Golder Associates Inc.
18300 NE Union Hill Road, Suite 200
Redmond, Washington 98052
Telephone: (425) 883 0777
Fax: (425) 882 5498

Golder Associates

WEST PLAINS GEOPHYSICAL ORIENTATION SURVEY
QUALITY ASSURANCE PROJECT PLAN

Submitted to:

Water Resources, Utilities Division
Public Works Department
County of Spokane, Washington

Submitted by:

Golder Associates Inc.
Redmond, Washington
18300 N.E. Union Hill Road, Suite 200
Redmond, Washington 98052

Matthew A. Benson, L.G.
Senior Geophysicists

Richard Sylwester, L.E.G, L.G.
Associate

Distribution:

1 Copy	Mike Hermanson, Spokane County
1 Copy	Robert Lindsay, Spokane County
1 Copy	John Covert, Washington Department of Ecology
1 Copy	Bryony Stasney, Golder Associates Inc.
1 Copy	Matthew Benson, Golder Associates Inc.
1 Copy	Richard Sylwester, Golder Associates Inc.

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APPROVAL SHEET

Mike Hermanson — Date
Spokane County

Robert Lindsay — Date
Spokane County

John Covert — Date
Washington Department of Ecology

DISTRIBUTION LIST:

Mike Hermanson, Spokane County
Robert Lindsay, Spokane County
John Covert, Washington Department of Ecology
Bryony Stasney, Golder Associates Inc.
Richard Sylwester, Golder Associates Inc.

1.0 INTRODUCTION

The purpose of this document is to present a quality assurance project plan (QAPP) for a geophysical orientation survey within the West Plains area of Spokane County. The West Plains is located just west of the City of Spokane, at the boundary of WRIA 54 (Lower Spokane River Watershed), WRIA 56 (Hangman Creek Watershed) and WRIA 34 (Palouse River Watershed) and includes land within these three Water Resource Inventory Areas (WRIAs). The project is funded by the Washington Department of Ecology (Ecology).

The project objective is to identify geophysical tool(s) that have the potential to delineate the top of the basement rocks across the West Plains.

This QAPP describes the quality assurance program associated with the geophysical survey, and presents details regarding the project organization, data quality objectives, data acquisition and documentation, response actions and data validation. The QAPP is intended to outline a systematic approach to data collection and management that will help ensure project data collected for Spokane County is reliable for meeting the project purpose.

1.1 Project Background

The West Plains area is located west of the City of Spokane and includes the City of Airway Heights, the City of Medical Lake, the City of Four Lakes and Fairchild Air Force Base.). A formal boundary for the West Plains does not exist. However, the West Plains is generally considered as the relatively low lying land that occurs west of the Spokane River and is surrounded by low lying hills and buttes that occur north of Cheney, east of Rearden and south of Four Mound Prairie. Two primary drainages, Deep Creek and Coulee Creek, flow in an easterly direction across the northern portion of the West Plains and discharge into the Spokane River.

The geology of West Plains is comprised of (from the youngest to the oldest units): sand and gravel deposits that occur within palaeochannels; the Columbia River Basalt Group; and, crystalline basement rocks (such as granite and quartzite). The crystalline basement rocks are exposed on a number of topographic highs such as Olson Hill (just north of Medical Lake), Booth Hill and Fancher Butte (west of Medical Lake) and McDowell Hill (south of Coulee Creek and north of Deep Creek). The crystalline basement rocks also underlie the basalts and the sand / gravel units across the West Plains. Recent geologic mapping by Washington State Department of Natural Resources (DNR) and by Eastern Washington University (EWU) has improved understanding of the distribution and occurrence of geologic units across the West Plains. However the topography and nature of the subsurface contact between the basement rocks and overlying basalts / sediments are not well understood.

The primary aquifers in the West Plains area occur within the paleochannel deposits and within the Wanapum and Grande Ronde Basalt flows. The basement rocks generally provide poor yield to wells and are considered as aquitards (i.e., barriers to groundwater flow). Recharge to the West Plains aquifers is from precipitation (rain and snowmelt) and occurs at about 15 to 19 inches annually. The Washington State Department of Ecology (Ecology) has compiled groundwater level information for a number of wells located across the West Plains and has concluded that in some areas groundwater levels within the basalt aquifers are declining (Covert, 2007). Documented groundwater level declines between 2001 and 2003 range from about 15 feet in a Medical Lake well to about 120 feet in a Four Lakes well between 1997 and 2005 (TetraTech and GeoEngineers, 2007). Aquifer testing data also suggests that well interference occurs between some of West Plains municipal wells (Covert, 2007). The conceptual model for the West Plains hydrogeology suggests that the nature and topography of the bedrock surface controls groundwater flow and that the basalts are divided into small, compartmentalized aquifers.

1.2 Project Description and Schedule

The purpose of this project is to identify and test geophysical technique(s) that could be used to delineate the contact between the basalt and the crystalline basement rock beneath the West Plains. The geophysical techniques (including equipment and processing) will need to consider cultural interference associated with development (e.g., roads, power lines and buried utilities) as well as the geophysical attributes of the geologic contacts. For example, the contact between the basement rock and the basalt at the Medical Lake Craig Road well is beneath about 500 feet of clay. Clay deposits have also been noted in areas where the contact between the basement granite and basalt is exposed at the surface (e.g., around West Medical Lake). Geophysics (primarily seismic reflection) has been used across the West Plains to delineate the configuration of the Deep Creek, Airport and Airway Heights palaeochannels (McCollum, 2009; Budinger, 2001; GeoEngineers, 2002; GeoEngineers, 2007). However, this investigation did not identify deeper reflectors that may have been associated with the basalt – basement contact.

A pilot study was conducted in December 2008 at a site where basement rock ranged between an outcrop to less than 100 feet below the ground surface with overlying basalts and fluvial sediments. The site provided ideal conditions for evaluating the effectiveness of various geophysical methods. Seismic refraction, seismic reflection, time-domain electromagnetics, electrical resistivity imaging, and gravity methods were tested during the pilot study. Only seismic refraction, seismic reflection and gravity methods proved successful in mapping the depth and topography of the surface of the basement rock.

1.3 Project Organization

Project oversight and review will be provided by Mike Hermanson of Spokane County. Mr. Hermanson will be responsible for reviewing and approving the QAPP, the work plan, and the final project report.

The Golder Associates project manager is Matthew Benson. Mr. Benson will be responsible for managing project costs, schedule, and quality control for all geophysical activities. This includes ensuring that this QAPP is adhered to by project personnel and that all project activities are properly documented in the project file. The project manager is also responsible for informing the County on a regular basis the technical and financial progress of the project.

The Golder Associates quality manager is Richard Sylwester. Mr. Sylwester will be responsible for project quality assurance including following this QAPP and for verifying that the geophysical data collected meets quality objectives.

1.4 Project Schedule

This project is expected to be finished in June of 2009. Major field activities are scheduled to begin in March 2009. The table below summarizes the schedule of project activities.

TABLE 1

Project Schedule

Date	Monitoring Activities
January 2009	Submission of Quality Assurance Project Plan and Work Plan
March 2009	Begin geophysical field trials at select locations
April 2009	Complete geophysical field trials at select locations, process data from all field trials and prepare orientation survey draft report.
May 2009	Drill confirmation borehole, prepare orientation survey final report
June 2009	Submit final project deliverables

1.5 Data Quality Objectives

Data quality objectives (DQOs) for geophysical surveys are used to outline procedures that help ensure data quality is sufficient to meet project objectives. Data quality objectives for this project focus on properly functioning equipment, properly trained personnel, data management, and documentation of project activities.

1.5.1 Equipment Function

At the beginning of each survey day, each geophysical system will be assembled, properly warmed-up, calibrated, and tested according to the manufacturer's specifications and recommendations as listed in the operating manual.

1.5.2 Staff Training

No special training or certifications are required for the field data collection team on this project; however, adherence to standard operating procedures described in Section 2.0 and Appendix A of the QAPP is required to ensure compliance with DQOs. The Golder project manager is responsible for training personnel.

1.5.3 Data Management

At the end of each survey day, a back-up copy will be made for each electronic data file, field notebook, and quality control form. Raw geophysical data files will be copied to the Golder network server and archived in the project database. Paper field documents will be scanned and saved in pdf format and stored on the Golder network in the project documents folder.

1.5.4 Project Documentation

The geophysical fieldwork will be documented in the following ways:

- *Field Notebooks*. Bound notebooks with all-weather paper will be used by field staff to document daily field activities. Field notebooks will include:
    - Golder project number
    - Date
    - Names of field personnel

- Survey location
- Weather conditions
- Health and Safety briefing documentation
- Site visitors

- *Quality Control Forms*. Field staff will use forms to document data collection details related to data processing. Quality control forms will include:

  - Golder project number
  - Date and time of measurement
  - Location information
  - Data File Names
  - Instrument, equipment, and model calibration and maintenance information
  - All other field information pertinent to the project

- *Project Reports*. The Golder Project Manager will provide weekly project status reports to the client. These reports will detail current technical and financial progress, and any unusual situations or events impacting the project.

Additional project files may be generated during the course of the project, and will be maintained by the project manager. These files will be a combination of paper and electronic files, and may include such items as communications (telephone, fax, e-mail and written correspondence) between project team members, processed field data, interpretations.

At the completion of the project, Golder will provide field notebooks, quality control forms, project status reports and other communications and electronic data files to the client, if requested.

2.0 DATA ACQUISITION AND PROCESSING

The geophysical survey will be completed in accordance with Golder Associates Technical Procedures and ASTM International standard guides for seismic refraction, seismic reflection, and gravity methods. Golder Associates Technical Procedures for these methods are included in Appendix A. Due to copyright restrictions, the ASTM standard guidelines are not included in an appendix.

Geophysical data collection procedures allow for flexibility in the survey design and equipment requirements. Specific equipment and techniques may vary depending on site conditions. Survey techniques and instrument settings may be changed during the course of the survey as required.

2.1 Seismic Refraction

Perform equipment set-up procedures and functional tests of the equipment as outlined in the operator's manual. Lay out the spread of geophones at equal spacing along the line. Properly connect all geophones to the geophone cable, and connect the geophone cable and trigger wire to the seismograph. Perform a test shot to verify the seismic source triggers the seismograph. Inspect the seismogram to confirm all seismograph channels are recording data and that all geophones are connected and functioning.

Record the following instrument parameters and field geometry in the field notebook.

- Refraction line location; orientation and length
- Geophone interval and location of geophone 1
- Shot number, location and distance to closest geophone
- File name
- Line number and spread number
- Seismic record length in milliseconds
- Sample rate of the seismograph
- Elevation of each geophone

Use a sledgehammer to strike the metal plate on the ground at the first shot location. Verify first arrival shot energy on all channels in the record. If the record is of poor quality more shots may be averaged into the record to enhance the signal-to-noise ratio. When the first arrivals are clearly visible, record the shot in the notebook, store the data file in the memory of the seismograph, and proceed to the next shot location. Normally two forward, one middle, and two reverse shots are recorded for each geophone spread. The distance of the far offset forward and reverse shots will generally be one full length of the geophone spread. When data from the final shot location is recorded, the spread can be moved forward on the same line or picked up and moved to a new line.

Seismic refraction data will be processed using seismic refraction software packages such as SIPT2 (Rimrock Geophysics), FirstPix/Gremix (Interpex Ltd), and SeisImager 2D (Geometrics). The basic data processing procedure is as follows:

- Assign field geometry to each seismic record in the spread
- Enter elevation data for each geophone

- Pick first arrival times
- Assign each arrival time to a seismic layer
- Determine seismic velocities for each seismic layer
- Calculate a depth model
- Plot seismic model

Variations in this procedure may occur, particularly if the Generalized Reciprocal Method (GRM) is used for data processing. Consult the appropriate software manuals for specific details on processing the seismic refraction data.

2.2 Seismic Reflection

Perform equipment set-up procedures and functional tests of the equipment as outlined in the operator's manual. Lay out geophones at equal spacing along the line. Connect all geophones to the geophone cable, and connect the geophone cable and trigger wire to the seismograph. Perform a test shot to verify the seismic source triggers the seismograph. Inspect the seismogram to confirm all seismograph channels are recording data and that all geophones are connected and functioning.

Record the following instrument parameters and field geometry in the field notebook or seismic observer notes.

- Reflection line location; length and orientation
- Geophone interval and location of geophone 1
- Shot number, shot location, and locations of first and last active geophone
- File name
- Line number and spread number
- Seismic record length in milliseconds
- Sample rate of the seismograph
- Elevation information for each geophone

Perform a walk-away test to determine optimum recording parameters, specifically geophone spacing, source offset, source type, record length, and sampling interval. Use a sledgehammer to strike the metal plate on the ground at the first shot location. Verify first arrival shot energy is visible on all channels in the record. If the record is of poor quality more shots may be averaged into the record to enhance the signal-to-noise ratio. When the first arrivals are clearly visible, record the shot in the notebook, store the data file in the memory of the seismograph, and proceed to the next shot location.

Common mid-point reflection profiling is a technique used to produce a continuous profile along the seismic line. Source and geophone locations are generally equally spaced. Source spacing should remain constant at a whole number increment. Each shot location should be offset from the geophones so the optimum range of source-to-receiver offsets is recorded. Each progressive move of the source location along the line should be accompanied by a move of the geophone locations such that the source-geophone geometry remains fixed. This results in a seismic record for each source location. Rolling forward of the source-receiver array can be accomplished using a mechanical roll-along box or within the acquisition software, depending on the seismograph.

Seismic reflection data may be processed using software packages such as Seismic Processing Workshop (Parallel Geosciences), Seistrix (Interpex Ltd.), and Winseis (Kansas Geological Survey. The basic data processing procedure is as follows:

- Reformat field data to proper format for specific software package
- Trace editing
- First arrival muting
- Surgical muting
- Assign field geometry
- Static corrections
- CMP sorting
- Velocity analysis
- Spectral analysis
- Normal move out correction
- Band pass filtering
- CDP stack
- Correct to proper datum
- Plot seismic model

Variations in this procedure may occur. Consult the appropriate software manuals for specific details on processing the seismic refraction data.

2.3 Gravity

Perform equipment set-up procedures and functional tests of the equipment as outlined in the operator's manual. This includes checking the levels, sensitivity, temperature, and reading line of the meter. Determine the location of the regional base station to be used to tie the local survey to gravity station network. Identify a suitable location at each specific survey site to use as a local base station. This should be a relatively flat area on a hard surface, such as a concrete pad or rock outcrop.

Record the following instrument parameters and field geometry in the field notebook.

- Regional base station name, location, and gravity value
- Serial number and calibration constant of gravity meter
- Local base station coordinates and elevation

For each gravity station, record the following:

- Station number
- Station coordinate and elevation
- Gravity measurement 1
- Gravity measurement 2
- Measurement time

Lay out the line or grid of gravity stations. Visit the regional base station and record gravity measurements. Immediately proceed to the local base station and record two measurements. Begin the loop of gravity measurements, recording two measurements for each gravity station. The operator should ensure that the meter is not bumped, regardless of whether the meter's mass is clamped or not. If the gravity meter is bumped during a survey and/or a tare is suspected, the operator must re-occupy the local base station and begin a new loop with the station where the tare is suspected. The local base station should be re-occupied every 3 hours during the survey day. Following the last measurement of the survey day, the local base station, the operator must return to the regional base station to complete final loop of stations.

Gravity data may be processed using seismic refraction software packages such as GravMaster (AOA Geophysics) and Montaj (Geosoft). The basic data processing procedure is as follows:

- Import gravity station data into spreadsheet
- Instrument drift correction
- Earth tide correction
- Latitude correction
- Free-air (elevation) correction
- Calculate a gravity anomaly map or profile
- Calculate gravity depth model

Variations in this procedure may occur. Consult the appropriate software manuals for specific details on processing the gravity data.

3.0 QUALITY ASSURANCE OVERSIGHT PROCESS

3.1 Quality Assurance Review Process

A quality assurance review process will be performed to identify potential problems with the geophysical data and to initiate corrective actions that re-establish DQO's. The assessment will include routine evaluation of the field data with respect to documentation in the field notebook, quality control forms used during data collection, file name, file size, and proper back-up. A field audit may also be performed to confirm data acquisition procedures conform to the technical procedures and ASTM guidelines.

3.2 Quality Assurance Response Actions

Should the assurance review process detect deficiencies with project data or documentation, a response action will be initiated. The nature of a response action will depend upon the severity of the problem, but will begin with a review of field procedures. Generally, there are two types of response action, preventive and corrective. Preventive response actions are measures designed to prevent the problem from being repeated. Corrective response actions are designed to correct the problem.

4.0 DATA VALIDATION

Project documentation will be reviewed on a monthly basis by the quality manager through detailed examination of raw data files, field notebooks, observer logs, and health and safety forms. The quality manager will work with the project manager and field staff members to correct any identified deficiencies in work product.

5.0 QUALITY ASSURANCE PROJECT PLAN IMPLEMENTATION

5.1 Review and Approval Process

This QAPP will be distributed to all personnel and organizations listed on the distribution list. All personnel involved are to sign and date the Approval section of this QAPP and return the signed portion to the Golder project manager. By signing the Approval section, the signatory agrees that he/she has read and understands their role in the geophysical orientation survey, and will adhere to all sections of the QAPP. Additionally, all personnel involved in the project should retain the QAPP for reference throughout the project.

5.2 Review and Revision Process

The QAPP will be periodically reviewed by the Golder project manager who will propose changes, if needed. Any modification to this QAPP will require formal approval by those listed in the Approval section of this QAPP.

6.0 REFERENCES

Budinger & Associates, Inc., 2001, Results of seismic refraction survey, paleo-channel investigation, Airway Heights, WA: Report by Budinger & Associates, Inc., Spokane, Wash. for URS Consultants, Inc., Spokane, Wash., April 27, various pages.

Covert, J., 2007. West Plains Aquifer System – Groundwater Resource Issues. Presentation at West Plains Informational Meeting in Cheney, WA. February 1, 2007.

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Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies, Washington State Department of Ecology, Environmental Assessment Program, Publication No. 04-03-030, July 2004. Revision of Publication No. 1-03-003, February, 2001.

McCollum, L., 2009. Verbal communication between Linda McCollum (Eastern Washington University) and Bryony Stasney (Golder). January 19, 2009.

Standard Guide for Use of the Time Domain Electromagnetic Method for Subsurface Investigation, ASTM Designation: D6820-02, American Society for Testing and Materials, 2007.

Standard Guide for Using the Gravity Method for Subsurface Investigation, ASTM Designation: D6430-99, American Society for Testing and Materials, 2005.

Standard Guide for Using the Seismic-Reflection Method for Shallow Subsurface Investigation, ASTM Designation: D7128-05, American Society for Testing and Materials, 2005.

TetraTech and GeoEngineers, 2007. Water Resource Inventory Area (WRIA) 54 Multi-Purpose Water Storage Assessment. October, 2007.

APPENDIX A

GOLDER ASSOCIATES TECHNICAL PROCEDURES

TP 1.1-9 – TEM Surveying

TP 1.1-14 - Land Seismic Refraction Survey

TP 1.1-15 - Land Seismic Reflection

TP 1.1-17 - Microgravity Surveying

Golder Associates Inc.

Technical Procedure

Number: TP-1.1-9

Title: TEM Surveying (ZONGE Instrumentation)

Prepared By:	Approved	Approved	Effective Date	Rev. Level
[signature]	[signature]	[signature]	8-17-93	-0-
[signature]	[signature]	[signature]	3-11-96	-1-

TP-1.1-9
Rev. 1
RECORD OF REVISIONS

Section	Description of Revisions
2.	Changed Nanotem to NT-20 & throughout
3.	Added more detail to all definitions
7.	Changed gauge size for insulated wire; added specific marked intervals for wire
8.	Expanded Loop Setup procedure
8.4	Revised throughout
8.5 & Exhibit B	Changed Procedure Alteration Checklist to Field Change Request
Exhibit A	Included column for block number

1. PURPOSE

This technical procedure establishes a uniform methodology for executing a Transient Electromagnetic Method (TEM) survey to detect subsurface conditions using ZONGE TEM instrumentation.

2. APPLICABILITY

This technical procedure is applicable to all TEM surveys conducted using ZONGE TEM Instrumentation (GDP-16 receiver, ZT-20 or NT-20 transmitter).

3. DEFINITIONS

3.1 Primary Field

The primary field is defined as the electromagnetic field generated by the transmitter loop when a current is applied to the loop.

3.2 Secondary Field

The secondary field is defined as the electromagnetic field generated by eddy currents induced into the subsurface by the primary field and is a function of the subsurface electrical properties. The receiver measures the decay of this secondary field after the turn-off time of the transmitter.

3.3 Eddy Currents

Eddy currents are defined as the currents induced into the subsurface by the primary field which produce a secondary EM field.

3.4 Turn-off Time (Ramp Time)

Turn-off time is defined as the time required to bring the current in the transmitter loop to zero. Turn-off times vary depending on loop size and the gauge of wire used, but generally range from 20 to 100 microseconds.

3.5 Decay Curve

The decay curve is a plot of the voltage measured by the receiver versus time after the turn-off time of the transmitter. The rate of decay of this field is dependent on the change in resistivity with depth. This curve is used to calculate an apparent resistivity versus time curve.

3.6 Apparent Resistivity

Apparent resistivity is calculated by the instrument based on the measured voltages from the secondary field. It is a bulk measurement and includes a contribution from all subsurface layers within the effective depth of investigation. The resistivity of a homogeneous isotropic ground which would give the same voltage-current relationship as measured.

4. REFERENCES

ZONGE Engineering and Research Organization, Inc., 1992, Instruction Manual for GDP-16 Multi-Function Receiver.

INTERPEX Ltd., 1993, Users Manual for TEMIX Software Version 3.0.

Society of Exploration Geophysicists, 1991, Electromagnetic Methods in Applied Geophysics, Nabighian, M.N., Ed., Vol. 2, 972 pp.

Telford, W.M., Geldart, L.P., Sheriff, R.E., and Keys, D.A., 1976, Applied Geophysics, Cambridge University Press, 860 pp.

5. DISCUSSION

The Transient Electromagnetic (TEM) method is used to identify subsurface structure based on differing electrical properties of rock types. The TEM method can be used to map the bedrock surface, hydrostratigraphic units, groundwater and saltwater intrusion, and explore for ore bodies. A TEM system consists of a transmitter and receiver loop, control console, and power source. The transmitter loop (commonly square and 20 to 500 m on a side) consists of insulated wire laid on the ground and connected to a regulated current source. The receiver can be a multiple-turn coil in the center of the loop or a larger loop that is coincident with, or offset from, the transmitter loop. A current run through the transmitter loop is cycled on and off in pulses of alternating polarity inducing eddy currents into the ground. These eddy currents decay with time, creating a time-varying secondary magnetic field that is measured by the receiver during the time-off cycle. As these eddy currents decay they are increasingly influenced by the electrical properties of deeper layers in the subsurface. As a general rule, the depth of exploration is between one and three times the transmitter loop diameter. A series of measurements made after the turn-off time produce a decay curve which is then used to calculate a resistivity-depth model of the subsurface based on a best-fit to the observed data.

No geophysical method can detect all subsurface features and care must be exercised in decisions based solely on geophysical information.

6. RESPONSIBILITY

6.1 Field Geophysicist

All Field Geophysicists engaged in conducting TEM surveys are responsible for compliance with this procedure.

7. EQUIPMENT AND MATERIALS

- ZONGE GDP-16 receiver console and connecting cables;
- ZONGE ZT-20 or NT-20 transmitter and power cable;
- 2-12 volt batteries;
- High-quality insulated 12 to 20-gauge wire with banana plug leads and marked at intervals equal to the length of one loop side;
- 2-3 tape measures (300 ft);
- Stakes, flagging, and fluorescent paint;
- Field log book; or Field Survey Forms; (see exhibit A);
- ZONGE GDP-16 instruction manual;
- 2 Brunton compasses;
- ZONGE SHRED and TEMAVG, software and users manuals;

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Zonge TEM Survey Form

Job No: ______________________ Location: ______________________

Date: ______________________ Area or Profile Number: ______________________

Operator: ______________________ Weather: ______________________

Instrument Settings: ____

Block Number	Sounding #	Loop Size	Frequency	Cycles	Current	Ramp Time	Total Delay	Comment

EXHIBIT **A**

EXAMPLE ZONGE TEM SURVEY FORM

TECHNICAL PROCEDURE-1.1-9

- INTERPEX TEMIX-Z software and users manual;
- Right-angle prism (optional); and
- Portable computer and printer.

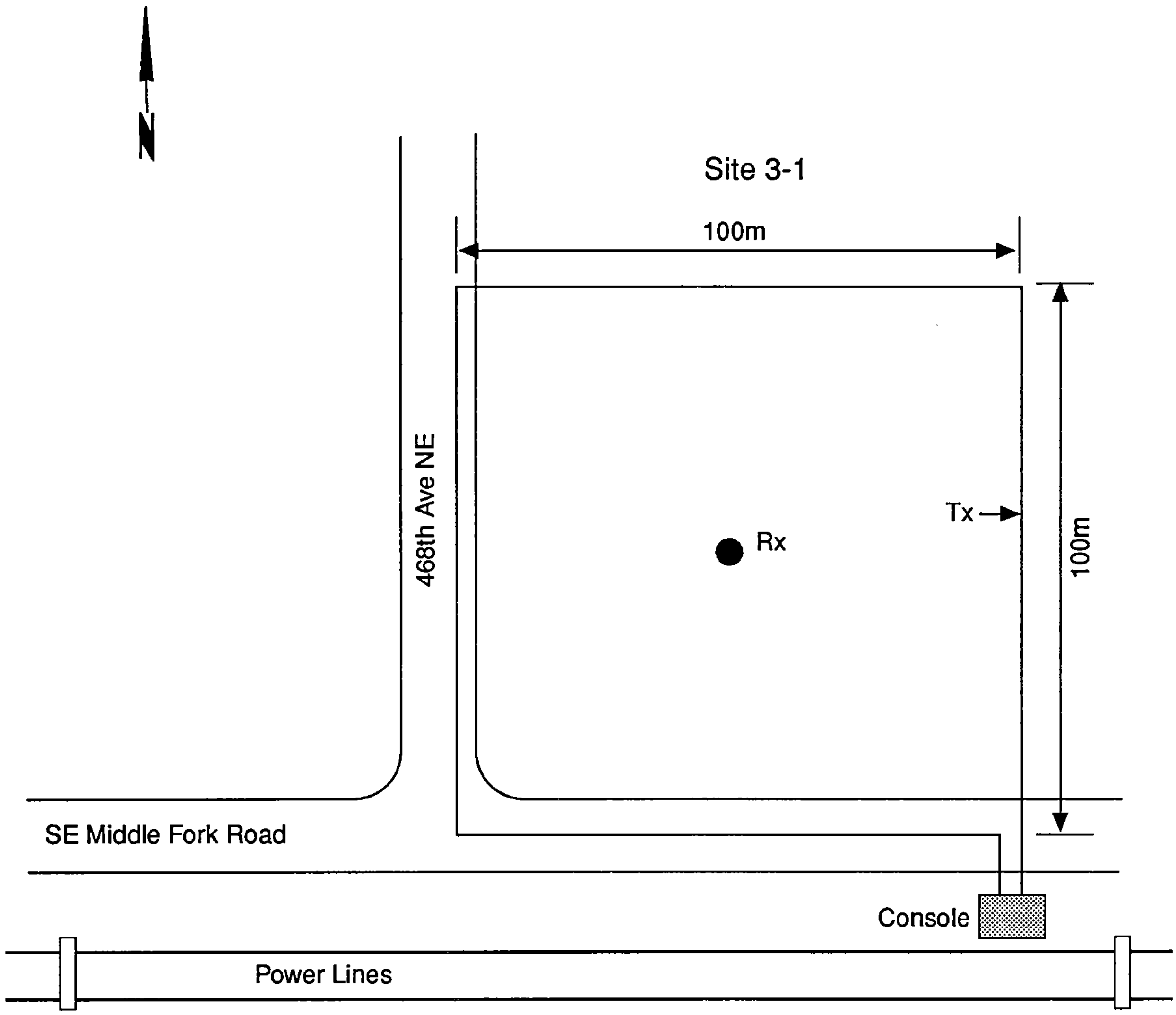
8. PROCEDURE

8.1 Loop Setup

The size of the loop, data density, and the equipment used will depend on the survey objectives. General guidance for survey design is provided here, but each survey will require development of a specific design:

- Determine the loop size based on the depth of interest. A general rule is the maximum exploration depth equals one to three times the loop diameter;
- Select a transmitter mode. In Nanotem mode, the transmitter has a faster turn-off time and should be used for shallow investigations (less than 100 ft). However, in nanotem mode the transmitter is limited to a 12 volt power source and 4 ampere transmitter loop current. This restriction may limit the penetration depth. In zerotem mode, the turn-off time is larger, but larger loops sizes and a higher transmitter current allow deeper penetration depths than Nanotem mode.
- Select wire size. The gauge of wire used determines the current in the transmitter loop and affects the turn-off time. Higher gauge (smaller diameter) wire allows less current to flow and a faster turn-off time than lower gauge wire. Use higher gauge wire for shallow investigations and lower gage wire for deeper investigations.
- Using the resistance of the selected wire and loop size, calculate the input current. Currents of 2 to 10 amperes are commonly needed for TEM exploration.

Lay out the loop using a Brunton compass (or right angle prism) to turn the right angles of a square loop. Use previously established marks on the wire to determine the location of the turns. Flag and label the site location if it will be necessary to reoccupy it. Make a sketch of the sounding loop in the field log book, and note the coordinate references used. Figure 8-1 shows an example survey layout sketch.



Location: 2 miles east of North Bend, WA on Middle Fork Road

FIGURE **8-1**
EXAMPLE SOUNDING LAYOUT SKETCH
TECHNICAL PROCEDURE-1.1-9

8.2 Equipment Set-up and Functional Tests

Perform equipment set up and functional tests of the equipment as outlined in the ZONGE GDP-16 instruction manual.

8.3 Survey Procedure and Documentation

Consult the GDP-16 Instruction Manual to ensure that the proper data collection parameters have been entered into the GDP-16 console prior to recording data. Choose a frequency (repetition rate for cycling the transmitter current) that is appropriate for the site and depth of exploration. Higher frequencies are used for shallow exploration and resistive environments and lower frequencies are used for deeper exploration and conductive environments. Initially, it is good practice to record data at several frequencies.

Record the following information for each sounding station on the Field Survey Forms (Exhibit A) or in the field log book:

- Sounding number or location;
- Data block number for which the header and data are stored;
- Loop size;
- Frequency used for the sounding;
- Number of cycles (stacks) performed;
- The current in the transmitter loop;
- Turn-off (ramp) time displayed on the transmitter;
- The total delay displayed on the TEM transmitter;
- The SEM (standard error of the mean) and V/A (voltage/amperes) at the beginning and end of the sounding and the data window selected. These are read off the GDP-16 during acquisition.
- Other appropriate comments (e.g., surface features, soil conditions, geology)

Each sounding will be repeated three times to evaluate the repeatability of the decay curve.

All field log books, functional test data, and Survey Forms shall be forwarded to the project files.

8.4 Data Processing

All survey data will be downloaded to a computer using a data transfer program like KERMIT. The raw data will be run through SHRED and TEMAVG software to convert the data to a format that can be read by TEMIX-Z. The LFILE mode switch in TEMAVG will be set equal to BOTH so that a [sounding number].EL file is output for each sounding. The [sounding number].EL file displays a comparison of the response at each time window, including the variation in response among the three repeat soundings. This variation will be used to determine the onset of noise on the decay curve.

Subsequent modeling of the data will be performed using the TEMIX-Z software package developed by Interpex. A plot of the measured apparent resistivity curve will be produced for each sounding. A smooth model inversion will be run to produce a stepped resistivity-depth model consisting of as many as 19 subsurface layers. This smooth model will be used to guide the manual input of a discrete model consisting of fewer (normally less than five) layers. This model will be submitted to an TEMIX inversion process that will adjust the model parameters to achieve a best-fit to the measured data. If the inversion process can not converge to a reasonable fit, the initial model will be edited and reprocessed.

Using TEMIX-Z an equivalence analysis will be performed on each of the final discrete models to determine the how well individual layers and resistivities are resolved by the observed data. A plot of the equivalence analysis will be produced.

Consult the TEMIX Users Manual for a more detailed explanation of these data reduction techniques.

Presentation of the data will vary with the survey objectives. Geo-electric cross sections and map-view contour maps resistivity are common forms of presentation.

8.5 Field Change Request

Variation from established procedure requirements may be necessary due to unique circumstances encountered on individual projects. All variations from established procedures shall be documented on Field Change Request (Exhibit B) and reviewed by the Project Manager and the QA Manager.

The Project Manager may authorize individual Field Geophysicists to initiate variations as necessary. If practical, the request for variation shall be reviewed by the Project Manager and the QA Manager prior to implementation. If prior review is not possible, the variation may be implemented immediately at the direction of the Field Geophysicist, provided that the Project

FIELD CHANGE REQUEST

Golder Associates

Job/Task Number: ______________________

Other Affected Documents: ______________________

Requested Change: ______________________

Reason for Change: ______________________

Change Requested by: ______________________ Date ____________

Reviewed by: ______________________ Date ____________
GAI Project Manager

Comments: ______________________

Reviewed by: ______________________ Date ____________
GAI QA Manager

Comments: ______________________

EXHIBIT **B**
FIELD CHANGE REQUEST FORM
TP-1.1-9

Manager is notified of the variation within 24 hours of implementation, and the Field Change Request is forwarded to the Project Manager and QA Manager for review within 2 workingdays of implementation. If the variation is unacceptable to either reviewer, the activity shall be reperformed or action shall be taken as indicated in the Comments section of the Field Change Request form.

All completed Field Change Request forms shall be maintained in project records.

IP3-1024/0914TT1.TP

Golder Associates

Technical Procedure

Number: TP-1.1-14
Title: LAND SEISMIC REFRACTION SURVEY

Prepared by	Approved by	Approved by	Effective Date	Rev. Level
[signature]	[signature]	[signature] 2-1-96	2-16-96	-1-

TP-1.1-14

Revision 1

RECORD OF REVISION

Section	Description
7.	Expanded list of equipment and materials
8.3 and Figure 1	Added seismic refraction data sheet
8.4	Added new section for explosives procedure and documentation
Figure 2	Added new Blasting Record form
8.6 & Figure 3	Changed Procedure Alteration Checklist to Field Change Request

1. PURPOSE

This technical procedure establishes uniform methodology for executing a shallow seismic refraction survey to map subsurface structures.

2. APPLICABILITY

This technical procedure is applicable to all seismic refraction surveys using Bison, or equivalent, instrumentation.

3. DEFINITIONS

3.1 P-waves. Compressional or sound waves that have the highest velocity of all the seismic waves.

3.2 First arrivals. The first wave to arrive at a geophone from a seismic source.

3.3 Geophone spread. The arrangement of geophones in relation to the position of the energy source.

4. REFERENCES

Haeni, F.P., 1988, Application of Seismic-Refraction Techniques to Hydrologic Studies: U.S. Geological Survey, Techniques of Water-Resources Investigations of the U.S.G.S., Book 2, Chapter D2, U.S. Government Printing Office, Washington, D.C.

Bison Instruments, Inc., 1990, Bison 7000 Series DIFP Seismograph Instruction Manual, Minneapolis, Minnesota.

5. DISCUSSION

Seismic refraction methods measure the time it takes for a P-wave generated by a sound source to travel down through the layers of the Earth and back up to detectors placed on the land surface. By measuring the traveltime of the sound wave and applying the laws of physics that govern the propagation of sound, the subsurface geology can be inferred. The field data, therefore, will consist of measured distances and seismic traveltimes. From this time-distance information, velocity variations and depths of individual layers can be calculated and modeled.

The seismic refraction method depends on the seismic velocity of the subsurface material increasing with depth. Geologic layers that have a seismic velocity slower than the layer above it can not be detected. Also, layers that do not have a significant velocity contrast from the surrounding layers or are relatively thin can not be detected.

The total depth of exploration for the seismic refraction method is limited by the power of the seismic source and the space available for the survey. The sources described in this procedure can detect layers to a depth of 100 feet in good conditions. Deeper exploration is possible with using more powerful explosives such as Kinestik.

6. RESPONSIBILITY

6.1 Field Geophysicists

All field geophysicists engaged in conducting seismic refraction surveys are responsible for compliance with this procedure.

7. EQUIPMENT AND MATERIALS

- Bison 7000 24 channel seismograph or equivalent
- 24 vertical geophones, 7 to 15 Hz
- Geophone cable with takeouts at 10 to 50 ft intervals
- Sledgehammer with plate
- Inertia trigger switches
- Trigger cable
- Blaster and appropriate cables (optional)
- Electric trigger shotgun shells (optional)
- Shovel (optional)
- Stakes, flagging, and compass
- Field logbook
- Bison 7000 operating manual
- Day boxes (optional)
- Kinestik blasting agents (optional)
- Detonators - Class C or 1.10 (optional)
- Seismic Data Sheets
- Blasting Record forms (optional)
- MSHA - approved ohmmeter (optional)

8. PROCEDURE

8.1 Establish the Survey Line

Establish an origin (Station 0) and reference the line from this origin to compass bearings. Previously established survey control coordinates should be used wherever possible. Otherwise, reference the origin to a significant landmark.

8.2 Equipment Set-up and Functional Tests

Perform equipment set up procedures and functional tests of the equipment, as outlined in the Bison 7000 operating manual. Lay out geophone lines and place geophones at 5 to 50-foot intervals along the survey line. Properly connect all geophones to the appropriate takeout and connect all geophone lines and trigger cables to the seismograph.

Perform a test shot using the sledgehammer as the seismic source. All shot locations should be in line with the geophones or only offset a short distance from this line. Print the results and verify that all channels are functioning and that the recording time and field geometry are correctly set on the seismograph.

8.3 Survey Procedure and Documentation

Record the following instrument parameters and field geometry in the field logbooks or on the seismic refraction data sheet (Figure 1):

- Geophone interval and location of Geophone #1;
- Shot number, location and distance to closest geophone;
- Shot direction: near (closest to the first geophone), middle (between the first and last geophones), far (closest to the last geophone);
- Seismic record length in milliseconds;
- Sample rate of the seismograph;
- Spread number;
- Record file name.

Using a sledgehammer or shotgun shells at the first shot location, record the shot and store the record in the digital memory of the seismograph. Print the record and verify that all first arrivals are visible. If the record is of poor quality more shots may be averaged into the record to enhance the signal to noise ratio or the shot may be completely redone.

When the first arrivals are clearly visible on the record then proceed to the next shot location and repeat the above steps. Normally, two forward, one middle and two reverse shots will be recorded into each geophone spread. The offset of the forward and reverse shots from the closest geophone depends on the objectives of the survey.

More than one geophone spread may be required in order to completely cover the length of the seismic line. When this occurs the spread number of each shot should be noted in the field logbook.

The relative elevation changes along the seismic line must be determined. This can be accomplished with a detailed topographic map or with direct measurements with a surveying system depending on the resolution requirements of the seismic survey.

All printouts, digital records and field logbooks shall be forwarded to the project files.

8.4 Explosives Procedure and Documentation (optional)

The field person in charge of the storage, transportation and use of 1.1D (Class C) or 1.4D (Class A) explosives shall have completed a MSHA approved blasting safety training course or equivalent, and shall have all necessary state, county, or city licenses or permits for the particular job location. This person shall be referred to as the "blaster" in this section.

The blaster shall insure that the handling, storage, transportation, and detonation of the explosives is done in accordance with federal, state, and local regulations. It is strongly recommended that only 1.1D (Class C) detonators and Kinestik blasting agents, or equivalent, be used. These products are much safer to use than 1.4D (Class A) explosives and, thus, have less stringent regulations.

The blaster shall record the following purchase information on the Blasting Record form (Figure 2):

- Description of detonators and blasting agents
- Name and location of supplier
- Date and quantity purchased
- Code date of detonators and blasting agents

The blaster shall also inventory the explosives every day and record the following information on the Blasting Record form:

- Location of detonations
- Design of shot (amounts and depths of burial)
- Date used
- Seismic line number and number of individual shots per line
- Number used and remaining of detonators and blasting agents
- Time of air blasts

The blaster shall sign the Blasting Record form and forward the original to the explosives records file with the office manager and a copy to the project file.

8.5 Data Reduction

All shot records will be downloaded from the seismograph to a computer for further processing and interpretation. The files may be transferred from the seismograph using the data transferring program MENU. Consult the Bison 7000 manual for specific details on data downloading.

The seismic refraction data may be processed using a variety of seismic refraction software packages such as SIP (Rimrock Geophysics, Golden, CO), SeisREFA (Oyo Corp., Houston, TX) or ViewSeis (ViewLog Ltd., Toronto, Canada). The basic processing procedure is as follows:

- Assign field geometry to each seismic record;
- Enter elevation changes along the seismic line;
- Pick the times of the first arrivals;
- Assign each arrival to a seismic layer;
- Determine seismic velocities of each layer from the data or other sources;
- Calculate and plot a depth model.

Variations in this procedure may occur especially if the Generalized Reciprocal Method (GRM) is used. Consult the appropriate software manuals and references for specific details on processing the seismic refraction data.

The results of the depth model may be displayed in a cross-section or plotted on a map depending on the requirements of the project.

8.6 Field Change Request

Variations from the established procedure requirements may be necessary due to unique circumstances encountered in the field. All variations from established procedures shall be documented on Field Change Request (Figure 3) and reviewed by the Project Manager and the QA Manager.

The Project Manager may authorize individual Field Geophysicists to initiate variations as necessary. If practical, the request for variations shall be reviewed by the Project Manager and the QA Manager prior to implementation. If prior review is not possible, the variation may be implemented immediately at the direction of the Field Geophysicist, provided that the Project Manager is notified of the variation within 24 hours of implementation, and the Field Change Request is forwarded to the Project Manager and QA Manager for review within 2 working days of implementation. If the variation is unacceptable to either reviewer, the activity shall be repeated or action shall be taken as indicated in the Comments section of the checklist.

All completed Field Change Requests shall be maintained in project records.

Golder Associates

SEISMIC REFRACTION SPREAD DATA SHEET

PROJECT NAME:		LINE & SPREAD #:	
JOB #:		DATE:	
FIELD CREW:			

LINE GEOMETRY

Geo.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Shot Loc.:																								
Spacings:																								
Locations:																								

SKETCH OF LINE LOCATION

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1		2		3		4		5		6		7		8		9		10		11		12	

Shot #/Near, Far, Mid/ Geo#	File #	Shot Loc.	Shot Offset X/Y	Source Type/ Stacks	Source depth	Sample rate/ # of samples	Delay (ms)	Filters (HC/LC)	Saved	Print	Time

FIGURE 1

SEISMIC REFRACTION SPREAD SHEET FORM

TP-1.1-14

IP3 1024/SRSDS 1.1.14

Golder Associates

BLASTING RECORD
Golder Job Number:

Federal BATF License
9WA017206D12068

PURCHASE RECORDS (attach original documents)

Detonator Description	Company	Location	Date	Qty #	Code Date	Box

Blasting Agents Description	Company	Location	Date	Qty #	Code Date	Box

SHOT RECORDS

Location:
Shot Design:

Date	Seismic Line	# of shots	Cap Count		box	BA Count		box	Comments (Record time of air shots)
			used	remaining		used	remaining		

Page _____ of _____
Copy: Project File

Signature

Date

FIGURE 2
BLASTING RECORD FORM
TP-1.1-14

FIELD CHANGE REQUEST

Job/Task Number: ______________________________

Other Affected Documents: ______________________________

Requested Change: ______________________________

Reason for Change: ______________________________

Change Requested by: ______________________ Date __________

Reviewed by: ______________________ Date __________
GAI Project Manager

Comments: ______________________________

Reviewed by: ______________________ Date __________
GAI QA Manager

Comments: ______________________________

FIGURE 3
FIELD CHANGE REQUEST FORM
TP-1.1-14

Golder Associates

Technical Procedure

Number: TP-1.1-15
Title: LAND SEISMIC REFLECTION

Prepared by	Approved by	Approved by	Effective Date	Rev. Level
[signature]	Robert H. C[signature]	[signature] 2-1-96	2-16-96	-1-

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Verify current revision level prior to use.

Golder Associates

Technical Procedure

Number: TP-1.1-15
Title: LAND SEISMIC REFLECTION

Prepared by	Approved by	Approved by	Effective Date	Rev. Level
[signature]	[signature]	[signature] 2-1-96	2-16-96	-1-

RECORD OF REVISION

Section	Description
8.4	Added new section for explosives procedure and documentation
Figure 1	Added new Blasting Record form
8.6 & Figure 2	Changed Procedure Alteration Checklist to Field Change Request

1. PURPOSE

This technical procedure establishes uniform methodology for executing a shallow seismic reflection survey to map subsurface structures.

2. APPLICABILITY

This technical procedure is applicable to all seismic reflection surveys using Bison, or equivalent, instrumentation.

3. DEFINITIONS

3.1 P-waves. Compressional or sound waves that have the highest velocity of all the seismic waves.

3.2 First arrivals. The first wave to arrive at a geophone from a seismic source. This is a direct or a refracted wave.

3.3 Geophone spread. The arrangement of geophones in relation to the position of the energy source.

3.4 Reflection. Energy from a seismic source that has been reflected from an acoustic impedance contrast between layers within the Earth.

3.5 Common-offset seismic reflection data. Seismic reflection data in which each geophone-shot distance is constant along the profile.

3.6 Common-depth point (CDP) seismic reflection data. Seismic reflection data in which signals that reflect from the same point on a reflector are stacked together.

3.7 Walk-away test. A sequence of seismic records having the first shot at one end of the geophone spread and subsequent shots shifted one geophone spread length away from the geophones.

4. REFERENCES

Davies, K.J. and King, R.F., 1992, The essentials of shallow reflection data processing: Quarterly Journal of Engineering Geology, Vol. 25, pp. 191-206.

Hunter, J.M., Burns, R.M., and Good, A.L., 1980, Optimum field techniques for bedrock reflection mapping with the multichannel engineering seismograph, *in* S.E.G. Preprint Series, Annual Meeting.

Knapp, R.W. and Steeples, D.W., 1986, High-resolution common-depth point seismic reflection profiling: Instrumentation: Geophysics, Vol. 51, No. 2, pp. 283-294.

Steeples, D.W., and Miller, R.D., 1988, Seismic reflection methods applied to engineering, environmental, and ground-water problems: *in* Symposium on the Application of Geophysics to Engineering and Environmental Problems, March 28-31, 1988, Golden, Colorado, sponsored by the Society of Engineering and Mineral Exploration Geophysicists, pp. 409-461.

5. DISCUSSION

The seismic reflection technique depends on the presence of seismic velocity contrasts in the subsurface whereas the seismic refraction method depends on increasing seismic velocity with depth. In many cases the contrasts occur at boundaries between geologic layers, although anthropogenic boundaries such as tunnels and mines also represents contrasts. A seismic source at the surface (e.g. sledge hammer or small explosives) generates a signal which produces echoes (reflections) as the signal comes in contact with seismic boundaries. These echoes are transmitted back to the surface and detected by geophones that are connected to a seismograph. The seismograph records the arrival of these reflections, which are later enhanced by computer processing in order to assist interpretation.

The classic use of seismic reflection techniques involves layered geologic units, but it is also effective to search for anomalies such as isolated sand or clay lenses and cavities. The shallow reflection method has been used successfully in mapping bedrock beneath alluvium and clay units in an aquifer, detecting abandoned coal mines, and in mapping shallow faults.

The common-offset method and common-depth point (CDP) method are two different techniques to collect seismic reflection data. Consult the above references to determine which method is best suited for the project.

This procedure allows for flexibility in the design and equipment requirements for an individual survey. Specific equipment configurations and survey techniques may vary depending on site conditions. Survey techniques and instrument settings may be changed during the course of a survey as required.

6. RESPONSIBILITY

6.1 Field Geophysicists

All field geophysicists engaged in conducting seismic refraction surveys are responsible for compliance with this procedure.

7. EQUIPMENT AND MATERIALS

- Bison 9000 24 channel seismograph or equivalent
- 24 vertical geophones, 40 to 100 Hz
- Geophone cable with takeouts at 10 to 50 ft intervals
- Sledgehammer with plate
- Inertia trigger switches
- Trigger cable
- Blaster and appropriate cables (optional)
- Electric trigger shotgun shells (optional)
- Shovel (optional)
- Roll-along box for CDP data (optional)
- Stakes, flagging, and compass
- Field logbook
- Bison 9000 operating manual

8. PROCEDURE

8.1 Establish the Survey Line

Establish an origin (Station 0) and reference the line from this origin to compass bearings. Previously established survey control coordinates should be used wherever possible. Otherwise, reference the origin to a significant landmark.

8.2 Equipment Set-up and Functional Tests

Prior to field work, the geometry of the geophone spread and instrument parameters must be determined based on the expected geology and the objectives of the survey. Consult article by Knapp and Steeples (1986) for specific details.

Perform equipment set up procedures and functional tests, as outlined in the Bison 9000 operating manual. Lay out geophone lines and place geophones at 5 to 20-foot intervals along the survey line. Properly connect all geophones to the appropriate takeout and connect all geophone lines and trigger cables to the seismograph. If a roll-along box is needed for CDP data then that should be connected between the geophone cables and the seismograph.

Perform a walk-away test using the sledgehammer as the seismic source. All shot locations should be in line with the geophones or only offset a short distance from this line. The first shot should be at most a few feet away from the first geophone and the subsequent shots should be spaced at intervals no greater than the length of the geophone spread. Print the results and verify that all channels are functioning and that the recording time and field geometry are correctly set on the seismograph. Consult article by Hunter, Burns and Good (1980) for specific information.

8.3 Survey Procedure and Documentation

Record the following instrument parameters and field geometry in the field logbook:

- Geophone interval and location of Geophone #1;
- Shot number, location and distance to closest geophone;
- Seismic record length in milliseconds;
- Sample rate of the seismograph;
- Spread number;
- Roll-along box station number (optional);
- Record file name.

Using a sledgehammer or shotgun shells at the first shot location, generate the sound, record the shot and store the record in the digital memory of the seismograph. Print the record and verify that all reflections of interest are visible. If the quality of the record is poor, more shots may be averaged into the record to enhance the signal-to-noise ratio or the shot may be completely redone.

The next shot location is shifted towards the geophone spread the distance of one geophone interval. If CDP data is being collected then the roll-along box should be advanced to the next station. Continue the above steps until data has been collected along the entire spread. If a longer seismic line is required, then the geophone spread and all other equipment should be shifted to the next segment down the line.

The relative elevation changes along the seismic line must be determined. This can be accomplished with a detailed topographic map or with direct measurements with a surveying system depending on the resolution requirements of the seismic survey.

All printouts, digital records, field maps, field logbooks and any other pertinent notes shall be forwarded to the project files.

8.4 Explosives Procedure and Documentation (optional)

The field person in charge of the storage, transportation and use of 1.1D (Class C) or 1.4 D (Class A) explosives shall have completed a MSHA approved blasting safety training course or equivalent, and have all necessary state, county, or city licenses or permits for the particular job location. This person shall be referred to as the "blaster" in this section.

The blaster shall insure that the handling, storage, transportation, and detonation of the explosives is done in accordance with federal, state, and local regulations. It is strongly recommended that only 1.1D (Class C) detonators and Kinestik blasting agents, or equivalent, be used. These products are much safer to use than 1.4D (Class A) explosives and, thus, have less stringent regulations.

The blaster shall record the following purchase information on the Blasting Record form (Figure 1):

- Description of detonators and blasting agents
- Name and location of supplier
- Date and quantity purchased
- Code date of detonators and blasting agents

The blaster shall also inventory the explosives every day and record the following information on the Blasting Record form:

- Location of detonations
- Design of shot (amounts and depths of burial)
- Date used
- Seismic line number and number of individual shots per line
- Number used and remaining of detonators and blasting agents
- Time of air blasts

The blaster shall sign the Blasting Record form and forward the original to the explosives records file with the office manager and a copy to the project file.

8.5 Data Reduction

All shot records will be downloaded from the seismograph to a computer for further processing and interpretation. The files may be transferred from the seismograph using the data transferring program MENU. Consult the Bison 9000 manual for specific details on data downloading.

The data can be processed with Seistrix 3 (Interpex, Golden, Colorado) or an equivalent software package. Consult the Seistrix 3 manual and the article by Davies and King (1992) for specific details on processing the seismic reflection data.

A cross-section of the seismic reflection data will be created showing the relationship between the two-way travel time and absolute depth. Interpretations of each significant event will be shown on the cross-section. If borehole information from along the line is available then it will be used to calibrate the depth scale of the cross-section.

8.6 Field Change Request

Variations from the established procedure requirements may be necessary due to unique circumstances encountered in the field. All variations from established procedures shall be documented on Field Change Request (Figure 2) and reviewed by the Project Manager and the QA Manager.

The Project Manager may authorize individual Field Geophysicists to initiate variations as necessary. If practical, the request for variations shall be reviewed by the Project Manager and the QA Manager prior to implementation. If prior review is not possible, the variation may be implemented immediately at the direction of the Field Geophysicist, provided that the Project Manager is notified of the variation within 24 hours of implementation, and the Field Change Request is forwarded to the Project Manager and QA Manager for review within 2 working days of implementation. If the variation is unacceptable to either reviewer, the activity shall be repeated or action shall be taken as indicated in the Comments section of the Field Change Request.

All completed Field Change Request shall be maintained in project records.

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Golder Associates

BLASTING RECORD
Golder Job Number:

Federal BATF License
9WA017206D12068

PURCHASE RECORDS (attach original documents)

Detonator Description	Company	Location	Date	Qty #	Code Date	Box
Blasting Agents Description	**Company**	**Location**	**Date**	**Qty #**	**Code Date**	**Box**

SHOT RECORDS

Location:
Shot Design:

Date	Seismic Line	# of shots	Cap Count		box	BA Count		box	Comments (Record time of air shots)
			used	remaining		used	remaining		

Page _____ of _____
Copy: Project File

Signature

Date

FIGURE 1
BLASTING RECORD FORM
TP-1.1-15

IP3 1024/BR1.1.15

FIELD CHANGE REQUEST

Golder Associates

Job/Task Number: ______________________

Other Affected Documents: ______________________

Requested Change: ______________________

Reason for Change: ______________________

Change Requested by: ______________________ Date ____________

Reviewed by: ______________________ Date ____________
GAI Project Manager

Comments: ______________________

Reviewed by: ______________________ Date ____________
GAI QA Manager

Comments: ______________________

Golder Associates Inc.

FIGURE 2
FIELD CHANGE REQUEST FORM
TP-1.1-15

Golder Associates

Technical Procedure

Number: TP-1.1-17
Title: MICROGRAVITY SURVEYING

Prepared by	Approved by	Approved by	Effective Date	Rev. Level
Ian Bishop 10/20	[illegible] 10/24	[illegible] 10/28/96	11-5-96 ~~21 Oct 96~~	-1-

RECORD OF REVISION
TP-1.1-17
Revision 1

Section	Description of Change
Throughout	Minor editorial changes and clarifications
1., 7. & 8.3	Added the utilization of a LaCoste & Romberg model G gravity meter and a Scintrex CG3 or CG3M gravity meter
8.4	Gravity spreadsheet should be run using EXCEL
8.5	Changed Procedure Alteration Checklist to Field Change Request

1. PURPOSE

This technical procedure establishes uniform methodology for executing a microgravity survey to detect subsurface features using a LaCoste & Romberg model D or model G gravity meter, or a Scintrex CG3 or CG3M gravity meter.

2. APPLICABILITY

This technical procedure is applicable to all microgravity surveys conducted using a LaCoste & Romberg or Scintrex gravity meter.

3. DEFINITIONS

A microgravity survey is a remote sensing method used to detect small variations in the earths gravitional field due to variable subsurface densities.

4. REFERENCES

Instruction manual, LaCoste & Romberg model G and D gravity meter, 1992.

Instruction manual, Scintrex Autograv Operator Manual Version 4.4.

5. DISCUSSION

Microgravity surveys are conducted to locate shallow subsurface abandoned mines, karst features, and areas of low density fill. These surveys can be performed in open fields, residential areas, constructions sites, and within buildings. The survey is conducted with a microgravity meter that is used to obtain precise measurements of gravity on evenly spaced grid nodes, typically on 5 m to 20 m centers, over the site.

6. RESPONSIBILITY

All Field Engineers engaged in conducting microgravity surveys are responsible for compliance with this procedure.

7. EQUIPMENT

- Gravity meter unit consisting of either a LaCoste & Romberg model D or model G gravity meter or a Scintrex CG3 or CG3M gravity meter with electronic levels and electronic readout, carrying box, base plate, two batteries, and battery charger.
- Combined steel rule and level, aka builders level (optional)
- Field logbook
- Time piece (decimal hours)
- LaCoste & Romberg model D or model G gravity meter operating manual with calibration table or Scintrex Autograv Operator Manual for the CG3 instruments

- Spare fuses and lamps, allen adjusting tool, electricians screw driver as required
- Laptop computer with EXCEL
- GRAVPROC spreadsheet
- Stakes, flagging, marker pens and/or fluorescent paint as required

8. PROCEDURE

8.1 Grid Survey

The surveyor will set out and survey in a regular metric grid using an EDM type surveying instrument. The spacing of the grid will be specified by the project manager. If possible, the grid should be referenced to an ordinance datum or previously established survey control coordinates. Otherwise, the primary axes should be referenced to compass bearings and related to significant landmarks.

Each station in grid should be referenced by a unique alphanumeric code such as (OE ON), OE, 5N or A, B, C .... for the rows and 1, 2, 3 ... for the columns, i.e., A1, A2, etc. The surveyed point should be a recognizable point, for example it could be the top of a wooden peg or the top of a survey nail. The X and Y co-ordinates should be accurate to +/-2cm. The data supplied by the surveyor should contain the station name, X and Y in meters and Z in centimeters. The ground around the survey station should be level enough to allow successful operation of the gravity meter. If there is an obstacle in the way, such as a tree, boulder, wall, etc., the station should be displaced along one of the grid lines by up to 1 m.

The surveyor will also record the co-ordinates of one or more base stations which may be in use during the survey and whose location does not fall on an existing survey station.

8.2 Equipment Set-Up and Functional Tests

Perform equipment set-up procedures and functional tests of the equipment as outlined in the relevant meter operating manuals, this includes checking the levels, sensitivity, temperature and the reading line.

If applicable, make a traverse with the equipment over a geologically characterized calibration site, and record the relative gravity readings in the field logbook for comparison with previous visits to the site.

8.3 Microgravity Survey Procedure and Documentation

At the start of the survey, the operator should record his name, date, site details, the serial number of the meter and the meter's calibration constant(s) in the field logbook.
Prior to starting the survey a position for a base station location must be found. If possible, this station should be within the survey grid but situated on a piece of solid level ground such as a concrete floor or an outcrop with a flat surface. This station should be labelled so that the surveyor can survey its position. A sketch should be made of the location of the base

station and its surroundings. A second sketch should be made of the entire survey grid, noting the whereabouts of buildings, fences and any other features of interest.

This base station will be visited at the start and end of the survey day and at hourly intervals in between to record instrumental fluctuations and earth tides. The base plate should be firm and not wobble. The machine should then be levelled using to the accuracy of the electric levels. The machine should be brought in to range as per the manual. For a LaCoste and Romberg meter, the counter should be between 90 and 110 machine units during this exercise. If the ambient temperatures are much warmer or cooler than the overnight storage temperatures for the meter, a period of time should be allowed for to allow the meter to stabilize.

To take a reading on a LaCoste and Romberg meter, the meter should be unlocked, and the nulling dial turned clockwise so that the null position of the galvanometer is always approached from the left hand side. If overshoot occurs, the null dial must be turned back, and the measure redone.

A minimum of four readings should be taken during each visit to the base station, three of which should be within +/-1 microgal (Model D or CG3m) or ±10 microgal (Model G or CG3). These should be written in the field logbook along with the time that each reading was taken and the name of the station. The base plate and machine should be placed in the same position every time the base station is visited. For a LaCoste and Romberg meter, the meter should be locked after the last reading and prior to moving the machine.

Following the visit to the base station, the grid should be traversed along successive lines, with the meter being operated in the same way as at the base station.

The operator should ensure that the meter is not knocked, whether the meter's mass is locked or unlocked. If the machine is knocked during a survey and/or a tare is suspected, the operator should revisit the current station after returning from an extra visit to the base station.

If, due to the size of the survey area, more than 1 base station is required, the base stations should be tied in by a minimum of five visits between the main base station and each of the other sub base stations.

All field logbooks and functional test data should be forwarded to the project files.

8.4 Data Reduction

At the end of each day, or after reasonable survey periods, the note book data should be typed into the gravity spreadsheet that runs under EXCEL. These data will comprise the station name, the average time and gravity reading for each station visit. The data measured during the base stations visits will also be added to this spreadsheet. The survey data will also be added to this spreadsheet, in the designated columns. There is a separate sheet for each day of data acquisition. The sheets are labelled according to the following example:

- Data acquired on September 24th.
- Sheet is called SEPT24.

The corrected data for each day of acquisition is then down loaded to an ascii file and combined with all the other days of data. The data is then processed and reduced by in-house software written using the MATLAB function library. Residual or anomaly files are contoured up using the GEOSOFT software system.

All stages of data reduction are backed up to disk and archived.

8.5 Field Change Request

Variations from the established procedure requirements may be necessary due to unique circumstances encountered in the field. All variations from established procedures shall be documented on Field Change Request (Figure 1) and reviewed by the Project Manager and the QA Manager.

The Project Manager may authorize individual Field Geophysicists to initiate variations as necessary. If practical, the request for variations shall be reviewed by the Project Manager and the QA Manager prior to implementation. If prior review is not possible, the variation may be implemented immediately at the direction of the Field Geophysicist, provided that the Project Manager is notified of the variation within 24 hours of implementation, and the Field Change Request is forwarded to the Project Manager and QA Manager for review within 2 working days of implementation. If the variation is unacceptable to either reviewer, the activity shall be repeated or action shall be taken as indicated in the Comments section of the Field Change Request.

All completed Field Change Request shall be maintained in the project records.

TP1-1-17.rv1

FIELD CHANGE REQUEST

Golder Associates

Job/Task Number: ______

Procedure Reference: ______

Other Affected Documents: ______

Requested Change: ______

Reason for Change: ______

Change Requested by: ______ Date ______

Reviewed by: ______ Date ______
Project Manager

Comments: ______

Reviewed by: ______ Date ______
QA Manager

Comments: ______

Golder Associates Inc.

FIGURE **1**

FIELD CHANGE REQUEST FORM

TP-1.1-17

PROJECT NO. IP3 1024.200 DRAWING NO. 68042 DATE 9/9/96 DRAWN BY EA

Golder Associates