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DOCUMENT CLEARANCE REQUEST — Manager's Approval

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4. Author: M. R. Adams — 8361 — 5. MSIN: H4-55

7. Desired Clearance/Release: Public Clearance ☒ Open Literature ☐ Oral Public — Limited Clearance ☐ Applied Technology ☐ Foreign Exchange — DOE Directed Release ☐ Conf. ☐ Media ☐ Other

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Document is approved as conforming to all applicable requirements. The above information is certified to be correct.

	23. Author	Immediate Manager	Issuing Manager (Level III)	24. Date
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Signature	M R Adams	[signature]	[signature]	6/19/89

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DOCUMENT CLEARANCE REQUEST
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Publications Services 6/27/89	✓						see attached	
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WHC-MR-0029

Procedures for Geophysical Site Surveys

1100-EM-1 Operable Unit

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Date Published
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Date: 1-3-89
OU #: 1100-EM-1
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Task Order or Work Order #

To: Project File

From: M. R. Adams

Subject: Approval of Procedures for Field Services Procured by Task/Work Order

The procedures for field services provided by task/work orders are approved by Westinghouse Hanford Company. Specific information regarding the service is indicated below:

1. Work Title Including Operable Unit Designation
   Geophysical Site Surveys, 1100-EM-1 Operable Unit

2. Type of Order: ____ Task Order Task # ____

   _X_ Work Order Order # ED 9304

   _X_ Statement of Work (check is present; do not proceed if absent).

3. Performing Organization:

   ____ Golder _X_ PNL ____ Kaiser ____ Other ________

4. Performing Personnel and Title:

   G. A. Sandness, Scientist

5. Approval Checklist: (Attach list of each document supplied, date of document, ID # if available, and revision indication, if available).
   Document supplied is "Procedures for Geophysical Site Surveys," 1100-EM-1 Operable Unit, dated December 19, 1988.

   _X_ Equipment operating manuals, instructions or procedures (Manuals referenced in procedure, kept with equipment operator).

   _X_ Calibration instructions or procedures

   _X_ Calibration record during operation

   _X_ Equipment maintenance instructions or procedures

   _X_ Equipment maintenance record during operation

   N/A Purchase records of parts or tools used specifically for operation specified in Statement of Work attached to Work or Task Order

   _X_ Safety precautions peculiar to equipment documented (Site safety precautions covered in Health and Safety Plan)

   _X_ Logbooks and/or notebooks for field data collection

   _X_ Radiation monitoring activities completed at all sites.

6. Approvals:

RI Project Coordinator (WHC)	1/03/89 Date
Field Team Leader (WHC) FET I	1/9/88 Date
Technical Lead (WHC)	1/3/89 Date
QA Officer (If impact Level I, II or III)	1-10-89 Date

PROCEDURES FOR GEOPHYSICAL SITE SURVEYS
1100-EM-1 OPERABLE UNIT

G.A. Sandness
Automation and Measurement Sciences Department
Pacific Northwest Laboratory
December 19, 1988

1.0 INTRODUCTION

Geophysical sensing methods measure variations in magnetic and electromagnetic fields, electrical currents and potentials, or acoustic impulses to detect and characterize natural or manmade features, objects, or materials in the ground. Some of the many available geophysical exploration methods have proven to be effective at the shallow depths (10 m or less) represented by typical, near-surface, chemical and radioactive waste burial sites. These methods are routinely used to detect waste materials or the subsurface structures (trenches, tanks, drums, etc.) in which those materials were deposited. They are also used to detect natural features (e.g., bedrock, the water table, voids, and sedimentary interfaces) which may influence the migration of chemical or radiological contaminants into the environment. The specific geophysical sensing methods to be initially employed in the planned CERCLA remedial investigations at the Hanford 1100-EM-1 Operable Unit are summarized as follows:

Method	Basic Physical Principle
Ground-penetrating radar	Electromagnetic waves are backscattered from objects or interfaces in the ground.
Magnetometry	Magnetic materials produce measurable anomalies in the ambient (earth's) magnetic field.
Electrical conductivity by electromagnetic induction	Measurable secondary magnetic fields are induced in conductive objects by an alternating magnetic field source at or above the ground surface.
Metal detector	Electromagnetic induction as above with a sensor specialized to detect metallic objects.

These methods, and others, have been successfully used to detect and characterize hazardous waste materials at many burial sites over the past decade and are now recognized as a vital part of waste site identification and assessment efforts. All of these methods provide information about buried objects and materials without requiring significant physical penetration of the ground. For this reason, they offer at least three important advantages, or benefits, in comparison with alternatives such as excavation and borehole sampling: 1) they can substantially reduce the time and cost of exploration and site characterization efforts, 2) they can increase the quality and quantity of site assessment data, and 3) they can enhance the safety of personnel. These benefits make the use of geophysical sensing methods almost mandatory in most waste burial site investigations.

2.0 GENERAL GEOPHYSICAL SURVEY PROCEDURES

The following sections of this document outline a set of operating procedures for each of the four geophysical survey methods listed above. These procedures include instrument calibration and maintenance, data collection, and data processing. Thus, they are dependent on the characteristics of the various instruments. There are, however, several broader aspects of survey procedure which pertain to all of the methods that we expect to employ in the site investigations that are currently planned for the 1100-EM-1 Operable Unit.

2.1 Measurement Locations

Reference points at the ground surface are needed at most waste burial sites to permit measurement locations to be defined and waste boundaries to be accurately mapped. This is often achieved by placing stakes into the ground to mark the nodes of a rectangular grid. Geophysical measurements are then normally made along straight lines that are parallel to, and sometimes coincident with, the grid lines. The reference grids for the sites in the 1100-EM-1 Operable Unit are described in the corresponding RI/FS Work Plan and in the Statement of Work for the geophysical surveys (Work Order No. ED9304). Stakes will be in place at these sites prior to the initiation of geophysical field work.

There are at least two reasons why the geophysical survey, or traverse, lines are not always coincident with the grid lines. First, it may be considered appropriate to collect geophysical data along survey lines that are more closely spaced than the grid lines. It would not be unusual, for example, to collect data along lines spaced 5 or 10 ft apart at a site where the grid (or stake) spacing is 100 ft. The locations of the survey lines, in this case, would be determined by measurements from the grid stakes and would be marked by paint, flags, or other easily movable markers. Second, the stakes are obstructions which make it impossible to maneuver survey vehicles and certain geophysical instruments directly along the grid lines. The normal procedure in this case is to collect data along a set of lines that are offset from the grid lines. The amount of offset and its direction relative to the grid are noted in a field notebook and are accounted for in the subsequent data analysis process.

It is important to note that other obstructions on the ground surface (e.g., bushes, rocks, surface debris, pipes, fences, posts, buildings, and fixed machinery) will often make it impossible to collect geophysical data along perfectly straight lines. A major interruption or diversion of a survey line would be noted and accounted for, but it is impractical to note minor diversions that are comparable to the lateral spatial resolution of the survey instrument or small in comparison to the size of the subsurface feature to be detected (detecting a large trench requires less navigational precision than detecting an isolated 55-gal drum, for example).

Most of the geophysical survey instruments that are planned for use at the Hanford waste burial sites produce output data at an effective rate of several samples per second. The normal survey mode is to transport these instruments along a survey line at a speed of a few feet per second. Thus, the along-track data spacing is typically 1 ft or less. The exact data spacing will vary with the speed at which the instruments are carried or pulled across the ground and cannot be accurately controlled. Except for situations where widely spaced data are appropriate (e.g., electromagnetic induction measurements of deep contamination plumes in groundwater), it is not cost effective to attempt to obtain a fixed data spacing. The normal procedure is to: 1) make the traverse speed as constant as possible to minimize variations in the data spacing; 2) interpolate the data (if digital) by means of a computer to adjust the data spacing to a selected value; and 3) to scale the final display product (e.g., map) to the desired dimensions. This approach minimizes the time needed to perform a survey, maximizes the cost effectiveness of the work, and ensures that the number of measurements in the along-track direction will be sufficient to detect both large and small targets.

2.2 Calibration/Data Analysis

The current state of the art in geophysical site assessment technology is such that the results of most surveys are only semi-quantitative. In other words, the amplitude of a measured quantity (e.g., a reflected radar signal, a magnetic field anomaly, or the apparent electrical conductivity of the ground) cannot be interpreted in a way that will yield an accurate quantitative characterization of a buried waste deposit or waste-related structure. Consequently, the most meaningful and accurate result of a geophysical survey is usually a map showing the locations of waste deposits or waste disposal structures. This type of product is based on the measurement of lateral variations in the measured quantity. Thus, the stability of the survey instrument and the accuracy of the survey lines are more important than a calibration of the instrument's response. The instrument calibrations that can be made and are meaningful are outlined in Sections 3-6.

2.3 Safety

There are minimal safety hazards associated with the use of the geophysical survey instruments that are planned for use at the Hanford Site. The instruments themselves have no significant radiation fields, exposed high voltages, or moving mechanical parts that constitute a hazard to the operator. The small all-terrain vehicle used by PNL for ground-penetrating radar surveys (see Section 3.1 below) will not be operated on steep slopes or embankments which, in the judgement of the operator, cannot be safely negotiated. Safety issues related to potential chemical or radioactive contamination of the site and to the possibility of ground subsidence over collapsing waste materials or containers will be addressed by the site safety officer prior to the initiation of geophysical field work by PNL.

2.4 Field Notebooks

Written descriptions of the geophysical field work will be recorded in field notebooks. The contents of these notebooks will include site descriptions, explanations of the work being performed, general field procedures, a list of the instruments used in the work, records of instrument settings, notations of anomalous occurences, and descriptive details relating to data collection (e.g., line numbers, traverse directions, obstructions, deviations, data record numbers, and data file names). A separate notebook will be used by each individual or group that is performing independent field work. The notebooks will remain at PNL, but copies will be provided to WHC.

2.5 Reports

Final reports will be submitted to WHC as outlined in the Statement of Work for the 1100-EM-1 Operable Unit. These reports will include:

- site description
- statement of survey objectives
- listing and description of the survey instrumentation
- outline of data collection procedures
- outline of data processing operations and data analysis procedures
- discussion of results
- raw data records
- intermediate data display products (maps, profiles, and graphs)
- one or more site maps showing the interpreted results of the geophysical surveys.

3.0 GROUND-PENETRATING RADAR PROCEDURES

3.1 System

Manufacturer	Geophysical Survey Systems, Inc (GSSI)
Components	a) Control unit, Model SIR 7 b) 120-MHz antenna, Model 3110 c) 300-MHz antenna, Model 3105A d) 500-MHz antenna, Model 3102 e) Calibrator, Model P731 Normal operation of the radar system involves two additional components: f) Digital data acquisition unit designed and constructed at PNL. g) Suzuki Quadrunner 250 all-terrain vehicle (ATV).
Power	Electrical power is provided by 12-volt automotive or marine batteries.
Accuracy	±0.5 nsec in signal travel time.

3.2 Manuals

a) GSSI SIR 7 operator's manual and circuit diagrams.
b) PNL operator's manual, data acquisition unit.

3.3 Calibration

A radar travel-time calibration signal will be recorded in the field as a special data record on the recording medium used for the rest of the radar field data (digital magnetic tape or disk). A calibration, utilizing the P731 calibrator, will be performed at least once per day during field operations and whenever a change is made in the timing parameters of the radar system. The performance of the calibration procedure and the location of the calibration data in the recorded data set will be noted in the operator's field notebook.

3.4 Maintenance

Daily procedures:

a) Inspection and cleaning (if needed) of cables, connectors, and tape recorder heads.
b) Battery inspection and charging prior to operation of the system. (During operation, battery status is indicated by a voltmeter and indicator lights on the radar control unit.)
c) ATV maintenance (gas, oil, tires).

The performance of these procedures will be noted in the operator's field notebook.

3.5 Data Collection

Operating Modes

a) Towed by the ATV. In this mode, a footage counter mounted on the ATV provides position data that are inserted into the data records.
b) Pulled by the operator, no footage counter.

The operating mode will be recorded in the operator's field notebook.

Normal travel speed — 2-5 ft/sec

Warm-up time — 1 minute

Procedures

System adjustments such as time scale, gain, filter, sampling rate, and signal frequency range (antenna selection) are site-dependent and will be made at the discretion of the operator. All instrument settings will be recorded in the operator's field notebook.

Data will normally be collected along straight lines defined by, or derived from, a survey grid marked by stakes. Pertinent data (e.g., direction, location, track number, obstructions) relating to each traverse will be recorded in the operator's field notebook.

The radar data will be recorded in digital form on magnetic tape cartridges or magnetic disks. Each cartridge or disk will be labeled and dated. The data will be transferred to a laboratory computer for processing as described below. The unprocessed data will be recorded on 9-track magnetic tape for long-term storage and transmittal to WHC.

3.6 Data Analysis

The radar data will be processed by PC or DEC VAX computers. Processing steps may include clutter removal, filtering, synthetic aperture focusing, and image enhancement. Intermediate output products will normally be amplitude-modulated radar profiles in the form of photographic prints. The final product will normally be a site map showing the interpreted locations, depths, and characteristics of waste materials and other waste-related features. This map may include the results of the other types of geophysical surveys performed at the site.

4.0 MAGNETOMETER PROCEDURES

4.1 Primary System

Manufacturer: Scintrex, Ltd.

Components:
a) Cesium vapor magnetometer, Model VIU-2302A1
b) Digital data recorder designed and constructed at PNL.

Power: 6-volt gel-cell battery pack

Accuracy: ±5 gammas

4.2 Alternative System

Manufacturer: Geometrics

Components: Proton precession magnetometer, Model G-816 or G-856.

Power: Internal batteries (size C, non-magnetic)

Accuracy: ±1 gamma

4.3 Manuals

a) Scintrex magnetometer operator's manual and circuit diagrams.

b) PNL operator's manual, digital data recorder.
c) Geometrics magnetometer operator's manual.

4.4 Calibration

The calibration of cesium vapor and proton precession magnetometers is determined by fundamental physical constants and is not adjustable by the user. A correct reading of the ambient magnetic field indicates that the instrument is functioning correctly. Short-term stability will be ascertained daily by a 1-minute sequence of measurements at a fixed field location. Long-term repeatability will be checked by repeating at least one survey line at each site. The performance of these steps will be documented in the operator's field notebook.

4.5 Maintenance

Daily battery charging and inspection of cables and connectors. During operation, low battery voltage is sensed by the magnetometer and is indicated on its front panel display.

4.6 Data Collection

Operating mode: The instrument will be carried by the operator.

Normal travel speed:
a) 3-5 ft/sec (cesium vapor magnetometer).
b) 1 ft/sec avg. (proton precession magnetometer).

Warm-up time:
a) 5 minutes (cesium vapor magnetometer).
b) 1 minute (proton precession magnetometer).

Procedures: Before beginning a survey, the operator will ensure that he is not carrying or wearing any ferromagnetic object (e.g., knife, steel belt buckle, or steel-reinforced boots) that can affect the magnetic measurement.

The cesium vapor magnetometer will be carried along the survey lines at a constant speed. Data will be automatically recorded in digital form at a rate of several samples per second.

The proton precession magnetometer will be moved along the survey lines in a start/stop mode. Readings will be made at selected distance increments and will be recorded either automatically (recorder) or manually (notebook)

Data stored in the digital data recorder will be periodically transferred to floppy disk via an on-site PC. Each floppy disk will be labeled, dated, and backed up. Pertinent data relating to each survey line will be recorded in the operator's field notebook.

Diurnal variations in the earth's magnetic field will be monitored by making periodic measurements at a fixed location. The measurement interval will be 1 hour or less. The details of this procedure will be recorded in the operator's field notebook.

4.7 Data Analysis

The magnetic data will be processed by a PC or VAX computer. Processing steps may include interpolation, filtering, correction for diurnal variations, and subtraction of the ambient field. Output products may include magnetic profiles, contour maps, and color-coded maps of magnetic amplitudes. The primary output product will normally be a site map showing the interpreted locations of magnetic waste materials. These results may be included on a more general site map that contains the results of other geophysical surveys.

5.0 ELECTROMAGNETIC INDUCTION PROCEDURES

5.1 System

Manufacturer — Geonics, Ltd.

Components —
a) Model EM31 ground conductivity meter.
b) Digital data acquisition unit as in Section 4.1.

Power — Internal batteries, size C

Accuracy — ±5%

5.2 Manuals

Geonics EM31 Operating Manual and circuit diagrams.

5.3 Calibration

Factory calibrated. Long-term stability will be checked prior to use at a given site by measurements at a selected test location (currently a parking lot at PNL's 2400 Stevens facility). Adjustments, if needed, will be made in accordance with the procedures listed in the EM31 Operating Manual. The time, location, procedures, and results of these measurements and adjustments will be recorded in the operator's field notebook.

5.4 Maintenance

Daily procedures:

a) Inspection of cables and connectors.

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b) Equipment functional checks as specified in the operator's manual.

The performance of these procedures will be noted in the operator's field notebook.

5.5 Data Collection

Operating mode: The instrument will be carried by the operator.

Normal travel speed: 3-5 ft/sec

Warm-up time: 1 minute

Procedures: The instrument will be carried along the survey lines at a constant speed. Data will be automatically recorded in digital form at a rate of several samples per second. Pertinent data related to each survey line will be recorded in the operator's field notebook.

The recorded data will be transferred to floppy disks which will be labeled, dated, and backed up.

5.6 Data Analysis: The data will be processed by a PC or VAX computer. Processing steps may include interpolation and filtering. Output products may include conductivity (apparent) profiles, contour maps, and color-coded maps. The primary output product will normally be a site map showing the interpreted locations of detected waste materials or subsurface structures. These results may be included on a more general site map that contains the results of other geophysical surveys.

6.0 METAL DETECTOR PROCEDURES

6.1 System

Manufacturer: Fisher Research Laboratory

Components: Model TW-6 M-Scope pipe and cable locator

Power: Internal batteries

Accuracy: Not defined

6.2 Manuals: Fisher M-Scope Operating Manual

6.3 Calibration: Uncalibrated instrument. Frequent adjustments are required on site to ensure good sensitivity. These are normally made by maximizing the response to a known target. This procedure will be recorded in the operator's field notebook.

6.4 <u>Maintenance</u>	Daily battery check utilizing the instrument's front-panel, battery-check function switch.

6.5 <u>Data Collection</u>

Operating mode	The instrument will be carried by the operator.
Normal travel speed	1-5 ft/sec
Warm-up time	1 minute
Procedures	The instrument will normally be carried along a survey line until a response is obtained. The instrument may then be moved in an areal pattern to define the boundaries of the detected object or material. The boundaries will be marked on the ground in a temporary manner and will be recorded on a data sheet or in the operator's field notebook.

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The field records will be replotted and presented either as a separate map or as a component of a more general site map containing the results of other geophysical surveys.