NOTICE

All drawings located at the end of the document.

Phase II Geologic Characterization Data Acquisition

Appendix F Shallow High-Resolution Seismic Reflection Surveying Geologic Characterization of the Rocky Flats Plant Indiana Street Work Plan

U S Department of Energy
Rocky Flats Plant
Golden, Colorado

January 1992

EG&G Rocky Flats, Incorporated

ADMIN RECORD

REVIEWED FOR CLASSIFICATION/UCNI
By
Date 5/12/92

PHASE II GEOLOGIC CHARACTERIZATION DATA ACQUISITION

APPENDIX F

Work Plan

Shallow High-Resolution Seismic Reflection Surveying
Geologic Characterization of the Rocky Flats Plant
Indiana Street

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EG&G ROCKY FLATS, INC.
AGREEMENT NO BA 56800PB
WORK ORDER NO BA 70774EB

ADMIN RECORD

REVIEWED FOR CLASSIFICATION/UCNI
By [illegible]
Date 5/12/92

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LIST OF ACRONYMS AND ABBREVIATIONS

CDP - Common Depth Point

CFR - Code of Federal Regulations

dB - Decibell

DOE - Department of Energy

DQO - Data Quality Objective

EBASCO - Ebasco Services Incorporated

EG&G - EG&G Rocky Flats Incorporated, EG&G Geometrics Incorporated

ft - Foot, feet

FQAC - Field Quality Assurance Coordinator

GPR - Ground Penetrating Radar

HR - High-resolution

Hz - Hertz

ms - Millisecond

NRC - Nuclear Regulatory Commission

OU2 - Operable Unit 2

RFP - Rocky Flats Plant

S/N - Signal to noise ratio

SEG - Society of Exploration Geophics

VSP - Vertical Seismic Profile

1 0 INTRODUCTION

EG&G Rocky Flats, Inc (EG&G) is performing remedial investigations, feasibility studies, and remedial/corrective actions at the Rocky Flats Plant (RFP) under the Department of Energy's (DOE's) Environmental Restoration Program Previous remedial investigations conducted at RFP have identified potential soil and groundwater contamination in the vicinity of the Medium Priority Sites (Operable Unit 2 (OU2)), Solar Evaporation Ponds, and Present Landfill These investigations have also identified the presence of paleochannels and possible faults in the Arapahoe Formation that may serve as potential migration pathways for contaminated groundwater Shallow High-Resolution (HR) seismic profiling has been used to identify the subsurface geology in these remedial investigations Three shallow HR seismic lines comprising 2,400 feet (ft) were acquired along Indiana Street in the summer of 1990 (EG&G) 1991b) * Additional HR seismic is needed to complete the coverage of seismic data along Indiana Street This workplan describes the acquisition parameters and techniques to be used during the collection, processing, and interpretation of 6,350 linear ft of additional HR seismic data along Indiana Street

1 1 GEOLOGIC CHARACTERIZATION PROGRAM

The Phase II geologic characterization program in effect at RFP is designed to identify and characterize contaminant migration pathways around RFP The proposed seismic reflection data will be used in conjunction with other data as part of the overall Phase II geologic characterization of RFP The results of the shallow HR seismic reflection program will be integrated with geologic and hydrogeologic data The integrated data package will be used as a decision tool to accomplish the following·

- Resolve prominent hydrogeological problems (map geologic structure and stratigraphy)
- Provide hydrogeologic data for the design of efficient monitoring and correction systems
- Optimize boring and monitoring well placement

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* All references cited in this workplan are listed in Appendix VI.

- Select hydrostratigraphic units for future studies (pump tests and water quality tests)
- Evaluate the construction and effectiveness of RFP subsurface drainage and water intercept systems.

2 0 GEOLOGY

2 1 GENERAL GEOLOGIC SETTING

Fluvial deposits of the Arapahoe and Laramie Formations are present beneath alluvium at RFP Fluvial deposits are complex geologic systems that often consist of broad, thick deposits of clays and silts of low permeability, and narrow, thin, and localized deposits of relatively more permeable sands The major constituents of fluvial deposits are often clays and silts, which can constitute approximately 90 percent of the sediment volume (Clarke, 1924) These low permeability clay and silt sediments act as hydrologic barriers or aquitards

In general, permeable sands make up a small (10 to 16 percent) volume of the sediments and are narrow, thin, and localized (Clarke, 1924) Sands are often only a few feet thick and a few tens of feet wide. These sands were deposited by ancient rivers and streams in channels many miles long This limited spatial extent makes stratigraphic correlation between boreholes difficult if the borehole spacing is greater than a few tens of feet

Localized sandstone lenses deposited in paleochannels may control the flow dynamics of the groundwater system. These sandstones constitute only a small volume of the total sediment, but because their permeabilities (and hydraulic conductivities) are many orders of magnitude greater than the silts and clays, they may dominate the groundwater system.

Faults and fractures in the Arapahoe, Laramie, and older formations beneath RFP may also play a role in groundwater flow The Rocky Mountain Front Range was uplifted during the Laramide Orogeny in late Cretaceous and early Tertiary time. Faulting associated with the uplift has been recognized east of the actual mountain front by several authors. (Spencer, 1961; Hurr, 1976,

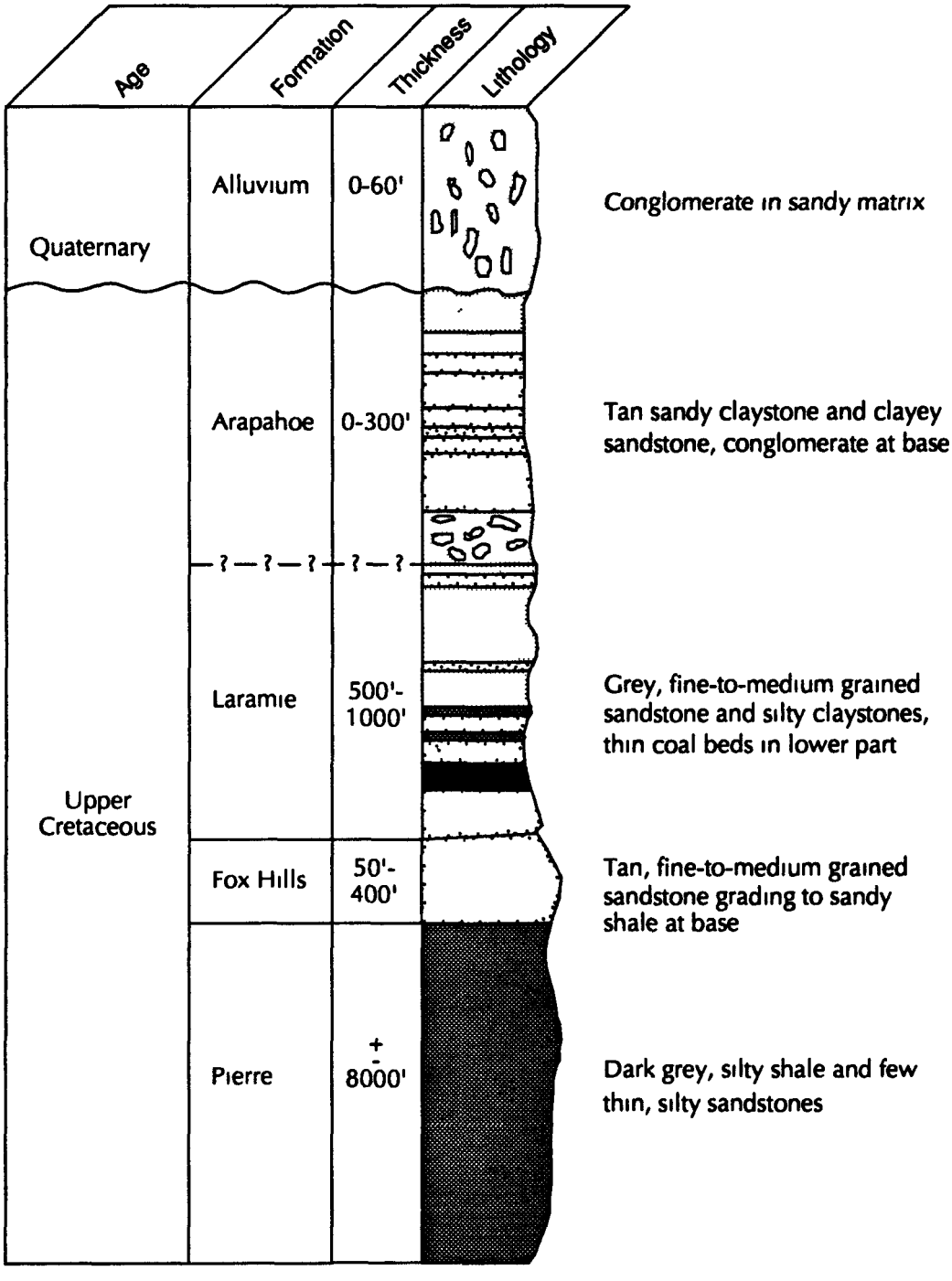
Stone 1985) Seismic data acquired by the Colorado School of Mines at RFP were recently reprocessed to reveal probable faulting in the Pierre shale (ASI, 1989)

2 2 ROCKY FLATS PLANT GEOLOGIC SETTING

RFP is situated on a gently eastward-sloping, relatively flat veneer of Quaternary Rocky Flats Alluvium, deposited unconformably over the erosional surface of the Arapahoe and Laramie Formations (Rockwell, 1987) (Figure 2-1) The Rocky Flats Alluvium is composed of poorly sorted cobbles, pebbles, and gravels in a sandy clay matrix It is deposited in laterally coalescing alluvial fans at the base of the Rocky Mountain Front Range in Colorado (Hurr, 1976) Calcium carbonate-cemented caliche is locally present in the Rocky Flats Alluvium (Rockwell, 1987)

Various other alluvial deposits occur topographically below the Rocky Flats Alluvium Colluvium (slope wash) occurs on the valley side slopes above the valley bottoms, while recent valley fill alluvium is deposited in active stream channels

At RFP, the Cretaceous Arapahoe and Laramie Formations are unconformably overlain by alluvium (Rockwell, 1987) Weimer (1973) suggests that the Arapahoe Formation consists of conglomerate lenses deposited in alluvial fans, overlain and flanked by stratigraphically complex fluvial claystones with interbedded lenticular sandstones and siltstones According to Davis and Weimer (1976), these Late Cretaceous sediments may represent a deltaic facies environment of deposition Specifically, deposition of the various units of the Arapahoe Formation is proposed to have occurred in a braided stream and channel margin environment (Berman et al , 1980) A conceptual model of the depositional environment that produced the Arapahoe Formation in the vicinity of RFP suggests the presence of anastomosing channels (low gradient channels with banks consisting of cohesive sediment derived from suspended load) superimposed upon a more extensive deltaic system (Figures 2-2 and 2-3) Anastomosing channels tend to remain within their banks.



Legend

Conglomerate	Siltstone
Sandstone	Shale
Claystone	Coal

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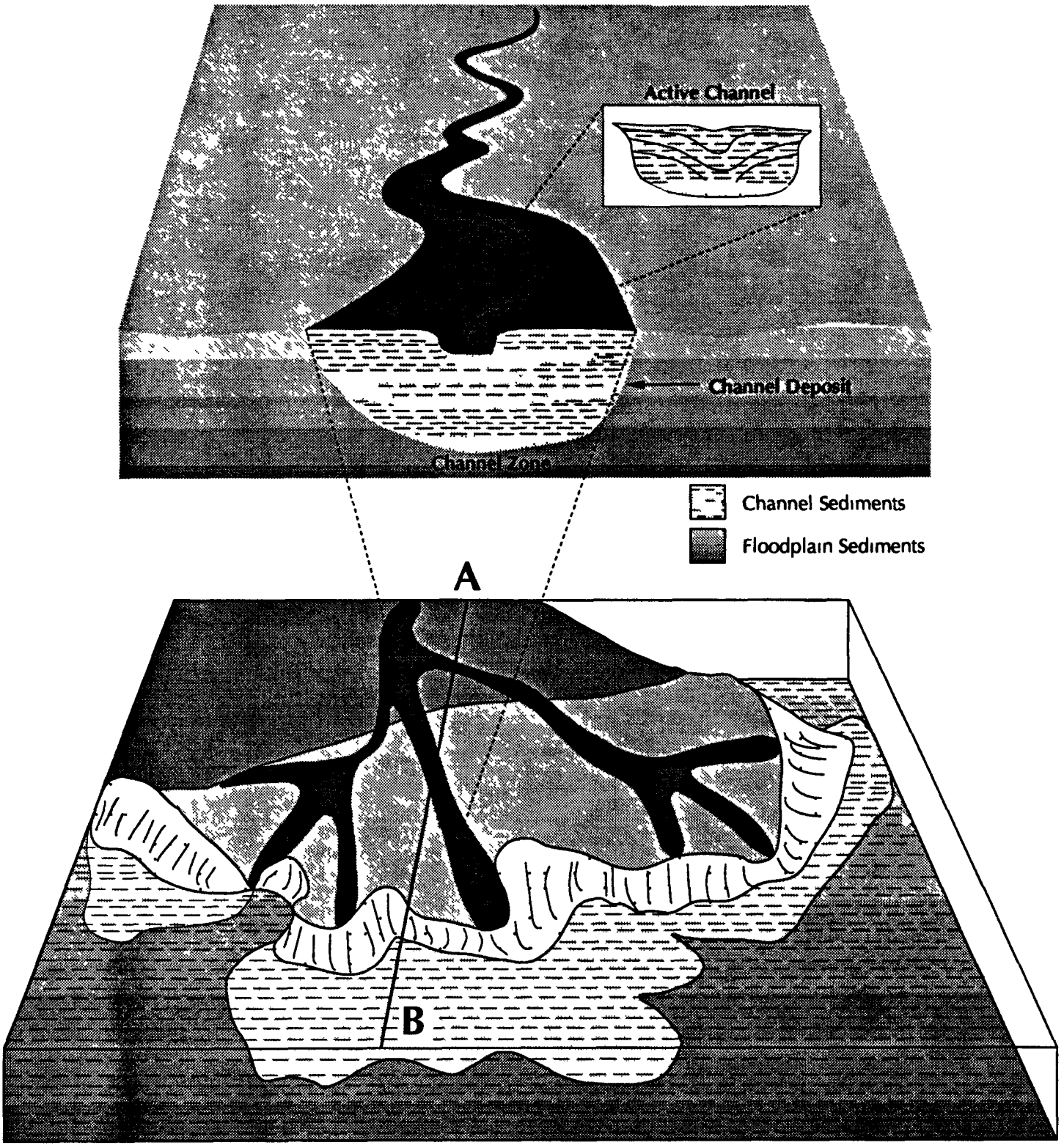
FIGURE 2-1

GENERALIZED STRATIGRAPHIC SECTION, ROCKY FLATS AREA

After LeRoy and Weimer, 1971



Legend

- Floodplain
- Deltaic Plain
- Delta Front
- Prodelta
- Marine Sediments

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Figure 2-2
UPPER CRETACEOUS DELTAIC DEPOSITIONAL MODEL

After Ferm, 1970

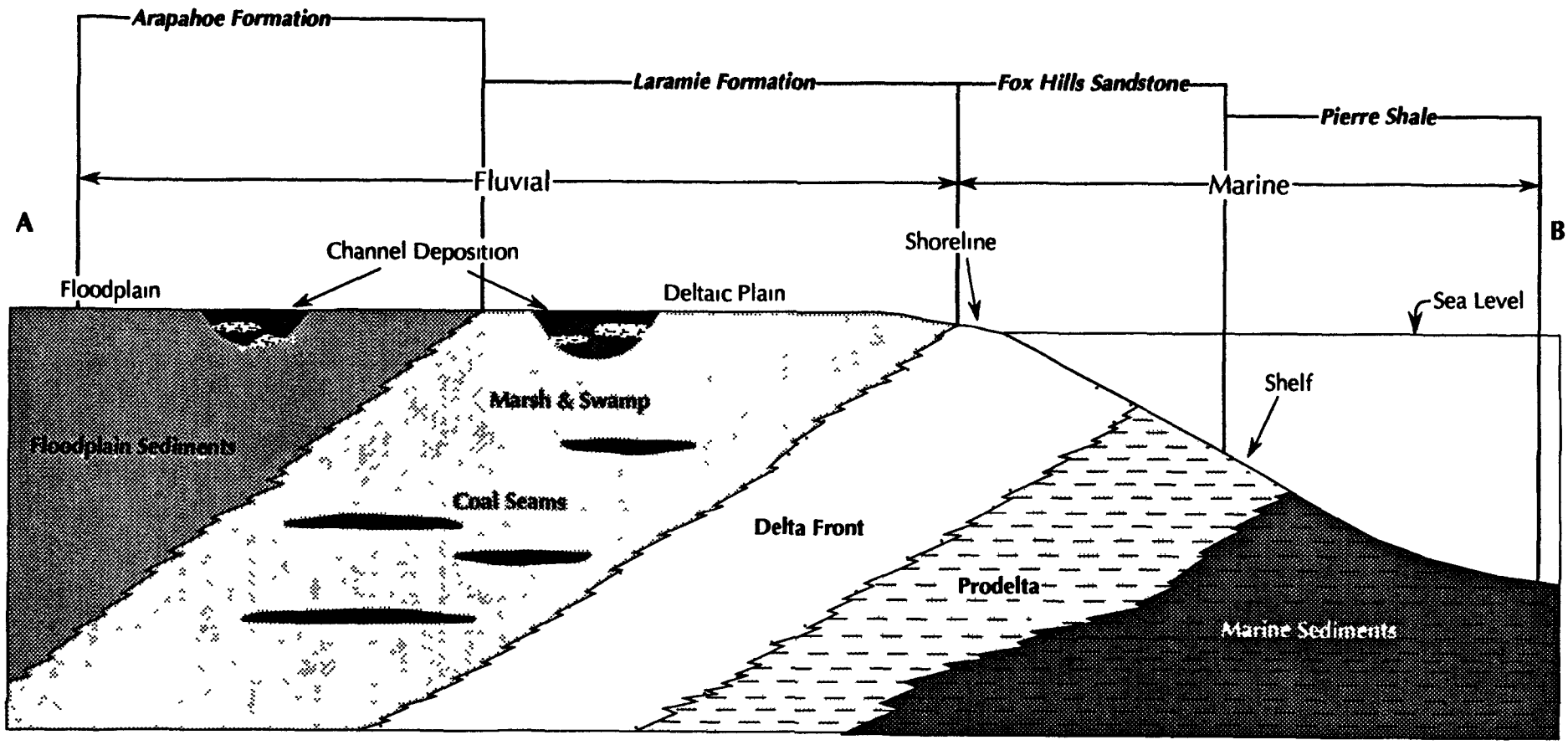

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FIGURE 2-3

UPPER CRETACEOUS DELTAIC DEPOSITIONAL MODEL, CROSS-SECTION A-B

After Ferm, 1970

The postulated deltaic depositional environment of the Arapahoe Formation is supported by evidence gathered during the HR seismic reflection survey field program (Tasks 2 and 3 of the geophysical characterization) performed in spring 1989 (Rockwell, 1989c) Exhibited on seismic profiles are discontinuous, silty, sandstone-filled paleochannels within claystone

The Laramie Formation, which locally underlies the Arapahoe Formation, is comprised of sandstones, siltstones, claystones, and coals deposited in fluvial-deltaic and lacustrine environments (Weimer, 1973). The Laramie Formation can be subdivided into a lower predominantly sandstone unit and an upper, predominantly claystone unit, both of which are exposed in outcrop or are revealed in cores from monitoring wells west and south of RFP (Rockwell, 1987).

3 0 FIELD PROGRAM

The nature of RFP geology requires exploration techniques that provide data with a vertical resolution of a few feet and lateral resolution of tens of feet or less The three current practical technologies with this resolution capability are drilling, ground-penetrating radar (GPR), and seismic reflection. Drilling programs with borehole spacings of 10 to 20 ft are prohibitively expensive Radar wave propagation has limited depth penetration at RFP due to the conductive nature of the near-surface soils (EG&G, 1991a). The combination of seismic reflection and a borehole exploration program, however, will provide the necessary lateral and vertical resolution to delineate the structural and stratigraphic nature of the Arapahoe Formation in a cost-effective manner.

Seismic reflection methods are based on the same scientific principles as radar and sonar Seismic reflection profiling consists of recording acoustic waves that are reflected from subsurface rock layers and fault planes. Recent advances in seismic data processing and seismic recording equipment make it possible to map reflections from thin beds and over much greater depth ranges than previously possible without losing data quality. A seismograph records acoustic vibrations detected by geophones The vibrations are caused by reflections from

geologic beds as thin as a few feet thick and from a depth range starting at 20 ft or less and continuing down to more than 500 ft Using the Common Depth Point (CDP) method of seismic reflection profiling, it is possible to identify and map lithologic beds and structural features (e g , top of bedrock, faults) and make thickness estimates of sandstone lenses Monitor wells and Boreholes may be required in future studies to characterize bedrock sandstones The results of the HR seismic reflection profile can be used as a decision tool to accurately locate subsequent boreholes.

Lithologic and geophysical borehole logging will provide comprehensive data that can be integrated with the seismic reflection data This integrated approach will provide a detailed understanding of the key geologic factors controlling potential contaminant migration

3 1 FIELD PROCEDURES AND DATA ACQUISITION

Seismic data will be collected to fill data gaps between existing seismic data profiles along Indiana Street According to the original Request for Proposal, the desired depth of investigation is 50 to 300 ft below ground surface with a vertical resolution of 3 ft The additional HR Seismic Survey will consist of 6,350 linear ft along Indiana Street in the east buffer zone (Figure 3-1) Three HR seismic profiles (WIN 1, WIN 2, and WIN 3), comprising 2,400 ft, already exist These data were acquired in summer 1990 (EG&G, 1991b) The data to be collected will overlap existing profiles by 100 feet Table 3-1 summarizes the data acquisition parameters that will be used

An EG&G Geometrics ES-2420 Digital Reflection Seismograph (or equivalent) will be used for the shallow HR seismic reflection survey This is a state-of-the-art seismic recorder with the ability to sample seismic data every 0 25 millisecond (ms) This sampling interval will allow detection of seismic events from beds as thin as 3 ft

The custom geophones and cables used during the OU2 HR seismic reflection survey will be used for the Indiana Street survey. For shallow HR seismic reflection work, a maximum distance

TABLE 3-1

Data Acquisition Parameters for the Seismic Survey*

Geophone Station Spacing	2 feet (ft)
Source Spacing	4 ft
Geophones Per Station	1
Geophone Frequency	100 Hertz (Hz)
Spread Length	192 ft
Far Offset	150 ft (approximate)
Cable Geometry	unbalanced split spread
Number of Recording Channels	96
Sample Rate	0 25 millisecond (ms)
Maximum Record Length	500 ms
Low-Cut Filter	100 Hz (or as required from noise tests)
Alias Filter	720 Hz
Filter Slope	18 and 52 decibel (db)/octave (instrument dependent)
Signal-to-Noise (S/N) Ratio	5 1 (minimum)
Common Depth Point (CDP) Fold	24

* Subject to change after review of actual field records

between geophone plugs along the cable (cable takeouts) should be 10 ft or less, as excess cable hinders field work and acts as an antenna for unwanted noise. Geophones will be spaced at 2 ft intervals. High-frequency 100 Hertz (Hz) geophones will be required to record the high-frequency energy necessary for the desired resolution (Knapp, 1988) and used for the Indiana Street Survey.

The seismic energy source to be used during data acquisition is based on source testing done during field tests for the OU2 seismic survey The selection of the energy source is based on several factors including energy and frequency content, repeatability, portability, efficiency, ease of use, and safety The energy source that best meets these criteria and provides optimal data is the industrial 8-gauge blank cartridge The actual cartridge, which looks very similar to an ordinary shotgun shell, is available in several charge sizes; however the 250- to 300- grain charge produced the best results during earlier seismic acquisition. The industrial 8-gauge cartridges are available with either percussion or electric detonation mechanisms. Electric cartridges are preferred because the detonation system has a safe and more reliable timing mechanism

The 8-gauge electric blanks will be buried to a maximum depth of 5 ft The burial of charges prevents blowout after discharge, minimizes the air wave, and maximizes downgoing energy A burial depth of 4 to 5 ft is usually sufficient to minimize the air wave Deeper depths yield results of diminishing quality, and increase the drilling costs Varying near-surface conditions may cause some variation in hole depth

A noise analysis was conducted during previous seismic field tests prior to collecting production data A noise analysis (called a "walkaway") consists of shooting into a normal geophone spread, such as is used in refraction surveying The noise analysis is used to determine the velocities, frequencies, and amplitudes of any surface waves In seismic reflection surveying, surface waves represent unwanted events, and care must be exercised to filter them out The results of the noise analysis allows the geophysicist to design optimum recording parameters, such as the near offset (distance between the closest geophone and a shotpoint) geophone station spacings, and the far

offset (distance between the farthest geophone and a shotpoint) The results of the noise analysis performed prior to data collection on Lines WIN 1, 2, and 3 will be utilized for data collection on Lines WIN 4, 5, 6, and 7.

The 2 ft geophone spacing with shotpoints spaced every 4 ft and the unbalanced split-spread geometry used during previous surveys will be maintained during data acquisition along Indiana Street. However, the acquisition geometry may be modified to distinguish more complex geology (dipping beds). An unbalanced split-spread geometry refers to a situation in which the charge is detonated between one end of a spread and its center This contrasts with a balanced split-spread geometry in which the charge is detonated at the center of the geophone spread The unbalanced split-spread geometry will be used because it inherently emphasizes and improves the resolution at certain depths

The close proximity of the proposed seismic lines to Indiana Street is an important concern as traffic can generate unwanted seismic signals (noise). Increasing the CDP fold will reduce the interfering background noise from vehicular traffic and other random sources such as wind or aircraft flying overhead. This technique of increasing CDP fold is the most commonly employed procedure and is one of the few effective methods to improve data quality in seismic reflection surveying Since increasing fold improves data quality, geological resolution is also improved The resulting increase in data quality will allow for the location, thickness, width, and the edges of the sandstone bodies to be delineated with increased accuracy In addition, qualitative estimation of porosity and sand thickness is often possible with high-quality seismic reflection data.

The data acquisition phase of seismic reflection surveying consists of shooting the seismic source into spreads of geophones The seismograph is configured for 96 recording channels, however, there are a total of 240 takeouts available (when all four geophone cables are connected end to end), each of which can be connected to a geophone. As shooting progresses forward, it is necessary to maintain the spread geometry This could be accomplished by physically moving

the entire spread to maintain the geometric relationships at successive shotpoints or by using an instrument called a roll-along switch A roll-along switch is used to activate geophones at the front of the spread and deactivate geophones at the rear of the spread as the shotpoints advance forward. During acquisition of the additional seismic along Indiana Street, an Input/Output RLS-240M Rota-Long roll-along switch will be utilized

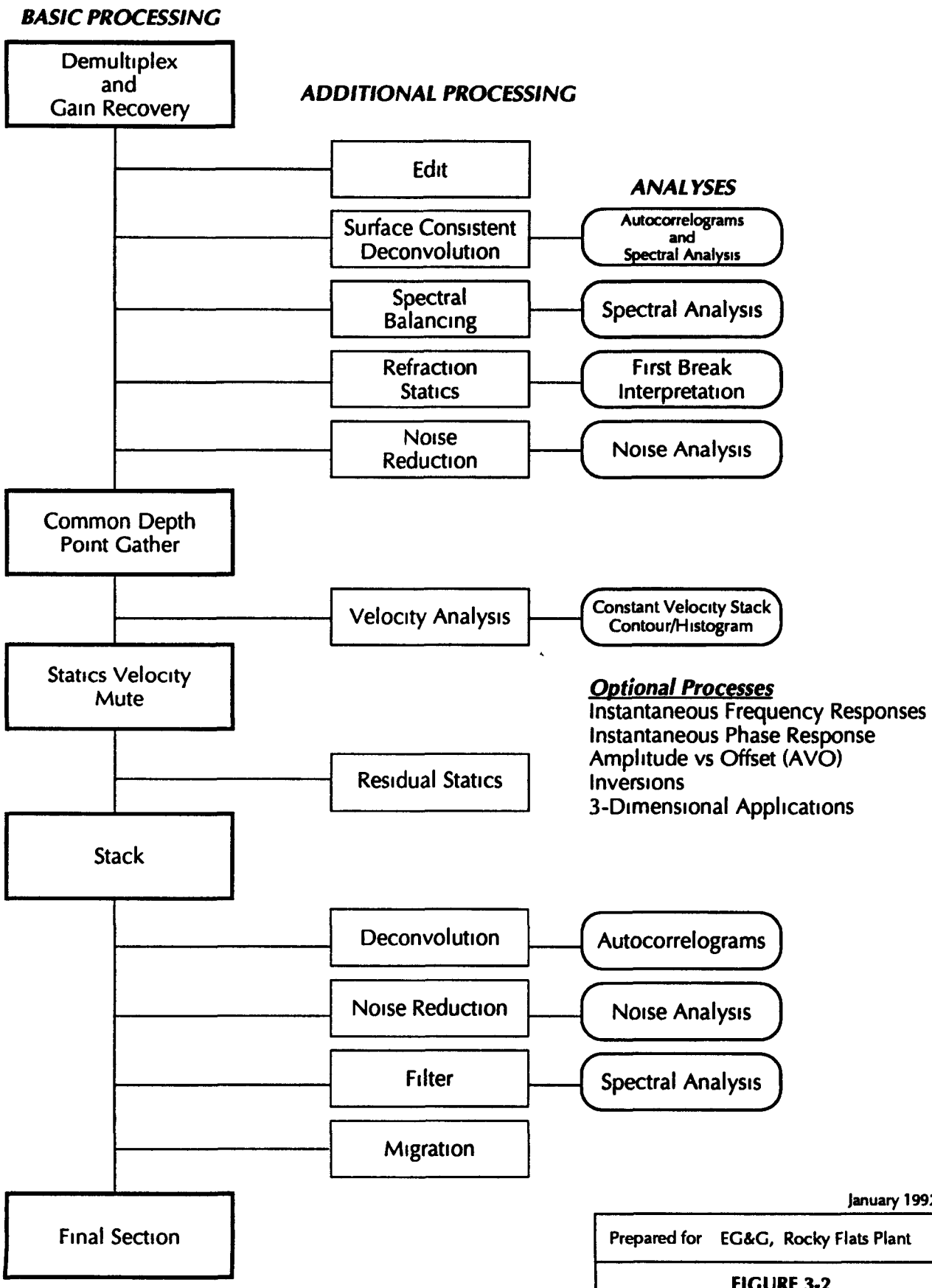
The shooting sequence is designed to provide CDP data along the spread With seismic reflection shooting, subsurface coverage is equal to one-half of the surface coverage of the geophone spread (Appendix I) To enhance the reflection data, shooting is designed to provide a number of different raypaths to the same subsurface point for each geophone For a spread of 24 geophones (if every geophone location also serves as a shotpoint location), the resulting CDP coverage for each geophone is 12 (1,200 percent CDP data). Previous HR seismic reflection experience at the RFP site indicates that 24-fold CDP data are required to image the paleochannels zones

All seismic reflection data will be recorded to a 9-track computer tape in SEG D format (SEG, 1980) Field tapes and survey data will be sent to the seismic data processing center for analyses.

3 2 DATA PROCESSING

The processing sequence (Figure 3-2) includes a variety of computer programs that are normally applied to CDP seismic data. These programs have many functions including sorting data traces into CDP format, applying static and velocity functions, editing and removing unwanted noise, enhancing frequency content, scaling the data for presentation, migrating data to remove raypath imaging problems, plotting the data, and enhancing data presentation.

Computer processing flow decisions are made by the processing geophysicist in consultation with the project geophysicist at various steps to ensure and improve data quality The exact processing flow is designed after data acquisition and initial data analysis The end result of data



January 1992

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FIGURE 3-2
SEISMIC DATA PROCESSING ROUTINES
After Sheriff, 1984

processing operations is the generation of two-dimensional seismic profiles representing geologic cross-sections through the earth.

3 3 DATA ANALYSIS AND INTERPRETATION

The objective of seismic data analysis and interpretation is to identify seismic events that relate to the geological features. Once the stratigraphic and structural relationships have been identified on the seismic profile, a thorough analysis of the profile and adjacent boreholes will be completed. This process will permit correlation between notable seismic features seen on the profile and the geologic character seen in borehole data. Often, particular reflections have distinctive characteristics that can be identified and correlated throughout a site For example, well-cemented sandstone units exhibit high acoustic impedances, and their responses are positive reflection events (Appendix I). On the other hand, coals result in low acoustic impedances and strong negative reflection events (Crowder et al , 1987).

The integration of existing geological and hydrological data with the seismic data interpretation will produce a geologic cross-section of the subsurface along the seismic line The seismic data will allow a detailed and continuous geological cross-section to be constructed between existing wells Continuous marker beds will be mapped and correlated between the wells and along the section profile. The seismic data are expected to identify and delineate important paleochannel deposits The identification and mapping of permeable zones in the Rocky Flats Alluvium and Arapahoe and Laramie Formations will be of particular interest

4 0 DATA QUALITY OBJECTIVES

Development of data quality objectives (DQOs) was initiated during Task 3 of the OU2 geophysical characterization. (Rockwell, 1989d)

DQOs have been developed considering the following concepts

- Precision - describes the acceptable degree of precision for the proposed activity and the nature and quantity of measurements necessary to evaluate the precision of the measuring process

- Accuracy - describes the acceptable degree of accuracy for the proposed study, evaluated by relating results to pre-existing geologic information and standard reference and calibration data

- Representativeness - describes the degree of representativeness the seismic measurement will have with the geology below the seismic line

- Comparability - describes the degree to which data resulting from this study is comparable to other geological information

- Completeness - describes the amount of data required to achieve the desired resolution

- Sensitivity - describes the least change in quantity a detector (such as a geophone) is able to perceive

- Readability - describes the least discernible change in a readout device (such as a seismograph) that can be readily estimated

4 1 PRECISION AND ACCURACY

Geophysical instruments are very precise and accurate measuring devices However, geophysical techniques depend on the detection of the contrasting physical parameters of subsurface materials

The signal to noise ratio (S/N) has been defined as "the energy of desired events (signal) divided by all remaining energy (noise) at the time" (Sheriff, 1984). It is the most important concept in data acquisition The S/N ratio affects the data quality from field acquisition to data processing and interpretation Unwanted interference from objects is called "noise " The success of any geophysical technique depends on the desired signal being equal to or greater than the noise Therefore, the S/N ratio must be at least 1.1. Some geophysical techniques can be employed in environments where the S/N ratio is less than unity These techniques use stacking methods to cancel random noise and enhance the signal.

The S/N ratio is greatly affected by the dynamic range of the instrument The dynamic range is the ratio of the maximum reading to the minimum reading that can be recorded by an instrument without change of scale

The optimum window for data resolution is 50 ft to 300 ft below ground surface, with a vertical resolution of 3 ft. The total coverage of the survey is 6,350 linear ft

The mapping of subcropping Arapahoe and Laramie paleochannel zones and structures in contact with various alluvial deposits, and the determination of the deeper extent of these Upper Cretaceous features will be of particular importance, as will the identification and mapping of intra-alluvial features

4 2 REPRESENTATIVENESS AND COMPARABILITY

Seismic reflection measurements will be correlated with lithologic and geophysical logs to ensure they are representative of the geology.

Seismic reflection data can be compared to other geophysical data collected in the vicinity of RFP Synthetic seismograms generated from downhole acoustic and density logs from boreholes in the area of geophysical survey lines are comparable to seismic reflection data The degree of comparability varies with the signal to noise ratio in the seismic data and the quality of the logs Vertical seismic profiling (VSP) data generally have a greater degree of comparability with seismic reflection data because the acquisition techniques are similar

4 3 COMPLETENESS

The degree of completeness of the seismic reflection data for the desired resolution (50 to 300 ft below ground surface with 3 ft vertical resolution) will be addressed in terms of instrumentation and techniques

4 4 SENSITIVITY

An EG&G Geometrics ES-2420 Digital Reflection Seismograph will be used during the seismic survey The manufacturer-specified sensitivity of this instrument is 9.8 microvolts.

4 5 READABILITY

The seismograph has the capacity to display discernible changes of 1 microvolt

5 0 QUALITY CONTROL/QUALITY ASSURANCE

The purpose of quality control/quality assurance is to plan and implement a comprehensive set of controls and systematic procedures to ensure that the data acquired is of a quality necessary to fulfill the DQOs.

Quality assurance criteria for work performed on nuclear power plants were mandated by the Nuclear Regulatory Commission (NRC) in 1970 General quality criteria are covered in 10 CFR 50, Appendix B Consulting firms performing work at nuclear power plants are required to develop quality assurance procedures Ebasco Services Incorporated's (EBASCO's) quality control and assurance policies conform with those mandated by the NRC and are discussed below.

5 1 INSTRUMENT CALIBRATION AND TESTING

To satisfy quality assurance procedures, each piece of geophysical equipment used during the project will be listed according to make, model, and serial number on field data sheets Checklists of equipment tests and calibrations will be filled out and retained in the project files In addition, the results of calibration and testing procedures may be stored on magnetic media or in field logbooks. If equipment is sent to the manufacturer for repair or maintenance, it will be recalibrated to manufacturer's specifications before return delivery Documentation of any recalibrations will be maintained in the project files. Instrument-specific calibration and testing procedures are described below.

5 1 1 EG&G Geometrics ES-2420 Digital Reflection Seismograph

Prior to operation, the Geometrics ES-2420 Digital Reflection Seismograph will be tested according to manufacturer's suggestions, both daily and monthly to ensure optimal accuracy and performance of the instrument. The manufacturer's operation manual will be kept with the

instrument at all times. The instrument tests performed daily and monthly will be recorded on checklists retained in the project files and written to tape prior to data acquisition activities Table 5-1 lists the equipment tests or procedures to be performed according to daily and monthly test sheets located in Appendix III and additional reference locations in the ES-2420 Operations Manual.

5 1.2 Mark Products Geophones

Prior to operation, the Mark Products L-40 A-2 100 Hz geophones will be tested with the cables to ensure optimal accuracy and performance Testing procedures will be written to tape or recorded in field logbooks Recommended testing procedures are outlined in the EG&G Geometrics Model ES-2420 Digital Reflection Seismograph Manufacturer's Operation Manual (EG&G Geometrics, 1984).

Tests to determine the continuity and integrity of the geophones and cables comprising each spread in the field will be performed immediately following installation. These procedures include geophone resistance leakage and noise monitor tests discussed in Sections 6 2 1, 6 2 2, and 6.2.3 of the Seismograph Operation Manual.

5 1.3 Input/Output RLS-240M Rota-Long Switch

Under normal operating conditions, preset mechanical alignments in the Input/Output RLS-240M Rota-Long Switch (generally referred to as a roll-along switch) do not usually require adjustment Although the switch itself is not calibrated, it will be used in conjunction with an ohmmeter to perform leakage and continuity tests on the seismic cable. In addition, breaks in geophone cable sections can be identified with the switch's break check.

TABLE 5-1

Seismograph Equipment Tests

Test or Procedure	Daily	Monthly	Reference*
Clean Tape Head	X	X	Sec IV 2 2
Set Acquisition Parameters	X	X	Sec I 5 1
Set Display and Plot Parameters	X	X	Sec I 5 2
Set Tape Recording Parameters	X	X	Sec I 5 3
Memory Test		X	Sec I 6 6
Post Acquisition Processing Test		X	Sec II 3 14
Tape Drive Functional Tests		X	Sec I 6 8
Staggered Tone Burst Test		X	Sec I 6 3 2
Noise and Offset Test	X	X	Sec I 6 5
Pulse Test of Alias Filters	X	X	Sec I 6 3 1
Pulse Test of Low-cut Filters	X	X	Sec I 6 3 1
Pulse Test of Notch Filters	X	X	Sec I 6 3 1
Harmonic Distortion Test without filters		X	Sec I 6 3 3
Harmonic Distortion Test with filters		X	Sec I 6 3 3
Notch Filter Depth and Frequency		X	Sec I 6 3 3
Crossfeed Test		X	Sec I 6 3 3
Inspect Files on Tape		X	Appendix III of this report
Test Completion		X	Appendix III of this report

* Reference Operations Manual, manuals are kept with the Seismic Recorder

5 1 4 Input/Output Source Synchronizer

The Input/Output Source Synchronizer will be tested daily prior to operation to ensure optimal accuracy and performance Test results will be recorded in field logbooks

Tests include a battery test, a blaster high voltage test, a cap test, an uphole phone test, and a simulated time break and uphole test Additionally, four categories of system tests for troubleshooting exist· operator problems, data transmission, visual checks, and analytical tests

5 2 FIELD DOCUMENTATION

Observations and measurements made during the field investigations will be documented in bound logbooks or appropriate Field Data Sheets.

5 2 1 Document Control and Security

All documents produced in the field (i e, field logbooks, observer notes, monitor, field data sheets, survey notes, etc) will be locked up at the end of each day's work by the Field Quality Assurance Coordinator (FQAC) or the person he/she designates.

All records produced in the field are the responsibility of the FQAC The FQAC will ensure that all documents are accurate, precise, and complete. The FQAC will have all field records available for inspection and review by the Project Quality Assurance Coordinator. A document control record will be used to determine who is in possession of the records at all times

5 2 2 Document Filing

At the end of each day, all field documentation will be completed and filed in the appropriate field file The following is a list of required documents or copies and the person responsible for ensuring the process is completed

Document	Responsible Party
Observers Notes	Observer
Field Logbooks	Recorder
Survey Notes	Surveyor
Health and Safety Logbook	Health and Safety Specialist
Data Transmittal Sheets	Project Geophysicist
Field Data Sheets	Recorder
Field Monitors	Geophysicist or Observer

5 2 3 Logbooks

Field logbooks will be reviewed by the FQAC to ensure that each entry is initialed and that all are dated. Logbook entries must be legible, written in black waterproof ink, and contain accurate and inclusive documentation of the project activities Language will be objective, factual, and free of terminology that might prove inappropriate. All pertinent information will be recorded in the logbooks from the time each operation begins (see Appendix III, Requirements for Field Logbooks). Entries made by individuals other than the person to whom the logbook was assigned will be initialed by the person making the entry When transferring a logbook to a person to whom it was not assigned, the person to whom it was originally assigned must sign over custody of the logbook and date it

5 2.4 Field Data Sheets

Field data sheets will be appropriately filled out in complete, factual, and accurate language Entries will be legible and written in black ink (see Appendix III).

5 2 5 Data Transmittal and Storage

When forwarding data to the processing center, copies of the observers log and survey notes will be made (and marked as copies) to accompany the original field data tape Data will be forwarded with a letter of transmittal to be returned to the sender for filing A courier will be

used to forward the data When the original tape data arrives at the processing center, a backup copy will be made prior to processing.

Care will be taken in the storing of original field data. There are no guidelines as to the statute of limitations for storage time; however, efforts will be made to store the data in fireproof containers and, in the case of magnetic tapes, environmentally controlled areas

5.3 AUDITS

Audits will be performed once a week by the FQAC or his/her designee while data is being acquired in the field. The purpose of the audits will be to confirm that the data are being acquired in accordance with standard operating procedures and ensure that the data are of the quality necessary to achieve the DQOs The audit checklist showing the specific items the auditor will look for is located in Appendix III

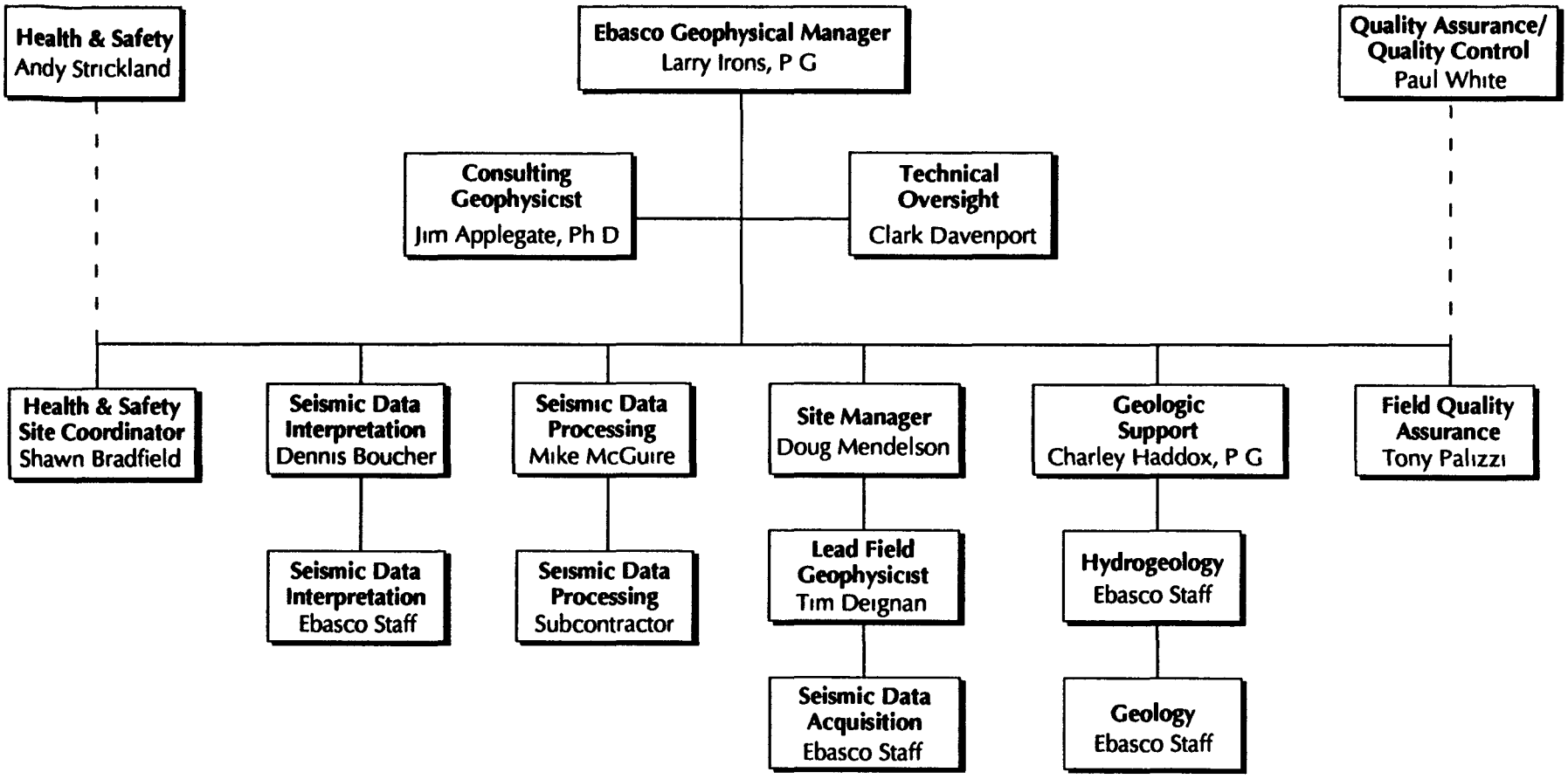
6 0 PROJECT MANAGEMENT

6 1 PROJECT ORGANIZATION

The proposed project organization is shown in Figure 6-1 The Geophysical Manager, Larry Irons, will be responsible for the overall quality of work performed in this HR seismic survey He will monitor the progress of each work assignment to ensure adequate resources are available and that potential problems are prevented or minimized The Geophysical Manager's review will concentrate on the technical quality, schedule, and cost for all work assignments He will also be responsible for maintaining direct communications with EG&G project staff

The Technical Oversight Manager, G Clark Davenport, will be responsible for effective day-to-day management of the project staff. He is charged with overseeing all project procedures and Quality Assurance/Quality Control (QA/QC) functions to be performed during the project

The Site Manager, Doug Mendleson, will have the responsibility and authority for implementing and executing the field investigation. He will be responsible for on-site management for the



January 1992

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Figure 6-1

Project Organization

duration of all activities at the site. The Lead Field Geophysicist, Tim Deignan, will be responsible for data acquisition

The Project QA/QC Coordinator, Paul White is responsible for the preparation, approval and implementation of QA/QC matters. The Project QA/QC coordinator and the field QA Coordinator, Tony Palizzi, ensure that specific QA operations are efficiently coordinated The authority and responsibilities of the QA/QC Coordinator are independant of the project team The QA/QC Coordinator is responsible for the following·

- Approval of all QA/QC procedures used on the project
- Review and validation of data for compliance with precision, accuracy, and completeness objectives
- Prompt notification of the Geophysical Manager of any QC deficiencies
- Provision of guidance and coordination to rapidly resolve any QA/QC problems
- Maintenance of all project QA records and assembly of project QA data for inspection by project management
- Independant review to ensure the quality of all deliverables from the project team to EG&G staff
- Interaction and communication with client QA personnel to resolve specific QA/QC concerns

The Health and Safety Coordinator, Andy Strickland, is responsible for the continued health and safety of the EBASCO field crew He and the Site Health and Safety Coordinator, Shawn Bradfield, will ensure that industry healtyh and safety standards are met in all phases of the field program

After the data acquisition phase, Mike McGuire will manage the data processing He will be in constant communication with the processing subcontractor to suggest processing routines and ensure the best quality final seismic displays.

The data interpretation will be coordinated by Dennis Boucher He will oversee the EBASCO geophysical staff and coordinate any needed support from the EBASCO geologic and hydrogeologic staff to ensure the data are interpreted in an accurate and consistent manner

6 2 PROJECT SCHEDULE

A summary project schedule is shown in Figure 6-2. This figure also indicates the activities that make up the field investigation. The schedule assumes a five-day per week work format, ready access to the site, and that health and safety personnel protective requirements are Level D

The schedule for the field investigation is based on the conditions and activities discussed in this work plan. If the work is performed as scheduled (Figure 6-2), the field portion of the project will be completed in 10 working days Modification of these assumptions may result in substantial schedule variences

6 3 REPORT

Following the completion of field activities both a draft and a final report will be prepared The schedule for these reports will be developed once the field activities have been initiated The development of this schedule will assume an approximate eight week data processing turn around time The report will include

- A summary of data acquisition activities
- A summary of data processing activities
- A discussion on the interpretation of the data
- Interpreted Seismic Profiles
- Conclusions and recommendations

The draft seismic report will be submitted to EG&G and DOE no later than four weeks after receiving the final seismic displays The interim final report will be submitted to EG&G and DOE no later than two weeks following the receipt of EG&G's and DOE's comments The document will be issued as final to EG&G and DOE after all comments have been addressed and a letter is received from DOE indicating that the report has been approved.

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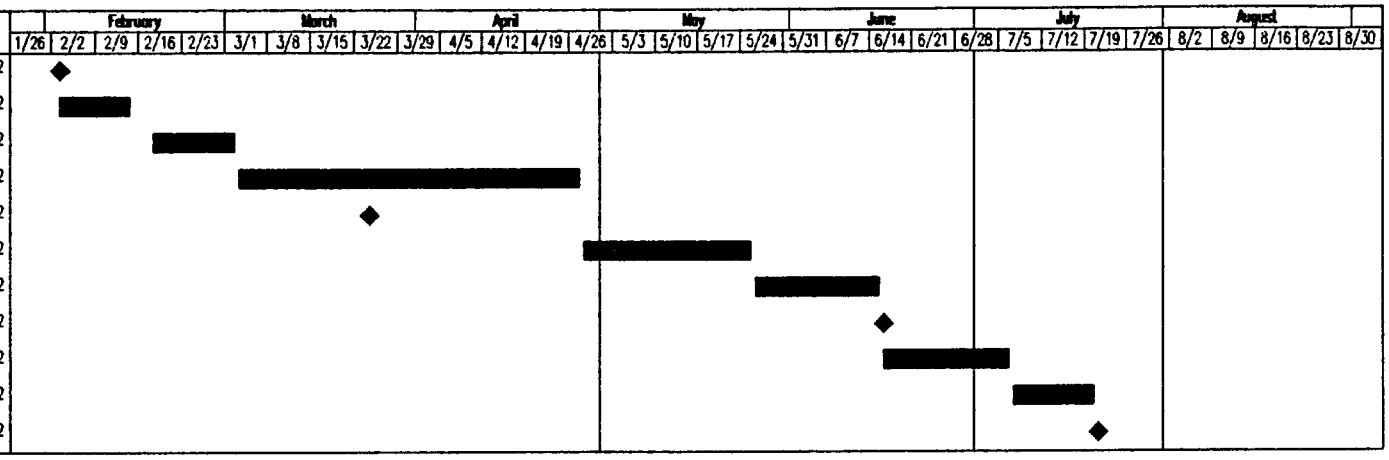
Rocky Flats Plant
Indiana Street Shallow Seismic Survey

ID	Name	Duration	Start	Finish
1	Notice to Proceed	0ed	2/3/92	2/3/92
2	Mobilize Seismic Crew & Equipt	2w	2/3/92	2/14/92
3	Seismic Field Survey	2w	2/18/92	3/2/92
4	Process Seismic Data	8w	3/3/92	4/27/92
5	Deliver Preliminary Profiles to EG&G	0ed	3/24/92	3/24/92
6	Interpret Seismic Data	4w	4/28/92	5/25/92
7	Prepare Draft Report	3w	5/26/92	6/15/92
8	Submit Draft Report to EG&G	0ed	6/16/92	6/16/92
9	EG&G Review	3w	6/16/92	7/6/92
10	Finalize Final Report	2w	7/7/92	7/20/92
11	Submit Final Report to EG&G	0ed	7/21/92	7/21/92



DURATION OF ACTIVITY

MILESTONE

U S DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden Colorado

Figure 6-2

PROJECT SCHEDULE

Appendix I

Theory of Seismic Reflection Techniques

SEISMIC REFLECTION TECHNIQUE

A seismic source generates energy that manifests itself as seismic waves Seismic waves propagate within solids as disturbances traveling through the materials with velocities dependant upon the elastic properties and densities of the materials Typical commercial seismic sources include explosives and vibrating machinery These sources generate two types of seismic waves, body and surface waves. Body waves consist of compressional (p) and shear (s) waves Since most of the energy generated by a seismic source is in the form of p-waves, these waves are of primary interest

Seismic wave energy attenuates with distance partly due to frictional heat loss through absorption of energy by the host material Absorption is dependent on the seismic medium, shales have the highest absorption rates, and granites have the lowest Since seismic waves propagate as spherical wave fronts, the wave spreads out over a spherical area Thus, the energy per unit area varies inversely as the square of the distance from the source

A seismic wave will travel through a medium along a ray path until a discontinuity is encountered A discontinuity can be caused by a change in lithology or fluid content of a porous medium At a discontinuity, part of the wave will be reflected and another part refracted in accordance with Snell's Law as illustrated in Figure A-1

The relative amplitude of a reflected wave from the boundary of two layers, Layer 1 and Layer 2, can be expressed in the form

$$R = \frac{d_2V_2 - d_1V_1}{d_2V_2 + d_1V_1}$$

where·

R = reflection coefficient
d = density in grams per cubic centimeter of medium
V = velocity of p-wave through medium

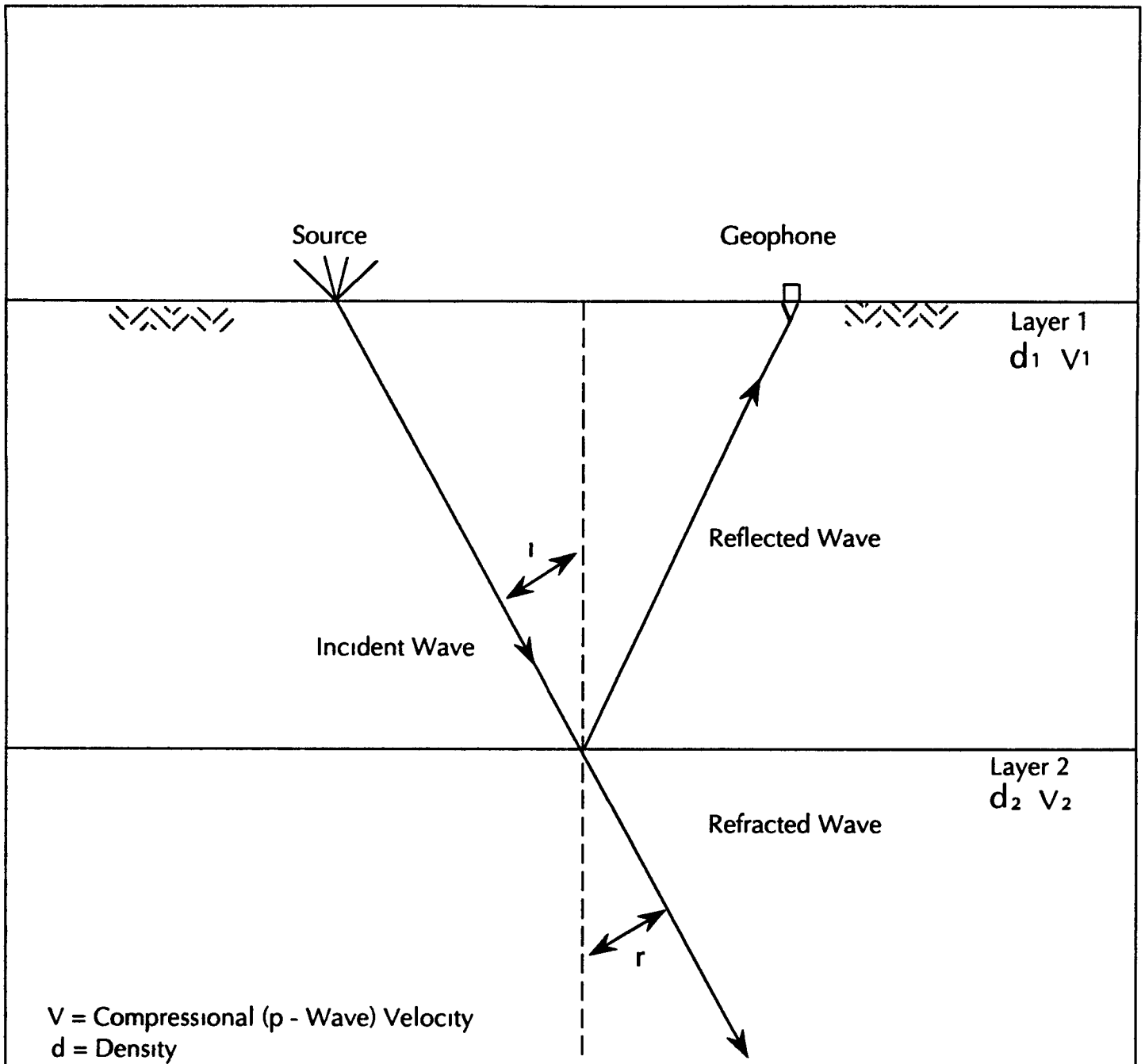


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FIGURE A-1

GEOMETRY OF SNELL'S LAW

The product of the density and velocity is known as the acoustic impedance If the acoustic impedance increases across an interface, then the reflected wave has a positive amplitude Conversely, if the acoustic impedance decreases across an interface, the reflected wave has a negative amplitude

The refracted p-wave makes an angle, r, expressed by the relation

$$\frac{\sin i}{\sin r} = \frac{V_1}{V_2}$$

where·

i = angle of incidence
r = angle of refraction
V_1 = velocity of p-wave through Layer 1
V_2 = velocity of p-wave through Layer 2

When sin i = V_1/V_2, sin r becomes unity and r becomes 90° The refracted wave does not penetrate the medium, but travels along the interface between the two materials Angles i and r are measured relative to the normal at the intersection of the interface and the incident wave

Where seismic waves strike any irregularity along a surface such as a corner or a point where there is a sudden change of curvature, the irregular feature acts as a point source radiating waves in all directions. Such radiation is known as diffraction The amplitude of a diffracted wave falls off rapidly with distance away from a source

Another seismic phenomenon, the interbed multiple reflection is illustrated in Figure A-2 A wave reflects upward from the interface between Layer 2 and Layer 3 Returning to the surface, the wave reflects downward from the Layer 1 - Layer 2 interface, because any change in acoustic impedance at an interface boundary can cause a reflection. The wave again reflects from the top of Layer 3 and successfully returns to the surface

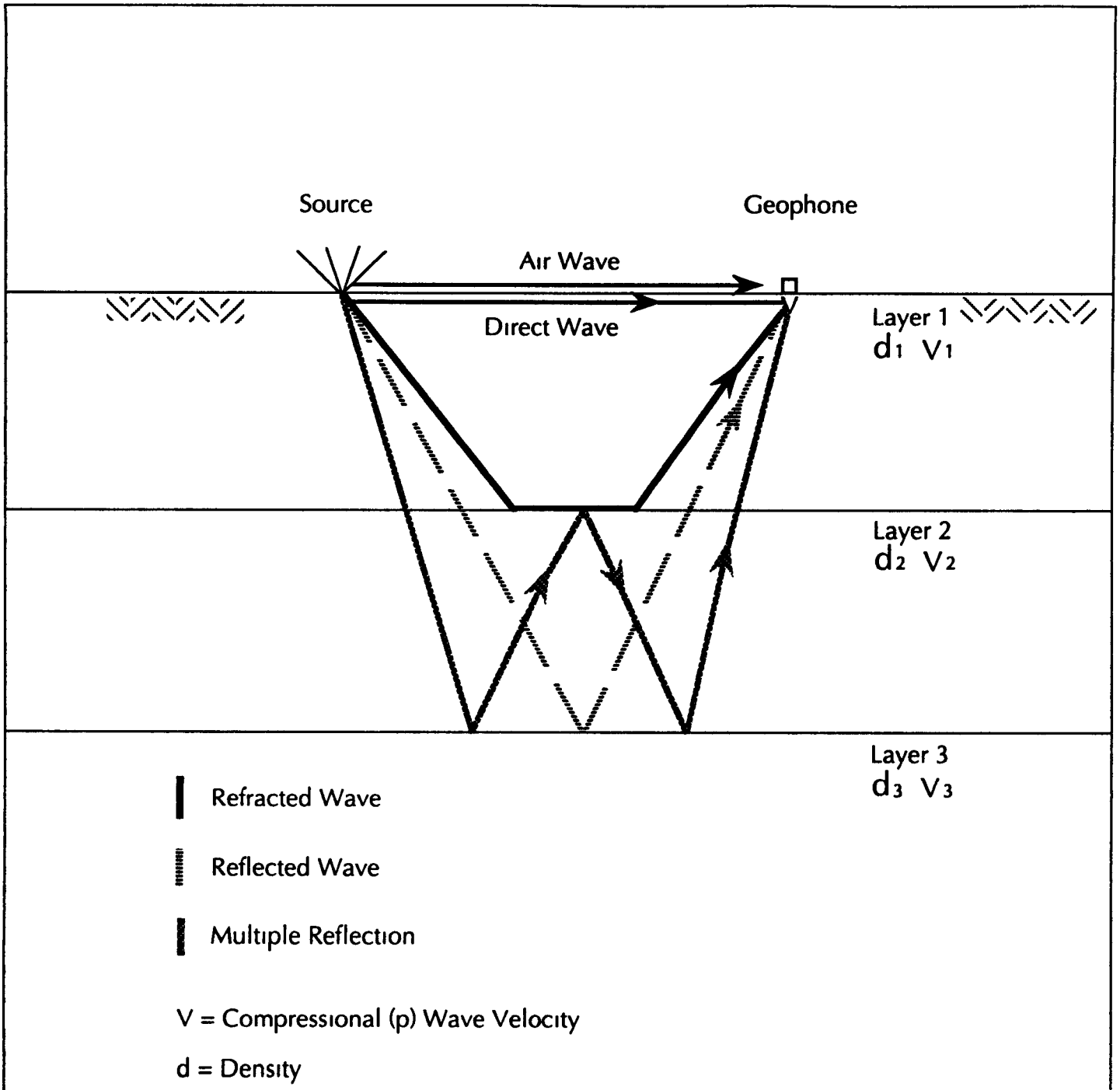

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FIGURE A-2

TYPES OF SEISMIC WAVES

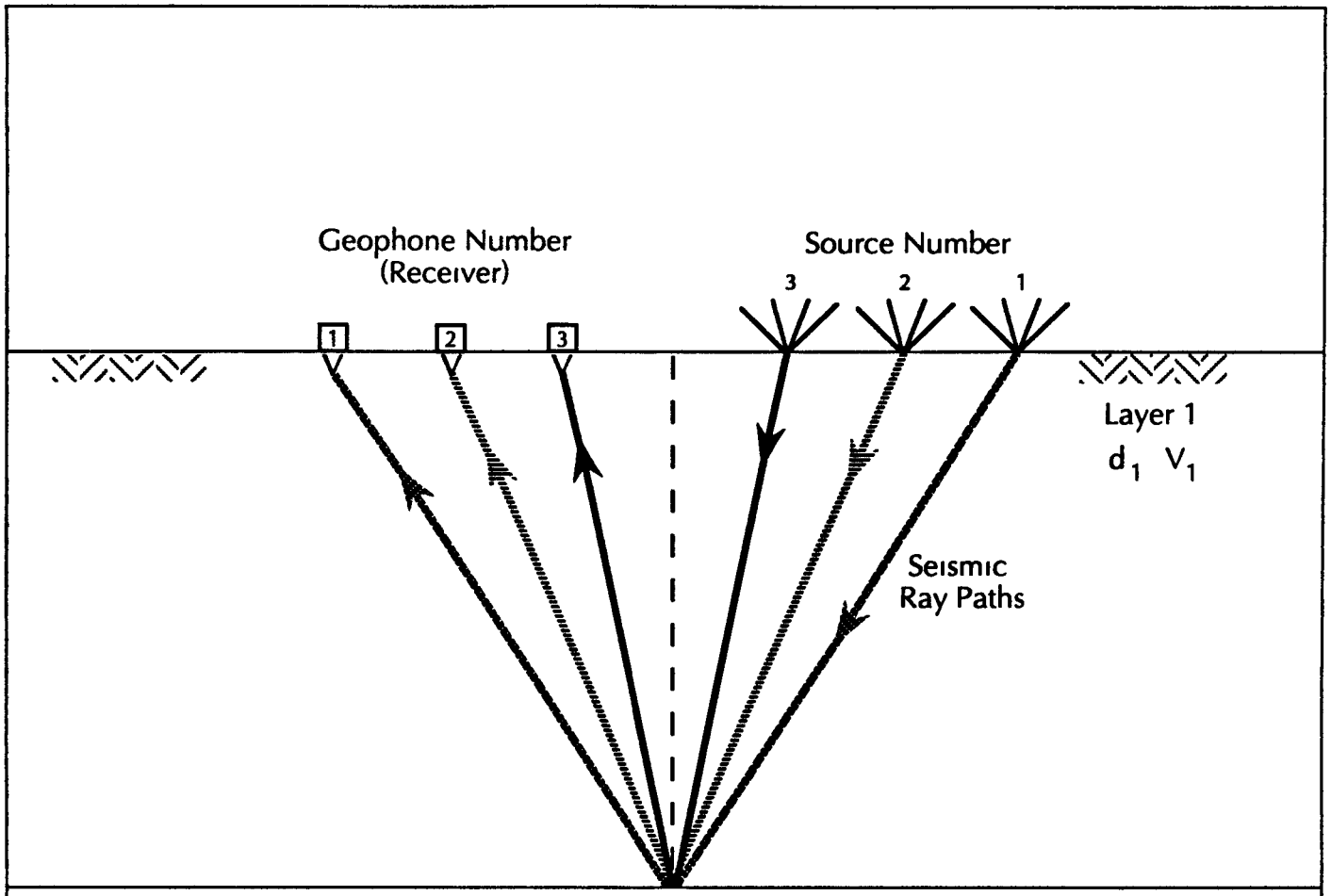
Figure A-2 also shows the types of seismic waves generated by a surface source that will be detected by a geophone. The air wave travels at the speed of sound in air (approximately 1,100 feet/second (fps) The direct wave travels from the source to the geophone within the uppermost medium. This wave is normally faster than the air wave but slower than the other illustrated waves The refracted wave has the earliest arrival time The reflected wave is slower than the refracted wave. A multiple reflected wave has a longer arrival time than the reflected wave because of the greater distance traveled Because of the varying velocities of the different waves it is possible to design seismic field parameters to record the waves of primary interest

According to signal theory, the amount of information present in a seismic reflection signal is proportional to the bandwidth The bandwidth of a seismic signal is the range of frequencies contained within The maximum frequency that can be recorded reliably is equal to one-half of the sampling frequency or rate This is known as the Nyquist frequency At a 0 25-millisecond (ms) sampling rate, the Nyquist frequency is 2,000 hertz (Hz)

COMMON DEPTH POINT METHOD

Seismic reflection techniques build on basic seismic principles Development of digital recording techniques in the 1960s catalyzed great advances in seismic reflection acquisition, processing, and interpretation Seismic noise is any unwanted signal sometimes it is random and other times it is coherent (e g , an operating water pump or a nearby electric powerline) To reliably interpret a seismic event, the signal-to-noise (S/N) ratio must be at least 1 1

The Common Depth Point (CDP) technique has enabled the recording and display of reflection events that have S/N ratios less than unity The CDP technique records reflections from multiple offsets at different source and receiver pairs as illustrated in Figure A-3 For each CDP the number of source and receiver pairs recorded is called the fold Six fold data, also called



January 1992

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FIGURE A-3

COMMON DEPTH POINT TECHNIQUE

600 percent stack, has six source and receiver pairs. The S/N ratio doubles for each quadruple increase in the CDP fold. The CDP fold can be calculated by:

$$CDP\ fold = \frac{receiver\ spacing}{2\ x\ source\ spacing}\ x\ number\ of\ recording\ channels$$

The processing of seismic reflection data is a statistically intensive procedure and requires human guidance at each step. After acquisition, the seismic reflection data are processed from source record format into CDP record format. Each CDP record will have the same number of traces equal to its fold. Because the distance between source and receiver is greater for the longer offsets of a reflection event (source-receiver 1 as opposed to source-receiver 3, Figure A-3), the recorded reflection event itself will record at a later time. The difference in time for a particular event on adjacent traces is termed normal moveout. Data are corrected for normal moveout during processing, and all traces in the CDP record are merged or summed together (stacked). This enhances the real events and cancels undesirable random noise, thus increasing the S/N ratio.

Before stacking, data are corrected for elevation variations, resulting in a static correction. After stacking, automatic statics are performed to correct for velocity variations in the near-surface weathered layer. Digital filters are applied at various steps in the processing to eliminate undesirable noise and enhance the reflection events. Post-stack filtering may include enhancing individual reflection events to improve the interpretation by statistically comparing adjacent seismic traces for continuous events versus random noise.

Seismic events recorded from a geophone appear to arrive from directly beneath the geophone. Where the reflecting horizon is dipping, the position of the event is incorrect. Dipping events migrate downdip. If necessary, these events can be migrated back to their true location. Depending on the data and objectives of the interpreter, this process can be done either before or after stacking (pre-stack or post-stack migration).

Recording shallow reflection events requires modification of standard seismic reflection techniques. In standard seismic reflection techniques 12 or more geophones are grouped together as an array Typical distances between groups are tens to hundreds of feet In shallow high-resolution (HR) seismic reflection work geophone arrays are eliminated and individual geophones are used. Geophone spacings are reduced to a few feet, depending on the depth to the shallowest target. Shallower targets require closer geophone spacings. The number of recording channels needed is dependent on the depth to the deepest target of interest and the geophone and source spacing. Vertical resolution is limited by the bandwidth of the recorded signal and the sampling frequency Horizontal resolution is limited by the bandwidth of the recorded signal and the geophone spacings

SEISMIC DATUM

The seismic datum is an arbitrary reference surface that corrects seismic data for local topographic variations. The start time of each record is corrected to the seismic datum In general, if this reference datum is below the ground surface then some shallow data will be lost If the datum is above the ground surface then the earliest seismic events are recorded and preserved on the seismic profile Conventional seismic reflection utilizes a seismic datum below the ground surface because there is little interest in shallow events, however, the high-resolution seismic programs at Rocky Flats are targeting the early or shallow events Therefore, a seismic datum above the ground surface is used For example, if a borehole has an elevation of 5,900 feet (ft), the seismic line intersecting the borehole might have a seismic datum elevation of 5,975 ft If a sandstone was encountered in the borehole at a depth of 120 ft, the seismic depth of the sandstone would be 195 ft on the seismic profile because the seismic datum is 75 ft higher than the borehole ground surface elevation

Appendix II

Seismic Reflection Equipment

INSTRUMENT SPECIFICATIONS

- EG&G Geometrics ES-2420 Digital Reflection Seismograph
- Mark Products L-40 A-2 100 Hertz (Hz) Geophones
- Input/Output RLS-240M Rota-Long Switch
- Input/Output Synchrafone I and II Source Synchronizer

In the event of unforeseen circumstances, equivalent instruments will be substituted for equipment listed below

EG&G GEOMETRICS ES-2420 DIGITAL REFLECTION SEISMOGRAPH

The following specifications apply to an operating environment of 0 to 40 degrees centigrade (C°), after a 5-minute warmup period (Source EG&G Geometrics, 1984)

Analog Performance Specifications

Preamplifier Gain	32 (30 1 decibels [dB])
	64 (36.1 dB)
	128 (42 1 dB)

Selected by switches on printed circuit board

Input Impedance	Differential, 20K ohms, 01 microfarads (μfd)
	Common Mode, 5K ohms, 02 μfd

Maximum Differential	@ 30 dB, 0 640 volts (V) peak to peak
Input Voltage.	@ 36 dB, 0 320 V
	@ 42 dB, 0 160 V

Maximum DC Common Mode

Voltage: 10 0 V

Transient Protection Transients with energy less than 0 75 Joule and voltage less than 200 V will not damage instrument

Alias Filters

6 dB Slope Cutoff Frequency (F_c in Hz)	Stop Band Frequency (Hz)	Stop Band Attenuation (dB)
45	125	80
180	500	80
360	1,000	78
720	2,000	78
1,440	4,000	78

6 dB corner frequency tolerance	3% max
Time delay, constant from 5 Hz to F_c within	± 2%
Time delay similarity between channels	± 2%

Low Cut Filter· Frequency: 5 to 320 Hz in 5 Hz increments

3 dB corner frequency tolerance 3% max

Type: Butterworth

Attenuation slope· 18 dB/octave

Notch Filter· 50 or 60 Hz or out, selected from front panel

6 dB bandwidth 9 Hz typical Frequency of origin (F_o) ±3 65 min ±6 80 max

50 dB bandwidth 0 5 Hz typical F_o ±0 1 min

Floating Point Digitizer

Instantaneous-floating-point amplifier with 16 gain ranges (6 dB per step) followed by a 15-bit analog-to-digital converter. Amplifier gain range is automatically selected for each sample to maximize the precision of the mantissa value

Exponent:	4-bit unsigned binary number representing the gain range, where zero represents maximum gain (minimum signal)
Mantissa·	15-bit, twos-complement binary
Full scale input voltage	± 10 24 V
Gain step relative accuracy.	0 1%
Analog/Digital (A/D) converter accuracy:	0 2%
A/D converter linearity	0 01%

System Response

Signal to Noise Ratio	100 dB (3 to 180 Hz, 42 dB preamp gain, 600 ohm input, notch & low-cut filters out, alias filter set to 180 Hz)
Frequency Response	Lower 3 dB frequency, 1 6 Hz ±10% Upper 3 dB frequency, determined by alias filter
Gain accuracy:	1%
Gain similarity between channels:	2%
Total Harmonic Distortion.	0 05% floating point average (FPA) in minimum gain, Preamp gain minimum Input. 0.226 voltage root mean square (Vrms) 3 to 1,000 Hz
Crossfeed	<80 dB, 3 to 2,000 Hz
Timing	Time base accuracy 0 002%

Sample skew.	Within 8 channel group, 1/40 milliseconds (ms)/channel

Operating Characteristics

Sample Interval, write-to-memory.	1/4, 1/2, 1, 2, or 4 ms Front panel selectable
Real time clock	Built in digital clock with time of day and day of year. Battery backup provides continuous timekeeping Basic accuracy 3 seconds per month at 25 C° Time recorded on tape
Maximum Record Length	Set from front panel to maximum of 99 seconds in direct-to-tape In stack-to-memory maximum length determined by sample interval 1/4 ms 4 096 seconds 1/2 ms 8 192 seconds 1 ms 16 384 seconds 2 ms 32 768 seconds 4 ms 65 536 seconds
Delay Start	Postpones sampling of data by front-panel selected delay up to 9 999 seconds in 0 001 second increments
ES2420 Acquisition Control Unit (ACU) Power Supply:	Operates from 10 to 18 V DC
DP2420 Printer Power Supply:	Operates from 10 to 14 V DC
DMT2420 Tape Drive Power Supply:	Operates from 10 to 16 V DC

Dimensions

ACU	28 x 16 x 23 5 inches (22 5 with 71 x 41 x 60 cm cover removed)
Expansion Module·	same as ACU
Portable Tape Deck:	same as ACU

Plotter.	15 x 15 x 18 inches 38 x 38 x 46 cm

Weights

Acquisition Control Unit·	110 lbs (50 Kilograms [Kg]) with 4 channels 7 lbs (3 Kg) for each additional 8-channel board set
Printer·	40 lbs (18 Kg)
Portable Tape Deck	100 lbs (45 Kg)
Environmental·	Operating temperature, 0° to 45° C continuous operation with built-in forced air cooling Can be operated in cyclic conditions to temperature of 50° C. Storage temperature - 40° to 70° C Humidity 10 to 95% noncondensing May be operated in vertical position in light rain (cover closed on tape recorder, protection for plotter) Weatherproof with transit lid closed

CRT Display

512 by 512 dot matrix graphic display of seismic data and acquisition parameters Can display at maximum expansion of one dot per sample, or compressed in 3 dB steps up to maximum of 16,196 samples on screen Also displays a time cursor and scale lines and selected parameters (battery voltage constant, file number, and status messages)

TAPE DATA FORMAT

Tape format.	Nine-track, SEG D, 2 1/2 byte, multiplexed
Data density.	1,600 bits per inch (bpi)

6Block size·	Fixed blocking, equal to an integral number of scans, as close as possible to a user selected maximum or ungapped
Channel set descriptor	One for all channels
Sample skew:	Not written to tape For each set of Channels (usually 8) supported by a Data Acquisition Memory (DAM) board - Preamplifier Filter (PF) board pair, sample skew starts at zero and increased by 1/40 ms per channel. The maximum sample skew for any channel in the system is thus 7/40 ms
Data word.	Ones complement, twenty bits with a one-bit sign, four-bit binary exponent, and 14-bit mantissa The least significant bit (LSB) is zero

Geophone Specifications - Mark Products L-40 A-2

Standard Frequency Range	100Hz
Frequency Tolerance	+7%
Standard Coil Resistance +10% (Ohms)	325, 510, 780
Distortion @ Resonance @ 0 7 inches/sec	0 2% MAX
Transduction Constant, V/inches/sec (Rc= circuit resistivity)	0 031 Rc
Open Circuit Damping (f=frequency)	$\frac{47\ 9}{f}$
Coil Current Damping (Rs=source resistivity)	$\frac{20\ 8\ Rc}{f\ (Rc + Rs)}$
Suspended Mass, Grams	5 7
Case-to-Coil Motion, p-p inches	0 080
Intrinsic Power Sensitivity milliwatts (mw)/in/sec	0 96
Basic Unit Diameter, inches	1 25
Basic Unit Height inches	1 37
Basic Unit Weight, oz	5 0

ROTA-LONG SWITCH SPECIFICATIONS - INPUT/OUTPUT RLS-240 M

The following specifications are presented in summary form from the operations manual (Input/Output, Inc., 1981a)

- 240 input stations
- 120 recording channels

- Unlimited types of recording configurations
- Size· 20 inches wide x 20 inches tall x 6 50 inches deep
- Auxiliary connector permits diagnostic cable tests with an ohmmeter or I/O Break Chek
- Weight. 40 pounds (lbs)

SYNCHRAFONE - INPUT/OUTPUT SYNCHRAFONE I AND II SOURCE SYNCHRONIZER

The following specifications are presented in summary form from the operations manual (Input/Output, Inc., 1981b)

- Contains radio within unit
- Digital display of uphole time
- Firing time repeatability at 1 ms
- Wire line and radio modes
- Four privacy codes
- Time break and uphole time output from Encoder
- Available as truck mount or portable

Appendix III

Field Documentation

Requirements for Field Logbooks

Label field logbook with name of project, project number, task number (if appropriate), and location of project, and record this information in Document Control Logbook When field logbook is assigned, it will be given a volume number and date of issue which will be entered into the Document Control Logbook.

Starting the job:

1 At the top of each page note the date, activity, and initials of person recording in the Field Logbook.

2 Record personnel on site and the operation they are performing

3. Include a detailed description of activity to be performed

4 Note the weather (severe changes in weather should be noted throughout the day)

5. Describe any cultural features at the site, i.e., buildings, power lines, underground utilities, roadways, etc.

6. Record ground surface conditions, ie e , natural or disturbed conditions, soil type, topography, surface water present, etc

7 Note arrival time at site

8 Begin a progress summary of data acquisition, including times for beginning and ending of each new activity, and the number of the line being shot

9 Include a discussion of any field problems which affect the planned progress

10. Include a discussion of any conditions affecting the quality of data

11. Include a discussion of any contact with the Project personnel concerning any deviations to the investigation plan, along with their justification and the time

12. Note any personnel entering or leaving the site and the time

13. Note the time when leaving the site.

14. At the end of each day cross out, initial, and date the remainder of the page.

15. Start a new page each day

In general:

Use black waterproof ink.

Define any abbreviations used

Put a single line through any errors, initial and date the entry

No erasures or corrections may be made by writeovers or white-out

Sheet ___ of ___

EBASCO SERVICES INCORPORATED
143 Union Blvd , Lakewood, CO 80228 303/988-2202

Daily Ammunition Inventory

Project _____

Task _____

Site of Use _____

Client _____

Time _____

Date _____

Personnel _____

Ammunition	8 Gauge Electric	8 Gauge Percussion	Detonator	Other
Number on Hand Before Daily Operations				
Number Removed from Magazine				
Number Buried				
Number Returned to Magazine				
Portion Returned Which are Duds				
Number on Hand at the End of the Day				

Comments

9/89

EBASCO SERVICES INCORPORATED
143 Union Blvd , Lakewood, CO 80228 303/988-2202

Shooting Log

Project _____
Task _____
Line No _____
Location _____
Client _____
Time _____
Date _____
Personnel Name _____
Name _____

Location Plan

Sheet ___ of ___

Station (Shotpoint)																
Depth (Center)																
Offset																
Size (Weight/No)																
Comments																

Station (Shotpoint)																
Depth (Center)																
Offset																
Size (Weight/No)																
Comments																

9/89

DAILY TEST SHEET - ES-2420 DIGITAL REFLECTION SEISMOGRAPH

Date_____ Time_____ Temp _____ Operator_____

Batt Volts_____ Serial Number ACU_____ Tape#_____

Preamplifier Gain_____

PROCEDURE OR TEST	CHECK
1. CLEAN TAPE HEAD Use prescribed method to clean tape head and other items in tape path	☐

2 SET SECONDARY MENU

Set Secondary Menu to the following settings

SAMPLE INTERVAL	1/4 ms
ACQUISITION MODE	STACK TO MEMORY
LOW CUT FILTER	OUT
ALIAS FILTER	720 Hz
NOTCH FILTER	OUT
RECORD LENGTH	_____ sec
START DELAY	0 000 sec
STACK LIMIT	1
ACQUISITION CHANNELS	ALL CHANNELS USED
PROTECTED CHANNELS	NONE
CHANNELS TO TEST	ALL CHANNELS USED
DISPLAY/PLOT CHANNELS	ALL CHANNELS USED
DISPLAY/PLOT MODE	WIGGLE TRACE
PLAYBACK GAIN MODE	FIXED GAIN
PLOT RANGE	0.0 - _____ sec
PLOT SUBDIVISION MARKS	ON
CONSTANTS	NOT APPLICABLE
CHANNELS TO/FROM TAPE	ALL CHANNELS USED
TAPE START FILE	START AT '0001' FOR NEW LINE
TAPE DRIVE	0 - END
TAPE BLOCK SIZE	4000 BLOCKS
TAPE DRIVE SPEED	37 INCHES PER SECOND
TAPE DENSITY	1600 BLOCKS PER INCH

TAPE LENGTH	1200 INCHES	
EXT HEADER LENGTH	NO EXT. HEADER	
TAPE PORT WIDTH . . .	NOT APPLICABLE	
TAPE PORT MODE	NOT APPLICABLE	
AUTO CYCLE TIME	EXT. TRIGGER	
TAPE FORMAT	MULTIPLEXED	
EOT DRIVE SELECT	MANUAL CHANGE	☐
DATE-TIME	CURRENT TIME	

Print copy of Secondary Menu and check against above list ☐

In Test Menu, check that gain is set to Floating Point ☐

Print Copy of Header Data ☐

3 NOISE AND OFFSET TEST

Clear Memory Set display gain to "FIXED GAIN - 93 db" display by entering "93" followed by the "trace size" key ☐

Install Shorting Plug (500 ohms) ☐

Change the configuration menu as follows
SAMPLE INTERVAL (field setting) _____ ms
ALIAS FILTER (field setting) _____ Hz
RECORD LENGTH (field setting) _____ sec ☐

Press "ARM" then "START" to make a record of instrument noise Inspect CRT display. ☐

There should be approximately 2 mm of noise on each trace If any trace has 5 mm of noise, that is excessive

Write a file with this data Note File No here _____(1) ☐

and on observers form

Print a copy of this record ☐

Press TEST, then "4" for Analog Performance Tests, then "1" for noise test, then ENTER. After test executes, print a copy ☐

The average noise level should be less than 1000 nanovolts. No channel should have more than 2000 nanovolts

Repeat test, except select "2" for Offset Test Print copy ☐

The pulse height will vary substantially among the traces, but no trace should exceed 1000 nanovolts If the test fails, repeat it and see if the same bad data occurs consistently. A trace may fail on occasion because of random chance

Repeat noise test with following configuration changes
ALIAS FILTER .... OUT
LOW CUT FILTER ... . 5 Hz
NOTCH FILTER .... OUT ☐

The noise will be much higher without the alias filter, but should be less than 3000 nanovolts

Repeat noise test with following configuration changes
LOW CUT FILTER .. .. OUT
NOTCH FILTER ... . ____ Hz ☐

The noise should be less than 3000 nanovolts.

4. PULSE TEST OF ALIAS FILTERS (**Test filters in use**)

Clear Memory, then change the configuration as follows
SAMPLE INTERVAL ..... _____ ms
NOTCH FILTER .... OUT
ALIAS FILTER .... _____ Hz

RECORD LENGTH . . . . . _____ sec ☐

Press TEST, then "2" to select. Signal Injection, then "1" to inject pulse, then ENTER. ☐

Reduce gain to approximately 21 db and increase time scale to adjust trace display so that the pulses on the CRT can be seen clearly

Traces should look similar Depending on the alias filter setting the pulse peak should be located as shown below Some change due to sample skew will be visible at this speed

Alias Filter	Pulse Peak Location
720 Hz	0.5 - 1 0 ms
360 Hz	1 0 - 2 0 ms
180 Hz	2.0 - 4 0 ms
90 Hz	4.0 - 8 0 ms
45 Hz	8.0 - 16 0 ms

Write a file with this data Note File No here _____(2) and on observers form. ☐

Print a copy of this record. ☐

5. PULSE TEST OF LOW-CUT FILTERS (**Test filters in use**)

Clear Memory, then change the configuration as follows

SAMPLE INTERVAL . . . . _____ ms
LOW CUT FILTER . . . _____ Hz
ALIAS FILTER . . . . . _____ Hz
RECORD LENGTH . . . . . _____ sec ☐

Wait 10 seconds.

Adjust Trace Size to FIXED GAIN = 54 db

Press TEST, then "2" for Signal Injection, then "1" for Pulse, then ENTER Adjust traces for best display of pulses on the CRT. Note that the sloped part of the trace is important, not early initial pulse from the Alias Filter ☐

Pulses should look similar on all traces Depending on the low cut filter setting the time of the second positive (to the right) peak should be as shown below.

Low Cut Filter	2nd Pos Peak Location
5 Hz	85 +/- 10 ms
10 Hz	45 +/- 6 ms
15 Hz	32 +/- 4 ms
45 Hz	10 +/- 1.5 ms
85 Hz	6 +/- 1 ms
165 Hz	6 +/- 1 ms
320 Hz	3.5 +/- 0.5 ms

Write a file with this data Note File No. here _____(3) and on observers form. ☐

Print a copy of this record ☐

6 PULSE TEST OF NOTCH FILTERS (**Test Filters in Use**)

Set Trace Display gain to 42 db, Time Scale to 5 ms.

Clear Memory. Change configuration to the following.

SAMPLE INTERVAL	_____ ms
LOW CUT FILTER	OUT
ALIAS FILER	_____ Hz
NOTCH FILTER	_____ Hz
RECORD LENGTH	_____ sec

☐

Wait 5 seconds.

Press TEST, then "2" for Signal Injection, then "1" for Pulse, then ENTER Adjust traces for best display of pulses on the CRT. ☐

Pulses should look similar on all traces The time from second positive peak to third positive peak should be 20 ms +/- 2 ms (for 50 hz filter) or 16 6 ms +/- 2 ms (for 60 Hz). Wiggles in traces should be similar in phase and amplitude.

☐

Write a file with this data. Note File No. here _____(4) and on observers form

Print a copy of this record ☐

7 Restore all settings to field program ☐

MONTHLY TEST SHEET - ES-2420 DIGITAL REFLECTION SEISMOGRAPH

Date_____ Time_____ Temp_____ Operator_____

Batt Volts_____ Serial Number ACU_____ Tape_____

Preamplifier Gain_____

PROCEDURE OR TEST	CHECK
1. CLEAN TAPE HEAD Use prescribed method to clean tape head and other items in tape path	☐

2 SET SECONDARY MENU

Set Secondary Menu to the following settings·

SAMPLE INTERVAL	1/4 ms
ACQUISITION MODE	STACK TO MEMORY
LOW CUT FILTER	OUT
ALIAS FILTER	720 Hz
NOTCH FILTER	OUT
RECORD LENGTH	2 0 sec
START DELAY	0.000 sec
STACK LIMIT	1
ACQUISITION CHANNELS	ALL AVAILABLE
PROTECTED CHANNELS	NONE
CHANNELS TO TEST	ALL AVAILABLE
DISPLAY/PLOT CHANNELS . .	ALL AVAILABLE
DISPLAY/PLOT MODE	WIGGLE TRACE
PLAYBACK GAIN MODE	FIXED GAIN
PLOT RANGE	0 0-2 0 sec
PLOT SUBDIVISION MARKS	ON
CONSTANTS	NOT APPLICABLE
CHANNELS TO/FROM TAPE	ALL AVAILABLE
TAPE START FILE	START AT "0001"
TAPE DRIVE	0 - END
TAPE BLOCK SIZE	4000 BLOCKS
TAPE DRIVE SPEED	37 INCHES PER SECOND

TAPE DENSITY	1600 BLOCKS PER INCH
TAPE LENGTH	1200 INCHES
EXT HEADER LENGTH	NO EXT HEADER
TAPE PORT WIDTH	NOT APPLICABLE
TAPE PORT MODE	NOT APPLICABLE
AUTO CYCLE TIME	EXT. TRIGGER
TAPE FORMAT	MULTIPLEXED
EOT DRIVE SELECT	MANUAL CHANGE
DATE-TIME	CURRENT TIME

Print copy of Secondary Menu and check against above list

In Test Menu, check that gain is set to Floating Point

Print Copy of Header Data.

3 TEST MEMORY

Press "Test" to select Test Menu, then press "5" to select Memory Test, select Short Memory Test, Press Enter, Test will execute automatically Use "Scroll" keys to examine results

If all memory is good, TEST PASSED will show next to each channel number. If any memory fails, a number will indicate bad memory locations If total number of errors exceeds 0, instrument should be serviced

Print copy of Results.

4 TEST PAP (If inatalled and in use)

Press "Compute" to select Post Acquisition Processor Menu, then press "Scroll Up" key two times to make PRM MEMORY TEST visible in PAP Menu Press "9" to start test. Test will take several minutes

If all memory is good, TEST PASSED will show next to each confidence level If any memory fails, a number will indicate bad memory locations If total number of errors exceeds 0, instrument should be serviced Since

defective PAP memory does not damage data, acquisition may continue if it can be conducted without the Post Acquisition Processor

Print copy of results

Return to PAP Menu, press "Scroll Up" key until AP Test is visible, then press "9" to select test menu Select the last test "ALL OF THE ABOVE "

Wait for the test to finish, then print copy of results

5. TAPE DRIVE FUNCTIONAL TESTS

WARNING THIS TEST MUST BE DONE ON A SCRATCH TAPE ANY DATA ON TAPE WILL BE DESTROYED BY THIS TEST

Mount a scratch tape on the digital tape recorder.

Put the recorder "on line" Press TEST to select the Test Menu, then press "7" to start the tape test After instructions on CRT are checked, press ENTER to start test. Test will run automatically for several minutes, showing specific test in progress on CRT. At completion of test, CRT will indicate status as number of Hard, Soft, and Data Errors

Print a copy of CRT by using COPY Switch on Plotter (do not use PRINT switch).

The number of Hard Errors should be less than three, and the number of soft or data errors should be less than ten each If the test fails, try again with another tape. The system will provide its own result, but the tape recorder may still be good enough to continue working. To check, try reading back the Staggered Tone Burst in the next test and inspect the data carefully for errors. A tape with a few errors is still usable.

Remove the scratch tape and mount a new data tape to record the test information

6 STAGGERED TONE BURST TEST

Clear Memory Press TEST to get Test Menu, the "2" to select Signal Injection, then "2" for Staggered Tone Burst, then ENTER. Wait for test to execute and display traces on CRT. Adjust the Trace controls until the Tone Burst is about 1 cm wide and 2 cm long Use Scroll Key to examine all the Tone Bursts ☐

Note· The number of traces on the CRT may be temporarily reduced to 1 to speed up the adjustment of trace scale factors After setting the display, return the display to "All Available Channels."

The tone bursts should appear in sequence, starting with trace number 1, then 2, and so on The length of the tone bursts may vary, but not the sequence.

The amplitude should be the same on all channels if the preamp gain is the same on all channels.

Write a file with this data Note File No. here_____(1) ☐

Print a copy of this record. ☐

Be careful The file number which shows in the Header is the previous file before you write to tape After you write to tape, the correct file number shows on top of the seismic traces display and in the header data

7. NOISE AND OFFSET TEST

Clear Memory Set display gain to "FIXED GAIN - 93 db" display by entering "93" followed by the "trace size" key. ☐

Install Shorting Plug (500 ohms). ☐

Change the configuration menu as follows

SAMPLE INTERVAL	2 ms
ALIAS FILTER	90 Hz
RECORD LENGTH	4 0 sec

☐

Press "ARM" then "START" to make a record of instrument noise. Inspect CRT display. ☐

There should be approximately 2 mm of noise on each trace. If any trace has 5mm of noise, that is excessive.

Write a file with this data Note File No here _____(2) ☐

Print a copy of this record ☐

Press TEST, then "4" for Analog Performance Tests, then "1" for noise test, then ENTER After test executes, print a copy. ☐

The average noise level should be less than 1000 nanovolts No channel should have more than 2000 nanovolts.

Repeat test, except select "2" for Offset Test Print copy ☐

The pulse height will vary substantially among the traces, but no trace should exceed 1000 nanovolts If the test fails, repeat it and see if the same bad data occurs consistently A trace may fail on occasion because of random chance

Repeat noise test with following configuration changes.

ALIAS FILTER	OUT
LOW CUT FILTER	5 Hz
NOTCH FILTER	OUT

☐

The noise will be much higher without the alias filter, but should be less than 3000 nanovolts.

Repeat noise test with following configuration changes·

LOW CUT FILTER	OUT
NOTCH FILTER	50 Hz

☐

The noise should be less than 3000 nanovolts

8 PULSE TEST OF ALIAS FILTERS (Test Filters in Use)

Clear Memory, then change the configuration as follows·

SAMPLE INTERVAL	1/4 ms
NOTCH FILTER	OUT
ALIAS FILTER	720 Hz
RECORD LENGTH	1 0 sec

☐

Press TEST, then "2" to select Signal Injection, then "1" to inject pulse then ENTER. ☐

Reduce gain to approximately 21 db and increase time scale to adjust trace display so that the pulses on the CRT can be seen clearly ☐

Traces should look similar The pulse peak should be between 0 5 and 1 0 ms inclusive. Some change due to sample skew will be visible at this speed

Write a file with this data. Note File No Here _____(3) ☐

Print a copy of this record ☐

Clear Memory, then change the configuration as follows

SAMPLE INTERVAL	1/2 ms
ALIAS FILTER	360 Hz
RECORD LENGTH	1.0 sec

☐

Repeat the test Adjust trace scale factors if necessary to improve display ☐

Traces should look similar. The pulse peak should be between 1.0 and 2 0 ms inclusive

Write a file with this data. Note File No here _____(4) ☐

Print a copy of this record. ☐

Clear Memory, then change the configuration as follows

SAMPLE INTERVAL	1 ms
ALIAS FILTER	180 Hz
RECORD LENGTH	2 0 sec

☐

Repeat the test. Adjust trace scale factors if necessary to improve display. ☐

Traces should look similar. The pulse peak should be between 2 0 and 4 0 ms inclusive.

Write a file with this data Note File No here _____(5) ☐

Print a copy of this record ☐

Clear Memory, then change the configuration as follows
SAMPLE INTERVAL .... 2 ms
ALIAS FILTER ..... . 90 Hz
RECORD LENGTH ..... 4 0 sec ☐

Repeat the test Adjust trace scale factors if necessary to improve display

☐

Traces should look similar The pulse peak should be between 4 0 and 8 0 ms inclusive

Write a file with this data Note File No here _____(6) ☐

Print a copy of this record. ☐

Clear Memory, then change the configuration as follows
SAMPLE INTERVAL .. .. 4 ms
ALIAS FILTER .... 45 Hz
RECORD LENGTH .... 8.1 sec ☐

Repeat the test. Adjust trace scale factors if necessary to improve the display ☐

Traces should look similar The pulse peak should be between 8 0 and 16 0 ms inclusive At this frequency, some variation will be visible from the effect of the low-frequency response of the system.

Write a file with this data Note File No. here _____(7) ☐

Print a copy of this record ☐

If the 1440 Hz Alias Filter is used, repeat the test with that filter and 1/4 ms sampling ☐

9. PULSE TEST OF LOW-CUT FILTERS

Clear Memory, then change the configuration as follows·

SAMPLE INTERVAL	1 ms
LOW CUT FILTER	5 Hz
ALIAS FILTER	180 Hz
RECORD LENGTH	8 1 sec

☐

Wait ten seconds.

Adjust Trace Size to FIXED GAIN = 54 db, Timescale to SUBMARKS = 20 ms. ☐

Press TEST, then "2" for Signal Injection, then "1" for Pulse, then ENTER Adjust traces for best display of pulses on the CRT Note that the sloped part of the trace is important, not early initial pulse from the Alias Filter ☐

Pulses should look similar on all traces The time of the second positive (to the right) peak should be at 85 ms +/- 10 ms

Write a file with this data Note File No here _____(8) ☐

Print a copy of this record. ☐

Clear Memory, then change the configuration as follows
LOW CUT FILTER . . . . . 10 Hz ☐

Wait ten Seconds.

Press TEST, then "2" for Signal Injection, then "1" for Pulse, then ENTER Increase Time Scale for best display of pulses on the CRT. ☐

Pulses should look similar on all traces. The time of the second positive (to the right) peak should be at 45 ms +/- 6ms

Write a file with this data Note File No here _____(9) ☐

Print a copy of this record ☐

Clear Memory, then change the configuration as follows·
LOW CUT FILTER . . . . . 15 Hz ☐

Wait 10 Seconds.

Press TEST, then "2" for Signal Injection, then "1" for Pulse, then ENTER
Increase Time Scale for best display of pulses on the CRT ☐

Pulses should look similar on all traces The time of the second positive (to the right) peak should be at 32 ms +/- 4 ms

Write a file with this data. Note File No here _____(10) ☐

Print a copy of this record ☐

Clear Memory, then change the configuration as follows·

SAMPLE INTERVAL	1/4 ms
LOW CUT FILTER	45 Hz
ALIAS FILTER	720 Hz
RECORD LENGTH	4 0 sec

☐

Wait 10 Seconds.

Press TEST, then "2" for Signal Injection, then "1" for Pulse, then ENTER
Increase Time Scale for best display of pulses on the CRT. ☐

Pulses should look similar on all traces The time of the second positive (to the right) peak should be at 10 ms +/- 1 5 ms

Write a file with this data. Note File No. here _____(11) ☐

Print a copy of this record. ☐

Clear Memory, then change the configuration as follows
LOW CUT FILTER .... 85 Hz ☐

Wait 10 Seconds

Press TEST, then "2" for Signal Injection, then "1" for Pulse, then ENTER
Increase Time Scale for Display of pulses on the CRT ☐

Pulses should look similar on all traces The time of the second positive (to the right) peak should be at 6 ms +/- 1 ms.

Write a file with this data. Note File No here _____(12) ☐

Print a copy of this record. ☐

Clear Memory, then change the configuration as follows
LOW CUT FILTER .... 165 Hz
ALIAS FILTER .... 1440 Hz ☐

Wait 10 Seconds.

Press TEST, then "2" for Signal Injection, then "1" for Pulse, then ENTER
Increase Time Scale for best display of pulses on the CRT. ☐

Pulses should look similar on all traces The time of the second negative (to the left) peak should be at 6 ms +/- 1 ms

Write a file with this data Note File No here _____(13) ☐

Print a copy of this record. ☐

Clear Memory, then change the configuration as follows
LOW CUT FILTER ..... 320 Hz ☐

Wait 10 Seconds.

Press TEST, then "2" for Signal Injection, then "1" for Pulse, then ENTER
Increase Time Scale for best display of pulses on the CRT ☐

Pulses should look similar on all traces The time of the second negative (to the left) peak should be at 3 5 ms +/- 0.5 ms

Write a file with this data Note File No here _____(14) ☐

Print a copy of this record. ☐

10. PULSE TEST OF NOTCH FILTERS

Set Trace Display gain to 42 db, Time Scale to 5 ms. ☐

Clear Memory Change configuration to the following

SAMPLER INTERVAL	1/4 ms
LOW CUT FILTER	OUT
ALIAS FILTER	720 Hz
NOTCH FILTER	50 Hz (or 60 Hz)
RECORD LENGTH	4 0 sec

☐

Wait 5 Seconds.

Press TEST, then "2" for Signal Injection, then "1" for Pulse, then ENTER
Adjust Traces for best display of pulses on the CRT. ☐

Pulses should look similar on all traces The time from second positive peak to third positive peak should be 20 ms +/- 2 ms (for 50 Hz filter) or 16 6 +/- 2 ms (for 60 Hz). wiggles in traces should be similar in phase and amplitude.

Write a file with this data. Note File No here _____(15) ☐

Print a copy of this record ☐

11. HARMONIC DISTORTION TEST WITHOUT FILTERS

Clear Memory. Change configuration to the following·

SAMPLE INTERVAL	4 ms
ACQUISITION MODE	DIRECT TO TAPE
LOW CUT FILTER	OUT
ALIAS FILTER	OUT
NOTCH FILTER	OUT

RECORD LENGTH .... 66 0 sec
START DELAY .... 1 0 sec ☐

Press TEST to select Test Menu, then "2" to select Signal Injection Set Sine Wave Frequency to 5 126953 Hz. Set Sine Wave Amplitude to 150 mv. ☐

Note· If preamp gain is set to 36 db, use amplitude of 300 mv. If preamp gain is set to 30 db, use amplitude of 500 mv and reduce test acceptance limits to 60 db.

Select Sine Wave Test and record a sine wave into memory. Inspect Sine Wave on CRT, adjusting traces if necessary ☐

Write a file with this data Note File No here _____(16) ☐

Print a copy of this record ☐

Press COMPUTE to select Post-Acquisition Processor Press "3" to select a program, use Scroll Up Key to locate Power Spectral Density Program Press "9" to select menu, set trace number to "1", Set Amplitude Recovery to "OFF". ☐

Check to see that source of data is Acquisition Memory ☐

Press Compute to return to PAP Main Menu, then "4" to execute Power Spectral Density. Wait for Processing to finish, then observe trace on CRT display. Adjust time scale to display 30 Hz on CRT ☐

The PSD display should show a tall spike at 5.127 Hz. If there is any significant harmonic distortion, this will be exhibited as spikes on 10 25, 15 4, 20 5, 25 6, 30.8, 35 9, 41 0 or 46 1 Hz. Ignore spikes at other frequencies. No spike should be taller than -66 db. It will be easier to identify these spikes on the CRT display because the cursor can be used to accurately measure the frequency and the trace scale to measure amplitude A spike may appear at 0 frequency, that is OK.

Print a copy of this record. ☐

Since there is one A/D converter and floating point amplifier for each 8 channels, it is only necessary to repeat this test for every group of 8 (or Aux) channels If the PSD shows many spikes on one of the channels, try another channel in the same group

Repeat processing and inspection for Trace 9 Print copy. ☐

Repeat processing and inspection for Trace 17 Print copy ☐

Repeat processing and inspection for AUX 2 Print copy ☐

Clear Memory, set Sine Wave Amplitude to 1 mv There will not be a record visible on the screen unless you increase the trace size to approximately 48 db ☐

Inject this sine wave into memory. ☐

Write a file with this data Note File No here _____(17) ☐

12 HARMONIC DISTORTION TEST WITH FILTERS

Clear Memory. Change configuration to the following

SAMPLE INTERVAL	2 ms
LOW CUT FILTER	5 Hz
ALIAS FILTER	90 Hz
NOTCH FILTER	OUT
RECORD LENGTH	33 0 sec

☐

Press TEST to select Test Menu, then "2" to select Signal Injection Set Sine Wave Frequency to 10 681152 Hz Set Sine Wave Amplitude to 150 mv. ☐

Note: If preamp gain is set to 36 db, use amplitude of 300 mv. If preamp gain is set to 30 db, use amplitude of 500 mv

☐

Select Sine Wave Injection Test and record a sine wave into memory

Write a file with this data. Note File No here _____(18) ☐

13. NOTCH FILTER DEPTH AND FREQUENCY

Clear Memory. Change configuration to the following:

SAMPLE INTERVAL	2 ms
LOW CUT FILTER	OUT
ALIAS FILTER	90 Hz
NOTCH FILTER	OUT
RECORD LENGTH	4.0 sec
PLOT RANGE	1 0 - 1.5 sec

☐

Set Sine Wave Frequency to 50 Hz and amplitude to 150 mv Set trace display gain to 9 db ☐

Inject the sine wave into memory and adjust the trace amplitude until it is equal to about 1 cm peak to peak Note playback gain _____db ☐

Write a file with this data. Note File No. here _____(19) ☐

Print a copy of this record. ☐

Clear Memory Change configuration to the following.

NOTCH FILTER	50 Hz (OR 60 Hz)

Set Trace Display Gain to 84 db. ☐

Inject the sine wave into memory and inspect all the traces Adjust the Playback Gain to make the largest traces equal to those in the previous test Note the gain here _____. ☐

The record should display noisy traces with excursions from 1 to 2 cm p-p If any trace has unusually large excursions, that indicates a defective notch filter The difference between the playback gain on this record and the previous one is the notch rejection in db. Note value here _____.

If any filters are worse than 66 db, then focus your attention on those particular channels Change the test frequency in 0 025 Hz steps and repeat the test to find the exact center frequency If any filter deviates from 50 (or 60) Hz by more than 0 1 Hz, it should be replaced when convenient

Write a file with this data Note File No. here _____(20) ☐

Print a copy of this record. ☐

14. CROSSFEED TEST

Clear Memory. Change configuration to the following.

SAMPLE INTERVAL	2 ms
ALIAS FILTER	90 Hz
NOTCH FILTER	OUT
RECORD LENGTH	4.0 sec

☐

Set Sine Wave Test Frequency to 40 Hz, Amplitude to 150 mv Set Trace Display Gain to 90 db. ☐

Select Test Menu, press "8" to select the Channels to Test Menu, then "3" to select the Even Channels Set the Traces to Display to show the Odd channels on the CRT. ☐

Inject the sine wave into memory and inspect all the traces ☐

The traces should be noisy, with different amplitudes, typically 1 or 2 cm ☐

Write a file with this data Note File No here _____(21) ☐

Print a copy of this record ☐

Select Test Menu, press "8" to select the Channels to Test Menu, then "2" to select the Odd Channels Set the Traces to Display to show the Even channels on the CRT. ☐

Clear Memory. Inject the sine wave into memory and inspect all the traces ☐

The traces should be noisy, with different amplitudes, typically 1 or 2 cm

Write a file with this data. Note File No here _____(22) ☐

Print a copy of this record ☐

Set traces to display to Channel 1 and adjust the amplitude until the excursion equals the largest value in either of the above tests, around 12 db
Set system to display all available channels. ☐

Read the playback gain The difference between this number and that used in the previous two tests is the Crossfeed Rejection. The worst channel should be better than 74 db and the typical value should be 80 db Note value here _____ ☐

Print a copy of this record ☐

15. INSPECT FILES ON TAPE

Rewind the tape to the Load Point. Inspect each file to see if it is on tape and has the proper appearance. Write the file number below ☐

Note that if you lose your place in the list, the Header read from tape can be inspected to see which acquisition parameters were used on the File in question.

Inspect the Staggered Tone Burst record sequence ☐

File Number for Staggered Tone Burst _____
File Number for Noise Test _____
File No for 720 Hz Alias Filter Pulse Test _____
File No for 360 Hz Alias Filter Pulse Test _____
File No. for 180 Hz Alias Filter Pulse Test _____
File No. for 90 Hz Alias Filter Pulse Test _____

File No. for 45 Hz Alias Filter Pulse Test _____
File No for 5 Hz Low Cut Filter Test _____
File No for 10 Hz Low Cut Filter Test _____
File No. for 15 Hz Low Cut Filter Test _____
File No for 45 Hz Low Cut Filter Test _____
File No. for 85 Hz Low Cut Filter Test _____
File No. for 165 Hz Low Cut Filter Test _____
File No for 320 Hz Low Cut Filter Test _____
File No for 50 Hz Notch Filter Pulse Test _____
File No for 5 Hz, 150 mv Sine Wave without Filter _____
File No for 5 Hz, 1 mv Sine Wave without Filter _____
File No for 10 7 Hz, 150 mv Sine Wave with Filter _____
File No. for 50 Hz Signal with Notch Filter OUT _____
File No for 50 Hz Signal with Notch Filter IN _____
File No for Even -> Odd Channel Crossfeed Test _____
File No for Odd -> Even Channel Crossfeed Test _____

If any file are missing, repeat the test and enter the file number above.

16 TEST COMPLETION

Rewind and remove tape. Remove the Write Enable Ring. ☐

Reset the Secondary Menu to the acquisition parameters specified for the survey. ☐

Send tape to processing center if required File Report with copies of plotted records Note any unusual results, repairs, or changes in procedure here.

_____

_____

NOTES ON PROCESSING THE ES-2420 MONTHLY TEST DATA

The monthly test procedure is designed to allow the operator of the system to verify that the ES-2420 is performing to a standard sufficient to acquire high quality seismic data

Since the Es-2420 differs substantially from older design systems, it requires different test procedures. For those who wish to confirm that the system is functioning properly by computer analysis, the following suggestions are provided

1 The staggered tone burst confirms that the data is being properly recorded on individual channels, and that the tape is being read properly Furthermore, general function of the preamplifiers, filters, multiplexer, floating point amplifier, and analog/digital (A/D) converter can be checked.

2 The noise record is used to compute the system noise and offset using programs referenced in the SEG standard for instrument specifications The internal noise and offset tests give comparable results.

3 The pulse test are used to check the system phase response, phase similarity, and frequency response using standard Fourier Transform algorithims There are many of these tests, because the ES-2420 has a broad selection of filters available Each control line is exercised by the frequencies selected

4 The harmonic distortion test injects a low-distortion sine wave which is near the maximum amplitude allowed into the system The dynamic range can be computed from the ratio of this value (150 millivolt (mv) for 42 decibel (db) preamp gain over the system input noise from paragraph 2 above.

The gain step linearity and A/D linearity can be checked by computing the harmonic distortion of the sine wave. Note that there is an A/D converter and floating point amplifier for each 8-channels in the system, and they can be compared with one another The accuracies of the A/D converters can be checked by comparing the foot mean square (RMS) signal from groups of 8 channels

5 A clean sine wave of 10 7 Hertz (Hz) is also injected with alias and low cut filters in

6. The notch filter depth test provides a pair of records, each a 150 mv sine wave, one with filters in and one without The rejection level can be computed as the ratio of these two signals in db.

7 For the crossfeed test, a pair of records is provided, one with a 150 mv signal injected into the even channels, and one with a 150 mv signal injected into the odd channels

SEISMIC OBSERVERS FORM

EBASCO SERVICES INC.
143 Union Blvd 18th Floor
Lakewood Colorado 80228
303/988-2202

Client _____ Party _____ Date ___/___/___ (Month Day Year) Line _____ (Code) _____ (No)

Company _____ County _____ State _____

Project Manager _____ Proj Geophy _____

Observer _____ Charge No ___ (OFS) ___ (Proj) ___ (Pt)

Page ___ of ___

GENERAL				SPREAD						SOURCE					
						Station No at Receiver Group for Following Traces					Charges Depth				
Source Point No	Digital Reel Number	Time of Day	File No	Recorder at Source Point	Sequencer Switch Setting	Station # 1 *			Station Last	Sta	Top	Bottom	No Impacts	Dead Traces	REMARKS (Additional remarks on back of sheet)

Note Use separate line for each record. Make original and copy send original to Project Geophysicist. Use separate sheet for each seismic line.

Daily Summary

No. Profiles _____

Miles Traversed _____

Total to Date for Month

No. Profiles _____

Miles Traversed _____

Weather ☐ Dry Ground ☐ Wet ☐ Rain ☐ Snow ☐ Lightning

Wind ☐ 0 12 mph ☐ 13 24 mph ☐ 25 40 mph

Temperature _____ F

Trail Conditions _____

Observer _____ (Signature)

RECEIVER/GEOPHONE SPREAD LAYOUT

Directions _____ (Increasing SP No.) Tr 1 to Tr 2

Channels ___ (Far) ___ (Near) (Back) SP ___ (Near) ___ (Far) (Front)

Distances ___ (Far) ___ (Near) (Back) SP ___ (Near) ___ (Far) (Front) Receiver Grp Int _____

Geophones per Grp. ___ (Total No) ___ (No. In Line) ___ (No XLine) Spacing ___ (In Line) ___ (XLine)

No. Fold _____

SOURCE

Source _____

SP Perp. Offset _____ SP Near Offset _____ SP Int. _____

No. Indiv Sources ___ (In Line) ___ (XLine) Spacing ___ (In Line) ___ (XLine)

No Moves per Source ___ (In Line) ___ (XLine) Dist each Move ___ (In Line) ___ (XLine)

AUXILIARY CHANNELS

1 _____

2 _____

3 _____

4 _____

INSTRUMENTS/EQUIPMENT

GEOPHONES ___ (Mfg.) ___ (Model) ___ (Base) Nat Freq. _____

SEISMOGRAPH/AMPLIFIER ___ (Mfg.) ___ (Model) ___ (No. Channels) Samp Int ___ ms Rec Len ___ Sec

Filter ___ (Low) ___ (High) HZ ___ (Low) ___ (High) DB/Oct, 60 Hz Rej ___ (In/Out) Serial No. _____

Shot Delay Time ___ Ms AGC Window ___ ms. SEG Tape Format ___ Density ___

Gain Mode IFP ___ Other _____

SUMMER ___ (Mfg.) ___ (Model) Mo Bit Threshold ___ Min Gain ___ Mode ___ (Zero or Add)

AUDIT CHECKLIST

Does the project file contain the following information

On each blank, enter (Y)es, (N)o or NA (Not Applicable)

_____ Project Number

_____ Project Engineer Name and Contact Phone

_____ Project Job Location

_____ Project Manager

_____ Project Geologist

_____ Project Geophysicist

_____ Geophysical Field Crew Composition

Project File - Geotechnical

Does the project job file contain the following geotechnical information.

_____ Purpose of Survey

_____ Depth to target (bedrock, water table, etc)

_____ Desired accuracy in the data

_____ Location of the site (geographically, geologically, and culturally)

Site Vicinity - location of:

_____ Houses

_____ Roads

_____ Railroads

_____ Power lines

_____ Underground utilities

_____ Pipelines

_____ Water wells

_____ Radio transmission towers

_____ Local noise sources (power plants, quarries, compressors, etc)

Site Ground Surface - description of.

_____ Natural site or landfill

_____ Soil types

_____ Swamps, lakes or streams

_____ Vegetation (clear, plowed field, heavy brush, trees, etc)

_____ Accessibility (car, foot, fences, ditches, etc)

_____ Topography (sand dunes, flat, irregular or extreme)

_____ Land ownership (restricted areas)

_____ Climatic conditions expected during course of survey

Subsurface Conditions - information about

_____ Depth to water table

_____ Character of near-surface materials

_____ Character of materials down to target

_____ Description of target (age, consolidation, erosional features, etc)

_____ Geologic history of the area

_____ Existing and planned borings

Investigation Plan

Configuration

Does the site map show the proper location of all proposed geophysical investigations

_____ Seismic lines, refraction, reflection

_____ Electrical resistivity profiles, soundings, dipole

_____ Magnetic profiles

_____ Gravity profiles

_____ Shear wave lines

_____ SP profiles

_____ Surface wave lines

_____ EM profiles, soundings

_____ Radon profiles

_____ Are the interval(s) on stations specified for all surveys?

_____ Are electrode array specifications given for resistivity surveying?

_____ Are the shotpoint locations and depths specified for each seismic spread, including on-line, end of spread, and off-sets, either in line or perpendicular?

_____ Have all deviations from the planned scope of work been recorded and justified?

Instrumentation and Procedures

Does the investigation plan make specific reference for the following equipment

_____ Geophones: type and number

_____ Cables: Length and take-out interval

_____ Signal Conditioning Amplifiers: Type

_____ Recorder and timing· Galvanometer. Type and number, paper specification, timing reference

_____ Shotbox, communication and zero time

_____ Transmitter, type

_____ Receiver, type

_____ Electrodes, type, number

_____ Multimeter, type

_____ SP electrodes, type, number

_____ Radar System

_____ Magnetometer, type

_____ Gravity meter

_____ Does the investigation plan specify the energy source (explosives or mechanical) for each type of Seismic Survey?

_____ Does the investigation plan list the procedures or describe how the desired data is to be obtained?

_____ Does the investigation plan indicate who is responsible for line surveying and any drilling, and how will they be accomplished?

Quality Assurance Criteria

_____ Has the purpose of each Survey been defined?

_____ Has a statement concerning the expected success of each procedure been made

Field Investigation

Prefielding, planning and scheduling

_____ Have the surveyor's been given a current investigation plan showing geophysical lines, and boring locations (for Right of Entry (RE) permitting)?

_____ Have all the operational requirements for access and public relations for the following items been established.

Surveying· brushed or dozed lines
Shot holes· hand augers or truck-mounted drills
Geophysical equipment. portable or truck-mounted

_____ Has any drilling been scheduled and confirmed?

_____ Has the explosive contractor been scheduled and confirmed with permits in order?

_____ Has the field crew been scheduled, notified and confirmed?

Preoperation

_____ Are all the scheduled items at the site (equipment, expendables and personal items)?

_____ Have the geophysical lines been surveyed and flagged or staked, and are elevations available?

_____ Are all the lines and borings permitted for access, and has the access been flagged or mapped?

_____ Are there any restricitons on either shooting (if necessary) or access, and are these exclusions well marked on a map or flagged in the field?

_____ Has the equipment been unpacked and checked out (see test checklist for details)?

_____ Has the crew been briefed on field safety requirements, conduct and proprietary information?

Daily Operation

Setup and Checkout

_____ Has the type, model and the instrument been recorded on the field data sheet Does the field data sheet contain

_____ Project number

_____ Project name

_____ Project location

_____ Line or sounding number

_____ Spread or profile; number, length (station to station)

_____ Observer's name (recording instrument)

_____ Date

_____ Has a daily test been performed and recorded?

Data Acquisition Records

_____ Are all necessary field data sheets present?

_____ Have all field data sheets been properly filled out (contain all data)?

_____ Are they legible?

_____ Are any equipment problems noted?

_____ For seismic surveys - are seismograms labeled properly

_____ For seismic surveys - are mag tapes labeled properly

Field Reports and Administrative Records

Field Logbook

Does the field logbook contain the following information

_____ Project job number

_____ Project name

_____ Site location

_____ A progress summary of data acquisition

_____ A discussion of any field problems affecting the planned progress

_____ A discussion of any conditions affecting the quality of the data

_____ A discussion of any contact with the Project personnel concerning any deviations to the investigation plan along with their justification

Preliminary Analysis (Data Reduction and Field Interpretation)

Original Data

_____ Is each item labeled, and in agreement with all the information contained in the field data sheet?

_____ Have calculations been properly performed?

_____ Has the data been corrected if necessary?

_____ Are the formulae for making data corrections given?

_____ Are the data properly plotted?

Depth Calculations (Original Data Work Sheets)

_____ Are the formula for making the depth calculations given?

_____ Do the calculation sheets contain the following information

_____ Project number

_____ Project name

_____ Site location or designation

_____ Geophysical line number

_____ Data used for depth calculation

_____ Depth calculation

_____ Are the plotted depths in agreement with the calculation sheets for each shotpoint?

Appendix IV

Glossary of Geophysical Terms

GLOSSARY

A selection of relevant geophysical terms extracted from
Encyclopedic Dictionary of Exploration Geophysics (Sheriff, 1984),
Applied Geophysics (Telford et al , 1976),
Geophysical Prospecting (Dobrin, 1976; Dobrin and Savit, 1988)

ACCELEROMETER - A geophone whose output is proportional to the acceleration of earth particles. For example, a moving coil geophone, with velocity response proportional to frequency (as may be the case below the natural frequency) operates as an accelerometer.

ACOUSTIC - IMPEDANCE Seismic velocity multiplied by density Reflection coefficient at normal incidence depends on changes in acoustic impedance

ACOUSTIC LOGGING - A borehole logging survey which will display any of several aspects of seismic-wave propagation, i e , a sonic, amplitude, character or 3D-log

AIR WAVE - Energy from the shot which travels in the air at the velocity of sound (V) V = 1051 + 1.1F feet/second (fps), where F = Fahrenheit temperature, or V = 331 5 + 0 607C meters/second (m/s), where C = Celsius temperature.

ALIAS - Data in sampled form have an ambiguity where there are fewer than two samples per cycle. This creates a situation where an input signal at one frequency appears to have another frequency at the output of the system Half of the frequency of sampling is called the folding or Nyquist frequency, f_N, and a frequency larger than this, $f_N + Y$, appears to have the smaller frequency f_N-Y To avoid this ambiguity, frequencies above f_N must be removed by an anti-alias filter before the sampling Otherwise the system will react as if the spectral characteristics were folded back at f_N. Thus, for a system sampled over 4 milliseconds (msec), or 250 times per second, the Nyquist frequency is 125 cycles per second (cps); if, for example, 50 cps is within the pass band, then 200 cps will also be passed if an anti-alias filter is not used, appearing upon output to have a 50 cps frequency. The pass bands obtained by folding about the Nyquist frequency are also called "alias bands," "side lobes," and "secondary lobes " Aliasing is an inherent property of all sampling systems and applies to digital seismic recording

and also to the sampling which is done by the separate elements of geophone and shotpoint arrays

ANALOG - (1) A continuous physical variable (such as voltage or rotation) which bears a direct relationship (usually linear) to another variable (such as earth motion) so that one is proportional to the other (2) Continuous, as opposed to discrete or digital.

ANOMALY - A deviation from uniformity in physical properties, often of exploration interest For example, a travel time anomaly, Bouguer anomaly, free-air anomaly.

APPARENT VELOCITY - (1) The phase velocity which a wavefront appears to have along a line of geophones. (2) The inverse of the slope of a time-distance curve

ATTENUATION - A reduction in amplitude or energy caused by the physical characteristics of the transmitting media or system Usually includes geometric effects such as the decrease in amplitude of a wave with increasing distance from a source. Also used for instrumental reduction effects such as might be produced by passage through a filter

AUTOMATIC GAIN CONTROL (AGC) - A system in which the output amplitude is used for automatic control of the gain of a seismic amplifier, usually individual for each channel, although multi-channel devices are sometimes used

BEDROCK - Any solid rock, such as may be exposed at the surface of the earth or overlain by unconsolidated material.

BODY WAVES - P-waves and S-waves, which travel through the body of a medium, as opposed to surface waves

CABLE - The assembly of electrical conductors used to connect the geophone groups to the recording instrument

CAPACITANCE - The ratio of charge (Q in coulombs) on a capacitor to the potential across it (V in volts) is the capacitance (C in farads)

$$C = Q/V$$

CHANNEL - (1) A single series of interconnected devices through which geophysical data can flow from sources to recorder. Most seismic systems are 24

channel, allowing the simultaneous recording of energy from 24 groups of geophones. (2) A localized elongated geological feature resulting from present or past drainage or water action; often presents a weathering problems (3) An allocated portion of the radio-frequency spectrum

CHANNEL WAVE - An elastic wave propagated in a layer of lower velocity than those on either side of it. Energy is largely prevented from escaping from the channel because of repeated total reflection at the channel boundaries or because rays which tend to escape are bent back toward the channel by the increasing velocity away from it in either direction

CHARACTER - (1) The recognizable aspect of a seismic event, usually in the waveform, which distinguishes it from other events Usually a frequency or phasing effect, often not defined precisely and hence dependent upon subjective judgment (2) A single letter, numeral, or special symbol in a processing system.

COMMON DEPTH POINT (CDP) - The situation where the same portion of subsurface produces reflections at different offset distances on several profiles

COMPRESSIONAL WAVE - An elastic body wave in which particle motion is in the direction of propagation (Same as P-waves, longitudinal wave, dilation wave)

CONVERTED WAVE - A wave which is converted from longitudinal to transverse, or vice versa, upon reflection or refraction at oblique incidence from an interface

CRITICAL ANGLE - Angle of incidence, q_c, for which the refracted ray grazes the surface of contact between two media (of velocities V_1 and V_2)

$$\sin q_c = V_1/V_2$$

CRITICAL DISTANCE - (1) The offset at which the reflection time equals the refraction time, that is, the offset for which the reflection occurs at the critical angle (see Sheriff, 1984 p. 45). (2) Sometimes incorrectly used for crossover distance, the offset at which a refracted event becomes the first break

CROSSFEED - Interference resulting from the unintentional pickup of information or noise on one channel from another channel Also crosstalk

CROSS-HOLE METHOD - Technique for measuring in situ compressional (p) and/or shear (s) wave velocities by recording transit times from a source within one borehole to receivers at the same elevation in one or more other boreholes Sources may be explosive or directional to enhance either p- or s-wave generation

CROSS SECTION - A plot of seismic events

DATUM - (1) The arbitrary reference level to which measurements are corrected (2) The surface from which seismic reflection times or depths are counted, corrections having been made for local topographic and/or weathering variations (3) The reference level for elevation measurements, often sea level

DELAY TIME - (1) In refraction work, the additional time required for a wave to follow a trajectory to and along a buried marker over that which would have been required to follow the same marker considered hypothetically to be at the ground surface or at a reference level. Normally, delay time exists separately under a source and under a detector, and is dependent upon the depth of the marker at wave incidence and emergence points Shot delay time plus geophone delay time equals intercept time (See Dobrin, 1988 p. 472) (2) Delay produced by a filter

DIELECTRIC CONSTANT - A measure of the capacity of a material to store charge when an electric field is applied. It is the dimensionless ratio of the capacitivity (or permittivity, the ratio of the electrical displacement to the electric field strength) of the material to that of free space

DIFFRACTION - (1) Scattered energy which emanates from an abrupt irregularity of rock type, particularly common where faults cut reflecting interfaces. The diffracted energy shows greater curvature than a reflection (except in certain cases where there are buried foci), although not necessarily as much as the curve of maximum convexity. It frequently blends with a reflection and obscures the fault location or becomes confused with dip (2) Interference produced by scattering at edges (3) The phenomenon by which energy is transmitted laterally along a wave crest When a portion of a wave train is interrupted by a barrier, diffraction allows waves to propagate into the region of the barrier's geometric shadow

DIGITAL - Representation of quantities in discrete units A digital system is one in which the information is contained and manipulated as a series of discrete numbers as opposed to an analog system, in which the information is represented by a continuous flow of the quantity constituting the signal

DOWN-HOLE METHOD - Technique for measurement of in situ compressional and shear wave velocities utilizing a seismic source at ground surface and a clamped triaxial geophone at depth in a borehole Shear wave energy is often enhanced by use of directional sources such as striking the ends of a weighted plank.

END LINE - Shotpoints that are shot near the end of the spread

FIRST BREAK - The first recorded signal attributable to seismic wave travel from a known source. First breaks on reflection records are used for information about the weathering Refraction work is based principally on the first breaks, although secondary (later) refraction arrivals are also used. Also first arrival.

FOLD - The multiplicity of common-midpoint data Where the midpoint is the same for 12 offset distances, e g, the stack is referred to as "12-fold"

FREQUENCY DOMAIN - A representation in which frequency is the independent variable; the Fourier transform variable when transforming from time

GAIN - An increase (or change) in signal amplitude (or power) from one point in a circuit or system to another, often from system input to output

GALVANOMETER - A part of a seismic camera consisting of a coil suspended in a constant magnetic field The coil rotates through an angle proportional to the electrical current flowing through the coil A small mirror on the coil reflects a light beam, which exhibits a visual record of the galvanometer rotation.

GEOPHONE - The instrument used to convert seismic energy into electrical voltage Same as seismometer

GEOPHONE STATION - Point of location of a geophone on a spread, expressed in engineering notation as 1+75 taken from 0+00 at the beginning of the line

GROUP VELOCITY - The velocity with which most of the energy in a wave train travels In dispersive media where velocity varies with frequency, the wave train changes shape as it progresses so that individual wave crests appear to travel at a different velocity (the phase velocity) than the overall energy as approximately enclosed by the envelope of the wave train The velocity of the envelope is the group velocity Same as dispersion

HYDROPHONE - (Pressure detector) A detector which is sensitive to variations in pressure, as opposed to a geophone which is sensitive to particle motion Used when the detector can be placed below a few feet of water, as in marine or marsh or as a well seismometer. The frequency response of the hydrophone depends on its depth beneath the surface

IMPEDANCE - The apparent resistance to the flow of alternating current, analogous to resistance in a dc circuit. Impedance is (in general) complex, of magnitude **Z** with a phase angle **g**. These can be expressed in terms of resistance **R** (in ohms), inductive reactance $X_L=2\pi L$ and capacitive reactance $X_c = {}^1/_2\pi fC$

$$Z = [R^2 + (X_L - X_C)^2]^{1/2},$$
$$g = \tan^{-1}[(X_L - X_C)/R]$$

Z is in ohms when frequency **f** is in hertz, **L** is inductance in henrys, and **C** is capacitance in farads

IN-LINE OFFSET - A spread which is shot from a shotpoint which is separated (offset) from the nearest active point on the spread by an appreciable distance (more than a few hundred feet) along the line of spread.

INPHASE - Electrical signal with the same phase angle as that of the exciting signal or comparison signal

LEAD - An electrical conductor for connecting electrical devices Geophones are connected to cables at the takeouts via leads on the geophones

LINE - A series of profiles shot in line.

LOVE WAVE - A surface seismic channel wave associated with a surface layer which has rigidity, characterized by horizontal motion perpendicular to the direction of propagation with no vertical motion

LOW-VELOCITY LAYER - A near-surface belt of very low-velocity material often abbreviated LVL, also called weathering

MAGNETIC PERMEABILITY - The ratio of the magnetic induction **B** to the inducing field strength **H** denoted by the symbol m.

$$m = B/moH$$

mo is the permeability of free space = $4\pi 10^{-7}$ weber/ampere meter or (henrys/meter) in SI system, and 1 gauss/oersted in the cgs system, so that the permeability **m** is dimensionless The quantity **mmo** is sometimes considered the permeability (especially in the cgs system)

MIGRATION- Originally, rearrangement of interpreted seismic data so that reflections and diffractions are plotted at the locations of the reflectors and diffracting points rather than with respect to observation points Now, generally a computer operation on raw data to accomplish this purpose.

MIS-TIE - (1) The time difference obtained on carrying a reflection, phantom, or some other measured quantity around a loop, or the difference of the values at identical points on intersecting lines or loops (2) In refraction shooting, the time difference from reversed profiles which gives erroneous depth and dip calculations

MULTIPLE - Seismic energy which has been reflected more than once Same as long-path multiple, short path multiple, peg-leg multiple, and ghost

MULTIPLEX - A process which permits transmitting several channels of information over a single channel without crossfeed Usually different input channels are sampled in sequence at regular intervals and the samples are fed into a single output channel; digital seismic tapes are multiplexed in this way Multiplexing can also be done by using different carrier frequencies for different information channels and in other ways

NOISE - (1) Any undesired signal; a disturbance which does not represent any part of a message from a specified source. (2) Sometimes restricted to energy which is random. (3) Seismic energy which is not resolvable as reflections In this sense noise includes microseisms, shot-generated noise, tape-modulation noise, harmonic distortions, etc Sometimes divided into coherent noise (including non-reflection coherent events)

and random noise (including wind noise, instrument noise, and all other energy which is non-coherent) To the extent that noise is random, it can be attenuated by a factor of n by compositing n signals from independent measurements (4) Sometimes restricted to seismic energy not derived from the shot explosion (5) Disturbances in observed data due to more or less random inhomogeneities in surface and near surface material

NOISE ANALYSIS- A profile or set of profiles designed to gather data for an analysis of coherent noise trains. Also called a **walkaway test**

NOISE SURVEY - A mapping of ambient, continuous seismic noise levels within a given frequency band As some geothermal reservoirs are a source of short-period seismic energy, this technique is a useful tool for detecting such reservoirs Also called ground noise survey

OBSERVER - The geophysicist in charge of recording and overall field operations on a seismic crew.

OFFSET- The distance from the source point to a geophone, or more commonly to the center of a geophone group. Often resolved into components **porpendicular offset**, the distance at right angles to the spread line, and, **in line offset**, the distance from the projection of the shotpoint onto the line of the spread.

ON-LINE - Shotpoints that are shot at any point on a spread other than at the ends of the spread.

OSCILLOGRAPH - An instrument that renders visible a curve representing the time variations of electric phenomena.

OSCILLOSCOPE - A type of oscillograph that visually displays an electrical wave on the screen of a cathode ray tube type

PERMITTIVITY - Capacitivity (q v.) of a three-dimensional material, such as a dielectric Relative permittivity is the dimensionless ratio of the permittivity of a material to that of free space; it is also called the dielectric constant

PHASE VELOCITY - The velocity with which any given phase (such as a trough or a wave of single frequency) travels; may differ from group velocity because of dispersion.

PLANT - The manner in which a geophone is placed on or in the earth, the coupling to the ground.

PROFILE - The series of measurements made from several shotpoints into a recording spread from which a seismic data cross section or profile can be constructed

PROFILING - A geophysical survey in which the measuring system is moved about an area (often along a line) with the objective of determining how measurements vary with location Specifically, a resistivity, IP, or electromagnetic field method wherein a fixed electrode or antenna array is moved progressively along a traverse to create a horizontal profile of the apparent resistivity.

RADAR - A system in which short electromagnetic waves are transmitted and the energy scattered back by reflecting objects is detected Acronym for "radio detection and ranging " Ships use radar to help "see" other ships, buoys, shorelines, etc Beacons sometimes provide distinctive targets Radar is used in aircraft navigation (see Doppler-radar), in positioning, and in remote sensing

RADIO FREQUENCY - A frequency above 3kHz Radio frequencies are subdivided into bands

RAYLEIGH WAVE - A seismic wave propagated along the free surface of a semi-infinite medium The particle motion near the surface is elliptical and retrograde, in the vertical plane containing the direction of propagation

RAYPATH - A line everywhere perpendicular to wavefronts (in isotropic media) The path which a seismic wave takes

REFLECTION SURVEY - A survey of geologic structure using measurements made of arrival time of events attributed to seismic waves which have been reflected from interfaces where the acoustic impedance changes

RESOLUTION - The ability to separate two features which are very close together

ROLL-ALONG SWITCH- A switch which permits connecting different geophone groups to the recording instruments, used in common-midpoint recording.

SEISMIC AMPLIFIER - An electronic device used to increase the electrical amplitude of a seismic signal (See geophone)

SEISMIC CAMERA - A recording oscillograph used to produce a visible pattern of electrical signals to make a seismic record

SEISMIC SOURCE- A device for generating seismic waves Or, the point at which seismic waves are generated

SEISMIC VELOCITY - The rate of propagation of a seismic wave through a medium

SEISMOGRAM - A seismic record.

SEISMOGRAPH- An instrument that detects, magnifies and records vibrations of the earth

SHEAR WAVE - A body wave in which the particle motion is perpendicular to the direction of propagation (Same as s-wave, equivoluminal, transverse wave).

SHOOTER - The qualified, licensed individual (powderman) in charge of all shotpoint operations and explosives handling on a seismic crew.

SHOT DEPTH - The distance down the hole from the surface to the explosive charge, often measured with loading poles With small charges the shot depth is measured to the center or bottom of the charge, but with large charges the distances to both the top and bottom of the column of explosives are usually given

SHOT INSTANT - (Time Break (TB), Zero Time) - The time at which a shot is detonated

SHOTPOINT - Point of location of the energy source used in generating a particular seismogram. Expressed either sequentially for a line (i.e. SP 3) or in engineering notation (i.e. SP 3+00).

SIGNAL ENHANCEMENT - A hardware development utilized in seismographs and resistivity systems to improve signal-to-noise ratio by real-time adding (stacking) successive waveforms from the same source point and thereby discriminating against random noise

SIGNAL-TO-NOISE RATIO SOUNDING- The energy (or sometimes amplitude) divided by all remaining energy (noise) at the time; abbreviated S/N

SOUNDING - Measuring a property as a function of depth, a depth probe or expander. Especially a series of electrical resistivity readings made with successively greater electrode spacing while maintaining one point in the array fixed, thus giving resistivity-versus-depth information (assuming horizontal layering), electric drilling, probing, VES (vertical electric sounding)

SPLIT SPREAD- A method of reflection shooting in which the source point is at (or perpendicularly offset from) the center of the geophone spread

SPREAD - The layout of geophone groups from which data from a single shot are recorded simultaneously

STATIC CORRECTIONS- Often shortened to **statics** Corrections applied to seismic data to compensate for the effects of variations in elevation, weathering, thickness, weathering velocity, or reference to a datum The objective is to determine the reflection arrival times which would have been observed if all measurements had been made on a flat plane with no weathering or low velocity material present.

STONELEY WAVE - A type of seismic wave propagated along an interface

SURFACE WAVE - Energy which travels along or near the surface (ground roll)

SYNTHETIC SEISMOGRAM - An Artificial seismic record manufactured from velocity log data used to compare with and actual seismogram to aid in identify events or in predicting how stratigraphic variations might affect seismic record Often constructed from sonic log data alone although density data may also be incorporated

TAKEOUT - A connection point to a multiconductor cable where geophones can be connected.

TIME BREAK (TB)- The mark on a seismic record which indicates the shot instant or the time at which the seismic wave was generated

TIME DOMAIN - 1. Expression of a variable as a function of time, as opposed to its expression as a function of frequency (frequency domain) Processing can be done using time as the variable, i.e , "in the time domain" For example, convolving involves taking values at successive time intervals, multiplying by appropriate constants, and recombining; this is equivalent to filtering through frequency-selective circuitry. It is also equivalent to Fourier transforming, multiplying the amplitude spectra, and adding the phase spectra ("in the frequency domain"), and then inverse-Fourier transforming

2. Time-domain induced polarization is called the pulse method (q v)

TOMOGRAPHY - The reconstruction of an object from a set of its projections Tomographic techniques are utilized in medical physics as well as in cross-borehole electromagnetic and seismic transmission surveys

TRACE - A record of one seismic channel This channel may contain one or more geophones A trace is made by a galvanometer

UPHOLE METHOD- Also called the Meissner technique, a method of reconstructing wave front diagrams by shooting at several depths and recording on a full surface spread of geophones. Derived wavefront diagrams yield a true picture of wavepaths and, therefore, layering in the subsurface

VELOCITY- A vector quantity which indicates time rate of change of displacement Usually refers to the propogation rate of a seismic wave without implying any direction Velocity is a property of the medium It is measured (or inferred) from sonic logs, normal moveout, in well shooting (vertical seismic profiles [VSP's]), and from refraction time-distance curves

WAVE TRAIN - (1) The sum of a series of propagating wave fronts emanating from a single source (2) The complex wave form observed in a seismogram obtained from an explosive source

Appendix V

Resumes of Key Personnel

PERSONNEL

The educational, training and experience level of personnel to be directly involved in geophysical surveying for a specific project will depend on the nature and scope of the project

Because of the highly specialized nature of the field work, all personnel involved in data acquisition will have a minimum education of a Bachelor's degree in geoscience or engineering Health and Safety personnel will not be required to have a geoscience/engineering degree

All personnel working in hazardous waste areas will be required to have a 40 hour Occupational Safety and Health Administration (OSHA) approved hazardous waste training course Persons located only at the seismograph will have the OSHA training requirement waived. The project manager will have the final decision for the type of personnel required to perform specific project related geophysical duties

Larry A. Irons - Senior Geophysicist

Mr Irons has over 12 years of experience in the application of geophysics for research, engineering, mining, hazardous waste, and petroleum. He is currently Geophysical Task Manager of a $3,000,000 work order as part of the Site Wide Investigation at the Rocky Flats Plant near Denver, CO This work involves the use of the shallow seismic reflection method to define contaminant pathways as a cost-effective alternative to traditional borehole methods. Prior to this work order, Mr Irons was technical manager for a $2,300,000 geophysical contract at the Rocky Flats Plant.

Prior to this contract, he performed geophysical oversight for ten independent Remedial Investigation (RI) tasks at the Rocky Mountain Arsenal as part of the Remedial Investigation/Feasability Study (RI/FS) being conducted by Ebasco Services Incorporated (EBASCO) Sites investigated at the Arsenal have potential to contain wastes generated during 40 years of chemical manufacturing operations that produced a variety of choking, blister, riot control, and nerve warfare agents, as well as organochlorine, organophosphorous, and organosulfur pesticides. The geophysical activities have involved the definition of disposal trenches, site characterization, and identification of potential contaminant pathways Techniques included magnetics, electromagnetics (EM), resistivity, seismic, and borehole geophysics, both airborne and on the ground Support was given to the Basin F remedial action using electromagnetics to detect buried metallic objects

Mr Irons was Task Manager for two tasks to evaluate monitoring well remediation technologies for the Respurce Conservation and Recovery Act (RCRA) and Washington State regulations at the Hanford Site near Richland, WA These tasks included cost/benefit optimization for various methods to prevent the potential movement of contaminated groundwater containing radionuclides down the sides of the well annulus The Hanford Site has been used for 40 years as part of the manufacturing process of atomic and nuclear weapons

Mr Irons has an extensive background in the application of geophysics for the petroleum industry He has managed geophysical budgets of up to $1 8 million Geophysical techniques utilized included seismic, magnetics, gravity, induced polarization, resistivity, and borehole geophysics for the exploration, development, and production of oil, natural gas, and carbon dioxide Mr. Irons has written numerous publications on the application of geophysical techniques to hazardous waste site investigations

Mr Irons is a registered Professional Geologist in the States of Tennessee and Arkansas. He received a B S in Geology in 1977 from the University of Nebraska He received a M S degree in Geology with a mathematics minor in 1979 from the University of Nebraska.

James K. Applegate - Geophysical Engineer

Dr Applegate obtained his Ph D in Geophysical Engineering from the Colorado School of Mines in 1974 His undergratrate degrees were also granted by the same institution Dr Applegate has extensive experience in the application of geophysical principles to the solution of geological problems in all areas of geoscience and geoengineering He has worked for large oil companies, consulting firms, and has taught both geology and geophysics in universities. He is a registered engineer, geologist, and geophysicist. His experience included both application and research in petroleum exploration, mineral exploration, geothermal exploration, and engineering geophysics

Dr Applegate's background includes work on nuclear power plant sites in Italy, Texas, California, and Arizona He participated in fault evaluation studies along the Alaskan pipeline He has extensive experience in applying innovative technologies to the determination of rock properties and the solution of engineering problems. Recent work has included tunnel detection, ground water exploration, and hazardous waste studies He has been involved in the selection and evaluation of nuclear waste repository sites in Washington, Nevada, Texas, Minnesota, Michigan, and Wisconsin Dr Applegate has provided consulting services to Ebasco for Rocky Flats Plant on the application of high-resolution seismic reflection methods.

Dr Applegate is experienced in the use of most geophysical techniques including surface and borehole methodologies He is particularly versed in high resolution seismic methods including 3-D and shear wave methods. This work has included the use of high resolution methods to map fractures and stratigraphic detail. Other work has involved the application of borehole to surface techniques including vertical seismic profiling (VSP) and electrical methods A particular forte is the integration of multiple geophysical data sets to produce a geologically sound interpretation He has made over 50 presentations at national and international meetings, and has written over 30 technical articles

G. Clark Davenport - Environmental Geophysics

Mr Davenport has over 23 years of experience in geophysics, of which more than 19 years have been involved in the planning and management of geophysical surveys for use in hazardous waste, ground water, civil and mining engineering and archaeological investigations He has directed geophysical surveys to delineate contaminant plumes and investigate hydrogeological conditions on a number of sites in the U S. Mr Davenport has designed and managed geophysical surveys used in remedial investigation/feasability study (RI/FS) investigations to detect buried metallics, ordinance and abandoned mine working filled with liquid contaminants The geophysical surveys used in these investigations included ground penetrating radar (GPR), magnetics, electromagnetics (EM), electrical resistivity, and self potential (SP). Mr. Davenport has directed goephysical surveys to determine aquifer depths and geometries in the U S , Spain, and Mexico He was involved in the collection and analysis of 120 kilometers of seismic reflection data used for siting of wells in the Cerro Prieto Geothermal Project Mr Davenport managed seismic refraction investigations to investigate in situ conditions for ten earthen dams as part of the Bureau of Reclamation's SEED Project. He also designed and managed self-potential surveys to define seepage for more than twenty dams in the U S , Mexico, and the Dominican Republic Mr. Davenport has managed and performed geophysical surveys as part of the Preliminary Safety Analysis Report (PSAR) for the siting of over twenty nuclear power plants in the U S., Mexico, Spain, South Africa, Korea, and Iran These projects consisted using of seismic reflection, seismic refraction, seismic cross hole, electrical resistivity, and vibration monitoring surveys to determine bedrock configuration and geometry and in situ dynamic properties. He co-authored the Dames & Moore Manual of Geophysical Practice (1974). This document was submitted to the Nuclear Regulatory Commission (NRC) as part of the required documentation for Quality Control/Quality Assuarance (QC/QA) procedures utilized in nuclear power plant siting investigations Mr Davenport performed QA audits of geophysical data acquisition, reduction analysis, and interpretation performed by contractors at the Byron Nuclear Power Station, Illinois and the Comanche Peak Steam Generating Station, Texas He also

designed and directed electrical resistivity surveys to determine cathodic protection design parameters on eleven sites in the Kingdom of Saudi Arabia.

Mr Davenport has been involved in a number of archaeological investigations, using geophysical techniques to assist archaeologists in planning their excavation activities. He serves as consultant to a number of law enforcement agencies, assisting in crime scene searches and presenting classes on the use of geophysical surveys in criminal investigations Mr. Davenport has served as chairman of the Engineering and Groundwater Committee of the Society of Exploration Geophysicists (1981-1983) and was a member of the ABET Committee of the AIME from 1980-1983

Mr Davenport received a Professional Degree of Geophysical Engineer from the Colorado School of Mines in 1964 He is a registered geophysicist in the State of California

William C. Brennan - Assistant Geophysicist

Mr Brennan holds B S degrees in both Geophysics and Geology from the University of Minnesota, Minneapolis

Mr. Brennan has 2 1/2 years experience in geophysics He is currently involved with a shallow, high resolution seismic reflection project for EG&G Rocky Flats, Inc (EG&G) at the Rocky Flats Plant. This work has been designed to define subsurface pathways in which contaminants could potentially migrate.

Mr Brennan has conducted several geophysical surveys at the Rocky Mountain Arsenal (RMA) hazardous waste site for the U.S Army Toxic and Hazardous Materials Agency (USATHAMA). His most recent geophysical work at RMA involved using shallow seismic refraction methods to try and delineate suspected subsurface bedrock channels believed to influence the flow of potentially contaminated groundwater Prior to that Mr Brennan participated in geophysical surveys using magnetics/gradiometrics and electromagnetic methods

Mr Brennan conducted a magnetics/gradiometrics survey in Level C protection designed to locate abandoned homestead water wells remaining when the U.S Army acquired possession of the property These wells were considered to be conduits for potentially contaminated groundwater from upper aquifers and thus it was necessary to located and properly abandon these wells

Prior to joining Ebasco Services, Incorporated (EBASCO) Mr. Brennan performed various geophysical surveys working as an independent contractor for a mineral exploration company. In remote areas of Wisconsin and North Minnesota, Mr Brennan used several geophysical techniques to identify conductors or potential ore bodies including Horizontal Loop Electro Magnetics (HLEM), Induced Polarization (IP), and Magnetics

Mr. Brennan is a Colorado State Certified First Responder trained in emergency medical care.

Timothy M. Deignan - Geophysical Engineer

Mr Deignan has five years of professional experience dedicated to engineering and environmental geophysics A majority of the geophysical projects he has been associated with have utilized various electromagnetic methods to determine hazardous waste site characteristics and groundwater behavior. Recently, he was the observer on the Rocky Flats Shallow High Resolution Seismic Project, which employed the EG&G Geometrics ES-2420 Digital Reflection Seismograph to acquire field data Mr Deignan has experience utilizing the hardware and software applications on the ES-2420, including the Post Aquisition Processor (PAP) He is competent in designing optmium field data acquisition parameters, and is extremely interested in specialized data processing techniques such as instantaneous phase, seismic reflectivity, and wavelet processing Project management experience has included program design for integrated electromagnetic and seismic surveys. These surveys have assessed drum disposal areas, abandoned underground storage tanks, and subsurface geology and hydrogeology. Mr Deignan has also been involved with geologic field mapping, soil properties identification, hydrologic investigations, and site characterization. In Mr. Deignan's past endeavors he has gained valuable experience in data acquisition, interpretation, and technical report generation.

Mr Deignan is well versed in computer methodologies and their application to geophysical modeling, data reduction, and interpretation He has experience with VAX systems, FORTRAN and PASCAL languages, and has used numerous scientific programs such as SURFER, GRAPHER, RESIX, EMIX-34, ACL (Analytical Compu Log), and LOGGER.

Mr. Deignan graduated from the Colorado School of Mines in 1987 with a degree in Engineering Geophysics He is currently working towards his M.S. degree in Environmental Engineering Geophysics at the School of Mines Mr. Deignan is health and safety trained

Dennis A. Boucher: Geologist

Mr Boucher has over 13 years of professional experience in performance and management of geological and geophysical studies, resource exploration and development, asbestos and chemical characterization groundwater studies, and contaminant migration paths He is currently involved with high resolution seismic data collection, interpretation, and integration with geologic data at the Rocky Flats Nuclear Weapons Plant

Mr Boucher has previously served as Senior Technical Consultant on groundwater studies at a RCRA facility in northern California Work in that capacity included technical review of groundwater data, technical writing, and revision of final reports. Mr Boucher has also served as a chemical characterization engineer at the Weldon Springs Remedial Action Project in St Charles, MO, where he designed and implemented a characterization sampling plan for asbestos and RCRA chemicals. Other project work has included collection and interpretation of geological and geophysical well data. Experience has included surface and subsurface structural and stratigraphic mapping in numerous areas in the Rocky Mountains and the Gulf Coast.

Mr Boucher is health and safety trained On-site sampling has included asbestos, bulk and wipe samples for polychlorinated biphenyls (PCBs), paint scrapings, radioactive samples, groundwater, chemical tracer samples, cores and drill cuttings.

Mr Boucher graduated from Windham College in 1973 with a degree in geology. He received a M S. degree in geology from McGill University in 1977.

Susan J. Havens: Geologist

Ms Havens joined Ebasco Services in 1988 with 4 1/2 years of experience in geological and geophysical interpretation Her work involves analysis and interpretation of technical data and preparation of reports and proposals Her specialization is in geological and geophysical investigations of hazardous waste sites; and has been involved with remedial investigations at the Rocky Flats Plant in Golden, CO, and the Rocky Mountain Arsenal in Commerce City, CO. Ms Havens' involvement on these projects includes interpretation and correlation of seismic reflection data with geophysical and geologic borelogs to determine contaminant migration pathways She is also familiar with a broad range of geophysical exploration techniques including high-resolution reflection seismic, refraction seismic, gravity surveys, DC resistivity, and ground penetration radar.

Ms Havens has also been involved with EBASCO's in-house Quality Assurance/Quality Control (QA/QC) program for technical products She served as the Field QA/QC Coordinator ensuring the quality of the high resolution seismic reflection data and as oversight on Geophysical Logging operations at Rocky Flats She also has provided internal consistency review for several technical reports covering all environmental media This work involved reviewing the text for technical merit, logical cohesiveness, and readability.

Ms Havens received a B S in Geology from Montana State University in 1983 She has been continuing her education with graduate classes in Engineering Geophysics, Groundwater Geophysics, Well Log Analysis, Hydrology, and Seismic Processing and Interpretation.

Sarah Condran - Geologist

Ms Condran has over two years of professional experience in the geological, hydrogeological and environmental areas Currently, she is involved in the geophysical investigation at the Department of Energy's Rocky Flats Plant Ms Condran has also worked as assistant Task Manager for one phase of the remedial investigation and feasibility study of the Rocky Mountain Arsenal (RMA) Ms. Condran's field experience includes soil sampling, borelog preparation, groundwater sampling and geophysical investigations utilizing protection Levels B through D

As a member of a seismic crew which conducted a shallow high-resolution seismic reflection survey, she has participated in all aspects of fieldwork including junior observer and seismograph operator at a site where radioactive as well as chemical contamination were present. As part of this project, she has prepared geologic cross-sections showing potential migration pathways for soil and groundwater contaminants

Ms. Condran has also worked as an assistant Task Manager of the Final Remedial Investigation (RI) Report for the RMA Western Study Area She assisted in all phases of report preparation including interpretation of soil and groundwater chemical data, assessing contaminant fate and transport, preparation of geologic and hydrogeologic maps, review for quality assurance and control and report management

Ms Condran has a B.S. in Geology from the University of New Hampshire

Douglas B. Mendelson, B.S. - Geologist

Mr Mendelson is an engineering geologist with a broad range of experience dealing with geophysics, geotechnical testing, field quality assurance/quality control (QA/QC) and field geology. He is currently site manager of the Rocky Flats Seismic Survey Geophysical Investigation at Rocky Flats Plant under the direction of the Resource Conservation and Recovery Act (RCRA). Other experience includes geotechnical and QC work at RMA Basin F, oil field soil sampling and analysis, rig monitoring, and log drafting and interpretation His field experience includes geological, soil and rock analysis, map drafting, and report preparation in the Big Horn Basin, WY. His surveying experience includes coordination of crew assignments, implementation of field work, instrumentation chief, data accumulation and analysis, map design, and report preparation

Mr Mendelson joined Ebasco Services Incorporated (EBASCO) in 1988 He has field and laboratory experience on the Rocky Mountain Arsenal Hazardous Waste site project for the U.S Army Toxic and Hazardous Materials Agency (USATHAMA). He was responsible for active field collection and laboratory analysis of contaminants, data analysis, and report preparation to management for planning of remedial action He worked to define and design criteria for placement of contaminants and soils in the interim remedial facility While conducting a field stratigraphic study, Mr Mendelson aided engineers in constituent parameter analysis and volumetric problem solving Assuming the job of QC Utilities inspector, responsibilities ranged through all aspects of the earth work, pipe assemblage and testing, and report and map preparation to management. As QC wastepile liner inspector, he maintained quality control over an 800,000 square foot liner, crew and materials, and leachate drainage system, as well as documenting and preparing daily and final reports and as-built drawings for management Mr. Mendelson continually served as liaison between engineering and construction personnel.

This past summer, Mr. Mendelson concentrated on preparing and writing proposals for geophysical investigations at Dugway Proving Grounds and Tooele, UT, for USATHAMA His

work included air photo analysis, research, report writing, editing, and proofreading different sections of these proposals

Mr. Mendelson is presently site manager of a geological investigation at the Rocky Flats Plant, Golden, CO, under the direction of RCRA He has guided the project from its inception through all stages of planning, procurement, permitting, delegation of crew tasks, and acting liaison between EBASCO, the contractor, and RCRA personnel He has managed to maintain work schedules, personnel and supply levels, changing work situations, and problem solving

Clifton G. Stubbs: Seismic/Decontamination Technician

Mr. Stubbs joined Ebasco Services Incorporated (EBASCO) in 1990 as the seismic/decontamination technician for EBASCO's base trailer at the Rocky Flats Plant His responsibilities include preparation of seismic sources, site construction projects, decontamination of trailer area, and assisting with crew activities and site management In addition, he assists with office activities by creating Lotus 123 worksheets and graphs and creating contour maps in CPS PC.

Mr Stubbs has prior experience as a decontamination technician at Rocky Mountain Arsenal He also has experience as a marketing director and store manager.

Appendix VI

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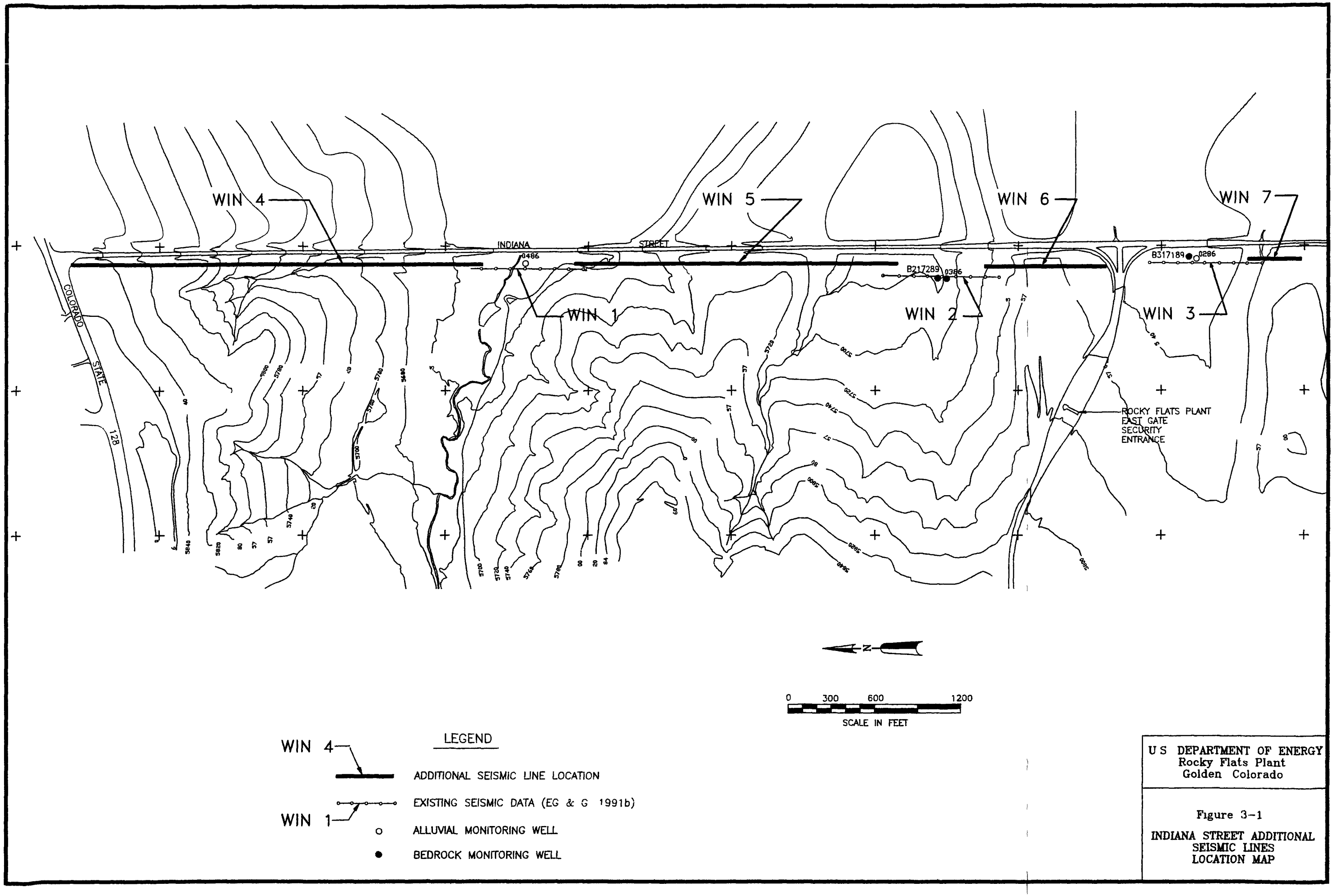

U S DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden Colorado

Figure 3-1

INDIANA STREET ADDITIONAL SEISMIC LINES LOCATION MAP