ROCKWELL INTERNATIONAL
NORTH AMERICAN SPACE OPERATIONS
ROCKY FLATS PLANT

Remedial Investigation Report For 903 Pad, Mound, and East Trenches Areas

Volume V

U S DEPARTMENT OF ENERGY

Rocky Flats Plant
Golden Colorado

31 December 1987

DRAFT

UNITED STATES DEPARTMENT OF ENERGY
ADMINISTRATION CONTRACT DE-AC04-76DPO3533

NOTICE

All drawings located at the end of the document.

APPENDIX A

SAMPLING PLAN

DEPARTMENT OF ENERGY
ALBUQUERQUE OPERATIONS OFFICE
ENVIRONMENT, SAFETY AND HEALTH DIVISION
ENVIRONMENTAL PROGRAMS BRANCH

COMPREHENSIVE ENVIRONMENTAL ASSESSMENT AND RESPONSE PROGRAM

PHASE 2
ROCKY FLATS PLANT
SITE-SPECIFIC MONITORING PLAN

(Work Plan for Performance of Remedial Investigations and Feasibility Studies for all High-Priority Sites)

SAMPLING PLAN

February 1987

DRAFT

TABLE OF CONTENTS

TABLES

1 INTRODUCTION

CEARP Phase 2 Confirmation consists of CEARP Phase 2a Monitoring Plan and CEARP Phase 2b site characterization (remedial investigation) The Sampling Plan is one component of the Monitoring Plan for Rocky Flats Plant The Monitoring Plan typically consists of five parts Synopsis Sampling Plan Technical Data Man agement Plan Health and Safety Plan and Quality Assurance/Quality Control (QA/QC) Plan Because of the Compliance Agreement made by the State of Colorado Environmental Protection Agency and Department of Energy (DOE) this Monitoring Plan also includes a Feasibility Study Plan

CEARP uses a three tiered approach in the preparation of monitoring plans the CEARP Generic Monitoring Plan the Installation Generic Monitoring Plan (IGMP) and Site Specific Monitoring Plans (SSMPs) This SSMP serves as the Work Plan for Performance of Remedial Investigations and Feasibility Studies for all High Priority Sites required by the Compliance Agreement Therefore the acronym used to refer to this plan is SSMP/RIFS This Rocky Flats Plant SSMP/RIFS Sampling Plan is the detailed work plan for implementation of CEARP Phase 2b site characterizations (remedial investigations) at Rocky Flats Plant and follows guidance provided in the IGMP/CSPCP This SSMP/RIFS Sampling Plan is complemented by and inseparable from the Technical Data Management Plan and the Quality Assurance/Quality Con trol Plan Sections of the Sampling Plan are supported by reference to the other plans and to the Synopsis Emphasis is placed on integration of efforts for each of the CEARP Phases Phase 3 (Technological Assessment) Phase 4 (Remedial Action) and Phase 5 (Compliance Verification and Monitoring)

Sampling at Rocky Flats Plant will be conducted using the integrated approach being implemented by CEARP The integrated approach is summarized in the Synop sis and detailed here The integrated approach includes characterization in stages in which the results from the previous stage of sampling are used to design the next stage This iterative process incorporates the experience and knowledge gained from each stage to minimize the total number of samples required to adequately character ize the site and to provide the necessary data base to prepare feasibility studies for alternative remedial actions The benefit of staged sampling is greater flexibility within the sampling program with a minimum of cost

1 1 PURPOSE

This SSMP/RIFS Sampling Plan provides the following basic components of sample/measurement collection and analysis for each high priority site at Rocky Flats Plant

- objectives and goals of the investigation
- justification for selected methods and procedures
- proposed sample locations
- proposed number and type of samples
- additional site specific information requirements

1 2 OBJECTIVES

The objectives of CEARP Phase 2b site characterizations (remedial investigations) at the high priority sites at Rocky Flats Plant are to

- verify and characterize contaminant sources

- determine the present areal and vertical extent of contamination

- estimate the potential for contaminant migration (including rate and direction) to support risk assessment studies

- support the technological assessments (feasibility studies) of alternative response actions including the alternative of no action and

- support identification of long term monitoring and verification requirements as appropriate

2 SITE SURVEY AND MAPPING

Following the guidance in the IGMP/CSPCP Sampling Plan all monitoring locations will be described in accordance with the Installation Coordinate System (ICS) for Rocky Flats Plant The existing coordinate system is a grid system in English units (feet) Elevations will be described in English units feet above MSL Surveying will be done in conformance with surveying procedures established in the IGMP/CSPCP

3 SITE SPECIFIC MONITORING

Environmental conditions at Rocky Flats Plant have been monitored since shortly after operations began in 1952 In addition special programs to characterize waste streams environmental conditions and past waste disposal practices have been conducted recently (DOE 1986b and DOE 1986f) CEARP Phase I identified approximately 70 sites or groupings of sites that could have adverse impacts on the environment Additional data collected during preparation of the RCRA Part B Operating Permit Application identified several more potential sites All potential sites at Rocky Flats Plant were designated as solid waste management units assigned a reference number and located on a base map (IGMP/CSPCP Sampling Plan Plate 1)

A list of solid waste management units is presented in Appendix 1 of the RCRA Part B Operating Permit Application (3004[u] Waste Management Units) (DOE 1986f) These solid waste management units are divided into three categories The first category includes those hazardous waste management units which will continue to operate and which require a RCRA Operating Permit The second category includes those hazardous waste management units which are being closed under RCRA Interim Status The third category includes those inactive waste management units (i e RCRA continuing release sites) that are identified under Section 3004(u) of RCRA Another class of sites is regulated under CERCLA These CERCLA areas identified at Rocky Flats Plant contain only radioactive wastes (DOE 1986f) However for ease in referencing these units and/or areas they have been collectively termed solid waste management units A preliminary prioritization of solid waste management units based on the CEARP Phase I Installation Assessment was performed and summarized in a report titled Preliminary Prioritization of Sites (DOE 1986h)

The high priority sites addressed in this SSMP/RIFS Monitoring Plan were selected and designated as high priority sites because of their suspected relationship to preliminarily identified contaminant plumes in groundwater Several solid waste management units are included in most of the high priority sites (Table 3 1 Synopsis) because of their physical proximity to each other This results in high priority sites that contain solid waste management units from various phases of CEARP This is consistent with the staged approach being used by CEARP for site characterizations (remedial investigations) where the higher priority solid waste management units within the high priority sites are investigated first and data from these characterizations (investigations) guide the remainder of the program

The four high-priority sites identified at Rocky Flats Plant (SSMP Plate I) are as follows

881 Hillside Site
903 Pad Area Site
Mound Area Site
East Burial Trenches Site

The three viable pathways for releases of contaminants from Rocky Flats Plant are air surface water and groundwater (DOE 1986b) Air pathway characterization studies will not be performed under CEARP as the air pathway has been adequately characterized and documented by previous studies (DOE 1986b RI 1986b) A site specific discussion of the other pathways at each high priority site is presented after each site description A plant wide discussion of pathways is presented in the SSMP/RIFS Synopsis

Investigations at each high priority site can be divided into source characterization and migration pathway and plume characterization Source characterization will generally consist of geophysical surveys soil gas surveys and soil waste sampling Migration pathway and plume characterization will generally include geophysical surveys soil gas surveys soil sampling monitor well installation groundwater sampling and surface water and sediment sampling All CEARP Phase 2b site characterizations (remedial investigations) will be implemented using an integrated approach in which geophysical and soil gas survey results are used to direct soil and groundwater sampling efforts

Invasive sampling will be performed at many of the high priority sites. General criteria that are considered in the sampling descriptions of this plan are as follows

If the solid waste management unit cannot be located through geo physical techniques its suspected location will be sampled

Invasive samples from a solid waste management unit will be taken only if the presence of containers of liquid or other hazardous condi tions is not anticipated

At least six samples will be submitted for laboratory analysis from each borehole depending on the amount of available material The reader is referred to Section 6 of the IGMP Sampling Plan for ration ale

The following sections present high priority site descriptions including discus sions of associated solid waste management units and migration pathways followed by detailed plans for source and migration pathway and plume characterization Complete descriptions of the solid waste management units are contained in the RCRA Part B Operating Permit Appendix 1 (DOE 1986f)

3 2 903 PAD AREA SITE

3 2 1 Site Description

3 2 1 1 Solid Waste Management Unit Descriptions

The 903 Pad Area Site is composed of five solid waste management units (SWMUs) as discussed below

Trench T 2 (SWMU Ref No 109) Trench T 2 is located south of the 903 drum storage area and west of the reactive metal destruction site The trench measures approximately 50 x 300 ft and was used prior to 1968 for disposal of sanitary sewage sludge and flattened drums con taminated with uranium and plutonium

903 Drum Storage Area (SWMU Ref No 112) The 903 Drum Stor age area was used from 1959 through the late 1960s for storage of drummed radioactively contaminated liquid waste (primarily lathe coolant a mixture of about 70% hydraulic oil and 30% carbon tetra chloride) Approximately 5240 drums were in storage when removal began (about 3570 of the drums also contained plutonium) After removal of the materials plutonium contaminated soil in the vicinity was moved to a relatively small area and covered with asphalt con crete (the 903 pad) Remedial work was completed in November 1969

Reactive Metal Destruction Site (SWMU Ref No 140) An area south of the 903 drum storage area known as Area 952 was used dur ing the 1950s and 1960s for disposal of reactive metals The site was primarily used for trench burial of lithium metal as lithium car bonate (400 to 500 pounds) In addition smaller quantities of sodium calcium magnesium and unknown liquids were reportedly destroyed on occasion at this area

903 Lip Area (SWMU Ref No 155) During drum removal and cleanup of the 903 drum storage area winds redistributed plutonium beyond the pad to the south and east The area was partially cleaned in 1976 and 1978 when about 4 7 million pounds of contaminated soil containing 0 56 Ci of plutonium was packaged and shipped to an off site DOE disposal facility Additional cleanup was performed along the eastern edge of the 903 Lip Area in 1984

Gas Detoxification Area (SWMU Ref No 183) Building 952 located south of the 903 drum storage area was used to detoxify various gases from leture bottles between June 1982 and August 1983 The lecture bottles held approximately one liter of compressed gas Vari ous gases were detoxified using commercial neutralization processes After neutralization glassware used in the process was triple rinsed crushed and deposited in the present landfill The neutralized gases released to the environment during detoxification would no longer be detectable

3 2 1 2 Surface Water

Surface water drains toward the north east and south from the 903 pad area The north and east flowing water enters Central Avenue ditch and then South Woman Creek (above the retention ponds) The south flowing surface water runs down the slope toward Woman Creek but enters the South Interceptor Ditch and is di verted to the retention pond

3 2 1 3 Groundwater

The 903 pad is underlain by about 4 to 20 ft of Rocky Flats Alluvium The slope to the south which is also included in the 903 pad area is underlain by 15 to ft of colluvium The colluvium consists primarily of silty clay with a trace of gravel and contains discrete gravel layers (possibly lenses) from 1 to 4 ft thick The valley fill with which the colluvium merges to the south (downhill) consists of 3 to 8 ft of sandy gravel Bedrock beneath the slope consists of interbedded claystones and sand stones of the Arapahoe Formation The uppermost bedrock is claystone and the in terbedded sandstones are on the order of 2 to 10 ft thick

The Rocky Flats Alluvium and colluvial materials on the slope toward Woman Creek appear to be unsaturated at the 903 Pad Area Site The uppermost groundwater occurs in bedrock (at least during the winter months) at a depth of approximately 10 to 25 ft below ground surface beneath the center of the slope

The results of groundwater sampling described by DOE (1986f) indicate highly variable groundwater quality conditions beneath the 903 Pad Area Site Data indicate that groundwater at this site has elevated TDS sodium radionuclides (plutonium and uranium) volatile organic compounds and nitrates

3 2 2 Source Characterization

3 2 2 1 Health and Safety Screening

Prior to any surveying or sampling activities at the 903 Pad Area Site a screening for radioactive and chemical contaminants will be conducted Radiation screening will be performed using a field instrument for detection of low energy radiation (FIDLER) and chemical screening will be done with a photoionization detector (PID) If significant surficial contamination is detected during screening detailed health and safety surveys will be performed Detailed surveys will consist of FIDLER and PID readings at each survey grid node as described in Section 3 2 2 2

3 2 2 2 Survey Grid

A 30 ft centered grid will be established at the 903 Pad Area Site as the basis for site surveys and sampling (Plate 2) Grid node locations will be surveyed to an accuracy of 1 ft

3 2 2 3 Surface Geophysics

Several types of geophysical surveys will be performed at the 903 Pad Area Site to identify and delineate source areas Each of these methods is discussed below Specific procedures and equipment specifications for these techniques are presented in Appendixes A and B of the IGMP/CSPCP Sampling Plan

Electromagnetics An electromagnetic induction survey of the 903 pad area will delineate the location of trenches within the site and the overall extent of waste disposal The electromagnetic induction survey will be performed with EM 34 3 and EM 31 terrain conductivity survey meters The EM 34 3 meter will be used in the horizontal and vertical dipole modes at a 20 m coil spacing for an effective survey depth of approximately 50 ft Measurements will be made at 60 ft centers within the survey grid The EM 31 survey will be conducted at 15 ft centers in a continuous mode within the survey grid Also closely spaced measurements will be made along the edges of anomalous areas for boundary definition

The electromagnetic data will be plotted and contoured The results will be in the form of a contour map indicating areas of anomalous conductivity

Magnetometer A magnetometer survey will be performed at the 903 Pad Area Site to identify areas containing buried metallic objects including drums Magnetometer readings will be collected at 15 ft centers within the survey grid Closely spaced measurements will be collected along the edges of anomalous areas for boundary definition The data will be plotted contoured and evaluated to indicate areas of magnetic anomalies

Metal Detection A detailed survey of the magnetic anomalies will be performed using a White s metal detector to precisely locate those areas where buried drums are suspected These locations will be flagged to prevent potential drum puncture during the soil sampling program

Electrical Resistivity Soundings Vertical electrical soundings will be conducted at approximately 10 locations within the 903 Pad Area Site These locations will be selected based on electromagnetic and magnetometer survey results The soundings will provide a vertical profile of resistivity which should indicate the depth of waste disposal water table and bedrock The soundings will be made to an effective depth of about 50 ft

3 2 2 4 Soil Gas Surveys

A soil gas survey will be carried out at the 903 Pad Area Site to identify and confirm the locations of the solid waste management units and if possible to rank these solid waste management units according to their priority within the site The soil gas survey will serve to characterize both the sources and plumes at the 903 pad area and will consist of survey lines running perpendicular to flow (Plate 2) Soil gas samples will be collected on 90 ft centers following the procedures in Appendix A of the IGMP/CSPCP Sampling Plan Based on the results of these data additional soil gas samples will be collected near sources to determine the boundaries of the solid waste management units

3 2 2 5 **Soil/Waste Sampling**

In order to characterize the sources at the 903 Pad Area Site soil and wastes beneath the 903 pad and on the hillside below will be sampled during CEARP Phase 2 (Plate 3) Precise sampling locations will be defined based on geophysical and soil gas survey results However it is anticipated that soil/waste sampling will consist of

four borings through the 903 pad to characterize subsurface materi als

five borings in the 903 lip area (three borings in the main lip area and two borings in the wind dispersal area to the east and west)

two borings adjacent to or through Trench T 2 to characterize its contents and and the materials below it and

three borings in the reactive metal destruction site to characterize its contents

Samples will be analyzed for the parameters listed in Table 3 1

3 2 3 **Migration Pathways and Plume Characterization**

3 2 3 1 **Soil Gas Surveys**

The soil gas survey conducted at the 903 Pad Area Site for source characteriza tion will also serve to detect and quantify the extent of any volatile organic ground water plumes Soil gas samples will be collected on 90 ft centers along the survey lines shown on Plate 2 at the same time as the source characterization soil gas sam pling If a plume is detected the soil gas survey will be expanded to delineate the plume

3 2 3 2 **Soil Sampling**

Soil sampling may be performed to delineate the extent of soil contamination and to characterize migration pathways at the 903 Pad Area Site. Specific sampling locations will be based on the soil gas survey results Samples will be collected from boreholes and monitoring well installations as described in Appendix A of the IGMP/CSPCP Sampling Plan and analyzed for the parameters listed in Table 3 1

3 2 3 3 Monitor Well Installation and Groundwater Sampling

Geophysical and soil gas survey results will be used to determine the exact number and locations of monitor wells at the 903 Pad Area Site Approximately eight new monitor wells are currently anticipated (Plate 4) These wells will probably include

- a well pair west of the 903 pad to characterize upgradient groundwater flow and quality
- a well pair east of the 903 pad to further evaluate groundwater flow in this area
- a well pair south of trench T 2 to track downgradient groundwater plumes and
- a well pair east of the perimeter road and north of pond C 1 to characterize downgradient groundwater quality in that direction

Existing well 65 86 in the drainage of Woman Creek will be sampled at the same time the newly installed wells are sampled

Groundwater samples will be collected from new and existing wells at the 903 Pad Area Site following the procedures in Appendix A of the IGMP/CSPCP Sampling Plan Samples will be analyzed for the parameters listed in Table 3 2 Based on results of soil/waste sampling performed during source characterization this parameter list may be modified to include additional contaminants

3 2 3 4 Surface Water and Sediment Sampling

Surface water samples will be collected from established sampling locations upstream and downstream of the 903 Pad Area Site (IGMP/CSPCP Sample Plan Plate 2) Included will be stations along the South Interceptor Ditch Woman Creek and Pond C 1 Surface water samples will also be collected from any springs or seeps occurring on the hillside below the pad Additional surface water and/or sediment samples may be collected depending on soil gas survey results Samples will be analyzed for the parameters in Tables 3 1 and 3 2 as appropriate

3 3 MOUND AREA SITE

3 3 1 Site Description

3 3 1 1 Solid Waste Management Unit Descriptions

The Mound Area Site is composed of four solid waste management units (SWMUs) as described below

Trench T 1 (Ref No 108) Trench T 1 is located just north of Central Avenue and immediately west of the old East Guard Gate (Gate 9) It was used from 1952 to 1962 and contains 125 drums filled with depleted uranium chips coated with small amounts of lathe coolant The trench was covered with 2 ft of soil and the corners marked however two drums were uncovered during weed cutting operations in 1982 The contents of one of the drums were tested and found to contain an oily sludge with 4 3 picocuries per gram of plutonium and 1 2 microcuries per gram of uranium

Mound Area (SWMU Ref No 113) The mound area is located north of Central Avenue and west of the East Guard Gate From 1954 to 1958 1405 drums filled with depleted uranium and beryllium wastes were buried in the mound area The wastes were mostly solid however some of the drums contained lathe coolant The drums were removed between 1967 and 1970 and shipped offsite as radioactive waste Although residual radioactive contamination may be present in the soils (0 8 to 112 5 dpm/g alpha activity) the contamination is thought to have come from the 903 drum storage area

Oil Burn Pit Number 2 (Ref No 153) Oil Burn Pit Number 2 west of the mound area was used in 1957 and from 1961 to 1965 to burn approximately 1083 drums of oil containing uranium The residues from the burning operations and some flattened drums were covered with soil In 1978 the pit was excavated to a depth of approximately 5 ft and 239 boxes of contaminated material were removed and shipped offsite to a DOE disposal facility

Pallet Burn Site (Ref No 154) In 1965 an area southwest of oil burn pit number 2 was reportedly used to destroy wooden pallets The nature of contamination if any of the pallets is not known Residues from the operation were removed in the 1970s

3 3 1 2 Surface Water

Surface water flow in the vicinity of the Mound Area Site is dominated by the Central Avenue ditch which crosses the plant site flowing to the east All water then flows northward toward South Walnut Creek Runoff from the mound area finally enters the retention ponds in South Walnut Creek (B series ponds)

3 3 1 3 Groundwater

All solid waste management units included in the Mound Area Site are located on the Rocky Flats surface and are underlain by as much as 16 ft of Rocky Flats Alluvium The alluvium consists of 11 ft of fine to medium sand on top of 5 ft of sandy gravel Bedrock beneath the alluvium consists of interbedded claystone and sandstone of the Arapahoe Formation Uppermost bedrock is claystone (1 5 ft thick) underlain by thin interbedded sandstones and claystones

Groundwater occurs in bedrock at about 18 ft below ground surface The alluvium is unsaturated Flow in the bedrock is probably both north (along strike toward the topographically lower drainage) and east (down dip)

Bedrock groundwater quality in the vicinity of the Mound Area Site is characterized by the presence of volatile organic compounds The groundwater sampling results presented by DOE (1986f) indicate that major ion chemistry in bedrock groundwater at the Mound Area Site is slightly different from alluvial groundwater upgradient of the plant However this groundwater has low concentrations of radioactive constituents (at background or lower) and has generally nondetectable metals

3 3 2 Source Characterization

3 3 2 1 Health and Safety Screening

Prior to any surveying or sampling activities at the Mound Area Site a screening for radioactive and chemical contaminants will be conducted Radiation screening will be performed with a field instrument for detection of low energy radiation (FIDLER) and chemical screening will be done with a photoionization detector (PID) If significant surficial contamination is detected during screening detailed health and safety surveys will be performed Detailed surveys will consist of FIDLER and PID readings at each survey grid node as described in Section 3 3 2 2

3 3 2 2 **Survey Grid**

A 30 ft centered grid will be established at the Mound Area Site as the basis for site surveys and sampling Grid node locations will be surveyed to an accuracy of 1 ft

3.3 2 3 **Surface Geophysics**

Several types of geophysical surveys will be performed at the Mound Area Site to identify and delineate source areas Each of these methods is discussed below Specific procedures and equipment specifications for these techniques are presented in Appendixes A and B of the IGMP/CSPCP Sampling Plan

Electromagnetics An electromagnetic induction survey of the Mound Area Site will be performed to determine the aerial extent of soil contamination The survey will be performed with an EM 34 3 terrain conductivity meter used in the horizontal and vertical dipole positions with intercoil spacing of 20 m This configuration yields an effective exploration depth of approximately 50 ft Measurements will be taken on 60 ft centers within the surveyed grid at the Mound Area Site An EM 31 terrain conductivity meter survey will be performed on approximately 10 ft centers along the edges of anomalous areas for boundary definition Conductivity measurements will be plotted and contoured to locate areas of increased or decreased conductivity as compared to background levels

Magnetometer A magnetometer survey using a portable proton magnetometer will be performed to complement the electromagnetic survey The magnetometer survey will identify areas that may contain buried metallic objects including drums Magnetometer measurements will be taken on approximately 10 ft centers along the edges of anomalous areas for boundary definition

The magnetometer data will be plotted and contoured to indicate areas of high magnetic susceptibility These areas indicate the possible presence of buried metallic objects

Metal Detection Areas that are found to contain metallic objects (from electromagnetic induction and magnetometer data) will be further investigated using a White s TM 60 S2 metal detector The metal detection survey will precisely locate buried metallic objects minimizing the potential for drum puncture during the soil investigation

Electrical Resistivity Soundings Approximately six vertical resistivity soundings will be conducted at the Mound Area Site to determine the approximate depth of the source areas A Bison Instrument Model 2365 resistivity instrument will be used to perform the resistivity soundings The soundings will provide a vertical profile of resistivity which should indicate the depth of waste disposal water table and bedrock

3 3 2 4 Soil Gas Surveys

A soil gas survey will be used at the Mound Area Site to identify and confirm the locations of the solid waste management units and if possible to rank these solid waste management units according to their priority within the site The soil gas survey will serve to characterize both the sources and plumes at the Mound Area Site and will consist of survey lines running perpendicular to flow Soil gas samples will be collected on 90 ft centers following the procedures in Appendix A of the IGMP/CSPCP Sampling Plan Based on the results of these data additional soil gas samples will be collected near sources to determine the boundaries of the solid waste management units

3 3 2 5 Soil/Waste Sampling

In order to characterize sources at the Mound Area Site soils and wastes in each solid waste management unit at the site will be sampled during CEARP Phase 2 (Plate 3) Specific sampling locations will be defined according to geophysical and soil gas survey results However it is anticipated that soil/waste sampling will consist of

- two borings in the mound area to identify any residual contaminants
- two borings through or adjacent to Trench T 1 to characterize its contents and
- two borings through the oil burn pit and the pallet burn site to identify potential contaminants

Samples will be analyzed for the parameters listed in Table 3 1

3 3 3 Migration Pathway and Plume Characterization

3 3 3 1 Soil Gas Surveys

The soil gas survey conducted at the Mound Area Site for source characteriza tion will also serve to detect and quantify the extent of any volatile organic ground water plumes Soil gas samples will be collected on 90 ft centers (Plate 2) at the same time that the source characterization soil gas sampling is taking place If a plume is detected the soil gas survey will be expanded to delineate the plume

3 3.3 2 Soil Sampling

Soil sampling may be performed to delineate the extent of soil contamination and to characterize migration pathways at the Mound Area Site Specific sampling locations will be based on the soil gas survey results Samples will be collected from boreholes and monitoring well installations as described in Appendix A of the IGMP/CSPCP Sampling Plan and analyzed for the parameters listed in Table 3 1

3 3.3 3 Monitor Well Installation and Groundwater Sampling

Geophysical and soil gas survey results will be used to determine the exact number and locations of monitor wells at the Mound Area Site Approximately six new monitor wells (three well pairs) are currently anticipated (Plate 4) These wells will probably include a well pair north of the mound area a well pair east of Trench T and a well pair northwest of the mound area and oil burn pit

Existing well 43 86 will be used to characterize upgradient alluvial groundwa ter quality

Groundwater samples will be collected from new and existing wells at the Mound Area Site following the procedures in Appendix A of the IGMP/CSPCP Sam pling Plan Samples will be analyzed for the parameters listed in Table 3 2 Based on results of soil/waste sampling performed during source characterization this pa rameter list may be modified to include additional contaminants

3 3 3 4 **Surface Water and Sediment Sampling**

Surface water samples will be collected from established sampling locations up stream and downstream from the Mound Area Site Included will be stations along the Central Avenue Ditch and South Walnut Creek Surface water samples will also be collected from any springs or seeps occurring on the hillside north of the mound area Additional surface water and/or sediment samples may be collected based on soil gas survey results Samples will be analyzed for the parameters in Tables 3 1 and 3 2 as appropriate

3 4 EAST TRENCHES SITE

3 4 1 Site Description

3 4 1 1 Solid Waste Management Unit Descriptions

The East Trenches Site consists of nine burial trenches (Trenches T 3 through T 11) located just east of the East Access Gate The trenches were used from 1954 to 1968 for disposal of depleted uranium flattened depleted uranium and plutonium contaminated drums and sanitary sewage sludge The trenches are approximately 50 x 300 ft each Trench T 3 (SWMU Ref No 110) received radioactively contaminated flattened drums and substantial quantities of sanitary sewage sludge The drums placed in Trenches T 4 through T 11 (SWMU Ref No 111) had radioactivity ranging from 800 to 8000 dpm/g Trenches T 4 and T 11 also contain some uranium and plu tonium contaminated planks from the solar evaporation ponds and sanitary sewage sludge The trenches are covered with soil

3 4 1 2 Surface Water

Surface water in the vicinity of the East Trenches Site flows both to the north (South Walnut Creek) and to the south (Woman Creek) Flows in the immediate area on top of the terrace are primarily sheet flow until they become concentrated by var ious ditches (extension of Central Avenue ditch to the north and access road ditches to the south) Flows which enter the Central Avenue ditch are carried to the reten tion pond system in South Walnut Creek (B series) Flows which enter either of the access road ditches leave the site flowing either to Walnut or Woman Creek below the retention ponds Flows to the south off the terrace are apparently not concentrated artificial ditches and enter the Woman Creek drainage both upstream and downstream from the retention ponds

3 4 1 3 Groundwater

The East Trench site is underlain by variable but relatively thick Rocky Flats Alluvium (approximately 28 to 45 ft thick) The alluvium is predominately sandy gravel with a few thin (2 to 3 ft thick) sand layers and thin (2 to 4 ft thick) clay layers Bedrock consists of claystones and sandstones of the Arapahoe Formation Both claystone and sandstone were found immediately beneath the alluvium in the vicinity of the trenches Sandstones encountered in drilling well 40 86 were thicker than those encountered elsewhere at the plant (21 ft thick)

Groundwater occurs in both alluvium and bedrock The depth to groundwater in the alluvium is approximately 20 to 25 ft below the ground surface Much of the recharge to the alluvial system is probably from irrigation because the Rocky Flats Alluvium is unsaturated west of the trench area Natural groundwater flow is in three directions north toward South Walnut Creek east towards the Plant boundary and south toward Woman Creek There is a large spring on the south facing slope between the terrace and Woman Creek that is fed by eastern and southern flows from the trench area Depth to water in the bedrock is unknown but based on data collected from installation of well 40 86 there appears to be a substantial downward gradient between the alluvium and the bedrock

Groundwater quality is characterized by the presence of volatile organic compounds TDS concentrations are slightly elevated and radioactive constituent concentrations are roughly equal to those in upgradient alluvial groundwater However volatile organic compounds were detected in three of the four wells near the trenches Specific information on the quality of groundwater in the bedrock is not available

3 4 2 Source Characterization

3 4 2 1 Health and Safety Screening

Prior to any surveying or sampling activities at the East Trenches Site a screening for radioactive and chemical contaminants will be conducted at each area to be investigated Radiation screening will be performed with field instruments for detection of low energy radiation (FIDLER) and chemical screening will be done with a photoionization detector (PID) If significant surficial contamination is detected during screening detailed health and safety surveys will be performed Detailed surveys will consist of FIFLER and PID readings at each survey grid node as described in Section 3 4 2 2

3 4 2 2 Survey Grid

A 30 ft centered grid will be established at the East Trenches Site as the basis for site surveys and sampling Grid node locations will be surveyed to an accuracy of 1 ft

3 4 2 3 Surface Geophysics

Several types of geophysical surveys will be performed at the East Trenches Site to identify and delineate source areas Each of these methods is discussed below Specific procedures and equipment specifications for these techniques are presented in Appendixes A and B of the IGMP/CSPCP Sampling Plan

Magnetometer A magnetometer survey will be performed over each trench to determine the general locations of buried metallic objects and/or drums A portable proton magnetometer manufactured by EG&G Geometrics will be used to measure variations in the earth s magnetic field created by materials of high magnetic susceptibility Magnetometer readings will be collected on 10 ft centers across the trenches within the surveyed grid The resulting data will be plotted and contoured to indicate areas of high magnetic susceptibility

Metal Detection A metal detector will be used as a follow up to the magnetometer survey to precisely locate buried metallic objects Buried metallic objects will be flagged so no drums will be punctured during the soil boring program

Electrical Resistivity Soundings Two vertical electric resistivity soundings will be performed at each trench for a total of 18 soundings to determine the depths of the trenches The resistivity sounding will be performed using a Bison Model 2365 resistivity meter with the BOSS cable system The resistivity data will be evaluated and the depth of electrical interfaces will be identified to indicate depth of trench depth to groundwater and depth to bedrock The effective depth of the resistivity survey will be approximately 50 ft

3 4 2 4 Soil Gas Surveys

A soil gas survey will not be used at the East Trenches Site for source characterization Section 3 4 3 1 discusses plume delineation with soil gas at the east trenches

3 4 2 5 Soil/Waste Sampling

In order to characterize the sources at the East Trenches Site the contents of each trench (T 3 through T 11) may be sampled Specific sampling locations will be defined according to geophysical survey results however at least two borings will be drilled into each trench or adjacent to each trench (one at each end) (Plate 3)

Samples will be analyzed for the parameters listed in Table 3 1

3 4 3 Migration Pathway and Plume Characterization

3 4 3 1 Soil Gas Surveys

The soil gas survey conducted at the East Trenches Site will serve to detect and quantify the extent of any volatile organic groundwater plumes Soil gas samples will be collected on 90 ft centers (Plate 2) following procedures in Appendix A of the IGMP/CSPCP Sampling Plan If a plume is detected the soil gas survey will be expanded to delineate the plume

3 4 3 2 **Soil Sampling**

Soil sampling may be performed to delineate the extent of soil contamination and to characterize migration pathways at the East Trenches Site Specific sampling locations will be based on the soil gas survey results Samples will be collected from boreholes and monitoring well installations as described in Appendix A of the IGMP/CSPCP Sampling Plan and analyzed for the parameters listed in Table 3 1

3 4 3 3 **Monitor Well Installation and Groundwater Sampling**

Geophysical and soil gas survey results will be used to determine the exact number and locations of monitor wells at the East Trenches Site Thirteen new monitor wells are currently anticipated (Plate 4) This monitoring system will likely consist of

- a well pair west of Trench T 3 to characterize upgradient alluvial water quality
- a well pair north of Trenches T 3 and T 4 to determine downgradient water quality north of the East Trenches Site
- two well pairs south and southeast respectively of Trenches T 5 through T 8 to characterize groundwater flow off the terrace
- an alluvial well south of the east access road and Trench T 10 to characterize alluvial groundwater flow east of Trench T 5 through T 9
- a well pair north of Trench T 5 to characterize downgradient groundwater quality east of Trenches T 3 T 4 T 10 and T 11 and
- a well pair south of the East Trenches Site on the Slocum Alluvium terrace below the Rocky Flats surface to define the downgradient extent of groundwater contamination south of the site

Existing wells 40 86 41 86 42 86 and 7 74 will also be used to further evaluate the groundwater flow systems and groundwater quality at the East Trenches Site

Groundwater samples will be collected from new and existing wells at the East Trenches Site following the procedures in Appendix A of the IGMP/CSPCP Sampling Plan Samples will be analyzed for the parameters listed in Table 3 2 Based on results of soil/waste sampling performed during source characterization this parameter list may be modified to include additional contaminants

3 4 3 4 **Surface Water and Sediment Sampling**

Surface water samples will be collected from established sampling locations up stream and downstream from the East Trenches Site Included will be stations along the Central Avenue Ditch the South Interceptor Ditch South Walnut Creek and Woman Creek Surface water samples will also be collected from any springs or seeps occurring on the hillsides north or south of the east trenches Additional surface wa ter and/or sediment samples may be collected based on soil gas survey results Sam ples will be analyzed for the parameters in Tables 3 1 and 3 2 as appropriate

Table 3 1 Source Sampling Parameters

Metals[a b]
Hazardous Substance List Metals
Beryllium
Chromium (hexavalent)
Lithium
Strontium

Organics
Hazardous Substances List Volatiles[b]
Oil and Grease[a]

Radionuclides[b]
Gross Alpha
Gross Beta
Uranium 233 234 and 238
Americium 241
Plutonium 239
Strontium 90
Cesium 137
Tritium

Other
TCLP
EP Toxicity
Characteristics (e g., ignitability corrosivity reactivity)
pH
Cation Exchange Capacity

---

[a]These analyses will be performed on only one third of the samples
[b]These analyses may be performed on sediments

Table 3 2 Groundwater and Surface Water Sampling Parameters

Field Parameters
pH
Specific Conductance
Temperature
Dissolved Oxygen*

Indicators
Total Dissolved Solids
Total Suspended Solids*

Metals**
Hazardous Substances List Metals***
Beryllium***
Calcium
Chromium (hexavalent)***
Iron
Lithium***
Magnesium
Manganese
Potassium
Sodium
Strontium***
Zinc

Anions
Carbonate
Bicarbonate
Chloride
Sulfate
Nitrate

Organics
Hazardous Substances List Volatiles
Oil and Grease***

Radionuclides
Gross Alpha
Gross Beta
Uranium 233 234 and 238
Americium 241
Plutonium 239
Strontium 90
Cesium 137
Tritium

Table 3 2 (Continued)

Other
EP Toxicity
Characteristics (e g ignitability corrosivity reactivity)

---

* for surface water samples only
** dissolved metals for groundwater samples
total and dissolved metals for surface water samples
***These analyses will be performed on only one third of the samples

4 SAMPLE CONTAINERS PRESERVATION AND HOLDING TIMES

Protocols for sample containers sample preservation and holding times will conform to those specified in the CGMP and IGMP/CSPCP Sampling Plans and Quality Assurance/Quality Control Plans

5 SAMPLE CONTROL AND DOCUMENTATION

Procedures for sample control and documentation will conform to those specified in the CGMP and IGMP/CSPCP Quality Assurance/Quality Control Plans

6 SAMPLE HANDLING TRANSPORT AND STORAGE

Procedures for sample handling transport and storage will conform to those specified in the CGMP and IGMP/CSPCP Quality Assurance/Quality Control Plans

7 SAMPLE PREPARATION AND ANALYSES

Procedures for sample preparation and analyses will conform to those specified in the CGMP and IGMP/CSPCP Quality Assurance/Quality Control Plans

8 REFERENCES

DOE 1986b Comprehensive Environmental Assessment and Response Program Phase 1 Draft Installation Assessment Rocky Flats Plant US Department of Energy unnumbered draft report April 1986

DOE 1986f Resource Conservation and Recovery Act Part B Operating Permit Application for USDOE Rocky Flats Plant Hazardous and Radioactive Mixed Wastes US Department of Energy unnumbered report November 1986

DOE 1986g Resource Conservation and Recovery Act Part B Post Closure Care Permit Application for USDOE Rocky Flats Plant Hazardous and Radioactive Mixed Wastes US Department of Energy unnumbered report November 1986

DOE 1986h Draft Preliminary Prioritization of Sites US Department of Energy unnumbered draft report July 1986

Hurr 1976 R T Hurr Hydrology of a Nuclear Processing Plant Site Rocky Flats Jefferson County Colorado US Geological Survey Open File report 76 268 1976

RI 1986a Annual Environmental Monitoring Report January December 1985 Rockwell International Rocky Flats Plant Golden Colorado report RFP ENV 85 April 1986

RI 1986b Rocky Flats Plant Radioecology and Airborne Pathway Summary Report Rockwell International Rocky Flats Plant Golden Colorado unnumbered report December 1986

Robson 1981 Robson S G J C Romero and S Jawistowski Geologic Structure Hydrology and Water Quality of the Arapahoe Aquifer in the Denver Basin Colorado US Geologic Survey Hydrologic Atlas HA 647 1981

APPENDIX B

GEOPHYSICAL INVESTIGATIONS

REPORT OF GEOPHYSICAL INVESTIGATIONS
903 PAD, MOUND AND EAST TRENCHES AREAS
ROCKY FLATS PLANT
GOLDEN COLORADO

Prepared by

Roy F Weston Inc
215 Union Boulevard
Suite 600
Lakewood Colorado 80228

and

Chen and Associates
96 South Zuni
Denver Colorado 80223

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SECTION 1

INTRODUCTION

Geophysical surveys of the 903 Pad Mound and East Trenches areas of the Rocky Flats Plant Jefferson County Colorado have been completed as specified in the CEARP IGMP/SSMP Sampling Plan dated February 1987 for the facility The surveys were completed as part of the CEARP investigations of high priority sites at the Rocky Flats Plant

The purpose of the geophysical surveys was to attempt to identify the location of known SWMUs or other potential sources and/or plumes of environmental contaminants by locating areas of high or low responses (anomalies) on various geophysical instruments Once anomalies have been identified borings and monitoring wells will be located to verify the significance of these anomalous areas as part of the overall site investigation program In addition electrical resistivity was used to provide information about site stratigraphy Stratigraphic information was obtained by performing vertical electrical soundings (VES) at various locations across the site

SECTION 2

SITE BACKGROUND

2 1 903 PAD AREA

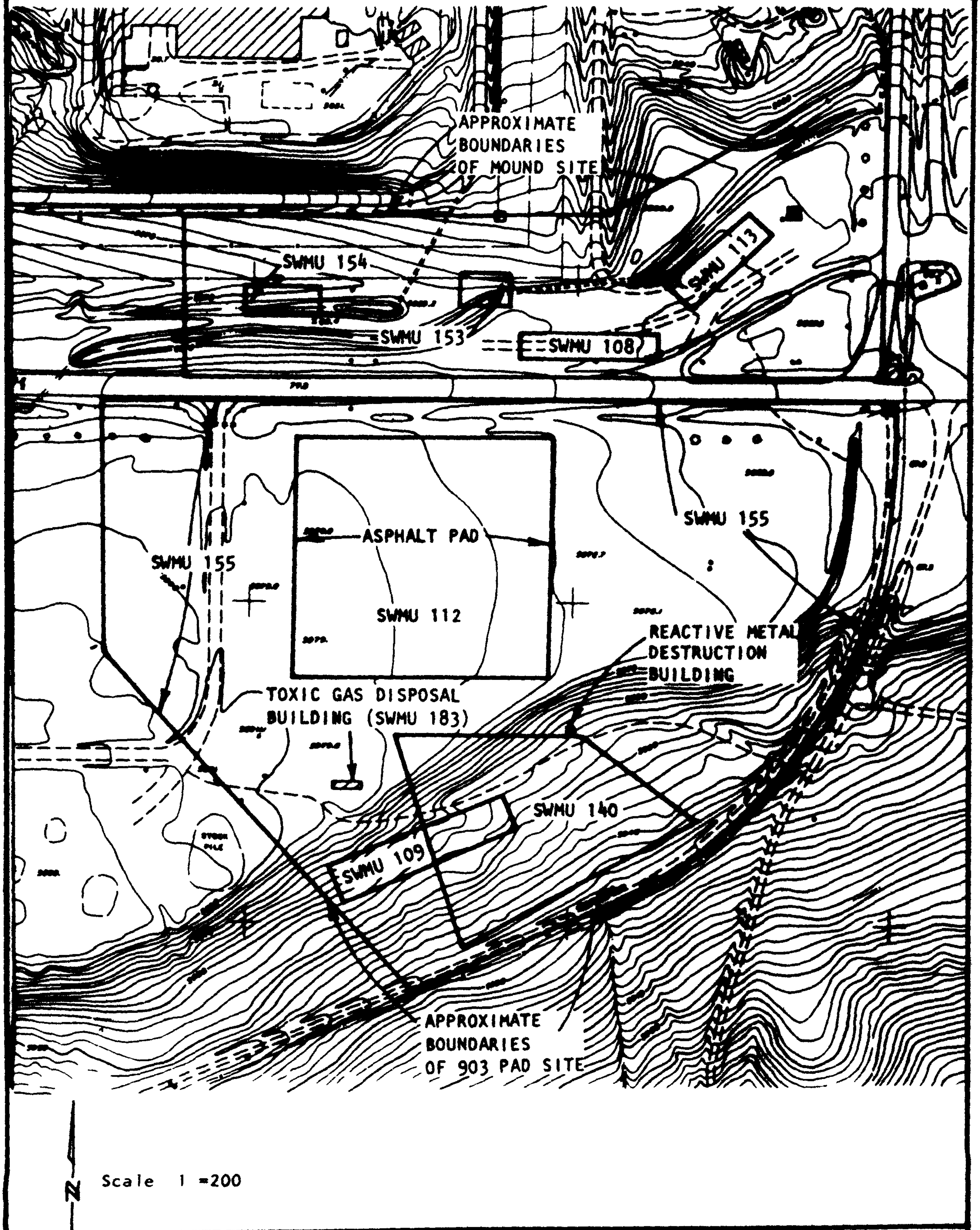
Information available at the time that the geophysical surveys were done indicate that surficial materials at the 903 Pad area consist of about 4 to 20 feet of Rocky Flats Alluvium The Rocky Flats Alluvium is a poorly sorted deposit of sand gravel and cobbles that contains some clay horizons The slope to the south which is also included in the 903 Pad Area is underlain by 15 to 22 feet of colluvium The colluvium consists primarily of silty clay with a trace of gravel and contains discrete gravel layers (possibly lenses) from 1 to 4 feet thick The vallev fill with which the colluvium merges to the south (downhill) consists of 3 to 8 feet of sandy gravel Bedrock beneath the slope consists of interbedded claystones and sandstones of the Arapahoe Formation The uppermost bedrock is claystone and the interbedded sandstones are on the order of 2 to 10 feet thick

The Rocky Flats Alluvium and colluvial materials on the slope toward Woman Creek appear to be unsaturated at the 903 Pad Area site The uppermost groundwater occurs in bedrock (at least during the winter months) at a depth of approximately 10 to 25 feet below ground surface beneath the center of the slope

The results of groundwater sampling described by DOE (1986f) indicate highly variable groundwater quality conditions beneath the 903 Pad Area site Data indicate that groundwater at this site has elevated TDS sodium radionu lides (plutonium and u anium) volatile organic compounds and nitrates

The 903 Pad Area is composed of five solid waste management units (SWMUs) as discussed below and identified on Figure 1

> **Trench T 2 (SWMU Ref No 109) Trench T 2 is located south of the 903 drum storage area and west of the reactive metal destruction site The trench measures approximately 50 x 300 feet and was used prior to 1968 for disposal of sanitary sewage sludge and flattened drums contaminated with uranium and plutonium**



WESTON

LOCATION OF 903 PAD AND MOUNT SITES

Fig 1

903 Drum Storage Area (SWMU Ref No 112) The 903 drum storage area was used from 1959 through the late 1960s for storage of drummed radioactively contaminated liquid waste (primarily lathe coolant a mixture of about 70% hydraulic oil and 30% carbon tetrachloride) Approximately 5 240 drums were in storage when removal began (about 3 570 of the drums also contained plutonium) After removal of the materials plutonium contaminated soil in the vicinity was moved to a relatively small area and covered with asphalt (the 903 Pad) Remedial work was completed in November 1969

Reactive Metal Destruction Site (SWMU Ref No 140) An area south of the 903 drum storage area known as Area 952 was used during the 1950s and 1960s for disposal of reactive metals The site was primarily used for trench burial of lithium metal as lithium carbonate (400 to 500 pounds) In addition smaller quantities of sodium calcium magnesium and unknown liquids were reportedly destroyed at this area

903 Lip Area (SWMU Ref No 155) During drum removal and cleanup of the 903 drum storage area winds redistributed plutonium beyond the pad to the south and east The area was partially cleaned in 1976 and 1978 when about 4 7 million pounds of contaminated soil containing 0 56 Ci of plutonium was packaged and shipped to an off site DOE disposal facility Additional cleanup was performed along the eastern edge of the 903 Lip Area in 1984

Gas Detoxification Area (SWMU Ref No 183) Building 952 located south of the 903 drum storage area was used to detoxify various gases from lecture bottles between June 1982 and August 1983 The lecture bottles held approximately one liter of compressed gas Various gases were detoxified using commercial neutralization processes After neutralization glassware used in the process was triple rinsed crushed and deposited in the present landfill The neutralized gases released to the environment during detoxification would no longer be detectable

2 2 MOUND AREA

All solid waste management units included in the Mound Area are located on and underlain by as much as 16 feet of Rocky Flats Alluvium The alluvium consists of 11 feet of fine to medium sand on top of 5 feet of sandy gravel Bedrock beneath the alluvium consists of interbedded claystone and sandstone of the Arapahoe Formation Uppermost bedrock is claystone (1 5 feet thick) underlain by thin interbedded sandstones and claystones

Groundwater occurs in bedrock at about 18 feet below ground surface The alluvium is unsaturated Flow in the bedrock is probably both north (along strike toward the topographically lower drainage) and east (down dip)

Bedrock groundwater quality in the vicinity of the Mound Area is characterized by the presence of volatile organic compounds The groundwater sampling results presented by DOE (1986f) indicate that major ion chemistry in bedrock groundwater at the Mound Area is slightly different from alluvial groundwater upgradient of the plant However this groundwater has low concentrations of radioactive constituents (at background or lower) and has generally nondetectable metals

The Mound Area is composed of four solid waste management units (SWMUs) as described below and identified in Figure 1

> Trench T 1 (Ref No 108) Trench T 1 is located just north of Central Avenue and immediately west of the old East Guard Gate (Gate 9) It was used from 1952 to 1962 and contains 125 drums filled with depleted uranium chips coated with small amounts of lathe coolant The trench was covered with 2 feet of soil and the corners marked however two drums were uncovered during weed cutting operations in 1982 The contents of one of the drums were tested and found to contain an oily sludge with 4 3 picocuries per gram of plutonium and 1 2 microcuries per gram of uranium
>
> Mound Area (SWMU Ref No 113) The Mound Area is located north of Central Avenue and west of the East Guard Gate From 1954 to 1958 1405 drums filled with depleted uranium and beryllium wastes were buried in the Mound Area The wastes were mostly solid however some of the drums contained lathe coolant The drums were removed between 1967 and 1970 and shipped off site as radioactive waste Although residual radioactive contamination may be present in the soils (0 8 to 112 5 dpm/g alpha activity) the contamination is thought to have come from the 903 drum storage area
>
> Oil Burn Pit Number 2 (Ref No 153) Oil Burn Pit Number 2 west of the Mound Area was used in 1957 and from 1961 to 1965 to burn approximately 1 083 drums of oil containing uranium The residues from the burning operations and some flattened drums were covered with soil In 1978 the pit was excavated to a depth of approximately 5 feet and 239 boxes of contaminated material were removed and shipped off site to a DOE disposal facility
>
> Pallet Burn Site (Ref No 154) In 1965 an area southwest of oil burn pit number 2 was reportedly used to destroy wooden pallets. The nature of the contamination if any of the pallets is not known Residues from the operation were removed in the 1970s

2 3 EAST TRENCHES AREA

The East Trench area is underlain by variable but relatively thick Rocky Flats Alluvium (approximately 28 to 45 feet thick) The alluvium is predominantly sandy gravel with a few thin (2 to 3 feet thick) sand layers and thin (2 to 4 feet thick) clay layers Bedrock consists of claystones and sandstones of the Arapahoe Formation Both claystone and sandstone were found immediately beneath the alluvium in the vicinity of the trenches Sandstones encountered in drilling well 40 86 were thicker than those encountered elsewhere at the plant (21 feet thick)

Groundwater occurs in both alluvium and bedrock The depth to groundwater in the alluvium is approximately 20 to 25 feet below the ground surface Much of the recharge to the alluvial system is probably from irrigation because the Rocky Flats Alluvium is unsaturated west of the trench area Groundwater flow is in three directions north toward South Walnut Creek east toward the Plant boundary and south toward Woman Creek There is a spring on the south facing slope between the terrace and Woman Creek that is fed by eastern and southern flows from the trench area

Groundwater quality is characterized by the presence of volatile organic compounds TDS concentrations are slightly elevated and radioactive constituent concentrations are roughly equal to those in upgradient alluvial groundwater However volatile organic compounds were detected in three of the four wells near the trenches Specific information on the quality of groundwater in the bedrock is not available

The East Trenches Area consists of nine burial trenches (Trenches T 3 through T 11) located just east of the East Access Gate (Figure 2) The trenches were used from 1954 to 1968 for disposal of depleted uranium flattened depleted uranium and plutonium contaminated drums and sanitary sewage sludge Trench T 3 (SWMU Ref No 110) received radioactively contaminated flattened drums and substantial quantities of sanitary sewage sludge The drums placed in Trenches T 4 through T 11 (SWMU Ref No 111) had radioactivity ranging from 800 to 8 000 dpm/g. Trenches T 4 and T 11 also contain some uranium and plutonium contaminated planks from the solar evaporation ponds and sanitary sewage sludge The trenches are covered with soil

SECTION 3

METHODS

3 1 GRID SURVEY

Grid systems were established on the 903 Pad Mound and East Trenches area in order to provide lateral control of measurement location Survey stations were staked at 60 foot intervals and marked with a coordinate designation based on the Rocky Flats Plant grid system All geophysical survey points were located based on this coordinate system

3 2 ELECTROMAGNETIC CONDUCTIVITY

Electromagnetic conductivity (EM) surveys of the 903 Pad and Mound areas were conducted using both EM 34 3 and EM 31 Terrain Conductivity Meters manufactured by Geonics Ltd Electromagnetic techniques of measuring terrain conductivity operate by imparting an alternating current to a transmitter coil Current passing through the transmitter coil produces a magnetic field which in turn induces small currents in the underlying strata Currents within the geologic materials produce a secondary magnetic field which is sensed by the receiver coil It has been shown that under certain constraints the ratio of the secondary to the primary magnetic field is proportional to terrain conductivity (Geonics 1980) This fact allows conductivity to be read directly from the instrument in units of millimhos per meter (mmhos/m)

The EM 34 3 unit measures the average conductivity of materials between two hand held coils spaced 10 20 or 40 meters apart The effective depth of penetration is variable by altering intercoil spacing and coil orientation EM 34 3 conductivity was measured at 377 survey stations in both horizontal and vertical dipole configurations with a coil separation of 10 meters Measurements taken in the horizontal dipole mode yielded an effective depth of exploration of 7 5 meters with the largest single contribution from near surface materials. Vertical dipole measurements yielded an effective depth of exploration of 15 meters with a smaller signal contribution from near surface materials The surveys were run on a 60 foot grid system This spacing was chosen to allow nearly continuous conductivity data to be obtained along the survey lines

The EM 31 unit measures the average conductivity of materials between two fixed coils spaced 3 7 meters apart This configuration yields an effective depth of exploration of 6 meters The survey was conducted at 15 foot intervals along east west oriented survey lines Survey lines were spaced at 30 foot intervals except where examination of the data showed that additional data collection would aid in the definition of anomalous areas A total of 3016 data points were collected with the EM 31

Both EM 34 3 and EM 31 were utilized to characterize the sites because of the characteristic differences between the two instruments The EM 34 3 is best suited to screen broad areas of a site for changes in conductivity The EM 34 3 is less sensitive to small conductors such as single drums or small pits than is the EM 31 because of its relatively large coil spacing However the EM 34 3 is capable of surveying to a greater depth and is less sensitive to surficial materials (soils) in the vertical dipole configuration than is the EM 31 This gives the EM 34 3 the capability of identifying contaminant plumes more readily than the EM 31 in areas were there is sufficient conductivity contrast

3 3 MAGNETOMETRY

A total of 111 magnetic survey lines were completed at the four subject sites The survey was conducted using an EG&G Geometrics Memory Proton Precession Magnetometer Model G 856X with a gradiometer option

The magnetic method used to measure the earth s total magnetic field intensity temporarily polarizes spinning hydrocarbon protons in the magnetometer sensor The temporary polarization is obtained through the amplification of a uniform magnetic field generated by a current passing through a coil of wire When the current is removed the spin of the protons causes them to revolve in the direction of the earth s magnetic field The spinning protons then generate a small signal in the same coil used to polarize them The signal is directly proportional to the magnetic field intensity by the proportionality constant known as the gyromagnetic ratio The frequency of the spinning protons is then measured by a digital counter as the absolute value of the earth s magnetic field intensity within an accuracy of 0 1 gammas

The presence of magnetic items in the near surface creates magnetic anomalies in the earth s magnetic field The location and sensitivity of the magnetic sensors becomes paramount for detection of these metallic items If the sensor is placed too close to the items the magnetic anomaly may overwhelm the ability of the sensor to obtain a reading By the same logic if the sensor is too far away the magnetic anomaly may not be large enough to affect the sensor

The magnetometer used was equipped with a gradiometer option allowing two field readings at different heights and a gradient reading based on the two readings obtained The unit makes a measurement of the earth s total magnetic field intensity and displays the result to an accuracy of 0 1 gammas The reading is automatically stored along with the day time of day line number and reading number in the digital memory The data is then retrieved at the end of the day by transferring it to a computer through the computer s communication port

The magnetic survey was conducted using three different grid spacings The grid spacing used on the 903 Pad and Mound areas had a north south spacing of 30 feet and an east west spacing of 15 feet The second grid system had a square pattern on a 10 foot by 10 foot spacing This was conducted around the existing trenches in the East Trenches area

3 4 RESISTIVITY

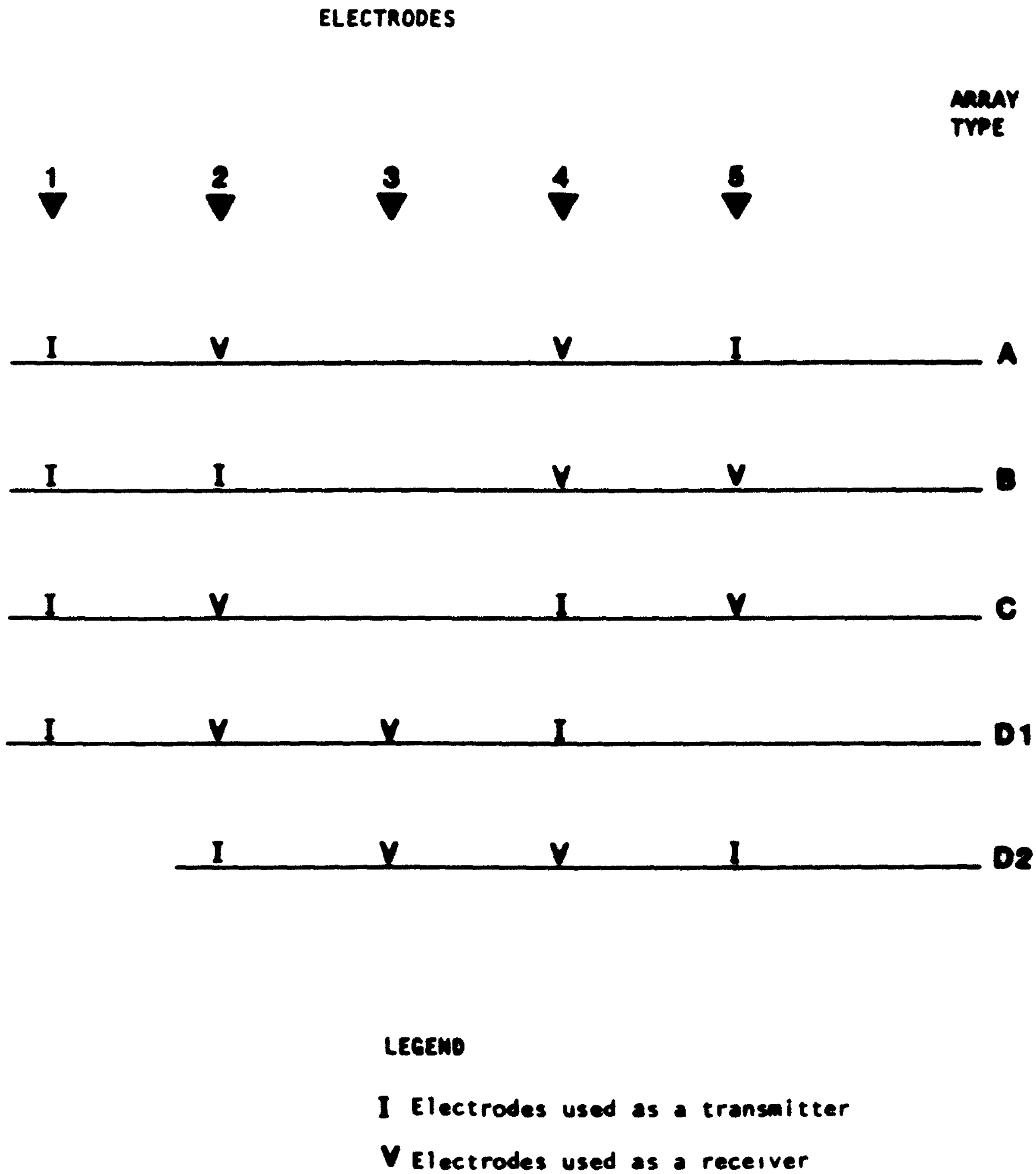
Vertical Electrical Soundings (VES) were made using a Bison Model 2390 transmitter and receiver This system is a microprocessor controlled signal enhancement unit with automatic self potential removal and current control The unit displays the readings in the form of a four decimal place display in millivolts The Bison offset sounding cable system (BOSS Model 2365) and steel electrodes were used for the VES surveys

The VES method measures the electrical resistivity of the soil and bedrock by passing an electrode into the subsurface from a pair of electrodes and measuring the electrical voltage with a second pair of electrodes Resistivity data is generally recorded as apparent resistivity ρ_a which can be found from the equation ρ_a = K x V/I where V is the observed voltage I is the injected current and K is the geometric shape factor The basic unit of VES measurement and apparent resistivity is the ohm meter K is the shape factor of the geometry of the electrode arrangement typically called an array

The Wenner array is the most commonly used array for hydrogeologic studies The Wenner array was selected for its ease of field operation and data analysis and its sensitivity to soil resistivity changes caused by stratigraphic variations and changes in moisture content. Its main advantages are that is has a much lower sensitivity to geologic noise and localized changes in soil resistivity unrelated to large scale features of interest and it returns a relatively high voltage for a small transmitter current Its major disadvantage lies in having a somewhat lower vertical resolution and lower horizontal resolution than other arrays For the Wenner array the geometric shape factor is given by K = 2 ρ a where a is the spacing between electrodes

Apparent resistivity values are not indicative of the resistivity at any single depth but is an average soil resistivity over a range of depths The depth of exploration is proportional to the a spacing used with the principal response coming from a depth of about 1/3 to 1/2 of the a spacing VES surveys are conducted by making a series of measurements starting with a small a spacing usually less than 1 meter and increasing the spacings logarithmically out to several tens or even hundreds of meters

The BOSS system utilizes an array of cables designed to allow completion of Wenner soundings very quickly The cables have electrode takeouts in a geometric series with the a spacing increasing by a factor of two Five different array measurements are made at each a spacing as shown on Figure 3 Measurements D 1 and D 2 consist of a pair of overlapping or offset Wenner arrays If the local stratigraphy consists of a series of flat layers both arrays D 1 and D 2 will give the same approximate apparent resistivities



WESTON

ARRAY TYPES USED IN BOSS SYSTEMS FOR VES SURVEYS

Fig 3

Millivolt values from the five array measurements at each a spacing are used to calculate a single Wenner resistivity reading Unfortunately the algebraic manipulations used to calculate the Wenner resistivity readings tend to amplify the effects of geologic noise and spread the noise over several a spacings Because of the amplification effects only those VES survey points with a lateral difference error of less than 33% as measured in the field were used The VES survey points which exceeded 33% were smoothed to reduce the error as much as possible and then were analyzed The smoothing technique digitized the data curves by reducing the high and low resistivity spikes in the field data prior to analyses for layer thickness and layer resistivity

Twenty six vertical electrical soundings (VES) were completed at the 903 Pad Mound and East Trenches areas The locations of the VES survey points are presented in Table 1

VES 10 and VES 11 were completed at the approximate middle of SWMU 111 1 north of the east entrance road at the East Trenches site Both surveys were conducted at right angles to one another VES 12 and VES 13 were completed at the east end of SWMU 111 8 and at right angles to one another VES 14 was completed at a magnetic anomaly at the reported location of SWMU 140 the reactive metal destruction trenches VES 15 was completed at an electromagnetic conductivity anomaly in the middle of the Mound site VES 16 was completed at a magnetic anomaly where a number of buried drums were exposed at the reported location of SWMU 109 VES 17 VES 18 VES 30 and VES 31 were completed at the middle of SWMU 110 VES 19 was located north of the northwest corner of the 903 asphalt pad in the Mound site as a background point VES 21 VES 22 and VES 27 were completed in the East Trenches site at the location of SWMU 111 4 VES 23 VES 24 VES 25 and VES 26 were also completed in the East Trenches site at SWMUs 111 2 and 111 3 respectively VES 28 VES 29 and VES 35 were completed at SWMU 111 6 at the far eastern end VES 33 was completed at the eastern end of SWMU 111 2 to verify the length of SWMU 111 2 VES 34 was completed at the eastern end of SWMU 111 4

TABLE 1

LOCATION OF VES SURVEYS

SURVEY NO.	ROCKY FLATS PLANT GRID SYSTEM COORDINATES
10	N 36730 E 24200
11	N 36730 E 24200
12	N 36675 E 23945
13	N 36675 E 23945
14	N 35720 E 22900
15	N 36440 E 23020
16	N 35640 E 22700
17	N 36810 E 23800
18	N 36810 E 23800
19	N 36380 E 224[illegible]0
20	N 36660 E 23200
21	N 36560 E 24520
22	N 36560 E 24520
23	N 36700 E 24750

TABLE 1

LOCATION OF VES SURVEYS
(CONTINUED)

SURVEY NO.	ROCKY FLATS PLANT GRID SYSTEM COORDINATES
24	N 36700 E 24750
25	N 36700 E 24800
26	N 36700 E 24800
27	N 36560 E 24550
28	N 36560 E 24640
29	N 36560 E 24640
30	N 36810 E 23800
31	N 36810 E 23800
32	N 36600 E 24870
33	N 36700 E 24860
34	N 36680 E 24980
35	N 36560 E 24630

3 5 METAL DETECTION

Metal detector surveys were conducted at magnetometer and electromagnetic conductivity anomalies at the four subject sites Additional surveys were completed at the reported locations of SWMUs and cultural features such as the underground utility vaults The objective of these surveys was to accurately define the areal extent of buried metallic objects A Whites Treasuremaster TM600 Series 2 metal detector was used to conduct the survey

A metal detector operates on a principle similar to a magnetometer Both instruments measured the earth s magnetic field intensity with the principal difference being that the metal detector is adjusted to be in phase with remnant magnetization present in the earth s magnetic field Any magnetic anomaly with sufficient amplitude to create an out of phase response in the metal detector is detected The in phase adjustment allows the instrument to look at coarse measurements of the earth s magnetic field typically on the order of 10 000 gammas Due to the nearness of the sensor to the items in question significant changes in the magnetic field intensity can be sensed Metal detectors are used exclusively to locate buried underground utilities and metallic items They are not used to define subsurface conditions as magnetometers are used

The TM600 is a two coil unit with electrical null controls sensitivity controls and a ground reject control The ground reject control allows the unit to automatically adjust to eliminate false responses due to changing ground conditions primarily from magnetite and associated minerals A multi purpose sensitivity meter is used to monitor the received target signals and a built in speaker produces a tone which is proportional to the signal received

A grid spacing on the order of 5 to 10 feet was instituted over the surveyed areas Two passes were made over the area in question at orientations 90° to one another This resulted in pinpointing the item in question and aided in defining the areal extent Upon location of the item a pin flag was placed to mark the areal extent in the field of the signal from the metal detector These areas were marked as locations to be avoided during subsequent soil sampling programs

SECTION 4

DATA REDUCTION

4 1 ELECTROMAGNETIC CONDUCTIVITY

Conductivity data were processed on a Univac 1160 mainframe Tektronix 4014 terminal and Tektronix 4663 plotter with a CPS 1 contouring program Contour intervals used for plotting conductivity data were 10 and 20 mmhos/m Intervals were chosen to show trends in areas of subtle changes while maintaining distinction in areas of contrasting data

The CPS 1 program contours data by dividing each grid cell into intermediate sub cells An intermediate grid value is then compared as the average of the four corner values and located at the center of the sub cell with diagonals to each corner The intersections of the contour locus with the sides and temporarily computed diagonals are determined using inverse linear interpolation The process continues until each chosen contour interval is completed

Interpretation of the electromagnetic conductivity data was based on visual examination of the contour plots Comparison of anomalous readings with magnetometric results and areas of known cultural interferences such as pipelines or fences was used to assist in interpretation

4 2 MAGNETOMETRY

Reduction of the magnetic data consisted of three phases The first phase removed diurnal variations in the earth s magnetic field from the field data using a linear interpolation method The field data were also checked for regional gradient effects Due to the small size of the subject sites this was not a problem. The second phase generated the gradient data from the field data by dividing the difference between the top and bottom sensors by the distance between sensors During the third phase contour plots of equal magnetic intensity were generated

The contour plots of the 903 Pad and Mound sites were generated as described above for electromagnetic data The contour plots of the East Trenches site were generated using the SURFER contouring software produced by Golden Software Golden Colorado Interpretation of the contour map and data was based on a visual comparison of published magnetic curves to determine whether the anomalies defined by the contour plots were due to geologic conditions or cultural features They were also compared to the electromagnetic conductivity survey plots to identify corresponding anomalies

4 3 ELECTRICAL RESISTIVITY

VES data were analyzed using one dimensional modelling One dimensional modelling assumes that the earth in the vicinity of the VES survey point can be represented by a series of flat lying layers each with a different electrical resistivity This interpretation yields accurate results assuming certain criteria

the geologic structure to be located has a significant resistivity contrast from its background

the lateral extent of these structures must be larger than their depths and

the layers must be relatively thick compared with their depths

The interpretations were determined using an automatic inverse resistivity modelling program similar to one developed by Dr Adel A R Zodhy of the Water Resource Division U S Geological Survey The inverse resistivity modelling program begins with a best fit estimation based on Ghosh coefficients and tentatively converges to the inverse resistivity (geoelectric) model which gives the least sum of square residuals for the field data The program then generates layer thicknesses depths and resistivities

For geologic environments such as that at the subject sites where more than four layers are present and the layers are not flat lying lateral interference affects calculations of both the layer thicknesses and layer resistivities Wherever the lateral difference error exceeded 33% the data was smoothed to reduce the lateral effects as much as possible and then were analyzed The smoothing technique used digitized data curves by reducing high and low resistivities prior to analysis for layer thicknesses and resistivities

4 4 METAL DETECTION

No data reduction was required for the metal detector survey Areas of buried metallic items were located in the field and marked with pin flags

SECTION 5

SURVEY RESULTS

5 1 903 PAD AND MOUND AREAS

5 1 1 Electromagnetic Conductivity

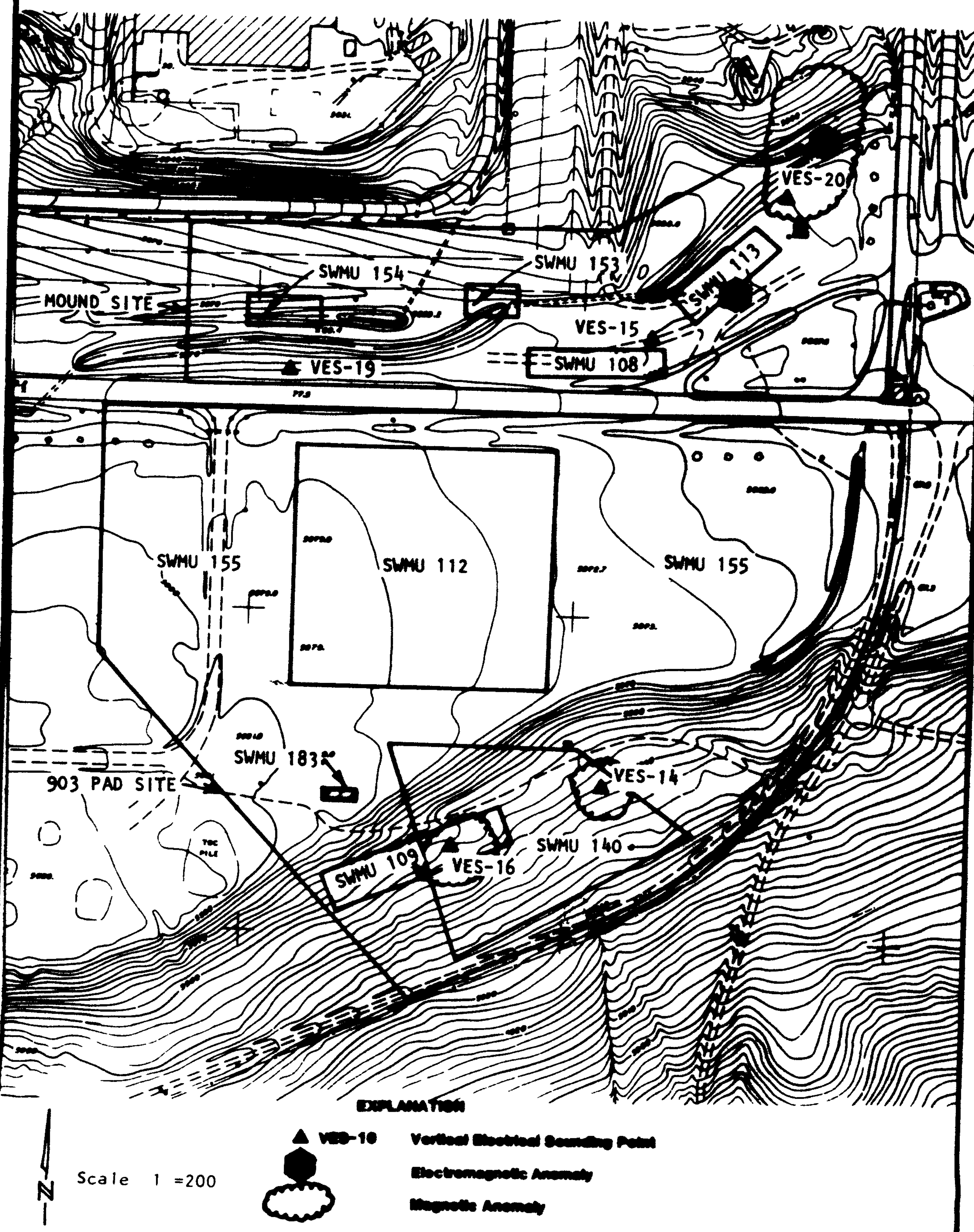
The results of the electromagnetic conductivity surveys of the 903 Pad and Mound Areas are presented as contour plots in Appendix 1 Examination of the contour plots indicates two areas of anomalous conductivity which are not readily explainable by the occurrence of cultural interferences The approximate locations based on the Rocky Flats grid system of the anomalous conductivity values for each instrument are as follows and as indicated on Figure 4

EM 34 Vertical	EM 34 Horizontal	EM 31
N 36860 E 23200	N 36860 E 23200	N 36860 E 23160
N 36470 E 23080	N 36440 E 23080	

The first anomalous area is located at the northeast corner of the survey area between the Mound Area (SWMU 113) and the wastewater treatment plant This anomaly was detected by both electromagnetic instruments and magnetometry The source of this anomaly is unknown

A second area of anomalous conductivity values was indicated by the EM 34 in the vicinity of grid station N 36470 E 23080 The location suggests a correlation between this anomaly and the Mound Area (SWMU 113) As can be seen on the EM 34 contour plots this anomaly is strongest on the vertical dipole contour plot weakly indicated on the horizontal dipole contour plot and absent on the EM 31 plot This suggests that the source of the anomaly is located at depth (>10 feet) rather than the near surface

A general trend toward higher conductivity values is evident on the southeast corner of the survey area This trend evident in each contour plot is thought to be the result of disturbed soils and increased moisture content on the slope south of the 903 Pad Area



WESTON

Location of VES Survey Points, Electromagnetic and Magnetic Anomalies at 903 Pad and Mound Sites

Fig 4

5 1.2 Magnetometry

903 Pad and Mound Sites The results of the magnetic survey of the 903 Pad and Mound areas are presented as a contour plot in Appendix 2 Three magnetic anomalies were detected in the 903 Pad and Mound areas as shown on Figure 4 Two of the anomalies were located south southeast of the 903 asphalt pad at approximately N 35600 E 22720 and N 35700 E 22900 These anomalies are thought to be associated with Trench T 2 (SWMU 109) and the Reactive Metal Destruction Trenches (SWMU 140) respectively The third anomaly located at the northeastern portion of the Mound site (N 36830 E 23185) was not readily explainable and corresponded to electromagnetic conductivity anomalies in this area

5 1 3 Electrical Resistivity

The results of the VES surveys conducted at the 903 Pad and Mound areas are presented as resistivity models Figures 3 3 3 4 3 5 3 7 and 3 8 in Appendix 3 The VES surveys were analyzed for stratigraphic interpretations as geoelectric models

At VES 14 (Figure 3 3) a layer approximately 1 5 feet thick with a resistivity of 347 ohm meters appears to represent colluvium This layer overlies a less resistive layer of 282 ohm meters with a thickness of 3 feet This appears to be composed of a slightly moist gravel Underlying this layer is a more resistive layer 330 ohm meters indicating a weathered bedrock An additional layer was analyzed at 186 ohm meters below the weathered bedrock which appears to represent claystone bedrock

At VES 15 (Figure 3 4) two highly resistive zones are present at the surface This appears to be the result of abandoned roadway materials and the resulting compaction due to wheel loads and the lower layer appears to be the result of dry gravel Below 15 feet the resistivity varies from 218 to 302 ohm meters which appears to represent a claystone bedrock sequence with increasing sand content at depth

The survey at VES 16 (Figure 3 5) indicates two highly resistive layers 2369 and 1156 ohm meters near the surface No plausible explanation could be developed based on visual observations of the area and a review of other geophysical data The presence of partially exposed drums may have induced significant lateral effects causing the two highly resistive layers to be developed in the computer model Below these resistive layers a similar response to VES 14 was analyzed These layers appear to be a sandstone and claystone bedrock sequence

VES 19 (Figure 3 7) was conducted as a background survey point for the Mound area. Two highly resistive layers 892 and 749 ohm meters were analyzed at the surface These appear to present colluvium overlying a dry gravel to a depth of 7 feet Below these layers are two other layers 410 and 390 ohm meters representing a sandstone sequence Underlying these layers appears to be a claystone sequence with a resistance of 164 ohm meters

VES 20 (Figure 3 8) was conducted at a series of electromagnetic conductivity and magnetic anomalies The response at VES 20 was similar to that of VES 19 The layers representing bedrock appeared to be a claystone bedrock sequence rather than a sandstone and claystone bedrock sequence

5 1 4 Metal Detection

Metal detector surveys in the 903 Pad and Mound areas consisted of investigating electromagnetic conductivity and magnetic anomalies and the reported locations of SWMU 108 109 113 140 153 and 154 Due to the presence of the electrified security fence around the PSZ and various underground utilities metal detector surveys in the Mound area could not be conducted Generation of magnetic noise affected the detector resulting in false readings

Buried metallic items were detected during the surveys of SWMU 109 and 140 in the 903 Pad area The items appear to be buried drums in SWMU 109 and metallic residues in SWMU 140 from the destruction of reactive metals The areas were located in the field and marked with pin flags for reference

5 2 EAST TRENCHES AREA

5 2 1 Magnetometry

The results of the magnetic surveys within the fenced areas at the East Trenches area are presented as contour plots (Figures 2 1 through 2 5) in Appendix 2 The purpose of conducting the surveys with the fenced areas was to better define the reported locations of the existing trenches The contour plots define the locations of concentrations of metallic items reported to be buried drums In general the existing trenches traverse east and west SWMU 110 (Figure 2 1) has an approximate length of 80 feet and an approximate width of 20 feet Two areas within the trench appear to have higher concentrations of metallic items than the rest of the trench SWMU 111 1 (Figure 2 2) has an approximate length of 120 feet and an approximate width of 20 feet Three areas within the trench appear to have higher concentrations of metallic items with the eastern and middle areas having the highest concentrations SWMU 111 2 and SWMU 111.3 (Figure 2 3) reportedly are next to one another SWMU 111 2 does not appear to have any significant quantities of metallic items and is poorly defined SWMU 111 3 has an approximate length of 60 feet and an approximate width of 20 feet Two areas within the trench appear to have higher concentrations of metallic items than the rest of the trench The western end of the trench has the highest concentration of metallic items SWMU 111 4 SWMU 111 5 and SWMU 111 6 (Figure 2 4) appear to have similar concentrations of metallic items These trenches are each approximately 80 feet in length and 15 to 20 feet in width SWMU 111 7 (Figure 2 5 was not well defined except for a small concentration of metallic items in the approximate middle of the trench SWMU 111 8 (Figure 2 6) was also poorly defined except for a high concentration of metallic items in the western end of the trench

5 2.2 Electrical Resistivity

Results of the VES surveys conducted at the East Trenches area are presented as resistivity models (Figures 3 1 3 2 3 6 and 3 9 to 3 17) in Appendix B Data interpretation of these VES surveys were limited to the determination of the depths to the bottoms of existing trenches Table 2 presents the results of the determination of the trench bottom depths for the East Trenches area

5 2 3 Metal Detection

Metal detector surveys within the fenced areas at the East Trenches area were conducted to better define the locations of buried metallic items. The metal detector was adjusted to maximize its sensitivity The fenced areas were then surveyed and locations of responses corresponding to buried metallic items were marked with pin flags in the field All of the fenced areas exhibited responses corresponding to buried metallic items Due to the design of the metal detector individual metallic items could not be located and only the boundaries of the areas could be defined and marked using pin flags

TABLE 2

TRENCH BOTTOM DEPTHS

VES NO.	Depth (ft)	SWMU NO.
10 & 11	12	111 7
12 & 13	13	111 8
17 & 18	11	110
21 & 22	14	111 6
23 & 24	6	111 2
27	8	111 6
28 & 29	11	111 5
30 & 31	16	110
32	8	111 4
33	18	111 2
34	9	111 3
35	9	111 5

NOTES

(1) Due to lateral effects VES 25 & 26 were not analyzed for SWMU 111 2
(2) Trench bottoms are not consistent in depth

SECTION 6

CONCLUSIONS

Geophysical surveys of the 903 Pad Mound and East Trenches areas of the Rocky Flats Plant were carried out in order to investigate and identify as possible the location of SWMUs and to provide information about subsurface conditions upon which to plan subsequent portions of the RI/FS investigation The data obtained resulted in the identification of areas of anomalous geophysical response to be investigated as specified in the CEARP IGMP/SSMP Sampling Plans Geophysical surveys in conjunction with soil gas results were used to plan areas for subsurface investigation monitoring well installation and groundwater sampling

The geophysical surveying techniques utilized in the 903 Pad and Mound Areas were apparently successful in identifying the locations of SWMUs 109 113 and 140 In addition an area of anomalous electromagnetic conductivity and magnetometry responses of unknown origin was identified on the northeast corner of the area Vertical electrical soundings were completed at five location across the 903 Pad and Mound areas The VES data was analyzed to provide a stratigraphic model of each location Metal detection was utilized at SWMUs 109 and 140 to identify buried metallic objects

Geophysical investigations of the East Trenches area included magnetometer surveys VES soundings and metal detection Magnetometer surveys of the trenches were successful in identifying those portions of the trenches which contain the highest concentrations of metallic objects VES soundings in the trenches were able to provide information on the depths of the trenches Identification of individual metallic objects through the use of a metal detector could not be accomplished

Quality control data for each instrument were collected as specified in the CEARP Quality Assurance Plan The resulting data indicates that instrument functions and operating procedures were properly conducted Details of quality control procedures are provided in Section 7

SECTION 7

QUALITY CONTROL

7 1 ELECTROMAGNETICS

The EM 31 and EM 34 3 instruments were operated in accordance with the operating instructions provided by the manufacturer Geonics Ltd In order to detect and correct for any drift of the instruments during the course of the surveys base stations were designated at the beginning of each survey Prior to beginning each day s survey measurements were taken at the base station and compared with previous readings Base station readings were repeated at frequent intervals throughout the survey day Other instrument functions checked during base station visits included meter null sensitivity checks and battery charge Quality control data from each instrument is provided in Table 3

7 2 RESISTIVITY

The VES system was operated in accordance with the operating instructions provided by the manufacturer Bison Instruments Inc The system was checked for drift at the base station established for the electromagnetic conductivity instruments (N 36200 E 22300) The system was set up and two sets of readings were obtained The two sets of readings were always within +/ 5% of one another

Upon completion of each VES survey the data were cross checked according to procedures provided by the manufacturer Millivolt readings were obtained from the five array patterns (see Figure 3) for each a spacing The cross checks were as follows

- A>C>D1
- D1~D2 and
- A C~B

TABLE 3

QUALITY CONTROL DATA

Instrument EM 34 3
Base Station N36200 E22300

Date	Time	Vertical Dipole	Horizontal Dipole	Battery	Null
3/31/87	0830	39	38	OK	OK
3/31/87	1150	35	36	OK	OK
3/31/87	1603	39	37	OK	OK
4/1/87	0850	37	37	OK	OK
4/1/87	1225	36	39	OK	OK
4/1/87	1520	12*	12*	OK	OFF 1 mmho/m
4/2/87	1250	40	38	OK	OK
4/2/87	1500	37	34	OK	OK
4/3/87	0845	40	38	OK	OK
4/3/87	1111	38	38	OK	OK
4/3/87	1600	36	38	OK	OK

Instrument EM 31
Base Station N36200 E22300

Date	Time	Reading	Battery	Null
4/14/87	0810	32	OK	OK
4/14/87	1255	32	OK	OK
4/14/87	1620	31	OK	OK
4/15/87	0810	31	OK	OK
4/15/87	1245	31	OK	OK
4/15/87	1620	30	OK	OK
4/16/87	0830	31	OK	OK
4/16/87	1230	32	OK	OK

*NOTE Readings collected prior to this base station check were retaken due to instrument drift

No repeat readings were required for any of the twenty six VES survey points A battery check was also conducted each morning and at the end of the survey day When the battery indicators approached 11 4 volts the batteries were recharged overnight

7 3 MAGNETOMETRY

The magnetometer was operated in accordance with the operating instructions provided by the manufacturer EG&G Geometrics Prior to beginning the magnetic survey a swing test was conducted at the base station to detect any directional sensitivity of the sensor Each swing test consists of three sets of four readings each taken with the sensor oriented at 90^{o} from the other If directional sensitivities were detected they were corrected by scrubbing the sensors with detergent and water The sensors were then retested The results of the swing tests are presented in Table 4

The magnetometer was held in a north south direction with the operator standing to the west of the sensors in an attempt to standardize any effects the operator and mode of operation would have on the instruments Batteries used in the instrument were industrial heavy duty D cell batteries with cardboard jackets to further reduce any effects to the instrument from metal clad batteries The batteries were changed whenever the voltage indicator fell below 8 5 volts

During the survey base station readings were obtained at the beginning and end of the day and at every 45 to 60 minutes throughout the survey The base station readings were used to remove diurnal effects of the earth s magnetic field from the field data Two sequential readings were also taken at the base station at the beginning and end of the survey day The sequential readings were obtained within three seconds of one another If the readings differed by more than 0 1 gamma from one another the readings were recorded in the field books All sequential readings differed by less than 0 1 gammas

The use of the digital memory in the magnetometer required that the beginning and ending stations along with the corresponding magnetometer readings be recorded at the start and finish of a traverse Upon downloading of the magnetometer these readings were cross checked for accuracy With the exception of an operator error all data cross checked satisfactorily

TABLE 4

SWING TEST RESULTS

Swing Test No.	Date	Swing	North (gammas)	East (gammas)	South (gammas)	West (gammas)
IV	4 21 87	1	54 856 2	54 855 9	54 855 9	54 856 0
		2	54 855 7	54 855 8	54 855 6	54 855 6
		3	54 856 1	54 856 0	54 855 9	54 856 0
V	4 30 87	1	54 856 2	54 856 3	54 853 3	54 853 1
		2	54 856 3	54 856 4	54 856 5	54 856 4
		3	54 856 6	54 856 5	54 856 6	54 856 7
VI	5 5 87	1	54 875 2	54 875 0	54 875 0	54 875 0
		2	54 875 8	54 875 7	54 875 7	54 875 6
		3	54 875 4	54 875 3	54 875 5	54 875 3
VII	5 12 87	1	54 877 7	54 877 9	54 877 9	54 877 8
		2	54 876 9	54 876 9	54 876 9	54 876 9
		3	54 876 9	54 877 0	54 876 9	54 875 9

Notes 1) Swing test IV accepted
2) Swing test V accepted
3) Swing test VI accepted
4) Swing test VII accepted

7 4 METAL DETECTOR

The metal detector was operated in accordance with operating instructions by the manufacturer White s Inc Each survey day began with adjusting the null controls and maximizing the sensitivity of the metal detector at the magnetometer base station The instrument was continuously adjusted until the nulling controls were at a maximum The sensitivity control was then adjusted to maximize the depth of signal reception During the surveys occasional minor adjustments were made to the ground reject control to fine tune the instrument when changing ground conditions were encountered

SECTION 8

REFERENCES

DOE 1986f Resource Conservation and Recovery Act Part B Operating Permit Application for USDOE Rocky Flats Plant Hazardous and Radioactive Mixed Wastes US Department of Energy Unnumbered Report November 1986

DOE 1987a Phase 2 Rocky Flats Plant Site Specific Monitoring Plan (Work Plan for Performance of Remedial Investigations and Feasibility Studies for all High Priority Sites) US Department of Energy Draft Report February 1987

DOE 1987b Phase 2 Rocky Flats Plant Installation Generic Monitoring Plan US Department of Energy Draft Report February 1987

Geonics Ltd (1980) Electromagnetic Terrain Conductivity Measurement at Low Induction Numbers Edited by J D McNeil October 1980

APPENDIX 1

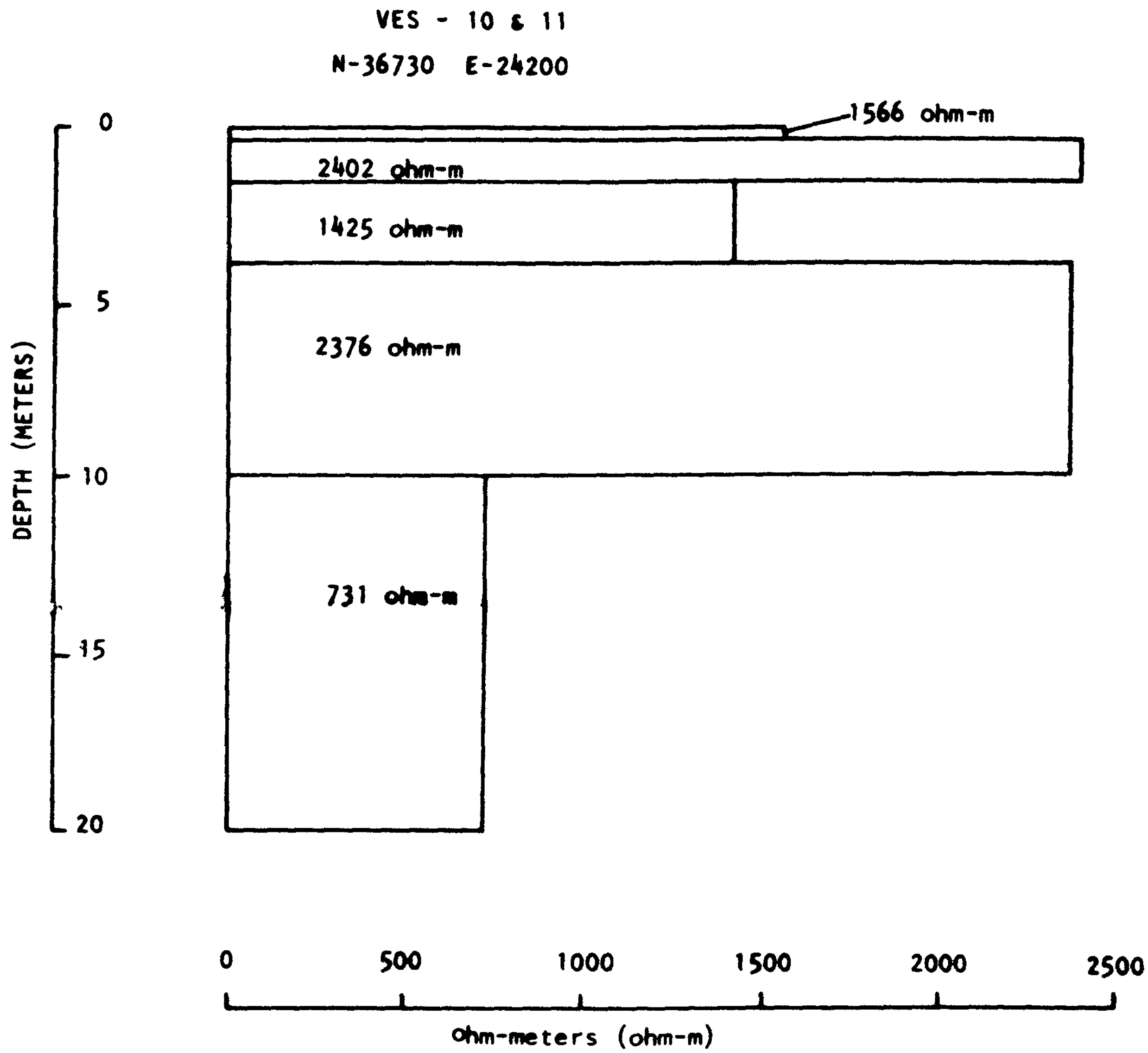
ELECTROMAGNETIC DATA

APPENDIX 2

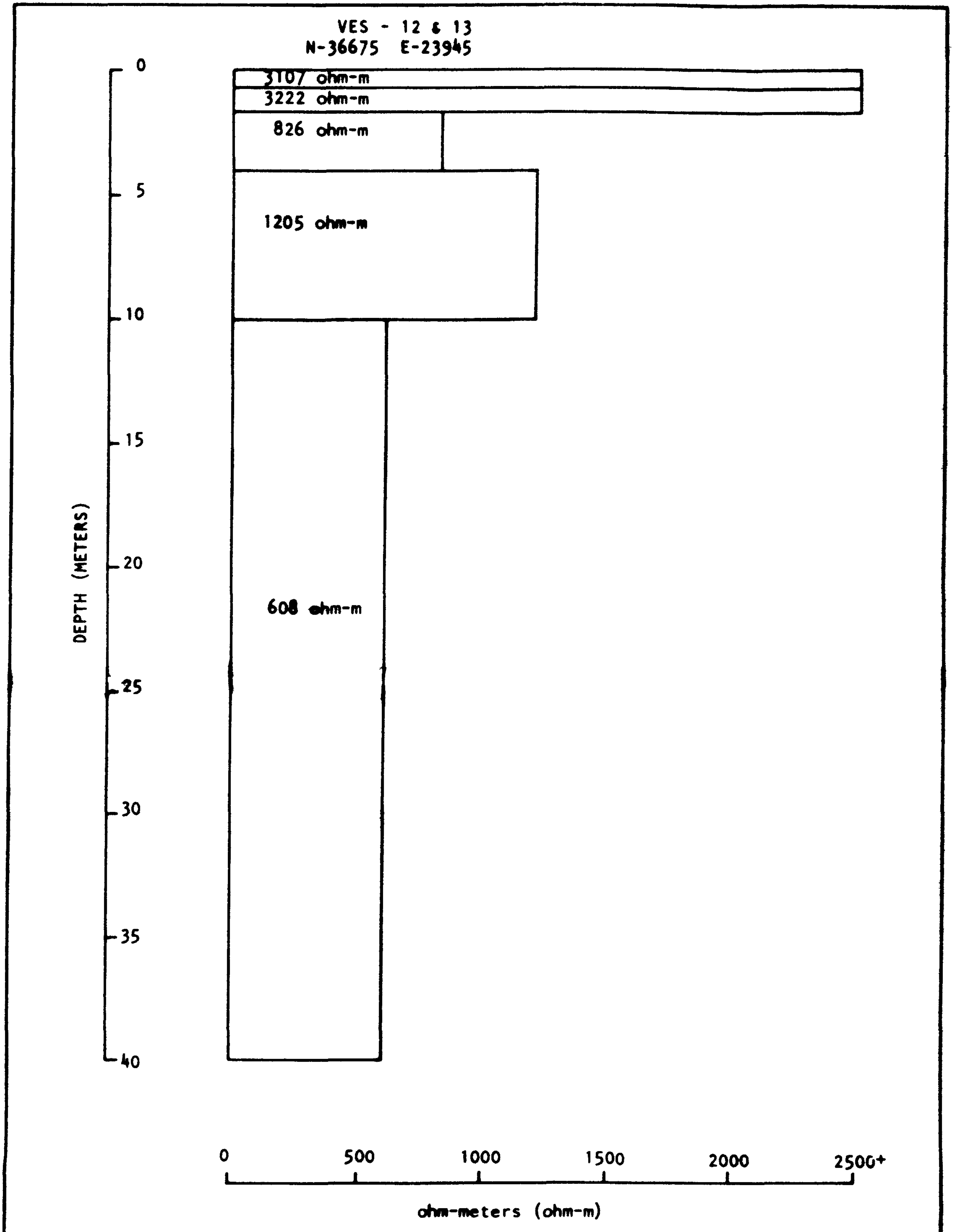
MAGNETOMETRY DATA

APPENDIX 3

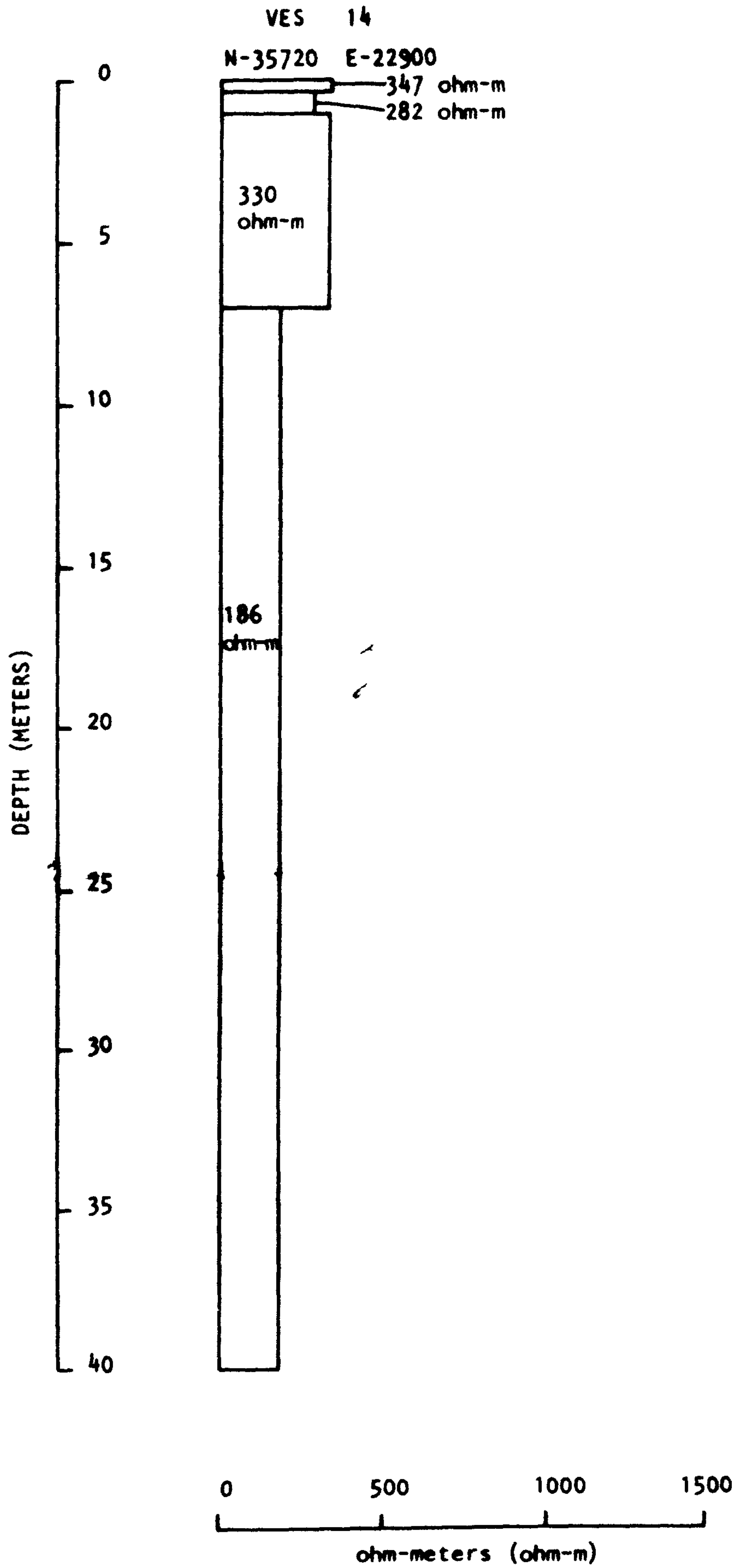
ELECTRICAL RESISTIVITY (VES) DATA



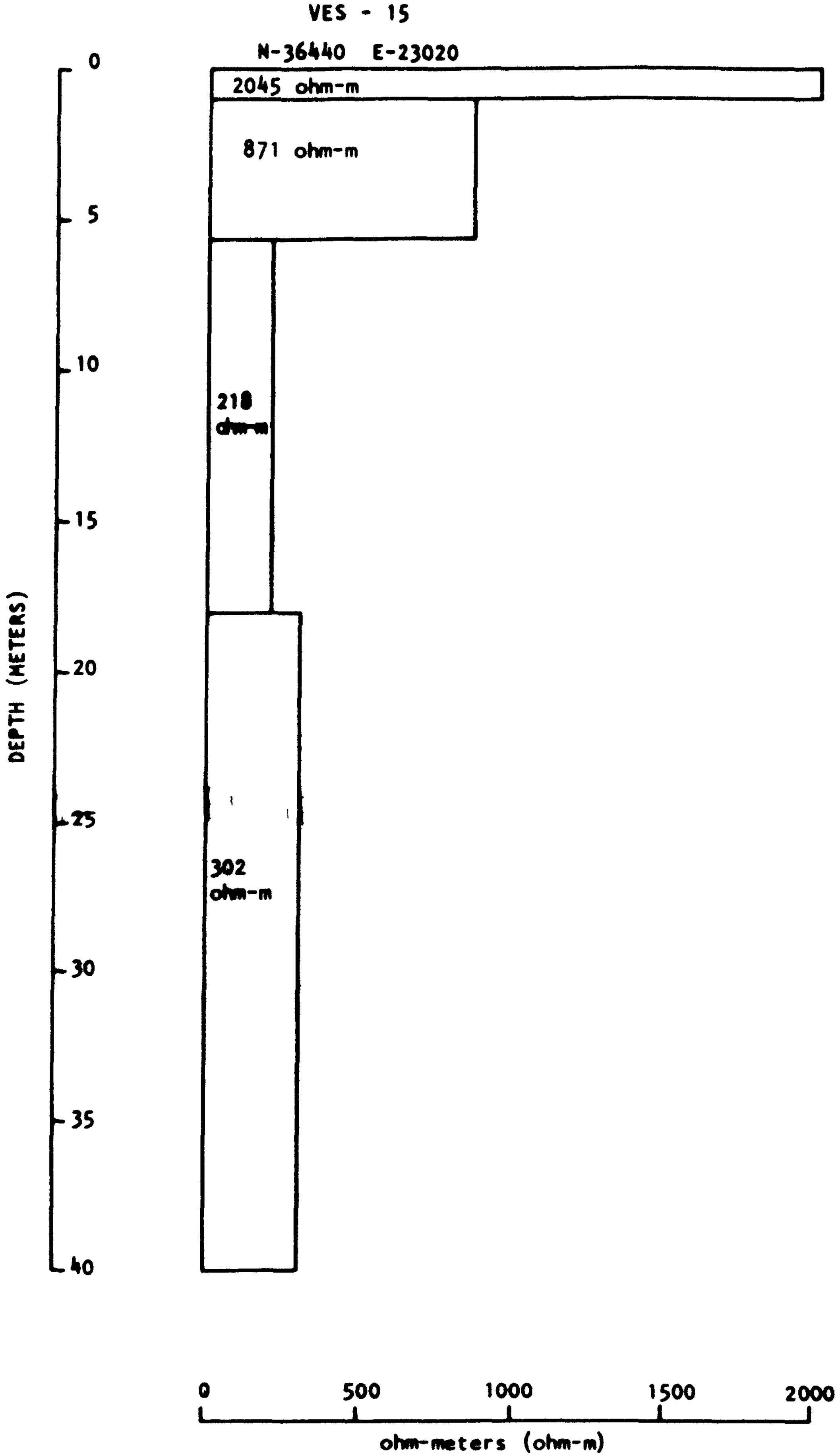
6 007 87	Chen & Associates	INVERSION RESULTS FOR VES 10 & 11	Fig 3-1



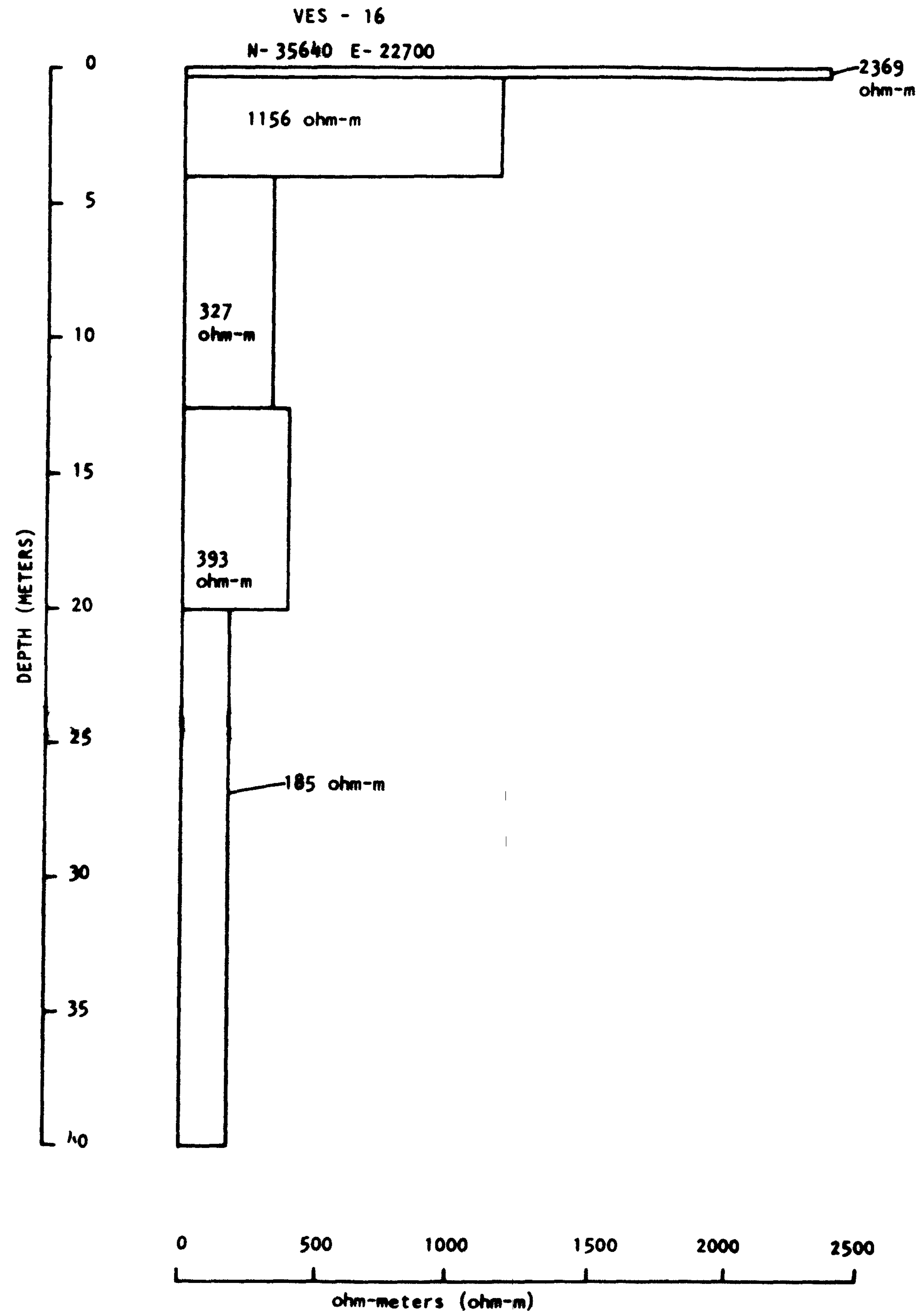
6 007 87	Chen & Associates	INVERSION RESULTS FOR VES-12 & 13	Fig 3-2



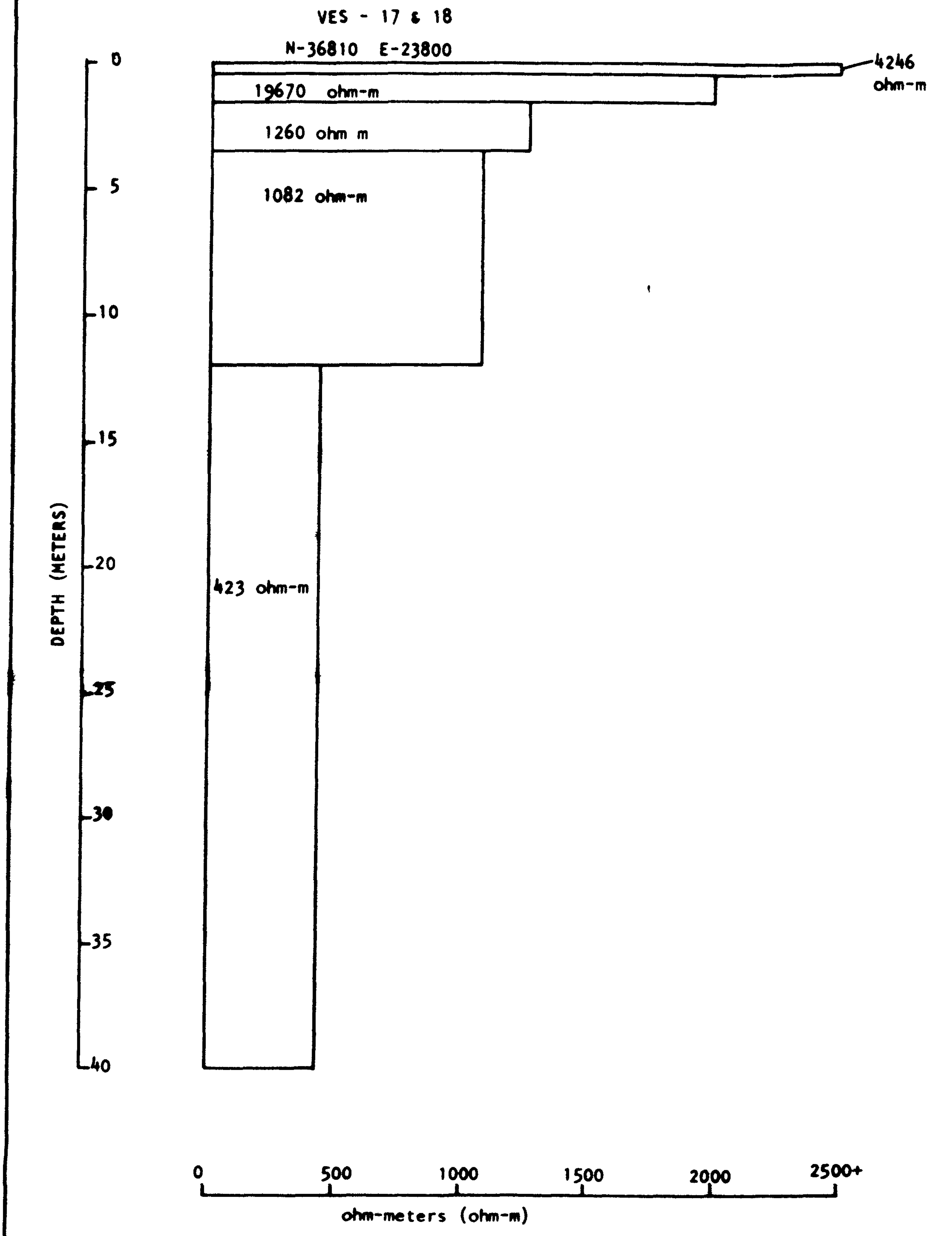
6 007 87	**Chen & Associates**	INVERSION RESULTS FOR VES-14	Fig 3-3



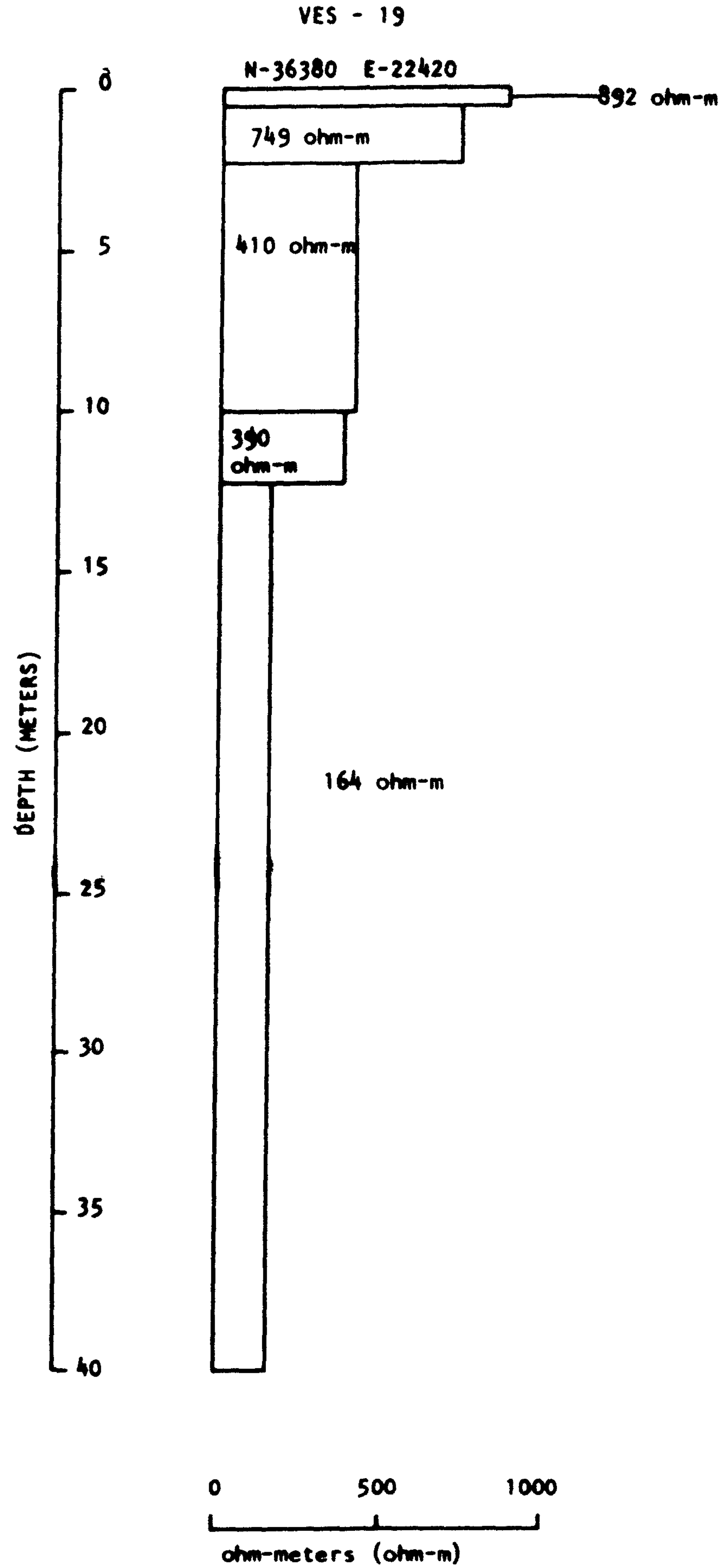
6 007 87	Chen & Associates	INVERSION RESULTS FOR VES-15	Fig 3-4



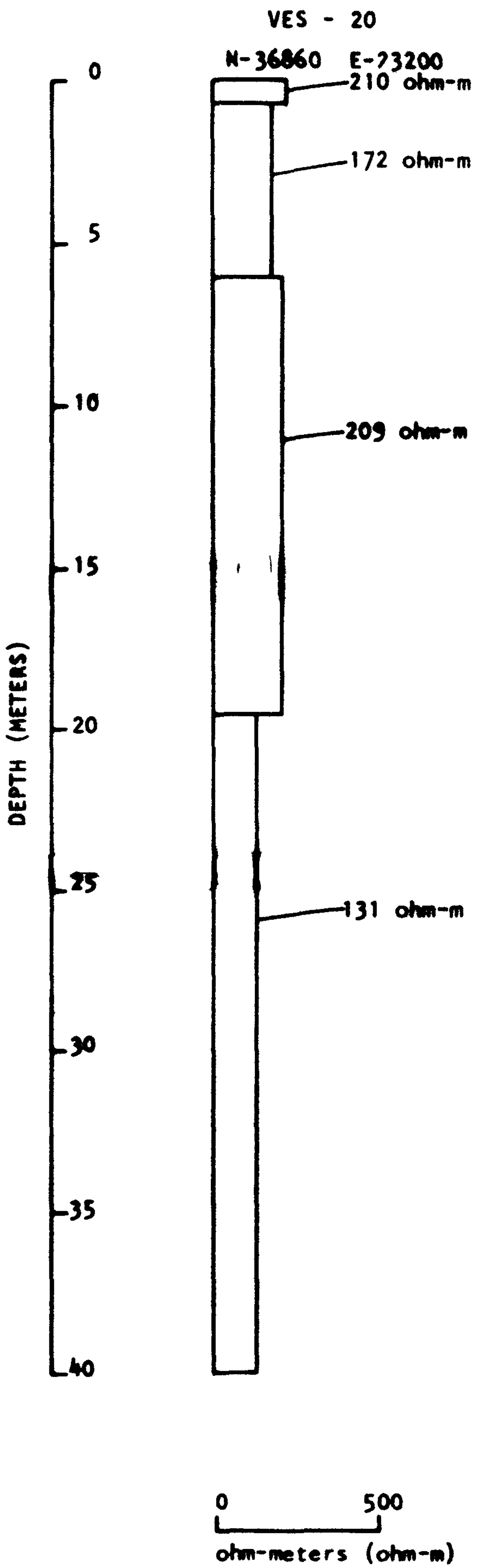
6 007 87	Chen & Associates	INVERSION RESULTS FOR VES-16	Fig. 3-8



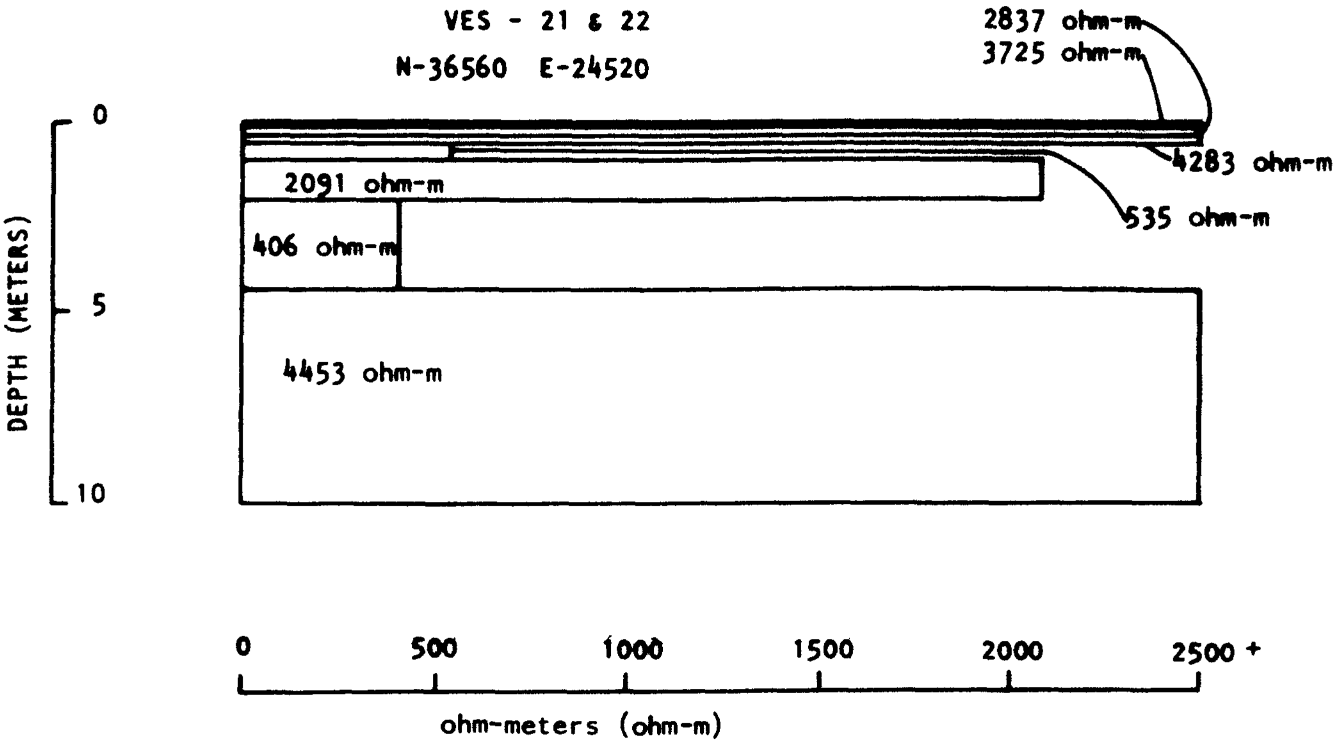
6 007 87	**Chen & Associates**	INVERSION RESULTS FOR VES - 17 & 18	Fig. 3-8



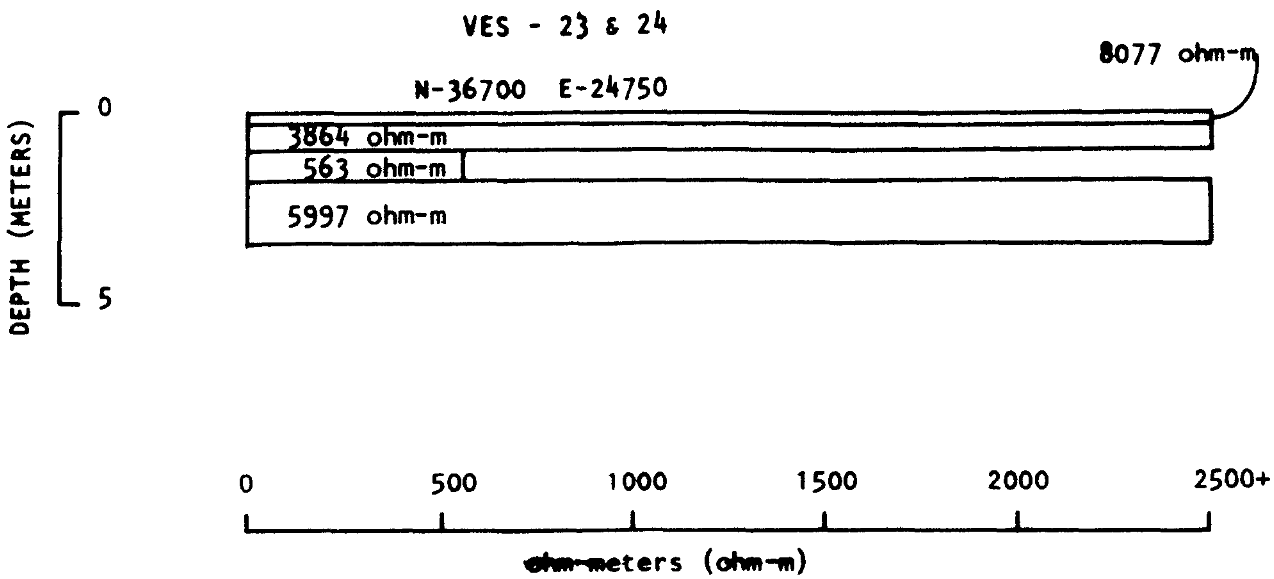
6 007 87	Chen & Associates	INVERSION RESULTS FOR VES - 19	Fig. 3-7



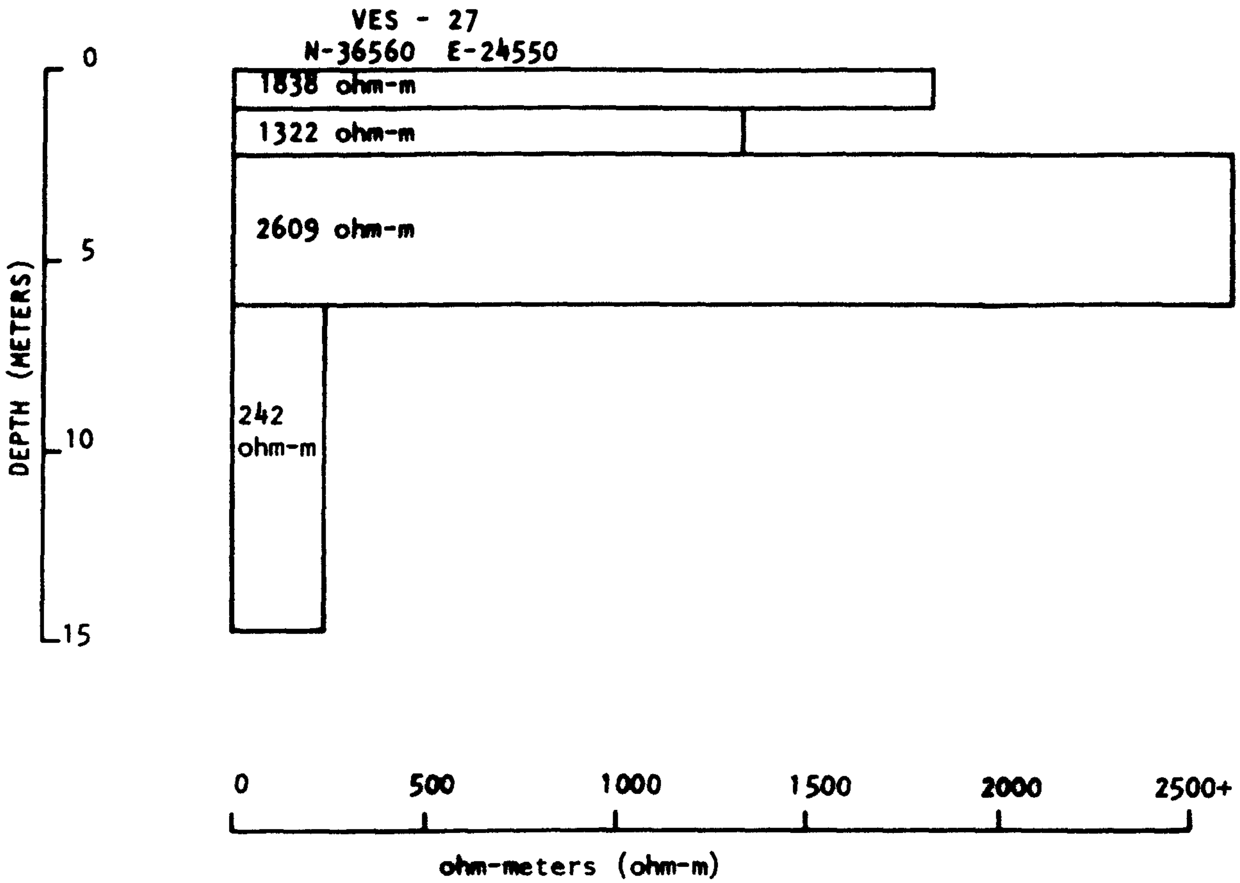
6 007 87	Chen & Associates	INVERSION RESULTS FOR VES - 20	Fig 3-8



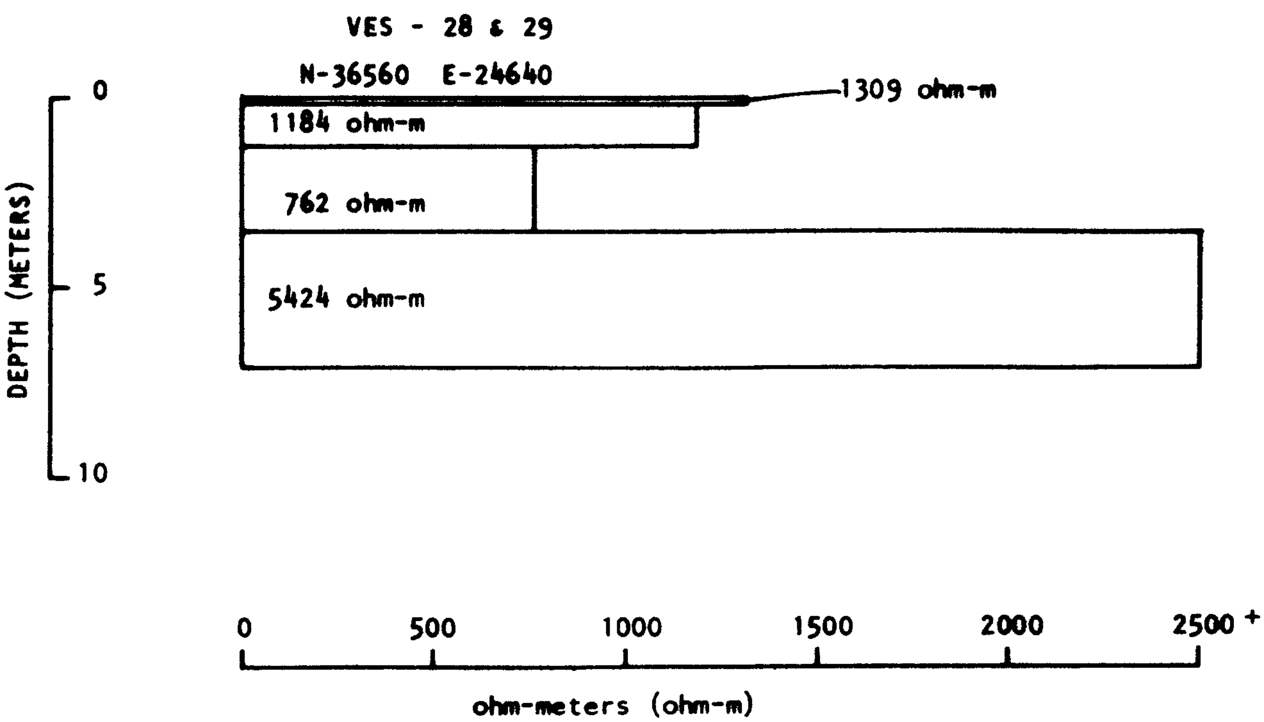
6 007 87	Chen & Associates	INVERSION RESULTS FOR VES- 21 & 22	Fig. 3-9



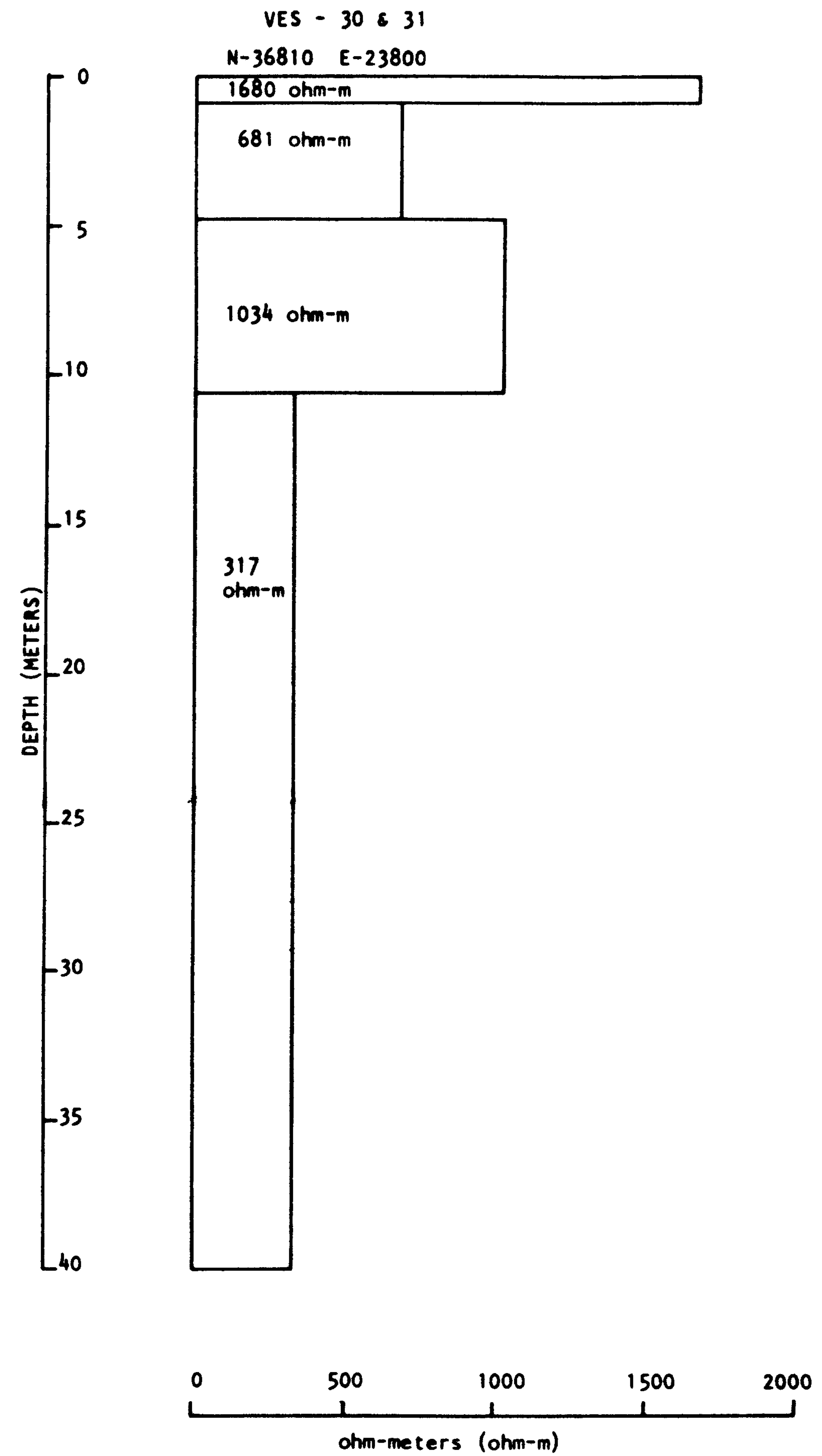
6 007 87	Chen & Associates	INVERSION RESULTS FOR VES- 23 & 24	Fig 3-10



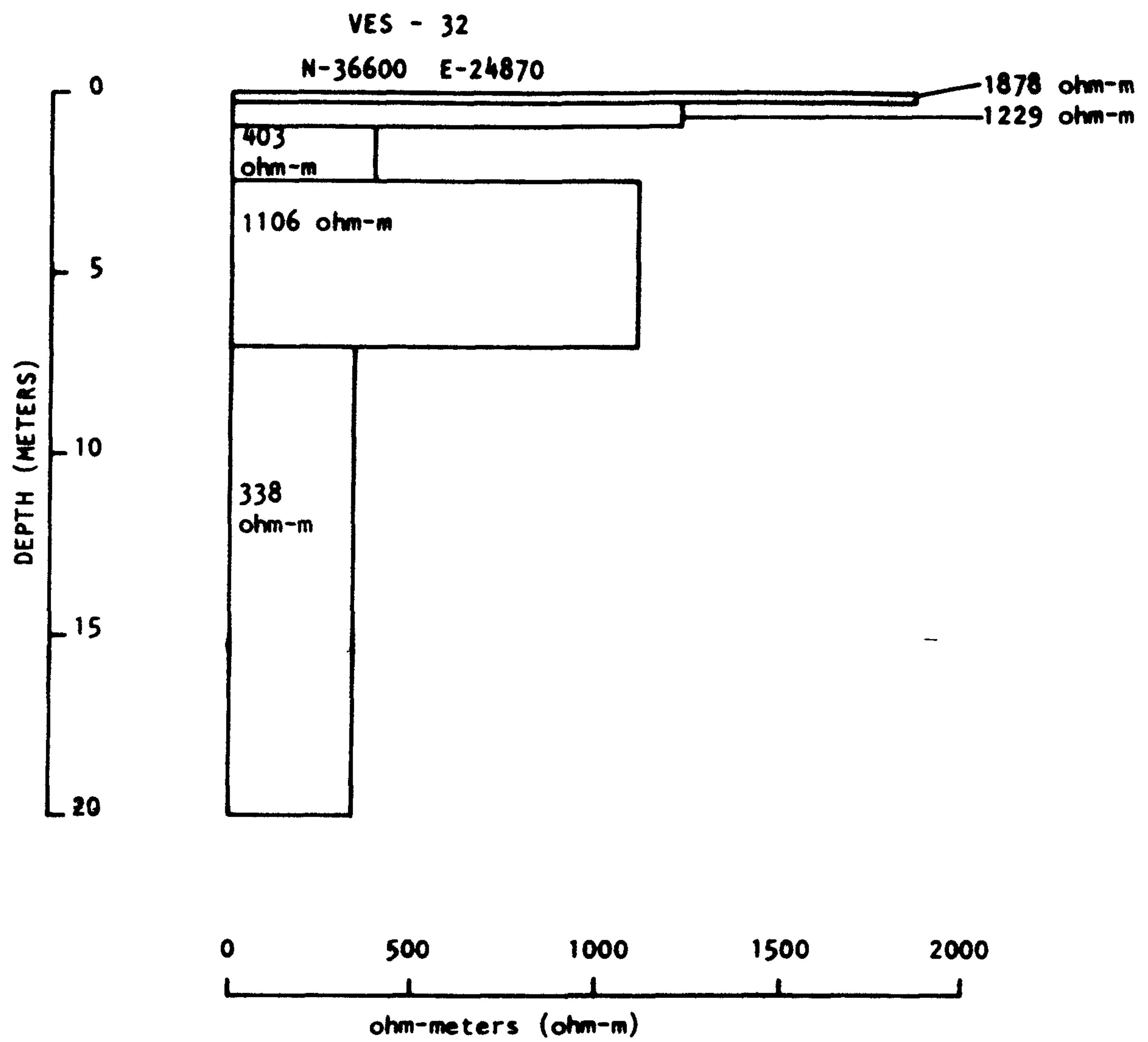
6 007 87	**Chen & Associates**	INVERSION RESULTS FOR VES- 27	Fig 3-11



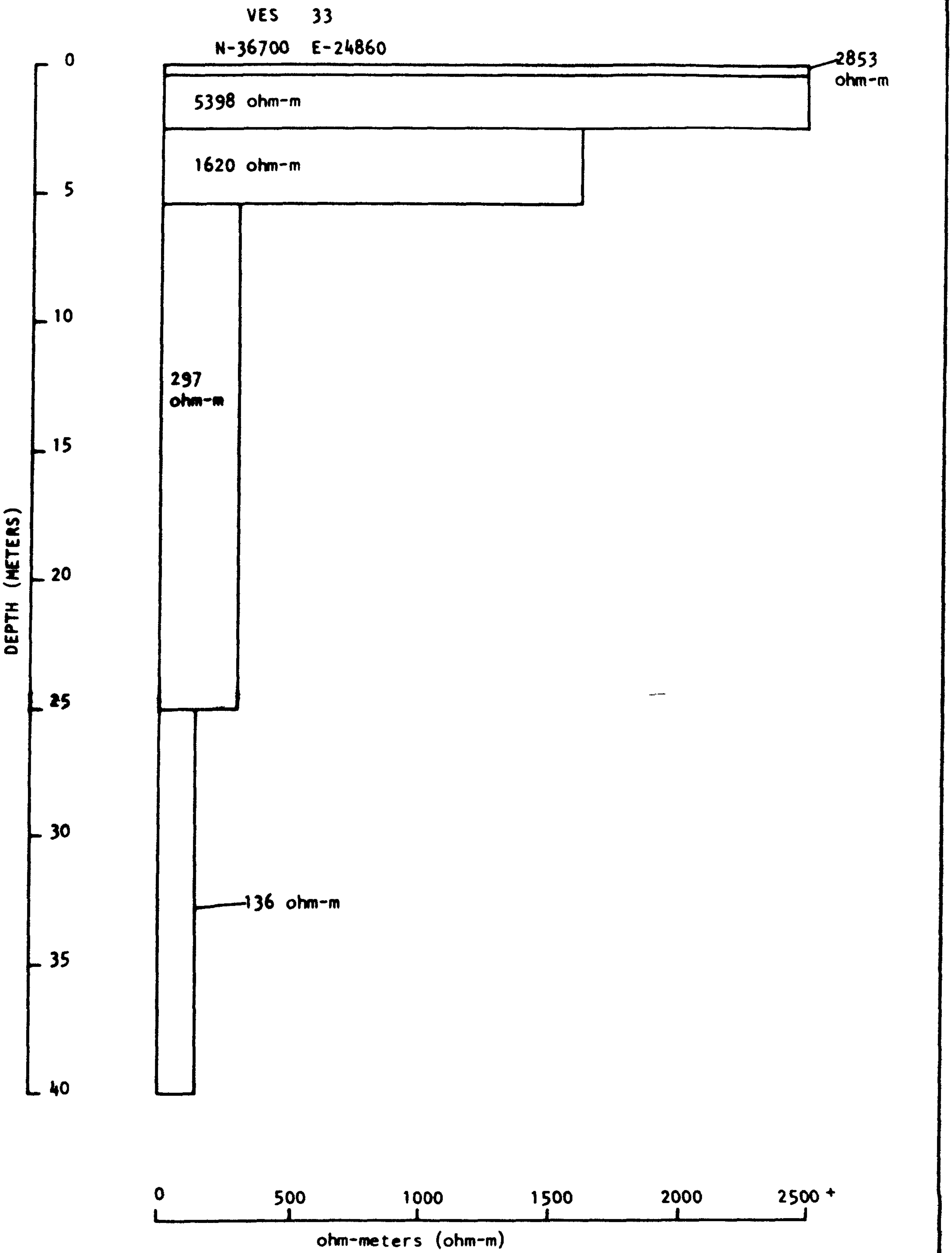
6 007 87	Chen & Associates	INVERSION RESULTS FOR VES-28 & 29	Fig. 3-12



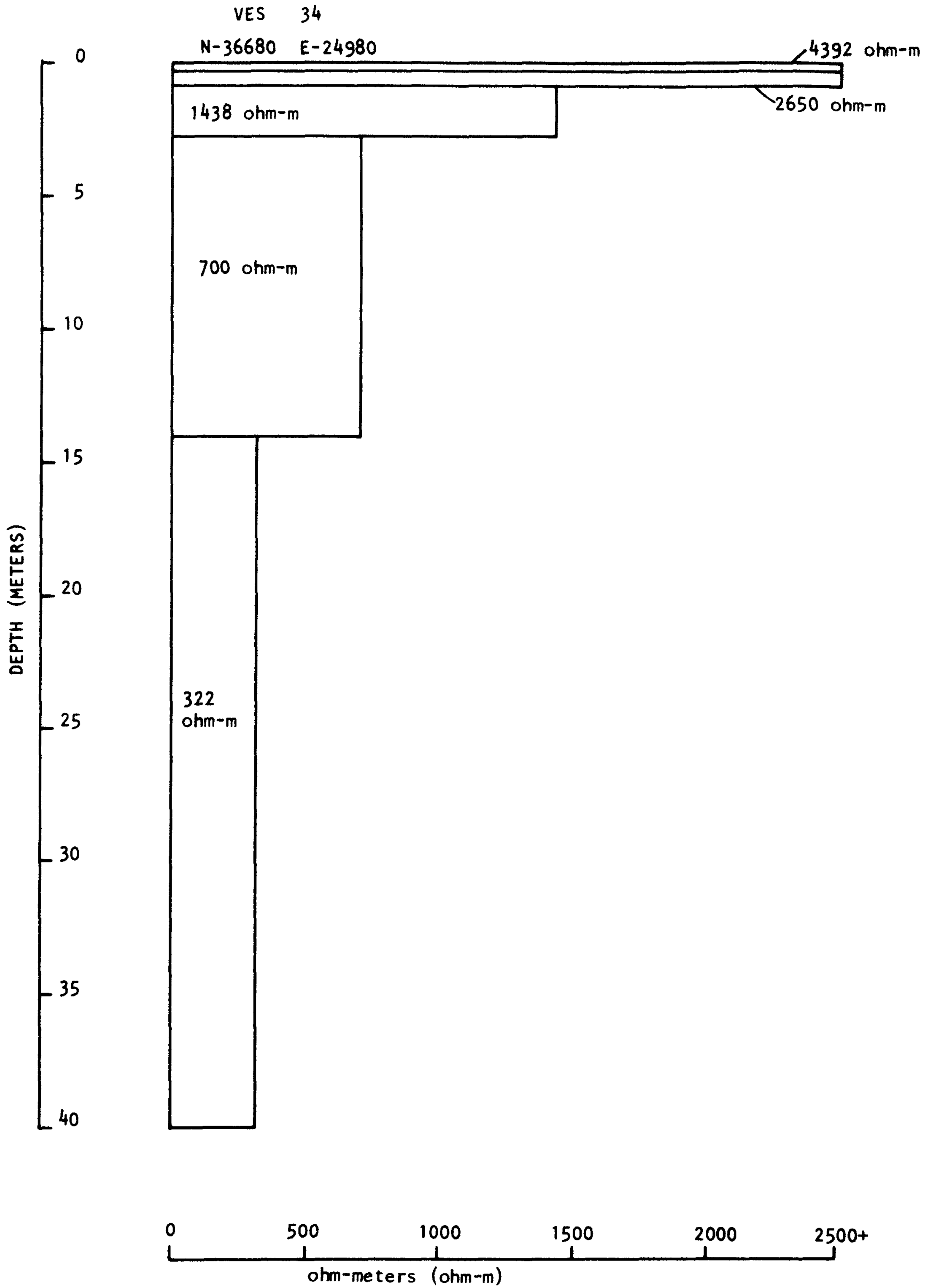
6 007 87	Chen & Associates	INVERSION RESULTS FOR VES-30 & 31	Fig. 3-13



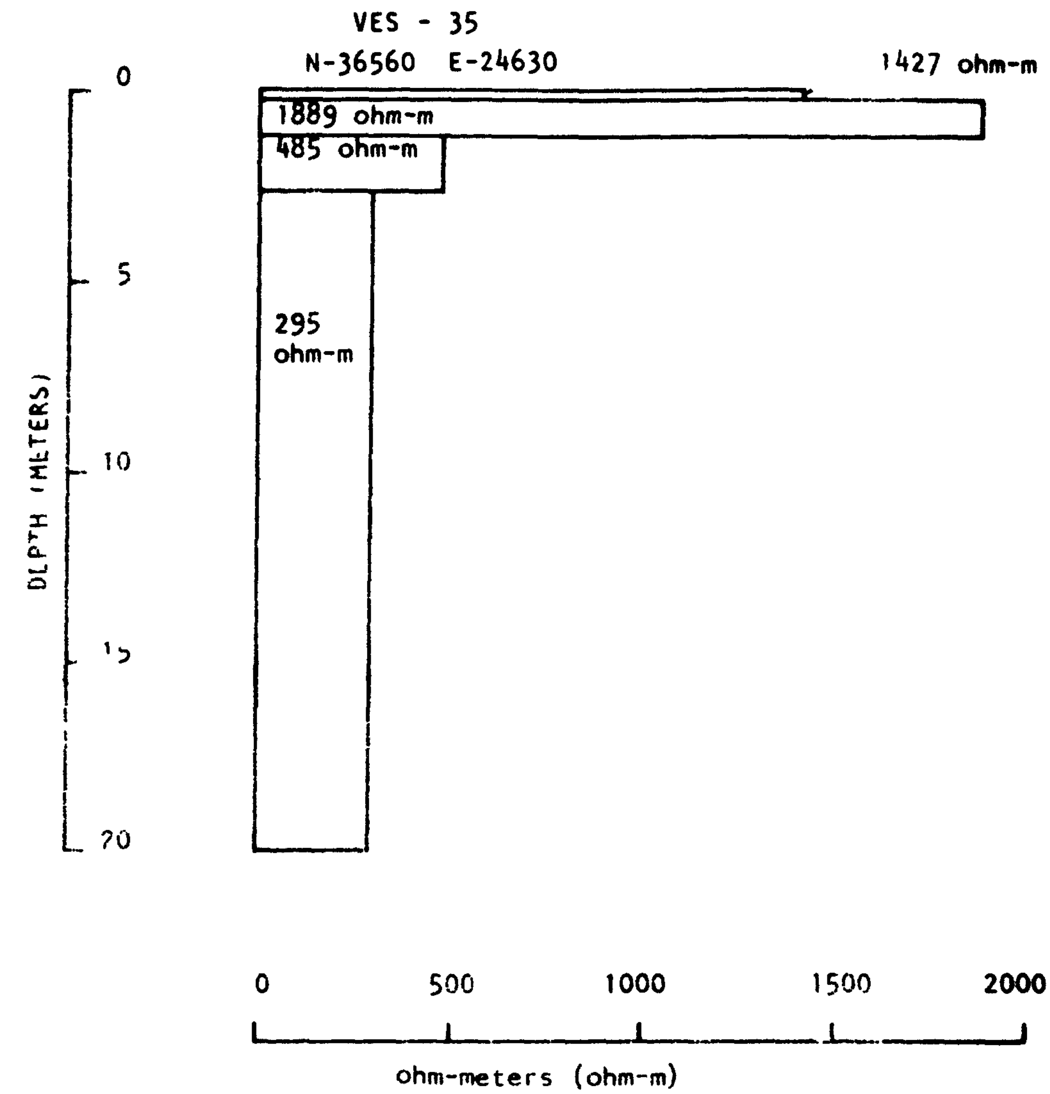
6 007 87	Chen & Associates	INVERSION RESULTS FOR VES-32	Fig 3-14



6 007 87	Chen & Associates	INVERSION RESULTS FOR VES-33	Fig 3-15



6 007 87	Chen & Associates	INVERSION RESULTS FOR VES-34	Fig 3-16



(007 87	**Chen & Associates**	INVERSION PESULTS FOR VE 5	**Fig 3-17**

APPENDIX C

SOIL GAS SURVEY

1 0 INTRODUCTION

A soil gas technique was used as a reconnaissance tool to locate and identify areas of subsurface organic contamination This method provides an efficient economical means by which trace quantities of subsurface organic contaminants can be detected on the ground surface For the 903 Pad Mound and East Trenches remedial investigation areas the objective of the work was to determine the presence and relative concentrations of 1 1 dichloroethene 1 1 1 trichloroethane carbon tetrachloride trichloroethene and tetrachloroethene in shallow soils These volatile organic compounds are known to be present in the ground water associated with these areas and the distribution of these compounds in shallow soils can be an indication of their lateral distribution in the ground water Thus the soil gas survey is used to provide a preliminary delineation of plume boundaries so that monitoring wells can be effectively placed to confirm contaminant plume locations

The Remedial Investigation Work Plan called for real time measurement of soil gas Real time measurements are extracted by inserting a hollow conduit into the soil to a given depth and evacuating a predesignated volume of gas After the system has been purged of any atmospheric air a sample is extracted and analyzed either on site or in a remote laboratory The advantage of this procedure is that data are in general available more quickly than time integrated methods The disadvantages are the added equipment required to do the sampling and analysis and a reduction in the mobility of the sampling vehicle Another disadvantage is that real time methods increase the lower detection limit

Considerations of decreased mobility lower detection limits and heavy traffic on grasslands influenced Rockwell s decision to re evaluate this method and to substitute it with Petrex s time integrated method

Petrex s time integrated method employs activated carbon to collect the contaminants for a period of time specifically determined for the site to concentrate the contaminant to a level that might otherwise be undetectable Time integration also alleviates any variations in the contaminant concentrations due to transient situations that might not reflect the true conditions (e g fluctuations in barometric pressure rain percolating through the soil and porosity differences in the soil) In addition all equipment required to perform the sampling can be carried into the target area by two individuals This reduces traffic in areas where heavy traffic might cause re suspension of soil possibly contaminated with radioactive contaminants Rather than mass per unit volume measurements that are the result of real time gas chromatographic analysis the time integrated results are measured in terms of ion counts determined by mass spectrometry of heat purged compounds from the activated carbon A synopsis of the Petrex method is shown in Attachment 1

2 0 PROCEDURE

2 1 METHODS

The sample collector consists of a ferromagnetic wire coated with an activated carbon which is inserted into a resealable glass tube A two inch rod is driven approximately eighteen inches into the soil and the sample collector is inserted into the resulting hole Soil is then packed into the hole covering the tube Attachment 2 contains the field instructions that were followed

The optimal exposure period for volatile organic detection was established by positioning time calibration collectors that were removed at 7 9 and 11 days and subsequently analyzed The analyses of these collectors indicated that soil gas flux was slow and therefore a twenty one day incubation period was established to maximize adsorption of soil gas compounds but allow completion of the work in the short time frame

After twenty one days the tubes were removed and the carbon was analyzed for contaminants by Curie Point mass spectrometry The carbon is burned at the Curie Point temperature of the ferromagnetic wire releasing and ionizing the adsorbed compounds The ions are subsequently separated and identified in the mass spectrometer Spectrographs representing total ion counts versus mass/charge were generated for each collector These fingerprints allow computerized identification of individual species

2 2 QUALITY ASSURANCE/QUALITY CONTROL

In order to assure contaminant free samples for emplacement and instrumental analysis quality control procedures were strictly followed Quality Assurance and Quality Control procedures are presented in Attachment 3 For example to assure contaminant free samplers the samplers are assembled in an inert atmosphere Samplers are periodically removed from each batch and analyzed to detect any contamination During mass spectral analysis calibration and periodic background checks are routine Duplicate and field blank Quality Assurance (QA) samples were taken during the soil gas sampling operation to ensure consistent results Duplicate samples were taken by placing two wires into the same tube Results of all the duplicate samples for the areas are presented in Table C 1 Ion counts of any contaminants if found are also shown Field blanks are taken by installing sealed tubes next to an open tube The field blank results are also presented in Table C 1

2 3 SURVEY GRID

Rocky Flats Plant coordinates were surveyed and staked to establish a sixty foot by sixty foot grid for which samplers were to be placed at nodes every 120 feet The Remedial Investigation Work Plan grid spacing for the soil gas stations (90 foot centers) was determined to be inconsistent with Petrex s recommended alignment Therefore samplers were placed every 120 feet along a grid line using sixty foot offsets for each successive grid line This offset grid was designed so that adjacent grid lines are sampled at non aligned stations thus interrupting the orthoganol pattern of a uniform grid One hundred and eight samplers were installed

TABLE C 1

SOIL GAS QUALITY ASSURANCE

SAMPLE LOCATION	DUPLICATE SAMPLES	FIELD BLANKS
120	TCE 0 408	
128	TCE 107 322 PCE 176 306	
138	0 0	
153	0 0	
168	0 0	
174	0 0	
179	0 0	
199	CCl_4 406 380/TCE 156 397/PCE 165 105	
203	CCl_4 1848 1738/TCE 2708 3253/PCE 1856 2048	
214	0 0	
223	0 0	
228	CCl_4 568 850/PCE 0 212	
244	0 0	
247	TCE 380 237	
259	CCl_4 800 587/TCE 23546 17158/PCE 37706 32102	
264	0 0	
290	CCl_4 539 3156/TCE 2124 6201/PCE 25094 73030	
292	CCl_4 594 1572/TCE 196 847/PCE 6580 14749	
306	CCl_4 408 967/PCE 4466 9776	
320	0 0	
322	TCE 863 0	
337	0 0	
343	CCl_4 1724 390/TCE 732 116/PCE 23564 5540	
358	CCl_4 1811 2634/TCE 819 1024/PCE 16679 21882	
371	CCl_4 4209 7921/TCE 2854 5083/ PCE 75094 108052	
384	0 0	
395		0
406	TCE 196 337/PCE 12318 9546	
414	TCE 389 326	
416	TCE 754 1484/PCE 155 122	
426	0 0	
429	CCl_4 754 803	
442		0
466	PCE 0 342	
486	PCE 760 375	
506	PCE 2950 3626	
525	0 0	
535A	0 0	
537	0 0	
569	0 0	
572	0 0	
574	0 0	

TABLE C 1
(continued)
SOIL GAS QUALITY ASSURANCE

SAMPLE LOCATION	DUPLICATE SAMPLES	FIELD BLANKS
574	0 0	
603	0 0	
631	0 0	
632	0 0	
641*	TCE 8321 4806	
651	0 0	
665B	0 0	
668	0 0	
681	0 0	
697	0 0	
701		0
718	TCE 101 0	
723	0 0	
734	0 0	
741		0
749	0 0	
754	0 0	
766	0 0	
776	0 0	
782	0 0	
794	0 0	
797	0 0	
803	TCE 212 0/PCE 20660 8420	
830	0 0	
831	PCE 683 399	
858	0 0	
878	0 0	
899	0 0	
920	0 0	
925	0 0	

* Wires bent or mangled

2 4 PLUME MAP

A relative ion count intensity map was prepared for each organic vapor of interest These relative intensities have been plotted to infer concentration gradients and source locations Sample locations are shown on Plate 4 2 and data are presented on Plates 4 3 through 4 7

APPENDIX C

ATTACHMENT 1

PETREX ENVIRONMENTAL ANALYSES

ATTACHMENT 1
PETREX ENVIRONMENTAL ANALYSES

A description of the Petrex Soil Gas Technique for collection and identification of trace volatile organic compounds is presented below

1 Collection Activated carbon which is bonded to a ferromagnetic wire is placed in a glass tube and buried just below the soil surface After a predetermined collection period (3 30 days) the tubes containing the carbon bearing wires are retrieved sealed and taken to the laboratory for mass spectrometric analysis

2 Analysis The organic gases adsorbed on the carbon are purged from the carbon separated according to ion mass counted and a mass spectrum of masses from 29 to 240 is drawn

3 Identification These mass spectra are compared with mass spectra derived from known volatile organic compounds and the compounds are identified

4 Derivation of relative total counts for mapping purposes The relative ion count intensity (relative intensities) of the gases collected on various collectors are correlated with sample locations on a map of the survey area These relative intensities are useful for inferring relative differences in the concentrations of the compounds in the soil or ground water which can be used to help determine the direction of source areas and/or direction of movement of contamination

NOTES OF CONSIDERATION

1 These surface collections and analyses cannot be used to determine the depth to the source contaminants

2 Because compounds can be differentiated by their spectra analyses from the carbon collectors can be used to help differentiate multiple source areas

3 Most areas have a natural background of trace emanations from naturally occurring compounds The distinction of this background from contamination is facilitated by Petrex s three and one half years in resource exploration and environmental surveys which have resulted in the examination of more than 50 000 of these spectra All of these spectra are available from developed spectra laboratory for use in identification of compounds

APPENDIX C

ATTACHMENT 2

FIELD INSTRUCTIONS

ATTACHMENT 2
FIELD INSTRUCTIONS

1) Dig sample location 10 12 inches deep and approximately 2 4 inches in diameter Do not contaminate the soil (Under asphalt or cement 2 3 below base of asphalt or cement)

2) Remove the cap and immediately place sampler (vertically with open end down) into sample location hole The sampler tube must be at least two inches below ground surface Immediately cover the sampler with soil

3) Return the cap to one of the clean plastic bags provided

4) Mark the sample location with flagging or other material Note the sample location on a base map and enter information in a field notebook

5) Retrieving samples (should be done at the recommended time intervals)

   (A) Remove the soil until tube is exposed

   (B) Take a cap from sealed plastic bag Check for blue teflon liner inside cap If liner has fallen out replace it

   (C) Remove tube from the hole If wire falls out of tube or if tube is broken use tweezers to handle wire

   (D) Wipe off the tube and threads thoroughly with a clean dry cloth If the tube threads and lip are not properly cleaned the cap will not seal and the sample will become contaminated

   (E) Seal tube with cap making sure the teflon liner is seated to tube lip

(F) Place sticker on cap top and number Number sequentially starting with 1 Use only numbers to identify samples For two wire samplers use two consecutive numbers Please underline all numbers for easy identification Do not duplicate cap numbers

(G) Record number or numbers of sampler corresponding to location on base map and field notebook

(H) Do not place tape sticker or glue on glass tube Stickers provided will adhere if placed on dry cap

6) When packaging exposed tubes please do not use Styrofoam or popcorn packaging as this can potentially introduce a contaminant Enclose tubes in two plastic bags as provided and wrap each package tightly with bubble wrap

The contents of this package should be as follows

______ Single Wire Tubes

______ Double Wire Tubes
To be placed in the survey area as if they were single wire tubes These samples are to be used internally as QC and calibration samples

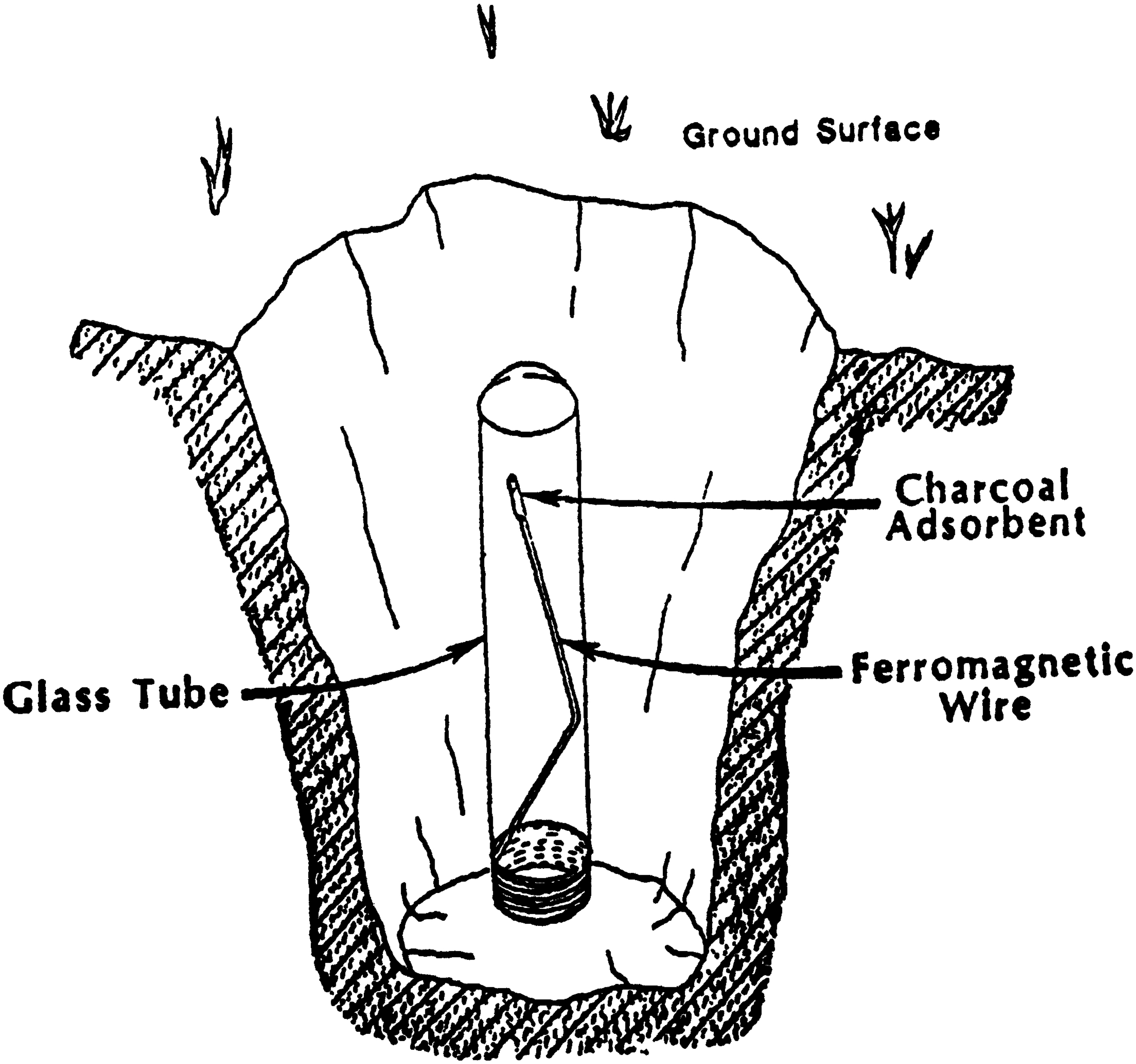
______ Field Blanks
To be placed in the survey area with the caps still on one blank placed each day until all blanks are used or place leftover blanks on last field day

______ Time Test
To be placed over an area of suspected volatile compounds When returning these samples to Petrex please label them with Project # ____________

______ Cap Labels

** CAUTION **

The most critical aspect of collector placement is not to expose the collector to contaminants Smoking exhaust fumes etc will contaminate the collector Hands must be kept free of organics including insect repellant sunblock gasoline motor oil cosmetics etc The lip and inside of the tubes caps and cap liners must not contact any contaminants


Ground Surface
Charcoal Adsorbent
Glass Tube
Ferromagnetic Wire

APPENDIX C

ATTACHMENT 3

PETREX QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES

ATTACHMENT 3
PETREX QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES

Wire Preparation

1 Sampler materials are processed through thermo chemical cleaning procedures

2 Adsorption wires (after construction) are cleaned by heating to 358 degrees C in a high vacuum system

3 Wires are packed under an inert atmosphere in respective vials

4 One collector out of every thirty is checked for contamination by mass spectrometry Based on the results the group of thirty collectors is approved for release into the field

Sampler Shipment and Field Handling

1 Five percent transportation blanks are included with each shipment Transportation blanks (2 5% of total) samplers are stored until analysis with the field samplers

Mass Spectrometer Tuning

1 An Extranuclear Quadrupole Mass Spectrometer is used for collector analysis Mass assignment and resolution are manually adjusted using a Perfluorotributylamine (PFTBA) standard The mass offset value is entered into the computer followed by comparisons of a computer generated PFTBA spectrum If correct mass (M/Z) values are obtained the operator proceeds

to the next tuning step If not Step 1 is repeated until correct masses are obtained

2 Peak intensity ratios are set from the major peaks in the PFTBA spectrum using the following values

Mass (M/Z)	Spectrum Intensities
69	= 100%
131	= 25% +/ 5%
219	= 35% +/ 5%
502	= 5% +/ 2%

3 During tuning the ion signal for mass (M/Z) 69 of PFTBA is measured at a specific sample pressure and detector voltage and compared to previous operation values

4 Electron energy (meter reading) is set to 15 electron volts and emission is set at 12 milliseconds All other operating parameters such as scans scan range mass offset are established in the computer program These values (sensitivity) can only be changed by the laboratory manager

5 Final detector voltage is established using the duplicate collector field sample

MASS SPECTROMETER ANALYSIS

1 Periodic (approximately every 20 samples) machine background analyses are performed to assure minimal influence from internal communication If there are peaks that are not related to atmospheric gases the supervisor is notified and the mass spectrometer is shut down and cleaned as necessary

2 A written sample number record is kept during the analysis to prevent accidental cross numbering

3 The mass spectrometer control program contains appropriate flag statements that prompt the operator with a warning if an inputted sample number has already been analyzed The operator then checks the current number along with the disk storage location of the previously entered number to identify the true numbering situation

APPENDIX D

DESCRIPTION OF REMEDIAL INVESTIGATION FIELD ACTIVITIES

1 0 INTRODUCTION

This appendix describes the remedial investigation drilling and sampling program implemented at the 903 Pad Mound and East Trenches Areas from June through October 1987 The program consisted of soil sample collection from 35 boreholes and installation and sampling of 27 new monitor wells to determine the nature and extent of soil and ground water contamination Surface water samples were collected from stations established along South Walnut Creek Woman Creek and the South Interceptor Ditch and from seeps in the area Borehole and well locations were tentatively identified in the RI Work Plan and surface water sampling locations were established by the CEARP Manager during the RI Drilling soil sampling packer testing and monitor well installation procedures are presented in the CEARP IGMP Sampling Plan (DOE 1987a) for Rocky Flats Plant and ground water and surface water sampling procedures implemented at Rocky Flats are presented in Section 4 0 of this appendix Section 2 0 of this appendix presents rationale for the final well and borehole locations and Section 3 0 discusses changes in drilling and soil sampling procedures

2 0 DRILLING LOCATIONS

Drilling locations for boreholes and wells at the 903 Pad Mound and East Trenches Areas are shown on Plate 4 1 These locations were tentatively identified in the RI Work Plan (DOE 1987b) Appendix A of this report contains excerpts of the RI Work Plan which pertain to the 903 Pad Mound and East Trenches Areas Actual drilling locations were selected based on geophysical survey results soil gas survey results field reconnaissance and site access Final locations were chosen by the Site Manager and approved by the Rockwell International CEARP Manager prior to drilling

2 1 BOREHOLE LOCATIONS

Soil samples were collected from boreholes at the 903 Pad Mound and East Trenches Areas to investigate reported Solid Waste Management (SWMU) locations and to investigate soil gas contaminant plumes Boreholes were generally located as shown in the RI Work Plan however some borehole locations were moved slightly to investigate detected soil gas contaminants or geophysical anomalies where they did not correspond to reported SWMU locations Presented below is a discussion of each borehole location organized by area

2 1 1 903 Pad Area

Nine of thirteen proposed boreholes were drilled at the 903 Pad Area Four boreholes (BH18 87 BH19 87 BH20 87 and BH21 87) were not drilled directly into the pad pending a review of all available information concerning contaminants beneath the pad Personnel health and safety requirements for drilling through the pad are also being reviewed by Plant representatives

As outlined in the RI Work Plan five boreholes are located at the 903 pad lip site (SWMU 155) to assess the extent of contamination in the the wind dispersal area Borehole BH29 87 is located due west of the 903 drum storage site as shown in the RI Work Plan BH29 87 was completed as a bedrock monitor well (9 87BR) after soil samples were collected in the upper portion of the hole Boreholes BH22 87 BH23 87 and BH24 87 were drilled due south of the 903 drum storage site to investigate soil contamination immediately adjacent to the pad BH22 87 is located as shown in the RI Work Plan BH23 87 is located at soil gas point 388 to investigate the tetrachloroethene (PCE) molecular count of 1088 and the trichloroethene (TCE) count of 512 in soil gas This location is approximately as shown in the RI Work Plan BH24 87 is located slightly south of the location shown in the RI Work Plan to investigate a PCE molecular count of 91 573 a TCE count of 3 969 and a carbon tetrachloride (CCl_4) count of 6 065 at soil gas point 371 BH30 87 is located due east of the 903 drum storage site as described in the RI Work Plan This borehole is located at soil gas point 354 to evaluate a PCE count of 32 777 a TCE count of 1 304 and a CCl4 count of 2 274 BH30 87 was completed as an alluvial monitor well after soil sample collection

Two boreholes were drilled adjacent to Trench T 2 (SWMU 109) on the hillside south of the 903 drum storage site Boreholes were not drilled directly into Trench T 2 because the magnetometer survey and metal detection survey identified buried metal (presumably flattened drums) in the center of the trench Borehole BH25 87 is located adjacent to this area of buried metal at soil gas point 412 where a PCE count of 25 042 and TCE count of 18 032 were detected in the soil gas BH27 87 was drilled adjacent to the east end of Trench T 2 and within the reactive metal destruction site as shown in the RI Work Plan This borehole is located at soil gas point 406 to evaluate a PCE molecular count of 10 932 and a TCE molecular count of 267

Three boreholes (including BH27 87) were drilled in the vicinity of the reactive metal destruction site (SWMU 140) south of the 903 drum storage site Borehole BH27 87 was drilled into the western edge of the site as discussed above BH28 87 is located in the eastern portion of the metal destruction site approximately as described in the RI Work Plan It is located at soil gas point 391 to evaluate the molecular counts of PCE (12 424) and TCE (1 315) in the soil gas BH26 87 is located south of the reactive metal destruction site at soil gas point 410 PCE (312 counts) and TCE (2709 counts) were detected in soil gas at this point

2 1 2 Mound Area

Eight boreholes were drilled and sampled at the Mound Area as proposed in the RI Work Plan Two boreholes were drilled into or adjacent to each of the four SWMUs at the Mound Area With the exception of Trench T 1 (SWMU 108) SWMUs in the Mound Area have been removed and only residual soil contamination was expected to exist Therefore borehole locations at the pallet burn site (SWMU 154) oil burn pit No 2 (SWMU 153) and the mound site (SWMU 113) were based on soil gas survey results

Boreholes BH31 87 and BH32 87 were drilled near the reported location of the pallet burn site (SWMU 154) at soil gas points 445 and 427 respectively At BH31 87 PCE (1 488 counts) and TCE (226 counts) were detected in soil gas Only PCE (1 086 counts) was detected in soil gas at point 427

Boreholes BH33 87 and BH34 87 are located near the reported location of oil burn pit No 2 (SWMU 153) These locations were chosen to evaluate the southern edge of CCl_4 molecular counts in soil gas apparently emanating from the oil burn pit This apparent soil gas plume could not be sampled further north due to poor access around the perimeter security zone (PSZ) fence BH33 87 was drilled at soil gas point 429 (CCl_4 count of 779) and BH34 87 was drilled at soil gas point 430 (CCl_4 count of 1 594) A high PCE molecular count (90 014) was also detected in soil gas at point 430

Boreholes BH35 87 and BH36 87 were located immediately adjacent to Trench T 1 (SWMU 108) to evaluate the extent of soil contamination around the trench Boreholes were not drilled directly into the trench because buried metal (presumably flattened drums) was detected in the trench with the magnetometer and metal detection surveys Boreholes adjacent to the trench were located to best investigate volatile organics detected in soil gas around the trench BH35 87 is located at soil gas point 438 where 154 molecular counts of PCE were detected and BH36 87 was located at soil gas point 432 where 283 counts of PCE were detected in soil gas

Boreholes BH37 87 and BH38 87 were drilled at the mound site to assess soil gas survey results and the extent of soil contamination BH37 87 is located within the mound site at soil gas point 462 where the highest molecular count of PCE (124 824) detected in the area occurred BH38 87 was drilled east of the revised mound site location as shown in the RI Work Plan

2 1 3 East Trenches Area

A total of 18 boreholes were drilled in the East Trenches Area as proposed in the RI Work Plan Drilling locations were chosen to meet Work Plan objectives and to investigate volatile organics detected in the soil gas Table D 1 presents soil gas results for each of the borehole locations at the East Trenches Area

Eight boreholes were drilled in the northern portion of the East Trenches Area (north of the East Access Road) Boreholes BH39 87 and BH40 87 are located adjacent to Trench T 3 (SWMU 110) as shown in the RI Work Plan BH39 87 is located at soil gas point 506 and BH40 87 is located at soil gas point 503 PCE was detected in the soil gas at both of these locations (Table D 1) Boreholes BH41 87 and BH42 87 were moved east of Trench T 4 (SWMU 111 1) to investigate soil gas results east of the northern trenches PCE and TCE values in soil gas at the northern trenches area were highest at soil gas point 490 (BH41 87) BH42 87 was located at soil gas point 500 where 1 1 1 trichloroethane (TCA) was detected in soil gas in addition to PCE and TCE

Boreholes BH43 87 and BH44 87 were drilled adjacent to Trench T 11 (SWMU 111 8) and boreholes BH45 87 and BH46 87 were located adjacent to Trench T 10 (SWMU 111 7) as shown in the RI Work Plan Soil gas results for these borehole locations are shown in Table D 1

Ten boreholes were drilled in the southern portion of the East Trenches Area (south of the East Access Road) Borehole locations in this area were modified from those described in the RI Work Plan to investigate volatile organics in the soil gas (Table D 1) Four boreholes were drilled near Trench T 9 Boreholes BH47 87 and

TABLE D 1

SOIL GAS RESULTS FOR BOREHOLE LOCATIONS AT THE EAST TRENCHES AREA

BOREHOLE NO.	SOIL GAS POINT	PCE (COUNTS)	TCE (COUNTS)	TCA (COUNTS)
BH39 87	506	3288	0	
BH40 87	503	894	0	
BH41 87	490	7655	25552	
BH42 87	500	155	350	720
BH43 87	NA	NA	NA	
BH44 87	520	943	0	
BH45 87	514	4956	0	
BH46 87	522	0	0	
BH47 87	564	1530	0	
BH48 87	580	347	0	
BH49 87	583	0	0	
BH50 87	579	0	0	
BH51 87	586	0	0	
BH52 87	578	0	0	
BH53 87	561	248	0	
BH54 87	577	0	620	424
BH55 87	547	0	0	651
BH56 87	533	103	0	

BH48 87 are located adjacent to Trench T 9 as shown in the RI Work Plan BH47 87 was drilled at soil gas point 564 where 1 530 counts of PCE were detected in soil gas and BH48 87 was drilled at soil gas point 580 where 347 counts of PCE were detected

Boreholes BH49 87 and BH53 87 were to be drilled east of Trench T 9 and west of Trenches T 6 and T 7 As the entire trench area is fenced no boreholes were drilled inside this fence Thus BH49 87 was moved south of Trench T 9 BH53 87 was moved north of Trench T 9 to soil gas point 561 where PCE was detected in the soil gas (248 molecular counts)

Boreholes BH50 87 BH51 87 BH52 87 and BH54 87 are located adjacent to Trenches T 7 and T 8 BH50 87 and BH51 87 were drilled as shown in the RI Work Plan on the west ends of Trenches T 7 and T 8 respectively BH52 87 and BH54 87 were drilled between Trenches T 7 and T 8 to investigate soil contamination between the trenches BH54 87 is located at soil gas point 577 where TCE (620 counts) and TCA (424 counts) were detected

Two boreholes (BH55 87 and BH56 87) were drilled north of Trench T 5 as shown in the RI Work Plan BH55 87 is located at soil gas point 547 to investigate the TCE molecular count of 651 and BH56 87 is located at soil gas point 533 where PCE (103 count) was detected in soil gas

2 2 MONITOR WELL LOCATIONS

Twenty seven new monitor wells were installed at the 903 Pad Mound and East Trenches Areas to assess ground water flow and quality Actual well locations generally followed those proposed in the RI Work Plan however some locations were modified slightly based on soil gas results site access and geologic conditions encountered during drilling A discussion of each well location and completion is presented below by area

2 2 1 903 Pad Area

Seven of eight proposed monitor wells were installed in the 903 Pad Area Four monitor well pairs (one alluvial well and one bedrock well) were proposed for the 903 Pad Area Five bedrock wells and two alluvial wells were installed instead due to geologic conditions encountered during drilling Well locations and completions are discussed individually below

Alluvial well 10 87 and bedrock well 9 87BR comprise the well pair located due west of the 903 drum storage site as described in the RI Work Plan Alluvial ground water flow in this area is from west to east so well 10 87 is completed in Rocky Flats Alluvium upgradient of the 903 Pad Bedrock well 9 87BR is completed in a subcropping sandstone encountered beneath surficial materials at this location

Another well pair was proposed south of Trench T 2 and the reactive metal destruction site Borehole BH26 87 was to be completed as the alluvial well of this well pair however thin unsaturated surficial materials were encountered in this borehole so an alluvial well was not completed Another hole was drilled and abandoned at the location of 11 87A southwest of BH26 87 where thin unsaturated colluvial materials were again encountered A third hole was drilled at the location of 11 87BR Thin surficial materials were encountered once more at this location but a saturated subcropping sandstone was also encountered Well 11 87BR was completed in this sandstone The bedrock well of this proposed well pair (12 87BR) also encountered a near surface saturated Arapahoe sandstone and is completed in that unit

A third well pair was proposed south of the 903 Pad Area This pair was moved to the east into a small swale which drains a portion of the 903 Pad Area The alluvial well (13 87BRA) at this location again encountered thin unsaturated surficial materials so no well was installed The bedrock well (14 87BR) was completed in a near surface saturated Arapahoe sandstone

The fourth well proposed well pair in the 903 Pad Area was drilled due east of the 903 drum storage site as described in the RI Work Plan Well 15 87 is the alluvial well of this pair and well 16-87BR is the bedrock well of the pair Well 16 87BR is completed downdip and downgradient in the same sandstone as well 9 87BR

2 2 2 Mound Area

Seven new wells were installed at the Mound Area as discussed in the RI Work Plan A new bedrock well (23 87BR) was installed adjacent to existing well 43 86 to complete this well pair Well 23 87BR is completed in a subcropping saturated sandstone

Another well pair was installed east of wells 43 86 and 23 87BR as shown in the RI Work Plan Well 17 87 is the alluvial well of this pair and is completed in Rocky Flats Alluvium Well 18 87BR is the bedrock well of this pair completed in an Arapahoe sandstone A third well pair was drilled north of the mound site as described in the RI Work Plan Well 19 87 the alluvial well of this pair is completed in Rocky Flats Alluvium The bedrock well of the pair (20 87BR) is completed in an Arapahoe sandstone

A fourth well pair is shown in the RI Work Plan northwest of the Mound Area inside the PSZ fence This well pair was moved north into the drainage of South Walnut Creek for easier access Alluvial well 21 87 is completed in South Walnut Creek valley fill alluvium and bedrock well 22 87BR is completed in Arapahoe sandstone

2 2 3 East Trenches Area

Thirteen new wells were installed at the East Trenches Area in accordance with the work plan An upgradient well pair (24 87 and 25 87BR) was installed west of the northern trench area Well 24 87 is completed in Rocky Flats Alluvium and well 25 87BR is completed in a saturated near surface Arapahoe sandstone An additional upgradient alluvial well (26 87) is completed in Rocky Flats Alluvium west of the southern trench area

Four well pairs were installed around the East Trenches Area as discussed in the RI Work Plan One well pair (alluvial well 35 87 and bedrock well 36 87BR) is located north of the area near existing well 3 74 Well 36 87BR is completed in a near surface saturated Arapahoe sandstone A second well pair was drilled north of Trench T 5 (alluvial well 33 87 and bedrock well 34 87BR) and a third pair is located south of Trench T 8 (alluvial well 27 87 and bedrock well 28 87BR) The fourth well pair is southeast of Trench T 8 (alluvial well 32 87 and bedrock well 31 87BR)

A fifth well pair was proposed south of the East Trenches Area in the RI Work Plan This pair (alluvial well 29 87 and bedrock well 30 87BR) was moved southwest of its proposed location and drilled into the berm of the South Interceptor

Ditch This location was chosen to investigate PCE in the soil gas near the interceptor ditch

3 0 DRILLING AND SOIL SAMPLING PROCEDURES

Procedures for drilling soil sampling packer testing and well installation are presented in the CEARP IGMP Sampling Plan (DOE 1987a) Drilling activities followed the procedures set forth in the Plan except for total organic field screening of soil samples and soil sample collection for laboratory chemical analyses Presented below is a discussion of deviations from these procedures

3 1 VOLATILE ORGANIC FIELD SCREENING PROCEDURES

Total organic field screening of soil samples was performed every five feet in boreholes BH22 87 through BH38 87 in the 903 Pad and Mound Areas Field screening techniques were only used on core runs from which a target sample was not collected for boreholes BH39 87 through BH56 87 in the East Trenches Area

Seventy five milliliters of soil was placed in an 8 ounce clear glass jar with an equal amount of distilled water The jar was then capped shaken and allowed to stand for 30 minutes The sample jars were labeled with the time date borehole number sample depth and geologist s initials After 30 minutes a reading was taken in the headspace of the jar with a photoionization detector (PID) calibrated to benzene and a flame ionization detector (FID) calibrated to methane The headspace readings were recorded in the field notebook

3 2 SOIL SAMPLE COLLECTION FOR LABORATORY CHEMICAL ANALYSIS

Continuous drive samples were collected from all boreholes from ground surface to total depth Total depth varied with the depth to bedrock but all boreholes extended at least two feet into bedrock The continuous samples were initially screened with a PID an FID and an alpha meter as soon as the sample barrels were opened Volatile organic field screening samples were then collected as described above These two field screening techniques in addition to visual inspection were used to identify suspected waste sources

3 2 1 Soil Sample Collection at the 903 Pad and Mound Areas

Both discrete target and composite samples were collected from boreholes for laboratory analyses Figure D 1 presents the sample collection and numbering scheme used for samples collected from boreholes BH22 87 through BH38 87 Target intervals were sampled in these boreholes as follows

1) at a waste source as identified by direct field readings off the core by either the PID or the OVA or by the field screening technique (designated a waste sample)

2) at the water table (designated a water table sample)

3) at the alluvium/bedrock contact (designated a contact sample) and

4) in bedrock below the alluvium/bedrock contact (designated a bedrock sample)

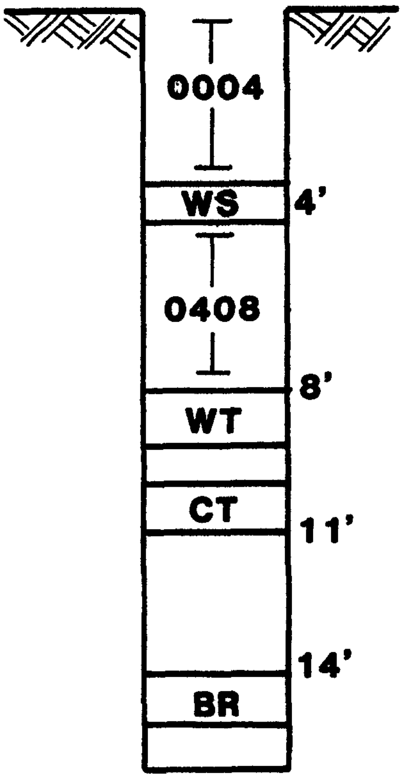
Waste sample intervals were centered around the waste source The sample interval extended far enough from the center of the source to collect the appropriate sample volume If field screening indicated more than one waste source in a

FIGURE D 1

903 PAD AND MOUND AREAS
BOREHOLE SAMPLE COLLECTION AND NUMBERING SCHEME

BH0587 0004

Borehole Number **Footage**



BH05870004
Composite sample collected from the ground surface to observed waste at four feet

BH058704WS
WS indicates a waste sample collected based on field screening techniques A discrete sample is centered around the waste source and the appropriate volume is collected

BH058704CS
Composite sample collected from waste a four feet to water table at eight feet

BH058708WT
WT indicates the water table sample depth to water table is eight feet A discrete sample is collected from the water table down until appropriate volume is collected

BH058711CT
CT indicates contact sample Depth to alluvium/bedrock contact is eleven feet A discrete sample is collected in alluvium from the contact up until appropriate volume is collected

BH058714BR
BR indicates the bedrock sample A discrete sample is collected from three feet below alluvium/bedrock contact down until appropriate volume is collected

borehole then either the maximum field screening value was sampled or more than one sample was collected depending on percent core recovery

Water table samples were collected in boreholes which encountered ground water The sample interval for these samples extended from the water table downward until the appropriate sample volume was collected

Contact samples were collected from the base of surficial materials at the alluvium/bedrock contact The sample interval extended from the base of surficial materials upward until the appropriate sample volume was collected

Bedrock samples were collected from three feet below the alluvium/bedrock contact downward until the appropriate sample volume was collected

Composite samples were collected from borehole intervals which were not sampled discretely If no wastes were observed in a borehole core was composited every ten feet to comprise a composite sample In boreholes where a waste source was observed composite samples were collected a maximum of every ten feet above and below the waste Composite sample intervals varied depending on the amount of available core the depth of the waste the depth to water and the depth to bedrock as discrete samples were collected before composite samples

3 2 2 Soil Sample Collection at the East Trenches Area

Soil sampling procedures were modified prior to drilling at the East Trenches Area to reduce volatilization of organics from core before it was packaged The new procedure described below was implemented on August 12 1987

Target samples and composite samples from BH39 87 through BH56 87 were collected differently from those previously discussed Figure D 2 presents the sample collection and numbering scheme used Target samples were collected

1) at a waste source as identified by the initial screening of the core with a PID FID and alpha survey meter (designated a direct hit sample)

2) at a waste source as identified by field screening (designated a field screen sample)

3) at the water table (designated a water table sample)

4) in alluvium in the sample run immediately above the alluvium/bedrock contact (designated an upper contact sample)

5) in the sample run containing the alluvium/bedrock contact (designated the contact sample) and

6) in bedrock in the sample run immediately below the sample run containing the alluvium/bedrock contact (designated a bedrock sample)

After the initial screening with a PID and FID and an alpha meter was completed on a core interval two four ounce precleaned glass jars were filled with soil for volatile organic analyses (VOA) If a direct hit was recorded during the screening then the two VOA jars were filled followed by three eight ounce precleaned clear glass jars for radiochemistry base neutral acids (BNA) pesticides and metals analyses

All of the target samples were collected as composite samples of each two two and one half or three foot core interval The sample run length varied slightly between the drilling rigs depending on the availability of the sampling barrels and core recovery

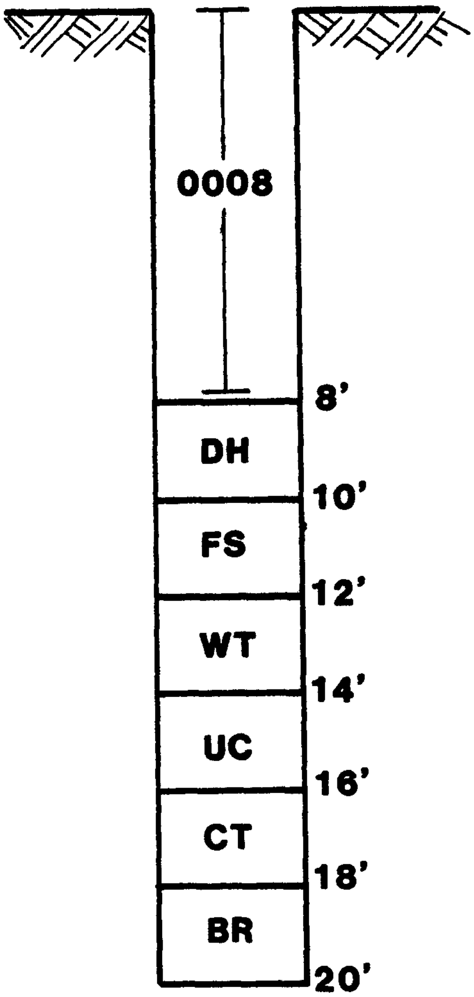
Drilling and soil sampling continued in the borehole until no PID or FID direct hit or field screen readings above background were detected

FIGURE D 2

EAST TRENCHES AREA
BOREHOLE SAMPLE COLLECTION AND NUMBERING SCHEME

BH3987 0008

Borehole Number **Footage**



BH39870008
: Composite sample collected from the ground surface to observed waste at eight feet VOAs submitted from six to eight foot interval

BH398708DH
: DH indicates a direct hit sample collected in the core run beginning at eight feet

BH398710FS
: FS indicates a field screen sample collected in the core run beginning at ten feet

BH398712WT
: WT indicates the water table sample The water table was encountered in the run from 12 to 14 feet

BH398714UC
: UC indicates the upper contact sample The sample was collected in the core run immediately above the run in which the alluvium/bedrock contact was encountered

BH398716CT
: CT indicates the contact sample The alluvium/bedrock contact was located in the run beginning at 16 feet

BH398718BR
: BR indicates the bedrock sample The sample was collected in the core run immediately below the run in which the alluvium/bedrock contact was encountered

Composite samples were collected from borehole intervals of eight feet in which no target samples were collected Three eight ounce glass jars (for radiochemistry BNA/pesticides and metal analyses) were composited and the two VOAs from the core interval nearest the base of the eight foot interval was used to complete the composite sample

4 0 GROUND WATER AND SURFACE WATER SAMPLING PROCEDURES

Ground water and surface water sampling procedures implemented during this RI are presented in Attachment 1 However the sampling collection order was modified somewhat from the order presented in Section 6 4 2 1 of the sampling procedures As many of the wells at Rocky Flats Plant produce small quantities of water for sampling this modification was made to collect priority samples Table D 2 presents the modified collection order

Other modifications occurred during first second and third quarters involving containers used for radiochemical analyses During the first second and fourth quarters a four liter polyethylene cubitainer was used to collect the samples However this entire sample volume was not used for radiochemical analyses during the first and second quarters as discussed in Appendix G In the third quarter one liter polyethylene bottles were used

During the first and second quarter sampling events samples collected for radiochemical analyses were not filtered However samples for radiochemical analyses were filtered during the third and fourth quarters Surface water samples were not filtered prior to radiochemical analyses

TABLE D 2

SAMPLING COLLECTION ORDER FOR RCRA AND

REMEDIAL INVESTIGATION SURFACE WATER AND GROUND WATER

Parameter	Container Type	Max Vol	Min Vol	Preservation
VOA	Septum Vial	2 40 ml	1 40 ml	Cool 4°C
Pu 239	Plastic	1 Liter +	1 Liter +	Filtered 25 ml HNO_3
Am 241	Plastic	1 Liter +	1 Liter +	Filtered HNO_3 pH<2
U 233 4 5 8	Plastic	1 Liter +	1 Liter +	Filtered HNO_3 pH<2
NO_3	Plastic	125 ml	50 ml	H_2SO_4 pH<2 Cool 4°C
Metals	Glass	1 Liter	400 ml	Filtered HNO_3 pH<2
Cr^{6+}	Amber glass	250 ml	250 ml	None
Sr 90	Plastic	1 Liter	600 ml	Filtered HNO_3 pH<2
H^3	Amber glass	250 ml	125 ml	Cool 4°C
Cl /SO_4 2	Plastic	1 Liter	700 ml	Cool 4°C
TDS/Alk	Plastic	1 Liter	500 ml	Cool 4°C
Carbonate/ Bicarbonate & Total Sus pended Solids	Plastic	1 Liter	500 ml	Cool 4°C
Gross B/ Gross A	Plastic	250 ml	150 ml	HNO_3 pH<2

APPENDIX D

ATTACHMENT 1

SAMPLING PROCEDURE FOR
GROUND WATER MONITORING PROGRAM

ROCKY FLATS PLANT

SAMPLING PROCEDURE FOR GROUND WATER MONITORING PROGRAM

L 6213 A

INFORMATION/R[illegible] COPY
MAY NOT BE CURRENT VERSION
DATE 11-24 1987

Author J A Blair

Approved By Tim J [illegible] Title Mgr Gen Chem

Approved By Duane [illegible] Title Mgr General Lab

Approved By ______ Title ______

Effective Date July 24, 1987

This procedure contains consecutively numbered pages 1 through 33

DISTRIBUTION

COPY	CUSTODIAN	LOCATION
1	D I Hunter (Master Copy)	RF 881
2	T H Elmont	RF 881
3	J A Blair	RF 881
4	J A Blair	RF 881
5	T C Greengard	RF T452F
6	J Zarret	RF 564

1 INTRODUCTION

This procedure will be used for routine ground water monitoring at the Rocky Flats Plant The procedure provides for

Equipment Decontamination
Water Level Measurement
Well Purging
Field Water Quality Measurements
Sample Collection Bottling and Preservation
Quality Assurance/Quality Control
Documentation and Data Management

2 HAZARDS SAFETY AND SAFEGUARDS CONTROL

2 1 The hazards and safety of this procedure are addressed in the Operation Safety Analysis (OSA) Number 452 01 and Number 121 1

2 1 1 Copies of OSA 452 01 have been distributed to the following

J A Blair (2) RF 881

B Lewis (1) RF T452B

2 1 2 Copies of OSA 121 1 have been distributed to the following

J A Blair (2) RF 881

D I Hunter RF 881

2 2 The following list of acids and bases are used in preserving the samples These will cause chemical burns upon contact with the skin or eyes Extreme caution should be used when handling these chemicals

2 2 1 Concentrated Sulfuric Acid (H_2SO_4) HMR 3 0 2

2 2 2 Concentrated Nitric Acid (HNO_3) HMR 3 0 0

2 2 3 10M Sodium Hydroxide (NaOH) HMR 3 0 1

3 SPECIAL EQUIPMENT

3 1 Standards Lab calibrated pH meter

3 2 Standards Lab calibrated conductivity temperature meter

3 3 Electric water level sounder This device is used to measure the total depth (TD) and water level of the well The cable is graduated to indicate the length of cable in the well

3 4 Dedicated pump system This consists of an air actuated bladder pump that will be dedicated to specific wells

3 5 Bladder pump This is used to pump wells with total depths over 50 feet and/or storage volumes of over 20 gallons

3 6 Oil less air compressor

3 7 Stainless steel and teflon bailers Some stainless steel bailers will be dedicated to specific wells Teflon or stainless steel bailers will be used to bail wells with total depths below 50 feet and/or storage volumes under 20 gallons

3 8 Tape measure

3 9 Field notebook and water level notebook

3 10 Watch

3 11 Calculator

3 12 Walkie Talkie

3 13 Voice beeper

3 14 Brushes

3 15 Calibrated bucket 5 gallon or larger

3 16 Coolers

3 17 Blue ice packs

3 18 Squirt bottles

3 19 Decon tubs

3 20 Decon spray tanks

4 MATERIALS

4 1 Chemicals and Reagents

4 1 1 Concentrated sulfuric acid (H_2SO_4)

4 1 2 Concentrated nitric acid (HNO_3) trace metal quality

4 1 3 10M sodium hydroxide (NaOH) Dissolve 400g NaOH in 800 ml deionized water in a 1 liter volumetric flask Bring up to volume and store in 1 liter plastic bottle

4 1 4 Deionized water

4 1 5 Alconox Solution Dissolve 0 5 cup of alconox powder per 3 gallon of deionized or distilled water

4 1 6 pH Buffers Prepare by directions on buffer bottle One buffer should be in the 4 0 6 0 range with the other in the 8 0 10 0 range Place buffers in sample cooler for storage

4 1 7 Conductivity Standard Dissolve 0 7459 g KCl (dried for 1 hour in a 110 C oven) in 1 liter of deionized water Lower the temperature of the standard by cooling in ice bath of 10 C Immediately take the measurement of the standard on the laboratory calibrated conductivity meter and record value on calibration sticker on bottle of standard Place standard in sample cooler for storage

4 2 Consumable Materials

4 2 1 Pen

4 2 2 Polypropylene rope

4 2 3 Plastic sheeting

4 2 4 Surgeons gloves

4 2 5 Neoprene gloves

4 2 6 Tyvex coveralls

4 2 7 Shoe coverings or booties

4 2 8 Sample bottles pre preserved in laboratory

4 2 9 Batteries

4 2 10 Chain of Custody sheets

5 STANDARDIZATION AND CALIBRATION

The pH meter and conductivity temperature meter will be calibrated by the Standards Lab on a quarterly basis The equipment should be kept clean and protected from temperature extremes

5 1 Calibration of pH Buffers in the Field

Calibration will be performed before each parameter is taken during both purging and sampling of the well

5 1 1 Turn on meter and check battery

5 1 2 Place pH buffers from cooler into labeled plastic beakers

5 1 3 Remove boot from electrode Rinse electrode with deionized water

5 1 4 Immerse bulb in lower pH buffer and adjust calibration knob to correct reading Record reading in logbook

5 1 5 Rinse electrode with deionized water

5 1 6 Immerse bulb in upper pH buffer and record reading in logbook Do not readjust calibration knob This is simply a check of calibration

5 1 7 Rinse bulb with deionized water

5 2 Calibration of Conductivity Standard in the Field

Calibration will be performed before each parameter is taken during both purging and sampling of the well

5 2 1 Turn on meter

5 2 2 Place conductivity standard from cooler into labeled plastic beaker

5 2 3 Rinse electrode with deionized water

5 2 4 Immerse probe into standard adjust temperature compensate knob to correct standard reading Record reading in logbook

5 2 5 Rinse probe with deionized water

6 OPERATING INSTRUCTIONS

6 1 Equipment Decontamination

All decontamination will be performed with one person acting as the clean person and one the dirty person Both people will wear new clean surgeons gloves The dirty person will handle all the equipment before cleaning and the clean person will handle the equipment after cleaning

6 1 1 Decontamination of the water level sounder should be performed after each reading and stored in a clean plastic bag

After reading has been taken decon the sounder directly out of the well One person should wind the sound on the reel while the other person rinses it with alconox solution followed by deionized water

6 1 2 Decontamination of the bailer should be performed after each use unless it is to be re used for additional purging or sampling of the same well In such a case the bailer should be placed in a clean plastic bag and labeled for the specific well

After use of the bailer is complete disassemble it and decon each part using a brush and alconox solution Then rinse each part with deionized water and reassemble Store the bailer in a clean plastic bag

6 1 3 Decontamination of the portable bladder pump should be performed after each use Decon the pump directly out of the well

One person should wind the pump on the reel while the other person rinses it with alconox solution followed by deionized water

After being completely deconed place the pump head in a five gallon container of deionized water and pump water through to clean the inside tubing

6 1 4 Decontamination of the sample bottles should be performed after they have been filled and labeled

Rinse each bottle with alconox solution followed by deionized water Place the bottles in cooler

6 2 Water Level Measurement

An accurate measurement of depth to water in a well is needed to monitor seasonal fluctuations of water levels and to calculate the volume to be purged from a well before water quality sample collection

6 2 1 Record the following in the logbook

6 2 1 1 Well Location

6 2 1 2 Identification number

6 2 1 3 Date/Time

6 2 2 Turn on well sounder check battery and lower cable into well until presence of water is indicated

6 2 3 Hold cable so thumb and index finger are touching the top of casing when probe just enters water (alarm will sound) Use the north rim of the inner casing for the depth to water reference point

6 2 4 Raise cable until alarm stops (i e probe is just above water level) Lower cable until alarm sounds again Check to see if thumb and index finger are at the same location as before Repeat one more time for a final verification

6 2 5 Read the measurement off the cable to the nearest half of the lowest dimension Record the water level in the logbook

6 2 6 Continue lowering the cable into the hole to determine the total depth (TD) When slack in the cable occurs pull the cable up until slack is gone

6 2 7 Hold cable the same as for water level and take measurement at the north rim of the inner casing for reference point Repeat one more time for a final verification

6 2 8 Read the measurement off the cable to the nearest half of the lowest dimension Record the TD in the logbook

6 2 9 Decon the sounder as stated in Section 6 1 1

6 3 <u>Well Purging</u>

The water standing in the well may have different chemical characteristics than the water in the formation because of volatilization of constituents and/or charges of oxidation and pH conditions For this reason the water standing in the well must be removed and water representative of the formation water brought into the well before the actual sample is collected This is known as well purging

Purging will consist of removing a minimum of three wellbore storage volumes from high production wells and a minimum of one wellbore storage volume from low production wells A high production well is a well from which three wellbore storage volumes can be removed in eight hours A low production well is a well from which three wellbore storage volumes cannot be removed in eight hours due to insufficient inflow to the well from the formation

Wellbore storage volume is the volume of water standing inside the casing i e the distance between the water level and the bottom of the casing (length of the water column in the well) multiplied by the inner cross sectional area of the casing

6 3 1 Calculate the wellbore storage volume using the formula below

Wellbore Storage Volume (liters) = (TD WL)*(A)

WSV = well storage volumes (liters)

TD = total depth (feet)

WL = water level (feet)

A = cross sectional area of well (liters/foot)

= 0 619 for 2 well

= 1 395 for 3" well

= 2 478 for 4" well

= 5 586 for 6" well

6 3 1 1 A well is considered dry if before purging the wellbore storage volume is below one liter calculated volume

6 3 1 2 Multiply the wellbore storage volume by three to get the minimum volume of water to be purged from the well

6 3 1 3 Record calculations and values for TD WL WSV and A in the field notebook Record to 2 significant figures if value is under 10 to 3 significant figures if value is over 10 and to 4 significant figures if value is over 100

6 3 2 Remove the appropriate number of calculated wellbore storage volumes of water from the well using the dedicated pump dedicated bailer or portable sampling pump Regardless of the type of equipment used to purge the well record the total volume purged and the time when purging begins and ends

During purging field water quality measurements will be taken four different times These will be spread out over the total purge volume of three wellbore storage volumes The field water quality measurements are described in Section 6 4 If the well appears to be going dry and all three wellbore storage purge volume will not be purged the four field water quality measurements should be obtained within the amount purged

6 3 3 The dedicated pump system consists of an air actuated bladder pump with downward flow checking valves on the inlet to the inside of the bladder and on the tubing above the outlet from the inside of the bladder Air is developed to the outside of the bladder and pressure is maintained long enough that the bladder is compressed and water inside it is forced into the discharge tubing Water is kept from exiting the bottom of the pump by the lower check valve The air pressure is vented to the surface through the same pressurizing tube (requiring a time dependent on length of tubing required air pressure and depth of submergence of the pump) Water forced into the discharge tubing is held by the upper check valve The cycle is repeated until discharge reaches the surface and purging begins Due to the mechanism of this purging the discharge is delivered to the surface in cyclic slugs but the pressurizing air is never in contact with the water The uppercheck valve has a small diameter bypass so that water in the discharge tubing after sampling will drain back into the well and will not freeze

When placing the dedicated pump into the well position the screen 6" 8" off the the bottom This will prevent plugging of the screen by silt at the bottom of the well

6 3 3 1 Appropriate clothing and gloves need to be worn to prevent contamination of equipment and personnel This also prevents cross contamination when traveling from one well to another

One person will be designated as the clean person They will wear surgeons gloves beneath Neoprene gloves They will perform field water quality measurements and dumping of the purge bucket

The other person will be designated as the dirty person and will handle all the down hole equipment including the pump and compressor They will wear white Tyvex coveralls booties and surgeons gloves beneath Neoprene gloves

All clothing should be removed and placed in the trash before traveling to the next well

6 3 3 2 Attach the compressor to the pump pressure inlet on the controller (Use oil less compressor to protect pneumatic logic components inside the controller)

6 3 3 3 Connect the red air hose between well cap and the pump supply on the controller

6 3 3 4 Position the refill and discharge knobs to enter position (12 o clock) and start the compressor Record start time of purging in the field notebook

6 3 3 5 Set gas pressure level to a pressure sufficient to lift the column of water in the discharge tubing plus 30 PSI but do not exceed 125 PSI total

6 3 3 6 Adjust the discharge knob so that venting occurs at the end of the slug discharge

6 3 3 7 Decrease the refill cycle time until the volume discharge in each cycle begins to decrease If decrease is immediate lengthen both the refill and discharge cycle times and repeat Steps 6 3 3 5 and 6 3 3 6

6 3 3 8 Measure volume produced in a container of known volume (e g plastic graduated bucket)

6 3 3 9 Continue pumping until the appropriate volume has been purged Record four field water quality measurements during purging in the field notebook Record time at the end of pumping and the total volume pumped in the field notebook

6 3 4 Bailing with a teflon or stainless steel bailer will be done when either a dedicated pump does not exist the dedicated pump is inoperable or the wellbore storage volume is less than 75 liters for all three volumes

6 3 4 1 Appropriate clothing and gloves need to be worn to prevent contamination of equipment and personnel This also prevents cross contamination when traveling from one well to another

One person will be designated as the clean person They will wear surgeon gloves beneath Neoprene gloves They will perform field water quality measurements and dumping of the purge bucket as well as assisting the dirty person in their bailing duties

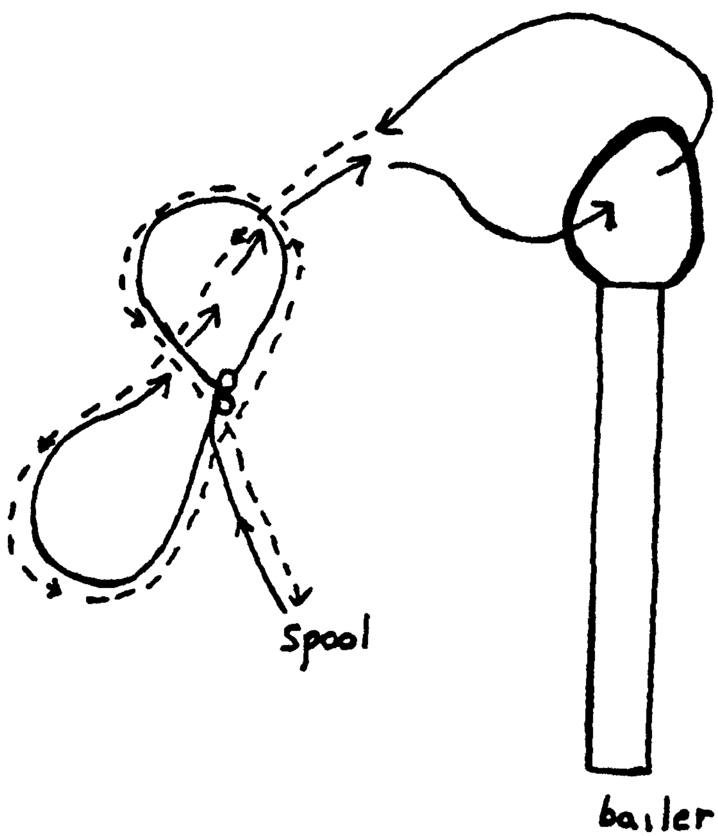
The other person will be designated as the dirty person and will remain on the plastic sheeting performing the bailing They will wear white Tyvex coveralls booties and surgeon gloves beneath Neoprene gloves Booties will be put on just prior to getting on the plastic and the person will remain on the plastic until bailing is complete

All clothing should be removed and placed in the trash before traveling to the next hold

6 3 4 2 Place a sheet of plastic over the casing Cut a hole in the plastic for the casing and spread sheet on the ground around the well The plastic and equipment should be arranged in such a manner as to enable the samplers to do all work while standing on the plastic The plastic is to keep all equipment clean and soil free All workers will only walk on the plastic with booties which have never touched the ground

6 3 4 3 Remove bailer from its holder and inspect check valve top bail and cord which the rope ties to (All personnel should be dressed in the appropriate clothing and gloves before handling any equipment) If any components are loose or damaged replace them Decontaminate equipment if any new parts are used Do not allow bailer or rope to contact anything but clean plastic

6 3 4 4 Tie a figure 8 knot with the rope onto the cord of the bailer First make a loop 6 in diameter and twist twice to form 2 small loops around base of large 6 loop with excess rope Second thread end of rope through 6" loop (see diagram) and out over to cord on bailer this forms the figure 8 Third thread end of rope through bailer cord and back through figure 8 in reverse order Follow end of rope through along the original rope in reverse order until you have passed through the 2 small original loops around the base This should bring the end of the rope back to the spool of rope Pull tight



6 3 4 5 Record start time in field notebook

Lower bailer into well Do not drop bailer into well at high speed because the check valve may dislodge or become damaged Fill the bailer with water and hoist to surface coiling rope into hands or onto plastic Pull directly up on rope when coiling Do not allow rope to rub against casing when pulling up Do not allow rope to fall off of plastic If it does get contaminated the rope must be changed before bailing again

6 3 4 6 Empty bailer into the graduated container of known volume

Continue bailing until appropriate volume has been purged as determined by volume in container

Record four field water quality measurements during purging in the field notebook Record time at the end of purging and total volume bailed in the field notebook

Decontamination described in Section 6 1 2 will be performed at this time

6 3 5 A portable pump will be used to purge a well when either a dedicated pump does not exist the dedicated pump is inoperable or the wellbore storage volume is greater than 75 liters for all three volumes

6 3 5 1 Appropriate clothing and gloves need to be worn to prevent contamination of equipment and personnel

The same clean and dirty person will be established for purging with the portable pump The same clothing will be used as designated in the previous section on bailing

6 3 5 2 Place clean decontaminated pump approximately one foot above the bottom of the well

Place the uphole end of the discharge in the graduated container of known volume

Record start time for pumping in the field notebook

6 3 5 3 Connect compressor to pump controller Turn on compressor and pump appropriate volume as measured in graduated container

Record four field water quality measurements during purging in the field notebook Record time at the end of purging and total volume purged in the field notebook

Decontamination as described in Section 6 1 3 will be performed at this time

6 4 Field Water Quality Measurements

Calibration and standardization should be performed according to Section 5 of this procedure before each field water quality sample is taken during sampling and purging of the wells

6 4 1 Collect sample in a beaker (rinse beaker with deionized water first)

6 4 2 Place pH probe and conductivity probe in the beaker

6 4 3 Read pH to the nearest tenth of a pH unit Stir the sample with the electrode to allow a stable reading Record reading in logbook

6 4 4 Read conductivity to two significant figures Stir the sample with the probe to allow a stable reading Record reading in logbook

6 4 5 Switch to temperature Read temperature to the nearest degree Stir the sample with the probe to allow a stable reading Record reading in logbook

6 4 6 Rinse all probes and beaker with deionized water

6 4 7 Leave meters on if more samples are to be taken otherwise turn meters off

6 5 Sample Collection, Bottling and Preservation

For purposes of sample collection a technically dry well is one that does not recharge sufficiently to provide at least 1 liter of sample within 24 hours of purging A well may be sampled for partial analyses as long as at least a liter is present in the well each 24 hours If after 24 hours the water volume is below 1 liter then the well is dry and only the partial samples will be analyzed

Samples will be collected with the dedicated pump when possible If a bailer or portable pump was used to purge the well then a bailer will be used to sample The portable pumps will not be used to sample a well

6 5 1 Preparing sample bottles will be done in the lab prior to going into the field

Preservation and sample size for each parameter(s) will be as follows

Parameter	Container Type	Volume	Preservation
Volatile Organics (VOA)	Septum vial	2 40 ml	Cool 4 C
Cyanide (CN)	plastic	1 liter	10M NaOH to pH>12
Total Dissolved Solids (TDS) and Alkalinity (Alk)	plastic	1 liter	Cool 4 C
Chloride (Cl^-) and Sulfate (SO_4 ^{2})	plastic	1 liter	Cool 4 C
Metals - filtered	glass	1 liter	5 ml HNO_3
Nitrate as N (NO_3 -N)	plastic	500 ml	H_2SO_4 to pH<2

Pu 239	plastic	500 ml	25 ml HNO_3
Tritium	amber glass	500 ml	None
Am 241 U 234 235 238 Sr 90 Gross Alpha Gross Beta (RADs)	plastic or glass	4 liter	HNO_3 to pH<2

6 5 1 1 Each sample bottle will be labeled with the following information

Well number/sample location
Parameter
Date/Time sampled
Preservation

6 5 1 2 Sample bottles will be placed in a cooler with blue ice

6 5 1 3 Chain of Custody forms will be picked up in the lab and filled out daily in the field (Figure 1 page 33)

6 5 2 The sample should be collected immediately after purging if possible If the well is essentially dry after purging measure the water level in the well on a periodic basis Collect volatile organic samples within four hours of purging Collect the rest of the samples as soon as there is sufficient volume in the well to fill sample bottles (at least 1 liter within 24 hours) Attempt to collect an aliquot for field water quality measurements four times during sampling

6 5 2 1 Collect samples in the following order

VOAs
CN
SO_4 ^{2} & Cl
Metals
TDS & Alk
NO_3 N
Pu
Tritium
RADs

6 5 3 The appropriate clothing and gloves need to be worn to prevent contamination of equipment and personnel The same clean and dirty person will be established for sampling as for purging

6 5 3 1 Take water level measurement with well sounder and record water level in field notebook

Calculate well storage volume to determine volume available to sample

6 5 3 2 Fill bottles according to sampling order using either a dedicated pump or bailer

6 5 3 3 Record time of sampling and date on sample bottle and in field notebook

6 5 3 4 When filling VOA bottles fill each vial to overflowing with sample Carefully place cap on the vial so that air is not captured and tighten Invert vial and tap lightly If bubbles are observed repeat process

6 5 3 5 Metal samples are filtered with a field filter pump in the field using a prefilter followed by 0 45 μm filter

6 5 3 6 Complete Chain of Custody form and indicate the time date well number and number of bottles sampled

6 5 3 7 Decon sample bottles as described in 6 1 4 and place in sample cooler for trip back to lab Samples should be delivered to lab within 4 hours of collection

6 6 Quality Assurance/Quality Control

Quality Assurance/Quality Control (QA/QC) will be maintained for both field sampling activities and laboratory analyses

6 6 1 The field sampling QA/QC program will include daily calibration of field instruments routine maintenance of equipment and quality control samples

6 6 1 1 Trip blanks will be taken once per week and will consist of a full set of sample bottles filled with deionized water from the lab These samples will be transported in coolers out to the days sampling sites and back to the lab for analysis

6 6 1 2 Field blanks will be taken once per week and will consist of filling a full set of sample bottles in the field at a sampling site These sample bottles are filled with deionized water and transported in coolers back to the lab for analysis

6 6 1 3 Duplicate samples will be taken once every two weeks These consist of a second full set of sample bottles being filled from a well currently being sampled They will be labeled with the Well Identification Dup and transported in coolers back to the lab for analysis

6 6 1 4 Equipment blanks will be taken 3 times per quarter They will consist of rinsing the equipment with deionized water (after equipment has been deconed) into a tub and then filling a full set of sample bottles with this rinse water The samples are then transported in coolers back to the lab for analysis

6 6 2 A maintenance log will be maintained to document equipment maintenance and calibration of instruments by the Standards Laboratory Daily calibrations will be kept in the field notebook (See Section 6 4)

6 6 3 Field audits will be performed by personnel from the laboratory on a quarterly basis Separate field audits will be performed by Health Safety and Environment (HS&E) personnel on a semiannual basis

6 6 3 1 Formal audit reports will be documented in the QA/QC files Formal memoranda documenting deviations from the procedures in this document will be prepared and rectification will be documented by the General Laboratory management

7 CALCULATIONS

7 1 Field calculations will be performed using a hand held calculator They will be computed and logged in the field notebook They will include units being used and the correct number of significant figures (See Section 6 3 1)

8 RECORDS

All sampling activities and calibrations will be documented in the field notebook and maintenance log book Such entries will be as descriptive and detailed as possible so that a particular situation can be reconstructed

Field notebooks will be bound with consecutively numbered pages The sampling supervisor or chemist will assign a number and title to each notebook

All entries will be made in ink If an incorrect entry is made the data will be crossed out with a single strike mark and initialed

8 1 The following will be logged in the field notebook at the start of a day

Personnel present
Date/Time
Initials of person making entries
Decontamination materials
Weather conditions
- Equipment
Calibration standard values

8 2 The following will be logged in the field notebook for each visit to each sampling location

Location and well identification
- Date/Time
- Field activity
- Comments/Observations

8 3 The following will be logged in the field notebook during purging activities

- Device used to purge
- Start time/end time for purging
- Field parameters (i e pH conductivity temperature)
Time for each parameter
Water level
- Total depth
Cross sectional area of well
Calculation for well storage volume

Example

A - Cross sectional area of well - 0 619 l/ft for 2" well

TD - Total Depth (ft)   101 4
WL - Water Level (ft)   68 2
                           33 2 ft

33 2 ft x 0 619 l/ft - 20 6 liters - 1 storage volume

3 storage volumes - 61 8 liters

	Start	2nd	3rd	Final
pH (S U)				
Conductivity (μmho/cm)				
Temperature (C)				
Time				

8 4 The following will be logged in the field notebook during sampling activities

Device used to sample
Start time/end time of sampling
Field parameters (i e pH conductivity temperature)
Time for each parameter
Water level
Total depth
Cross sectional area of well
Calculation for well storage volume recharged

Example

A - Cross sectional area of well - 0 619 l/ft for 2 well

TD - Total Depth (ft)   101 4
WL - Water Level (ft)   88 2
                           13 2 ft

13 2 ft x 0 619 l/ft - 8 2 liters recharge volume

	Start	2nd	3rd	Final
pH (S U)				
Conductivity (μmho/cm)				
Temperature (C)				
Time				

8 5 The maintenance log book will include maintenance for all calibrated field parameter instruments pumps compressors bailers well sounders etc

Each entry should include the following

Date/time sent for service
- Equipment being serviced
Personnel doing service
- Summary of maintenance performed
- Parts needed for repair
- Calibration if performed
- Date/time received back from service

8 6 The Chain of Custody form will be filled out in the field for each sample It will accompany the sample to the laboratory where it will be relinquished to the laboratory sample receive person (See Figure 1 page 33)

The following entries will be filled out on the Chain of Custody

- Samplers signatures
- Station No /Well No (including quality control samples)
- Date/time sampled
- Composite and/or grab sample
- Station location (brief description of location)
- Number of containers
- Types of samples collected (marked by circling or X out)
- Relinquished signature/Date/Time
- Remarks (i e well dry only partial sample sample bottle broke etc)

8 7 The laboratory sample receive person will log samples into the laboratory system fill out and distribute parameter worksheets and tag samples with lab I D A detailed procedure for logging in samples is outlined in "Sample Administration General Labs" L 6002 A

8 8 Field notebooks maintenance notebooks and all laboratory documentation will be kept on file within the General Labs for the current year and the previous year The four years previous to that will be held in Records Management files on the Rocky Flats Plantsite All records prior to the previous five years and current year will be sent to permanent storage at a designated location by Records Management

9 SHUTDOWN

9 1 All equipment used in the field will be unloaded from the sample vehicle at the end of each day and stored in locked facilities

9 2 All log notebooks maintenance notebooks Chain of Custody forms etc are returned to the laboratory office for storage overnight

9 3 Any remaining samples are delivered to the lab at the end of the day for refrigeration and storage

9 4 Sample vehicles are to be gassed up at the garage before the shift (7 30 8 30 am) or at the end of shift (2 30 3 30 pm)

10 REFERENCES

10 1 U S Environmental Protection Agency 3rd Edition November 1986 Test Methods for Evaluating Solid Waste SW 846

10 2 U S Environmental Protection Agency 1983 Methods for Chemical Analysis of Water and Wastes EPA 600/4 79 020

10 3 RCRA Part B Permit Application November 1986 U S DOE Rocky Flats Plant CO7890010526

Figure 1

ENVIRONMENTAL PROTECTION AGENCY
Office of Enforcement

CHAIN OF CUSTODY RECORD

A/B — B=Type & size of bottles
p1=1 L plastic p5 500ml plastic
p4 4 L plastic g120=120ml glass
voa=40ml VOA

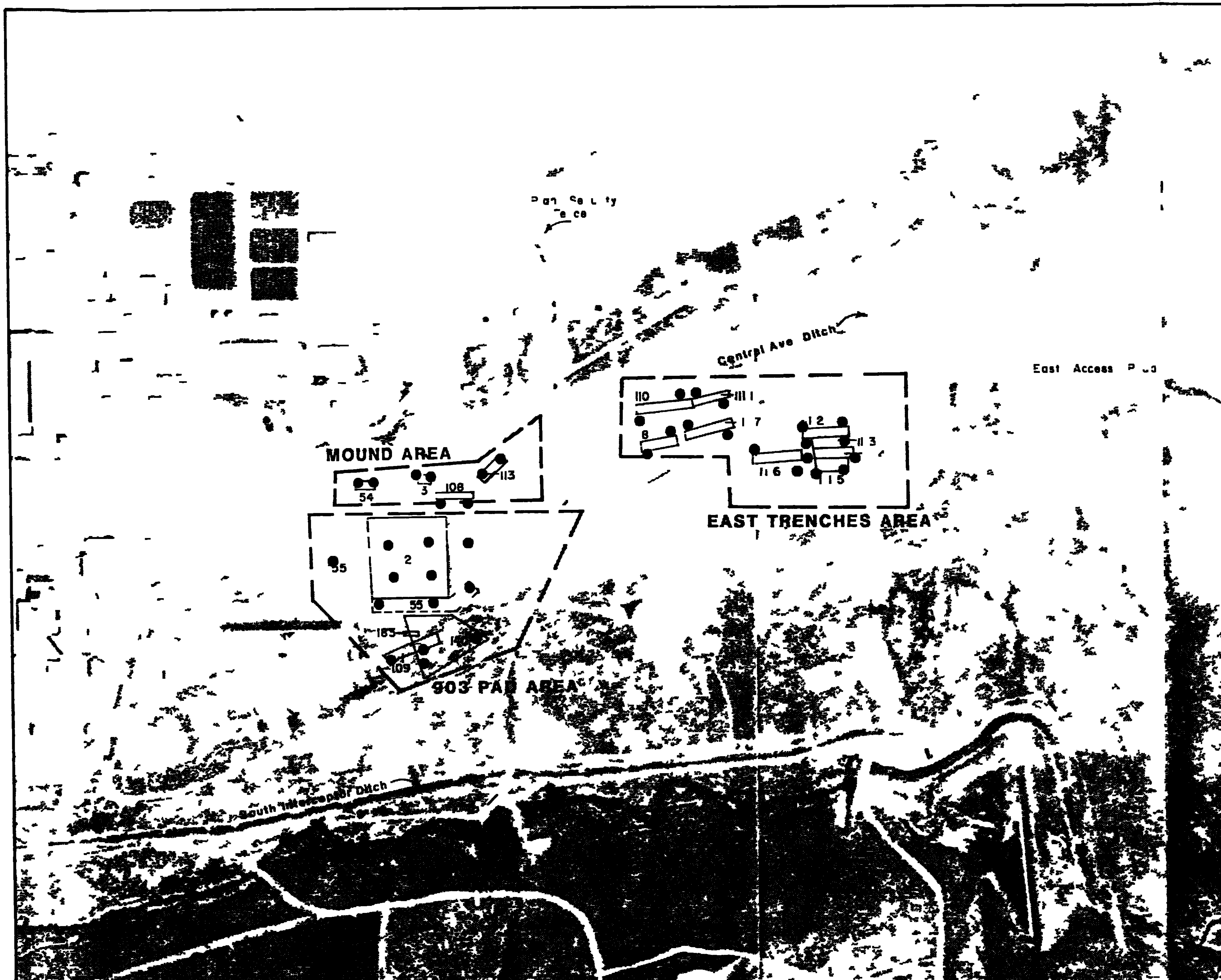
PROJ. NO.	PROJECT NAME
	Ground Water Monitoring Wells

SAMPLERS: (Signature)

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	NO. OF CONTAINERS	Volatile Organics	Metals	TDS & Alkalinity	CN	Cl & SO_4	NO_3 as N	Pu	Tritium	Gross Alpha & Beta, U, Am & Sr 90	REMARKS
							2 voa	1 p1	1 p1	1 p1	1 p1	1 p5	1 p5	2 g120	1 p4	
							2 voa	1 p1	1 p1	1 p1	1 p1	1 p5	1 p5	2 g120	1 p4	
							2 voa	1 p1	1 p1	1 p1	1 p1	1 p5	1 p5	2 g120	1 p4	
							2 voa	1 p1	1 p1	1 p1	1 p1	1 p5	1 p5	2 g120	1 p4	
							2 voa	1 p1	1 p1	1 p1	1 p1	1 p5	1 p5	2 g120	1 p4	
							2 voa	1 p1	1 p1	1 p1	1 p1	1 p5	1 p5	2 g120	1 p4	
							2 voa	1 p1	1 p1	1 p1	1 p1	1 p5	1 p5	2 g120	1 p4	
							2 voa	1 p1	1 p1	1 p1	1 p1	1 p5	1 p5	2 g120	1 p4	
							2 voa	1 p1	1 p1	1 p1	1 p1	1 p5	1 p5	2 g120	1 p4	
							2 voa	1 p1	1 p1	1 p1	1 p1	1 p5	1 p5	2 g120	1 p4	
							2 voa	1 p1	1 p1	1 p1	1 p1	1 p5	1 p5	2 g120	1 p4	
							2 voa	1 p1	1 p1	1 p1	1 p1	1 p5	1 p5	2 g120	1 p4	
							2 voa	1 p1	1 p1	1 p1	1 p1	1 p5	1 p5	2 g120	1 p4	
							2 voa	1 p1	1 p1	1 p1	1 p1	1 p5	1 p5	2 g120	1 p4	
							2 voa	1 p1	1 p1	1 p1	1 p1	1 p5	1 p5	2 g120	1 p4	

Relinquished by: (Signature)	Date / Time	Received by: (Signature)	Relinquished by: (Signature)	Date / Time	Received by: (Signature)
Relinquished by: (Signature)	Date / Time	Received by: (Signature)	Relinquished by: (Signature)	Date / Time	Received by: (Signature)
Relinquished by: (Signature)	Date / Time	Received for Laboratory by: (Signature)	Date / Time	Remarks	

Distribution: Original Accompanies Shipment; Copy to Coordinator Field Files



EXPLANATION

● Proposed Soil Boring Locations

☐ Location of Solid Waste Management Unit

Dashed box: Location of Areas of Interest Within Solid Waste Management Unit

101 Solid Waste Management Unit Reference Number (Rockwell International 1986a)

NOTES

1) Base map photo enlarged from aerial photography of Rocky Flats Plant taken May 20 1986

2) The locations of the solid waste management units have been located as accurately as possible based on information available prior to 1987 remedial investigation

Modifications to these locations as a result of on going studies and future site characterization will be made as required

1 =500

0 500 1000

PLATE III

903 Pad, Mound, and East Trenches Remedial Investigation

Proposed Soil Boring Locations

December 31 1987

EXPLANATION

- □ Proposed Alluvial Well
- ■ Proposed Bedrock Well
- ○ Initial CEARP Phase 2 Alluvial Well
- ● Initial CEARP Phase 2 Bedrock Well
- △ Existing Wells from Previous Investigations
- Location of Solid Waste Management Unit
- Location of Areas of Interest Within Solid Waste Management Unit
- 101 Solid Waste Management Unit Reference Number (Rockwell International 1986a)

NOTES

1) Base map photo enlarged from aerial photography of Rocky Flats Plant taken May 20 1986

2) The locations of the solid waste management units have been located as accurately as possible based on information available prior to 1987 remedial investigation

Modifications to these locations as a result of on going studies and future site characterization will be made as required

1 = 500

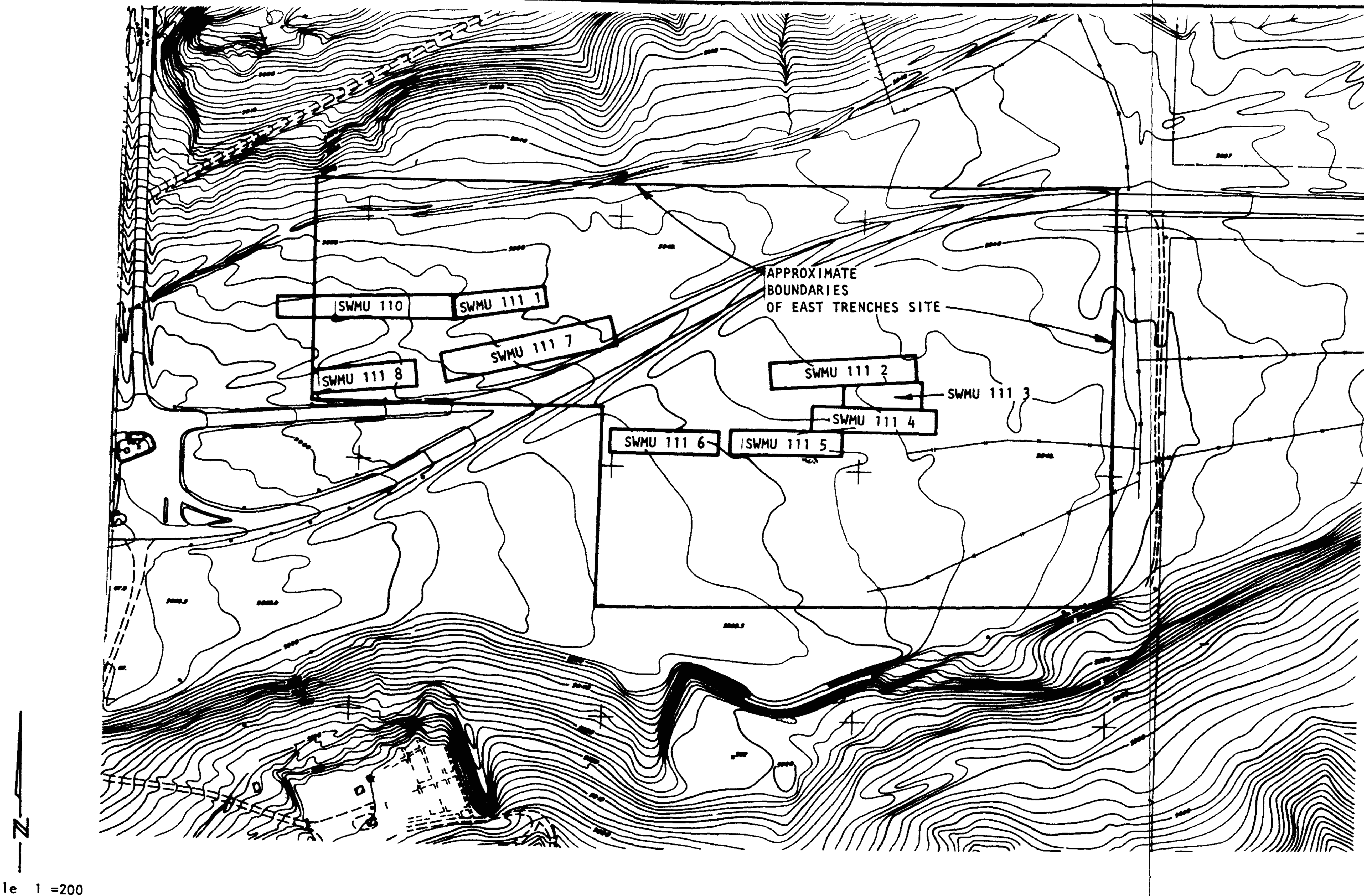
0 500 1000

PLATE IV

903 Pad, Mound, and East Trenches Remedial Investigation

Existing and Proposed Monitor Well Locations

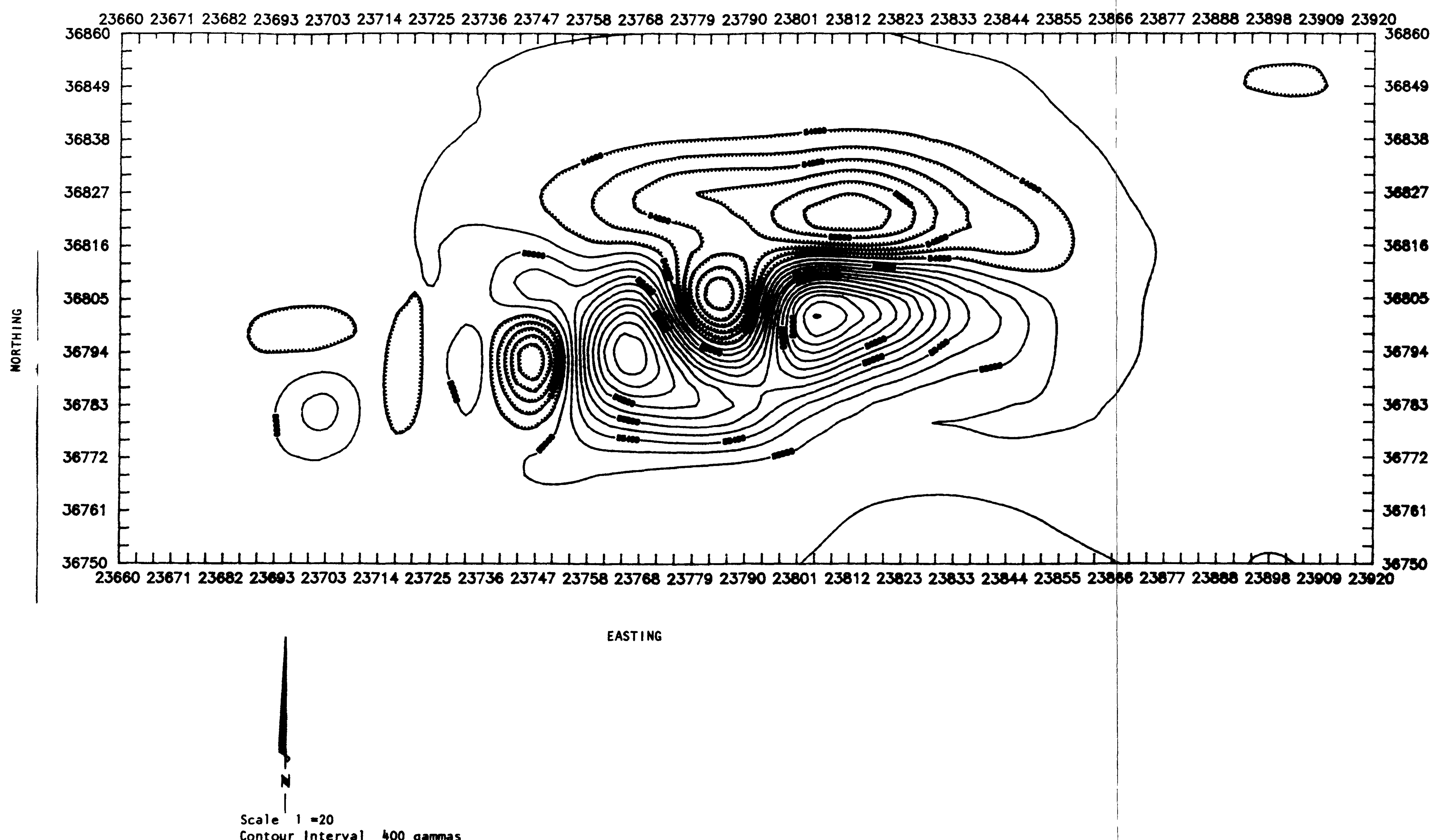
December 31 1987



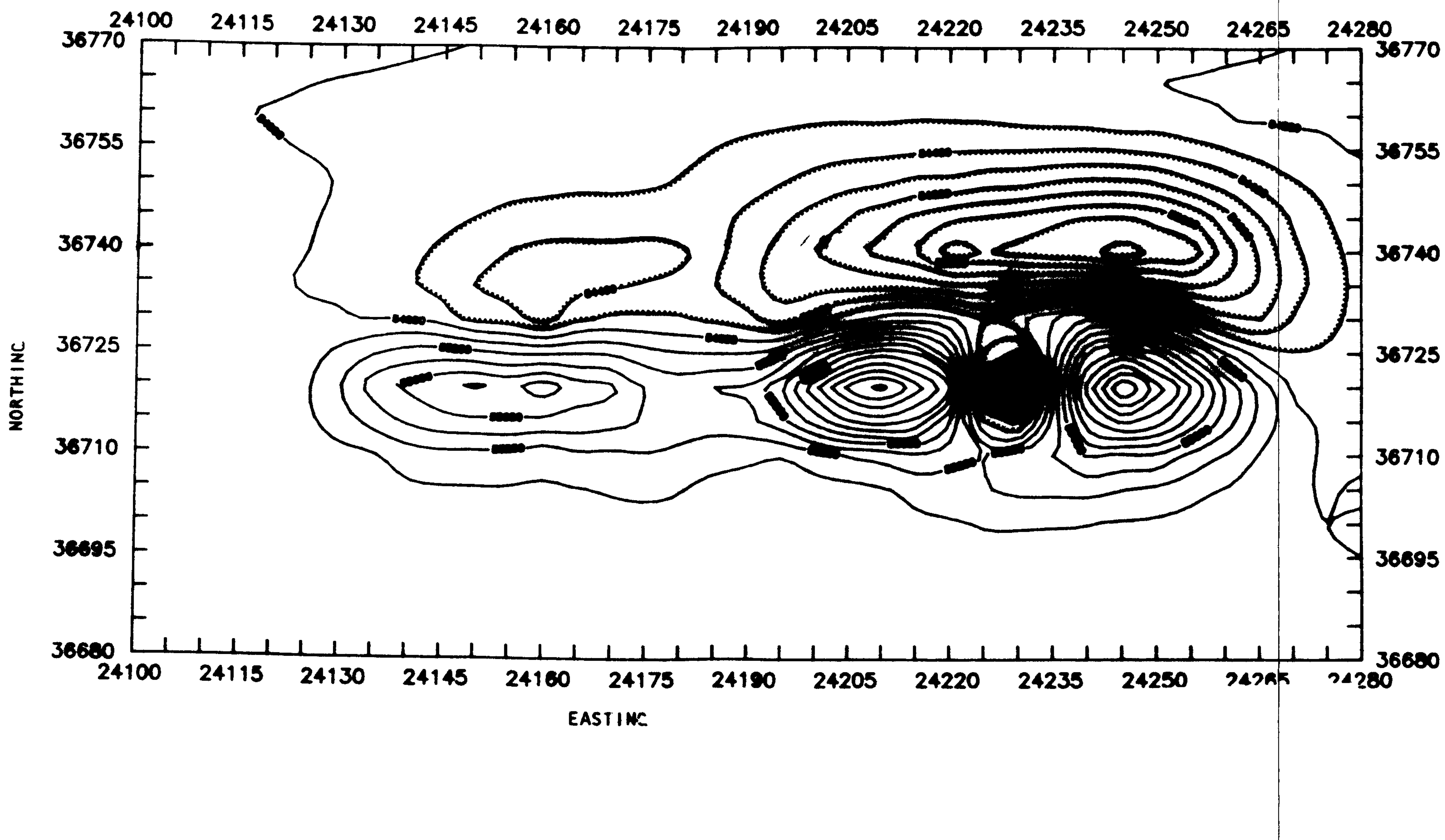
WESTON

LOCATION OF EAST TRENCHES SITE

Fig 2



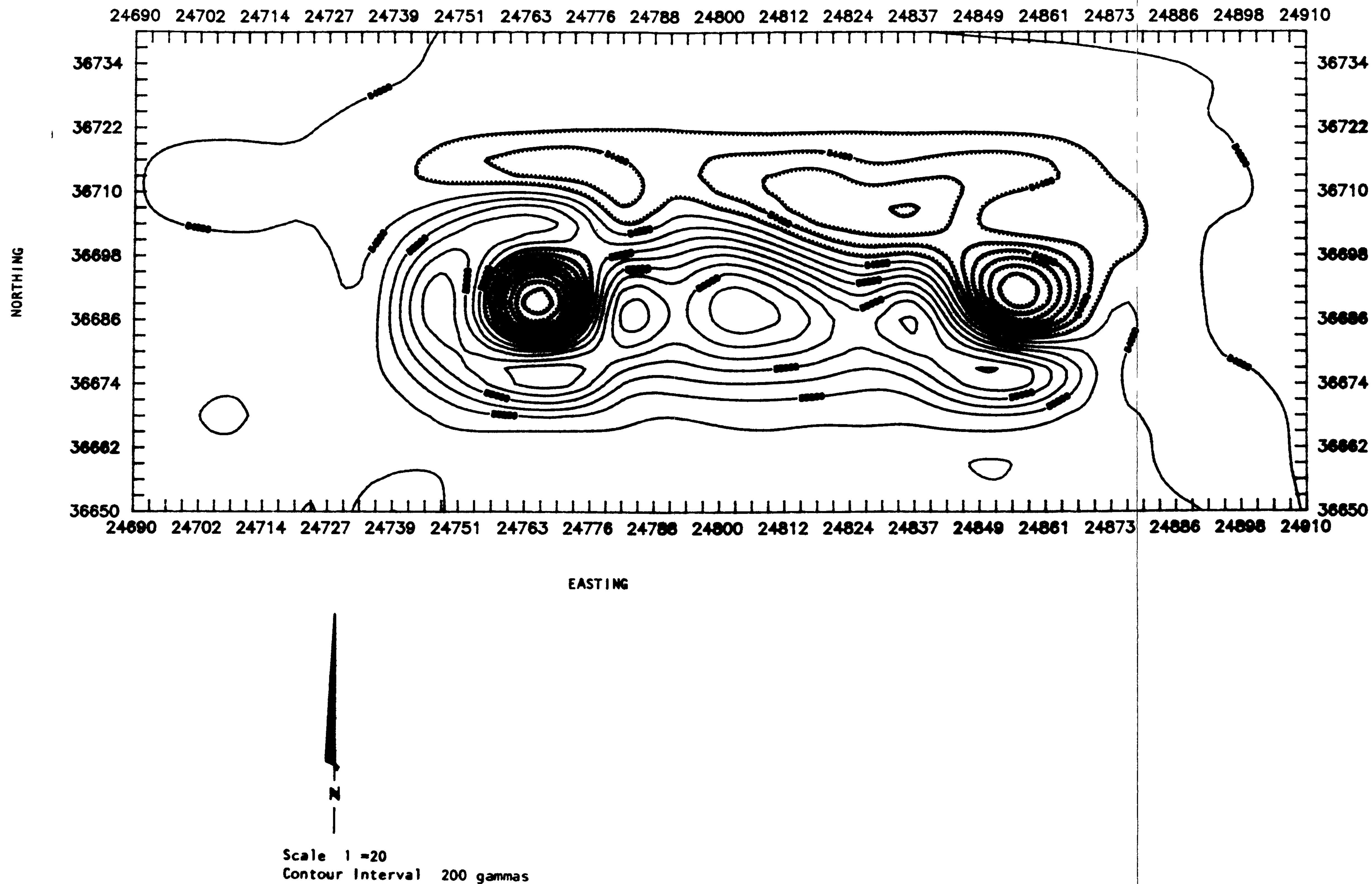
6 007 87	Chen & Associates		MAGNETIC CONTOUR MAP OF SWMU # 110	Fig. 2-1



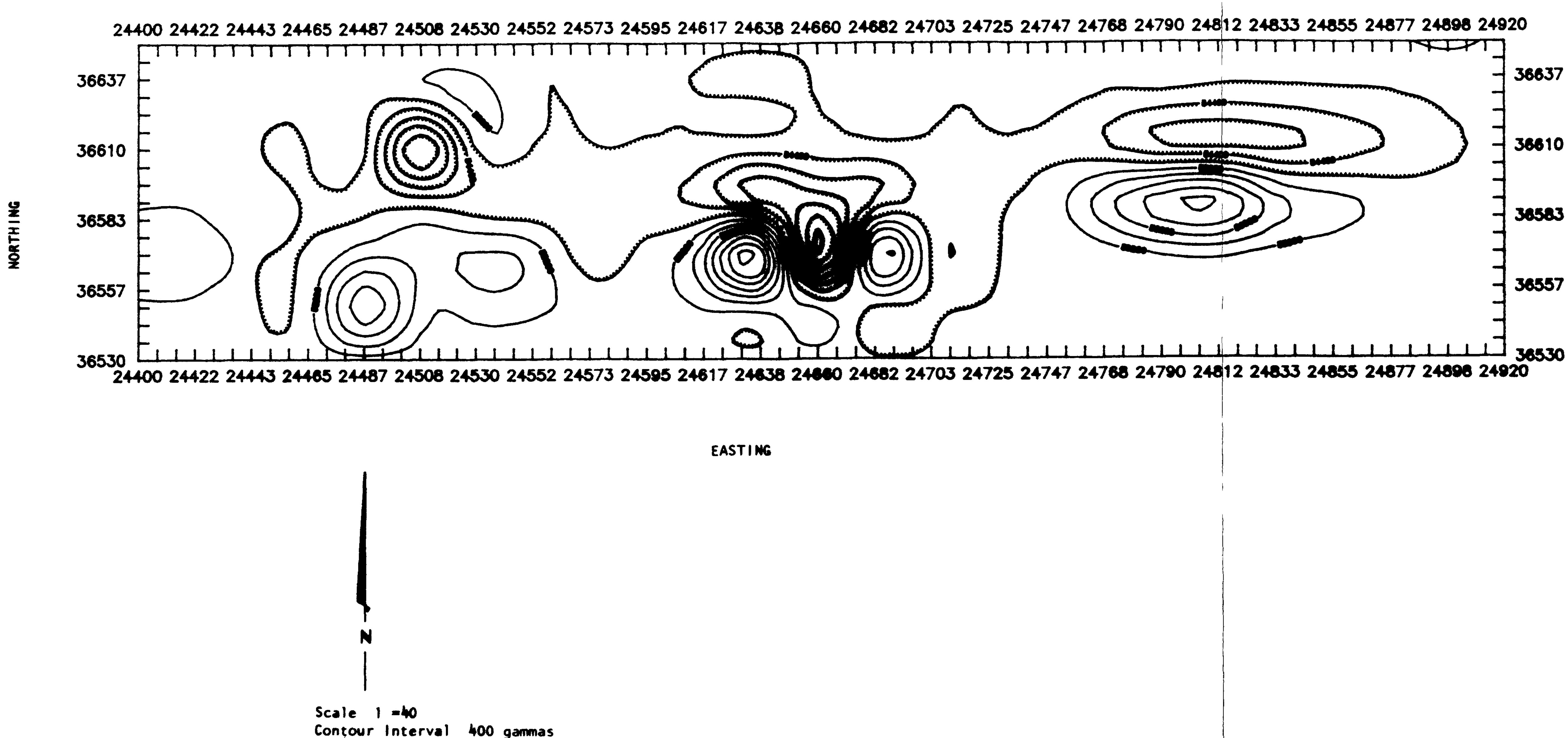
Scale 1 =20

Contour Interval 200 gammas

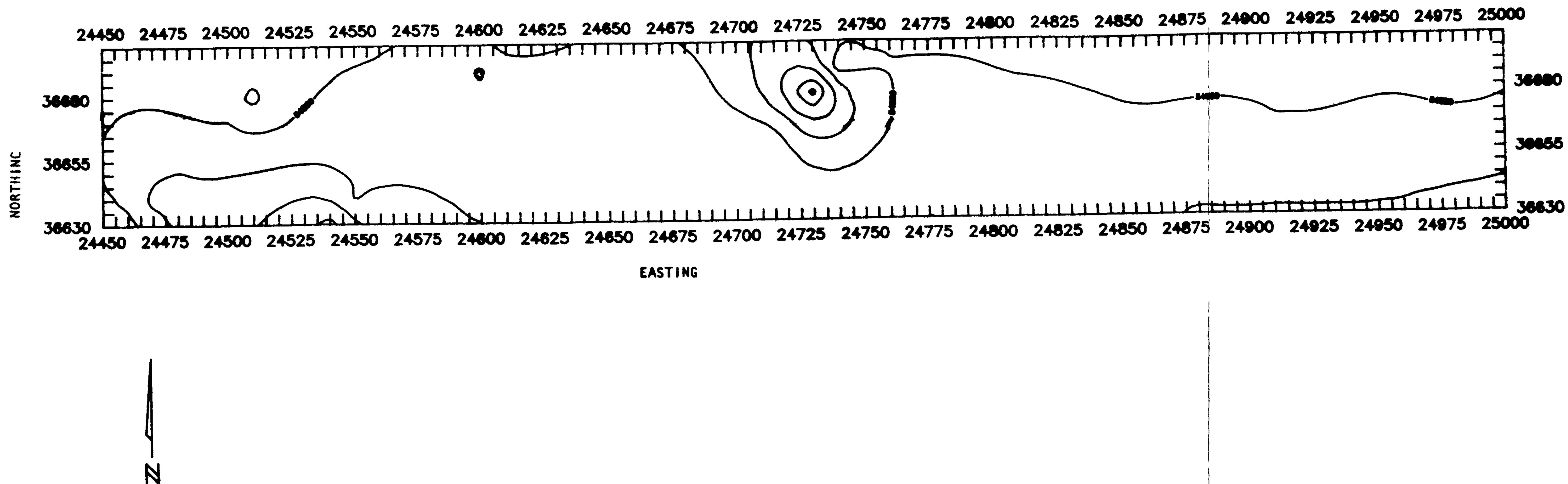
6 007 87	Chen & Associates		MAGNETIC CONTOUR MAP OF SWMU #111 1	Fig. 2-2



6 007 87	Chen & Associates		MAGNETIC CONTOUR MAP OF SWMU # 111 2 and 111 3	Fig. 2-3



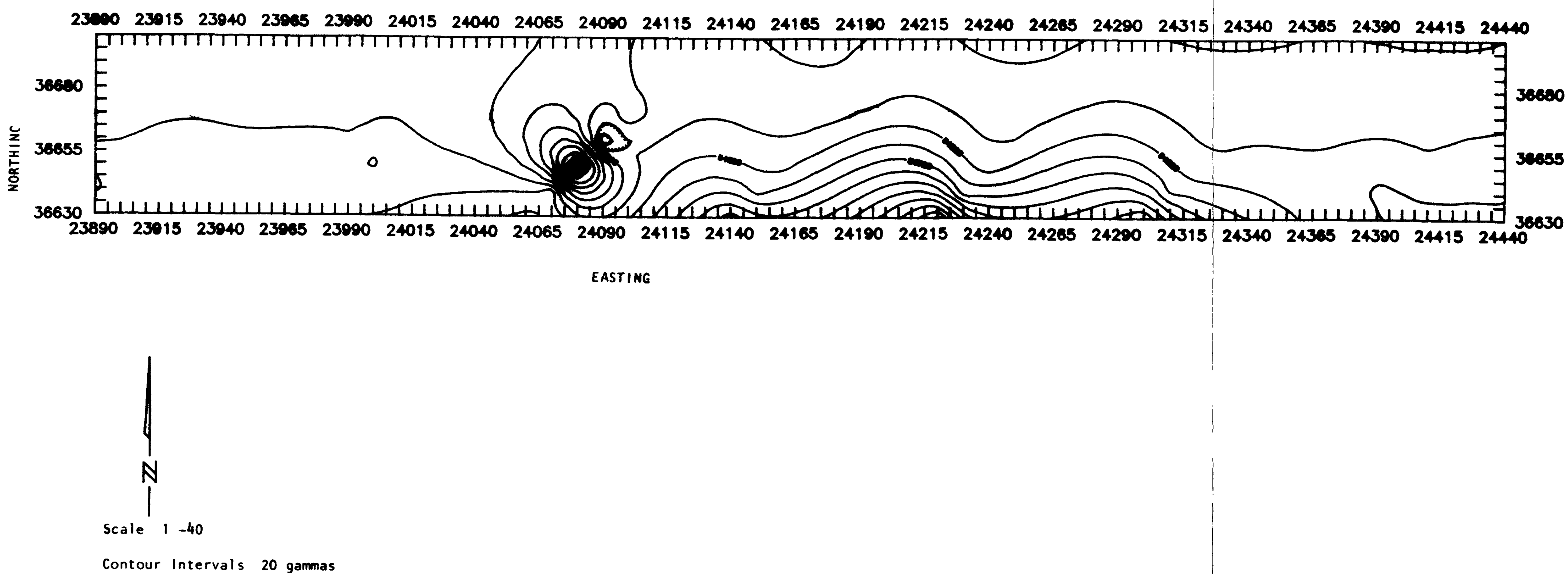
6 007 87	Chen & Associates		MAGNETIC CONTOUR MAP OF SWMU S #111 4 111 5 and 111 6	Fig 2-4



Scale 1 =40

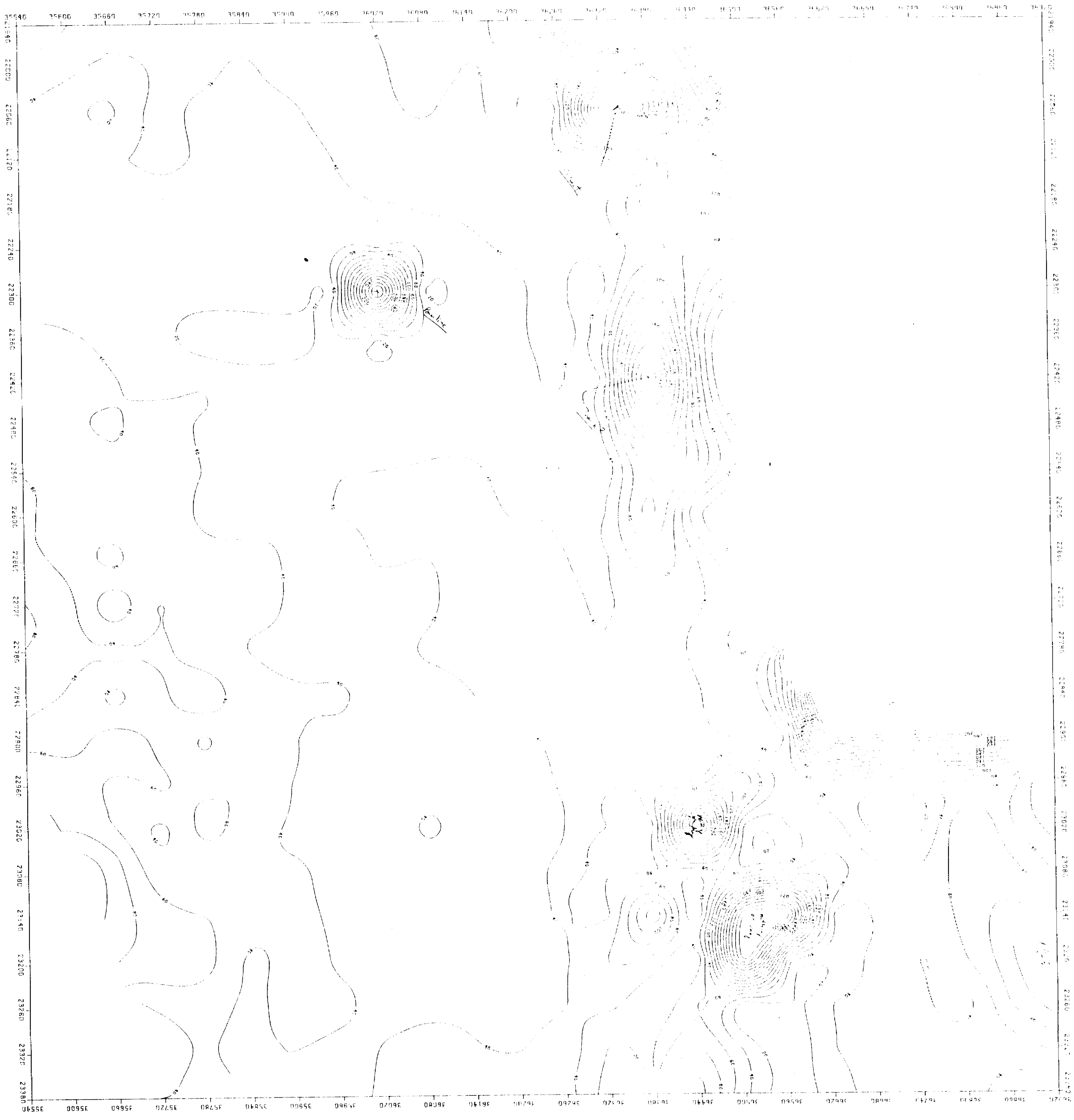
Contour Intervals 20 gammas

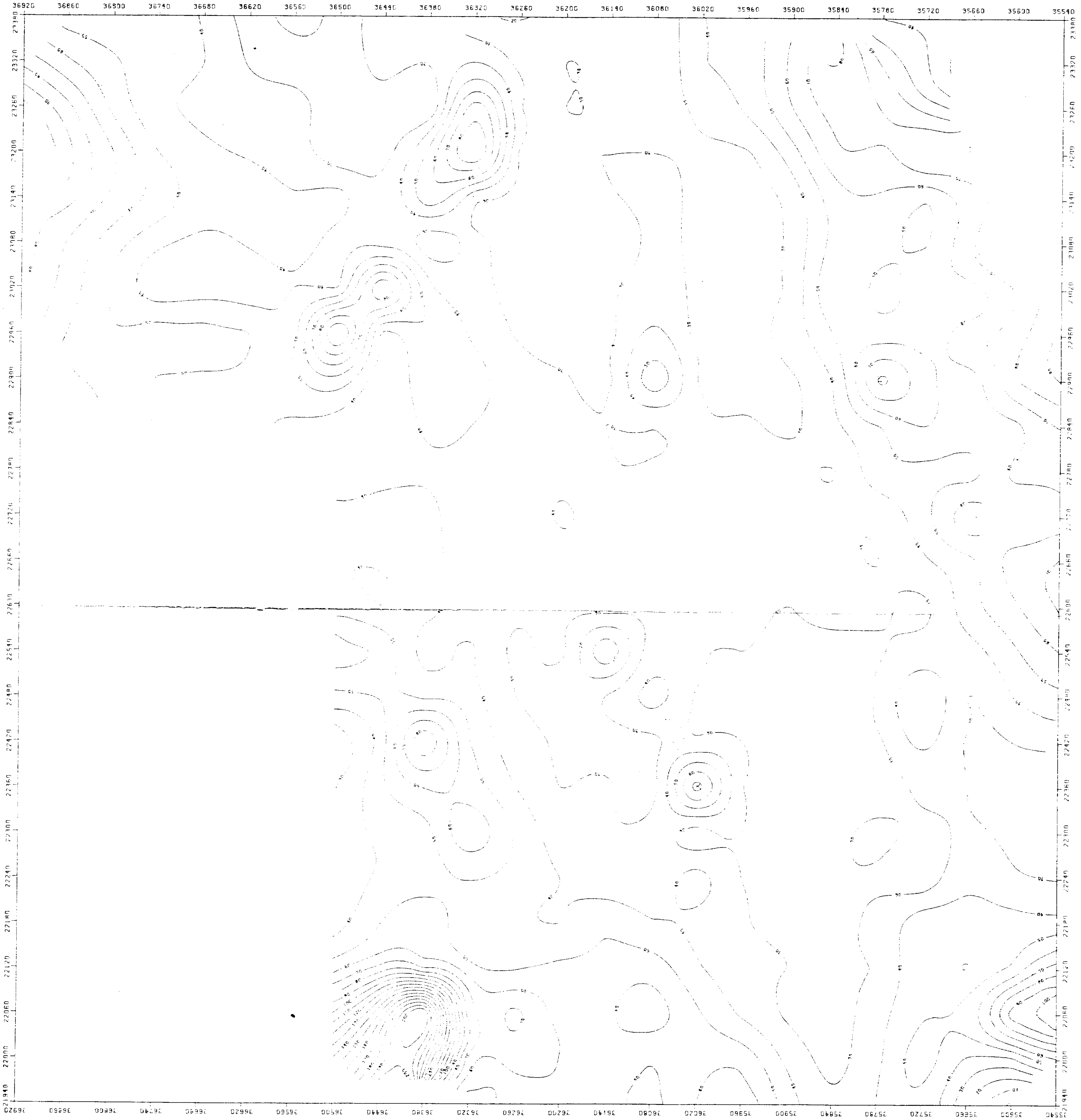
6 007 87 | **Chen & Associates** | MAGNETIC CONTO R MAP OF SWML #111 7 | Fig 2-5



6 007 8 | Chen & Associates | MAGNETIC CONTOUR MAP OF SWMU # 11' 8 | Fig 2-6

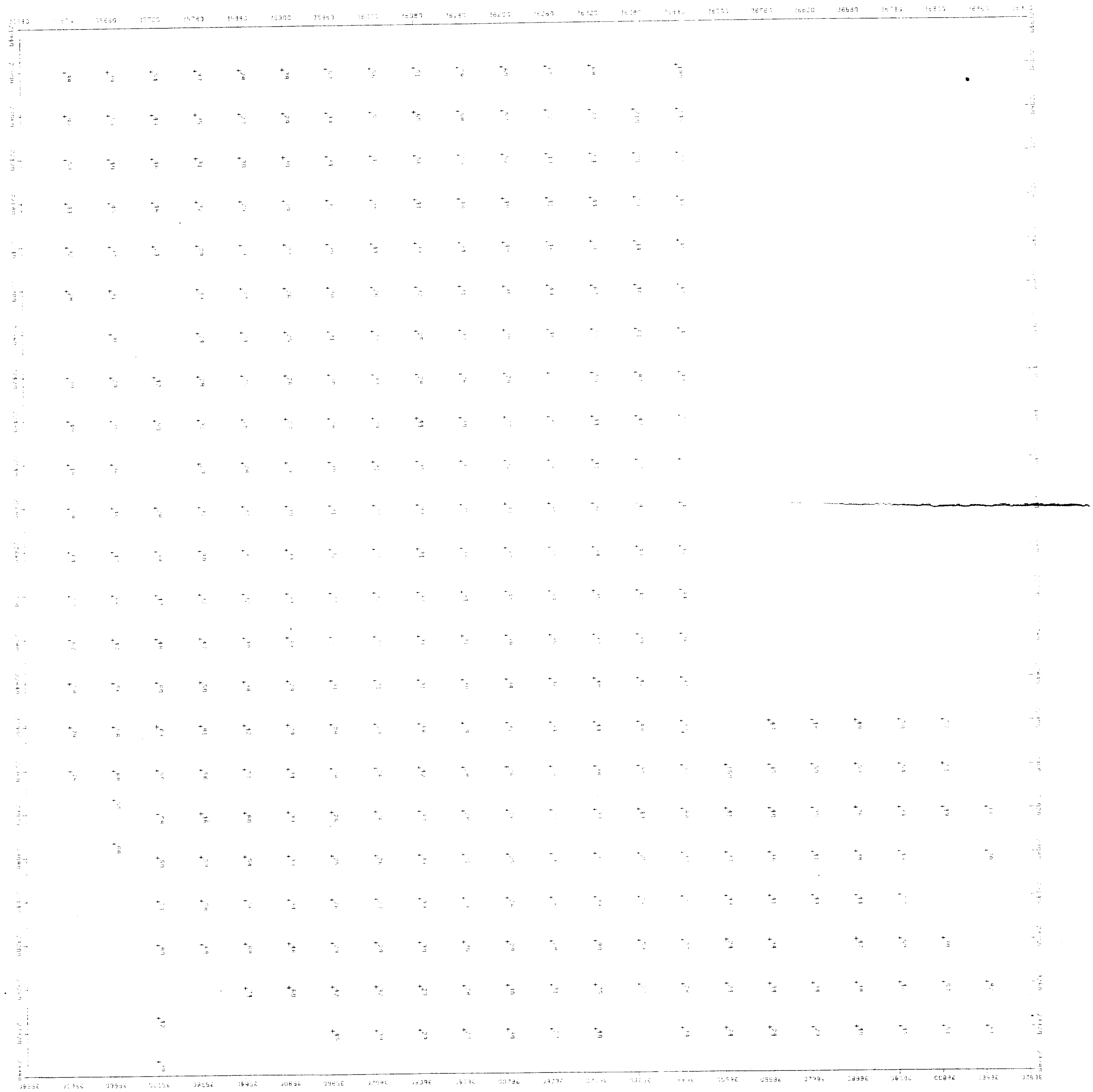
ROCKY FLATS 903 PAD AND MOUND AREAS - EM34 VERTICAL DIPOLE (4/19/87)

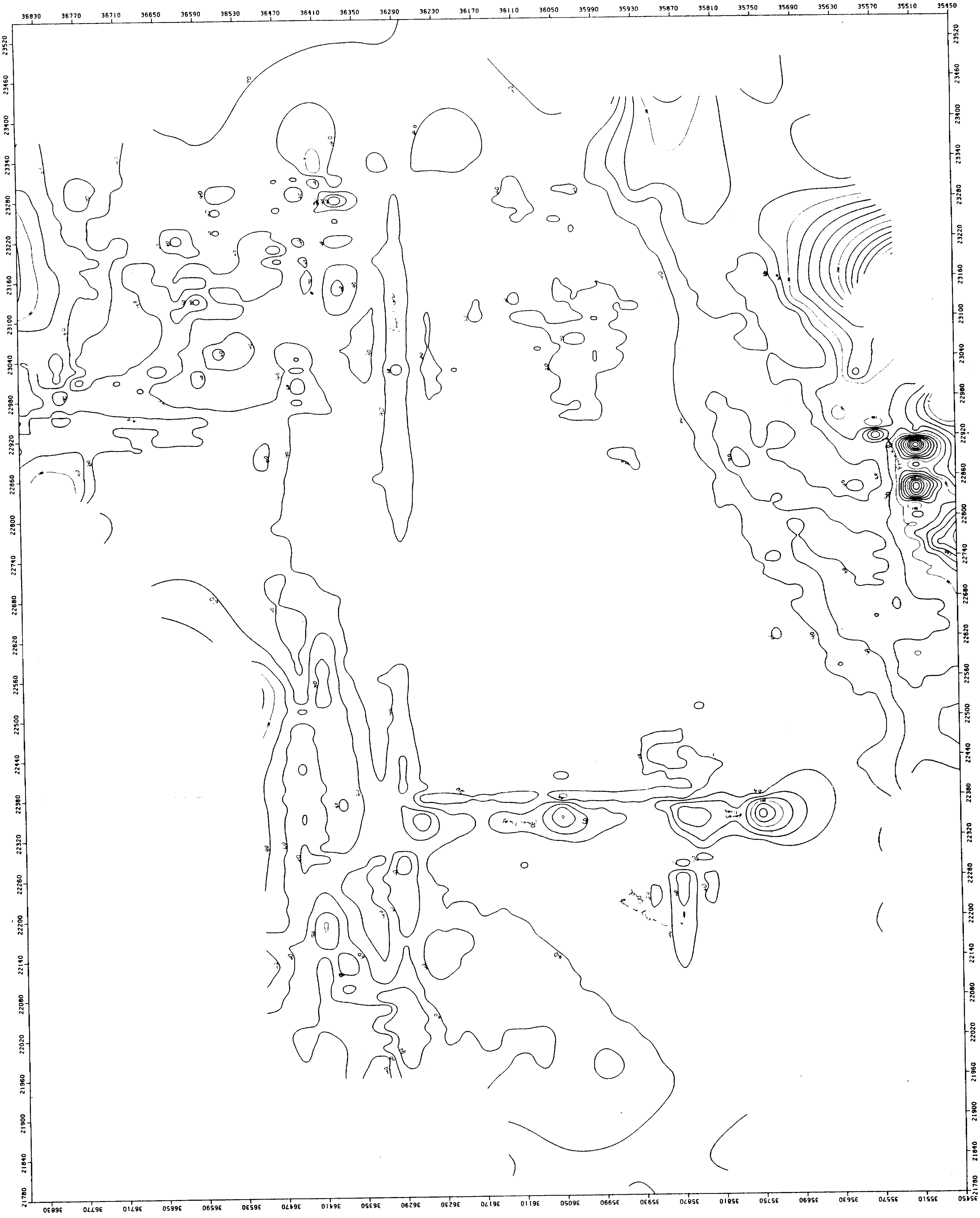




ROCKY FLATS 903 PAD AND MOUND AREAS - EM34 HORIZONTAL DIPOLE (9/14/92)

ROCKY FLATS 903 PAD AND MOUND AREAS - EM34 HORIZONTAL DIPOLE PLOT (4/14/87)





ROCKY FLATS ROY F WESTON SCALE 1 INCH = 60 FEET CI = 20 MMHOS/METER

EM 31 903 Pad and Mound Sites