Areas of anomalous response were outlined on the ground with orange spray paint. Before leaving the site, the HLA geophysicist accompanied CDM representative Jim Moore on an inspection of the verified anomaly locations.

## 4.2 HLA Horizontal Control Installation

A control grid was installed for the HLA survey areas by using a fiberglass tape measure and survey markers remaining from the WHC investigation to establish baselines along the perimeter of the original H-83-L survey area. The baselines were marked with wooden lath at the endpoints and PVC pin flags every 20 feet. Using the tape measure to form 30-, 40-, 50-foot right triangles, survey transects were installed perpendicular to the baselines and spaced 20 feet apart. In general, the control grid consisted of rows of PVC pin flags spaced 20 feet apart. The pin flags were removed after the geophysical survey was completed, but the wooden laths along the baselines were left in place so the HLA control grid could be reestablished

## 4.3 HLA Geophysical Survey

### 4.3.1 Electromagnetic (EM) Profiling Survey

EM profiling data were obtained by hand-carrying the portable EM system along survey transects spaced 20 feet apart. The EM profiles were positioned by interpolating transect alignments midway between the rows of pin flags. Two components of the EM signal (in-phase and terrain conductivity) were digitally recorded at 1-second intervals by the data logging system. The two components were

also recorded as continuous analog traces on a two-channel chart recorder. Survey transect number and instrument setting and scaling information were written on the analog records. Stationing along each transect was marked by inserting a special flagging record into the digital datafile and by scribbing the analog chart record at 20-foot intervals as a pin flag was passed. Analog EM profiles, without digital records, were also obtained along reconnaissance transects north and east of the HLA survey grid (Plate 2).

EM data were periodically transferred to a laptop computer and copied onto backup floppy disks. Each evening the analog chart records were reviewed to check that proper line number and stationing information had been recorded. Also recorded on the analog records was the name of the corresponding digital datafile. A total of 10,600 line feet of EM profiling data were collected for this investigation.

### 4.3.2 Magnetic Gradient (MAG) Survey

The MAG system used for this survey consisted of two magnetometers. One instrument was used as a base station and was positioned in a remote area of the site to monitor naturally occurring variations in the earth's magnetic field. The base station data were digitally recorded at 30-second intervals and transferred to a laptop computer after each field day.

A second magnetometer was used to perform the gradient survey. The gradient survey was conducted along transects spaced 20 feet apart. The MAG transects were offset 10 feet from the EM survey transects, and located along the rows of pin flags. This offset procedure produced a geophysical investigation with a 10-foot survey transect spacing.

Magnetic measurements were made by carrying the instrument along the survey transects and stopping to take readings at 10-foot intervals marked by the pin flags and at midpoints interpolated

between the flags. The operator provided line and station spacing information, and the instrument automatically stored in memory the total magnetic field readings obtained at each measurement station.

At the beginning of each day's surveying, magnetic measurements were first obtained along the baseline. As the MAG survey progressed, the baseline stations were reoccupied so time-varying magnetic noise (diurnal drift) could be monitored. This procedure was performed to back up the automatically recorded base station data. In addition, at selected stations, several successive magnetic strength readings were taken to validate instrument sensitivity and reproducibility and to check for short-period magnetic noise (micropulsations or sunspot activity).

Magnetic gradient data were periodically transferred in the field to a laptop computer and copied onto backup floppy disks. Each evening the gradient data were output to a line printer and the printout was annotated with transect number, stationing, and date.

A total of 10,600 linear feet of survey transect were traversed for the MAG survey, and a total of 2,120 magnetic measurements (2 measurements at each station) were obtained for this investigation.

### 4.3.3 HLA Anomaly Verification and Detailing Survey

After all data geophysical data were collected and reviewed, a preliminary anomaly location map was prepared. The geophysicist returned to the field and the anomalies were resurveyed along supplemental survey transects for verification and to finalize their locations and dimensions. This procedure helped pinpoint buried objects not located directly along the survey transects and removed any positioning errors caused by the interpolation of transect and station locations. The anomaly locations and dimensions were marked on the ground with orange spray paint and labeled PVC pin flags.

## 4.4 HLA Site Map Preparation

A site features map was prepared by walking the survey transects and plotting the locations of notable surface features on grid paper. The site features map served as a basemap on which our final interpretation is presented. In addition, the map shows significant surface features that help reference the geophysical coverage to the survey area. The map also shows other site features, such surface metal debris, that affected the geophysical measurements. The site map was digitized for presentation in this report (Plate 2).

## 5.0 DATA ANALYSIS AND INTERPRETATION

### 5.1 Field Data Reduction and Interpretation

EM chart records were inspected each evening for anomalous responses indicative of buried metal or other landfill materials. The printouts of the digital MAG gradient data were also inspected for anomalous readings indicative of buried ferrous metal. A diurnal drift curve was prepared from the MAG base station data using the software program GRAPHER. This curve was inspected for any large naturally occurring magnetic variations that could produce false anomalies and necessitate resurveying of selected MAG transects.

The locations of anomalous EM and MAG responses were plotted on the hand-drawn site features map. A copy of this map was provided to Mr. Moore to help direct CDM's ongoing excavation and trenching program.

### 5.2 Office Data Reduction and Interpretation

Upon the geophysicist's return to HLA's Novato, California, office, the digital EM data were output to a printer for checking and editing to ensure that proper station markers were in place. The EM data files were then processed using an HLA in-house software program that separates the terrain conductivity and in-phase data into different data files and assigns X-Y locations to each value. MAG data were reduced using Lotus 123 spreadsheet software to assign X-Y locations for each station.

Computer contour maps of the magnetic gradient (Plate 3), EM in-phase signal (Plate 4), and EM terrain conductivity (Plate 5) were generated using the Geosoft Mapping System, distributed by GEOSOFT, Inc., Toronto, Canada.

## 5.3 Criteria Used to Estimate the Location of Landfill Cells and Buried Objects

EM anomalies associated with subsurface disposal areas are usually evaluated in terms of increases in terrain conductivity over an established background value and/or changes in the in-phase signal. Background EM conductivity data obtained in areas of native-appearing soil at the H-83-L site were approximately 10 millihmos per meter (mmhos/m). The EM in-phase signal generally ranged between +50 and -50 millivolts.

The presence of subsurface disposal areas can be inferred from localized EM readings above or below background values, indicating the presence of subsurface features different from those in surrounding unaffected areas. A rapid change in in-phase response is an indicator of nearby metal. The amount of variation from background readings can provide an indication of the amount of landfill material present and/or its depth of burial.

Magnetic data show that the background total field strength is approximately 55,600 gammas, and the background magnetic gradient was generally less than 10 gammas per foot (gpf). The presence of buried ferrous metal can be inferred from localized readings above these background values. As with EM data, the amount of variation from background can provide an indication of the amount of ferrous metal present and/or its depth of burial.

The extent of disposal areas is determined by correlating areas of anomalous geophysical response between adjacent survey transects. Anomalous responses occurring in the same area along several adjacent transects are indicative of larger landfill cells, while anomalous responses that occur along a single transect without corresponding anomalies on adjacent transects are indicative of more localized debris.

Computer contour maps are often helpful when inspecting large data sets for indications of disposal

areas. Widespread EM and MAG anomalies indicative of large landfill cells are generally apparent as areas of tightly bunched contours. Color-shaded maps can further emphasize anomalous areas; however, because averaging and smoothing of the data occur during computer processing, the resulting contour maps often do not show the actual distribution of anomalous measurements, especially for more localized anomalies or along sharp boundaries between anomalous and background responses. A review of the analog EM chart records and an inspection of the gradient measurements on the MAG data printout was performed to determine the anomaly locations shown on Plate 2. This procedure is often more helpful when locating smaller concentrations of subsurface debris and delineating the limits of larger landfill cells more exactly.

## 6.0 RESULTS

### 6.1 WHC Anomaly Verification Survey

WHC anomalies A-1 through A 5 indicated on the map provided by CDM were verified by HLA. In general, these WHC anomaly locations corresponded to the mapped locations and to the placement of wooden stakes in the field. EM31-D and M-Scope scans indicated the presence of abundant metal debris in the shallow (upper 5 feet or less) subsurface at most anomaly locations. EM31-D scans also indicated the presence of more deeply buried metallic and nonmetallic debris.

No anomalous responses at WHC locations A-6 and A-7 were noted by the HLA geophysicist. HLA believes that anomalous responses previously measured at these locations were caused by surface and ry-near-surface metal objects that were subsequently removed during cleanup operations by CDM's excavation subcontractor. Specifically, anomaly A-6 was associated with pint- and quart-sized oil cans and wood telephone poles. While these objects were documented on the provided site map and also observed by the HLA geophysicist during the site orientation walkthrough, they were removed before HLA returned to survey the area. In addition, the HLA geophysicist removed a partially buried metal garbage can lid from the A-7 anomaly location before surveying that area.

Anomaly dimensions determined by HLA differed slightly from those indicated by WHC. The differences were insignificant and are attributed to HLA's free-walking verification survey, which was not confined to pre-established survey transects. By scanning along numerous crossing and intermediate traverses, the HLA geophysicist was able to more precisely delineate localized metal debris that strongly influenced anomaly dimensions.

## 6.2 HLA Geophysical Survey

Three additional anomalies, designated A-8 through A-10, were identified by HLA. The anomaly locations and approximate dimensions are shown on Plate 2. The magnetic gradient contour map is shown on Plate 3. The EM in-phase contour maps and EM conductivity are shown on Plates 4 and 5, respectively. Table 1 summarizes the anomaly locations and characteristics.

In general, the geophysical anomalies identified by HLA at site H-83-L are characterized by groupings of localized anomalous responses indicative of buried metal. These groupings probably delineate larger disposal areas containing both metallic and nonmetallic debris. The anomalous areas depicted on Plate 2 show the interpreted extent of subsurface disposal based on the distribution of more the localized anomalous responses within these areas. A more detailed discussion of anomaly characteristics follows.

Anomaly A-8 is in the northwest portion of the survey area near HLA grid coordinate 3+50N, 1+80E. The anomaly is shown on Plate 2 as two sub-areas. The larger sub-area to the south measures approximately 40 by 80 feet and is characterized by several closely spaced high amplitude MAG gradient anomalies of approximately 100 gammas per foot (gpf) and anomalous EM in-phase signal strengths of -500 millivolts (mv). The smaller sub-area to the north measures approximately 15 by 20 feet and is characterized by MAG gradients of 140 gpf with an EM in-phase anomaly of approximately 200 mv.

These responses are indicative of moderate amounts of ferrous metal buried approximately 5 feet below the surface. The two sub-areas may represent a single disposal pit; however, data obtained along transects 3+90N through 4+10N, between the two sub-areas, do not show anomalous responses indicative of non-native material. This result indicates two isolated disposal areas, although it is possible that a small amount of nonmetallic debris may be present between the two

areas.

Anomaly A-9 is at the northern edge of the survey area, near grid coordinates 4+80N, 3+50E (Plate 2). Supplemental geophysical survey data were obtained north of the survey grid to delineate the northern extent of this anomaly. Anomaly A-9 measures approximately 30 feet by 40 feet, and is characterized by MAG gradient anomalies of 220 gpf and anomalous EM in-phase signal strengths of approximately 800 mv. These responses are indicative of larger amounts of buried ferrous metal. The associated terrain conductivity anomalies are probably caused by buried metal and are not indicative of changes is soil properties.

Anomaly A-9 coincides with a shallow rectangular depression approximately 10 feet by 40 feet that appears to be a backfilled trench. EM in-phase anomalies and the highest MAG gradient readings were recorded within this area; however, lower MAG gradient anomalies of approximately 40 gpf were recorded within a 20-foot area around the apparent trench. These readings are possibly caused by localized near-surface metal outside the trench or by a large metal mass in the trench itself.

Anomaly A-10 is along the eastern edge of the survey area, near grid coordinates 1+50N, 6+00E. The anomaly consists of three sub-areas: a large area to the east measuring approximately 30 by 80 feet, and two small sub-areas to the west. Most of the east area is outside the survey grid, and supplemental geophysical survey data were obtained to delimit this anomaly. The east sub-area is characterized by several localized MAG gradient anomalies of approximately 150 gpf. This sub-area also exhibited EM in-phase anomalies during the verification survey but, as it is outside the survey grid, the millivolt anomaly values were not recorded. The geophysical anomalies recorded in the east area are indicative of substantial amounts of metal buried approximately 5 feet deep. The alignment of several localized anomalies in the east sub-area is indicative of a continuous disposal trench containing metallic and nonmetallic debris.

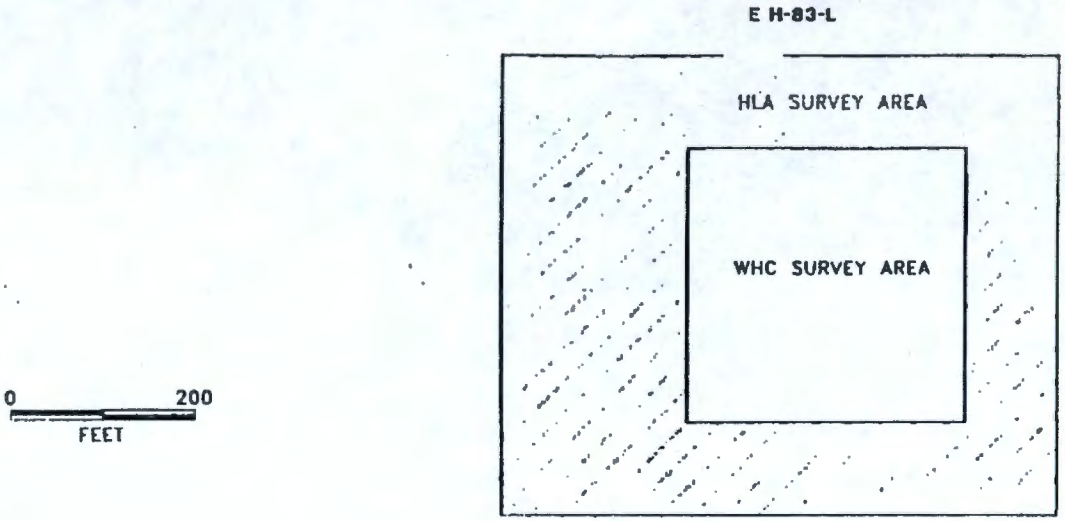
Of the two west sub-areas, the northern area exhibits a moderate EM in-phase anomaly of approximately 100 mv, without an associated MAG gradient anomaly. This response is indicative of a small elongated metal mass such as a steel cable or a piece of sheet metal similar to that found and removed from a nearby area. The southern area of the west sub-areas is characterized by a MAG gradient of 100 g/m and anomalous EM in-phase signals of approximately 200 mv, indicative of a larger metal mass.

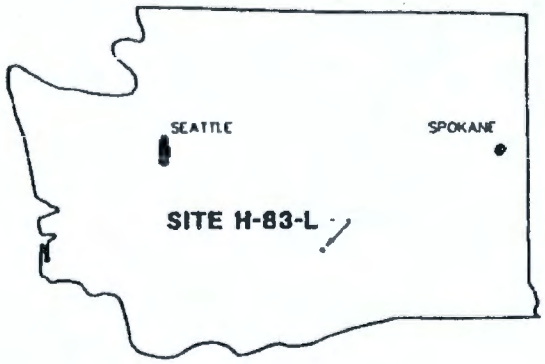
TABLE

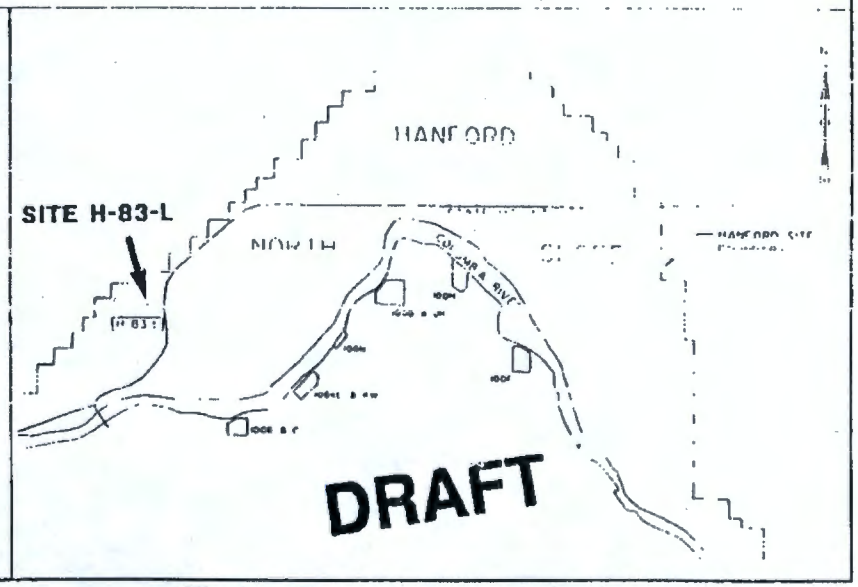
**Table 1. Geophysical Anomaly Locations and Characteristics, H-83-L Landfill**
**Hanford North Slope**
**Richland, Washington**

| Anomaly Designation | Survey Grid Coordinates (ft) | Anomaly Dimension (ft) | Approx. Depth of Burial (ft) | Interpretation of Subsurface Characteristics |
|---|---|---|---|---|
| A-8 | N3+50, E 1+80 | 40 x 80 | 5 | Disposal trench with metal and non-metal debris; localized shallow metal nearby |
| A-9 | N 4+80, E 3+50 | 30 x 40 | 5 | Disposal trench with metal and non-metal debris; possible small metal debris nearby |
| A-10 | N 1+50, E 6+00 | 30 x 80 | 5 | Disposal trench with metal and non-metal debris; smaller disposal pits nearby |

# PLATES

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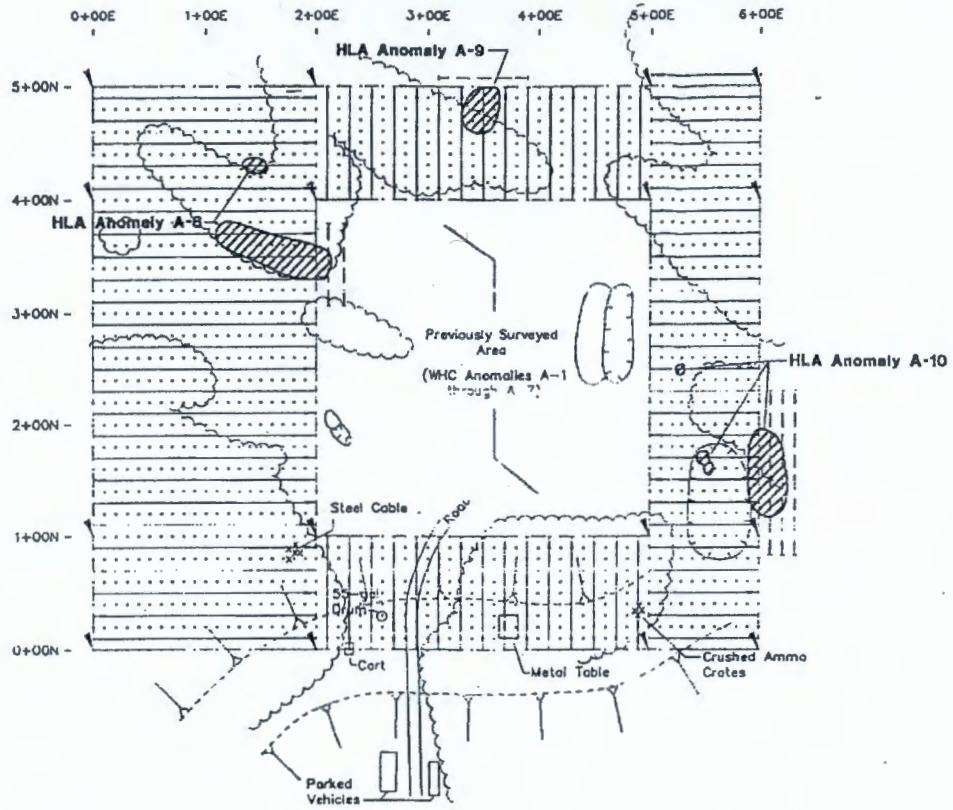
**Harding Lawson Associates**
Engineering and
Environmental Services

Site Location and Survey Area Maps
Site H-83-L
CDM Federal Programs
Landfill Characterization and Remediation
Hanford North Slope, Washington

PLATE **1**

| DRAWN | JOB NUMBER | APPROVED | DATE | REVISED DATE |
|---|---|---|---|---|
| Rws | 27969,2 | | 8/94 | |




## EXPLANATION

- EM31-D SURVEY TRANSECT
- RECONNAISSANCE EM31-D SURVEY TRANSECT (approximate location)
- MAGNETIC GRADIENT MEASUREMENT STATION
- GEOPHYSICAL ANOMALY INDICATIVE OF LANDFILL
- TOPOGRAPHIC LOW
- TOPOGRAPHIC HIGH
- VEGETATION
- LATH FROM PREVIOUS GEOPHYSICAL SURVEY
- LATH INSTALLED BY HLA

N

0 100 Feet

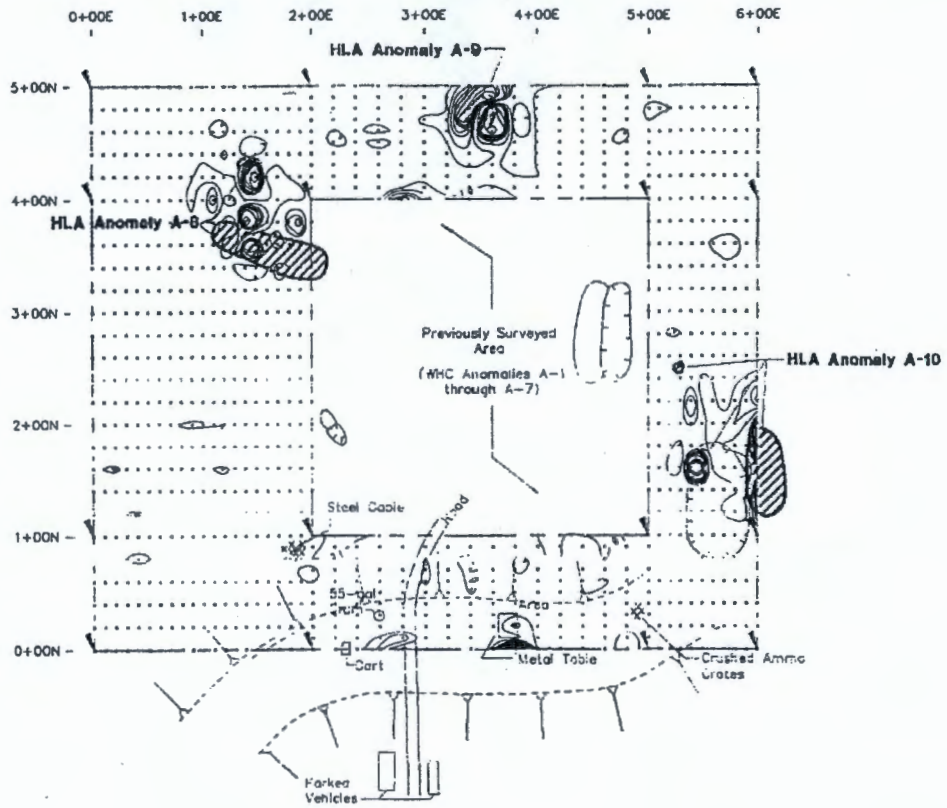
**DRAFT**

Harding Lawson Associates
Engineering and Environmental Services

Geophysical Survey Coverage and Results
Site H-83-L
CDM Federal Programs
Landfill Characterization and Remediation
Hanford North Slope, Washington

PLATE 2

| DRAWN | JOB NUMBER | APPROVED | DATE | REVISED DATE |
|---|---|---|---|---|
| Rws | 27969,2 | | 7/94 | |




## EXPLANATION

- MAGNETIC GRADIENT CONTOUR
  - CONTOUR INTERVAL = 10 GAMMAS PER FOOT, ZERO GRADIENT CONTOUR OMITTED FOR CLARITY
- MAGNETIC GRADIENT MEASUREMENT STATION
- GEOPHYSICAL ANOMALY INDICATIVE OF LANDFILL
- TOPOGRAPHIC LOW
- TOPOGRAPHIC HIGH
- VEGETATION
- INSTALALED SURVEY LATH

N

0 100
Feet

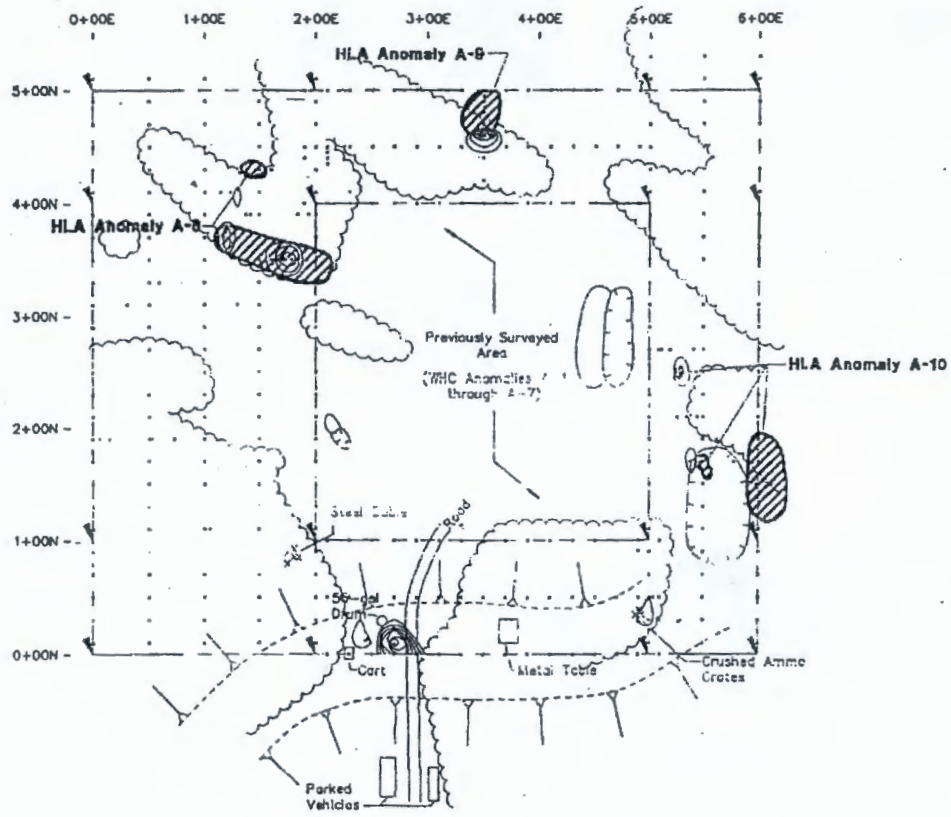
**DRAFT**

**Harding Lawson Associates**
Engineering and Environmental Services

Magnetic Gradient Contour Map
Site H-83-L
CDM Federal Programs
Landfill Characterization and Remediation
Hanford North Slope, Washington

PLATE 3

| DRAWN | JOB NUMBER | APPROVED | DATE | REVISED DATE |
|---|---|---|---|---|
| Rws | 27969.2 | | 8/94 | |




## EXPLANATION

- EM IN-PHASE SIGNAL CONTOUR
  CONTOUR INTERVAL = 50 MILLIVOLTS.
  ZERO MILLIVOLT CONTOUR
  OMITTED FOR CLARITY
- IN-PHASE SIGNAL DATA POINT USED FOR CONTOURING
- GEOPHYSICAL ANOMALY INDICATIVE OF LANDFILL
- TOPOGRAPHIC LOW
- TOPOGRAPHIC HIGH
- VEGETATION
- INSTALLED SURVEY LATH

N

0 100
Feet

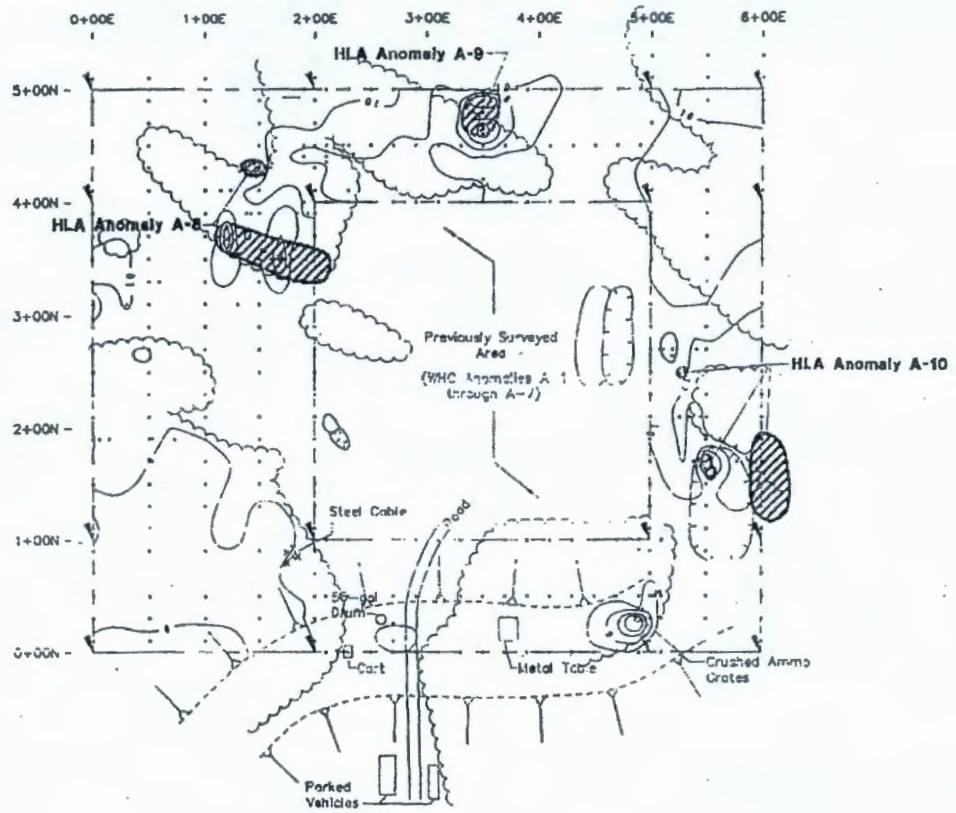
**DRAFT**

**Harding Lawson Associates**
Engineering and Environmental Services

EM In-Phase Signal Contour Map
Site H-83-L
CDM Federal Programs
Landfill Characterization and Remediation
Hanford North Slope, Washington

PLATE **4**

| DRAWN | JOB NUMBER | APPROVED | DATE | REVISED DATE |
|---|---|---|---|---|
| Rws | 27969.2 | | 8/94 | |




## EXPLANATION

- TERRAIN CONDUCTIVITY CONTOUR
  CONTOUR INTERVAL = 2 MILLIMHOS PER METER
- CONDUCTIVITY DATA POINT USED FOR CONTOURING
- GEOPHYSICAL ANOMALY INDICATIVE OF LANDFILL
- TOPOGRAPHIC LOW
- TOPOGRAPHIC HIGH
- VEGETATION
- INSTALLED SURVEY LATH

N

0 100
Feet

**DRAFT**

Harding Lawson Associates
Engineering and Environmental Services

Terrain Conductivity Contour Map
Site H-83-L
CDM Federal Programs
Landfill Characterization and Remediation
Hanford North Slope, Washington

PLATE 5

| DRAWN | JOB NUMBER | APPROVED | DATE | REVISED DATE |
|---|---|---|---|---|
| Rws | 27969,2 | | 8/94 | |

# APPENDIX

# GEOPHYSICAL METHODS AND EQUIPMENT

## APPENDIX

This section discusses the geophysical techniques used for this survey and the parameters measured by those techniques.

### Electromagnetics - EM31-D

The EM methods employs a portable power source, a transmitter, and receiver coils to induce and measure an electromagnetic current in the ground. Current flowing in the transmitter coil generates a magnetic field that induces small electrical currents in the ground beneath the instrument. These currents generate secondary magnetic fields that are detected by the receiver coil. The ratio of primary to secondary field strengths is proportional to terrain conductivity and can be read directly : the EM instrument meter, which is calibrated in units of conductivity. Decaying refuse and buried metal are electrically conductive compared to native soil, and therefore produce anomalous readings in measured conductivity values.

Two components of the EM field were measured: terrain conductivity (sometimes referred to as the quadrature phase component) as expressed in millimhos per meter (mmhos/m), and the in-phase component of the EM field, expressed in millivolts (a measure of signal strength). Terrain conductivity data can be used to locate backfilled trenches or pits, provided the conductivity of the backfill material contrasts with that of the surrounding native material. The in-phase mode of the EM field is particularly sensitive to metal objects and was used to locate buried metallic debris.

A Geonics Limited Model EM31-D terrain conductivity meter, which can measure subsurface conditions to a depth of approximately 20 feet, was used in this investigation. The EM31-D was nnected to a Molytek Model 221/222 portable two-channel chart recorder and an Omnidata

Polycorder Model 516 digital data logger for continuous data acquisition along the survey transects.

### Electromagnetics - M-Scope

The Fisher Research Laboratory Model TW-6 M-Scope is similar in principle to the EM31-D. The unit comprises a mobile transmitter and a receiver, which are connected by a handle. The transmitter radiates an electromagnetic field that is detected by the receiver. Nearby metal objects cause distortions in the field. The receiver, which has been previously tuned in an area free of metal, detects the distortions and produces an audible signal when held within approximately 4 feet of metal objects. The M-Scope has the advantage of being sensitive to smaller pieces of buried metal than the EM31-D.

### Magnetics

The magnetic technique measures the total intensity of the earth's magnetic field in units of magnetic intensity called gammas. Ferrous metal debris in a landfill creates variations (anomalies) in field intensity; the MAG instrument records these anomalies The magnetic sensor is a vessel filled with a proton-rich source such as kerosene. The protons behave as small spinning magnets, which orient themselves to the earth's magnetic field. A reading is initiated when an electrical current is passed through a wire coil around the sensor vessel. The current generates its own magnetic field and the protons readily align themselves to the new field. When the applied field is removed, the protons return to their original orientation. The returning motion (or precession) generates a small electrical signal that is related to the intensity of the earth's magnetic field at the sensor location. The intensity is a scalar measurement of the magnetic field vector independent of its orientation.

A pair of GEM Model GSM-19 proton precession magnetometers were used for this survey. One was used as a base station, and the other was deployed as a gradient magnetometer. The base station

uses a single magnetic sensor; it was placed in a remote location and programmed to automatically record the earth's magnetic field intensity every thirty seconds.

The gradient magnetometer uses two magnetic sensors spaced 2 feet apart on a staff and was carried along the survey transects. This arrangement allows for simultaneous measurement of the magnetic field at the two sensor locations. The difference between the two values divided by 2 is the vertical magnetic gradient in gammas per foot. As the effect of localized ferrous metal on the earth's magnetic field diminishes rapidly with distance, the gradient measurement is more sensitive to buried metal than single sensor magnetic field measurements. Moreover, the effects of diurnal magnetic drift and any regional magnetic gradient are removed by the gradient measurement approach.

**DISTRIBUTION**

Results of Geophysical Survey
H-83-L Landfill
Hanford North Slope
Richland, Washington

August 24, 1994

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---

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**TRANSMITTAL**

---

**To:** Mr. Jim Moore
CDM Federal Programs Corporation
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Golden, Colorado 80401

**From:** Roark Smith

**Date:** September 2, 1994

**Subject:** Hanford North Slope - Ten Potential Landfill Sites

**Project No.:** 27969 6

Enclosed please find one unbound copy of Harding Lawson Associates' draft report *Results of Geophysical Surveys at Ten Potential Landfill Sites, Hanford North Slope, Richland, Washington.* If you should have any questions or comments, please feel free to contact me at 415/884-3302.

# Results of Geophysical Surveys at Ten Potential Landfill Sites Hanford North Slope Richland, Washington

Prepared for

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HLA Project No. 27969 6


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**APPENDIX**

GEOPHYSICAL METHODS AND EQUIPMENT

**DISTRIBUTION**

## 1.0 INTRODUCTION

This report presents the results of Harding Lawson Associates' (HLA) surface geophysical investigation at 10 potential landfill sites (13 survey areas) on the North Slope of the Hanford Reservation near Richland, Washington. The ten sites are H-81-R, PSN 72/82, PSN-90, Igloo (two areas), Bridge Overview (two areas), H-12-C, H-83-C, PSN 12/14, PSN 01, and H-12-L (two areas) (Plate 1). Additionally, a confirmation survey was conducted at Site PSN 04 to verify the location of previously staked geophysical anomalies. The purpose of the investigation was to locate areas of buried metal and delineate possible landfill cells in support of CDM Federal Programs Corporation (CDM) site characterization activities. The scope and work procedures of HLA's investigation were described in the statement of work (SOW) telecopied by CDM to HLA on June 9, 1994.

The field work was performed during three work periods. The first work period lasted from June 19 through July 2, 1994, and was staffed by HLA geophysicist Roark W. Smith of HLA's Novato, California, office, and Gretchen R. Miller and Joanne A. Winters of HLA's Seattle, Washington, office. The second and third work periods lasted from July 5 through 15, and August 3 through August 4, 1994, and were staffed by Brian W. Hecker of HLA's Novato, California, office and Joanne A. Winters of HLA's Seattle, Washington, office. Guidance and logistical support were provided by Paul A. Karas and Jim Moore of CDM. Most of the field work was observed by various U.S. Army Corps of Engineers (COE) representatives.

This document was prepared for the sole use of CDM Federal Programs Corporation and its authorized subcontractors. No other party should rely on the information contained herein without the prior written consent of HLA.

## 2.0 GEOPHYSICAL METHODS

HLA used two geophysical methods during this investigation: electromagnetics (EM) and magnetics (MAG). The EM instruments used were a Geonics Model EM31-D terrain conductivity meter and a Fisher Model TW-6 M-Scope. The EM31-D was used to locate landfill cells by detecting conductivity changes associated with landfill materials. The M-Scope was used to detect shallowly buried metal typically found in landfills. The MAG instrument was a GEM Model GSM-19 magnetometer, which was used to detect ferrous metal debris. Because of vehicle access restrictions due to loose sandy soil, the presence of sensitive vegetation, and the fire danger associated with the vehicles' catalytic converters, ground penetrating radar was not used. A more detailed description of the methods and equipment used is presented in the Appendix.

## 3.0 GENERAL FIELD PROCEDURES

Before each day's field work, a safety briefing was given by HLA geophysics crew chief Roark W. Smith or Brian W. Hecker. Operational checks were made on all functional components of the two geophysical systems. Each system was tuned to local conditions according to the manufacturers' operations manuals. A calibration point for the EM system and a base station location for the MAG system were established at each site in an area of native soil identified during a walkaround survey. These points were occupied at the beginning and end of each day's surveying for instrument calibration and tuning. The background calibration values and tuning signal strengths were recorded in the geophysicist's field logbook.

The field work was conducted in three stages:

- Horizontal Control Installation
- Geophysical Survey
- Site Map Preparation.

### 3.1 Horizontal Control Installation

Twelve of the 13 investigation areas were marked prior to the geophysical survey by survey lath installed by the COE. Although the lath were not labeled, they corresponded to number designations shown on COE plot plans (Drawings HN-94-1/1, HN-94-1/2, HN-94-/3, HN-94-1/4, HN-94-1/5) provided to the HLA geophysicists. HLA understands that the boundaries of these survey areas were generally based on the distribution of surface debris, which had been removed by others before the

geophysical investigations. The survey areas as marked by the COE were generally trapezoidal in shape, and HLA installed slightly larger rectangular survey grids which included the COE-designated site boundaries.

Boundary limits for Site PSN 12/14 were not previously staked. COE representative Randy Chong showed Roark Smith (HLA) and Paul Karas (CDM) the proposed survey area during a site walkthrough, and boundary marking lath were then installed by HLA.

The control grid at each site was installed by using a fiberglass tape measure to establish a baseline between two of the site boundary marking laths. The baseline was marked with wooden lath at the endpoints and PVC pin flags every 20 feet. Using the tape measure to form 30-, 40-, 50-foot right triangles, survey transects were installed perpendicular to the baseline and spaced 20 feet apart. The transects were marked by alternating rows of yellow and orange PVC pin flags; stationing along the transects was marked every 20 feet. The pin flags were removed after the geophysical surveys were completed, but the wooden laths at the grid corners were left in place so the HLA control grid could be reestablished.

## 3.2 Geophysical Survey

The following sections describe generalized field procedures for the collection of EM and MAG data at the 10 landfill sites (13 areas).

### 3.2.1 Electromagnetic (EM) Profiling Survey

EM profiling data were obtained by hand-carrying the portable EM system along survey transects spaced 20 feet apart. The EM profiles were positioned by interpolating transect alignments midway between the rows of pin flags. Two components of the EM signal (in-phase and terrain conductivity)

were digitally recorded at 1-second intervals by the data logging system. The two components were also recorded as continuous analog traces on a two-channel chart recorder. Survey transect number and instrument setting and scaling information were written on the analog records. Stationing along each transect was marked by inserting a special flagging record into the digital datafile and by scribing the analog chart record at 20-foot intervals as a pin flag was passed. At selected sites, analog EM profiles, without digital records, were also obtained along reconnaissance transects outside of the HLA survey grid.

EM data were periodically transferred to a laptop computer and copied onto backup floppy disks. Each evening the analog chart records were reviewed to check that proper line number and stationing information had been recorded. Also recorded on the analog records was the name of the corresponding digital datafile.

### 3.2.2 Magnetic Gradient (MAG) Survey

The MAG system used for this survey consisted of two magnetometers. One instrument was used as a base station and was positioned in a remote area of the site to monitor naturally occurring variations in the earth's magnetic field. The base station data were digitally recorded at 30-second intervals and transferred to a laptop computer after each field day.

A second magnetometer was used to perform the gradient survey. The gradient survey was conducted along transects spaced 20 feet apart. The MAG transects were offset 10 feet from the EM survey transects, and located along the rows of pin flags. This offset procedure produced a geophysical investigation with a 10-foot survey transect spacing.

Magnetic measurements were made by carrying the instrument along the survey transects and stopping to take readings at 10-foot intervals marked by the pin flags and at midpoints interpolated

between the flags. The operator provided line and station spacing information, and the instrument automatically stored in memory the total magnetic field readings obtained at each measurement station.

At the beginning of each day's surveying, magnetic measurements were first obtained along the baseline. As the MAG survey progressed, the baseline stations were reoccupied so time-varying magnetic noise (diurnal drift) could be monitored. This procedure was performed to back up the automatically recorded base station data. In addition, at selected stations, several successive magnetic strength readings were taken to validate instrument sensitivity and reproducibility and to check for short-period magnetic noise (micropulsations or sunspot activity).

Magnetic gradient data were periodically transferred in the field to a laptop computer and copied onto backup floppy disks. Each evening the gradient data were output to a line printer and the printout was annotated with transect number, stationing, and date.

### 3.2.3 Anomaly Verification and Detailing Survey

After all geophysical data at a site were collected and reviewed, a preliminary anomaly location map was prepared. The geophysicist returned to the field and the anomalies were resurveyed using the EM31-D and TW-6 M-Scope along supplemental survey transects for verification, and to refine and finalize their locations and dimensions. This procedure helped pinpoint buried objects not located directly along the survey transects and removed any positioning errors caused by the interpolation of transect and station locations. The anomaly locations and dimensions were marked on the ground with a combination of painted lath and red pin flags.

A verification and detailing survey using the procedures described above was also performed at Site PSN 04 to locate anomalies previously identified by others.

## 3.4 Site Map Preparation

A map for each survey area was prepared by walking the survey transects and plotting the locations of notable surface features on grid paper. The site features map served as a basemap on which our final interpretation for each site is presented. In addition, the maps show significant surface features that help reference the geophysical coverage to the survey area, as well as other site features, such surface metal debris, that affected the geophysical measurements. The site maps were digitized for presentation in this report (Plates 2, 4, 6, 10, 11, 13, 15, 16, 17, 21, 25, 26, 28).

## 4.0 DATA ANALYSIS AND INTERPRETATION

### 4.1 Field Data Reduction and Interpretation

EM chart records were inspected each evening for anomalous responses indicative of buried metal or other landfill materials. The printouts of the digital MAG gradient data were also inspected for anomalous readings indicative of buried ferrous metal. A diurnal drift curve was prepared from the MAG base station data using the software program GRAPHER. This curve was inspected for any large naturally occurring magnetic variations that could produce false anomalies and necessitate resurveying of selected MAG transects.

The locations of anomalous EM and MAG responses were plotted on the hand-drawn site features maps. A copy of each map was provided to Mr. Moore to help direct CDM's ongoing excavation and trenching program.

### 4.2 Office Data Reduction and Interpretation

Upon the geophysicists' return to HLA's Novato, California, office, the digital EM data were output to a printer for checking and editing to ensure that proper station markers were in place. The EM data files were then processed using an HLA in-house software program that separates terrain conductivity and in-phase data into different data files and assigns X-Y locations to each value. MAG data were reduced using Lotus 123 spreadsheet software to assign X-Y locations for each station.

Computer contour maps of the magnetic gradient, EM in-phase signal, and EM terrain conductivity were generated using the Geosoft Mapping System, distributed by GEOSOFT, Inc., Toronto, Canada.

## 4.3 Criteria Used to Estimate the Location of Landfill Cells and Buried Objects

EM anomalies associated with subsurface disposal areas are usually evaluated in terms of increases in terrain conductivity over an established background value and/or changes in the in-phase signal. Background EM conductivity in areas of native-appearing soil at the 13 survey areas was generally less than 10 millihmos per meter (mmhos/m). The EM in-phase signal generally ranged between +50 and -200 millivolts.

The presence of subsurface disposal areas can be inferred from localized EM readings above or below background values, indicating the presence of subsurface features different from those in surrounding unaffected areas. A rapid change in in-phase response is an indicator of nearby metal. The amount of variation from background readings can provide an indication of the amount of landfill material present and/or its depth of burial.

Magnetic data show that the background total field strength is approximately 55,600 gammas, and the background magnetic gradient at all sites was generally less than 10 gammas per foot (g/f). The presence of buried ferrous metal can be inferred from localized readings above these background values. As with EM data, the amount of variation from background can provide an indication of the amount of ferrous metal present and/or its depth of burial.

The extent of a disposal area is determined by correlating areas of anomalous geophysical response between adjacent survey transects. Anomalous responses occurring in the same area along several adjacent transects are indicative of larger landfill cells, while anomalous responses that occur along a single transect without corresponding anomalies on adjacent transects are indicative of more localized debris.

Computer contour maps are often helpful when inspecting large data sets for indications of disposal

areas. Widespread EM and MAG anomalies indicative of large landfill cells are generally apparent as areas of tightly bunched contours. However, because averaging and smoothing of the data occur during computer processing, the resulting contour maps often may not show an accurate distribution of anomalous measurements, especially for more localized anomalies or along sharp boundaries between anomalous and background responses. A review of the analog EM chart records and an inspection of the gradient measurements on the MAG data printout was performed to determine the anomaly locations shown on the results maps. This procedure is often most helpful when locating smaller concentrations of subsurface debris and delineating the limits of larger landfill cells more precisely.

## 5.0 SITE CHARACTERISTICS AND RESULTS

Tables 1 and 2 summarize the results of the geophysical investigations at the ten potential landfill sites (13 survey areas). Geophysical anomalies indicative of subsurface debris were identified at seven of the thirteen areas investigated. The areas are Site PSN 90, Site Igloo-1, Site Igloo-2, Site Bridge Overview-1, Site H-83-C, Site PSN 12/14, and Site H-12-L-1. With the exception of Anomaly A-4 at Site PSN 90, all of the listed anomalies were identified during field data reduction and interpretation and were presented on the hand-drawn preliminary results maps provided to CDM in the field.

Anomalies at the Bridge Overview-1 site are indicative of small buried metal debris, and anomalies at PSN-90 are generally associated with a buried pipeline and large metal objects on the ground surface. The remaining four sites, Igloo-1, Igloo-2, H-83-C, and PSN 12/14, show indications of significant subsurface disposal. Large anomalies indicative of single disposal areas or a sequence of closely spaced backfilled trenches were identified at sites Igloo-1, Igloo-2, and H-83-C. Several separate disposal trenches were indicated at Site PSN 12/14, the largest of the 13 areas investigated. The terrain conductivity anomaly identified at Site H-12-L-1 is believed to be caused by increased soil moisture. The anomaly limits determined by HLA during the survey at Site PSN 04 were consistent with the areas staked in the field.

The extent and location of anomalies shown on the results maps are generally based on field checks of interpreted geophysical anomalies. Therefore, the mapped anomaly location may not always correlate well with anomaly location may not always correlate well with anomalous contours of digitally recorded geophysical data.

## 5.1 Site H-81-R

### 5.1.1 Site Description

The H-81-R investigation area was marked in the field by four COE staking lath and was very nearly rectangular. At the time of the survey, the site was sparsely vegetated and the terrain flat. No surface debris was observed. HLA used the southeast COE lath #1238 for a grid origin and extended a 160-foot-long baseline north through COE lath #1239. HLA installed a true rectangular survey grid at this site measuring 160 feet by 180 feet, or approximately 0.66 acre (Plate 2).

HLA obtained EM31-D data along approximately 1,600 linear feet of survey transect and MAG gradient measurements at 170 stations.

### 5.1.2 Results, H-81-R

Although no geophysical anomalies were identified within the survey grid at Site H-81-R, anomalous responses indicative of substantial buried metal were measured during a reconnaissance survey at a low mound approximately 175 feet north of the survey area (Plate 2). MAG gradients in this area were approximately 700 g/f, and EM in-phase anomalies of 500 millivolts (mv) were also measured.

Within the survey area, MAG gradients were generally less than 10 g/f. The EM in-phase signal ranged between -160 and -180 mv and the terrain conductivity was approximately 8 mmhos/m. Contour maps showing MAG gradient, EM in-phase, and terrain conductivity responses are presented on Plate 3. Because the anomalous area associated with the low mound is not within the survey grid, no digital data were recorded and the anomalous response is not shown on the contour maps.

## 5.2 Site PSN 72/82

### 5.2.1 Site Description

Site PSN 72/82 was characterized by a clearing in the sagebrush. The terrain was flat, and small amounts of barbed wire, two 1-gallon paint cans, and two low mounds were observed. The survey area was marked in the field by four COE staking lath forming a trapezoid. HLA used lath #1253 for a grid origin and extended a 200-foot-long baseline north through lath #1252. HLA installed a rectangular survey grid at this site measuring 200 feet by 150 feet, or approximately 0.69 acre (Plate 4).

HLA obtained EM31-D data along approximately 1,600 linear feet of survey transect and MAG gradient measurements at 198 stations.

### 5.2.2 Results, PSN 72/82

No geophysical anomalies indicative of landfill or buried debris were identified at Site PSN 72/82. MAG gradients were generally less than 10 g/f. EM in-phase signal ranged between -100 and -140 mv and the terrain conductivity was approximately 8 mmhos/m. Small variations is response associated with the barbed wire were noted, but they are not indicative of buried material. Contour maps showing the MAG gradient, EM in-phase, and terrain conductivity responses are presented on Plate 5.

## 5.3 Site PSN 90

### 5.3.1 Site Description

PSN 90 was characterized by sagebrush clearings, disturbed topography, and abundant surface debris.

Several mounds and depressions and areas with large pieces of metal were observed. The terrain, although generally flat, had an irregular topography indicating the area had been reworked. Metal sheet piles and asphalt and concrete rubble were observed. A linear depression, possibly a drainage ditch, passed through the northeast corner of the site.

The site boundary was marked by six COE lath and formed an irregular polygon. HLA incorporated the longest straight line segment of this polygon, between lath #1154 and #1155, into a 520-foot-long baseline that formed the eastern boundary of the survey area (Plate 6). HLA installed a rectangular survey grid that measured 520 feet by 280 feet, or approximately 3.34 acres. The HLA survey grid included the COE site boundary lath and suspicious areas west of the COE-designated site boundary.

HLA obtained EM31-D data along approximately 6,440 linear feet of survey transect and MAG gradient measurements at 696 stations. In addition, a reconnaissance EM31-D survey was performed in a suspect area east of the survey grid (Plate 6).

### 5.3.2 Results, PSN 90

Five geophysical anomalies indicative of substantial amounts of metal were detected at Site PSN 90. Their locations are shown on Plate 6. In general, large high-amplitude geophysical anomalies were recorded in the areas of surface and partially buried metal observed in the northern portion of the site. These anomalies are designated A-1, A-2, and A-3, and are characterized by MAG gradients in excess of 300 g/f and EM in-phase responses on the order of 1,000 mv. Because of interference from abundant surface metal, any more deeply buried debris, or nearby shallowly buried debris, would not have been detected in this area. A resurvey after the surface metal is removed and initial excavations of metal should be performed to verify that additional subsurface debris is not present in this area.

Anomaly A-4 is a smaller feature in the southern portion of the survey area near grid coordinates

0+30N, 1+80E. A-4 is characterized by MAG gradients of approximately 200 g/f and an EM in-phase response of 150 mv indicative of localized shallow metal debris.

Anomaly A-5 is associated with a buried metal pipe in the eastern portion of the site (Plate 6). Using an RD-400 pipe and cable locating device manufactured by Radiodetection Corp, the pipeline was traced to a nearby water well pump shack.

A variation in MAG gradient associated with the mounded area near grid coordinate 1+40 N, 1+10 E is noted. Because of the absence of an associated anomalous EM31-D response, HLA believes this MAG gradient variation may be caused by the higher elevation at the measurement stations on the mound. This caused an localized change in the position of the magnetic instrument sensors relative to native soil and volcanic bedrock, which can be highly magnetic and strongly influence magnetic response. It is also possible that the mound contains small pieces of buried metal.

Five localized single-point MAG gradient anomalies are also noted. They are believed to be caused by small pieces of surface metal located along a survey transect.

The background MAG gradient at Site PSN 90 is generally less than 20 g/f. The background EM in-phase signal is approximately 100 mv, and the background terrain conductivity is approximately 30 mmhos/m. The relatively high background conductivity compared with other sites at Hanford North Slope, is probably due to the greater moisture and clay content of the soil at this site, which is located in a cultivated area. Contour maps showing the MAG, EM in-phase, and terrain conductivity responses are presented on Plates 7, 8, and 9, respectively.

## 5.4 Site Igloo-1

### 5.4.1 Site Description

The Igloo-1 site had a gently mounded ground surface with lineations suggesting the area had been reworked by a bulldozer. The site was sparsely vegetated by low grass. The area of investigation was marked in the field by four COE staking lath that formed a trapezoid. HLA established a 160-foot-long baseline through lath #102 and #103 and installed a rectangular survey grid that measured 160 feet by 120 feet, or approximately 0.44 acre.

HLA obtained EM31-D data along approximately 1,200 linear feet of survey transect and MAG gradient measurements at 117 stations. A reconnaissance EM31-D survey was also performed at a pit and mound east of the survey grid.

### 5.4.2 Results, Igloo-1

The geophysical survey coverage and results for the Igloo-1 site are shown on Plate 10. A single large and well-defined area of anomalous geophysical response measuring approximately 50 feet by 120 feet was identified. The area is characterized by MAG gradients from 100 to over 400 g/f and EM in-phase signals in excess of 2,000 mv. These responses are indicative of large amounts of metal, probably within 5 feet of the ground surface. The associated terrain conductivity anomaly is believed to be caused by the buried metal and is not indicative of changes in soil properties. Contour maps showing the MAG, EM in-phase, and terrain conductivity responses are also presented on Plate 10.

## 5.5 Site Igloo-2

### 5.5.1 Site Characteristics

The southern portion of Igloo-2 was characterized by gently mounded ground surface with lineations suggesting the area had also been reworked by a bulldozer. The ground surface dips to the southwest where it encompasses a wash that terminates into a hummocky area that also appeared reworked. The site was sparsely vegetated by low grass and a band of sagebrush. The area of investigation was marked in the field by four COE staking lath forming a trapezoid. HLA established a 310-foot-long baseline between lath #126 and #127 and installed a rectangular survey grid that measured 310 feet by 160 feet. Based on the preliminary results of the EM31-D survey, a 40- by 40-foot extension was added to the southeast corner of the grid, forming a survey area of approximately 1.16 acres.

HLA obtained EM31-D data along approximately 2,840 linear feet of survey transect and MAG gradient measurements at 272 stations.

### 5.5.2 Results, Igloo-2

The geophysical survey coverage and results for the Igloo-2 site are shown on Plate 11. Contour maps showing the MAG gradient, EM in-phase, and terrain conductivity responses are presented on Plate 12. A single large and well-defined area of anomalous geophysical response similar to that found at Igloo-1 was identified. This area measured approximately 70 feet by 120 feet and was characterized by MAG gradients from 100 to over 500 g/f and EM in-phase signals in excess of 2,000 mv. These responses are indicative of large amounts of metal that is probably within 5 feet of the ground surface. The associated terrain conductivity anomaly is probably caused by the buried metal and is not indicative of changes in soil properties.

## 5.6 Site Bridge Overview-1

### 5.6.1 Site Description

The Bridge Overview-1 site was characterized by sandy soil and gently sloping terrain. Wood debris and patches of glass, cinders, and small metal debris such as nails and bottle caps, were observed on the surface. The site was partially vegetated with sagebrush. The investigation area was marked by four COE lath forming a trapezoid. HLA established a 300-foot-long baseline, between lath #1261 and #1262, and installed a rectangular survey grid that measured 300 feet by 200 feet, or approximately 1.37 acres.

HLA obtained EM31-D data along approximately 3,000 linear feet of survey transect and MAG gradient measurements at 336 stations. A reconnaissance EM31-D survey was also performed to delimit the extent of two geophysical anomalies identified along the western edge of the survey grid.

### 5.6.2 Results, Bridge Overview-1

Four geophysical anomalies indicative of buried debris were identified at the Bridge Overview-1 site. The anomaly locations are shown on Plate 13 and contour maps showing the MAG gradient, EM in-phase, and terrain conductivity responses are presented on Plate 14.

All of the anomalies are of moderate amplitude and indicative of small metal debris probably buried within 5 feet of the ground surface. Although surface debris was observed near all anomaly locations, the four identified anomalies are believed to be indicative of buried objects. Partially buried stovepipes were removed at an area of anomalous response near grid coordinates 2+50 N, 0+90 E (Plate 13). HLA believes that similar small metal debris is buried at the four designated anomaly locations. Additional localized areas of anomalous response are apparent on the contour

maps, but they are attributed to surface debris and have been disregarded.

Anomaly A-1 is near grid coordinate 1+40N, 0+80E. It is characterized by an EM31-D response with a small MAG gradient variation indicative of small but elongated masses of buried metal, possibly additional sheet metal stovepipes.

Anomalies A-2 and A-3 are along the western edge of the survey grid. They are characterized by EM31-D responses, without associated MAG gradient anomalies, indicative of nonferrous metal, or possibly more sheet metal stovepipes. Anomaly A-4 at grid coordinate 0+50 N, 1+00 E is similar in nature.

## 5.7 Site Bridge Overview-2

### 5.7.1 Site Description

The Bridge Overview-2 investigation area was marked in the field by four COE staking lath forming a trapezoid. Located in a saddle between two hills, the site slopes gently south. The ground surface was covered by low grass, and wood debris was piled near the northeast corner of the site. HLA used lath #1265 for a grid origin and extended a 200-foot-long baseline north through lath #1268. HLA installed a rectangular survey grid at this site which measured 200 feet by 100 feet, or approximately 0.46 acre (Plate 15).

HLA obtained EM31-D data along approximately 1,100 linear feet of survey transect and MAG gradient measurements at 121 stations.

### 5.7.2 Results, Bridge Overview-2

No geophysical anomalies were identified at the Bridge Overview-2 site. MAG gradients were generally less than 15 g/f. The EM in-phase signal ranged between -40 and -60 mv and the terrain conductivity was approximately 7 mmhos/m. Contour maps showing the MAG gradient, EM in-phase, and terrain conductivity responses are presented on Plate 15.

## 5.8 Site H-12-C

### 5.8.1 Site Description

The H-12-C site is characterized by a linear depression approximately 200 feet long, 40 feet wide, and 4 feet deep. HLA used COE lath #1191 for a grid origin and extended a 200-foot-long baseline through lath #1194. HLA installed a rectangular survey grid at this site which measured 200 feet by 40 feet. The geophysical survey transects were extended an additional 20 feet to cover the northern flank of the depression, creating a survey area measuring 200 feet by 60 feet, or approximately 0.27 acre (Plate 16).

HLA obtained EM31-D data along approximately 800 linear feet of survey transect and MAG gradient measurements at 77 stations.

### 5.8.2 Results, H-12-C

No geophysical anomalies were identified at Site H-12-C. MAG gradients were generally less than 10 g/f. The EM in-phase signal ranged between -160 and -180 mv and the terrain conductivity ranged between 20 and 24 mmhos/m. The higher conductivities measured near the center this site are probably due to moisture associated with the topographic depression. Contour maps showing the

MAG gradient, EM in-phase, and terrain conductivity responses are presented on Plate 16.

## 5.9 Site H-83-C

### 5.9.1 Site Description

Site H-83-C was characterized by two sagebrush clearings. The terrain is generally flat, with a raised area in the north showing partially buried sheet metal, possibly roofing material, and asphalt rubble (Plate 17). Another larger raised area, possibly a soil-covered foundation or loading dock, was noted south of the survey area. The southern raised area is approximately 100 feet wide and several hundred feet long.

Some of the COE site boundary lath were lying on the ground and possibly not in their original position, so the HLA geophysicist determined the survey area based on clearings in the sagebrush, observed surface and partially buried debris, and the site boundary lath remaining in place. HLA gridded a 350- by 200-foot area, with a 100- by 160-foot extension in the northeast, for a total survey area of approximately 1.91 acres. HLA obtained EM31-D data along approximately 4,200 linear feet of survey transect and MAG gradient measurements at 468 stations. In addition, a reconnaissance EM31-D survey was performed at the large raised area south of the survey grid and at a smaller mound east of the survey grid.

### 5.9.2 Results, H-83-C

The geophysical survey coverage and results for Site H-83-C are presented on Plate 17. Contour maps showing the recorded MAG gradient, EM in-phase, and terrain conductivity response are presented on Plates 18, 19, and 20, respectively. Data for the reconnaissance survey over the low mound and portion of the south revised areas are not presented on these plates. In general, a single

large area of anomalous response measuring approximately 160 feet by 200 feet was identified in the eastern portion of the survey grid. The anomaly is characterized by MAG gradients ranging from approximately 70 g/f to over 1,000 g/f and EM in-phase signals greater than 1,000 mv. These responses are indicative of large amounts of metal buried within the upper 5 feet. The associated terrain conductivity anomaly is probably caused by the buried metal and is not indicative of changes in soil properties.

A buried pipeline was detected between the two raised areas. The pipeline was traced using the RD-400 pipe and cable locator, but its pathway could not be located exactly in the anomalous area because of interference from the abundant near-surface metal. The approximate underground pathway was marked in the field with spray paint and shown on Plate 17.

The reconnaissance EM31-D survey at the southern raised area indicated the presence of buried metal throughout the feature. The EM31-D response and the broad, flat nature of the raised area suggest a reinforced concrete structure, possibly a foundation or a loading dock. The reconnaissance survey at the smaller mound east of the survey area also indicated the presence of a reinforced concrete structure.

## 5.10 PSN 12/14

### 5.10.1 Site Characteristics

In general, Site PSN 12/14 was a gentle hillside, with numerous areas of irregular or disturbed terrain. This site was primarily covered with sparse to dense sagebrush, with low grass and sand in disturbed areas. With guidance from COE personnel, HLA established a 1,200-foot-long baseline along an arbitrarily determined OW line that spanned the survey area. Perpendicular survey transects were extended from this baseline. The HLA-installed survey grid measured approximately

1,200 feet east-west by approximately 700 feet north-south, or approximately 12.24 acres.

HLA obtained EM31-D data along approximately 26,500 linear feet of survey transect and MAG gradient measurements at 2,926 stations.

### 5.10.2 Results, PSN 12/14

Fourteen geophysical anomalies indicative of landfill deposits or buried debris were identified at Site PSN 12/14. Anomalies A-1, A-8, A-11, and A-14 are large high amplitude geophysical anomalies that were recorded in areas of observed surficial and partially buried metal. Buried debris may also be present at these anomaly locations. Anomaly A-13 was also a large high amplitude anomaly indicative of landfill deposits. Although no metal was observed at the surface, this anomaly was associated with a berm and a surface depression

Moderate amplitude anomalies indicative of landfilling were noted at A-2, A-3, A-4, A-5, A-6, A-7, A-9, A-10, and A-12. With the exception of A-2 and A-9, these anomalies are interpreted to be areas of buried metal. A-2 is a moderate amplitude conductivity anomaly not associated with in-phase or magnetic anomalies; HLA believes this anomaly to be the result of a nonmetallic source such as conductive leachate, increased soil salinity, finer grained soil, decaying buried debris, or increased moisture. Anomaly A-9 is a moderate- to low amplitude in-phase anomaly. Because this anomaly is not associated with MAG or conductivity anomalies, we interpret it to be indicative of small and probably widely dispersed buried nonferrous metal.

Generally, anomalous MAG gradients at PSN 12/14 ranged from -300 to 1,700 g/f with a background of less than 20 g/f. Anomalous EM in-phase signals ranged from -2,660 to 1,740 mv, and terrain conductivity ranged from -19 to 88 mmhos/m, with a background of approximately 15 mmhos/m. Contour maps showing the MAG, EM in-phase, and terrain conductivity responses are presented on

Plates 22 through 24.

## 5.11 Site PSN 01

### 5.11.1 Site Characteristics

Site PSN 01 was generally flat with a narrow, shallow depression extending northwest across the site. This site was primarily covered with low grass and bordered on the east and west by sparse sagebrush. The approximately rectangular study area was marked in the field by four COE survey lath. HLA used the southeast COE lath #1215 for a grid origin and extended a 140-foot-long baseline north through COE lath #1218, as shown on Plate 25. HLA installed a true rectangular survey grid at this site that measured 160 feet north-south by 90 feet east-west, or approximately 0.34 acre.

HLA obtained EM31-D data along approximately 720 linear feet of survey transect and MAG gradient measurements at 90 stations.

### 5.11.2 Results, PSN 01

No geophysical anomalies indicative of landfill deposits or buried debris were identified at Site PSN 01. MAG gradients were generally less than 5 g/f, although isolated values ranged from -25 to 20 g/f. The EM in-phase signal ranged from -60 to 5 mv and terrain conductivity was approximately 8 mmhos/m. The low magnitude of the isolated magnetic anomalies and the lack of associated EM anomalies suggest that the MAG anomalies are the result of minor isolated metal objects and not landfill deposits. Contour maps showing the MAG, EM in-phase, and terrain conductivity responses are presented on Plate 25

## 5.12 Site H-12-L-1

### 5.12.1 Site Characteristics

Site H-12-L-1, a rectangular topographic depression with up to 15 feet of relief, was characterized by low grasses and weeds, with more dense and vigorous vegetation near the bottom of the depression. Cultural features at this site included a small vault near the southwest corner and possible buildings remnants near the southeast corner. The survey area was marked in the field by three COE survey lath; the lath for the northwest corner was missing. The map provided for this site indicated that the original area was approximately rectangular. HLA used the southwest COE lath #1203 for a grid origin and extended a 200-foot-long baseline east through COE lath #1202, as shown on Plate 26. HLA installed a true rectangular survey grid at this site that measured 220 feet east-west by 140 feet north-south, or approximately 0.72 acre.

HLA obtained EM31-D data along approximately 1,550 linear feet of survey transect and MAG gradient measurements at 180 stations.

### 5.12.2 Results, H-12-L-1

No geophysical anomalies indicative of large-scale landfill deposits or buried metal debris were identified at Site H-12-L-1. However, an area of elevated terrain conductivity was measured that may be associated with soil contamination. MAG gradients were generally less than 3 g/f, but isolated values ranging from -5 to 98 g/f were observed at the small vault and possible former building site. The EM in-phase signal ranged between -46 and 26 mv and terrain conductivity ranged from 20 to 38 mmhos/m, with a background of approximately 22 mmhos/m.

A widespread 30 to 38 mmhos/m terrain conductivity anomaly was identified in the topographic

depression and associated with the vigorous vegetation. Because no MAG or in-phase anomalies were associated with this conductivity anomaly, HLA interprets the anomaly to be indicative of a nonmetallic source, such as increased salinity or moisture. It is also possible that the elevated conductivity is the result of electrically conductive leachate originating from contamination.

The localized MAG anomalies near the southeast and southwest corners of the survey area are likely the effect of observed cultural features. Contour maps showing the MAG, EM in-phase, and terrain conductivity responses are presented on Plate 27.

## 5.13 Site H-12-L-2

### 5.13.1 Site Characteristics

Site H-12-L-2 was characterized by low grasses and cactus and was bordered by sagebrush to the north and south. The survey area marked in the field by four COE survey lath was approximately rectangular. HLA used the northeast COE lath #207 and extended a 120-foot-baseline through COE lath #1208. HLA projected a survey grid origin approximately 80 feet southwest of COE lath #1208 near COE lath #1205, as shown on Plate 28. HLA installed a true rectangular survey grid at this site measuring 120 feet east-west by 80 feet north-south, or approximately 0.23 acre.

HLA obtained EM31-D data along approximately 480 linear feet of survey transect and MAG gradient measurements at 63 stations.

### 5.13.2 Results, H-12-L-2

No geophysical anomalies indicative of landfill deposits or buried debris were identified at Site H-12-L-2. MAG gradients were generally less than 3 g/f. The EM in-phase signal ranged

between -60 and 10 mv and terrain conductivity ranged from 20 to 25 mmhos/m. Contour maps showing the MAG, EM in-phase, and terrain conductivity responses are presented on Plate 28.

## 5.14 Site PSN 04

### 5.14.1 Site Characteristics

Site PSN 04 comprised four distinct survey areas identified as PSN 04 north, south, east, and west. These sites were generally flat or gently sloping Vegetation ranged from sparse grass to dense sagebrush. Localized shallow depressions and mounds indicating areas of disturbed soil were present.

At the request of CDM personnel, HLA performed a followup investigation performed to verify the locations of anomalies identified by IT Corporation in a previous geophysical investigation. IT Corporation provided geophysical survey coverage of all four survey areas, so HLA did not complete a thorough resurvey of the sites.

CDM personnel indicated six geophysical anomalies requiring further investigation. These anomalies had been marked in the field using survey lath and numbered consecutively within each area. All anomaly location lath appeared to be in place except at PSN 04 north. Therefore the investigation at PSN 04 north included a reconnaissance survey south of the road to find the most probable location of the previously identified geophysical anomaly.

HLA performed walkaround EM31-D and M-Scope traverses throughout the area of each previously identified anomaly to search for evidence of buried metal or other anomalous conditions. No digital data were recorded in these areas. Instead, the extent of any anomalous readings was marked on the ground surface with orange marking paint and also recorded on a map provided by CDM.

### 5.14.2 Results, PSN 04

Numerous geophysical anomalies indicative of landfill deposits or buried debris were verified and field located at Sites PSN 04, south, east, and west. In general, the areas where geophysical anomalies had been previously identified were characterized by conductivity, in-phase, and M-Scope anomalies. Typically, the anomaly limits determined by HLA were consistent with the areas staked in the field. However, localized concentrations of buried metal or conductive materials were delineated both within and slightly outside the anomaly boundaries. These are the areas HLA marked in the field with orange print.

At PSN 04 north, HLA defined an area approximately 20 feet in diameter indicative of a buried metal object. A small unmarked survey lath was found on the ground near this anomaly, but because it appeared to be outside the southeast corner of the survey area, HLA cannot be certain that it identifies the anomaly located by IT. HLA did not review IT's geophysical data for these areas and was unaware of their criteria for selecting anomaly limits. Therefore, HLA recommends that CDM include the areas marked in the field by HLA with those reported by the previous contractor.

# TABLES

**Table 1. Summary of Results, Ten Potential Landfill Sites (13 Survey Areas)**
**Hanford North Slope**
**Richland, Washington**

| Site Designation | Site Size (Acres) | Results | Remarks |
|---|---|---|---|
| H-81-R | 0.66 | No anomalies identified in survey grid | 1 anomaly indicative of buried metal identified north of survey grid. |
| PSN 72/82 | 0.69 | No anomalies identified | — |
| PSN 90 | 3.34 | 5 anomalies identified | 3 anomalies caused by large metal objects on surface and possibly additional buried metal. 1 anomaly caused by buried pipe; additional localized buried metal detected. |
| Igloo-1 | 0.44 | 1 large anomaly identified | Anomaly indicative of large amounts of buried metal. |
| Igloo-2 | 1.16 | 1 large anomaly identified | Anomaly indicative of large amounts of buried metal. |
| Bridge Overview-1 | 1.37 | 4 small anomalies identified | Anomalies indicative of localized small buried metal debris; much debris on surface. |
| Bridge Overview-2 | 0.46 | No anomalies identified | — |
| H-12-C | 0.27 | No anomalies identified | — |
| H-83-C | 1.91 | 1 large anomaly identified in survey area | Anomaly indicative of large amounts of buried metal associated with raised area; partial anomaly detected at second raised area south of survey grid; buried pipe detected. |

**Table 1. Summary of Results, Ten Potential Landfill Sites (13 Survey Areas)**
**Hanford North Slope**
**Richland, Washington**

| Site Designation | Site Size (Acres) | Results | Remarks |
|---|---|---|---|
| PSN 12/14 | 12.24 | 14 anomalies identifed | See Table 2. |
| PSN 01 | 0.34 | No anomalies identified | — |
| H-12-L-1 | 0.72 | 1 anomaly identified | Terrain conductivity anomaly probably caused by increased soil moisture or possibly soil contamination. |
| H-12-L-2 | 0.23 | No anomalies identified | — |

**Table 2. Geophysical Anomaly Locations and Characteristics, PSN 12/14 Landfill**
**Hanford North Slope**
**Richland, Washington**

| Anomaly Designation | Survey Grid Coordinates (ft) | Anomaly Dimension (ft) | Interpretation of Subsurface Characteristics |
|---|---|---|---|
| A-1 | S 2+10, W 0+80 | 300 x 60 | Disposal trench with metal and non-metal debris; localized shallow metal nearby. |
| A-2 | S 1+50, W 1+30 | 120 x 120 | Change in soil characteristics, non-metallic debris; soil moisture increase or leachate. |
| A-3 | S 3+80, W 1+40 | 80 x 60 | Disposal cell with metal and non-metal debris; localized shallow metal nearby. |
| A-4 | S 4+30, W 1+90 | 70 x 40 | Disposal cell with metal and non-metal debris; localized shallow metal nearby |
| A-5 | S 4+30, W 2+90 | 50 x 20 | Localized metal debris. |
| A-6 | S 5+80, W 1+10 | 80 x 80 | Localized metal debris. |
| A-7 | S 7+10, W 0+80 | 60 x 40 | Localized metal debris. |
| A-8 | S 6+80, W 2+10 | 150 x 80 | Disposal trench with metal and non-metal debris; localized shallow metal nearby. |
| A-9 | S 6+30, W 2+70 | 220 x 70 | Disposal cell with metal and non-metal debris; localized shallow metal nearby. |

**Table 2. Geophysical Anomaly Locations and Characteristics, PSN 12/14 Landfill**
**Hanford North Slope**
**Richland, Washington**

| Anomaly Designation | Survey Grid Coordinates (ft) | Anomaly Dimension (ft) | Interpretation of Subsurface Characteristics |
|---|---|---|---|
| A-10 | S 6+10, W 3+90 | 60 x 30 | Localized metal debris. |
| A-11 | S 8+10, W 4+80 | 200 x 50 | Disposal trench with metal and non-metal debris; localized shallow metal nearby. |
| A-12 | S 7+70, W 5+40 | 40 x 40 | Localized metal debris. |
| A-13 | S 7+30, W 5+60 | 100 x 60 | Disposal trench with metal and non-metal debris; localized shallow metal nearby. |
| A-14 | S 10+60, W 4+00 | 190 x 130 | Disposal cell with metal and non-metal debris; localized shallow metal nearby. |

# PLATES

# APPENDIX

# GEOPHYSICAL METHODS AND EQUIPMENT

## APPENDIX

This section discusses the geophysical techniques used for this survey and the parameters measured by those techniques.

### Electromagnetics - EM31-D

The EM method employs a portable power source, a transmitter, and receiver coils to induce and measure an electromagnetic current in the ground. Current flowing in the transmitter coil generates a magnetic field that induces small electrical currents in the ground beneath the instrument. These currents generate secondary magnetic fields that are detected by the receiver coil. The ratio of primary to secondary field strengths is proportional to terrain conductivity and can be read directly on the EM instrument meter, which is calibrated in units of conductivity. Decaying refuse and buried metal are electrically conductive compared to native soil, and therefore produce anomalous readings in measured conductivity values.

Two components of the EM field were measured: terrain conductivity (sometimes referred to as the quadrature phase component) as expressed in millimhos per meter (mmhos/m), and the in-phase component of the EM field, expressed in millivolts (a measure of signal strength). Terrain conductivity data can be used to locate backfilled trenches or pits, provided the conductivity of the backfill material contrasts with that of the surrounding native material. The in-phase mode of the EM field is particularly sensitive to metal objects and was used to locate buried metallic debris.

A Geonics Limited Model EM31-D terrain conductivity meter, which can measure subsurface conditions to a depth of approximately 20 feet, was used in this investigation. The EM31-D was connected to a Molytek Model 221/222 portable two-channel chart recorder and an Omnidata

Polycorder Model 516 digital data logger for continuous data acquisition along the survey transects.

### Electromagnetics - M-Scope

The Fisher Research Laboratory Model TW-6 M-Scope is similar in principle to the EM31-D. The unit comprises a mobile transmitter and a receiver, which are connected by a handle. The transmitter radiates an electromagnetic field that is detected by the receiver. Nearby metal objects cause distortions in the field. The receiver, which has been previously tuned in an area free of metal, detects the distortions and produces an audible signal when held within approximately 4 feet of metal objects. The M-Scope has the advantage of being sensitive to smaller pieces of buried metal than the EM31-D.

### Magnetics

The magnetic technique measures the total intensity of the earth's magnetic field in units of magnetic intensity called gammas. Ferrous metal debris in a landfill creates variations (anomalies) in field intensity; the MAG instrument records these anomalies. The magnetic sensor is a vessel filled with a proton-rich source such as kerosene. The protons behave like small spinning magnets, which orient themselves to the earth's magnetic field. A reading is initiated when an electrical current is passed through a wire coil around the sensor vessel. The current generates its own magnetic field and the protons readily align themselves to the new field When the applied field is removed, the protons return to their original orientation. The returning motion (or precession) generates a small electrical signal that is related to the intensity of the earth's magnetic field at the sensor location. The intensity is a scalar measurement of the magnetic field vector independent of its orientation.

A pair of GEM Model GSM-19 proton precession magnetometers were used for this survey. One was used as a base station, and the other was deployed as a gradient magnetometer. The base station

uses a single magnetic sensor; it was placed in a remote location and programmed to automatically record the earth's magnetic field intensity every 30 seconds.

The gradient magnetometer uses two magnetic sensors spaced 1 meter apart on a staff and was carried along the survey transects. This arrangement allows for simultaneous measurement of the magnetic field at the two sensor locations. The difference between the two values is converted to the vertical magnetic gradient, expressed in gammas-per-foot (g/f). As the effect of localized ferrous metal on the earth's magnetic field diminishes rapidly with distance, the gradient measurement is more sensitive to buried metal than single sensor magnetic field measurements. Moreover, the effects of diurnal magnetic drift and any regional magnetic gradient are removed by the gradient measurement approach.

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Ten Potential Landfill Sites
Hanford North Slope
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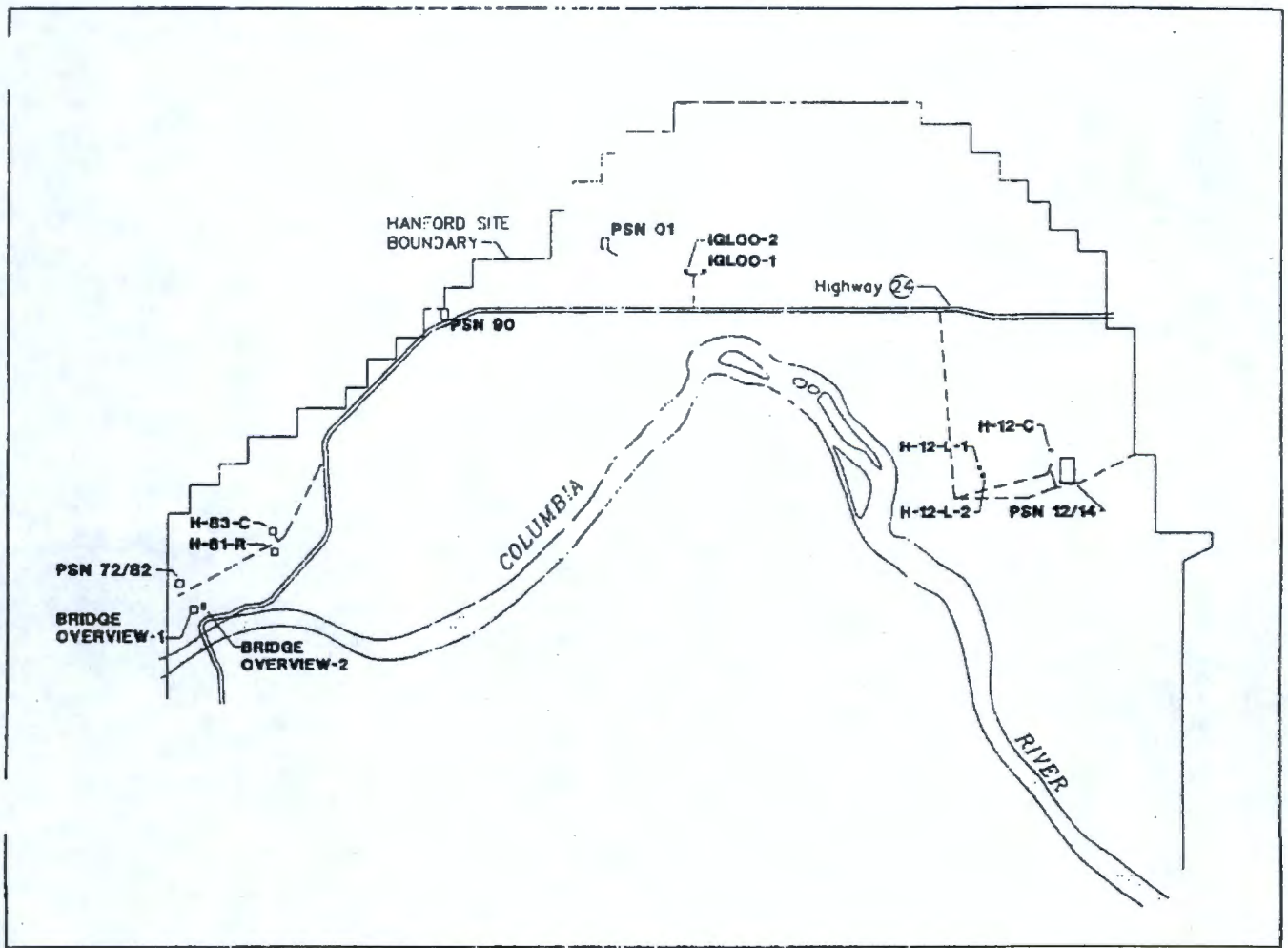


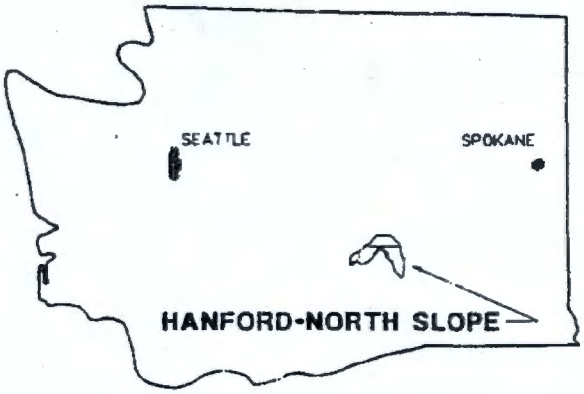


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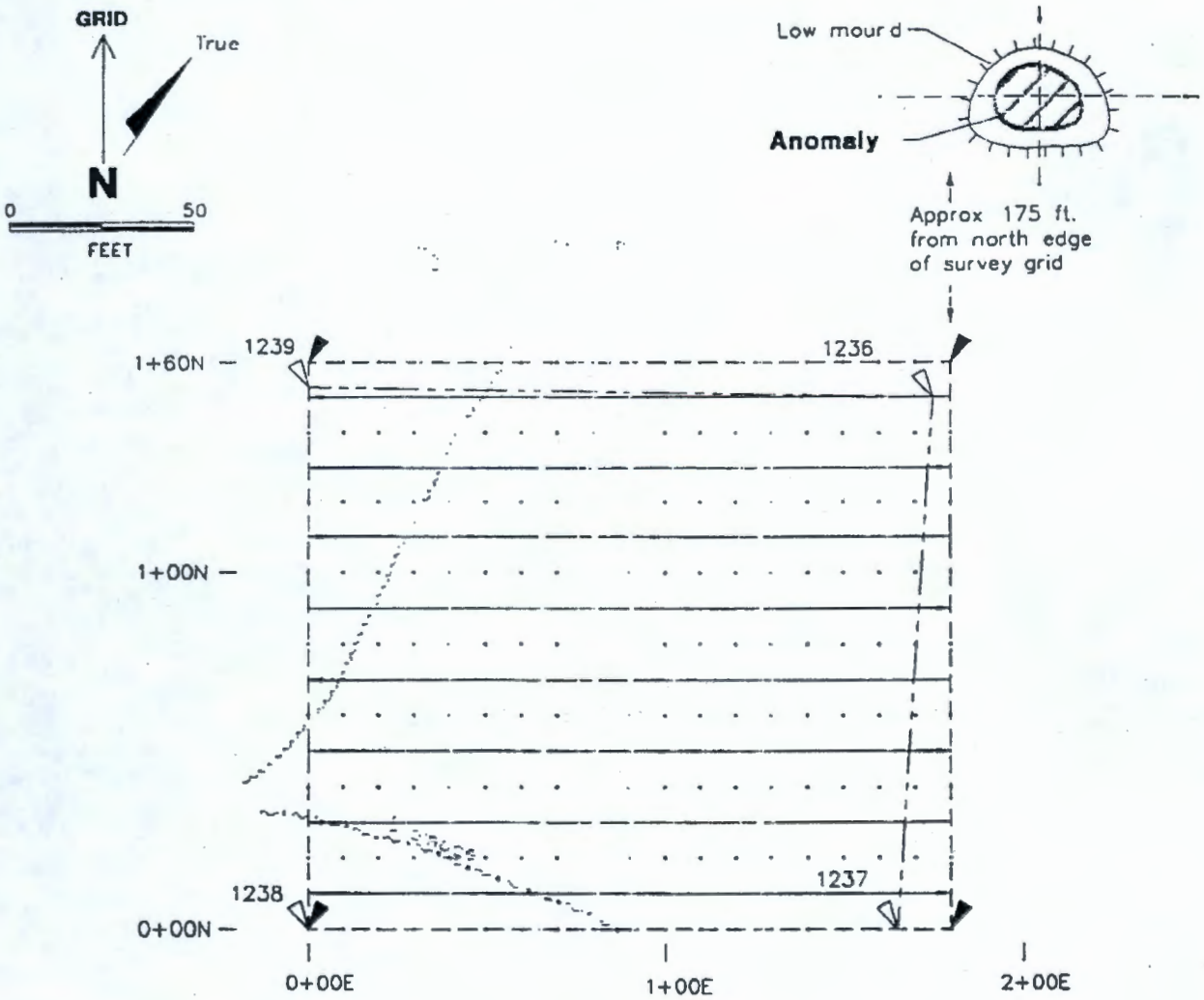
Location Map
Ten Potential Landfill Sites
CDM Federal Programs
Landfill Characterization and Remediation
Hanford North Slope, Washington

PLATE 1

| DRAWN | JOB NUMBER | APPROVED | DATE | REVISED DATE |
|---|---|---|---|---|
| PCB | 27969,6 | | 8/94 | |




## EXPLANATION

GEOPHYSICAL ANOMALY INDICATIVE OF BURIED METAL

EM31--D SURVEY TRANSECT

RECONNAISSANCE EM31-D SURVEY TRANSECT (approximate location)

MAGNETIC GRADIENT MEASUREMENT STATION

1253 — COE Mark Designation Number

US ARMY COE SITE BOUNDARY AND COE INSTALLED MARKING LATH

HLA SURVEY AREA BOUNDARY AND HLA INSTALLED MARKING LATH

DRAFT

H81RCR.DWG

**Harding Lawson Associates**
Engineering and Environmental Services

**Geophysical Survey Coverage and Results**
**Site H-81-R**
CDM Federal Programs
Landfill Characterization and Remediation
Hanford North Slope, Washington

PLATE **2**

| DRAWN | JOB NUMBER | APPROVED | DATE | REVISED DATE |
|---|---|---|---|---|
| PCB | 27969.6 | | 8/94 | |

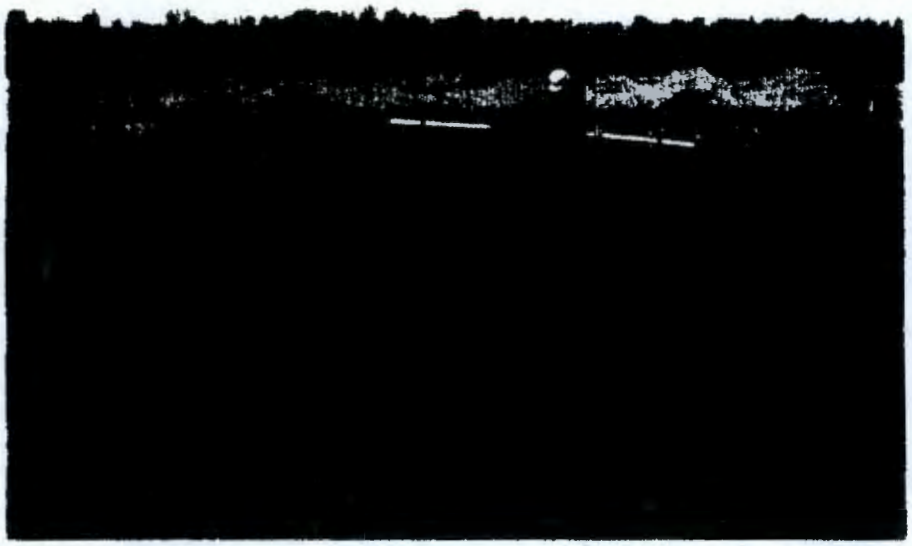
# Photographic Record

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc

Site Name: Hanford North Slope, Washington

**Description:**

Geophysical Survey at the H-06-L West Site Using EM31-D Equipment



**Description:**

Small Geophysical Anomaly Marked in the Field, H-06-L West Site

# Photographic Record

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

Site Name: Hanford North Slope, Washington

**Description:**

Excavation of a Shallow Landfill Cell H-06-L West Site

**Description:**

Typical Metallic Debris Excavated from a Landfill Cell at the H-06-L West Site

# Photographic Record

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc

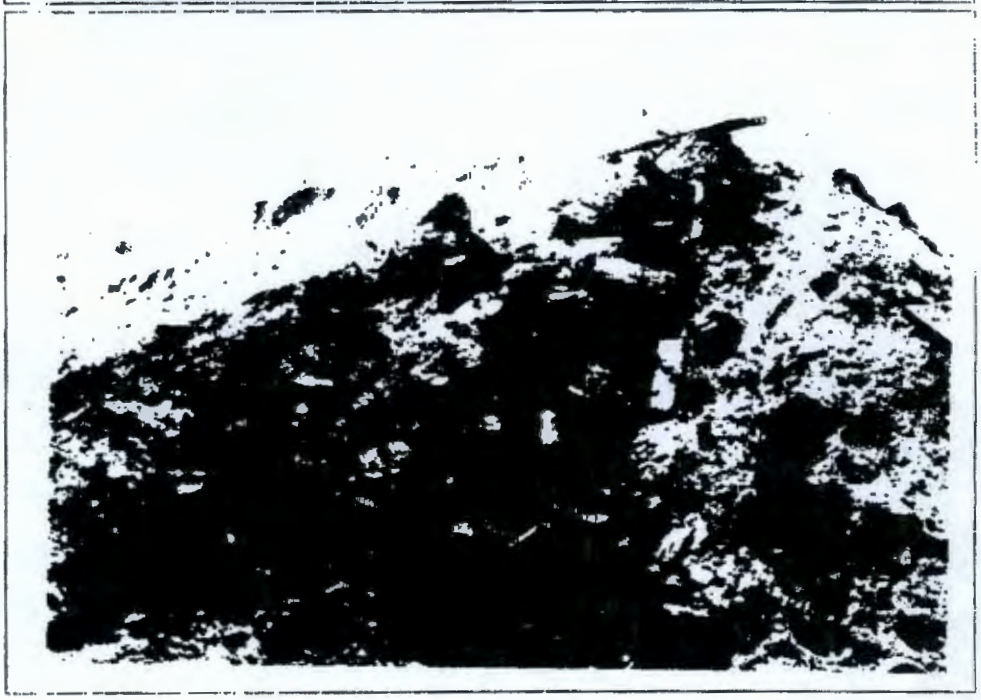
Site Name: Hanford North Slope, Washington

**Description:**

Collection of a Soil Sample from a Rusted and Crushed Drum Excavated from a H-06-L West Landfill Cell

**Description:**

Typical Burn Pit Debris, H-06-L West Site



# Photographic Record

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

Site Name: Hanford North Slope, Washington

**Description:**

Rusted and Crushed Drum and Associated Soil Contaminated With Paint Chips. H-06-L West Site

**Description:**

Collection of a Sample of Oily Soil Recovered With a Crushed Drum, H-06-L West Site

# Photographic Record

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

Site Name: Hanford North Slope, Washington

**Description:**

Rusted and Crushed Drum and Coiled Barbed Wire. H-06-L West Site

**Description:**

Empty Pesticide Cans Labeled as Containing Kerosene and DDT (5%). H-06-L West Site.
Note: Holes Present in the Bottom of Each Can

# Photographic Record

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc

Site Name: Hanford North Slope, Washington

**Description:**

Petroleum-Contaminated Soils Staged for Offsite Disposal at the H-06-L West Site. Excavation in Foreground

**Description:**

Petroleum-Contaminated Soils Staged for Offsite Disposal at the H-06-L West Site

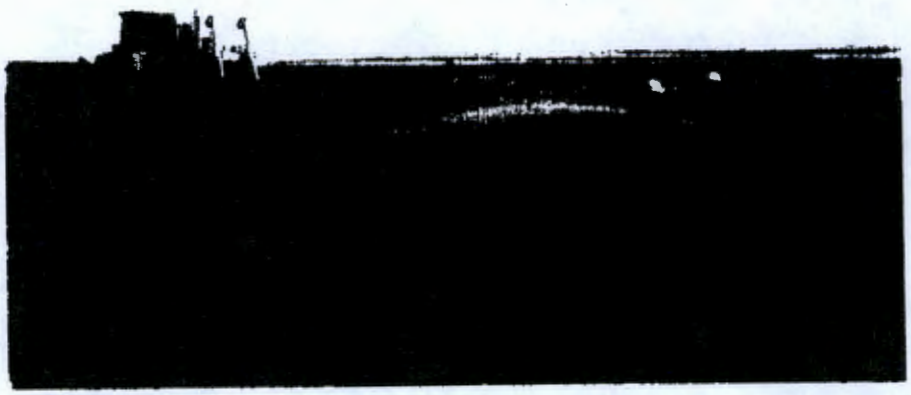
# Photographic Record

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc

Site Name: Hanford North Slope, Washington

**Description:**

Replacing Cover Material on an Excavated Landfill Cell, H-06-L West Site



**Description:**

Excavation of a Burn Pit, H-06-L East

# Photographic Record

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

Site Name: Hanford North Slope, Washington

**Description:**

Excavation of DDT-Contaminated Soils at the H-06-L East Site

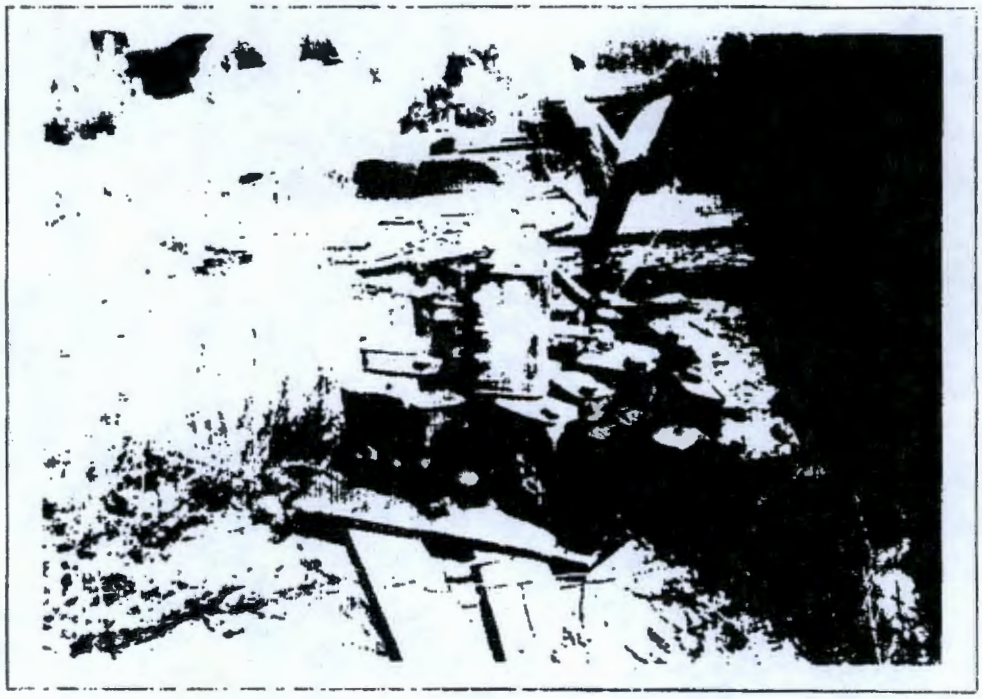
# Photographic Record

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc

Site Name: Hanford North Slope, Washington

**Description:**

Full Lubricating Oil Cans at the H-83-L Site



# Photographic Record

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

Site Name: Hanford North Slope, Washington

**Description:**

Exploratory Trench Excavated Through a Shallow Anomaly at the H-83-L Site

# Photographic Record

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee inc

Site Name: Hanford North Slope, Washington

**Description:**

Spent Rocket Motor Removed From a H-83-L Excavation

# Photographic Record

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc

Site Name: Hanford North Slope, Washington

**Description**

Sampling of Petroleum-Contaminated Soils at the Vehicle Rack, PSN 90 Site

**Description:**

Excavation of a Sheet-Steel Structure at the PSN 90 Site

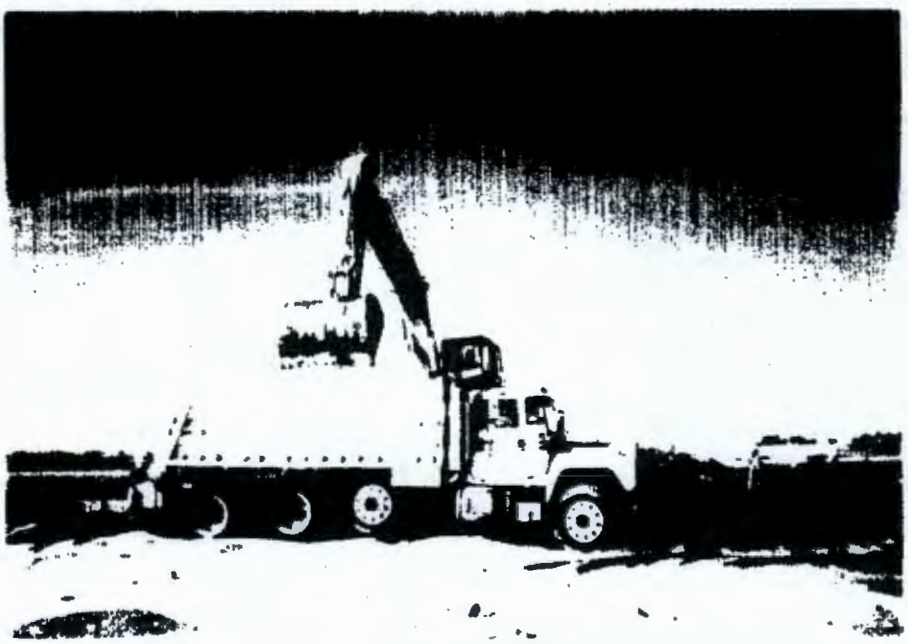
# Photographic Record

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc

Site Name: Hanford North Slope, Washington

**Description:**

Loading of DDT-Contaminated Soils Onto Trucks for Transportation and Offsite Disposal, H-06-L Site



**Description:**

Loading of DDT-Contaminated Soils onto a Truck for Offsite Disposal, H-06-L East Site

ANALYTICAL DATA SUMMARY
BACKGROUND SOIL SAMPLES
HANFORD NORTH SLOPE, WASHINGTON

| COMPOUND | CDM No. | 94H06L(E)-BG1-01-002 | 94H06L(W)-BG2-01-002 | 94H06L(W)-BG2-02-002 | 94H06L(W)-BG3-01-002 | 94H83L-BG1-01-002 | 94BOV2-BG1-01-002 | 941214-BG1-01-002 | 94PSN90-BKG-01-002 | 94IGL-BKG-01-002 | 94H83C-BKG-01-002 | 94H83C-BKG-02-002 | 94PSN04(S)-BG01-01-001 | 94H12L-BG1-01-001 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | HEIS No. | BOBSY8 | BOBSZ0 | BOBSZ1 | BOBSZ3 | BOC3B0 | BOC3C0 | BOC3C6 | BOC3C2 | BOC3C3 | BOC3C4 | BOC3C5 | BOC3F9 | BOC3G1 |
| | ESE No. | 24 | 26 | 27 | 31 | 2 | 41 | 42 | 3 | 4 | 5 | 6 | 11 | 13 |
| [illegible] (NCI/KG) | | 9.2 | -- | -- | -- | 20.7 | 5.5 | 6.3 | 25.4 | -- | -- | 6.5 | -- | -- |
| [illegible] (NCI/KG) | | 17.3 | -- | -- | 21 | 19.2 | 35.1 | 19.7 | 27.8 | 31.4 | 37.7 | 28.1 | -- | -- |
| [illegible] (MG/KG) | | 6.71 | 4.71 | 5.11 | 3.07 | 1.02 | 1.1 | 1.76 | 5.42 | 3.98 | 2.76 | 2.56 | 3.17 | 1.47 |
| [illegible] (MG/KG) | | 120 | 114 | 117 | 133 | 62.7 | 34.9 | 74.4 | 136 | 131 | 93 | 96.1 | 111 | 54.6 |
| [illegible]UM (MG/KG) | | 7.15 | 7.69 | 7.47 | 7.66 | 3.73 | 7.73 | 10.9 | 9.06 | 10.3 | 12.5 | 12.2 | 4.51 | 4.41 |
| [illegible]TONE (UG/KG) | | -- | -- | -- | -- | 20 | -- | -- | -- | -- | -- | -- | -- | -- |
| [illegible] (UG/KG) | | -- | -- | 120 | 4500 | -- | -- | 120 | 220 | 2100 | -- | -- | 160 | 280 |
| [illegible] (UG/KG) | | -- | -- | -- | -- | -- | -- | -- | -- | 1800 | -- | -- | -- | -- |
| [illegible] (UG/KG) | | 8.02 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| [illegible] | | 1.57 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1.85 | -- |
| [illegible] | | 12.9 | 1.66 | 1.47 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |

NCI/KG = Nanocuries Per Kilogram
MG/KG = Milligrams Per Kilogram
UG/KG = Micrograms Per Kilogram

ANALYTICAL DATA SUMMARY (cont'd)
BACKGROUND SOIL SAMPLES
HANFORD NORTH SLOPE, WASHINGTON

| COMPOUND | Average of Detected Concentrations | Range of Detected Concentrations | Standard Deviation of Detected Concentrations |
|---|---|---|---|
| GROSS ALPHA (NCI/KG) | 12.27 | 6.3-25.4 | 8.58 |
| GROSS BETA (NCI/KG) | 26.37 | 17.3-37.7 | 7.43 |
| | | | |
| ARSENIC (MG/KG) | 3.30 | 1.02-6.71 | 1.79 |
| BARIUM (MG/KG) | 98.28 | 34.9-136 | 32.56 |
| CHROMIUM (MG/KG) | 8.10 | 3.73-12.5 | 2.85 |
| ACETONE (UG/KG) | 20.00 | 20.00 | NA |
| BIS(2-ETHYLHEXYL)PHTHALATE (UG/KG) | 1071.43 | 120-4500 | 1673.59 |
| DI-N-BUTYL PHTHALATE (UG/KG) | 1800.00 | 1800.00 | NA |
| DDD-4,4' (UG/KG) | 8.02 | 8.02 | NA |
| DDE-4,4' (UG/KG) | 1.71 | 1.57-1.85 | 0.20 |
| DDT-4,4' (UG/KG) | 5.34 | 1.47-12.9 | 6.54 |

I/KG = Nanocuries Per Kilogram
MG/KG = Milligrams Per Kilogram
UG/KG = Micrograms Per Kilogram

ANALYTICAL DATA SUMMARY
SOIL AND WASTE CHARACTERIZATION SAMPLES
HANFORD NORTH SLOPE, WASHINGTON

| COMPOUND | MTCA Method A | MTCA Method B Carc. | MTCA Method B Non-Carc. | Average of Background Detections | CDM No. | 94H06L(W)-A20-01-004 | 94H06L(W)-A20-02-006 | 94H06L(W)-A19-01-008 | 94H06L(W)-A19-02-007 | 94H06L(W)-A19-03-005 | 94H06L(W)-A19-04-005 | 94H06L(W)-A17-01-003 | 94H06L(W)-A16-01-002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | HEIS No. | BOBSW3 | BOBSW4 | BOBSW5 | BOBSW6 | BOBSW7 | BOBSW8 | BOBSW9 | BOBSX0 |
| | | | | | ESE No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| GROSS ALPHA (NCI/KG) | NA | NA | NA | NRQ | | 20.9 | -- | -- | 18.7 | 11 | -- | -- | -- |
| GROSS BETA (NCI/KG) | NA | NA | NA | NRQ | | 29.2 | -- | -- | 16.4 | 17.2 | 27.7 | -- | -- |
| | | | | | | | | | | | | | |
| ARSENIC (MG/KG) | 20 | 1.43 | 60 | 3.25 | | 2.26 | 3.01 | 3.21 | 2.86 | 3.75 | 3.52 | 41.6 | 4.32 |
| SELENIUM (MG/KG) | NA | NA | 400 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| MERCURY (MG/KG) | 1 | NA | 24 | -- | | -- | -- | -- | -- | -- | -- | 0.116 | -- |
| BARIUM (MG/KG) | NA | NA | 5600 | 301.44 | | 80 | 61.9 | 87.4 | 96.2 | 100 | 107 | 91.9 | 90.9 |
| CADMIUM (MG/KG) | 2 | 0.164 | 8 | -- | | -- | -- | -- | 1.38 | -- | -- | -- | 0.671 |
| CHROMIUM (MG/KG) | 100 | NA | 400(Cr VI) | 8.01 | | 6.4 | 6.21 | 9.02 | 7.66 | 7.45 | 5.56 | 14.5 | 25 |
| LEAD (MG/KG) | 250 | NA | NA | -- | | -- | -- | -- | 61.8 | -- | 11.6 | -- | 217 |
| SILVER (MG/KG) | NA | NA | 400 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ACETONE (UG/KG) | NA | NA | 8.0E+06 | 6.29 | | -- | -- | -- | -- | -- | -- | -- | -- |
| METHYLENE CHLORIDE (UG/KG) | 500 | NA | NA | -- | | 7 | 7.1 | -- | -- | -- | -- | -- | -- |
| METHYLISOBUTYLKETONE (UG/KG) | NA | NA | 4.0E+06 | -- | | -- | -- | -- | -- | -- | -- | 78 | -- |
| 1-1-2-TRICHLOROETHANE (UG/KG) | NA | 17500 | 3.2E+05 | -- | | -- | -- | | -- | -- | | | |
| XYLENE-TOTAL (UG/KG) | 20000 | NA | NA | -- | | -- | -- | -- | -- | -- | 5.2 | -- | -- |
| ACENAPHTHENE (UG/KG) | NA | NA | 4.8E+06 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ACENAPHTHYLENE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ANTHRACENE (UG/KG) | NA | NA | 2.4E+07 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| BENZO(A)ANTHRACENE (UG/KG) | NA | 137 | NA | -- | | | | | | | | | |
| BENZO(B)FLUORANTHENE (UG/KG) | NA | 137 | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| BENZO(K)FLUORANTHENE (UG/KG) | NA | 137 | NA | -- | | -- | | | | -- | -- | -- | -- |
| BENZO(A)PYRENE (UG/KG) | NA | 137 | NA | -- | | -- | | | | -- | | -- | -- |
| BUTYLBENZYLPHTHALATE (UG/KG) | NA | NA | 1.6E+07 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| BIS(2-ETHYLHEXYL)PHTHALATE (UG/KG) | NA | 71400 | 1.6E+06 | 1072.14 | | | -- | -- | -- | -- | -- | -- | -- |
| CHRYSENE (UG/KG) | NA | 137 | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| DIBENZOFURAN (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | | | -- | |
| DI-N-BUTYL PHTHALATE (UG/KG) | NA | NA | 8.0E+06 | 945.43 | | -- | -- | -- | -- | -- | -- | -- | -- |
| DIETHYL PHTHALATE (UG/KG) | NA | NA | 6.4E+07 | 47.36 | | -- | -- | -- | -- | -- | -- | -- | -- |
| 2-4-DINITROTOLUENE (UG/KG) | NA | NA | 1.6E+05 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| DI-N-OCTYL PHTHALATE (UG/KG) | NA | NA | 1.6E+06 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| FLUORANTHENE (UG/KG) | NA | NA | 3.2E+06 | | | | | | -- | -- | -- | -- | -- |
| FLUORENE (UG/KG) | NA | NA | 3.2E+06 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| 2-METHYLNAPHTHALENE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| NAPHTHALENE (UG/KG) | NA | NA | 3.2E+05 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| N-NITROSODIPHEAMINE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| PENTACHLOROPHENOL (UG/KG) | NA | 8330 | 2.4E+06 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| PHENANTHRENE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| PYRENE (UG/KG) | NA | NA | 2.4E+06 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ALDRIN (UG/KG) | NA | 58.8 | 2400 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| BHC-G (LINDANE) (UG/KG) | 1000 | 769 | 24000 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| CHLORDANE (UG/KG) | NA | 769 | 4800 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| DDD-4,4' (UG/KG) | NA | 4170 | NA | 1.46 | | 62.7 | -- | -- | 54.7 | | -- | -- | -- |
| DDE-4,4' (UG/KG) | NA | 2940 | NA | 0.55 | | 298 | | -- | 37.4 | 74 | 85.5 | 83.1 | 34.4 |
| DDT-4,4' (UG/KG) | 1000 | 2940 | 4.0E+04 | 1.42 | | 125 | -- | -- | 177 | 64.6 | 78.6 | 879 | 39 |
| DIELDRIN (UG/KG) | NA | 62.5 | 4000 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ENDOSULFAN-B (UG/KG) | NA | NA | NA | 0.4 | | -- | -- | -- | 4.52 | -- | -- | -- | -- |
| ENDRIN (UG/KG) | NA | NA | 24000 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ENDRIN ALDEHYDE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| METHOXYCHLOR (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | 1.92 | -- | -- | -- | -- |
| PCB-1248 (UG/KG) | 1000 | 130 | NA | -- | | -- | -- | -- | 344 | -- | -- | -- | -- |
| PCB-1254 (UG/KG) | 1000 | 130 | NA | -- | | -- | -- | -- | 344 | -- | -- | -- | -- |
| 2-HEXANONE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| 2-BUTANONE (MEK) (UG/KG) | NA | NA | 4.8E+07 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ALPHA-BHC (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ENDRIN KETONE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| HEPTACHLOR (UG/KG) | NA | 222 | 40000 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | | | | | | | | | | | |
| HYDROCARBONS-PETROL (MG/KG) | 200 | NA | NA | -- | | -- | -- | -- | 5850 | -- | -- | 85900 | 3610 |
| HEAVY OILS (MG/KG) | 200 | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |

ANALYTICAL DATA SUMMARY (cont'd)
SOIL AND WASTE CHARACTERIZATION SAMPLES
HANFORD NORTH SLOPE, WASHINGTON

| COMPOUND | MTCA Method A | MTCA Method B Carc. | MTCA Method B Non-Carc. | Average of Background Detections | CDM No. | 94H06L(W)-A16-02-003 | 94H06L(W)-A07-01-001 | 94H06L(W)-A07-02-005 | 94H06L(W)-A05-01-004 | 94H06L(W)-A05-02-003 | 94H06L(W)-A05-03-004 | 94H06L(W)-A04-01-005 | 94H06L(W)-A04-02-012 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | HEIS No. | BOBSX1 | BOBSX2 | BOBSX3 | BOBSX5 | BOBSX7 | BOBSX8 | BOBSX9 | BOBSY0 |
| | | | | | ESE No. | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| GROSS ALPHA (NCI/KG) | NA | NA | NA | NRQ | | -- | 18.5 | 27 | 11.8 | 29.2 | 43.6 | 45.8 | -- |
| GROSS BETA (NCI/KG) | NA | NA | NA | NRQ | | -- | 12.6 | 22.8 | 17 | 37.6 | 8.1 | 27 | -- |
| ARSENIC (MG/KG) | 20 | 1.43 | 60 | 3.25 | | 8.18 | 3.68 | 8.2 | 2.54 | 1.89 | 4.68 | 5.02 | 3.96 |
| SELENIUM (MG/KG) | NA | NA | 400 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| MERCURY (MG/KG) | 1 | NA | 24 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| BARIUM (MG/KG) | NA | NA | 5600 | 301.44 | | 105 | 96 | 147 | 82.3 | 82.9 | 125 | 112 | 101 |
| CADMIUM (MG/KG) | 2 | 0.164 | 8 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| CHROMIUM (MG/KG) | 100 | NA | 400(Cr VI) | 8.01 | | 10.7 | 11.3 | 18.2 | 9.22 | 14.6 | 7.67 | 10.4 | 9.2 |
| LEAD (MG/KG) | 250 | NA | NA | -- | | -- | 39.6 | 11.9 | -- | 111 | -- | 15.6 | 12 |
| SILVER (MG/KG) | NA | NA | 400 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ACETONE (UG/KG) | NA | NA | 8.0E+06 | 6.29 | | -- | -- | -- | -- | -- | -- | -- | 11 |
| METHYLENE CHLORIDE (UG/KG) | 500 | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| METHYLISOBUTYLKETONE (UG/KG) | NA | NA | 4.0E+06 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| 1-1-2-TRICHLOROETHANE (UG/KG) | NA | 17500 | 3.2E+05 | -- | | -- | -- | -- | -- | 9.5 | -- | -- | -- |
| XYLENE-TOTAL (UG/KG) | 20000 | NA | NA | -- | | -- | | | | | | | |
| ACENAPHTHENE (UG/KG) | NA | NA | 4.8E+06 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ACENAPHTHYLENE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ANTHRACENE (UG/KG) | NA | NA | 2.4E+07 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| BENZO(A)ANTHRACENE (UG/KG) | NA | 137 | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| BENZO(B)FLUORANTHENE (UG/KG) | NA | 137 | NA | | | | | | -- | | | -- | -- |
| BENZO(K)FLUORANTHENE (UG/KG) | NA | 137 | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| BENZO(A)PYRENE (UG/KG) | NA | 137 | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| BUTYLBENZYLPHTHALATE (UG/KG) | NA | NA | 1.6E+07 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| BIS(2-ETHYLHEXYL)PHTHALATE (UG/KG) | NA | 71400 | 1.6E+06 | 1072.14 | | -- | -- | -- | -- | -- | -- | -- | 160 |
| CHRYSENE (UG/KG) | NA | 137 | NA | -- | | -- | -- | -- | -- | -- | -- | -- | |
| DIBENZOFURAN (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | 380 | -- |
| DI-N-BUTYL PHTHALATE (UG/KG) | NA | NA | 8.0E+06 | 945.43 | | | | | | -- | | | -- |
| DIETHYL PHTHALATE (UG/KG) | NA | NA | 6.4E+07 | 47.36 | | -- | -- | -- | -- | -- | -- | -- | -- |
| 2-4-DINITROTOLUENE (UG/KG) | NA | NA | 1.6E+05 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| DI-N-OCTYL PHTHALATE (UG/KG) | NA | NA | 1.6E+06 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| FLUORANTHENE (UG/KG) | NA | NA | 3.2E+06 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| FLUORENE (UG/KG) | NA | NA | 3.2E+06 | -- | | -- | -- | -- | -- | -- | -- | -- | |
| 2-METHYLNAPHTHALENE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | 3600 | -- |
| NAPHTHALENE (UG/KG) | NA | NA | 3.2E+05 | -- | | -- | -- | -- | -- | -- | -- | 960 | -- |
| N-NITROSODIPHEAMINE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| PENTACHLOROPHENOL (UG/KG) | NA | 8330 | 2.4E+06 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| PHENANTHRENE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | 570 | -- |
| PYRENE (UG/KG) | NA | NA | 2.4E+06 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ALDRIN (UG/KG) | NA | 58.8 | 2400 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| BHC-G (LINDANE) (UG/KG) | 1000 | 769 | 24000 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| CHLORDANE (UG/KG) | NA | 769 | 4800 | -- | | -- | 37700 | -- | -- | -- | -- | -- | -- |
| DDD-4,4' (UG/KG) | NA | 4170 | NA | 1.46 | | -- | 42700 | -- | -- | -- | -- | 31 | 115 |
| DDE-4,4' (UG/KG) | NA | 2940 | NA | 0.55 | | 1.59 | 9330 | -- | 3.18 | 5.23 | -- | 8.92 | 79 |
| DDT-4,4' (UG/KG) | 1000 | 2940 | 4.0E+04 | 1.42 | | -- | 254000 | -- | 6.72 | 5.54 | -- | 67.8 | 284 |
| DIELDRIN (UG/KG) | NA | 62.5 | 4000 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ENDOSULFAN-B (UG/KG) | NA | NA | NA | 0.4 | | -- | -- | -- | -- | -- | -- | -- | -- |
| ENDRIN (UG/KG) | NA | NA | 24000 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ENDRIN ALDEHYDE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| METHOXYCHLOR (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| PCB-1248 (UG/KG) | 1000 | 130 | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| PCB-1254 (UG/KG) | 1000 | 130 | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| 2-HEXANONE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| 2-BUTANONE (MEK) (UG/KG) | NA | NA | 4.8E+07 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ALPHA-BHC (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ENDRIN KETONE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| HEPTACHLOR (UG/KG) | NA | 222 | 40000 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| HYDROCARBONS-PETROL (MG/KG) | 200 | NA | NA | -- | | -- | 125 | -- | -- | 128 | -- | 2040 | 381 |
| HEAVY OILS (MG/KG) | 200 | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |

ANALYTICAL DATA SUMMARY (cont'd)
SOIL AND WASTE CHARACTERIZATION SAMPLES
HANFORD NORTH SLOPE, WASHINGTON

| COMPOUND | MTCA Method A | MTCA Method B Carc. | MTCA Method B Non-Carc. | Average of Background Detections | CDM No. | 94H06L(E)-A14-01-001 | 94H06L(E)-A14-02-001 | 94H06L(E)-A12-01-010 | 94H06L(E)-A12-02-012 | 94H06L(B)-A11-01-007 | 94H06L(E)-A01-01-010 | 94H06L(B)-CS1-01-000 | 94H06L(B)-SV1-01-001 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | HEIS No. | BOBSY1 | BOBSY2 | BOBSY3 | BOBSY4 | BOBSY5 | BOBSY6 | BOBSY7 | BOBSY9 |
| | | | | | ESE No. | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 25 |
| GROSS ALPHA (NCI/KG) | NA | NA | NA | NRQ | | 14 | -- | -- | -- | 11.8 | 2 | 24.3 | 10.9 |
| GROSS BETA (NCI/KG) | NA | NA | NA | NRQ | | 25.5 | -- | -- | 23.1 | 21.9 | 35 | 24.5 | 25.9 |
| ARSENIC (MG/KG) | 20 | 1.43 | 60 | 3.25 | | 6.88 | 6.96 | 5.84 | 6.94 | 7.67 | 8.12 | 4.87 | 3.89 |
| SELENIUM (MG/KG) | NA | NA | 400 | -- | | -- | -- | -- | -- | -- | 0.514 | -- | -- |
| MERCURY (MG/KG) | 1 | NA | 24 | -- | | -- | -- | -- | -- | -- | 0.124 | -- | -- |
| BARIUM (MG/KG) | NA | NA | 5600 | 301.44 | | 105 | 111 | 119 | 145 | 120 | 119 | 96.2 | 73.2 |
| CADMIUM (MG/KG) | 2 | 0.164 | 8 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| CHROMIUM (MG/KG) | 100 | NA | 400(Cr VI) | 8.01 | | 14.1 | 14.9 | 13.8 | 15.6 | 19.1 | 15.4 | 11.3 | 8.15 |
| LEAD (MG/KG) | 250 | NA | NA | -- | | 10.4 | -- | 36 | 13.8 | -- | 11.2 | -- | 27.2 |
| SILVER (MG/KG) | NA | NA | 400 | -- | | -- | -- | 1.05 | -- | -- | -- | -- | -- |
| ACETONE (UG/KG) | NA | NA | 8.0E+06 | 6.29 | | -- | -- | -- | -- | -- | -- | -- | -- |
| METHYLENE CHLORIDE (UG/KG) | 500 | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| METHYLISOBUTYLKETONE (UG/KG) | NA | NA | 4.0E+06 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| 1-1-2-TRICHLOROETHANE (UG/KG) | NA | 17500 | 3.2E+05 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| XYLENE-TOTAL (UG/KG) | 20000 | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ACENAPHTHENE (UG/KG) | NA | NA | 4.8E+06 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ACENAPHTHYLENE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ANTHRACENE (UG/KG) | NA | NA | 2.4E+07 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| BENZO(A)ANTHRACENE (UG/KG) | NA | 137 | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| BENZO(B)FLUORANTHENE (UG/KG) | NA | 137 | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| BENZO(K)FLUORANTHENE (UG/KG) | NA | 137 | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| BENZO(A)PYRENE (UG/KG) | NA | 137 | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| BUTYLBENZYLPHTHALATE (UG/KG) | NA | NA | 1.6E+07 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| BIS(2-ETHYLHEXYL)PHTHALATE (UG/KG) | NA | 71400 | 1.6E+06 | 1072.14 | | -- | -- | -- | -- | -- | -- | -- | -- |
| CHRYSENE (UG/KG) | NA | 137 | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| DIBENZOFURAN (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| DI-N-BUTYL PHTHALATE (UG/KG) | NA | NA | 8.0E+06 | 945.43 | | -- | -- | -- | -- | -- | -- | -- | -- |
| DIETHYL PHTHALATE (UG/KG) | NA | NA | 6.4E+07 | 47.36 | | -- | -- | -- | -- | -- | -- | -- | -- |
| 2-4-DINITROTOLUENE (UG/KG) | NA | NA | 1.6E+05 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| DI-N-OCTYL PHTHALATE (UG/KG) | NA | NA | 1.6E+06 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| FLUORANTHENE (UG/KG) | NA | NA | 3.2E+06 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| FLUORENE (UG/KG) | NA | NA | 3.2E+06 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| 2-METHYLNAPHTHALENE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | 77000 | -- | -- |
| NAPHTHALENE (UG/KG) | NA | NA | 3.2E+05 | -- | | -- | -- | -- | -- | -- | 3200 | -- | -- |
| N-NITROSODIPHEAMINE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| PENTACHLOROPHENOL (UG/KG) | NA | 8330 | 2.4E+06 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| PHENANTHRENE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | 16000 | -- | -- |
| PYRENE (UG/KG) | NA | NA | 2.4E+06 | -- | | -- | -- | -- | -- | -- | 5400 | -- | -- |
| ALDRIN (UG/KG) | NA | 58.8 | 2400 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| BHC-G (LINDANE) (UG/KG) | 1000 | 769 | 24000 | -- | | -- | -- | 5.38 | -- | -- | -- | -- | -- |
| CHLORDANE (UG/KG) | NA | 769 | 4800 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| DDD-4,4' (UG/KG) | NA | 4170 | NA | 1.46 | | 3790 | 1630 | 2780 | -- | -- | 786000 | -- | 597 |
| DDE-4,4' (UG/KG) | NA | 2940 | NA | 0.55 | | 2130 | 1870 | 3650 | 146 | -- | 44400 | -- | 1660 |
| DDT-4,4' (UG/KG) | 1000 | 2940 | 4.0E+04 | 1.42 | | 11600 | 5600 | 3910 | 167 | -- | 2080000 | -- | 806 |
| DIELDRIN (UG/KG) | NA | 62.5 | 4000 | -- | | -- | -- | 64.3 | 3.53 | -- | -- | -- | -- |
| ENDOSULFAN-B (UG/KG) | NA | NA | NA | 0.4 | | -- | -- | -- | -- | -- | -- | -- | -- |
| ENDRIN (UG/KG) | NA | NA | 24000 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ENDRIN ALDEHYDE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| METHOXYCHLOR (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| PCB-1248 (UG/KG) | 1000 | 130 | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| PCB-1254 (UG/KG) | 1000 | 130 | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| 2-HEXANONE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| 2-BUTANONE (MEK) (UG/KG) | NA | NA | 4.8E+07 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ALPHA-BHC (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ENDRIN KETONE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| HEPTACHLOR (UG/KG) | NA | 222 | 40000 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| HYDROCARBONS-PETROL (MG/KG) | 200 | NA | NA | -- | | -- | -- | 165000 | -- | 43.2 | 4920 | -- | -- |
| HEAVY OILS (MG/KG) | 200 | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |

ANALYTICAL DATA SUMMARY (cont'd)
SOIL AND WASTE CHARACTERIZATION SAMPLES
HANFORD NORTH SLOPE, WASHINGTON

| COMPOUND | MTCA Method A | MTCA Method B Carc. | MTCA Method B Non-Carc. | Average of Background Detections | CDM No. | 94H06L(W)-A04-03-020 | 94H06L(W)-A04-04-008 | 94H06L(W)-SV2-01-001 | 94H06L(W)-WC1-01-000 | 94H06L(W)-WC2-01-000 | 94H06L(E)-A01-02-005 | 94H06L(E)-A01-03-005 | 94H06L(E)-A01-01-014 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | HEIS No. | BOBSZ2 | BOBSZ3 | BOBSZ4 | BOBSZ7 | BOBSZ8 | BOBT00 | BOBT01 | BOBT02 |
| | | | | | ESE No. | 28 | 29 | 30 | 32 | 33 | 34 | 35 | 36 |
| GROSS ALPHA (NCI/KG) | NA | NA | NA | NRQ | | -- | 2.8 | -- | -- | 4.2 | 25.4 | -- | 22.9 |
| GROSS BETA (NCI/KG) | NA | NA | NA | NRQ | | 31.8 | 26.6 | -- | -- | 10.4 | 16 | 21.2 | 34.1 |
| | | | | | | | | | | | | | |
| ARSENIC (MG/KG) | 20 | 1.43 | 60 | 3.25 | | 1.44 | 4 | 1.64 | 3.64 | 1.82 | 5.42 | 5.54 | 7.97 |
| SELENIUM (MG/KG) | NA | NA | 400 | -- | | -- | -- | -- | -- | -- | -- | 0.34 | -- |
| MERCURY (MG/KG) | 1 | NA | 24 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| BARIUM (MG/KG) | NA | NA | 5600 | 301.44 | | 79.9 | 109 | 87.9 | 142 | 171 | 125 | 107 | 151 |
| CADMIUM (MG/KG) | 2 | 0.164 | 8 | -- | | -- | -- | -- | 1.55 | 1.77 | -- | -- | -- |
| CHROMIUM (MG/KG) | 100 | NA | 400(Cr VI) | 8.01 | | 10.3 | 10.2 | 6.44 | 9.42 | 56.4 | 14.9 | 16 | 20.3 |
| LEAD (MG/KG) | 250 | NA | NA | -- | | -- | -- | -- | 1140 | 1810 | 24.5 | 23.6 | 13.9 |
| SILVER (MG/KG) | NA | NA | 400 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ACETONE (UG/KG) | NA | NA | 8.0E+06 | 6.29 | | -- | -- | -- | -- | -- | -- | -- | -- |
| METHYLENE CHLORIDE (UG/KG) | 500 | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| METHYLISOBUTYLKETONE (UG/KG) | NA | NA | 4.0E+06 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| 1-1-2-TRICHLOROETHANE (UG/KG) | NA | 17500 | 3.2E+05 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| XYLENE-TOTAL (UG/KG) | 20000 | NA | NA | -- | | -- | -- | -- | -- | 220 | -- | -- | -- |
| ACENAPHTHENE (UG/KG) | NA | NA | 4.8E+06 | -- | | -- | -- | -- | 9700 | -- | -- | 220 | -- |
| ACENAPHTHYLENE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ANTHRACENE (UG/KG) | NA | NA | 2.4E+07 | -- | | -- | -- | -- | 14000 | -- | -- | -- | -- |
| BENZO(A)ANTHRACENE (UG/KG) | NA | 137 | NA | -- | | -- | -- | -- | 8300 | -- | -- | -- | -- |
| BENZO(B)FLUORANTHENE (UG/KG) | NA | 137 | NA | -- | | -- | -- | -- | 6800 | -- | -- | -- | -- |
| BENZO(K)FLUORANTHENE (UG/KG) | NA | 137 | NA | -- | | -- | -- | -- | 2300 | -- | -- | -- | -- |
| BENZO(A)PYRENE (UG/KG) | NA | 137 | NA | -- | | -- | -- | -- | 5300 | -- | -- | -- | -- |
| BUTYLBENZYLPHTHALATE (UG/KG) | NA | NA | 1.6E+07 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| BIS(2-ETHYLHEXYL)PHTHALATE (UG/KG) | NA | 71400 | 1.6E+06 | 1072.14 | | -- | -- | -- | -- | 1400 | -- | -- | -- |
| CHRYSENE (UG/KG) | NA | 137 | NA | -- | | -- | -- | -- | 8600 | -- | -- | -- | -- |
| DIBENZOFURAN (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | 8500 | -- | -- | -- | -- |
| DI-N-BUTYL PHTHALATE (UG/KG) | NA | NA | 8.0E+06 | 945.43 | | -- | -- | -- | -- | 530 | -- | -- | -- |
| DIETHYL PHTHALATE (UG/KG) | NA | NA | 6.4E+07 | 47.36 | | -- | -- | -- | -- | -- | -- | -- | -- |
| 2-4-DINITROTOLUENE (UG/KG) | NA | NA | 1.6E+05 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| DI-N-OCTYL PHTHALATE (UG/KG) | NA | NA | 1.6E+06 | -- | | -- | -- | -- | -- | 1600 | -- | -- | -- |
| FLUORANTHENE (UG/KG) | NA | NA | 3.2E+06 | -- | | -- | -- | -- | 24000 | -- | -- | -- | -- |
| FLUORENE (UG/KG) | NA | NA | 3.2E+06 | -- | | -- | -- | -- | 14000 | -- | -- | -- | -- |
| 2-METHYLNAPHTHALENE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | 12000 | 140 | 3800 | 2900 | -- |
| NAPHTHALENE (UG/KG) | NA | NA | 3.2E+05 | -- | | -- | -- | -- | 8000 | 250 | -- | -- | -- |
| N-NITROSODIPHEAMINE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| PENTACHLOROPHENOL (UG/KG) | NA | 8330 | 2.4E+06 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| PHENANTHRENE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | 57000 | -- | 2700 | 2500 | -- |
| PYRENE (UG/KG) | NA | NA | 2.4E+06 | -- | | -- | -- | -- | 18000 | -- | 750 | 850 | -- |
| ALDRIN (UG/KG) | NA | 58.8 | 2400 | -- | | -- | -- | -- | -- | -- | 52.7 | 54.9 | -- |
| BHC-G (LINDANE) (UG/KG) | 1000 | 769 | 24000 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| CHLORDANE (UG/KG) | NA | 769 | 4800 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| DDD-4,4' (UG/KG) | NA | 4170 | NA | 1.46 | | -- | -- | -- | 150 | 15.1 | 269000 | 276000 | 4.78 |
| DDE-4,4' (UG/KG) | NA | 2940 | NA | 0.55 | | -- | -- | 37.2 | 422 | 25 | 22100 | 28000 | 16.6 |
| DDT-4,4' (UG/KG) | 1000 | 2940 | 4.0E+04 | 1.42 | | -- | -- | 14.5 | 356 | 161 | 695000 | 611000 | 184 |
| DIELDRIN (UG/KG) | NA | 62.5 | 4000 | -- | | -- | -- | -- | -- | -- | 1980 | 2630 | 8.34 |
| ENDOSULFAN-B (UG/KG) | NA | NA | NA | 0.4 | | -- | -- | -- | -- | -- | -- | -- | -- |
| ENDRIN (UG/KG) | NA | NA | 24000 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ENDRIN ALDEHYDE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| METHOXYCHLOR (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| PCB-1248 (UG/KG) | 1000 | 130 | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| PCB-1254 (UG/KG) | 1000 | 130 | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| 2-HEXANONE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| 2-BUTANONE (MEK) (UG/KG) | NA | NA | 4.8E+07 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ALPHA-BHC (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ENDRIN KETONE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| HEPTACHLOR (UG/KG) | NA | 222 | 40000 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | | | | | | | | | | | |
| HYDROCARBONS-PETROL (MG/KG) | 200 | NA | NA | -- | | -- | 82 | | 255 | 57.2 | 437 | 428 | |
| HEAVY OILS (MG/KG) | 200 | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |

ANALYTICAL DA... SUMMARY (cont'd)
SOIL AND WASTE CHARACTERIZATION SAMPLES
HANFORD NORTH SLOPE, WASHINGTON

| COMPOUND | MTCA Method A | MTCA Method B Carc. | MTCA Method B Non-Carc. | Average of Background Detections | CDM No. | 94H06L(E)-A01-05-012 | 94H06L(E)-A01-06-010 | 94H06L(E)-A01-07-008 | 94H06L(E)-A01-08-011 | 94H06L(E)-A01-09-011 | 94H06L(E)-A01-10-011 | 94H06L(E)-A01-11-012 | 94H06L(E)-A01-12-012 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | HEIS No. | BOBT03 | BOBT04 | BOBT06 | BOBT07 | BOBT08 | BOBT09 | BOBT10 | BOBT11 |
| | | | | | ESE No. | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 |
| GROSS ALPHA (NCI/KG) | NA | NA | NA | NRQ | | -- | 21.9 | 0 | 52 | 15.4 | 0 | 0 | 0 |
| GROSS BETA (NCI/KG) | NA | NA | NA | NRQ | | 18.9 | 23.3 | 19.4 | 24.4 | 30.9 | 26.8 | 21.3 | 31.1 |
| | | | | | | | | | | | | | |
| ARSENIC (MG/KG) | 20 | 1.43 | 60 | 3.25 | | 7.75 | 7.42 | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| SELENIUM (MG/KG) | NA | NA | 400 | -- | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| MERCURY (MG/KG) | 1 | NA | 24 | -- | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| BARIUM (MG/KG) | NA | NA | 5600 | 301.44 | | 139 | 131 | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| CADMIUM (MG/KG) | 2 | 0.164 | 8 | -- | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| CHROMIUM (MG/KG) | 100 | NA | 400(Cr VI) | 8.01 | | 21.3 | 17 | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| LEAD (MG/KG) | 250 | NA | NA | -- | | 12.1 | 10.6 | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| SILVER (MG/KG) | NA | NA | 400 | -- | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| ACETONE (UG/KG) | NA | NA | 8.0E+06 | 6.29 | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| METHYLENE CHLORIDE (UG/KG) | 500 | NA | NA | -- | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| METHYLISOBUTYLKETONE (UG/KG) | NA | NA | 4.0E+06 | -- | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| 1-1-2-TRICHLOROETHANE (UG/KG) | NA | 17500 | 3.2E+05 | -- | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| XYLENE-TOTAL (UG/KG) | 20000 | NA | NA | -- | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| ACENAPHTHENE (UG/KG) | NA | NA | 4.8E+06 | -- | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| ACENAPHTHYLENE (UG/KG) | NA | NA | NA | -- | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| ANTHRACENE (UG/KG) | NA | NA | 2.4E+07 | -- | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| BENZO(A)ANTHRACENE (UG/KG) | NA | 137 | NA | -- | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| BENZO(B)FLUORANTHENE (UG/KG) | NA | 137 | NA | | | | | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| BENZO(K)FLUORANTHENE (UG/KG) | NA | 137 | NA | -- | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| BENZO(A)PYRENE (UG/KG) | NA | 137 | NA | -- | | | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| BUTYLBENZYLPHTHALATE (UG/KG) | NA | NA | 1.6E+07 | -- | | | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| BIS(2-ETHYLHEXYL)PHTHALATE (UG/KG) | NA | 71400 | 1.6E+06 | 1072.14 | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| CHRYSENE (UG/KG) | NA | 137 | NA | -- | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| DIBENZOFURAN (UG/KG) | NA | NA | NA | -- | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| DI-N-BUTYL PHTHALATE (UG/KG) | NA | NA | 8.0E+06 | 945.41 | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| DIETHYL PHTHALATE (UG/KG) | NA | NA | 6.4E+07 | 47.36 | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| 2-4-DINITROTOLUENE (UG/KG) | NA | NA | 1.6E+05 | -- | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| DI-N-OCTYL PHTHALATE (UG/KG) | NA | NA | 1.6E+06 | -- | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| FLUORANTHENE (UG/KG) | NA | NA | 3.2E+06 | -- | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| FLUORENE (UG/KG) | NA | NA | 3.2E+06 | -- | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| 2-METHYLNAPHTHALENE (UG/KG) | NA | NA | NA | -- | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| NAPHTHALENE (UG/KG) | NA | NA | 3.2E+05 | -- | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| N-NITROSODIPHEAMINE (UG/KG) | NA | NA | NA | -- | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| PENTACHLOROPHENOL (UG/KG) | NA | 8330 | 2.4E+06 | -- | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| PHENANTHRENE (UG/KG) | NA | NA | NA | -- | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| PYRENE (UG/KG) | NA | NA | 2.4E+06 | -- | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| ALDRIN (UG/KG) | NA | 58.8 | 2400 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| BHC-G (LINDANE) (UG/KG) | 1000 | 769 | 24000 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| CHLORDANE (UG/KG) | NA | 769 | 4800 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| DDD-4,4' (UG/KG) | NA | 4170 | NA | 1.46 | | -- | -- | 148 | -- | 8.81 | 11 | 2.87 | 5.92 |
| DDE-4,4' (UG/KG) | NA | 2940 | NA | 0.55 | | -- | 0.862 | 210 | -- | 1.09 | 7.92 | 2.81 | 6.84 |
| DDT-4,4' (UG/KG) | 1000 | 2940 | 4.0E+04 | 1.42 | | 4.31 | 7.16 | 2230 | 14.9 | 23.5 | 302 | 254 | 121 |
| DIELDRIN (UG/KG) | NA | 62.5 | 4000 | -- | | -- | 0.856 | 164 | -- | -- | 4.45 | 2.22 | 6.95 |
| ENDOSULFAN-B (UG/KG) | NA | NA | NA | 0.4 | | -- | -- | -- | -- | -- | -- | -- | -- |
| ENDRIN (UG/KG) | NA | NA | 24000 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ENDRIN ALDEHYDE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| METHOXYCHLOR (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| PCB-1248 (UG/KG) | 1000 | 130 | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| PCB-1254 (UG/KG) | 1000 | 130 | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| 2-HEXANONE (UG/KG) | NA | NA | NA | -- | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| 2-BUTANONE (MEK) (UG/KG) | NA | NA | 4.8E+07 | -- | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| ALPHA-BHC (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ENDRIN KETONE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| HEPTACHLOR (UG/KG) | NA | 222 | 40000 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | | | | | | | | | | | |
| HYDROCARBONS-PETROL (MG/KG) | 200 | NA | NA | -- | | | | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |
| HEAVY OILS (MG/KG) | 200 | NA | NA | -- | | -- | -- | NRQ | NRQ | NRQ | NRQ | NRQ | NRQ |

ANALYTICAL DATA SUMMARY (cont'd)
SOIL AND WASTE CHARACTERIZATION SAMPLES
HANFORD NORTH SLOPE, WASHINGTON

| COMPOUND | MTCA Method A | MTCA Method B Carc. | MTCA Method B Non-Carc. | Average of Background Detections | CDM No. | 94H83L-A06-01-001 | 94H83L-A06-02-002 | 94H83L-A06-03-002 | 94H83L-CS2-02-000 | 94H83L-A03-01-005 | 94PSN90-VR-01-003 | 94PSN90-VR-02-001 | 94PSN04-A1/4-004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | HEIS No. | BOC399 | BOC3B1 | BOC3B2 | BOC3B3 | BOC3B5 | BOC3B8 | BOC3B9 | BOC3F8 |
| | | | | | ESE No. | 1 | 3 | 4 | 5 | 6 | 1 | 2 | 10 |
| GROSS ALPHA (NCI/KG) | NA | NA | NA | NRQ | | 20.6 | 17.4 | 9.2 | 0 | 0.9 | 6.3 | 2 | 20.4 |
| GROSS BETA (NCI/KG) | NA | NA | NA | NRQ | | 20.8 | 19.1 | 19.4 | 18.4 | 16.7 | 18.4 | 16.3 | 17.1 |
| ARSENIC (MG/KG) | 20 | 1.43 | 60 | 3.25 | | 0.978 | 1.16 | 1 | 2.12 | 1.15 | 4.52 | 2.41 | 9.24 |
| SELENIUM (MG/KG) | NA | NA | 400 | -- | | -- | -- | 0.271 | -- | -- | -- | -- | -- |
| MERCURY (MG/KG) | 1 | NA | 24 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| BARIUM (MG/KG) | NA | NA | 5600 | 301.44 | | 70.1 | 71.2 | 77.6 | 34.8 | 61.1 | 116 | 79.4 | 71.3 |
| CADMIUM (MG/KG) | 2 | 0.164 | 8 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| CHROMIUM (MG/KG) | 100 | NA | 400(Cr VI) | 8.01 | | 5.88 | 4.71 | 5.16 | 3.53 | 6.13 | 7.99 | 19 | 10.7 |
| LEAD (MG/KG) | 250 | NA | NA | -- | | 11.6 | -- | -- | -- | -- | -- | 70.9 | -- |
| SILVER (MG/KG) | NA | NA | 400 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ACETONE (UG/KG) | NA | NA | 8.0E+06 | 6.29 | | -- | 17 | 24 | -- | 95 | -- | -- | -- |
| METHYLENE CHLORIDE (UG/KG) | 500 | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| METHYLISOBUTYLKETONE (UG/KG) | NA | NA | 4.0E+06 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| 1-1-2-TRICHLOROETHANE (UG/KG) | NA | 17500 | 3.2E+05 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| XYLENE-TOTAL (UG/KG) | 20000 | NA | NA | -- | | | | | -- | -- | -- | -- | -- |
| ACENAPHTHENE (UG/KG) | NA | NA | 4.8E+06 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ACENAPHTHYLENE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ANTHRACENE (UG/KG) | NA | NA | 2.4E+07 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| BENZO(A)ANTHRACENE (UG/KG) | NA | 137 | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| BENZO(B)FLUORANTHENE (UG/KG) | NA | 137 | NA | | | | -- | | -- | -- | -- | -- | -- |
| BENZO(K)FLUORANTHENE (UG/KG) | NA | 137 | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| BENZO(A)PYRENE (UG/KG) | NA | 137 | NA | -- | | -- | -- | -- | -- | -- | -- | -- | |
| BUTYLBENZYLPHTHALATE (UG/KG) | NA | NA | 1.6E+07 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| BIS(2-ETHYLHEXYL)PHTHALATE (UG/KG) | NA | 71400 | 1.6E+06 | 1072.14 | | -- | -- | -- | -- | -- | -- | -- | -- |
| CHRYSENE (UG/KG) | NA | 137 | NA | -- | | -- | -- | -- | -- | | | -- | -- |
| DIBENZOFURAN (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| DI-N-BUTYL PHTHALATE (UG/KG) | NA | NA | 8.0E+06 | 945.43 | | | -- | -- | -- | | | -- | -- |
| DIETHYL PHTHALATE (UG/KG) | NA | NA | 6.4E+07 | 47.36 | | -- | -- | -- | -- | -- | -- | -- | -- |
| 2-4-DINITROTOLUENE (UG/KG) | NA | NA | 1.6E+05 | -- | | -- | -- | -- | -- | -- | -- | 3000 | -- |
| DI-N-OCTYL PHTHALATE (UG/KG) | NA | NA | 1.6E+06 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| FLUORANTHENE (UG/KG) | NA | NA | 3.2E+06 | -- | | -- | -- | -- | -- | -- | -- | | |
| FLUORENE (UG/KG) | NA | NA | 3.2E+06 | -- | | -- | -- | -- | -- | | | | |
| 2-METHYLNAPHTHALENE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| NAPHTHALENE (UG/KG) | NA | NA | 3.2E+05 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| N-NITROSODIPHEAMINE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| PENTACHLOROPHENOL (UG/KG) | NA | 8330 | 2.4E+06 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| PHENANTHRENE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| PYRENE (UG/KG) | NA | NA | 2.4E+06 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ALDRIN (UG/KG) | NA | 58.8 | 2400 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| BHC-G (LINDANE) (UG/KG) | 1000 | 769 | 24000 | -- | | -- | -- | -- | -- | -- | -- | 5.63 | -- |
| CHLORDANE (UG/KG) | NA | 769 | 4800 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| DDD-4,4' (UG/KG) | NA | 4170 | NA | 1.46 | | -- | -- | -- | -- | -- | -- | 41 | -- |
| DDE-4,4' (UG/KG) | NA | 2940 | NA | 0.55 | | -- | -- | -- | -- | -- | -- | 80.3 | 3.8 |
| DDT-4,4' (UG/KG) | 1000 | 2940 | 4.0E+04 | 1.42 | | -- | -- | -- | -- | -- | -- | 490 | 3.63 |
| DIELDRIN (UG/KG) | NA | 62.5 | 4000 | -- | | -- | -- | -- | -- | -- | -- | 3.22 | |
| ENDOSULFAN-B (UG/KG) | NA | NA | NA | 0.4 | | -- | -- | -- | -- | -- | -- | -- | -- |
| ENDRIN (UG/KG) | NA | NA | 24000 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ENDRIN ALDEHYDE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| METHOXYCHLOR (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| PCB-1248 (UG/KG) | 1000 | 130 | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| PCB-1254 (UG/KG) | 1000 | 130 | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| 2-HEXANONE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | 13 | -- | -- | -- |
| 2-BUTANONE (MEK) (UG/KG) | NA | NA | 4.8E+07 | -- | | -- | -- | -- | -- | 35 | -- | -- | -- |
| ALPHA-BHC (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| ENDRIN KETONE (UG/KG) | NA | NA | NA | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| HEPTACHLOR (UG/KG) | NA | 222 | 40000 | -- | | -- | -- | -- | -- | -- | -- | -- | -- |
| HYDROCARBONS-PETROL (MG/KG) | 200 | NA | NA | -- | | 14900 | -- | -- | -- | 168000 | -- | -- | -- |
| HEAVY OILS (MG/KG) | 200 | NA | NA | -- | | 11400 | -- | -- | -- | 10200 | -- | -- | -- |

magnetic intensity decreases inversely proportional to the square of the distance from an object, relatively high values may represent small objects close to the sensor or larger objects at depth or some radial distance away.

The instrument used in the magnetometer survey is an Envi-Mag, a portable, microprocessor-based, proton precession magnetometer. The Envi-Mag takes total field readings in units of nano-Teslas (nT) at 0.5 second intervals. With such a fast sampling rate, measurements can be obtained while walking. Data is acquired rapidly while maintaining a close sampling interval. The data was stored by the magnetometer and later transferred to a computer for data display and analysis.

### 2.1.2 EM Device

A Garrett EM device was also used for tank detection. This device is useful for shallow metal detection. A transmitter coil in the instrument induces a primary magnetic field in the near subsurface. In the presence of metals, a secondary magnetic field is produced and measured by a receiver coil. The device produces an audible tone and a needle response on a semi-quantitative scale, but no record of the output is recorded.

For such large targets as the crushed tanks, the depth of detection of the EM device is limited to approximately 9 to 12 feet. With this EM device, surface area is more critical for detection than the mass of the target and edges of targets are readily detected. The EM device was used to sweep the approximate perimeter of the buried tanks to further refine the edges of the tanks.

## 2.2 Field Methods

A rectangular grid 400 feet (north-south) by 80 feet (east-west) was established over the disposal area using cloth tapes for distance measurement and a surveying instrument for establishing right angles. The grid in the east-west direction was centered relative to the two signs marking the disposal area, and the northern edge of the grid was established at the northern boundary sign.

The grid consisted of north-south survey lines with stations along each line. The lines were marked at each end of the survey area and at 50-foot intervals along the lines. The lines are spaced 10 feet apart. The lines are numbered 0 to 80 beginning at the western boundary, and the stations numbered 0 to 400 beginning at the southern boundary (refer to Figure 2).

Magnetometer readings were obtained while walking along each line. With total field measured every 0.5 seconds, readings were obtained along each line at a spacing of between 2.2 and 2.6 feet. An event marker was triggered at each 50-foot station to tie the readings to the grid. The magnetometer linearly interpolates the data between the 50-foot station stakes.

Magnetic field strengths vary with time. With large magnetometer surveys, field strength is often periodically recorded at one or several set locations during the survey to record field strength variations with time. As our magnetometer data was acquired within an hour, no base or tie-line readings were performed.

A reconnaissance of the disposal area was performed to visually locate any surface debris that may account for any magnetic anomalies recorded. Other than some iron pipes and brackets located outside the survey boundaries approximately 115 feet east of line 80, station 125, no significant debris was observed in the vicinity of the disposal area.

After reviewing the magnetometer data, it was decided to follow this work with an EM search. Though tank depths and locations were determined, an EM search was conducted to further refine the perimeter of the tanks as this is critical in planning the borings.

## 3.0 DATA INTERPRETATION

### 3.1 General

The field data was contoured with computer software supplied with the magnetometer to delineate magnetic anomalies and to evaluate tank locations. In addition, the data was transferred to a commercial spreadsheet software package, and individual survey lines were profiled to aid in data interpretation.

Figure 2 shows the contoured magnetometer data. Values of total field range between 53,058 and 58,092 nT. However, over most of the survey area, the non-anomalous, total field background is generally between 55,680 and 55,720 nT. An area of large anomalous values of total field are indicated between stations 60N and 160N on lines 0E through 60E. This area roughly corresponds with the area previously identified as containing the buried tanks.

The magnitude of the anomalous values above and below the background level is consistent with values expected for large storage tanks. Minor anomalies can be seen outside of the area identified above, but the magnitude of these anomalies are too small for tanks and may be from scattered, small metallic debris. The data confirms the previous magnetometer work, that the tanks are grouped into one portion of the disposal area, with the rest of the disposal area free from large magnetic debris.

### 3.2 Tank Location

Large metal tanks generally act as magnetic dipoles. At the latitude and longitude of the site, the field lines of the earth's magnetic field are inclined approximately 70 degrees from the horizontal. An anomaly produced by a dipole in such an inclined field often takes the form of a sinusoidal wave with the positive portion of the anomaly to the south and the negative portion to the north. The source of the anomaly is located between the high and the low.

This field strength behavior is apparent on Figure 3, which shows the contoured data for just the strongly anomalous area. The contoured data takes the form of an elongate high generally trending parallel to the survey lines. An elongate low parallels the high and is displaced to the north relative to the high. The southern portions of both the high and low areas are offset to the east between about stations 80N and 95N.

As previously discussed, the tanks are approximately located between the highs and the lows in the total field data. Having multiple targets in such close proximity, however, complicates interpretation of the anomaly, as the anomaly is a composite from several sources. To confirm and further refine the tank locations, the EM device was used. The EM device is particularly useful for determining the location of the edges of targets.

The shaded area on Figure 3 shows the inferred location of the tanks. The perimeter of this area was marked with orange pin flags during the second visit to the site. We were not able to determine the actual lateral boundaries between two adjacent tanks using either the magnetometer or the EM device.

### 3.3 Tank Depth

To determine the depth of the tanks, the half width rule for dipoles was used. In this method, the depth of the anomaly source is related to the half-width of the anomaly. The half-width is the horizontal distance between the maximum of the anomaly and the point where the total field is one-half the maximum value. For dipole sources the depth to the center of the source is twice the half-width.

Profiles drawn across the anomaly were used to determine the half-width and thus depth to the center of the source. From the half-width rule, a depth of about 7 feet to the center of the crushed tanks was determined. There is uncertainty with this method, particularly in that we are measuring a composite anomaly from more than one object. This method also generally over-estimates depths.

## 4.0 DISCUSSION AND RECOMMENDATIONS

To drill an angle hole beneath the crushed tanks without hitting the tanks, the bottom, outside edge of the adjacent tank or tanks needs to be determined. The perimeter of the combined tank mass was determined with the magnetometer and EM device and is marked in the field. The depth to the bottom of the tanks below the marked perimeter, however, is more problematic and requires some assumptions.

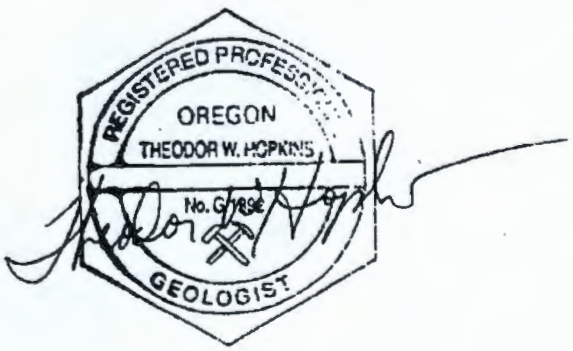
The approximate depth to the center of the tank mass is estimated to be 7 feet below the ground surface. The depth to the top of the tanks and the thickness of the crushed tanks can not be determined from the data, so the depth to the bottom of the tanks is unknown. Further, the tanks may have been stacked during burial, with one tank on top of another. The dimensions of the individual tanks are not known, but the number of local, paired highs and lows along the composite anomaly suggests less than 6 to 10 tank locations in plan view. This would support the possibility of stacked tanks.

Disposal documentation provided by the COE indicates that the contaminated soil was buried 4 feet below grade. As the crushed tanks were place on top of the contaminated soil, the report of the previous 2,4-D site study suggested that this implied that the contaminated soil was buried much deeper than 4 feet. Four feet may, however, be a reasonable estimate of the soil cover over the tanks.

If one assumes that 4 feet of soil covers the tops of the tanks and the center of the tanks is estimated to be 7 feet below grade, then the bottom of the tanks would be 10 feet below grade. In our opinion, 10 feet below grade may be excessive as it appears that burying the tanks to this depth would be unlikely with such a wide area available for disposal. An estimated depth of 10 feet to the bottom of the tanks would, in our opinion, err on the side of safety when planning the borings. It is our recommendation that the borings planned for sampling beneath the tanks be drilled with an appropriate offset and inclination to pass at least 10 feet below the flagged perimeter of the tanks.

Included in this report is an appendix entitled "Important Information About Your Subsurface Waste Management (Remediation) Report" to assist you and others in the use and limitations of our report.

SHANNON & WILSON, INC.



4/6/94

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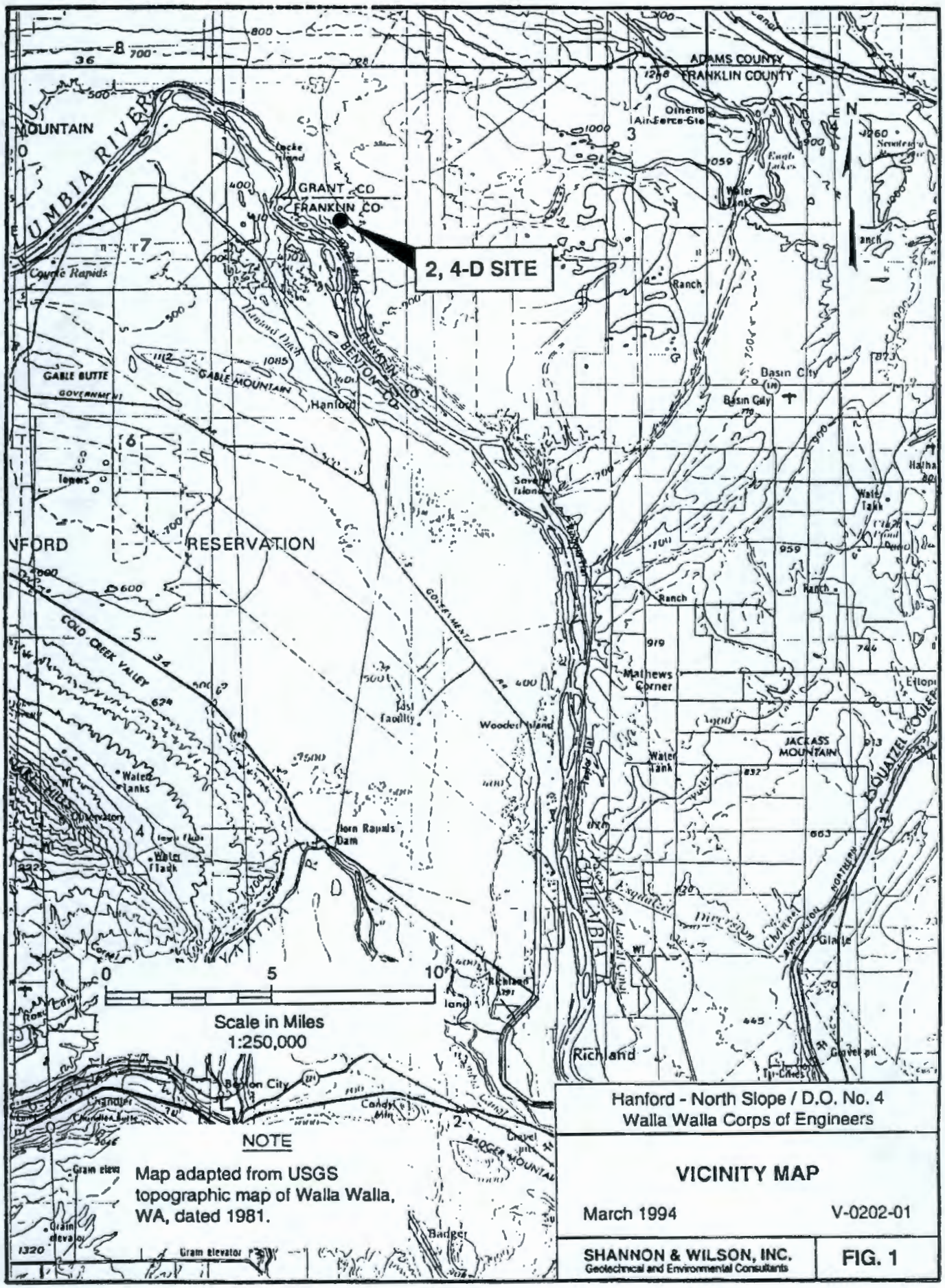
Vice President

TWH:JTA/twh
4-5-94/V0202-01.RPT/V0202-lkd/lkd




NOTE

Map adapted from USGS topographic map of Walla Walla, WA, dated 1981.

Hanford - North Slope / D.O. No. 4
Walla Walla Corps of Engineers

**VICINITY MAP**

March 1994 V-0202-01

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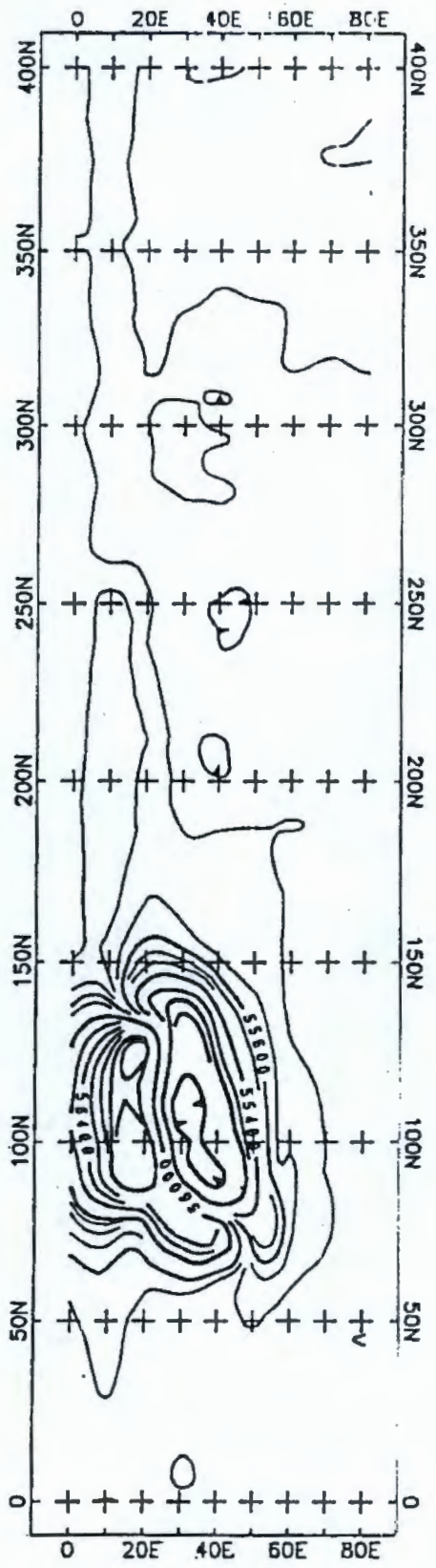
**FIG. 1**



**LEGEND**

56000 — Contours of Total Field Magnetometer Data in Nano-Teslas.

+ Staked Stations

0 50 100

Scale in Feet

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Walla Walla Corps of Engineers

**CONTOURED MAGNETOMETER DATA 2, 4-D SITE**

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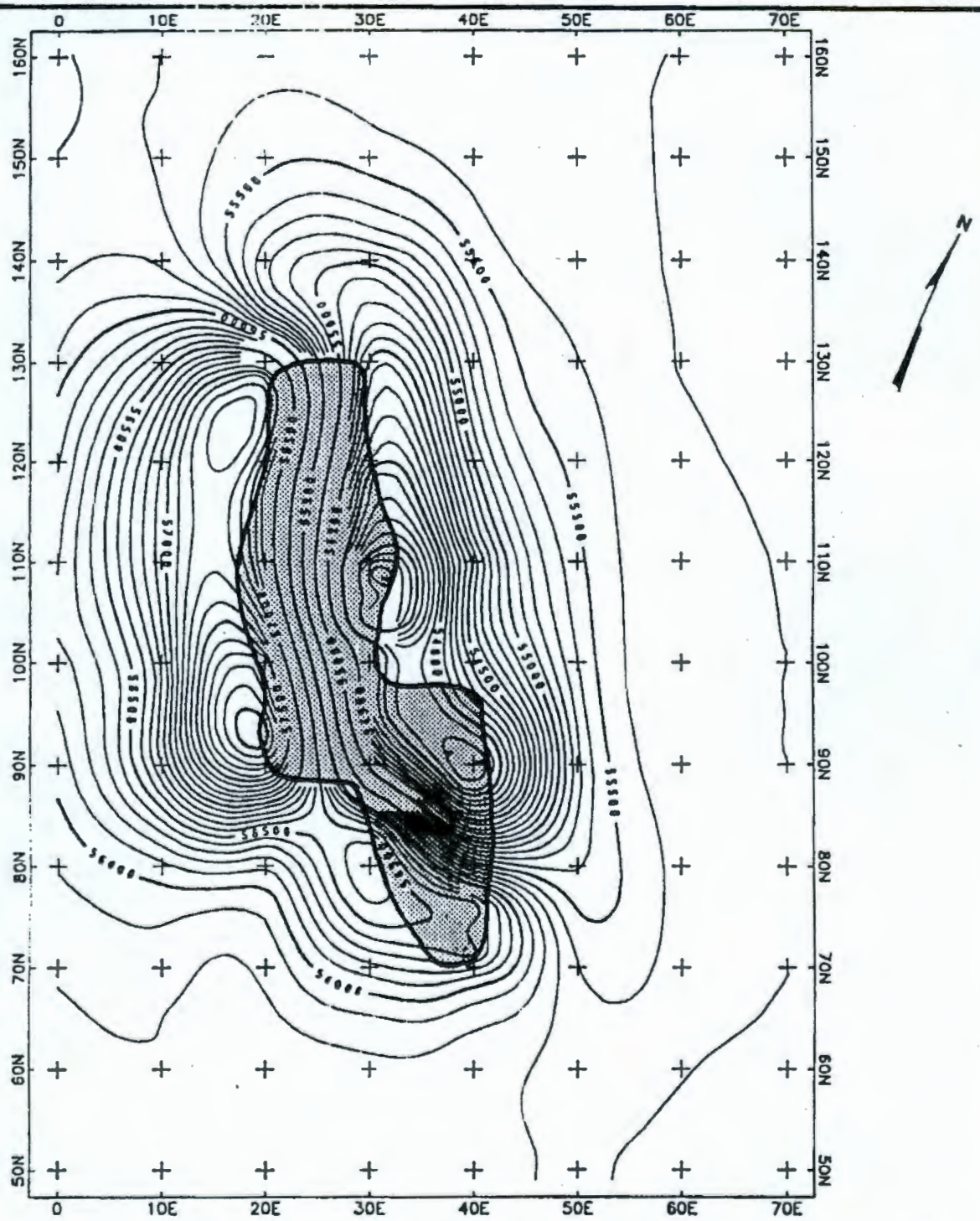
**FIG. 2**




LEGEND

Location of Crushed Tanks

Contours of Total Field Magnetometer Data in Nano-Teslas.

NOTES

1. Boundary of buried tanks interpreted from magnetometer data and shallow electro magnetic device.
2. Cross ticks shown at 10-foot stations are for location purposes only. Stations at 50-foot intervals were actually staked in the field.

Hanford - North Slope / D.O. No. 4
Walla Walla Corps of Engineers

**TANK LOCATIONS**
**2, 4-D SITE**

March 1994 V-0202-01

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**FIG. 3**

# APPENDIX

## IMPORTANT INFORMATION ABOUT YOUR SUBSURFACE WASTE MANAGEMENT (REMEDIATION) REPORT

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants



Dated: March 31, 1994

To: U.S. Army Corps of Engineers
Walla Walla, Washington

# Important Information About Your Geotechnical Engineering/ Subsurface Waste Management (Remediation) Report

## GEOTECHNICAL SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES AND PERSONS.

Consulting geotechnical engineers prepare reports to meet the specific needs of specific individuals. A report prepared for a civil engineer may not be adequate for a construction contractor or even another civil engineer. Unless indicated otherwise, your consultant prepared your report expressly for you and expressly for purposes you indicated. No one other than you should apply this report for its intended purpose without first conferring with the consultant. No party should apply this report for any purpose other than that originally contemplated without first conferring with the geotechnical engineer/geoscientist.

## AN ENGINEERING REPORT IS BASED ON PROJECT-SPECIFIC FACTORS.

A geotechnical engineering/subsurface waste management (remediation) report is based on a subsurface exploration plan designed to consider a unique set of project-specific factors. Depending on the project, these may include: the general nature of the structure and property involved; its size and configuration; its historical use and practice; the location of the structure on the site and its orientation; other improvements such as access roads, parking lots, and underground utilities; and the additional risk created by scope-of-service limitations imposed by the client. To help avoid costly problems, have the consulting engineer(s)/scientist(s) evaluate how any factors which change subsequent to the date of the report, may affect the recommendations. Unless your consulting geotechnical/ engineer and/or scientist indicates otherwise, your report should not be used: 1) when the nature of the proposed project is changed (for example, if an office building will be erected instead of a parking garage, or if a refrigerated warehouse will be built instead of an unrefrigerated one, or chemicals are discovered on or near the site); 2) when the size, elevation, or configuration of the proposed project is altered; 3) when the location or orientation of the proposed project is modified; 4) when there is a change of ownership; or 5) for application to an adjacent site. Geotechnical/civil engineers and/or scientists cannot accept responsibility for problems which may occur if they are not consulted after factors which were considered in the development of the report have changed.

## SUBSURFACE CONDITIONS CAN CHANGE.

Subsurface conditions may be affected as a result of natural changes or human influence. Because a geotechnical/waste management engineering report is based on conditions which existed at the time of subsurface exploration, construction decisions should not be based on an engineering report whose adequacy may have been affected by time. Ask the geotechnical/waste management consultant to advise if additional tests are desirable before construction starts. For example, groundwater conditions commonly vary seasonally.

Construction operations at or adjacent to the site and natural events such as floods, earthquakes, or groundwater fluctuations may also affect subsurface conditions and, thus, the continuing adequacy of a geotechnical/waste management report. The geotechnical/civil engineer and/or scientist should be kept apprised of any such events, and should be consulted to determine if additional tests are necessary.

## MOST GEOTECHNICAL RECOMMENDATIONS ARE PROFESSIONAL JUDGMENTS.

Site exploration and testing identifies actual surface and subsurface conditions only at those points where samples are taken. The data were extrapolated by your consultant who then applied judgment to render an opinion about overall subsurface conditions. The actual interface between materials may be far more gradual or abrupt than your report indicates. Actual conditions in areas not sampled may differ from those predicted in your report. While nothing can be done to prevent such situations, you and your consultant can work together to help minimize their impact. Retaining your consultant to observe subsurface construction operations can be particularly beneficial in this respect.

## A REPORT'S CONCLUSIONS ARE PRELIMINARY.

The conclusions contained in your geotechnical engineer's report are preliminary because they must be based on the assumption that conditions revealed through selective exploratory sampling are indicative of actual conditions throughout a site. Because actual

subsurface conditions can be discerned only during earthwork, you should retain your geotechnical engineer to observe actual conditions and to finalize conclusions. Only the geotechnical engineer who prepared the report is fully familiar with the background information needed to determine whether or not the report's recommendations based on those conclusions are valid and whether or not the contractor is abiding by applicable recommendations. The geotechnical engineer who developed your report cannot assume responsibility or liability for the adequacy of the report's recommendations if another party is retained to observe construction.

## THE GEOTECHNICAL ENGINEERING/SUBSURFACE WASTE MANAGEMENT (REMEDIATION) REPORT IS SUBJECT TO MISINTERPRETATION.

Costly problems can occur when other design professionals develop their plans based on misinterpretation of a geotechnical engineering/subsurface management (remediation) report. To help avoid these problems, the geotechnical/civil engineer and/or scientist should be retained to work with other project design professionals to explain relevant geotechnical, geological, hydrogeological and waste management findings and to review the adequacy of their plans and specifications relative to these issues.

## BORING LOGS AND/OR MONITORING WELL DATA SHOULD NOT BE SEPARATED FROM THE ENGINEERING/WASTE MANAGEMENT REPORT.

Final boring logs developed by the geotechnical/civil engineer and/or scientist are based upon interpretation of field logs (assembled by site personnel), field test results, and laboratory and/or office evaluation of field samples and data. Only final boring logs and data are customarily included in geotechnical engineering/waste management reports. These final logs should not, under any circumstances, be redrawn for inclusion in architectural or other design drawings, because drafters may commit errors or omissions in the transfer process.

To minimize the likelihood of boring log or monitoring well misinterpretation, contractors should be given ready access to the complete geotechnical engineering/waste management report prepared or authorized for their use. If access is provided only to the report prepared for you, you should advise contractors of the report's limitations, assuming that a contractor was not one of the specific persons for whom the report was prepared and that developing construction cost estimates was not one of the specific purposes for which it was prepared. While a contractor may gain important knowledge from a report prepared for another party, the contractor should discuss the report with your consultant and perform the additional or alternative work believed necessary to obtain the data specifically appropriate for construction cost estimating purposes. Some clients hold the mistaken impression that simply disclaiming responsibility for the accuracy of subsurface information always insulates them from attendant liability. Providing the best available information to contractors helps prevent costly construction problems and the adversarial attitudes which aggravate them to a disproportionate scale.

## READ RESPONSIBILITY CLAUSES CLOSELY.

Because geotechnical engineering/subsurface waste management (remediation) is based extensively on judgment and opinion, it is far less exact than other design disciplines. This situation has resulted in wholly unwarranted claims being lodged against geotechnical/waste management consultants. To help prevent this problem, geotechnical/civil engineers and/or scientists have developed a number of clauses for use in their contracts, reports and other documents. These responsibility clauses are not exculpatory clauses designed to transfer the engineer's or scientist's liabilities to other parties; rather, they are definitive clauses which identify where the engineer's or scientist's responsibilities begin and end. Their use helps all parties involved recognize their individual responsibilities and take appropriate action. Some of these definitive clauses are likely to appear in your report, and you are encouraged to read them closely. Your engineer/scientist will be pleased to give full and frank answers to your questions.

The preceding paragraphs are based on information provided by the
ASFE/Association of Engineering Firms Practicing in the Geosciences, Silver Spring, Maryland