NOTICE

All drawings located at the end of the document.

PHASE II RI/FS WORK PLAN

ROCKY FLATS PLANT

903 PAD, MOUND, and EAST TRENCHES AREAS

OPERABLE UNIT NO. 2

U.S. DEPARTMENT OF ENERGY
Rocky Flats Office
Golden, Colorado

December 1989

Rockwell International
Aerospace Operations
Rocky Flats Plant

Volume I - Text

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By K L Lattanzi
Date 11/15/91

ADMIN RECORD

DRAFT PHASE II REMEDIAL INVESTIGATION/FEASIBILITY STUDY

WORK PLAN

903 PAD, MOUND, AND EAST TRENCHES AREAS

(OPERABLE UNIT NO. 2)

ROCKY FLATS PLANT

U.S. Department of Energy
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Rocky Flats Plant
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DECEMBER 1989

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EXECUTIVE SUMMARY

This document presents the work plan for the Phase II Remedial Investigation/ Feasibility Study (RI/FS) of the 903 Pad, Mound, and East Trenches Areas (Operable Unit No. 2) at the Rocky Flats Plant. An initial (Phase I) field program was completed during 1987, and a draft RI report was submitted to EPA and CDH on December 31, 1987 (Rockwell International, 1987a). This Phase II RI Work Plan presents site-specific plans for further field work to characterize sources and the extent of soils, surface water, and alluvial ground-water contamination. It is based on results presented in the draft RI report as well as subsequent surface water and ground-water sampling and analysis. In order to fully characterize the location, extent, and orientation of bedrock sandstones and subsequently the extent of contamination within these units, a seismic geophysical program is currently being implemented at Operable Unit No. 2. A separate Phase III RI Work Plan will be prepared in 1990 presenting results of the ongoing seismic survey and plans for a bedrock ground-water investigation.

This Phase II RI/FS Work Plan for the 903 Pad, Mound, and East Trenches Areas presents results of the Phase I RI; defines data quality objectives and data needs based on that investigation; specifies RI/FS tasks; and presents a Field Sampling Plan. Section 1.0 presents site locations and descriptions, and Section 2.0 presents results of the Phase I RI. Included in Section 2.0 are Phase I characterization results for site geology and hydrology as well as the nature and extent of contamination in soils, ground water, surface water, and sediments. Section 3.0 discusses data quality objectives for the Phase II investigation. Section 4.0 specifies RI/FS tasks to be performed, and Section 5.0 presents the Field Sampling Plan to meet the RI/FS objectives.

The 903 Pad, Mound, and East Trenches Areas, located on the east side of the Rocky Flats Plant security area, were selected for investigation because of their suspected relationship to ground-water contamination. Based on initial sampling results, carbon tetrachloride, tetrachloroethene, and trichloroethene are the primary volatile organic contaminants found in the unconfined ground-water flow system at these areas. Trace metals frequently occurring above background levels include strontium, zinc, nickel, and to a lesser extent chromium, manganese, and selenium. Also major ions and total dissolved solids are somewhat elevated above background throughout and downgradient of the 903 Pad, Mound, and East Trenches Areas. Uranium is the only radionuclide occurring above background in the unconfined ground-water flow system.

There is considerable interaction between surface water and ground water. As a result, organic contamination is observed in seeps downgradient of the 903 Pad and in the upper reaches of South Walnut Creek at the Mound Area. Also, there are somewhat elevated concentrations of total dissolved solids, major ions, strontium, zinc, and uranium at many of the surface water stations.

With the exception of plutonium and americium which occur at high concentrations in surface soils, other radionuclides and trace metals do not appear to be soil contaminants at the 903 Pad, Mound, and East Trenches Areas. Plutonium and americium were released to soils in the area via wind dissemination during clean-up efforts at the 903 Drum Storage Site. These radionuclides occur in surface soils throughout the 903 Pad, Mound, and East Trenches Areas and other areas downwind to the southeast.

The overall objectives of the Phase II are source characterization and determination of the magnitude and extent of alluvial ground-water and surface water contamination. Boreholes will be drilled into waste sources to characterize any waste materials remaining in place and to assess the maximum contaminant concentrations in soils directly beneath the sites. In addition, ground-water monitoring wells will be installed adjacent to some of the boreholes to characterize ground-water quality directly beneath the sites. This plan calls for drilling and sampling 41 boreholes and the installation of 30 "source" monitoring wells. Fifty-eight additional monitoring wells will be installed to further characterize ground-water flow and quality in surficial materials at the 903 Pad, Mound, and East Trenches Areas.

Nineteen surface water stations were established south of the 903 Pad and East Trenches Areas in the Woman Creek drainage during the 1986 and 1987 investigations, and 12 stations were established north of the Mound and East Trenches Areas in the South Walnut Creek drainage. These 31 stations will also be sampled during the Phase II RI investigation.

In order to assess the extent of plutonium and americium in surficial soils within Plant boundaries, 57 surface soil samples will be collected over an 800 acre area to the southeast of the 903 Pad. To delineate the vertical distribution of plutonium and americium, 24 locations have been identified for subsurface sampling.

1.0 INTRODUCTION

This document presents the work plan for the Phase II Remedial Investigation/ Feasibility Study (RI/FS) of the 903 Pad, Mound, and East Trenches Areas (Operable Unit No. 2) at the Rocky Flats Plant. It addresses characterization of wastes and surficial materials in these areas. In addition to this Phase II plan, a comparable work plan for the Phase III RI/FS will be completed in 1990. Phase III work will focus on bedrock investigations.

This investigation is part of a comprehensive, phased program of site characterization, remedial investigations, feasibility studies, and remedial/corrective actions currently in progress at the Rocky Flats Plant. These investigations are pursuant to the U.S. Department of Energy (DOE) Environmental Restoration (ER) Program [formerly known as the Comprehensive Environmental Assessment and Response Program (CEARP)], a Compliance Agreement between DOE, the U.S. Environmental Protection Agency (EPA) and the State of Colorado Department of Health (CDH) dated July 31, 1986, and a draft Inter-Agency Agreement (IAG) being developed among DOE, EPA, and CDH. The program developed by DOE, EPA, and CDH in response to the agreements addresses RCRA and CERCLA issues and has been integrated with the ER Program. In accordance with the draft IAG, the CERCLA terms "Remedial Investigation" and "Feasibility Study" in this document are considered equivalent to the RCRA terms "RCRA Facility Investigation" (RFI) and "Corrective Measures Study" (CMS).

1.1 ENVIRONMENTAL RESTORATION PROGRAM

The ER Program is designed to investigate and clean up contaminated sites at DOE facilities. The ER Program is being implemented in five phases. Phase 1 (Installation Assessment) includes preliminary assessments and site inspections to assess potential environmental concerns. Phase 2 (Remedial Investigations) includes planning and implementation of sampling programs to delineate the magnitude and extent of contamination at specific sites and evaluate potential contaminant migration pathways. Phase 3 (Feasibility

Studies) evaluates remedial alternatives and develops remedial action plans to mitigate environmental problems identified as needing correction in Phase 2. Phase 4 (Remedial Design/Remedial Action) includes design and implementation of site-specific remedial actions selected on the basis of Phase 3 feasibility studies. Phase 5 (Compliance and Verification) implements monitoring and performance assessments of remedial actions, and verifies and documents the adequacy of remedial actions carried out under Phase 4. Phase 1 has already been completed at Rocky Flats Plant (U.S. DOE, 1986), and Phases 2, 3, and 4 are currently in progress for Operable Unit No. 1 (881 Hillside Area) and Operable Unit No. 2 (903 Pad, Mound, and East Trenches Areas) at Rocky Flats Plant.

With respect to Phase 2 activities at Operable Unit No. 2, an initial (Phase I) field program was completed during 1987, and a draft RI report was submitted to EPA and CDH on December 31, 1987 (Rockwell International, 1987). This Phase II RI Work Plan presents site-specific plans for further field work to characterize sources and extent of alluvial ground-water contamination. It is based on results presented in the draft RI report as well as subsequent ground-water sampling and analysis. A draft interim remedial action plan has been developed to pump and treat contaminated alluvial ground water has been developed for Operable Unit No. 2 (Rockwell International, 1989). A final remedial action will be proposed based on the Phase II and Phase III investigations.

Results of the Phase I RI indicate that a stratigraphically complex bedrock hydrogeologic system exists beneath the 903 Pad, Mound and East Trenches Areas. In order to fully characterize the location, extent, and orientation of bedrock sandstones and subsequently the extent of contamination within these units, a seismic geophysical program is currently being implemented at Operable Unit No. 2. A separate Phase III RI Work Plan will be prepared in 1990 presenting results of the ongoing seismic survey and plans for a bedrock ground-water investigation.

1.2 WORK PLAN OVERVIEW

This Phase II RI/FS Work Plan for the 903 Pad, Mound, and East Trenches Areas presents results of the Phase I RI; defines data quality objectives and data needs based on that investigation; specifies RI/FS tasks; and presents a Field Sampling Plan (FSP). This section (1.0 Introduction) presents site locations and descriptions, and Section 2.0 presents results of the Phase I RI. Included in Section 2.0 are Phase I characterization results for site geology and hydrology as well as the nature and extent of contamination in soils, ground water, surface water, and sediments. Section 3.0 discusses data quality objectives for the Phase II investigation. Section 4.0 specifies RI/FS tasks to be performed, and Section 5.0 presents the FSP to meet RI/FS objectives.

1.3 BACKGROUND AND PHYSICAL SETTING

1.3.1 Background

The Rocky Flats Plant is a government-owned, contractor-operated facility, which is part of the nationwide nuclear weapons production complex. The Plant was operated for the U.S. Atomic Energy Commission (AEC) from its inception in 1951 until the AEC was dissolved in January 1975. At that time, responsibility for the Plant was assigned to the Energy Research and Development Administration (ERDA), which was succeeded by the DOE in 1977. Dow Chemical U.S.A., an operating unit of the Dow Chemical Company, was the prime operating contractor of the facility from 1951 until June 30, 1975. Rockwell International was selected to succeed Dow Chemical as the prime contractor responsible for operating the Rocky Flats Plant, beginning July 1, 1975.

1.3.1.1 Plant Operations

The primary mission of the Rocky Flats Plant is to fabricate nuclear weapon components from plutonium, uranium, and other non-radioactive metals (principally beryllium and stainless steel). Parts made at the Plant are shipped elsewhere for assembly. In addition, the Plant reprocesses components after they are removed from obsolete weapons for recovery of plutonium.

Both radioactive and nonradioactive wastes are generated in the production process. Current waste handling practices involve on-site and off-site recycling of hazardous materials, on-site storage of hazardous and radioactive mixed wastes, and off-site disposal of solid radioactive materials at another DOE facility. However, both storage and disposal of hazardous and radioactive wastes occurred on site in the past. Preliminary assessments under the ER Program identified some of the past on-site storage and disposal locations as potential sources of environmental contamination.

1.3.1.2 Previous Investigations

Various studies have been conducted at the Rocky Flats facility to characterize environmental media and to assess the extent of radiological and chemical contaminant releases to the environment. The investigations performed prior to 1986 are summarized in Rockwell International (1986a) and include:

1) Detailed descriptions of the regional geology (Malde, 1955; Spencer, 1961; Scott, 1960, 1963, 1970, 1972 and 1975; Van Horn, 1972 and 1976; U.S. DOE, 1980; Dames and Moore, 1981; and Robson et al., 1981a and 1981b).

2) Several drilling programs beginning in 1960 that resulted in the construction of approximately 60 monitor wells by 1982;

3) An investigation of surface and ground water flow systems by the U.S. Geological Survey (Hurr, 1976);

4) Environmental, ecological, and public health studies which culminated in an environmental impact statement (U.S. DOE, 1980);

5) A summary report on ground-water hydrology using data from 1960 to 1985 (Hydro-Search, Inc., 1985);

6) A preliminary electromagnetic survey of the Plant perimeter (Hydro-Search, Inc., 1986);

7) A soil gas survey of the Plant perimeter and buffer zone (Tracer Research, Inc., 1986); and

8) Routine environmental monitoring programs addressing air, surface water, ground water, and soils (Rockwell International, 1975 through 1985, 1986b, and 1987b).

In 1986, two major investigations were completed at the Plant. The first was the ER Program Phase 1 installation assessment (U.S. DOE, 1986) which included analyses and identification of current operational activities, active and inactive waste sites, current and past waste management practices, and potential environmental pathways through which contaminants could be transported. A number of sites were identified that could potentially have adverse impacts on the environment. These sites were designated as solid waste management units (SWMUs) by Rockwell International (1987c) and were divided into three categories:

1) hazardous waste management units that will continue to operate and need a RCRA operating permit,

2) hazardous waste management units that will be closed under RCRA interim status, and

3) inactive waste management units that will be investigated and cleaned up under Section 3004(u) of RCRA or CERCLA. No RCRA or CERCLA regulatory distinction in the use of the terms "site", "unit", or "SWMU" is intended in this document.

The second major investigation completed at the Plant in 1986 involved a hydrogeologic and hydrochemical characterization of the entire Plant site. Plans for this study were presented in Rockwell International (1986c and 1986d), and study results were reported in Rockwell International (1986e). Investigation results indicated four areas to be significant contributors to environmental contamination, with each area containing several sites. The areas are the 881 Hillside Area, the 903 Pad Area, the Mound Area, and the East Trenches Area.

Sites at the 881 Hillside Area were selected as High Priority Sites because of the elevated concentrations of volatile organic compounds detected in the ground water, the relatively permeable soils, and the proximity of the area to a surface water drainage. A RI/FS for the 881 Hillside Area (Operable Unit No. 1) is currently in progress. Phase I of the RI was completed in July, 1987, and Phase II was completed in March 1988 (Rockwell International, 1988a). A draft FS report was also completed in March 1988 (Rockwell International, 1988b), and a draft interim remedial action plan was developed for the 881 Hillside Area in October 1989 (Rockwell International, 1989b). A Phase III RI/FS Work Plan is currently being prepared for Operable Unit No. 1.

The 903 Pad, Mound, and East Trenches Areas were designated as Operable Unit No. 2. A Phase I RI of Operable Unit No. 2 was completed in December 1987 (Rockwell International, 1987a), and a draft Phase II RI Sampling Plan was submitted to the EPA and CDH in June 1988 (Rockwell International, 1988c). This revised Phase II RI/FS Work Plan incorporates agency comments on that draft plan.

1.3.2 Physical Setting

The Rocky Flats Plant is located in northern Jefferson County, Colorado, approximately 16 miles northwest of Denver (Figure 1-1). The Plant consists of approximately 6,550 acres of federally owned land in Sections 1 through 4 and 9 through 15 of T2S, R70W, 6th Principal Meridian. Major buildings are located within the Plant security area of approximately 400 acres. The security area is surrounded by a buffer zone of approximately 6,150 acres (Figure 1-2).

1.3.2.1 Topography

The natural environment of the Plant and vicinity is influenced primarily by its proximity to the Front Range of the Rocky Mountains. The Plant is directly east of the north-south trending Rocky Mountains, with an elevation of approximately 6,000 feet above sea level. Rocky Flats Plant is located on a broad, eastward sloping plain of overlapping alluvial fans developed along the Front Range. The fans extend about five miles in an eastward direction from their origin in the abruptly rising Front Range and terminate on the east at a break in slope to low rolling hills. The continental divide is about 16 miles west of the Plant.

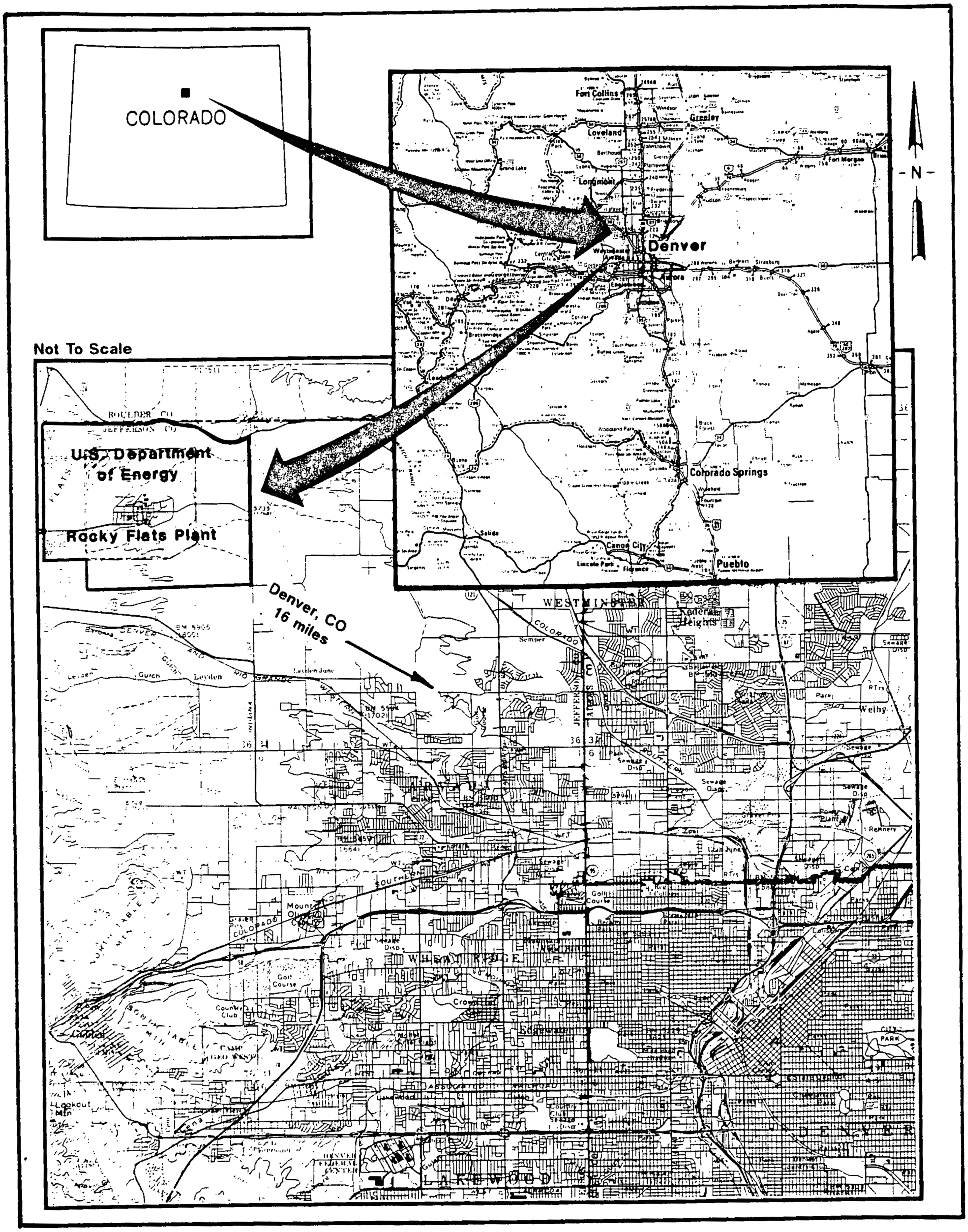


FIGURE 1-1 LOCATION OF ROCKY FLATS PLANT

The operational area at the Plant is located near the eastern edge of the fans on a terrace between stream-cut valleys (North Walnut Creek and Woman Creek).

1.3.2.2 Surface Water Hydrology

Three intermittent streams drain the Rocky Flats Plant with flow generally from west to east. These drainages are Rock Creek, Walnut Creek, and Woman Creek (Figure 1-2). Rock Creek drains the northwestern corner of the Plant and flows northeast through the buffer zone to its off-site confluence with Coal Creek. An east-west trending topographic divide bisects the Plant separating the Walnut and Woman Creek drainages. North and South Walnut Creeks and an unnamed tributary drain the northern portion of the Plant security area. These three forks of Walnut Creek join in the buffer zone and flow to Great Western Reservoir approximately one mile east of the confluence. Woman Creek drains the southern Rocky Flats Plant buffer zone flowing eastward to Standley Reservoir. The South Interceptor Ditch lies between the Plant and Woman Creek. The South Interceptor Ditch collects runoff from the southern Plant security area and diverts it to Pond C-2, where it is monitored in accordance with the Plant National Pollutant Discharge Elimination System (NPDES) permit prior to discharge to Woman Creek.

1.3.2.3 Regional and Local Hydrogeology

Geologic units at the Rocky Flats Plant (in descending order) are the surficial units (Rocky Flats Alluvium, various terrace alluviums, valley fill alluvium, and colluvium) (Figure 1-3) and bedrock (Arapahoe Formation, Laramie Formation, and Fox Hills Sandstone) (Figure 1-4). The Denver Formation does not occur in the vicinity of the Plant. Ground water occurs under unconfined conditions in both the surficial and bedrock units. In addition, confined ground-water flow occurs in bedrock sandstones.

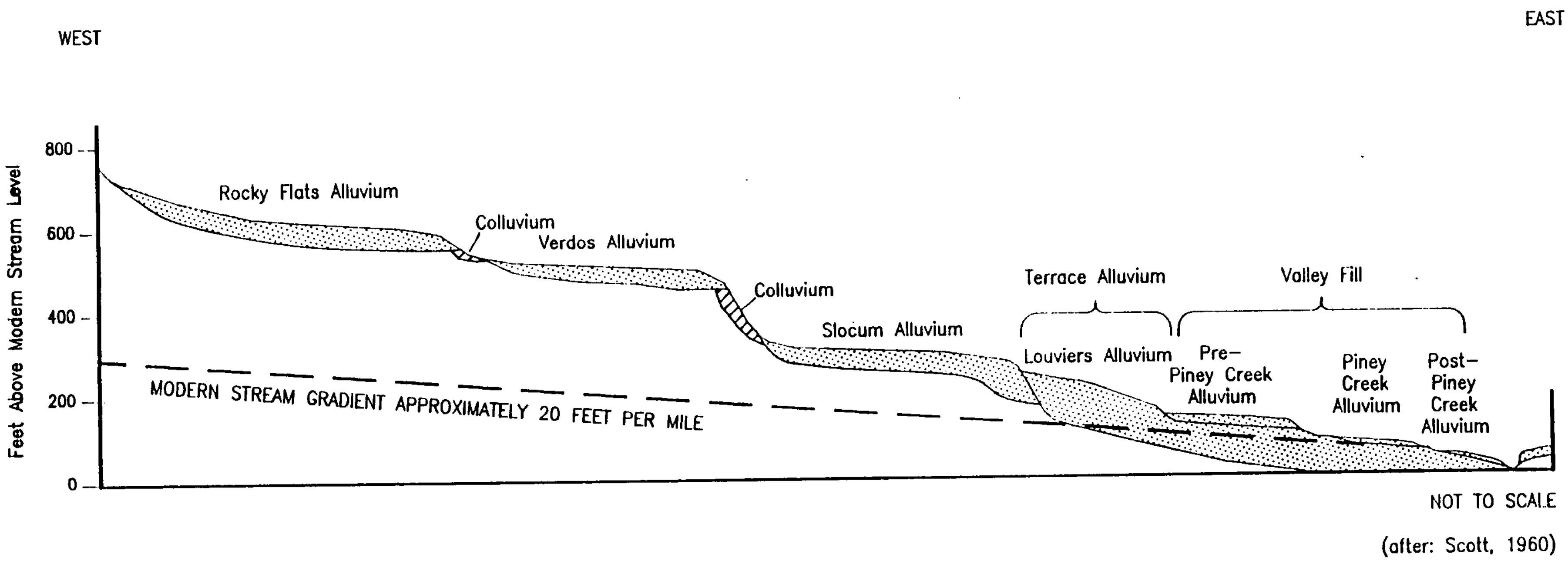
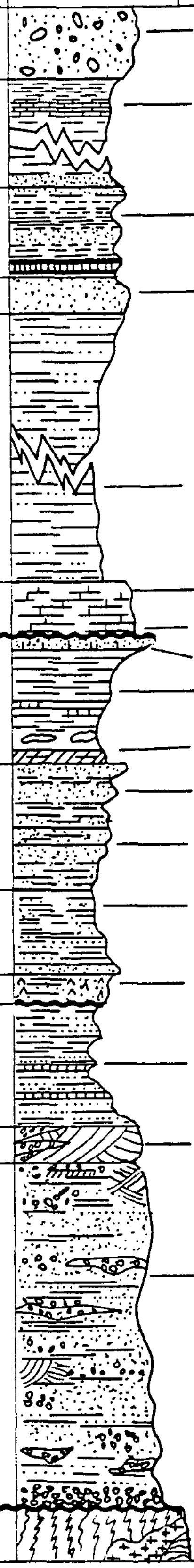


FIGURE 1-3

EROSIONAL SURFACES AND ALLUVIAL DEPOSITS
EAST OF THE FRONT RANGE, COLORADO

AGE	FORMATION	Thickness (feet)	GRAPHICS	SUMMARY DESCRIPTION
TERTIARY	Green Mountain	600'		Boulder conglomerate with occasional thin siltstone lenses
TERTIARY / UPPER CRETACEOUS	Denver–Arapahoe	1200'		Tan sandy claystone and clayey sandstone; conglomerate at base; includes Table Mountain "flow" rocks to the north.
UPPER CRETACEOUS	Laramie	500'		Gray, fine–to–medium–grained sandstone and silty clays; thin coal beds in lower part
UPPER CRETACEOUS	Fox Hills	60'		Tan, fine–to–medium–grained sandstone and sandy shale
UPPER CRETACEOUS	Pierre	± 8000'		Dark gray, silty shale and few thin, silty sandstones
UPPER CRETACEOUS	Niobrara	350'		Dark gray, very calcareous shale. "Foraminifers" abundant (Smoky Hills Member) Light gray, dense, fossiliferous limestone (Fort Hays Member)
UPPER CRETACEOUS	Benton	420'		Brown, sandy, fossiliferous limestone Dark gray shale with bentonite streaks; thin limestones in middle part; few cone–in–cone concretions in lower part Dark gray, brittle silty shale (Mowry)
LOWER CRETACEOUS	Dakota Group: So. Platte	270'		Light gray, fine–to–medium–grained sandstone, several dark gray shales in middle part
LOWER CRETACEOUS	Dakota Group: Lytle	100'		Light gray, fine–to–coarse–grained, locally conglomeratic sandstone; frequent red and green siltstone interbeds
Jurassic	Morrison	365'		Gray to greenish–gray to red shale and siltstone; thin limestones in middle part; lenticular sandstones in upper and lower part
Jurassic	Ralston Creek	110'		Light tan siltstone and light red; silty shale; gypsiferous; sandstone at base and locally conglomeratic
TRI–ASSIC?	Lykins	400'		Red siltstone with two laminated limestones in lower part
PERMIAN	Lyons	120'		Grayish–white, fine–to–medium–grained cross–bedded sandstone; conglomeratic lenses frequent
PENNSYLVANIAN	Fountain	1000'		Red, fine–to–coarse–grained sandstone and conglomerate; arkosic; thin, lenticular red siltstones frequent throughout
PRECAMBRIAN				Gneiss, schist, and small granitic intrusions

(after: LeRoy and Weimer, 1971)

FIGURE 1-4

GENERALIZED STRATIGRAPHIC SECTION, GOLDEN–MORRISON AREA

Rocky Flats Alluvium

The Rocky Flats Alluvium underlies a large portion of the Plant. The alluvium is a broad planar deposit consisting of a topsoil layer underlain by up to 100 feet of silt, clay, sand, and gravel. Unconfined ground-water flow occurs in the Rocky Flats Alluvium which is relatively permeable. Recharge to the alluvium is from precipitation, snowmelt, and water losses from ditches, streams, and ponds that are cut into the alluvium. General water movement in the Rocky Flats Alluvium is from west to east and towards the drainages. Ground-water flow is also controlled by buried channels in the top of bedrock. The water table in the Rocky Flats Alluvium rises in response to recharge during the spring and declines during the remainder of the year. Discharge from the alluvium occurs at minor seeps in the colluvium that covers the contact between the alluvium and bedrock along the edges of the valleys. The Rocky Flats Alluvium thins east of the Plant boundary and does not directly supply water to wells located downgradient of Rocky Flats Plant.

Other Alluvial Deposits

Various other alluvial deposits occur topographically below the Rocky Flats Alluvium in the Plant drainages. Colluvium (slope wash) mantles the valley side slopes between the Rocky Flats Alluvium and the valley bottoms. In addition, remnants of younger terrace deposits including the Verdos, Slocum, and Louviers Alluvia occur occasionally along the valley side slopes. Recent valley fill alluvium occurs in the active stream channels.

Unconfined ground-water flow occurs in these surficial units. Recharge is from precipitation, percolation from streams during periods of surface water runoff, and by seeps discharging from the Rocky Flats Alluvium. Discharge is by evapotranspiration and by seepage into other geologic formations and streams. The direction of ground-water flow is generally downslope through colluvial materials and then along the course of the stream in valley fill materials. During periods of high surface water flow, water is lost to bank storage in the valley fill alluvium and returns to the stream after the runoff subsides.

Arapahoe Formation

The Arapahoe Formation underlies surficial materials beneath the Plant. The Arapahoe consists of claystone with thin lenticular sandstones. Total formation thickness varies up to 270 feet (Robson et. al., 1981a). The permeable zones of the Arapahoe are lenticular sandstones within the claystone. The lenticular sand bodies are composed of fine-grained sands and silts, and their hydraulic conductivity is low compared to the overlying Rocky Flats Alluvium. A seismic inflection survey is currently being implemented at the Plant to further characterize bedrock geology.

The Arapahoe Formation is recharged by leakage from streams and ground-water movement from overlying surficial deposits. The main recharge areas are under the Rocky Flats Alluvium, although some recharge from the colluvium and valley fill alluvium likely occurs along the stream valleys. Recharge is greatest during the spring and early summer when rainfall and stream flow are at a maximum and water levels in the Rocky Flats Alluvium are high. Ground-water movement in the Arapahoe Formation is generally toward the east; although flow within individual sandstones is not fully characterized at this time. Regionally, ground-water flow in the Arapahoe Formation is toward the South Platte River in the center of the Denver Basin (Robson et al., 1981a).

Laramie Formation and Fox Hills Sandstone

The Laramie Formation underlies the Arapahoe and is composed of two units, a thick upper claystone and a lower sandstone. The claystone is greater than 700 feet thick and is of very low hydraulic conductivity; therefore, the U.S. Geologic Survey (Hurr, 1976) concludes that Plant operations will not impact any units below the upper claystone unit of the Laramie Formation.

The lower sandstone unit of the Laramie Formation and the underlying Fox Hills Sandstone comprise a regionally important aquifer in the Denver Basin known as the Laramie-

Fox Hills Aquifer. These units subcrop west of the Plant and can be seen in clay pits excavated through the Rocky Flats Alluvium. The steeply dipping beds of these units quickly flatten to the east. Recharge to the aquifer occurs along the rather limited outcrop area exposed to surface water flow and leakage along the Front Range (Robson et al., 1981b).

1.3.2.4 Meteorology

The area surrounding the Rocky Flats Plant has a semiarid climate characteristic of much of the central Rocky Mountain region. Approximately forty percent of the 15-inch annual precipitation falls during the spring season, much of it as wet snow. Thunderstorms (June to August) account for an additional thirty percent of the annual precipitation. Autumn and winter are drier seasons, accounting for nineteen and eleven percent of the annual precipitation, respectively. Snowfall averages 85 inches per year, falling from October through May (U.S. DOE, 1980).

Special attention has been focused on dispersion meteorology surrounding the Plant due to the remote possibility that significant atmospheric releases might affect the Denver metropolitan area. Studies of air flow and dispersion characteristics (e.g., Hodgin, 1983 and 1984) indicate that drainage flows (winds coming down off the mountains to the west) turn and move toward the north and northeast along the South Platte River valley and pass to the west and north of Brighton, Colorado. These drainage flows are of particular interest because they occur under stable atmospheric dispersion conditions (generally at night) when atmospheric mixing is limited (U.S. DOE, 1986).

1.3.2.5 Surrounding Land Use and Population Density

The Rocky Flats Plant is located in a rural area. Approximately 50 percent of the area within ten miles of the Rocky Flats Plant is in Jefferson County. The remainder is located in Boulder County (40 percent) and Adams County (10 percent). According to the 1973 Colorado Land Use Map, 75 percent of this land was unused or was used for agriculture. Since that time, portions of this land have been converted to housing, with several new housing subdivisions being started within a few miles of the buffer zone. One such subdivision is located south of the Jefferson County Airport and several are located southeast of the Plant.

A demographic study using 1980 census data shows that approximately 1.8 million people lived within 50 miles of the Rocky Flats Plant in 1980 (Rockwell International, 1987b). Approximately 9,500 people lived within five miles of the Plant in 1980. The most populous sector was to the southeast, toward the center of Denver. This sector had a 1980 population of about 555,000 people living between 10 and 50 miles from Rocky Flats. Recent population estimates registered by the Denver Regional Council of Governments (DRCOG) for the eight county Denver metro region have shown distinct patterns of growth between the first and second halves of the decade. Between 1980 and 1985, the population of the eight county region increased by 197,890, a 2.4 percent annual growth rate. Between 1985 and 1989 a population gain of 71,575 was recorded, representing a 1.0 percent annual increase (the national average). The 1989 population showed an increase of 2,225 (or 0.1 percent) from the same date in 1988 (DRCOG, 1989).

There are eight public schools, within six miles of the Rocky Flats Plant. The nearest educational facility is the Witt Elementary School, which is approximately 2.7 miles east of the Plant buffer zone. The closest hospital is Centennial Peaks Hospital located approximately seven miles northeast. The closest park and recreational area is the Standley Lake area, which is approximately five miles southeast of the Plant. Boating, picnicking, and limited overnight camping are permitted. Several other small parks exist in communities within ten miles. The closest major park, Golden Gate Canyon State Park, located approximately 15 miles to the southwest, provides 8,400 acres of general camping and outdoor recreation. Other national and state parks are located in the mountains west of the Rocky Flats Plant, but all are more than 15 miles away.

Some of the land adjacent to the Plant is zoned for industrial development. Industrial facilities within five miles include the TOSCO laboratory (40-acre site located two miles south), the Great Western Inorganics Plant (two miles south), the Frontier Forest Products yard (two miles south), the Idealite Lightweight Aggregate Plant (2.4 miles northwest), and the Jefferson County Airport and Industrial Park (990-acre site located 4.8 miles northeast).

Several ranches are located within ten miles of the Plant, primarily in Jefferson and Boulder Counties. They are operated to produce crops, raise beef cattle, supply milk, and breed and train horses. According to the 1987 Colorado Agricultural Statistics, 20,758 acres of crops were planted in Jefferson County (total land area of approximately 475,000 acres) and 68,760 acres of crops were planted in Boulder County (total land area of 405,760 acres). Crops consisted of winter wheat, corn, barley, dry beans, sugar beets, hay, and oats. Livestock consisted of 5,314 head of cattle, 113 hogs, and 346 sheep in Jefferson County, and 19,578 head of cattle, 2,216 hogs, and 12,133 sheep in Boulder County (Post, 1989).

1.3.2.6 Ecology

A variety of vegetation thrives within the Plant boundary. Included are species of flora representative of tall grass prairie, short grass plains, lower montane, and foothill ravine regions. None of these vegetative species are on the endangered species list. It is evident that the vegetative cover along the Front Range of the Rocky Mountains has been radically altered by human activities such as burning, timber cutting, road building, and overgrazing for many years. Since the acquisition of the Rocky Flats Plant property, vegetative recovery has occurred as evidenced by the presence of grasses like big bluestem and sideoats grama (two disturbance sensitive species). No vegetative stresses attributable to hazardous waste contamination have been identified (U.S. DOE, 1980).

The animal life inhabiting the Rocky Flats Plant and its buffer zone consists of species associated with western prairie regions. The most common large mammal is the mule deer, with an estimated 100-125 permanent residents. There are a number of small carnivores, such as the coyote, red fox, striped skunk, and long-tailed weasel. A profusion of small herbivores can be found throughout the Plant and buffer zone consisting of species such as the pocket gopher, white-tailed jackrabbit, and the meadow vole (U.S. DOE, 1980).

Commonly observed birds include western meadowlarks, horned larks, mourning doves, and vesper sparrow. A variety of ducks, killdeer, and red-winged black birds are seen in areas adjacent to ponds. Mallards and other ducks frequently nest and rear young on several of the ponds. Common birds of prey in the area include marsh hawks, red-tailed hawks, ferruginous hawks, rough-legged hawks, and great horned owls (U.S DOE, 1980).

Bull snakes and rattlesnakes are the most frequently observed reptiles. Eastern yellow-bellied racers have also been seen. The eastern short-horned lizard has been reported on the site, but these and other lizards are not commonly observed. The western painted turtle and the western plains garter snake are found in and around many of the ponds (U.S. DOE, 1980).

1.4 SITE LOCATIONS AND DESCRIPTIONS

This RI/FS Work Plan addresses the 903 Pad, Mound, and East Trenches Areas located on the east side of the Rocky Flats Plant security area. Several sites are included in each area because of their physical proximity to each other. Figure 1-5 shows the locations of each area and the sites within each area. Each site has been assigned a SWMU reference number by Rockwell International (1987c).

Site descriptions presented in the following sections are taken from the Rocky Flats Plant CEARP Phase 1 Report (U.S. DOE, 1986) and the RCRA Part B Operating Permit Application (Rockwell International, 1987c). These descriptions are based on historical records, aerial photography review, and interviews with Plant personnel. Further characterization of each site based on the Phase I RI and other historical reports is also included in the following discussions.

1.4.1 903 Pad Area

Five sites are located within the 903 Pad Area (Figure 1-5). These sites are:

- 903 Drum Storage Site (SWMU Ref. No. 112);
- 903 Lip Site (SWMU Ref. No. 155);
- Trench T-2 Site (SWMU Ref. No. 109);
- Reactive Metal Destruction Site (SWMU Ref. No. 140); and
- Gas Detoxification Site (SWMU Ref. No. 183).

Descriptions of each site within the 903 Pad Area are provided in the following sections.

1.4.1.1 903 Drum Storage Site (SWMU Ref. No. 112)

The 903 Drum Storage Site is located in the eastern portion of the Plant security zone. This area was used from October 1958 to January 1967 for storage of radioactively contaminated oil drums (Calkins, 1970). Presented below is a description of drums stored at the drum storage site from Calkins (1970).

> "Most of the drums transferred to the field were nominal 55-gallon drums, but a significant number were 30-gallon drums. Not all were completely full. Approximately three-fourths of the drums were plutonium-contaminated, while most of the balance contained uranium. Of those containing plutonium, most were lathe coolant consisting of a straight-chain hydrocarbon mineral oil (Shell Vitrea) and carbon tetrachloride in varying proportions. Other liquids were involved, however, including hydraulic oils, vacuum pump oil, trichloroethylene, perchloroethylene, silicone oils, acetone still bottoms, etc. Originally, contents of the drums were indicated on the outside, but these markings were made illegible through weathering and no other good records were kept of the contents. Leakage of the oil was recognized early, and in 1959 or possibly earlier ethanolamine was added to the oil to reduce the corrosion rate of the steel drum."

Drum leakage was noted at the 903 Drum Storage Site in 1964 during routine drum handling operations. Corrective action consisted of transferring the contents of leaking drums to new drums and fencing the area to restrict access. Approximately 420 drums leaked to some degree, and of these, about 50 leaked their entire contents. An estimated 5,000 gallons of liquid containing 86 grams (g) [5.3 curies (Ci)] of plutonium leaked into the soil (Dow Chemical, 1971). A heavy rainstorm in 1967 spread contaminants to a ditch south and southeast of the drum storage site (Rockwell International, 1987c).

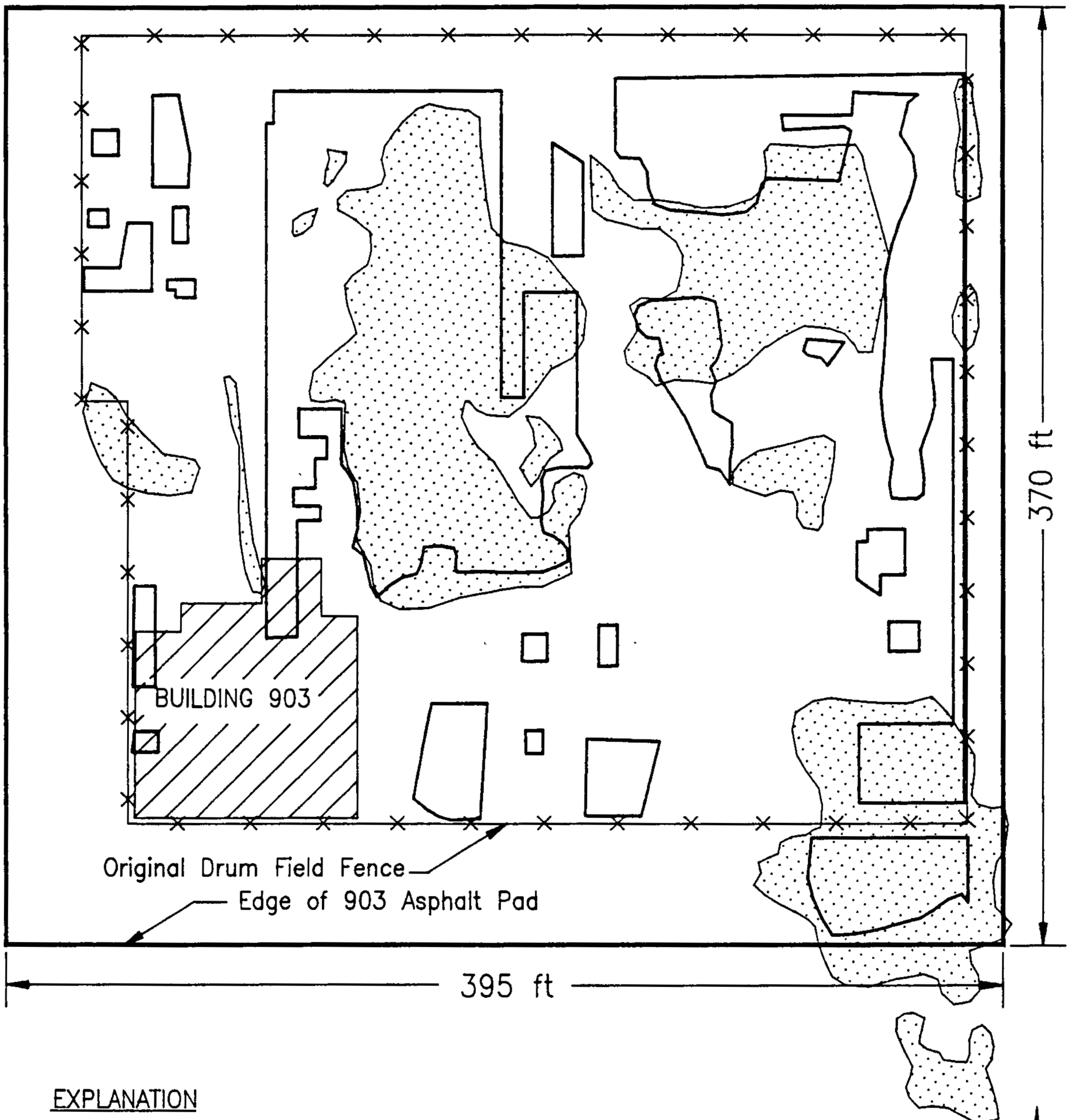
Figure 1-6 outlines drum locations and soil staining at the 903 Drum Storage Site based on a review of historical aerial photography. As seen on this figure, drum storage occurred primarily in the northern and eastern portions of the area. Drums were not stored in the southwest portion where Building 903 was constructed in 1967, and were only briefly stored at the southeast corner. It appears that the drums stored south of the fenced area were placed at this location during clean-up operations, as they appear only in the 1968 aerial photos.

The shipment of drums to the 903 Drum Storage Site ended in January 1967, when drum removal efforts began. Removal of all drums and wastes was completed in June 1968. Presented below is a chronology of the 903 Drum Storage Site clean-up as described by Freiberg (1970).

- "From January 23, 1967, through March 10, 1967, uranium oil drums which were in good condition were transferred to Building 774 and processed.
- Building 903 ... on March 10, 1967, started processing oil drums. This building was designed to prefilter the oil prior to transferring plutonium contaminated oil to Building 774 for final processing.
- From March 10, 1967 through May 18, 1967, there were a total of 191 drums of plutonium contaminated oil filtered and shipped to Building 774.
- On May 18, 1967, operations at Building 903 were discontinued due to the amount of time this process was taking.
- Drum-to-drum transfer in the field began May 18, 1967, and the drums shipped to Building 774 without prior filtration in Building 903.
- From March 17, 1967 through May 10, 1967, in addition to the plutonium transfers, there were 297 drums of uranium contaminated Alk-Tri waste shipped to Building 774 and processed.
- May 10, 1967 through May 28, 1968, a total of 4,826 drums containing 50 gallons of oil each were sent to Building 774 and processed.
- In addition to the oil storage area drums, there were a total of 650 drums from Building 776 current generation sent to Building 774 for processing. A pipeline installed from Building 776 to Building 774 eliminated this additional oil drum generation.
- During the transfer operations, it was noted that at the bottom of all drums a deposit of sludge remained after removal of the oil. this sludge varied in depth

FIGURE 1-6

APPROXIMATE LOCATIONS OF DRUM STORAGE
903 PAD DRUM STORAGE SITE



EXPLANATION

AREA OF SOIL STAINING BASED ON AERIAL PHOTOGRAPHS FROM: 4/29/67, 4/10/68, 5/24/69.

BARREL STORAGE LOCATIONS BASED ON AERIAL PHOTOGRAPHS FROM: 5/5/63, 4/29/65, 4/29/67, 9/10/68.

NOTE: BUILDING 903 LOCATION BASED ON AERIAL PHOTOGRAPHS FROM 4/10/68.

from 1/2 inch to 3 inches and averaged approximately 1 inch. By drum counter results the sludge within the empty drums contained a total of 5,152 grams of plutonium. These empty drums were later disposed of by adding Oil Dry and MicroCel to absorb the sludge. The drums containing the plutonium sludge and absorbent were then incased in plastic, placed in boxes, and shipped to the burial grounds."

There were originally a total of 5,237 drums at the drum storage site when clean-up operations began in 1967. After transfer of the contents to new drums, 4,826 drums were transported to Building 774 of which 3,572 drums contained plutonium contaminated oil. This leaves the contents of 411 drums unaccounted for. The most probable explanation for this discrepancy according to Freiberg (1970) is a combination of the following factors:

1. All of the drums originally sent to the storage site were not completely full;
2. Some of the volume was taken up by the sludge which was discarded with the empty barrels; and
3. Leakage out of the barrels and onto the ground occurred.

Information provided by Freiberg (1970) indicates that a total of approximately 5,000 gallons of oil leaked from drums onto the ground at the drum storage site. Based on oil samples taken from barrels, the average plutonium concentration was 4.54×10^{-3} grams per liter (g/l) [280 pico Curies/liter (pCi/l)]. Thus, approximately 86 g (5.3 Ci) of plutonium were released to soils at the drum storage site.

In November 1968, site grading began at the 903 Drum Storage Site in preparation for applying an asphalt cap over the area. This work included moving "slightly" contaminated soil from around the fenced area to inside the fenced area (Freiberg, 1970). A total of 33 drums of radioactively contaminated rocks were removed from the area in May 1969, and two courses of clean fill material were placed over the site during the late summer of 1969. The asphalt was applied in October 1969, and in February 1970 additional road base course material was applied to soils directly east and south of the asphalt pad due to soil contamination (Freiberg, 1970).

The asphalt containment cover is rectangular and oriented north-south (370 feet) and east-west (395 feet). The pad dips slightly to the northeast at a drop of one foot per 100 feet. The asphalt cover is approximately eight centimeters (cm) (3.2 inches) thick and it is underlain by approximately fifteen cm (six inches) of loose gravel and eight cm of fill dirt (Navratil et. al, 1979).

1.4.1.2 903 Lip Site (SWMU Ref. No. 155)

During drum removal and clean-up activities associated with the 903 Drum Storage Site, winds redistributed plutonium beyond the pad to the south and east. An estimated one Ci (16.3 g) of plutonium was redistributed beyond the asphalt pad, and of that one Ci, approximately 0.56 Ci (9.1 g) is believed to have been deposited in the 903 Lip Site (Barker, 1982). The most contaminated area was immediately adjacent to the pad to the south and southeast. Surveys at the time of the drum removal project and subsequent annual soil sampling from 1969 to 1972 showed a maximum plutonium concentration of 2,258 pico Curies per gram (pCi/g) [5,680 disintegrations per minute per gram (dpm/g)] in the top five cm (two inches) of soil at the 903 Lip Site (Barker, 1982).

Soil clean-up efforts were undertaken in 1976, 1978, and 1984 to remove plutonium contaminated soils from the 903 Lip Site. The 1976 soil removal operation began in June 1976 and ended in September 1976. This clean up consisted of hand-excavating contaminated soils from the area until soil contamination levels were below the detection limit of the Field Instrument for Detection of Low Energy Radiation (FIDLER). The detection limit of the FIDLER is 250 counts per minute (cpm). The FIDLER "counts" are an instrument dependent measure of surface activity and cannot be converted to plutonium concentration in the soil. The excavated area was covered with clean top soil and reseeded with native grasses. Thirty-five boxes weighing a total of 125,000 pounds were removed and shipped off-site for disposal during the 1976 clean-up (Barker, 1982).

Although the 1976 soil removal technique did not result in any personnel exposures or environmental impacts, hand-excavation was inefficient considering the large amount of contaminated soils requiring removal at the 903 Lip Site. In June 1978, a second soil removal project began using a front end loader alone or in conjunction with a bull dozer. All soil that exceeded 2,000 cpm, as determined by a FIDLER survey, was removed. Cleaned areas were resurveyed and soil removal continued until background readings (approximately 250 cpm by a FIDLER survey) were obtained. Topsoil was then applied to the excavated area, and the site was revegetated with native grasses. During the 1978 soil removal, 1448 boxes weighing approximately 4.7 million pounds were removed and shipped off-site (Barker, 1982).

Approximately 0.5 Ci (8.2 g) of plutonium were removed from the 903 Lip Site during the two soil removal projects. This quantity is based on an average soil plutonium concentration of 545 pCi/g (1,200 dpm/g) and a soil density of one gram per cubic centimeter ($gcm^{3)}$ (Barker, 1982).

A third soil clean up was performed along the eastern edge of the 903 Lip Site in 1984. A total of 214 tri-wall pallets of contaminated soil were removed from the area. The excavated area was backfilled with clean topsoil (Setlock, 1984).

1.4.1.3 Trench T-2 Site (SWMU Ref. No. 109)

Trench T-2 is located south of the 903 Drum Storage Site and west of the Reactive Metal Destruction Site within the 900 Area. This trench was used prior to 1968 for the disposal of sanitary sewage sludge and flattened drums contaminated with uranium and plutonium. This trench is believed to measure approximately 15 feet wide by 200 feet long by 5 feet deep (Rockwell International, 1987c). Barrels were noted in the western end of Trench T-2 during 1987 investigations (Figure 1-5).

1.4.1.4 Reactive Metal Destruction Site (SWMU Ref. No. 140)

The Reactive Metal Destruction Site is located on the hillside south of the 903 Drum Storage Site. This site was used during the 1950s and 1960s primarily for the destruction of lithium metal (U.S. DOE, 1986). Approximately 400 to 500 pounds of metallic lithium were destroyed on the ground surface in this area and the residues, primarily nontoxic lithium carbonate, buried. Smaller unknown quantities of sodium, calcium, and magnesium, solvents, and unknown liquids were also destroyed at this location (Rockwell International, 1987c).

Based on review of historical aerial photography, the Reactive Metal Destruction Site was used from 1968 to 1971. Barrels were noted in the southwestern corner of SWMU 140 during 1987 investigations (Figure 1-5).

1.4.1.5 Gas Detoxification Site (SWMU Ref. No. 183)

Building 952, located south of the 903 Drum Storage Site, 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 each. The gases consisted of various types of nitrogen oxides, chlorine, hydrogen sulfide, sulfur tetrafluoride, methane, hydrogen fluoride, and ammonia which were used in Plant research and development work. Gas detoxification was accomplished by using various commercial neutralization processes available at the time. 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 (Rockwell International, 1987c).

1.4.2 Mound Area

The Mound Area is composed of four sites (Figure 1-5). These are:

- Mound Site (SWMU Ref. No. 113);

- Trench T-1 Site (SWMU Ref. No. 108);
- Oil Burn Pit No. 2 Site (SWMU Ref. No. 153); and
- Pallet Burn Site (SWMU Ref. No. 154).

These sites are described individually below.

1.4.2.1 Mound Site (SWMU Ref. No. 113)

The Mound Site, located north of Central Avenue in the eastern Plant security area was used between April 1954 and September 1958 for drum disposal. Approximately 1,405 drums containing primarily depleted uranium and beryllium contaminated lathe coolant (a mixture of about 70% hydraulic oil and 30% carbon tetrachloride) were placed in the Mound Site. However, it is likely that some of the coolant also contained enriched uranium and plutonium. Some drums also contained Perclene (Smith, 1975). Perclene was a brand name of tetrachloroethene (PCE) (Sax and Lewis, 1987). Some of the drummed wastes placed in the Mound Site were in solid form (Rockwell International, 1987c).

Clean up of the Mound Site was accomplished in May 1970, and the materials removed were packaged and shipped to an off-site DOE facility for disposal. Listed below is an inventory of the 1,405 drums removed from the Mound Site in 1970 (Dow Chemical, 1971).

No. of Drums	Contents
903	30-gallon drums of depleted uranium solid waste;
21	30-gallon drums of depleted uranium oil waste;
12	30-gallon drums of plutonium contaminated oil waste. "The plutonium content was so low that it was measurable only by the most sensitive laboratory techniques."
102	55-gallon drums of depleted uranium solid waste;
282	55-gallon drums of depleted uranium oil waste; and
85	55-gallon drums of enriched uranium oil waste.
1,405	TOTAL DRUMS

Subsequent surficial soil sampling in the vicinity of the excavated Mound Site indicated 0.8 to 112.5 dpm/g (0.4 to 51 pCi/g) activity. This radioactive contamination is thought to have come from the 903 Drum Storage Site via wind dispersion rather than from the Mound Site, as it was limited to the surface (Rockwell International, 1987c).

1.4.2.2 Trench T-1 Site (SWMU Ref. No. 108)

The trench was used from 1954 until 1962 and contains approximately 125 drums filled with approximately 25,000 kilograms (kg) (11,364 pounds) of depleted uranium chips (Dow Chemical, 1971) and plutonium chips coated with small amount of lathe coolant (Rockwell International, 1987c). The estimated dimensions of Trench T-1 are 15 feet wide by 200 feet long by 5 feet deep (Rockwell International, 1987c). Trench T-1 was covered with about two feet of soil, and the corners were marked (Rockwell International, 1987c).

Weed cutting activities in October and November 1968 unearthed two drums inadequately covered with fill material. Both drums were sampled and analyzed for total plutonium and uranium content before they were disposed off-site. One of the drums sampled contained an oil-water mixture with 55 pCi/l of plutonium and 2.3×10^5 pCi/l of uranium. The other drum contained an oily sludge with 4.6 pCi/g of plutonium and 1.2×10^6 pCi/g uranium (Illsley, 1983).

1.4.2.3 Oil Burn Pit No. 2 Site (SWMU Ref. No. 153)

Oil Burn Pit No. 2 is actually two parallel trenches which were used in 1957 and from 1961 to 1965 to burn approximately 1,082 drums of oil containing uranium (Rockwell International, 1987c). In March and April of 1957, the contents of an estimated 169 uranium contaminated waste oil drums were burned. No further burning took place until 1961. Frequent burning of waste oil took place from June 1961 to May 1965. The contents of approximately 914 drums were burned during this time. The drums used for the oil burning

- East Spray Irrigation Sites (SWMU Ref. Nos. 216.2 and 216.3)

Trenches T-3, T-4, T-10, and T-11 are located north of the east access road, and Trenches T-5 through T-9 are south of the east access road. The wastes in these trenches have not been disturbed since their burial. The spray irrigation areas are located east of Trenches T-5 through T-9 (Figure 1-5).

1.4.3.1 Trenches T-3 through T-11 (SWMU Ref. Nos. 110 and 111.1-111.8)

These trenches as well as Trench T-2 were used from 1954 to 1968 for disposal of approximately 125,000 kg of sanitary sewage sludge contaminated with uranium and plutonium and approximately 300 flattened empty drums contaminated with uranium (Illsley, 1983). Radiation content of the sewage sludge ranged from 8.4 x 10^5 dpm/kg (382 pCi/g) to 7.9 X 10^6 dpm/kg (3,590 pCi/g) (Owen and Steward, 1973). "Earlier pits involve mostly uranium with an increasing plutonium fraction in later pits." (Owen and Steward, 1973). Total alpha radioactivity in Trenches T-2 to T-8 is estimated to be 100 to 150 millicuries (0.1 to 0.15 Ci) (Dow Chemical, 1971). Trenches T-4 and T-11 also contains some plutonium and uranium contaminated asphalt planking from the solar evaporation ponds (Illsley, 1983).

According to Illsley (1983), samples were collected from Trenches T-9, T-10, and T-11, and the results were as follows:

> "Samples from T-11 contained plutonium in the range from 4.5 to 50 pCi/g and uranium-238 in the range between 0.9 and 158 pCi/g. Trench T-10 was found to contain uranium in the range between 40 and 126 pCi/g and ^{239}Pu in the range from 0.18 to 14 pCi/g.... Plutonium concentrations in collected samples varied from 0.40 to 68 pCi/g and uranium was found in the range between 2.4 and 450 pCi/g" in Trench T-9."

The sampling dates and collection methods of these samples are unknown.

1.4.3.2 East Spray Irrigation Sites (SWMU Ref. Nos. 216.2 and 216.3)

SWMU numbers 216.2 and 216.3 are currently areas used for spray irrigation of sewage treatment plant effluent. These areas have been designated as SWMUs because effluent containing low concentrations of chromium was inadvertently sprayed in the area in February and March 1989. The chromium entered the sanitary sewage treatment plant on February 23, 1989 subsequent to a spill of chromic acid in Building 444 (Rockwell International, 1989).

2.0 PHASE I SITE EVALUATION

2.1 PHASE I REMEDIAL INVESTIGATION

The Phase I RI consisted of the following field activities:

1) Electromagnetic, resistivity, and magnetometer geophysical surveys;
2) A soil gas survey;
3) Soil sample collection from 33 boreholes (Figure 2-1);
4) Completion of 10 alluvial and 14 bedrock monitoring wells (Figure 2-1);
5) Ground-water sampling of new and previously existing wells;
6) Slug testing of 13 wells;
7) Packer testing of cored bedrock wells;
8) Collection of 22 surface water and seep samples; and
9) Air monitoring for total long lived alpha, plutonium, and volatile organics during field activities.

In addition to the Phase I investigation at the 903 Pad, Mound, and East Trenches Areas, several monitor wells were installed in these areas as part of a Plant-wide hydrogeologic investigation in 1986 (Rockwell International, 1986e). Surface water, soil, and air samples have also been collected at these areas as part of various investigations. Section 2.2 presents results of the Phase I RI and a brief characterization of each pathway at the 903 Pad, Mound, and East Trenches Areas. The nature and extent of contamination associated with these pathways is discussed in Section 2.3.

2.2 SITE CONCEPTUAL MODEL

A site-specific conceptual model of the 903 Pad, Mound, and East Trenches Areas has been developed based on the Phase I RI results and previous investigations. This model describes contaminant sources and pathways through which contaminant transport may occur from these areas.

2.2.1 Geology

2.2.1.1 Surficial Geology

Surficial materials at the 903 Pad, Mound, and East Trenches Areas consist of the Rocky Flats Alluvium, colluvium, and valley fill alluvium unconformably overlying bedrock (Figure 2-2). The area is situated on a terrace of Rocky Flats Alluvium which extends eastward from the Plant. The Rocky Flats Alluvium consists of a poorly to moderately sorted, poorly stratified, deposit of clays, silts, sands, gravels, and cobbles. A portion of the 903 Pad Area extends south off the terrace toward the South Interceptor Ditch. Colluvium is present on the hillside south of the 903 Pad and East Trenches Areas and on the hillside north of the Mound Area. Valley fill alluvium is present in the drainage of Woman Creek south of the 903 Pad and East Trenches Areas and in the South Walnut Creek drainage north of the Mound Area.

Buried channels and ridges eroded into the top of bedrock are present at the base of the Rocky Flats Alluvium (Figure 2-3). One such paleochannel is located north of the 903 Pad Area along Central Avenue. The paleochannel is approximately 300 feet wide and 2,000 feet long. It trends east-northeast beneath the east access road and bends to the southeast just south of well 33-87. A 150 foot wide paleoridge is located east of well 15-87 south of the paleochannel. Another paleoridge occurs beneath the northern edge of the pediment margin east of the Mound Area and north of the East Trenches (well 35-87).

2.2.1.2 Bedrock Geology

The Cretaceous Arapahoe Formation underlies surficial materials at the 903 Pad, Mound, and East Trenches Areas. The Arapahoe Formation consists of fluvial claystones with interbedded lenticular sandstones, siltstones, and occasional lignite deposits. Contacts between these lithologies are both gradational and sharp.

The Arapahoe Formation was deposited by meandering streams which flowed east-southeast from the Front Range Uplift (Weimer, 1973). The fining upward sandstone sequences within the formation are representative of both laterally accreted point bar deposits and floodplain splay deposits. Laterally accreted point bar deposits occur by the slow migration of fluvial channels, and splay deposits are formed by breaching of channel banks during floods (Blatt and others, 1980). Overbank flood deposits consist of very fine sand and mud deposited near the stream channel or on the stream flood plain. Channel fill deposits are formed in abandoned channels by a reduction in stream discharge or by cutoff of a meander (formation of oxbow lakes) (Blatt and others, 1980).

Bedrock in the 903 Pad, Mound, and East Trenches Areas is predominantly claystone. However, numerous subcropping Arapahoe sandstones were also encountered. Current knowledge of sandstone location and extent is based upon borehole logs. A program to profile the Arapahoe Formation through seismic reflection is now in progress to better characterize bedrock sandstones. Upon completion of this program and review of its results, the site conceptual model of bedrock geology will be revised, and a Phase III Sampling Plan will be prepared.

2.2.2 Hydrogeology

Unconfined ground-water flow occurs in surficial materials and subcropping sandstones. In addition, subcropping claystone may be saturated in some locations. Confined ground-water flow occurs in deeper sandstone units.

2.2.2.1 Unconfined Flow System

Recharge/Discharge Conditions

Ground water is present in the Rocky Flats Alluvium, colluvium, valley fill alluvium, and subcropping sandstones under unconfined conditions. Recharge to the water table occurs as infiltration of incident precipitation and as seepage from ditches and creeks. In addition, retention ponds along South Walnut Creek and Woman Creek probably recharge the valley fill alluvium.

The shallow ground-water flow system is quite dynamic, with large water level changes occurring in response to precipitation events and stream and ditch flow. Alluvial water levels are highest during the spring and early summer months of May and June. Water levels decline during late summer and fall, and some wells go dry at this time of year.

Alluvial ground water discharges to seeps, surface water drainages, colluvium, and subcropping Arapahoe sandstone at the 903 Pad, Mound, and East Trenches Areas. Seeps occur along the edge of the pediment margin (at the alluvium/bedrock contact) and on the hillside slopes. Seeps on the hillsides may be due to thinning of colluvial materials. Ground water in valley fill materials discharges to Woman or South Walnut Creeks.

Ground-water Flow Directions

Ground-water flow in the unconfined system is generally from west to east in response to local topography. Figure 2-4 presents the unconfined potentiometric surface measured in April 1988 and represents the most extensive area of saturation at Operable Unit No. 2 since the Phase I RI. Shown on this figure are water level data for wells completed in both surficial materials and subcropping sandstones which exhibit unconfined conditions. Because of the bedrock highs beneath the Rocky Flats Alluvium in the vicinity of the East Trenches Area, ground-water flow is diverted either toward the paleochannels or off the edge of the Rocky Flats terrace. Water diverted toward the paleochannel flows northeast following the trend of the channel in the top of bedrock. Ground water flowing toward the pediment edges emerges as seeps at the contact between the alluvium and claystone bedrock (contact seeps), is consumed by evapotranspiration, or flows through colluvial materials following topography toward the valley fill alluvium. Once ground water reaches the valley fill alluvium, it either flows down-valley in the alluvium, is consumed by evapotranspiration, or discharges to the creek. During the driest periods of the year, evapotranspiration consumes so much water that there is no flow in either the colluvium or the valley fill alluvium. Wells completed in these areas are dry during some portion of the year.

Ground-Water Flow Rates

Hydraulic conductivity values were developed for surficial materials from drawdown-recovery tests performed on 1986 wells during the initial site characterization (Rockwell International, 1986e) and from slug tests performed on select 1986 and 1987 wells during the 1987 Phase I RI.

For the Rocky Flats Alluvium, hydraulic conductivities for all tests ranged from 4×10^{-5} centimeters per second (cm/s) at well 39-86 to 5×10^{-2} cm/s at well 42-86. The geometric mean hydraulic conductivity for all tests was 4×10^{-4} cm/s. Based on an average horizontal gradient of 0.02 feet/foot (ft/ft) at the 903 Pad, Mound and East Trenches Areas, an assumed effective porosity of 0.1, and a mean hydraulic conductivity of 4×10^{-4} cm/s, the average ground-water velocity in the Rocky Flats Alluvium is 85 feet per year (ft/yr) (Rockwell International, 1987a).

The geometric mean hydraulic conductivity based on drawdown-recovery tests for the Woman Creek valley fill alluvium is 7×10^{-4} cm/s, and the range is from 5×10^{-5} cm/s at well 68-86 to 3×10^{-3} cm/s at well 65-86. No slug tests were performed on wells completed in Woman Creek valley fill. Using the same gradient and effective porosity as for the Rocky Flats Alluvium and a mean hydraulic conductivity of 7×10^{-4} cm/s, the average ground-water velocity in Woman Creek valley fill is 145 ft/yr (Rockwell International, 1987a).

South Walnut Creek valley fill is less conductive than that along Woman Creek based on lithologic descriptions and hydraulic conductivity tests of well 35-86. A drawdown-recovery test and a slug test have been performed in well 35-86. The hydraulic conductivity of South Walnut Creek Alluvium calculated from the drawdown-recovery test was 9×10^{-5}

cm/s. Results of the slug test indicated a hydraulic conductivity of 1 x 10^{-4} cm/s. Using the mean conductivity of 9.5 x 10^{-5} cm/s, an effective porosity of 0.1, and an average gradient of 0.02 ft/ft, the average flow velocity in South Walnut Creek valley fill is 20 ft/yr (Rockwell International, 1987a).

The average ground-water flow velocities calculated for various surficial materials assume the materials are fully saturated year-round. However, as discussed above, portions of the Rocky Flats Alluvium, colluvium, and valley fill alluviums are not saturated during the entire year. Based on water level data from the area, alluvial wells are dry approximately three months during the year (generally August through October). Thus, ground-water flow occurs only nine months of the year. This results in reduced average ground-water velocities in all alluvial materials (approximately 65 ft/yr in Rocky Flats Alluvium, 110 ft/yr in Woman Creek valley fill alluvium, and 15 ft/yr in South Walnut Creek valley fill alluvium.

2.2.2.2 Confined Ground-Water Flow System

The greatest potential for ground-water flow in the Arapahoe Formation occurs in the sandstones contained within the claystones. Ground-water recharge to sandstones occurs as infiltration from alluvial ground water where sandstones subcrop beneath the alluvium and by leakage from claystones overlying the sandstones. In addition to flow through Arapahoe Formation sandstones, unconfined ground-water flow may occur in weathered claystones where they underlie saturated surficial materials.

Flow within individual sandstones is assumed to be from west to east but the geometry of the ground-water flow path in the bedrock is not fully understood at this time due to its dependence upon the continuity of the sandstones and their hydraulic interconnection. Evaluation of the lateral extent and degree of interconnection of the sandstone units is a primary goal of an ongoing program of profiling the Arapahoe Formation through seismic reflection studies.

2.2.3 Surface Water Hydrology

2.2.3.1 South Walnut Creek

The headwaters of South Walnut Creek have been filled during construction of Plant facilities. Most upstream flow begins as flow from a buried culvert located west of Building 991 (See Figure 1-5). During Phase I RI surface water sampling (Rockwell International, 1987a), flows in the upper reach of South Walnut Creek have been measured at 0.1 to 0.4 cubic feet per second (cfs) during the first three quarters of 1989. This flow is routed beneath Building 991 in a corrugated metal pipe. The discharge from the corrugated metal pipe is augmented by flow from a concrete pipe at a point due north of the Mound Area. The flow from the concrete pipe apparently originates as seepage from the hillside south of Building 991 and flows into a ditch along the slope. The combined flows then enter the South Walnut Creek retention pond system. Below the retention ponds, South Walnut Creek joins North Walnut Creek and an unnamed tributary within the buffer zone before flowing into Great Western Reservoir located approximately one mile east of this confluence.

The South Walnut Creek retention pond system consists of five ponds (B-1, B-2, B-3, B-4, and B-5) that retain surface water runoff and Plant discharges for monitoring and evaluation before downstream release of these waters. All flow downstream of the most downstream pond (Pond B-5) originates from Pond B-5 and is measured and monitored for quality in accordance with the Plant's NPDES permit (discharge point 006). Ponds B-1 and B-2 are reserved for spill control, surface water runoff, or treated sanitary waste of questionable quality, and Pond B-3 is a holding pond for sanitary sewage treatment plant effluent. The normal discharge of Pond B- 3 is to a spray system located in the vicinity of the East Trenches. Ponds B-4 and B-5 receive surface water runoff from the central portion of the Plant and occasional discharges from Pond B-3. The surface water runoff received by Pond B-4 is collected by the Central Avenue Ditch and upper reaches of South Walnut Creek.

2.2.3.2 Woman Creek

Woman Creek is located south of the Plant with headwaters in largely undisturbed Rocky Flats Alluvium. Runoff from the southern part of the Plant is collected in the South Interceptor Ditch located due north of the creek and delivered to Pond C-2. Pond C-1 (upstream of C-2) receives stream flow from Woman Creek. The discharge from Pond C-1 is diverted around Pond C-2 into the Woman Creek channel downstream. Water in Pond C-2 is discharged to Woman Creek in accordance with the Plant NPDES permit (discharge point 007).

Flow in Woman Creek and the South Interceptor Ditch is intermittent, appearing and disappearing along various reaches. During the 1986 initial site characterization, measurable flow occurred at less than one-half of the ten stations located along Woman Creek and the South Interceptor Ditch (Rockwell International, 1986e). All recorded flows were less than ten gallons per minute. During the 1986 and 1987 investigations, there was no surface flow in Woman Creek downstream of Pond C-2. The intermittent surface water flow observed for Woman Creek and the South Interceptor Ditch is indicative of frequent interaction with the shallow ground-water system.

2.3 NATURE AND EXTENT OF CONTAMINATION

2.3.1 Background Characterization

In order to facilitate the interpretation of chemical results in non-background areas, a background characterization program has been implemented to define the spatial and temporal variability of naturally occurring constituents. Field work was conducted in 1989 and a draft Background Geochemical Characterization Report was prepared and submitted to the regulatory agencies December 15, 1989 (Rockwell International, 1989d). The document summarizes the background data for ground water, surface water, sediments, and geologic materials, and identifies preliminary statistical boundaries of background variability. Spatial variations in the chemistry of geologic materials and water were addressed by placing sample locations throughout background areas at the Plant. The goal of evaluating temporal variations in water chemistry has not yet been achieved because at least two years of quarterly data are needed. The draft report will be updated in 1990 by incorporation of analytical data that were unavailable in December 1989, including a second round of ground-water samples for which laboratory analyses were not available. The information in the draft background geochemical report has been used to preliminarily characterize inorganic contamination at the 903 Pad, Mound, and East Trenches Areas.

The boundary of background variability was quantified through the calculation of tolerance intervals assuming a normal distribution. The upper limit of the tolerance interval or the maximum detected value for each parameter analyzed in background ground-water, surface water, sediment, and geologic samples are provided in Tables 2-1 through 2-4, respectively. Maximum detected values are provided where there were insufficient data to calculate tolerance intervals. This condition resulted from there being an insufficient number of samples, or where there was an insufficient number of detectable concentrations for a given analyte. Background samples were not analyzed for EPA Contract Laboratory Program (CLP) Target Compound List (TCL) organics, because they are not expected to be present.

To assess the presence of inorganic contamination at the 903 Pad, Mound, and East Trenches Areas, site-specific chemical data are compared to the background tolerance intervals or the maximum detected value if a tolerance interval could not be calculated. A constituent concentration that is greater than the upper limit of the one-sided 95% tolerance interval at the 95% confidence level will be considered to preliminarily represent contamination. However, there is no statistical significance associated with site specific chemical concentrations being above the maximum detected background value.

2.3.2 Soils

The extent of soil contamination at the 903 Pad, Mound, and East Trenches Areas is based on soil samples collected during Phase I RI field activities. Soil samples were taken from boreholes drilled into and adjacent to known SWMU locations and analyzed for the

TABLE 2-1

BACKGROUND GROUND-WATER (ROUND 1)
TOLERANCE INTERVAL UPPER LIMITS
MAXIMUM DETECTED VALUE

Analyte	Units	Rocky Flats Alluvium (11 Samples)	Colluvium (2 Samples)	Valley Fill Alluvium (8 Samples)	Weathered Claystone (4 Samples)	Weathered Sandstone (2 Samples)	Unweathered Sandstone (7 Samples)
Dissolved Metals							
Aluminum	mg/l	ND	ND	ND	ND	ND	0.327*
Antimony	mg/l	ND	ND	ND	ND	ND	ND
Arsenic	mg/l	ND	ND	ND	ND	ND	0.0186*
Barium	mg/l	ND	ND	ND	ND	ND	ND
Beryllium	mg/l	ND	ND	ND	ND	ND	ND
Cadmium	mg/l	ND	ND	ND	ND	ND	ND
Calcium	mg/l	85	76.8*	138	73.4*	65.7*	64.6
Cesium	mg/l	ND	ND	ND	ND	ND	ND
Chromium	mg/l	ND	ND	ND	ND	0.0122*	ND
Cobalt	mg/l	ND	ND	ND	ND	ND	ND
Copper	mg/l	ND	ND	ND	ND	ND	ND
Iron	mg/l	0.266*	ND	0.94*	ND	ND	ND
Lead	mg/l	ND	ND	ND	ND	ND	ND
Lithium	mg/l	ND	0.172*	0.028	.031*	0.0106*	ND
Magnesium	mg/l	5.79*	15.3*	26.57	45.3*	9.41*	ND
Manganese	mg/l	0.365	0.088*	0.686*	0.126*	0.292*	0.0182*
Mercury	mg/l	ND	ND	0.003*	.008*	ND	ND
Molybdenum	mg/l	0.0136*	ND	ND	0.015*	0.015*	0.112*
Nickel	mg/l	0.0432*	ND	ND	ND	ND	ND
Potassium	mg/l	7.73*	ND	ND	ND	ND	21.89*
Selenium	mg/l	ND	ND	0.0114*	ND	ND	0.041*
Silver	mg/l	ND	ND	ND	ND	ND	ND
Sodium	mg/l	13.4	98.7*	88	36.9*	25.6*	599
Strontium	mg/l	0.159*	ND	ND	ND	ND	0.451*
Thallium	mg/l	ND	ND	ND	0.01*	ND	ND
Tin	mg/l	ND	ND	ND	ND	ND	
Vanadium	mg/l	ND	ND	ND	ND	ND	ND
Zinc	mg/l	0.141*	ND	0.0212*	0.107*	ND	0.564

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TABLE 2-1 (cont.)

BACKGROUND GROUND-WATER (ROUND 1)
TOLERANCE INTERVAL UPPER LIMITS
MAXIMUM DETECTED VALUE

Analyte	Units	Rocky Flats Alluvium (11 Samples)	Colluvium (2 Samples)	Valley Fill Alluvium (8 Samples)	Weathered Claystone (4 Samples)	Weathered Sandstone (2 Samples)	Unweathered Sandstone (7 Samples)
Other							
Total Dissolved Solids	mg/l	352	520*	947	320*	170*	1761
Carbonate	mg/l	ND	ND	ND	ND	ND	49
Bicarbonate	mg/l	436	470*	719	400*	140*	412
Chloride	mg/l	15.6	20*	40.29	11*	15*	607
Sulfate	mg/l	45.1	86*	150	44*	16*	950
Nitrate	mg/l	2.98	0.18*	0.69*	0.58*	1.6*	0.610
Cyanide	mg/l	.0038*	ND	ND	0.0036*	ND	ND
pH	----	8.6 (5.98)	7.4* (7.1)**	8.68 (6.12)	8.2* (7.4)**	7.5* (7.2)**	10.57 (7.43)
Dissolved Radionuclides							
Gross Alpha	pCi/l	12.543	27*	13.515	12*	7*	13*
Gross Beta	pCi/l	14.570	12*	18.530	7*	2*	15*
Uranium 233, 234	pCi/l	1.647	11*	6.481	5.8*	1.1*	12.936
Uranium 235	pCi/l	0.000	0.3*	0.232	0.2*	0*	0.135
Uranium 238	pCi/l	0.195	7.7*	5.084	3.2	0.6*	3.3507
Strontium 89, 90	pCi/l	0.552	0.1*	0.878	0.1	-0.1*	0.2*
Plutonium 239, 240	pCi/l	0.009	0*	0.012	0.03	0.01*	0.000
Americium 241	pCi/l	0.000	0*	0.012	0	0.01*	0.019
Cesium 137	pCi/l	0.603	0.2*	0.776	0.4	0.3*	0.7*
Tritium	pCi/l	309	100*	505	100	100*	731

* - Maximum Detected Value
** - Minimum Detected Value
ND - Not Detected at Contract Required Detection Limit
() - Tolerance Internal Lower Limit for Two-Sided Parameter

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TABLE 2-2

BACKGROUND SURFACE WATER (ROUNDS 1 and 2)
TOLERANCE INTERVAL UPPER LIMITS
OR MAXIMUM DETECTED VALUE

Analyte	Units	Round 1 (9 samples) Total	Round 1 (9 samples) Dissolved	Round 2 (7 samples) Total	Round 2 (7 samples) Dissolved
Metals					
Aluminum	mg/l	64.10*	0.485*	8.444	0.454*
Antimony	mg/l	ND	ND	ND	ND
Arsenic	mg/l	0.116*	ND	ND	ND
Barium	mg/l	4.49*	ND	0.294*	ND
Beryllium	mg/l	0.0097*	ND	ND	ND
Cadmium	mg/l	0.0690*	ND	ND	ND
Calcium	mg/l	254.11	99.14	105.03	93.27
Cesium	mg/l	2.53*	ND	ND	ND
Chromium	mg/l	0.0598*	ND	0.0115*	ND
Cobalt	mg/l	0.0730*	ND	ND	ND
Copper	mg/l	0.180*	ND	ND	ND
Iron	mg/l	692.59	4.69*	12.070	0.453*
Lead	mg/l	0.233*	0.0055*	0.0308*	0.0131*
Lithium	mg/l	ND	ND	0.0192*	0.0166*
Magnesium	mg/l	27.71	11.98	17.578	15.74
Manganese	mg/l	1.140	0.826	1.101	0.232
Mercury	mg/l	0.001	0.002	0.004*	0.0004*
Molybdenum	mg/l	0.199*	ND	0.026	0.032
Nickel	mg/l	0.251*	ND	ND	ND
Potassium	mg/l	9.86*	ND	ND	ND
Selenium	mg/l	ND	ND	ND	ND
Silver	mg/l	0.148*	0.0125*	ND	ND
Sodium	mg/l	43.020	44.81	42.651	43.22
Strontium	mg/l	1.341	0.35	ND	ND
Thallium	mg/l	ND	ND	ND	ND
Tin	mg/l	0.969*	ND	ND	ND
Vanadium	mg/l	0.364*	ND	ND	ND
Zinc	mg/l	0.723*	.032	0.0892*	0.0228*

TABLE 2-2 (cont.)

BACKGROUND SURFACE WATER (ROUNDS 1 and 2)
TOLERANCE INTERVAL UPPER LIMITS
OR MAXIMUM DETECTED VALUE

Analyte	Units	Round 1 (9 samples) Total	Round 1 Dissolved	Round 2 (7 samples) Total	Round 2 Dissolved
Other					
Total Dissolved Solids	mg/l	329.52	NA	365.15	NA
Carbonate	mg/l	ND	NA	ND	NA
Bicarbonate	mg/l	389.72	NA	344.21	NA
Chloride	mg/l	89.11	NA	82.56	NA
Sulfate	mg/l	50.20	NA	65.30	NA
Nitrate	mg/l	2.45	NA	2.1*	NA
Cyanide	mg/l	ND	NA	0.0043*	NA
pH	----	9.02 (5.89)	NA	8.3 (6.44)	NA
Radionuclides					
Gross Alpha	pCi/l	266	5.805	106	NA
Gross Beta	pCi/l	213	9.335	79	NA
Uranium 233, 234	pCi/l	1.250	3.684	1.326	NA
Uranium 235	pCi/l	0.106	0.364	0.000	NA
Uranium 238	pCi/l	0.937	2.311	0.977	NA
Strontium 89, 90	pCi/l	2.160	1.452	1.243	NA
Plutonium 239, 240	pCi/l	1.066	0.017	0.112	NA
Americium 241	pCi/l	0.111	0.014	0.014	NA
Cesium 137	pCi/l	12.788	0.591	1.059	NA
Tritium	pCi/l	266	NA	863	NA

NA - Not Analyzed
ND - Not Detected
* - Maximum Detected Value
() - Tolerance Interval Lower Limit for Two-Sided Parameter

TABLE 2-3

BACKGROUND SEDIMENT
TOLERANCE INTERVAL UPPER LIMITS
OR MAXIMUM DETECTED VALUE

Analyte	Units	Upper Limit (9 Samples)
Total Metals		
Aluminum	mg/l	24789
Antimony	mg/l	ND
Arsenic	mg/l	13.0*
Barium	mg/l	182*
Beryllium	mg/l	ND
Cadmium	mg/l	ND
Calcium	mg/l	72551
Cesium	mg/l	ND
Chromium	mg/l	43.38
Cobalt	mg/l	ND
Copper	mg/l	22.0*
Iron	mg/l	28308
Lead	mg/l	39.502
Lithium	mg/l	ND
Magnesium	mg/l	4110*
Manganese	mg/l	372.20
Mercury	mg/l	ND
Molybdenum	mg/l	ND
Nickel	mg/l	29.9*
Potassium	mg/l	ND
Selenium	mg/l	ND
Silver	mg/l	6.8*
Sodium	mg/l	ND
Strontium	mg/l	175*
Thallium	mg/l	ND
Tin	mg/l	ND
Vanadium	mg/l	50.2*
Zinc	mg/l	92.688

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TABLE 2-3 (cont.)

BACKGROUND SEDIMENT
TOLERANCE INTERVAL UPPER LIMITS
OR MAXIMUM DETECTED VALUE

Analyte	Units	Upper Limit (9 Samples)
<u>Other</u>		
Nitrate	mg/l	ND
pH	----	9.03 (8.77)
<u>Total Radionuclides</u>		
Gross Alpha	pCi/l	60
Gross Beta	pCi/l	50
Uranium 233, 234	pCi/l	1.669
Uranium 235	pCi/l	0.176
Uranium 238	pCi/l	1.755
Strontium 89, 90	pCi/l	1.390
Plutonium 239, 240	pCi/l	0.096
Americium 241	pCi/l	0.029
Cesium 137	pCi/l	1.578
Tritium	pCi/l	0.408

ND - Not Detected
* - Maximum Detected Value
() - Tolerance Interval Lower Limit for Two-Sided Parameter

TABLE 2-4

BACKGROUND GEOLOGIC MATERIALS
TOLERANCE INTERVAL UPPER LIMITS
MAXIMUM DETECTED VALUE

Analyte	Units	Rocky Flats Alluvium (70 Samples)	Colluvium (28 Samples)	Weathered Claystone (17 Samples)	Weathered Sandstone (4 Samples)
Total Metals					
Aluminum	mg/l	25312	21663	13495	10300*
Antimony	mg/l	ND	ND	16.2*	ND
Arsenic	mg/l	15.86	7.7	15.05	3.6*
Barium	mg/l	155.8	345.8	240.1	165*
Beryllium	mg/l	11.27	17.75	11.8	2.2*
Cadmium	mg/l	3.2*	1.8*	ND	ND
Calcium	mg/l	43079	20811	10183	5940*
Cesium	mg/l	ND	274*	ND	ND
Chromium	mg/l	37.9	26.8	16.57	10.7*
Cobalt	mg/l	18.2*	15.9*	29.7*	20.5*
Copper	mg/l	20.03	26.7	30.62	19.6*
Iron	mg/l	22916	29991	41295	12300*
Lead	mg/l	18.04	26.4	34.5	13.4*
Lithium	mg/l	44.4	32.1	33.37	7.0*
Magnesium	mg/l	4425	6151	4896	2520*
Manganese	mg/l	422.9	545.1	656	305*
Mercury	mg/l	0.58*	0.44*	0.35*	0.27*
Molybdenum	mg/l	38.65	32.78	33.68	11.2*
Nickel	mg/l	43.27	35.4	56.95	14.3*
Potassium	mg/l	3336	2789	1400*	ND
Selenium	mg/l	ND	ND	ND	ND
Silver	mg/l	40.9*	33.5*	18.7*	12.7*
Sodium	mg/l	ND	3680*	ND	ND
Strontium	mg/l	226*	111.1	144.42	69.2*
Thallium	mg/l	ND	ND	ND	ND
Tin	mg/l	338*	441*	274*	268*
Vanadium	mg/l	54.67	58.2	47.7	22.2*
Zinc	mg/l	52.64	98.1	106.7	79.9*

TABLE 2-4 (cont.)

BACKGROUND GEOLOGIC MATERIALS
TOLERANCE INTERVAL UPPER LIMITS
MAXIMUM DETECTED VALUE

Analyte	Units	Rocky Flats Alluvium (70 Samples)	Colluvium (28 Samples)	Weathered Claystone (17 Samples)	Weathered Sandstone (4 Samples)
<u>Other</u>					
Sulfide	mg/l	13*	5*	5*	2*
Nitrate	mg/l	4.3*	4.274	2.0*	1.9*
pH	----	9.64 (6.06)	9.48 (6.96)	10.14 (7.04)	9.2* (8.0)**
<u>Total Radionuclides</u>					
Gross Alpha	pCi/l	37.108	51.710	52.302	37
Gross Beta	pCi/l	36.886	35.135	35.743	29
Uranium 233, 234	pCi/l	1.491	1.759	1.985	0.8
Uranium 235	pCi/l	0.087	0.169	0.258	0.1
Uranium 238	pCi/l	1.353	1.675	1.643	1.0
Strontium 89, 90	pCi/l	0.768	0.776	0.786	0.4
Plutonium 239, 240	pCi/l	0.017	0.023	0.020	0.01
Americium 241	pCi/l	0.018	NR	NR	NR
Cesium 137	pCi/l	0.082	0.113	ND	0.0
Tritium	pCi/l	0.410	0.299	0.322	0.39

ND - Not Detected
NR - Data Not Received
* - Maximum Detected Value
** - Minimum Detected Value
() - Tolerance Interval Lower Limit for Two-Sided Parameter

parameters listed in Table 2-5. Boreholes were drilled into SWMUs to the extent practical; however, boreholes were not drilled into sites still containing wastes (the trenches and 903 Pad) due to potential health hazards to field workers and potential for release of waste constituents to the environment. Figure 1-5 shows site locations, and Figure 2-1 shows Phase I RI borehole locations.

With the exception of plutonium and americium which occur in high concentrations in surface soils, other radionuclides and trace metals do not appear to be soil contaminants at the 903 Pad, Mound and East Trenches Areas. Trace metal and radionuclide concentrations have been compared to the upper limit of the background tolerance interval or background range as appropriate. Concentrations exceeding these limits are presented in Appendix A. The basis for this conclusion is discussed here, whereas organic plutonium, and americium contamination of soils is discussed on a site-by-site basis in subsequent sections.

Radionuclides are analyzed by counting sub-atomic particle emissions, which is a random function. Since radioactive disintegration is a statistical process and therefore has a probability distribution, results are reported as a measured value with an associated two standard deviation propagated error term indicated in parentheses immediately following the measured value. Radionuclide concentrations where the error term is larger than the measured value can be considered not statistically different from background because of the significant overlap of the probability distributions. On the other hand, if the measured value minus the error term for a sample is greater than the measured value plus the error term for the upper limit of the background range, it can be considered statistically different from background.

Table 2-6 presents the percent of samples for each radionuclide detected above background at the surface and in the subsurface. Examination of this table indicates that plutonium and americium are detected above background concentrations predominantly in the surface soil samples. Furthermore, plutonium and americium occur in some samples at concentrations significantly above their upper tolerance intervals. The highest detected

TABLE 2-5

PHASE I RI
SOURCE SAMPLING PARAMETERS
SOIL AND WASTE SAMPLES

METALS

Hazardous Substances List - Metals

- Aluminum
- Antimony
- Arsenic
- Barium
- Beryllium
- Cadmium
- Calcium
- Chromium
- Cobalt
- Copper
- Iron
- Lead
- Magnesium
- Manganese
- Mercury
- Nickel
- Potassium
- Selenium
- Silver
- Sodium
- Thallium
- Tin
- Vanadium
- Zinc

Other Metals

- Chromium (hexavalent)
- Chromium (trivalent)
- Lithium
- Strontium

ORGANICS

Hazardous Substances List -- Volatiles

- Chloromethane
- Bromomethane
- Vinyl Chloride
- Chloroethane
- Methylene Chloride
- Acetone
- Carbon Disulfide
- 1,1-Dichloroethene
- 1,1-Dichloroethane
- trans-1,2-Dichloroethene
- Chloroform
- 1,2-Dichloroethane
- 2-Butanone
- 1,1,1-Trichloroethane
- Carbon Tetrachloride
- Vinyl Acetate
- Bromodichloromethane
- 1,1,2,2-Tetrachloroethane
- 1,2-Dichloropropane
- trans-1,3-Dichloropropene
- Trichloroethene
- Dibromochloromethane
- 1,1,2-Trichloroethane
- Benzene
- cis-1,3-Dichloropropene

TABLE 2-5 (CONTINUED)

PHASE I RI
SOURCE SAMPLING PARAMETERS
SOIL AND WASTE SAMPLES

ORGANICS (CONT.)

Hazardous Substances List - Volatiles (Continued)

- 2-Chloroethyl Vinyl Ether
- Bromoform
- 2-Hexanone
- 4-Methyl-2-pentanone
- Tetrachloroethene
- Toluene
- Chlorobenzene
- Ethyl Benzene
- Styrene
- Total Xylenes

Hazardous Substances List -- Semi-Volatiles

- N-Nitrosodimethylamine
- Phenol
- Aniline
- bis(2-Chloroethyl)ether
- 2-Chlorophenol
- 1,3-Dichlorobenzene
- 1,4-Dichlorobenzene
- Benzyl Alcohol
- 1,2-Dichlorobenzene
- 2-Methylphenol
- bis(2-Chloroisopropyl)ether
- 4-Methylphenol
- N-Nitroso-Dipropylamine
- Hexachloroethane
- Nitrobenzene
- Isophorone
- 2-Nitrophenol
- 2,4-Dimethylphenol
- Benzoic Acid
- bis(2-Chloroethoxy)methane
- 2,4-Dichlorophenol
- 1,2,4-Trichlorobenzene
- Naphtalene
- 4-Chloroaniline
- Hexachlorobutadiene
- 4-Chloro-3-methylphenol(para-chloro-meta-cresol)
- 2-Methylnaphthalene
- Hexachlorocyclopentadiene
- 2,4,6-Trichlorophenol
- 2,4,5-Trichlorophenol
- 2-Chloronaphthalene
- 2-Nitroaniline
- Dimethyl Phthalate
- Acenaphthylene
- 3-Nitroaniline
- Acenaphthene
- 2,4-Dinitrophenol
- 4-Nitrophenol
- Dibenzofuran
- 2,4-Dinitrotoluene
- 2,6-Dinitrotoluene
- Diethylphthalate
- 4-Chlorophenyl Phenyl ether
- Fluorene
- 4-Nitroaniline
- 4,6-Dinitro-2-methylphenol

TABLE 2-5 (CONTINUED)

PHASE I RI
SOURCE SAMPLING PARAMETERS
SOIL AND WASTE SAMPLES

ORGANICS (CONT.)

Hazardous Substances List -- Semi-Volatiles (Continued)

- N-nitrosodiphenylamine
- 4-Bromophenyl Phenyl ether
- Hexachlorobenzene
- Pentachlorophenol
- Phenanthrene
- Anthracene
- Di-n-butylphthalate
- Fluoranthene
- Benzidine
- Pyrene
- Butyl Benzyl Phthalate
- 3,3'-Dichlorobenzidine
- Benzo(a)anthracene
- bis(2-ethylhexyl)phthalate
- Chrysene
- Di-n-octyl Phthalate
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Benzo(a)pyrene
- Indeno(1,2,3-cd)pyrene
- Dibenz(a,h)anthracene
- Benzo(g,h,i)perylene

Hazardous Substances List -- Pesticides/PCBS

- alpha-BHC
- beta-BHC
- delta-BHC
- gamma-BHC (Lindane)
- Heptachlor
- Aldrin
- Heptachlor Epoxide
- Endosulfan I
- Dieldrin
- 4,4'-DDE
- Endrin
- Endosulfan II
- 4,4'-DDD
- Endrin Aldehyde
- Endosulfan Sulfate
- 4,4'-DDT
- Endrin Ketone
- Methoxychlor
- Chlordane
- Toxaphene
- AROCLOR-1016
- AROCLOR-1221
- AROCLOR-1232
- AROCLOR-1242
- AROCLOR-1248
- AROCLOR-1254
- AROCLOR-1260

Other Organics

- Oil and Grease

TABLE 2-5 (CONTINUED)

PHASE I RI
SOURCE SAMPLING PARAMETERS
SOIL AND WASTE SAMPLES

RADIONUCLIDES	
	Gross Alpha
	Gross Beta
	Uranium 233+234, 235 and 238
	Americium 241
	Plutonium 239+240
	Strontium 89 + 90
	Cesium 137
	Tritium
OTHER	
	pH

TABLE 2-6

PERCENT OF SAMPLES WITH RADIONUCLIDES ABOVE BACKGROUND

Radionuclide	Percent of Surface Samples Above Background	Percent of Subsurface Samples Above Background
Uranium (Total)	4	8
Strontium 89 + 90	4	0
Plutonium 239 + 240	46	2
Americium 241	43	1
Cesium 137	11	2

concentrations for plutonium 239 + 240 and americium 241 were 180 $\pm$ 10 pCi/g and 22 $\pm$ 6 pCi/g, respectively. In contrast, uranium, strontium and cesium occur infrequently above background and are not localized in surficial materials (Appendix A). Moreover, the concentrations of these radionuclides were within a factor of approximately two of the upper limit of their background tolerance intervals and were random in vertical and horizontal occurrence. This suggests these concentrations represent natural variations outside the calculated background tolerance intervals.

In general, metal concentrations in soil samples from the 903 Pad, Mound, and East Trenches Areas were within the background levels (Appendix A). Metals which occurred above background include (parenthesis indicate percent of the samples exceeding the background range): antimony (0.4%), arsenic (18%), mercury (1.3%), cadmium (30%), manganese (7%), and barium (0.4%). None of these metal concentrations exceeded a factor of two of the upper limit of the background tolerance interval or range. The upper limit of background for arsenic and cadmium, which occurred more frequently above background than the other cited metals, was based on a maximum detection value rather than a tolerance interval. Thus, the concentrations of these metals in downgradient samples may actually be statistically insignificant. Because of the random and generally infrequent occurrence of elevated metal concentrations, the observed metal concentrations likely represent natural variations of metals in the soils.

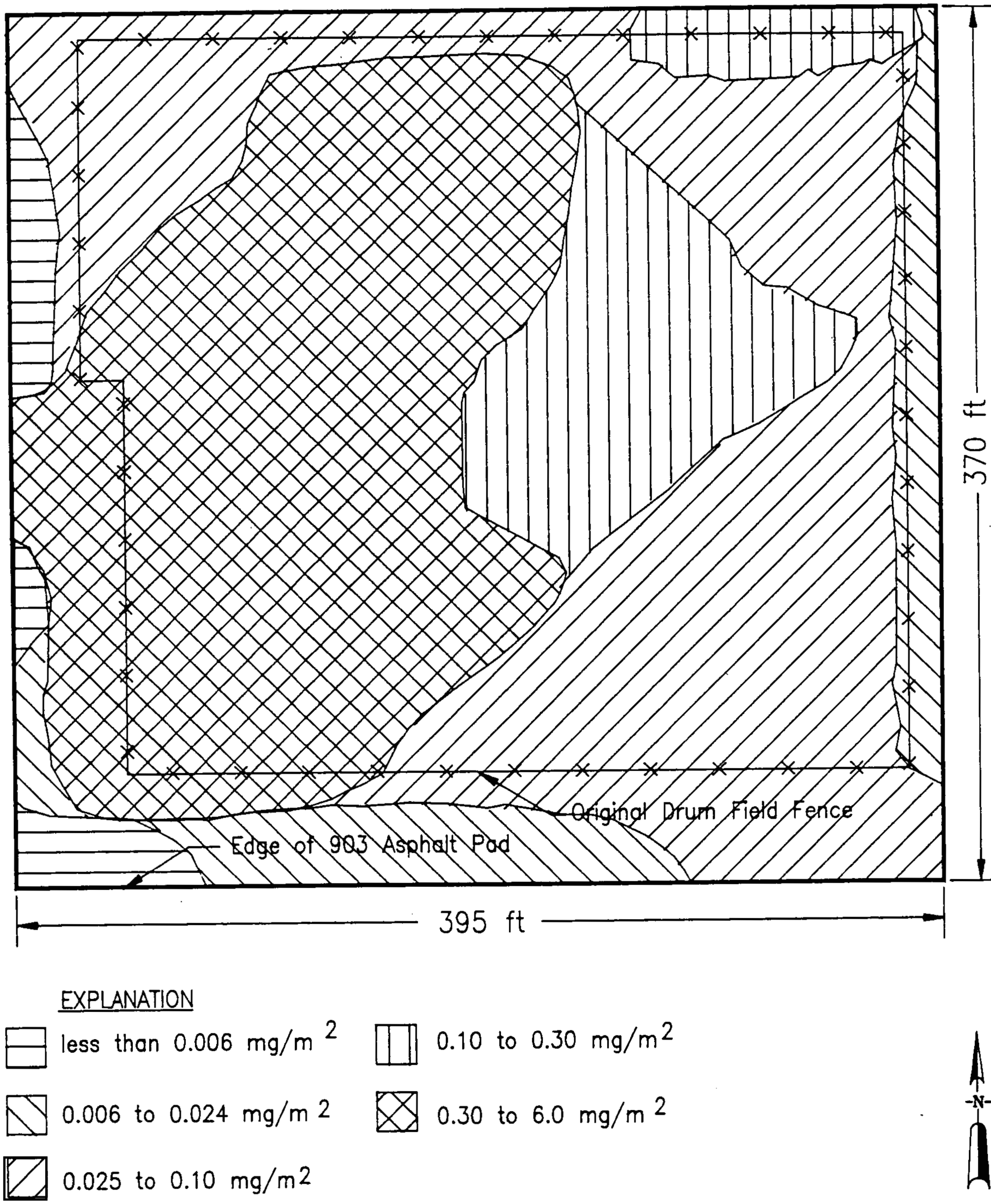
2.3.2.1 903 Pad Area

<u>903 Drum Storage Site (SWMU Ref No. 112)</u>

Prior to the emplacement of the asphalt cover at the 903 Pad, a plutonium surface survey was conducted in 1968 subsequent to drum removal (Owen, 1968). The results of this survey are presented in Figure 2-5. This survey indicates widespread contamination throughout the 903 Drum Storage Site. However, the highest survey values occur beneath the western half of the pad where drums were stored and Building 903 was located.

FIGURE 2-5

RESULTS OF 1968 PLUTONIUM SURFACE SURVEY
903 DRUM STORAGE SITE



This survey was conducted in 1968, prior to the placement of fill and asphalt containment cover. No correction has been made for penetration into soil. Results are relative.

Modified after Owen (1968)

After the emplacement of the asphalt cover, the soils beneath the 903 Pad were sampled in two sampling events for a total of ten excavations. The purpose of both sampling events was characterization of plutonium and uranium concentrations beneath the Pad; other contaminants were not described. The excavation locations are shown in Figure 2-6.

In the earlier of the two sampling events (Seed et. al, 1971), four excavation sites (Figure 2-6) were located on the basis of a gross gamma survey on the asphalt cover. Four - two to four square foot holes were hand dug to various depths. The total mass of plutonium yielded from excavations SW and NC were approximately 10 milligrams (mg) and 0.2 - 0.3 mg, respectively. Approximately 25 kg and 6 kg of depleted uranium were recovered from excavations No. 14 and No. 17, respectively. Reportedly, no sample contained both plutonium and uranium. Two conclusions drawn from this study pertinent to waste characterization are: (1) no evidence was found of radionuclides moving upwards from the original ground level into the fill material; and (2) at all four locations activity extended no more than one inch into a clay layer which was found 4-15 inches below the original ground surface. See Table 2-7 for a summary of the results.

In the later sampling event (Navratil et al., 1979), six soil samples (Figure 2-6) were taken from beneath the 903 Pad. These soil samples were examined to determine the extent and distribution of plutonium and americium. The average plutonium and americium concentrations reported for the six samples are shown in Table 2-8. A summary of pertinent conclusions drawn from this study are:

(1) plutonium and americium are associated with smaller soil fractions;

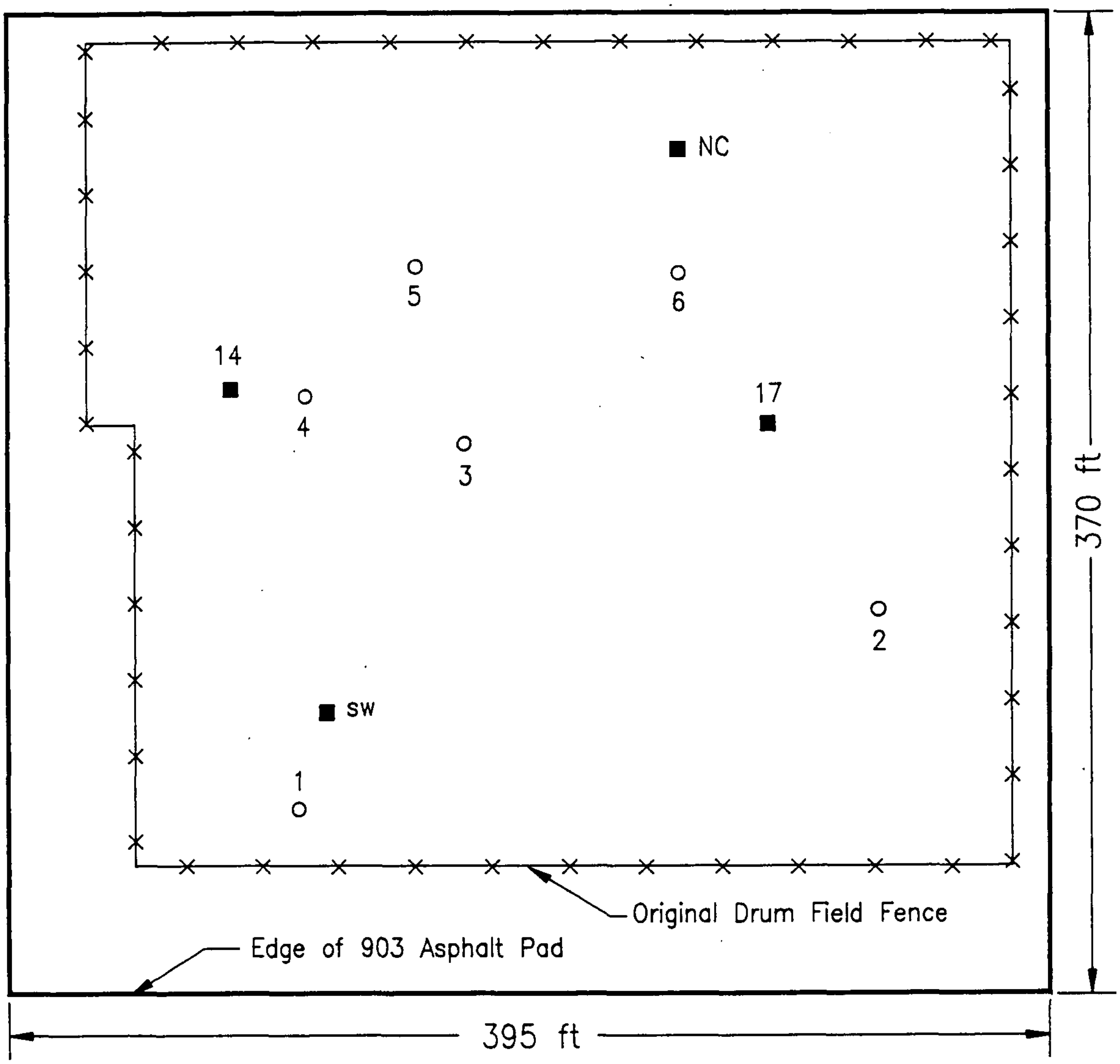
(2) an estimated 18,000 tons of contaminated soil underlies the asphalt pad; and

(3) experimental data on 903 Pad soil indicate that plutonium and americium soil contamination can be reduced by wet screening (Navratil et. al, 1979).

In summary, plutonium and americium are present beneath the 903 Pad and appear to be restricted to shallow depths below the original ground surface. The distribution of other contaminants in the soils beneath the 903 Pad, however, has not been investigated.

FIGURE 2-6

LOCATION OF SAMPLES FROM BENEATH THE 903 PAD



EXPLANATION

■ Sample reported in Seed et al. (1971)

o Sample reported in Navratil et al. (1979)

3 Sample Identifier (See text)

-N-

Modified after figure appended to Navratil et al. (1979)

TABLE 2-7

SUMMARY OF RESULTS REPORTED BY SEED ET AL. (1971)

Hole	Gamma Acvitity Thru Asphalt (cpm)	Maximum Gamma Reading in Hole (cpm)	Maximum α Reading in Hole (dpm)	Active Material	Where Activity First Detected	Vertical Thickness Activity Layer (inches) Below Original Ground Surface
No. 14*	55,000	3×10^6	5,000	Depleted Uranium	Original Ground Layer	6-8
SW	16,000	<16,000	20,000	Plutonium	Original Ground Layer	4-6
No. 17	35,000	2×10^6	5,000	Depleted Uranium	Original Ground Layer	1-2
NC	16,000	20,000	1,000	Plutonium	Original Ground Layer	<1

Table modified after Seed et al. (1971). Based on wet chemical analysis.

* This hole was identified as No. 32 in original table, however, review of text indicates this was mislabeled and should be hole No. 14 (no hole 32 was excavated).

CPM = Counts per minute

TABLE 2-8

SUMMARY OF RESULTS FOR SOIL SAMPLING BENEATH THE 903 PAD

Sample	Radionuclide Content				Sampling Depth from Top of Pad	
	Pu_{239} dpm/g	pCi/g	Am_{241} dpm/g	pCi/g	cm*	inches
1	940	427	620	282	46	18
2	1,400	636	1,100	500	61	24
3	8,000	3,636	1,000	455	56	22
4	45,000	20,455	4,200	1,909	66	26
5	14,000	6,364	4,100	1,864	61	24
6	17,000	7,727	5,000	2,273	61	24

Table modified from Navratil et al. (1979)

* The sampling depth shows the soil removal depth required to reach soil readings ≤250 dpm/g.

dpm/g = Disintegrations per minute per gram.

Hazardous Substances List (HSL) volatile organics were below detection limits in boreholes surrounding the 903 Pad. However, volatile organics are present in ground water at the site and are expected to be present in soils directly beneath the 903 Pad. Based on soil boring results, the extent of volatile organic soil contamination at the 903 Drum Storage Site appears to be confined to the area immediately beneath and adjacent to the pad. Additional boreholes will be drilled through and immediately adjacent to the pad during the Phase II RI to validate this conclusion.

903 Pad Lip Site (SWMU Ref. No. 155)

Based on results of a soil boring program (Rockwell International, 1987a), it appears that soil within the 903 Pad Lip Site is contaminated with plutonium, americium, and phthalates. Radionuclide contamination (plutonium and americium) appears to be limited to surficial soils, as these contaminants were only found in the uppermost samples; however, this conclusion will be confirmed during Phase II RI field activities.

Trench T-2 Site (SWMU Ref. No. 109)

Based on the Phase I RI results, soils in the vicinity of Trench T-2 are contaminated with plutonium, americium, trichloroethene (TCE), 1,1,1-trichloroethane (1,1,1-TCA), PCE, and possibly acetone and phthalates. Plutonium and americium contamination is particularly high in composite soil samples that include the ground surface, and volatile organic contamination is highest south of the trench in BH25-87. Plutonium was detected in the zero to nine foot composite sample at 3.2 ± 0.4 pCi/g, and americium was detected at 0.22 ± 0.18 pCi/g. The maximum concentrations of volatile organics detected in borehole BH25-87 were 16,000 micrograms per kilogram (μg/kg) of TCE, 10,000 μg/kg of PCE, 250 μg/kg of 1,1,1-TCA, and 1,100 μg/kg of acetone (also detected in the blank). It is postulated that radionuclide contamination originated from the 903 Drum Storage Site via wind dispersion, and that solvent contamination is due to a release from Trench T-2. Additional surficial soil sampling is necessary in the area to ascertain the depth of radionuclide contamination and additional boreholes in and around the trench are needed to define the extent of solvent contamination.

Reactive Metal Destruction Site (SWMU Ref. No. 140)

Solvent contamination in soils was found in BH28-87 at the Reactive Metal Destruction Site. PCE at 210 μg/kg, carbon tetrachloride (CCl_4) at 100 μg/kg, and carbon disulfide at 58 μg/kg were all above detection limits below the water table in BH28-87. Additional soil samples will be collected from this site during the Phase II RI to fully characterize the extent of soil contamination.

Plutonium was elevated above background levels in the surface and nine-foot bedrock samples from BH28-87. Surficial radionuclide contamination in this area is attributed to wind dispersal of plutonium from the 903 Drum Storage Site. Surficial soil sampling will be performed during the Phase II RI to confirm this hypothesis.

2.3.2.2 Mound Area

Mound Site (SWMU Ref. No. 113)

No volatile organic contamination was found in soil samples from the Mound Site during the Phase I investigation. Additional soil sampling of the surface materials will be performed in the area to identify possible impacts of radionuclide contamination resuspended from the 903 Drum Storage Site. Based on review of historical air photos, the Mound Site location was revised westward during preparation of the Phase I RI report. Additional boreholes are needed in the revised SWMU location.

Oil Burn Pit No. 2 Site and Trench T-1 Site (SWMU Ref. Nos. 153 and 108)

Analytical results indicated the presence of HSL organics in soil samples [acetone, methylene chloride, 1,2-dichloroethane (1,2-DCA), N-nitrosodiphenylamine, di-n-butyl phthalate, and bis(2-ethylhexyl) phthalate]. The detected volatiles are all estimated at concentrations below the detection limit or were present in the associated laboratory blanks at concentrations within a factor of two of the concentration in the sample (not reportable following CLP protocol). Of the semi-volatiles listed above, only bis(2- ethylhexyl)phthalate was found at non-estimated concentrations only slightly above the detection limits. Therefore, it is concluded that there is not significant organic contamination of soils in the vicinity of SWMUs 108 and 153. Additional soil samples will be collected during the Phase II RI to confirm this conclusion.

Plutonium and americium were elevated in composited surface soil samples adjacent to Trench T-1 (boreholes BH35-87 and BH36-87). Plutonium was detected at 1.5 $\pm$ 0.2 pCi/g and americium was detected at 0.30 $\pm$ 0.13 pCi/g in the 0 to 12 foot composite sample from borehole BH35-87. Plutonium was also detected at 0.53 $\pm$ 0.16 pCi/g in borehole BH36-87 (zero to five foot composite sample). Since radionuclide contamination is limited to soil samples which include the ground surface, wind dispersal of plutonium and americium from the 903 Drum Storage Site is the likely source of these contaminants. Surficial soils will be sampled at these sites to confirm this hypothesis.

Pallet Burn Site (SWMU Ref. No. 154)

Analytical results of soil samples from boreholes BH31-87 and BH32-87 indicate the presence of low concentrations of HSL organics. Maximum volatile organic levels in borehole BH31-87 were 32 μg/kg of 1,2-DCA, 110 μg/kg of acetone, and 20 μg/kg of PCE. Maximum volatile organic concentrations in borehole BH32-87 were 29 μg/kg of 1,2-DCA and 170 μg/kg of acetone. Soil sampling is needed to evaluate the depth and extent of the plutonium in soils. Furthermore, review of aerial photographs and historical documents during the Phase I RI resulted in revision of the Pallet Burn Site location as discussed in Section 1.0. Additional soil samples will therefore be collected from borings at both possible Pallet Burn Site locations during Phase II activities.

2.3.2.3 East Trenches Area

Trenches T-3, T-4, T-10, and T-11 (SWMU Ref. Nos. 110, 111.1, 111.7, and 111.8)

Plutonium was elevated in the surface sample from BH39-87 (0.82 $\pm$ 0.12 pCi/g). Additional surficial soil sampling is necessary within this group of trenches to characterize surficial radionuclide contamination.

HSL organics were either not present above detection limits or present as suspected laboratory contaminants in boreholes BH39-87 or BH40-87. However, volatile organics are present in well 3-74 north of Trench T-3, and 1,1,1-TCA was above detection limits in BH43-87 (maximum concentration of 130 μg/kg), BH45-87 (maximum concentration of 180 μg/kg), and BH46-87 (maximum concentration of 190 μg/kg). Additional soil sampling will be performed at these sites.

Trenches T-5 through T-9 (SWMU Ref. Nos. 111.2 through 111.6)

Based on analytical results of soil samples, 1,2-DCA, acetone, and plutonium are present in soils around the southern trenches. The 1,2-DCA contamination appears to be limited to bedrock samples, and acetone concentrations are also at depth. Additional soil sampling within these trenches is planned. Plutonium contamination is limited to the uppermost soil samples. Additional sampling will be performed to confirm that plutonium occurs only at the surface.

2.3.3 Ground Water

Presented below is a discussion of ground-water quality at the 903 Pad, Mound, and East Trenches Areas. Samples were analyzed for the parameters listed in Table 2-9. With respect to volatile organics, the discussion is based on the most recent data from the second quarter of 1989. With respect to inorganic chemistry, first quarter 1988 site data is compared to the appropriate tolerance intervals for background ground-water quality. First quarter 1988 data was chosen because it is the most recent data pertaining to the same season for which the background ground-water tolerance intervals were calculated.

2.3.3.1 Volatile Organic Contamination

Based on initial sampling results, CCl_4, PCE, and TCE are the primary volatile organic contaminants found in the unconfined ground-water flow system. Figures 2-7 through 2-9 graphically present data for these parameters for the second quarter 1989 for both unconfined alluvial and bedrock wells. Volatile organics data are presented in Appendix B, and Table 2-10 presents volatile organics above detection limits in the unconfined ground-water system.

Carbon Tetrachloride

Based on review of Figure 2-7, the 903 Pad and the northern East Trenches appear to be sources of CCl_4 ground-water contamination. Flow from the 903 Pad has transported CCl_4 to the east, southeast, and northeast away from the source. The highest concentrations of CCl_4 occurred in wells southeast of the pad (1-71 and 15-87).

Although it appears that CCl_4 has been transported by ground-water flow to the northeast, it also appears as if the northern East Trenches are a second source of CCl_4. CCl_4 concentrations are greater downgradient (in wells 36-87 and 42-86) of these trenches than they are upgradient of the trenches in wells 17-87 and 25-87. CCl_4 was not detected in the

TABLE 2-9

PHASE I RI
GROUND-WATER 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

- Aluminum
- Antimony
- Arsenic
- Barium
- Beryllium
- Cadmium
- Calcium
- Chromium
- Cobalt
- Copper
- Iron
- Lead
- Magnesium
- Manganese
- Mercury
- Nickel
- Potassium
- Selenium
- Silver
- Sodium
- Thallium
- Tin
- Vanadium
- Zinc

Other Metals

- Chromium (hexavalent)
- Lithium
- Strontium

ANIONS

- Carbonate
- Bicarbonate
- Chloride
- Sulfate
- Nitrate

ORGANICS

Oil and Grease

Hazardous Substances List - Volatiles***

- Chloromethane
- Bromomethane
- Vinyl Chloride
- Chloroethane
- Methylene Chloride
- Acetone
- Carbon Disulfide
- 1,1-Dichloroethene
- 1,1-Dichloroethane
- trans-1,2-Dichloroethene
- Chloroform

TABLE 2-9 (CONTINUED)
GROUND-WATER AND SURFACE WATER SAMPLING PARAMETERS

ORGANICS

Hazardous Substances List - Volatiles*** (Continued)

- 1,2-Dichloroethane
- 2-Butanone
- 1,1,1-Trichloroethane
- Carbon Tetrachloride
- Vinyl Acetate
- Bromodichloromethane
- 1,1,2,2-Tetrachloroethane
- 1,2-Dichloropropane
- trans-1,3-Dichloropropene
- Trichloroethene
- Dibromochloromethane
- 1,1,2-Trichloroethane
- Benzene
- cis-1,3-Dichloropropene
- 2-Chloroethyl Vinyl Ether
- Bromoform
- 2-Hexanone
- 4-Methyl-2-pentanone
- Tetrachloroethene
- Toluene
- Chlorobenzene
- Ethyl Benzene
- Styrene
- Total Xylenes

RADIONUCLIDES

- Gross Alpha
- Gross Beta
- Uranium 233+234, 235, and 238
- Americium 241
- Plutonium 239+240
- Strontium 90
- Cesium 137
- Tritium

* For surface water samples only
** Dissolved metals for ground-water samples, total and dissolved metals for surface water samples
*** Ground-water samples from the first quarter of 1987, and all surface water samples were analyzed for 9 of the HSL volatiles. These volatiles are the chlorinated solvents historically detected in the ground water and are as follows: PCE, TCE, 1,1-DCE, 1,2-DCA, t-1,2-DCE, 1,1,1-TCA, 1,1,2-TCA, CCl_4 and $CHCl_3$.

TABLE 2-10

VOLATILE ORGANIC COMPOUNDS DETECTED IN
UNCONFINED GROUND WATER
SECOND QUARTER 1989

Matrix	Well	Date Sampled	Carbon Tetra-chloride (ug/l)	Tetra-chloro-ethene (ug/l)	Trichloro-ethene (ug/l)	Chloro-form	Methylene Chloride	1,1-Di-Chloro-ethane (ug/l)	1,1-Di-Chloro-ethene (ug/l)	Vinyl Chloride (ug/l)	Acetone (ug/l)	Carbon Disulfide (ug/l)	Total-1,2-Dichloro-ethene (ug/l)	Toluene (ug/l)
Rocky Flats Alluvium	33-86	5/04/89	Dry											
	39-86	5/08/89												
	41-86	5/10/89												
	42-86	5/08/89	1,100	300	190	21J								
	43-86	5/04/89	Dry											
	10-87	5/02/89	Dry						5J					
	15-87	5/01/89	1,100J	190	120	21								
	17-87	5/03/89	47J	160R	17	4J								
	19-87	5/04/89	Dry											
	24-87	5/09/89	Dry											
	26-87	5/09/89	Dry											
	27-87	5/10/89	15	31	4J	3J								
	32-87	5/09/89	Dry											
	33-87	5/09/89	Dry											
	35-87	5/09/89	Dry											
Colluvium	63-86	4/13/89	Dry											
	67-86	5/09/89	Dry											
	29-87	4/24/89												
	44-87	4/13/89	Dry											
Valley Fill Alluvium	35-86	5/03/89			11			59	13	470			3J	
	36-86	5/04/89												
	37-86	5/03/89		30R										
	64-86	5/31/89		8J							2J			
	65-86	4/13/89										3J		
	66-86	6/02/89				26	1J							
	21-87	5/03/89												

TABLE 2-10

VOLATILE ORGANIC COMPOUNDS DETECTED IN
UNCONFINED GROUND WATER
SECOND QUARTER 1989

Matrix	Well	Date Sampled	Carbon Tetra-chloride (ug/l)	Tetra-chloro-ethene (ug/l)	Trichloro-ethene (ug/l)	Chloro-form	Methylene Chloride	1,1-Di-Chloro-ethane (ug/l)	1,1-Di-Chloro-ethene (ug/l)	Vinyl Chloride (ug/l)	Acetone (ug/l)	Carbon Disulfide (ug/l)	Total-1,2-Dichloro-ethene (ug/l)	Toluene (ug/l)
Weathered Claystone	1-71	5/01/89	690J	69	230	200			5J					
	2-71	5/01/89		8	440	7		8						
	1-74	5/03/89		45,000	1,800									
	3-74	5/08/89	1,100	50	25	11J								
Weathered Sandstone	62-86	4/17/89									2JB			
	9-87	5/01/89												
	11-87	5/02/89	Dry											
	12-87	5/02/89	Dry											
	14-87	4/24/89	160J	4J	68	16								
	23-87	5/03/89		74R										
	25-87	5/08/89	290	840	120	5J								
	36-87	5/08/89	610	350E	12,000	290E			22J					2J

J - Value estimated below detection limit
E - Value estimated
R - Value rejected by data validation
B - Compound also detected in associated blank.

Mound Area at well 1-74. The CCl_4 plume is not well defined downgradient of 903 Pad Area or the northern East Trenches.

Tetrachloroethene

Although PCE was detected in wells southeast (downgradient) of the 903 Pad and Trench T-2 (2-71, 15-87, and 1-71), the Mound Area appears to be the primary source of PCE within the study area (Figure 2-8). The highest concentration of PCE was detected within the Mound Area at well 1-74 [45,000 micrograms per liter (μg/l)]. A plume of PCE concentrations greater than 100 μg/l extends east (downgradient) from the Mound Area to at least well 36-87. The extent of this plume is not well defined.

Trichloroethene

All three RI areas appear to be sources of TCE based on review of Figure 2-9. Southeast of the 903 Pad and Trench T-2, TCE was detected in wells 1-71, 2-71, 14-87, and 15-87 indicating the 903 Drum Storage Site and possibly Trench T-2 and the Reactive Metal Destruction Site are TCE sources. TCE was also elevated at the Mound Area in wells 1-74, 17-87 and 35-86, indicating this area is yet another source. The highest concentration of TCE was detected downgradient of Trenches T-3 and T-4 in well 36-87 (12,000 μg/l). Thus, the northern East Trenches appear to be the major source of TCE in ground water. Low concentrations of TCE were estimated below detection limits downgradient of the southern East Trenches. The extent of TCE within alluvial ground water is not fully characterized.

2.3.3.2 Inorganic and Radionuclide Contamination

Unlike volatile organic compounds, inorganic compounds occur naturally in ground water. Inorganic contamination has been tentatively identified by comparing the ground-water chemistry at the 903 Pad, Mound and East Trenches Areas to the background ground-water tolerance intervals or ranges (Appendix B).

Thirteen wells were dry in the 903 Pad, Mound and East Trenches Areas during the first quarter of 1988 and two wells did not have sufficient water for analysis of inorganic compounds. Twenty-three wells were sampled for analysis of metals, radionuclides, and other inorganic compounds, and in every well at least one constituent was in excess of the associated background values (Table 2-11).

Major Ions

Major ions and total dissolved solids (TDS) are somewhat elevated above background throughout and downgradient of the 903 Pad, Mound, and East Trenches Areas. However, notably high concentrations were observed at wells 29-87 and 2-71. Well 29-87 is southeast of the 903 Pad at the South Interceptor Ditch. TDS, sulfate, chloride, sodium, and calcium were 3,219 milligrams per liter (mg/l), 891 mg/l, 819 mg/l, 395 mg/l, and 355 mg/l, respectively. Concentrations of these analytes at well 2-71 were 1,247 mg/l, 278 mg/l, 363 mg/l, 214 mg/l, and 117 mg/l, respectively. The high concentrations at well 29-87 appear to represent a localized source of salinity. The saline water at well 2-71 appears to be migrating south as ground water at well 11-87 is locally more elevated in these major ions.

Metals

Trace metals frequently occurring above background levels include strontium, zinc, nickel, and to a lesser extent chromium, manganese, and selenium. Strontium was generally less than one mg/l except at well 29-87 where the concentration was 4.95 mg/l. Isolated high concentrations of zinc and nickel occur in ground water at the Mound Area (1.5 mg/l and 0.52 mg/l respectively at well 19-87) and East Trenches Area (0.98 mg/l and 0.38 mg/l, respectively at well 32-87). High concentrations were also observed at well 29-87 (0.6 mg/l and 0.47 mg/l, respectively). Again, elevated trace metals in ground water at well 29-87 appears to reflect a local source for this contaminations.

TABLE 2-11

Dissolved Metal Inorganic and Dissolved Radionuclide Concentrations
Exceeding Background in Unconfined Ground Water
First Quarter 1988

Matrix	Well	Ba	Ca	Cr	Cu	Fe	Pb	Li	Mg	Mn
Rocky Flats Alluvium	33-86	Dry								
	39-86	A	B						B	
	41-86		B						B	
	42-86	A	B						B	
	43-86	Dry								
	10-87	Dry								
	15-87		B	A					B	
	17-87		B		B				B	
	19-87	Dry								
	24-87	Dry								
	26-87	Dry								
	32-87		B		B				B	
	33-87	Dry								
	35-87	Dry								
Colluvium	63-86	Dry								
	67-86	Dry								
	29-87		C	A	A				C	C
	44-87	Dry								
Valley Fill Alluvium	35-86		B						B	C
	36-86	Dry								
	37-86	Insufficient Sample for Analyses								
	64-86							BJ		
	65-86									
	66-86									
	21-87	Insufficient Sample for Analyses								
Weathered Claystone	1-71	A				A				
	2-71		C			A			CJ	
	1-74		C							
	3-74		C							

Matrix	Well	Mo	Ni	K	Se	Ag	Na	Sr	V	Zn
Rocky Flats Alluvium	33-86									
	39-86						B	C		
	41-86						B	C		
	42-86						B	C		C
	43-86									
	10-87									
	15-87					A		C		C
	17-87		C				B	C		
	19-87									
	24-87									
	26-87									
	32-87		C				B	C		A
	33-87									
	35-87									
Colluvium	63-86									
	67-86									
	29-87		A	A	A		C	A		A
	44-87									
Valley Fill Alluvium	35-86						B			C
	36-86									
	37-86									
	64-86	A	A				B			
	65-86									C
	66-86		A							C
	21-87									
Weathered Claystone	1-71									
	2-71	C		A		A		C	A	
	1-74									
	3-74									

TABLE 2-11

Dissolved Metal Inorganic and Dissolved Radionuclide Concentrations
Exceeding Background in Unconfined Ground Water
First Quarter 1988

Matrix	Well	Ba	Ca	Cr	Cu	Fe	Pb	Li	Mg	Mn	Mo	Ni	K	Se	Ag	Na	Sr	V	Zn
Weathered Sandstone	62-86			C					C			A	A	A		C			
	9-87		C																
	11-87		C					CJ	C	C		A		A		C			
	12-87							C				A				C			
	14-87			C				CJ					A	A		C		A	A
	23-87		C				A		C										
	25-87		C																
	36-87		C																A

TABLE 2-11

Dissolved Metal Inorganic and Dissolved Radionuclide Concentrations Exceeding Background in Unconfined Ground Water First Quarter 1988

Matrix	Well	TDS	Cl	NO_3	SO_4	HCO_3	CO_3	CN	Alpha	Beta	U233-U234	U235	U238	Pu239, Pu240	Am241
Rocky Flats Alluvium	33-86	Dry													
	39-86	B	B	B			NR	NR	B				B		
	41-86	B	B	B	B		NR	NR		B	B	B	B		
	42-86	B	B	B			NR	NR			B		B		
	43-86	Dry													
	10-87	Dry													
	15-87	B	B	B			NR	NR					B		
	17-87	B	B				NR	NR			B		B		
	19-87	Dry													
	24-87	Dry													
	26-87	Dry													
	32-87	B	B	B	B		NR	NR			B		B		
Colluvium	63-86	Dry													
	67-86	Dry													
	29-87	C	C	C	C		NR	NR		B	B		B		
	44-87	Dry													
Valley Fill Alluvium	35-86	B	B				NR								
	36-86	Dry													
	37-86	Insuffcent Sample for Analyses													
	64-86		B		B		NR	NR							
	65-86		B				NR	NR							
	66-86		B				NR	NR							
	21-87	Insufficient Sample for Analyses													
Weathered Claystone	1-71		C	C			NR	NR							
	2-71	C	C	C	C		NR	NR			C		C		
	1-74	C	C	C			NR	NR							
	3-74	C	C	C			NR	NR							

TABLE 2-11

Dissolved Metal Inorganic and Dissolved Radionuclide Concentrations
Exceeding Background in Unconfined Ground Water
First Quarter 1988

Matrix	Well	TDS	Cl	NO_3	SO_4	HCO_3	CO_3	CN	Alpha	Beta	U233-U234	U235	U238	Pu239, Pu240	Am241
Weathered Sandstone	62-86	C	C				NR	NR	C						
	9-87	C		C	C		NR	NR			NR	NR	NR		NR
	11-87	C	C		C	C	NR	NR	C		C		C		NR
	12-87	C	C				NR	NR	C	C	C	C	C	NR	
	14-87	C	C				A	NR		C					
	23-87	C	C	C			NR	NR			C		C		
	25-87	C	C	C			NR	NR			C		C		
	36-87	C	C	C			NR	NR	C	C	C	C	C		

A - In excess of minimum detection limit used in background.
B - In excess of upper tolerance limit.
C - In excess of maximum concentration detected in background.
NR - Analysis not performed.
J - Present below detection limit.

No detects above background for any well: Al, As, Be, Cd, Cs, Co, Hg, Tl

Analysis not performed for: Sn, pH, Sr_{89+90}, Cs_{137}, Ra_{226}

Radionuclides

Uranium 238 is the most widely distributed isotope of uranium present above background at the 903 Pad, Mound and East Trenches Areas, although there also are above background occurrences of uranium 233 + 234 and uranium 235. Other radionuclides were not detected above background.

With respect to the 903 Pad Area, the maximum concentration of uranium 238 detected is 28 ± 2 pCi/l at well 12-87 (weathered sandstone completion). This well is within the 903 Lip Site and downgradient of the 903 Pad. Other wells within or downgradient of the 903 Pad Area which exhibit uranium 238 in excess of background are wells 2-71 (inferred weathered claystone completion), 11-87 (weathered sandstone completion), 15-87 (Rocky Flats Alluvium completion), and 29-87 (colluvium completion). Delineating the edge of the uranium 238 plume are three wells downgradient of the 903 Pad where uranium 238 was detected at background. These wells are 62-86 and 14-87 (weathered sandstone completions) and 01-71 (inferred weathered claystone completion). The presence of uranium 238 at background in 14-87 suggests that the uranium 238 detected at 29-87 (10 ± 1 pCi/l) may be from a local source.

Uranium 238 has been detected above background in the Mound Area in wells 23-87 (weathered sandstone completion) and well 17-87 (Rocky Flats Alluvium completion). The limit of uranium 238 contamination is in the vicinity of wells 1-74 (weathered claystone completion) and 35-86 (valley fill alluvium completion) which do not exhibit uranium 238 above background.

Uranium 238 has been detected above background in the East Trenches Area in the following wells: 25-87 and 36-87 (weathered sandstone completions); 42-86, 32-87, 41-86 and 39-86 (Rocky Flats Alluvium completions). The areal distribution of uranium 238 near the East Trenches is not well defined. The only well that exhibited uranium 238 at background levels is 3-74 (weathered claystone completion) which is downgradient of Trenches T-3 and T-4.

2.3.4 Surface Water

Twenty-six surface water and surface seep samples in the vicinity of the 903 Pad, Mound, and East Trenches Areas were collected during field activities. The following discussion is based on volatile organic data from June 1989 (water was present at most stations and all data have been received and validated), and inorganic and radiochemistry data from first round 1989 surface water sampling (March 1 - May 1). The latter data are compared to first round 1989 background data to preliminarily assess if inorganic or radionuclide contamination exist at these stations.

A discussion of surface water chemistry for the 903 Pad, Mound, and East Trenches Areas is also one of ground-water chemistry as most of the surface water samples collected for this investigation are from seeps that represent the surfacing of ground water. In addition there is frequent interaction of surface water and ground water in the drainages. The seeps are ponded water located downslope and southeast of the 903 Pad Area or located downslope and north of the Mound Area. Surface water flowing in drainages was sampled at stations on the South Interceptor Ditch and Woman Creek just upstream of Pond C-2 and at stations upstream of the B series ponds on South Walnut Creek. The B series ponds were not sampled for this investigation, as they will be subsequently investigated as part of another operable unit. Surface water locations are shown on Figure 2-10 and data are presented in Appendix C.

2.3.4.1 Surface Water Stations Southeast of 903 Pad Area

There are many seeps downslope to the southeast of the 903 Pad. On-site surface water stations established at these seeps are designated SW-50, SW-51, SW-52, SW-53, SW-55, SW-57, SW-58, and SW-77. Off-site downgradient stations include SW-62, SW-63, and SW-64 (seeps); SW-27, SW-30, SW-54, and SW-70 (South Interceptor Ditch); and SW-26, SW-28, and SW-29 (Woman Creek).

With the exception of SW-58, all of the on-site seeps contain TCE at concentrations less than 50 $\mu g/l$, and there are spatially sporadic occurrences of PCE, chloroform ($CHCl_3$), CCl_4, 1,2-dichloroethene (1,2-DCE), and acetone. SW-64 was the only downgradient off-site seep where volatile organic contamination was observed (TCE = 12$\mu g/l$; $CHCl_3$ = 27 $\mu g/l$). The volatile organic concentrations in these seeps suggest that a solvent plume within alluvial ground water is migrating to the southeast, which is consistent with the alluvial ground-water flow direction. However, volatile organics have not been detected at surface water stations on the South Interceptor Ditch and Woman Creek.

With respect to inorganic and radionuclide contamination, there are somewhat elevated concentrations of TDS, major ions, strontium, zinc, and uranium at most of these stations. Unlike the absence of volatiles in surface water at stations along the South Interceptor Ditch (SW-70, SW-30, SW-54, and SW-27), all have somewhat elevated uranium concentrations (uranium 238 and uranium 233 + 234 each less than five pCi/l). Although the 903 Pad Area can not be ruled out as the source of the uranium, the occurrence of elevated uranium as far upgradient as SW-70 suggests the 881 Hillside Area as a potential source. Alluvial ground water at the 881 Hillside contains above background levels of uranium.

The 1987 radiochemistry data indicated elevated plutonium and americium concentrations in the seeps southeast of the 903 Drum Storage Site. It is postulated that this represents particulate forms of these radionuclides originating from contaminated soils at the surface. This is concluded because:

1) the seeps represent surfacing ground water, and ground water does not appear to be contaminated with these radionuclides;

2) the seep samples contained substantial suspended solids and were not filtered prior to analysis; and

3) surface soils are contaminated with plutonium in the vicinity of these seeps.

Surface water (and ground-water) sampling at these stations will continue for the Phase II RI to better define surface water/ground-water interaction and the extent of contamination. Samples will be analyzed for both total and dissolved radionuclides and metals.

2.3.4.2 Upper South Walnut Creek

At the Mound Area, station SW-60 is a corrugated metal pipe discharging South Walnut Creek flow which originates to the west of SW-56 (not sampled in 1989). Station SW-56 and SW-101 are on a ditch that appears to be seepage from the base of the hill to the south. The ditch is not part of the main flow of South Walnut Creek, as the creek is routed beneath this area by the corrugated metal pipe. Water in the ditch eventually discharges to South Walnut Creek through a concrete pipe (SW-61). The flow in South Walnut Creek upstream of Pond B-4 is primarily the combined flow from the discharge of these pipes (SW-60 and SW-61). A spring located at the base of the hill to the south and downstream of SW-60 and SW-61 was also sampled (SW-59).

The upper reach of South Walnut Creek, as characterized by the discharge at SW-60, contains CCl_4 (74 μg/l) and lesser concentrations of PCE, TCE, and $CHCl_3$. It also contains above background levels of strontium, zinc, nitrates, TDS, and uranium. The nitrate, uranium, and major ion concentrations are typical of the alluvial ground water in the vicinity of the 903 Pad and Mound Areas. CCl_4, PCE, TCE, and elevated zinc are also present in the alluvial ground water at the Mound Area. However, flow through this pipe originates inside the perimeter security zone (PSZ). The source of this surface water contamination will be investigated as part of another operable unit at the Plant.

The flow at SW-101 discharges downstream through a culvert at SW-61. At SW-101, $CHCl_3$ was 66 μg/l, TCE was 5 μg/l, and PCE was 14 μg/l. At SW-61, $CHCl_3$ was absent; however, TCE and PCE were present at similar levels, and CCl_4 was present at 33 μg/l. Dissolved zinc and total uranium concentrations were just above background limits at SW-61 (no data are available for SW-101). Although $CHCl_3$ has only been estimated below detection limits in ground water at the Mound Area, this area is a suspected source of volatile organics in South Walnut Creek.

The seep, SW-59, located downstream of the confluence of SW-60 and SW-61, has elevated nitrate and major ion concentrations that are similar to alluvial ground water of the Mound Area. Radionuclides were at background concentrations, but strontium and zinc were significantly elevated. Also, of note was the presence of volatile organics. 1,1,1-TCA was 15 μg/l, $CHCl_3$ was 20 μg/l, CCl_4 was 200 μg/l, TCE was 60 μg/l, and PCE was 57 μg/l. TCE, PCE, and CCl_4 are elevated in the alluvial ground water of the Mound Area. There may also be a very localized source of 1,1,1-TCA and $CHCl_3$ at the Mound Area contributing to the contamination at this seep.

Further surface water (and ground-water sampling) and analysis will be conducted to better define the extent and source of the contamination. However, potential sources outside the Mound Area will be investigated as another operable unit.

2.3.4.3 Seeps at the East Trenches Areas

Of the three seeps at the East Trenches Areas (SW-65, SW-102, and SW-103), SW-65 had no organic contamination, SW-102 was dry, and SW-101 had 7 μg/l of CCl_4. Numerous trace metals, nitrate and cyanide, were elevated at these stations, and major ions and TDS were somewhat elevated. Total uranium was also elevated at SW-103. Like the 903 Pad and Mound Areas, the chemistry of these seeps is similar to the local ground water.

Sampling of both surface water and ground water will continue to better define the extent of surface and ground-water contamination in this area.

2.3.5 Sediments

Sediment stations have been established along the Woman Creek and the South Walnut Creek drainages. As shown on Figure 2-10, stations SED-28, SED-29, and SED-25 are located within the South Interceptor Ditch in the Woman Creek drainage. SED-30 and SED-31 are seeps on the South Interceptor Ditch berm near station SED-29. SED-27 and SED-26 are along Woman Creek just upstream of Pond C-2. Stations SED-11, SED-12, and SED-13 are located along South Walnut Creek. SED-11 is the most upgradient station, SED-12 is just upstream of Pond B-1, and SED-13 is just downstream of Pond B-5.

Data discussed herein are for samples collected in March 1989. Volatile organic compound concentrations and concentrations of inorganic analytes and radionuclides that are above the background tolerance interval or range are presented in Appendix D.

2.3.5.1 Woman Creek Drainage

With the exception of acetone which was present in the sediment sample from SED-30 at 200 mg/kg, there were no volatile organic compounds present above detection limits in the sediments of the Woman Creek drainage. The acetone also was present in the blank for this sample and was undetected in two other sampling events for this station in 1989. Acetone is not a likely sediment contaminant at this location.

Of the metals, beryllium, silver, and tin were notably elevated above background in the sediment of the South Interceptor Ditch and Woman Creek. Concentrations of silver are greater than five times the upper limit of the background range (as high as 49.1 mg/kg) at stations SED-29, SED-30, and SED-25. Beryllium was not detected in the background samples (<1.1 mg/kg) but occurs at concentrations ranging from 3.8 to 15.0 mg/kg in all the sediment samples collected from the South Interceptor Ditch and Woman Creek. Although tin was not above background (<22.8 mg/kg) at SED-27, SED-28, and SED-31, it occurred in a range from 364 to 819 mg/kg in stations SED-25, SED-26, SED-29, and SED-30.

Of the radionuclide data that exist for the March 1989 sampling, it is noted that plutonium was above background at stations SED-25, SED-26, SED-29, and SED-30, ranging in concentration from 0.3 to 3.3 pCi/g. This is likely attributable to wind dissemination of plutonium contaminated surface soil from the 903 Pad Area.

2.3.5.2 South Walnut Creek Drainage

Limited 1989 data exist for the three sediment stations on South Walnut Creek. There is no data for SED-12 and SED-13, and only volatiles, metals, and other inorganics data exist for SED-11.

At SED-11, $CHCL_3$, CCl_4, TCE, and PCE were present at 10, 52, 17, and 39 μg/kg, respectively. This is consistent with the data for SW-61 that indicates these are surface water contaminants at this location.

Similar to the Woman Creek drainage, beryllium, silver, and tin are elevated in the sediments at SED-11. They occurred at concentrations of 2.5, 15.0, and 404 mg/kg, respectively. Zinc, which is a known contaminant of ground water and surface water in this vicinity, was also notably elevated occurring at a concentration of 735 mg/kg (the upper limit of the background tolerance interval is 93 mg/kg).

Sediment samples were taken in October 1989 at stations along South Walnut Creek as well as Woman Creek and the South Interceptor Ditch. The resulting data should suffice as confirmatory information regarding the concentrations of volatile organics, metals, other inorganics, and radionuclides in the sediments. For the Phase II RI, physical characteristics of the sediments (background and "downgradient") and the spatial distribution of the metal concentrations will be examined to assess the adequacy of the background sediment geochemical characterization and thus whether metals are contaminants in the sediments at the 903 Pad, Mound, and East Trenches Areas.

2.3.6 Air

Air quality studies at the Plant are performed continuously and reported annually in the Annual Environmental Monitoring Reports (e.g., Rockwell International, 1975 through 1985, 1986b, and 1987b). In addition, the air pathway was further characterized in Rockwell International (1986f).

Air samplers for routine ambient air monitoring at the Plant are located at various locations on and off the Plant site. The ambient air program monitors radionuclide concentrations; conventional air quality parameters are also monitored on site at a dedicated location inside the perimeter security fence, west of the East Guard Gate.

The Plant Radioactive Ambient Air Monitoring Program (RAAMP) consists of 51 high-volume particulate air samplers which operate continuously. Twenty-three of the 51 samplers are within or directly adjacent to the Plant security area (on-site samplers) and 14 are located around the property boundary (perimeter samplers). An additional 14 samplers are located in neighboring towns (community samplers).

The 903 Pad Area is recognized as the principal source of airborne plutonium contamination at the Plant. Historically, the particulate samplers located immediately east, southeast, and northeast of the 903 Pad, Mound, and East Trenches Areas have shown the highest plutonium concentrations. This finding is corroborated by the results of soil surveys which indicate elevated plutonium concentrations to the east, particularly the southeast of the area. However, the RAAMP has found ambient air samples to be well within applicable regulations and guidelines for the protection of human health and the environment for all radioactive contaminants (Rockwell International, 1987a).

2.3.7 Biota

The biota at the 903 Pad, Mound and East Trenches Area have been previously studied. A survey was conducted for the Final Environmental Impact Statement, Rocky Flats Plant Site (U. S. DOE, 1980), and previous studies were summarized in the Radioecology and Airborne Pathway Data Summary Report (Rockwell International, 1986f). The Radioecology and Airborne Pathway Data Summary Report addresses the plutonium released from the 903 Drum Storage Site and its effects on the immediate environment. Field studies were conducted over several years which compared various biological measurements and pathological data between ecologically similar study areas of widely varying plutonium levels. Soil plutonium concentrations were measured along with biological measurements such as vegetation community structure and biomass, litter mass, arthropod community structure and biomass, small mammal species occurrence, population density, biomass, reproduction, and physical size of whole carcasses and organs. In addition, pathological examination of small mammals, including x-ray for skeletal sarcomas, microscopy for lung tumors, and necropsy for general pathology and parasite occurrence were carried out.

It concluded that:

> "while minor differences in certain biological attributes between study areas were observed, none could be related to plutonium levels. Pathological conditions and parasites were found in some rodents, but occurrence frequencies between control and contaminated areas were similar. No evidence of cancers or other radiogenic diseases was found. These observations and measurements, combined with intensive field observations over a period of five years, led to the conclusion that plutonium contamination at Rocky Flats has not produced demonstrable ecological changes. Furthermore, the levels of plutonium observed in tissues of plants and animals in contaminated areas were insufficient to produce the doses that would be required to produce obvious biological changes. Subcellular biological changes, such as chromosome aberrations, cannot be ruled out at Rocky Flats. However, even if chromosome aberration frequencies were increased in the more highly contaminated areas, population-level changes would likely not persist because of the surrounding reservoir of normal genetic information, and of natural selection."
>
> "Based on all the plutonium work conduced in the terrestrial environs at Rocky Flats, there is strong evidence that the element is not likely to pose an ecological hazard unless extremely high levels (greater than one milliCurie per square meter) occur. The major reason for this is the extremely low geological mobility of the common chemical forms of the element amply demonstrated in this and other research. Although, uncertainty exists as to possible long-term changes in biological availability of plutonium, we expect gradual soil penetration and dispersion to diminish the present hazard potential with time" (Whicker, 1979).

Aquatic studies, conducted by Colorado State University, examined phytoplankton, some detritus and small zooplankton uptake of plutonium from the B-series holding ponds. This study showed than an "increase in trophic-level concentration of plutonium did not occur apparently due to a selective mechanism that discriminated against plutonium at this level. This would result in a decreased potential hazard when considering the transfer of plutonium through ingestion routes" (Paine, 1980).

Other aquatic studies revealed that 77% of the plutonium associated with crayfish is found in their exoskeleton. Fish flesh and bone from the A and C-series ponds were never above the minimum detectable activity for plutonium.

2.4 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Section 121(d) of CERCLA, as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), requires that Fund-financed, enforcement, and Federal facility remedial actions comply with applicable or relevant and appropriate (ARAR) Federal laws, or more stringent promulgated State laws.

Health-based, chemical-specific ARARs pertinent to ground-water quality have been identified for the EPA TCL organic and Target Analyte List (TAL) inorganic compounds found above detectable levels. Radionuclides and conventional pollutants have also been identified and screened. Chemical-specific ARARs are derived primarily from federal and state health and environmental statutes and regulations. Health effect assessments, health advisories, chemical advisories, and guidance documents were also considered when establishing clean-up standards, but were not considered to be ARARs. These and any proposed standards are classified as items to be considered (TBCs). A summary of chemical-specific ARARs for the contaminants found at the 903 Pad, Mound, and East Trench Areas is presented in Table 2-12. When more than one chemical-specific ARAR was identified for a contaminant, a screening process was used to determine the specific ARAR to be applied. This screening process involves three steps as outlined below:

TABLE 2-12
CHEMICAL SPECIFIC ARARs
FOR COMPOUNDS AND ELEMENTS DETECTED
AT THE 903 PAD, MOUND, AND EAST TRENCHES

Chemical	Maximum Concentration in Ground Water[a]	ARAR (ug/l)	Standard Criteria or Guidance	Comment
Organic Compounds				
Vinyl Chloride	520	2	SDWA MCL is applicable	ARAR is exceeded
Carbon Tetrachloride	1100	5	CDH Surface Water Drinking Water Standard is applicable	ARAR is exceeded
1,1 Dichloroethane	59	5U	RCRA Subpart F Substance is to be Considered (TBC)	Appendix IX Substance; TBC is exceeded
Chloroform	330	100	SDWA standard for total trihalomethanes is applicable	ARAR is exceeded
1,1 Dichloroethene	32	7	CDH Surface Water Drinking Water Standard is applicable	ARAR is exceeded
Tetrachloroethene	33,000	5U	CDH Surface Water; Fish and Water Ingestion Standard is applicable	ARAR is exceeded
1,1,1 Trichloroethane	63	200	CDH Surface Water Drinking Water Standard is applicable	ARAR is not exceeded
1,1,2,2-Tetrachloroethane	45,000	5U	RCRA Subpart F is R&A	ARAR is exceeded
Trichloroethene	49,000	5	CDH Surface Water; Drinking Water Standard is applicable	ARAR is exceeded

TABLE 2-12 (cont.)
CHEMICAL SPECIFIC ARARs
FOR COMPOUNDS AND ELEMENTS DETECTED
AT THE 903 PAD, MOUND, AND EAST TRENCHES

Chemical	Maximum Concentration in Ground Water[b] (mg/l)	ARAR (mg/l)	Standard Criteria or Guidance	Comment
Metals				
Aluminum	2.68	5.0	CDH Agriculture Standard is applicable	ARAR is not exceeded
Antimony	0.118	0.06U	RCRA Subpart F is R&A	ARAR is exceeded
Arsenic	0.040	0.05	CDH Surface Water; Drinking Water Standard is applicable	ARAR is not exceeded
Barium	0.932	1.0	CDH Surface Water; Drinking Water Standard is applicable	ARAR is not exceeded
Cadmium	0.006	0.01	CDH Surface Water; Drinking Water Standard is applicable	ARAR is not exceeded
Calcium	991	NS	No Standard	--
Chromium III	0.122	.05	CDH Surface Water; Drinking Water Standard is applicable	Analytical result is total chromium. ARAR may be exceeded
Chromium VI	0.122	.05	CDH Surface Water; Drinking Water Standard is applicable	Analytical result is total chromium. ARAR may be exceeded
Copper	0.836	0.2	CDH Ground Water; Agriculture Standard is applicable	ARAR is exceeded

TABLE 2-12 (cont.)
CHEMICAL SPECIFIC ARARs
FOR COMPOUNDS AND ELEMENTS DETECTED
AT THE 903 PAD, MOUND, AND EAST TRENCHES

Chemical	Maximum Concentration in Ground Water[b] (mg/l)	ARAR (mg/l)	Standard Criteria or Guidance	Comment
<u>Metals (cont.)</u>				
Iron	4.35	0.3	CDH Surface Water; Drinking Water Standard is applicable	Analytical results are soluble iron; soluble iron exceeds ARAR
Lead	0.024	0.05	CDH Surface Water; Drinking Water Standard is applicable	ARAR is not exceeded
Lithium	0.22	2.5	CDH Ground Water Standard is applicable	ARAR is not exceeded
Magnesium	136	NS	No Standard	--
Manganese	1.27	0.05	CDH Surface Water; Drinking Water Standard is applicable	Analytical results are soluble manganese; ARAR is exceeded
Mercury	0.013	0.002	CDH Surface Water; Drinking Water Standard is applicable	ARAR is exceeded
Molybdenum	0.135	0.1	CDH Ground Water; Agriculture Standard is applicable	ARAR is exceeded
Nickel	1.41	0.2	CDH Ground Water Agriculture Standard is applicable	ARAR is exceeded
Potassium	31	NS	No Standard	--
Selenium	0.37	0.01	CDH Surface Water; Drinking Water Standard is applicable	ARAR is exceeded

TABLE 2-12 (cont.)
CHEMICAL SPECIFIC ARARs
FOR COMPOUNDS AND ELEMENTS DETECTED
AT THE 903 PAD, MOUND, AND EAST TRENCHES

Chemical	Maximum Concentration in Ground Water[b] (mg/l)	ARAR (mg/l)	Standard Criteria or Guidance	Comment
Metals (cont.)				
Silver	0.128	0.05	CDH Surface Water; Drinking Water Standard is applicable	ARAR is exceeded
Sodium	405	NS	No Standard	--
Strontium	7.71	NS	No Standard	Background is TBC. TBC is exceeded
Vanadium	0.245	0.1	CDH Ground Water; Agriculture Standard is applicable	ARAR is exceeded
Zinc	2.77	2.0	CDH Ground Water; Agriculture Standard is applicable	ARAR is exceeded

TABLE 2-12 (cont.)
CHEMICAL SPECIFIC ARARs
FOR COMPOUNDS AND ELEMENTS DETECTED
AT THE 903 PAD, MOUND, AND EAST TRENCHES

Chemical	Maximum Concentration in Ground Water[b] (mg/l)	ARAR (mg/l)	Standard Criteria or Guidance	Comment
Conventional Pollutants				
Nitrite	15.4	1.0	CDH Ground Water Standard is applicable	Analytical results are total nitrate plus nitrate nitrogen. Reanalysis required to determine if nitrite ARAR is exceeded
Nitrate	15.4	10.0	CDH Ground Water Standard is applicable	Analytical results are total nitrate nitrogen. Results indicate that nitrate ARAR is exceeded
Chloride	947	250	CDH Ground Water Standard is applicable	ARAR is exceeded
Sulfate	1157	250	CDH Ground Water Standard is applicable	ARAR is exceeded
Bicarbonate as $CaCO_3$	642	NS	No Standard	
T.D.S.	3219	400	CDH Ground Water Standard is applicable	ARAR is exceeded

TABLE 2-12 (cont.)
CHEMICAL SPECIFIC ARARs
FOR COMPOUNDS AND ELEMENTS DETECTED
AT THE 903 PAD, MOUND, AND EAST TRENCHES

Chemical	Maximum Concentration in Ground Water[b] (pCi/l)	ARAR (pCi/l)	Standard Criteria or Guidance	Comment
Radionuclides				
Gross Alpha	250	15	CDH Ground Water Standard is is applicable	ARAR is exceeded
Gross Beta	327	50	SDWA MCL is applicable	ARAR is exceeded
$Pu^{238,239,240}$	0.522	15	CDH Surface Water Standard is applicable	ARAR is not exceeded
Am^{241}	0.831	4	CDH Surface Water Standard is applicable	ARAR is not exceeded
H^{3}	560	20,000	CDH Surface Water Standard is applicable	ARAR is not exceeded
$Sr^{89,90}$	5.0	8	CDH Surface Water Standard is applicable	ARAR is not exceeded
$Uranium^{total}$	62	40	CDH Surface Water Standard is applicable	ARAR is exceeded

(a) - Maximum compound concentrations determined from first and second quarter 1989 data.
(b) - Maximum compound concentrations determined from 1987 and 1988 database.
U - Detection limit
J - Estimated below detection limit
B - Compound also present in blank
TBC - To be considered
(c) - Below minimum detectable activity (MDA)

1. The most stringent human health or agricultural-based promulgated standard among the Safe Drinking Water Act (SDWA), Maximum Contaminant Level (MCL), and CDH ground and surface water standards was first applied (applicable).

2. For a RCRA Appendix VIII hazardous constituent, in the absence of any promulgated standard in step 1 above, the most stringent RCRA Land Disposal Restriction or RCRA Subpart F limit was applied (relevant and appropriate).

3. In the absence of an ARAR in steps 1 or 2 above, the most stringent of the Clean Water Act Water Quality Criteria, or the proposed CDH ground-water and surface water standards was applied (TBC).

The screening process includes consideration of both ground-water and surface water standards because of the significant interaction of alluvial ground water and surface water in the drainages of the Rocky Flats Plant. Of the elements/compounds detected in alluvial ground water at the 903 Pad, Mound, and East Trenches Areas, there are no ARARs for calcium, magnesium, potassium, sodium, bicarbonate, and strontium. However, the TDS ARAR establishes the acceptable aggregate concentration for the above major ions (excludes strontium). Until an acceptable risk based concentration is established for strontium, its background concentration is TBC.

As can be seen in Table 2-12, several of the volatile organics, metals, and major ions that were analyzed have exceeded chemical-specific ARARs during the period 1987 to 1989 at some location in the 903 Pad, Mound, and East Trenches Areas. This is not to say that releases of these constituents are occurring, for the concentrations of some substances may be due to a past release or to natural geochemical processes. However, the listing of Table 2-12 has been presented to identify parameters for which analyses should be made in Phase II and their respective minimum acceptable detection limits. The FS will evaluate technologies that address these constituents.

2.5 SAMPLING AND ANALYSIS REQUIREMENTS FOR REMEDIAL ALTERNATIVES EVALUATION

The purpose of this section is to identify potential remedial technologies which are consistent with the available information regarding contamination at Operable Unit No. 2.

Based on the available site information, the contaminated media or areas for which remedial alternatives will be developed include wastes, soil/sediment, ground water, and surface water. The following preliminary general remedial response actions have been identified for further review and evaluation:

- Complete or partial removal of wastes and contaminated soils;
- In-situ contaminated soils treatment;
- Ground-water collection;
- Infiltration and ground-water containment controls;
- In-situ ground-water treatment/immobilization; and
- Ground-water/surface water treatment.

In addition, combinations of these general response actions may be appropriate and will be evaluated during the FS. Table 2-13 presents these general response actions along with potential component technologies.

As shown in Table 2-14, there are specific requirements that are necessary to evaluate the preliminarily identified technologies. These data will provide for a thorough comparative evaluation of the technologies with respect to implementability, effectiveness, and cost, and allow for informed decisions to be made with respect to selection of preferred technologies. The Field Sampling Plan (Section 5.0) reflects these information requirements.

TABLE 2-13

RESPONSE ACTIONS AND REMEDIAL TECHNOLOGIES

GENERAL RESPONSE ACTIONS	ASSOCIATED REMEDIAL TECHNOLOGIES
Complete or Partial Removal of Contaminated Soils	• Off-Site Landfill • On-Site Treatment*/Backfill
In-Situ Contaminated Soils Treatment	• Immobilization • Soil Flushing • Vapor Extraction
Ground-Water Collection	• Well Array • Subsurface Drains
Infiltration and Ground-Water Containment Controls	• Capping • Subsurface Barriers
In-Situ Ground-Water Treatment/ Immobilization	• Immobilization • Aeration • Bioreclamation
Ground-Water/Surface Water Treatment	• Biological Treatment • UV/Peroxide or UV/Ozone • Air Stripping • Carbon Adsorption • Ion Exchange • Electrodialysis • Reverse Osmosis

* Thermal Treatment, Solvent Extraction, Attrition Scrubbing for Plutonium Decontamination

TABLE 2-14

REMEDIAL TECHNOLOGY DATA REQUIREMENTS

TECHNOLOGY	DATA PURPOSE	DATA NEEDED
Off-Site Disposal	Evaluate RCRA Land Ban and Radioactivity Restrictions	- 40 CFR 268 Table CCWE and Appendix III Analyses - Full Suite of Radionuclide Analyses
	Cost Analysis	- Vertical and Horizontal Extent* of Contamination
Thermal Treatment	Effectiveness	- Full Suite of Organic and Inorganic Analyses*
	Cost Effectiveness	- BTU Content
Attrition Scrubbing	Effectiveness	- Gradation (sieve analysis) - Full Suite of Radionuclide Analyses for each soil fraction
	Secondary Waste Characteristics	- Full Suite of Organic Analyses
Solvent Extraction	Effectiveness (adsorption characteristics of soils)	- Soil Type - Soil Organic Matter Content
Immobilization (soils)	Determine Viscosity of Grout Material	- Soil Grain Size Distribution (sieve analysis)
Soil Flushing/Bioreclamation	Effectiveness	- Soil Organic Matter Content - Soil Classification - Soil Permeability - BOD
Vapor Extraction	Effectiveness	- Subsurface Geological Characteristics - Depth to Ground Water - Soil Permeability
Well Array/Subsurface Drain	Storativity (transient flow)	- Aquifer tests
Capping/Subsurface Barriers	Suitability of On-Site Soils for Use	- Gradation (Sieve Analysis) - Atterberg Limits (Plasticity Tests) - % Moisture - Compaction (Proctor) - Permeability (Triaxial Permeability) - Strength (Triaxial or Direct Shear)

TABLE 2-14 (cont.)

REMEDIAL TECHNOLOGY DATA REQUIREMENTS

TECHNOLOGY	DATA PURPOSE	DATA NEEDED
Capping/Subsurface Barriers (continued)	Effectiveness	- Location of Subcropping Sandstones - Hydraulic Conductivity of Bedrock Materials
	Construction Feasibility	- Grade - Depth to Bedrock
Immobilization (Ground Water Contaminants)	Determine Viscosity of Grout Material	- Soil Grain Size Distribution (sieve analysis)
In-Situ Aeration (Ground Water)	Effectiveness	- Subsurface Geological Characteristics - Depth to Ground Water - Soil Permeability
In-Situ Bioreclamation (Ground Water)	Effectiveness	- Soil Organic Matter Content - Soil Classification - Soil Permeability - BOD - Dissolved Oxygen - NO_3, PO_4^{3-}, pH
Above Ground Biological Treatment	Effectiveness	- Soil Organic Matter Content - Soil Classification - Soil Permeability - BOD
UV Peroxide Oxidation	Process Control	- Iron and Manganese
Air Stripping	Process Control	- Hardness
Other Water Treatment Technologies	*	- *

* The nature and extent of contamination determined through soils and water analyses for the parameters listed in Tables 2-5 and 2-9 is critical to determining the technical feasibility and cost effectiveness of the technologies listed here.

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4) Unconfined ground-water flow occurs in surficial materials, subcropping sandstones, and potentially in weathered subcropping claystones. The flow system in surficial materials is not fully saturated year round. Flow in weathered claystones has not been sufficiently documented, and flow directions in subcropping sandstones are poorly defined due to the complex stratigraphy.

5) Confined ground-water flow occurs in deeper sandstones. This flow system is poorly defined at this time due to the complex stratigraphy and facies changes.

6) Ground-water recharge occurs as infiltration of incident precipitation and flow from ditches and surface water drainages.

7) Discharge from the unconfined ground-water flow system occurs as evapotranspiration, seeps and springs at the edge of the Rocky Flats pediment, to surface water in Woman Creek and South Walnut Creek, and to bedrock sandstones.

8) Wastes have been removed from the 903 Drum Storage Site, the Pallet Burn Site, the Oil Drum Pit No. 2 Site, and the Mound Site. Wastes remain in place in all eleven trenches within the area. Further characterization of potential contaminant sources is warranted.

9) Boreholes were drilled adjacent to SWMUs in the Phase I RI, and soil samples were collected and analyzed for HSL organics and metals, radionuclides, and inorganics. Further characterization of soils beneath SWMUs is needed.

10) Surficial soils in the area are contaminated with plutonium, americium, and possibly uranium due to wind dispersal of these radionuclides during clean-up of the 903 Drum Storage Site in the late 1960s. Based on soil sampling results, these compounds appear to be limited to the surface; although further definition of their extent is needed.

11) The unconfined ground-water flow system contains volatile organic compounds The principal volatile organics present are PCE, CCL_4, and TCE. The extent of these contaminants in alluvial ground water has not been fully determined.

12) Radionuclides were elevated in sediment and unfiltered surface water samples collected during the Phase I RI. Wind dispersal of radionuclides during clean-up of the 903 Drum Storage Site is the likely source of these contaminants; although confirmation of this hypothesis is needed.

3.2 SITE-SPECIFIC PHASE II RI OBJECTIVES AND DATA NEEDS

Based on the Phase I RI conclusions and the conceptual site model presented in Section 2.0, the site-specific Phase II RI objectives and associated data needs have been developed (Table 3-1). Specific plans for obtaining the needed data are presented in Section 5.0 (Field Sampling Plan).

3.0 PHASE II RI/FS WORK PLAN DATA QUALITY OBJECTIVES

The primary objective of a RI is to collect the data necessary to determine the nature, distribution, and migration pathways of contaminants. The RI also supports the evaluation of remedial alternatives (U.S. EPA, 1987). The five general goals of a RI are:

1) characterize site physical features;
2) define contaminant sources;
3) determine the nature and extent of contamination;
4) describe contaminant fate and transport; and
5) provide a baseline risk assessment (U.S. EPA, 1988a).

Data quality objectives (DQOs) are qualitative and quantitative statements which specify the quality and quantity of data collection required by the RI (U.S. EPA, 1987). Through application of the DQO process, site-specific RI/FS goals are established, and data needs are identified for achieving those goals. This section of the RI/FS Work Plan reviews conclusions from the Phase I RI as a basis for Phase II RI objectives and identifies data needs to meet the outlined objectives.

3.1 PHASE I RI CONCLUSIONS

Several investigations have been conducted in the vicinity of the 903 Pad, Mound, and East Trenches to date as discussed in Sections 1.0 and 2.0. General conclusions from these investigations are as follows.

1) Surficial materials in the area consist of Rocky Flats Alluvium, colluvium and valley fill alluvium.
2) Bedrock beneath surficial materials consists of Arapahoe Formation claystones and sandstones dipping slightly to the east (approximately 1.5 degrees). Bedrock materials are weathered below the base of surficial materials in the study area.
3) The bedrock stratigraphy is complex because numerous subcropping sandstones occur within the claystones which appear to be lenticular and discontinuous (A seismic geophysical program is underway to further characterize the location and extent of bedrock sandstones and claystones).

TABLE 3-1

Objective	Data Need
Characterize Site Physical Features	
1) Determine the extent of saturation and ground-water flow directions for the unconfined flow system both spatially and temporally.	- Install additional monitoring wells and piezometers. - Maintain a database of water levels from which potentiometric surface maps, saturated thickness maps, cross sections, and hydrographs can be prepared.
2) Describe the interaction between the surface water and ground-water pathways.	- Compare water levels and water quality data from surface water sampling locations and ground-water monitoring wells to evaluate the interconnection between these two media. Data analysis will also rely on ground-water flow directions and seep locations.
3) Quantify material properties	- Perform aquifer tests to develop hydraulic conductivity and storativity values for surficial materials.
Characterize Contaminant Sources	
1) Characterize the nature and distribution of waste materials remaining on-site.	- Collect samples from boreholes drilled directly through SWMUs where possible. Collect waste samples as well as soil samples from beneath the wastes. Analyze samples for TCL volatiles, semi-volatiles, and pesticides/PCBs, TAL metals, as well as radionuclides and inorganics.
2) Characterize soils beneath wastes as well as soils at sites where wastes have been removed as potential contaminant sources.	- Same as above.
3) Identify which sites are sources of volatile organic compounds in ground water.	- Install alluvial ground-water monitoring wells directly beneath sites to assess ground-water levels and quality. - Install alluvial ground-water monitoring wells directly up- and downgradient of each site to pinpoint the source of volatile organic compounds.

TABLE 3-1 (continued)

Objective	Data Need
Characterize the Nature and Extent of Contamination	
1) Determine the horizontal and vertical extent of surficial radionuclide soil contamination due to wind dispersion.	- Collect surficial soil scrapes following Colorado Department of Health sampling procedures and analyze for radionuclides. To define the horizontal extent of radionuclide contamination, these samples will be collected within the RI study area as well as in the Plant buffer zone.
	- To define the vertical extent of radionuclide migration into the soil profile, collect soil samples from test pits dug in the same areas as surficial soil sample collection.
2) Determine the nature and extent of ground-water contamination in surficial materials.	- Install alluvial ground-water monitoring wells in surficial materials located between areas of known ground-water contamination and areas with no ground-water contamination to delineate the extent of volatile organic compounds. Collect ground-water samples and analyze for TCL volatiles, semi-volatiles and pesticides/PCBs, TAL metals, radionuclides, and inorganics
3) Characterize surface water quality.	- Continue collection of surface water and sediment samples from existing monitoring stations on a quarterly basis. Analyze samples for TCL volatiles, TAL metals, radionuclides, and inorganics. Analyze surface water samples for both dissolved and total metals and radionuclides to determine if constituents are suspended or dissolved. Continue routine flow rate measurements at surface water stations.
Provide A Baseline Risk Assessment	
1) Describe contaminant fate and transport.	- Use existing literature and field data to describe the physicochemical processes associated with site contaminants.

TABLE 3-1 (continued)

Objective		Data Need
Provide A Baseline Risk Assessment		
2)	Assess the threat to public health and the environment from the no action remedial alternative.	- Prepare a baseline risk assessment as part of the RI data analysis based on Phase I and Phase II RI results.

The highest quality data possible will be collected by following the Rocky Flats Plant ER Program Standard Operating Procedures (SOP) and through adherence to the Rocky Flats Plant ER Program Quality Assurance/Quality Control (QA/QC) Plan. Organic and metal analyses will be performed using CLP routine analytical services (RAS), and other analyses (radionuclides and inorganics) will be performed in accordance with the QA/QC plan specified methods. In addition, analytical methods with detection limits below or near chemical-specific ARARs (Table 3-2) will be used to facilitate comparison of resulting data to ARARs.

TABLE 3-2

COMPARISON OF CHEMICAL-SPECIFIC ARARS AND TBCS TO ANALYTICAL DETECTION LIMITS

ANALYTE	ARAR OR TBC	DETECTION LIMIT
Copper	0.2 mg/l	0.025 mg/l
Iron	0.3 mg/l	0.1 mg/l
Manganese	0.05 mg/l	0.015 mg/l
Mercury	0.002 mg/l	0.0002 mg/l
Molybdenum	0.1 mg/l	0.04 mg/l
Nickel	0.2 mg/l	0.04 mg/l
Selenium	0.01 mg/l	0.005 mg/l
Thallium	0.015 mg/l	0.01 mg/l
Zinc	2.0 mg/l	0.02 mg/l
Cobalt	0.05 mg/l	0.05 mg/l
Vanadium	0.1 mg/l	0.05 mg/l
Carbon Tetrachloride	0.005 mg/l	0.005 mg/l
1,1-Dichloroethene	0.007 mg/l	0.005 mg/l
Chloroform	0.10 mg/l	0.005 mg/l
1,2-Dichloroethane	0.005 mg/l	0.005 mg/l
t-1,2-Dichloroethene	0.00003 mg/l	0.005 mg/l
Methylene Chloride	0.005 mg/l	0.005 mg/l
Tetrachloroethene	0.005 mg/l	0.005 mg/l
1,1,1-Trichloroethane	0.20 mg/l	0.005 mg/l
Trichloroethene	0.005 mg/l	0.005 mg/l
Vinyl Chloride	0.002 mg/l	0.01 mg/l*
Gross Alpha	15 pCi/l	2 pCi/l
Gross Beta	50 pCi/l	4 pCi/l
Pu ^{238,239,240}	15 pCi/l	0.01 pCi/l
Americium ^{241}	4 pCi/l	0.01 pCi/l
Strontium ^{90}	8 pCi/l	1 pCi/l
Uranium ^{total}	40 pCi/l	0.6 pCi/l
Chloride	250 mg/l	5 mg/l
Sulfate	250 mg/l	5 mg/l
Total Dissolved Solids	400 mg/l	5 mg/l

* Detection limit exceeds ARAR or TBC.
TBC = to be considered

4.0 REMEDIAL INVESTIGATION/FEASIBILITY STUDY TASKS

4.1 REMEDIAL INVESTIGATION TASKS

4.1.1 Task 1 - Project Planning

The project planning task includes all efforts required to initiate this Phase II RI of Operable Unit No. 2. Activities undertaken for this project have included detailed review of the Phase I RI results as well as other previous investigation results, review of historical aerial photography, preliminary evaluation of ARARs, and scoping of the Phase II RI. Results of these activities are presented in Sections 2.0 (Introduction) and 3.0 (Phase I RI Site Evaluation).

During the Phase I RI, complex bedrock stratigraphy was recognized beneath the 903 Pad, Mound, and East Trenches Areas. A seismic reflection program is currently being implemented to further define the location, extent, and orientation of bedrock sandstone units beneath the area. Results of this investigation will be evaluated in scoping of the Phase III RI for Operable Unit No. 2.

Two project planning documents, including this Work Plan, have been prepared which pertain to this Phase II RI as required by the draft Inter-Agency Agreement between DOE, EPA, and CDH. This Work Plan presents results of the project planning task in addition to plans for the Phase II RI. A Field Sampling Plan (FSP) is included in this document which presents the locations, media, and frequency of sampling efforts. The second document required by the IAG is a Sampling and Analysis Plan (SAP). Included in the SAP are a Quality Assurance Project Plan (QAPP) and Standard Operating Procedures (SOP) for all field activities. The current versions (January 1989) of the Rocky Flats Plant ER Program QAPP (Rockwell International, 1989e) and SOP have been submitted previously to EPA and CDH. The QAPP and SOP are being revised and will be submitted in July 1990 in accordance with the draft IAG.

4.1.2 Task 2 - Community Relations

In accordance with the draft IAG, the Communications Department at Rocky Flats is developing a Plant-wide Community Relations Plan to actively involve the public in the decision-making process as it relates to environmental restoration activities. A work plan has been completed and forwarded to EPA, CDH, and the public for review. The work plan specifies activities planned to complete the Plant-wide Community Relations Plan, including plans for community interviews. The draft Community Survey Plan will be completed in January 1990, and the draft Community Relations Plan will be completed in September 1990 in accordance with the draft IAG schedules. Accordingly, a site-specific Community Relations Plan is not required for Operable Unit No. 2.

The Communications Department also is continuing other public information efforts to keep the public informed of environmental restoration activities and other issues which relate to Plant operations. A Speakers Bureau program sends speakers to civic groups and educational organizations, while a public tour program allows the public to visit Rocky Flats. Road tours of areas such as the 903 Pad, Mound and East Trenches Areas are common during public tours, as well as other tours arranged for public officials. An Outreach Program also is in place where Plant officials will visit elected officials, the news media, and business and civic organizations to further discuss issues related to Rocky Flats and environmental restoration activities. The Communications Department also receives numerous public inquiries which are answered during telephone conversations, or by sending written informational materials to the requestor.

4.1.3 Task 3 - Field Investigation

The Phase II RI/FS field investigation is designed to meet the objectives outlined in Section 4.0. The following activities will be performed as part of the field investigation:

- Drill and sample soils and wastes within SWMUs;
- Sample surficial soils for radionuclides;
- Install and sample alluvial ground-water monitoring wells;
- Perform aquifer tests and geotechnical tests;
- Collect surface water and sediment samples.

Sample locations, frequency, and analyses are presented in Section 6.0. All field activities will be performed in accordance with the Rocky Flats Plant ER Program SOP.

4.1.4 Task 4 - Sample Analysis and Data Validation

Analytical methods for chemical analyses are provided in the ER Program QA/QC Plan (Rockwell International, 1989e). Also provided in this document are the analytical detection limits, sample container and volume requirements, preservation requirements, and sample holding times.

Data will be reviewed and validated by the ER Program staff. Results of data review and validation activities will be documented in data validation reports. EPA data validation functional guidelines will be used for validating organic and inorganic (metals) data (U.S. EPA, 1988b). Validation methods for radiochemistry and major ions data have not been published by the EPA; however, data and documentation requirements have been developed by ER Program QA staff. Data validation methods for these data are derived from these requirements. Details of the data validation process are described in the QA/QC Plan (Rockwell International, 1989e).

4.1.5 Task 5 - Data Evaluation

Data collected during the Phase II RI will be incorporated into the existing database and used to better define site characteristics, source characteristics, and the nature and extent of contamination, and to support the evaluation of proposed remedial alternatives.

4.1.5.1 Site Characterization

Geologic and hydrologic data will be incorporated into existing site maps and cross-sections. Geologic data will be used to detail the stratigraphy of surficial materials and weathered bedrock within source areas and to map the eastern extent of paleochannels in the top of bedrock. Hydrologic data will be used to evaluate seasonal variations in water levels, ground-water flow and the extent of saturated surficial materials. Also evaluated will be storativity, ground-water velocity and the interaction between ground water and surface water.

4.1.5.2 Source Characterization

Analytical data from source boreholes will be used to:

- Verify SWMU locations;
- Characterize the nature of source contaminants;
- Characterize the lateral and vertical extent of source contaminants
- Determine the maximum on-site contaminant concentrations; and
- Quantify the volume of source materials.

At those SWMU locations which are trenches, geologic data from the source boreholes will determine the vertical extent of the trenches and will characterize any matrix material encountered.

4.1.5.3 Nature and Extent of Contamination

Analytical data from soil, sediment, ground-water, and surface water sampling efforts will be used to characterize the nature and extent of contamination. The criteria for the identification of contamination will be analyte specific. For volatile organic compounds, any detectable concentrations in samples that are not attributable to laboratory contamination will be considered likely evidence of contamination. For inorganic compounds (including radionuclides) only those concentrations which exceed expected concentrations in background shall constitute evidence of contamination. The statistical techniques which shall be used to compare concentrations of inorganic compounds collected as part of the Phase II RI to background concentrations are documented in the Background Geochemical Characterization Report (Rockwell International, 1989d). Essential to the implementation of these statistical techniques for ground-water and borehole samples is the classification of each analytical datum by an appropriate geologic unit (such as Rocky Flats Alluvium or colluvium). This identification of the appropriate geologic unit will be based on geological data collected during the Phase II RI.

The extent of contamination will be delineated through the use of contaminant isopleths maps and possibly cross sections. The possibility of using kriging to contour the isopleths of the most widely distributed contaminants will be investigated, and kriged contours will be generated if appropriate. Investigations to date indicate difficulty in identifying the source of contamination because of the close proximity of several possible sources. The statistical technique of principal component analysis will be investigated as a method of identifying the effects of multiple sources. The ability to estimate the individual effects of multiple sources at intermediate sampling sites will aid in the mapping of plumes and in the understanding of the transport of contaminants by the ground-water flow system.

Comparisons of analytical data from ground water and surface water will be made to investigate the movement of contaminants from one pathway to another. Temporal variations of contaminant concentrations in ground water and surface water will be evaluated both for seasonality and long-term trends.

Analytical data from surficial soil scrapes and vertical soil profiles will be evaluated in order to characterize the areal and vertical distribution of plutonium and americium contamination in remedial investigation areas and in other Plant areas (buffer zone) to the south and east.

4.1.5.4 Evaluation of Proposed Remedial Alternatives

The evaluation of proposed remedial alternatives will be based primarily on the information derived for the purpose of site characterization and source characterization. Geotechnical data from source boreholes will be used to evaluate the effectiveness of:

- attrition scrubbing;
- solvent extraction;
- soil immobilization;
- soil flushing/bioreclamation; and
- capping/subsurface barriers.

4.1.6 Task 6 - Baseline Risk Assessment

A baseline risk assessment will be prepared for the 903 Pad, Mound, and East Trenches Areas as part of the Phase II RI/FS to evaluate the potential threat to the public health and the environment in the absence of remedial action. The baseline risk assessment will provide the basis for determining whether or not remedial action is necessary in the area and serve as the justification for performing remedial action (U.S. EPA, 1988a).

Several objectives will be accomplished under the risk assessment task including identification and characterization of the following (U.S. EPA, 1988a):

- toxicity and levels of hazardous substances present in relevant media (e.g., air, ground water, soil, surface water, sediment, and biota);
- environmental fate and transport mechanisms within specific environmental media such as physical, chemical, and biological degradation processes and hydrogeological conditions;
- potential human and environmental receptors;
- potential exposure routes and extent of actual or expected exposure;

- extent of expected impact or threat; and the likelihood of such impact or threat occurring (i.e., risk characterization); and
- level(s) of uncertainty associated with the above.

The public health risk assessment and the environmental evaluation will be performed in accordance with EPA and other guidance documents listed in Table 4-1. The risk assessment will address the potential public health and environmental impacts associated with the site under the no-action alternative (no remedial action taken). This assessment will aid in the selection of site remedies based on the contaminants of concern and the environmental media associated with potential risks to public health and the environment.

4.1.6.1 Public Health Evaluation

The risk assessment process is divided into four tasks (U.S. EPA, 1988a), including:

- Contaminant identification;
- Exposure assessment;
- Toxicity assessment; and
- Risk characterization.

The task objectives and description of work for each task are described below.

Contaminant Identification

The objective of contaminant identification is to screen the information that is available on hazardous substances or wastes present at the site and to identify contaminants of concern to focus subsequent efforts in the risk assessment process. Previous work characterizing aspects of the Rocky Flats Plant and the surrounding area has been done. Additional sampling and analysis of various media will take place in order to support the

TABLE 4-1

EPA GUIDANCE DOCUMENTS WHICH WILL BE USED IN THE RISK ASSESSMENT TASK

- Risk Assessment Guidance for Superfund, Human Health Evaluation Manual Part A, Interim Final (U.S. EPA, 1989a)

- Superfund Exposure Assessment Manual (U.S. EPA, 1988c)

- Exposure Factors Handbook (U.S. EPA, 1989b)

- The Endangerment Assessment Handbook (U.S. EPA, 1985)

- CERCLA Compliance With Other Laws Manual (U.S. EPA, 1988d)

- Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (U.S. EPA, 1988a)

- Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference (U.S. EPA, 1989c)

- Risk Assessment Guidance for Superfund -- Environmental Evaluation Manual (U.S. EPA, 1989d)

- Data Quality Objectives for Remedial Response Activities: Development Process (U.S. EPA, 1987) human health risk assessment, the ecological assessment and to characterize the site. For this risk assessment, all contaminants at Operable Unit No. 2 will be considered unless the following criteria are met for their deletion:

- Determination that a chemical has not been detected above risk based detection limits;
- Environmental fate information which shows that exposure will not occur; or
- A low frequency of occurrence (less than 10 percent) in environmental media.

All chemicals that are deleted and the rationale for their deletion will be discussed in the completed risk assessment.

Exposure Assessment

The objectives of the exposure assessment are to identify actual or potential exposure pathways, to characterize potentially exposed populations, and to determine the extent of exposure. An exposure pathway is comprised of four elements:

1) a source and mechanism of chemical release to the environment;
2) an environmental transport medium (e.g., air, groundwater) for the released constituent;
3) a point of potential contact of humans or biota with the affected medium (the exposure point); and
4) an exposure route (e.g., inhalation of contaminated dust) at the exposure point.

The exposure assessment process will include the following actions:

- analyze the probable fate and transport of compounds for both the present and the future uses;
- identify the human populations in the area, typical activities that would influence exposure, and sensitive population subgroups;

- identify potential exposure pathways under current and future land use conditions;
- develop exposure scenarios for each identified pathway and select those scenarios that are plausible and that can be quantitatively evaluated;
- identify scenarios assuming both existing and potential future uses; and
- identify the exposure parameters to be used in assessing the risk for all scenarios.

Appropriate exposure scenarios will be identified for the site including a residential scenario. Other scenarios which could potentially be considered include commercial/industrial, and/or recreational. Factors to be examined in the pathway and receptor identification process will include:

- Location of contaminant source;
- Local topography;
- Local geohydrology/surface water hydrology;
- Surrounding land use;
- Local water use;
- Prediction of contaminant migration; and
- Persistence and mobility of migrating contaminants.

For each migration pathway and for current and future conditions, receptors will be identified and characterized. Potential receptors will be defined by the appropriate exposure scenarios.

Toxicity Assessment

In accordance with EPA's risk assessment guidelines, the projected concentrations of indicator chemicals at exposure points will be compared with ARARs to judge the degree and extent of risk to public health and the environment (including plants, animals, and ecosystems). Because many ARARs do not exist for certain media (such as soils) nor are all

ARARs necessarily health based, this comparison is not sufficient in itself to satisfy the requirements of the risk assessment process. Moreover, receptors may be exposed to contaminants from more than one medium so that their total dose might exceed Reference Doses (RfDs) or the dose might result in an excess cancer risk for noncarcinogenic health effects, (greater than 1 in 1,000,000). Nevertheless, the comparison with standards and criteria is useful in defining the exceedance of institutional requirements. Aside from the ARARs listed in Table 2-12, the following criteria will be examined:

- drinking water health advisories;
- ambient water quality criteria for protection of human health;
- Center for Disease Control and Agency for Toxic Substances and Disease Registry soil advisories; and
- National Ambient Air Quality Standards.

Critical toxicity values (i.e., numerical values derived from dose-response information for individual compounds) will be used in conjunction with the intake determinations to characterize risk. Toxicity reference values from EPA's Integrated Risk Information System (IRIS) will be used in preference to other EPA reference values such as those found in the health effects assessment documents, SPHEM or PHRED.

A summary of any toxicological studies performed will be provided for target chemicals in the baseline risk assessment. The quality of these studies and their usefulness in estimating human health risks will be described. A more detailed explanation of the toxic effects of target chemicals will be provided in the appendices to the human health risk assessment and the environmental evaluation. Toxicity reference values will also be summarized. For the human health risk assessment, this will include a brief description of the studies upon which selected reference values were based, the uncertainty factors used to calculate RfDs, and the EPA weight-of-evidence classification for carcinogens. For those chemicals without EPA toxicity reference values, a literature search, including computer data bases, will be conducted for selected compounds. A toxicity value will then if possible, be derived from this information. EPA will be consulted regarding the appropriateness of the data and the methodologies to be used in deriving reference values. Uncertainties regarding the toxicity assessment will be discussed.

Three different types of critical toxicity values will be used:

- the acceptable daily intake for subchronic exposure (AIS);
- the acceptable intake for chronic exposure (AIC); and
- the carcinogenic potency factor (for carcinogenic chemicals only).

Risk Characterization

Risk characterization involves integrating exposure assumptions and toxicity information to quantitatively estimate the risk of adverse health effects. Risk characterization will be performed in accordance with EPA guidance. A quantitative risk estimate will be performed for all chemicals. To assess the potential adverse health effects associated with access to the site, the potential level of human exposure to the selected chemicals must be determined. Intakes of exposed populations will be calculated separately for all appropriate pathways of exposure to chemicals. Then for each population-at-risk, the total intake by each route of exposure will be calculated by adding the intakes from each pathway. Total oral, inhalation, and dermal exposures will be estimated separately. Because short-term (subchronic) exposures to relatively high concentrations of chemicals may cause different effects than those caused by long-term (chronic) exposures to lower concentrations, two intake levels will be calculated for each route of exposure to each chemical, i.e., a subchronic daily intake (SDI) and a chronic daily intake (CDI).

An uncertainty analysis will be performed to identify and evaluate non-site and site specific factors that may produce uncertainty in the risk assessment, such as assumptions inherent in the development of toxicological endpoints (potency factors, reference doses). Moreover, site-specific factors which may produce uncertainty will also be discussed.

Risk will be quantified by comparison of contaminant intakes at exposure points to quantitative criteria for protection of human health. The risk assessment portion will include examination of scientific literature to identify daily acceptable intakes of contaminants. Quantitative risk estimates will be made if data are available.

The results of the baseline risk assessment will be used to define and evaluate the remedial alternatives during the FS.

4.1.6.2 Environmental Evaluation

The objective of the environmental evaluation for Operable Unit No. 2 is to determine if the contaminants have caused or are causing any adverse environmental impact. The data to be collected will be utilized in conjunction with existing data to determine the bio-availability and toxicity of the contaminants to the flora and fauna of the 903 Pad, Mound, and East Trenches Areas.

The environmental evaluation will be conducted per guidance provided in the "Risk Assessment Guidance for Superfund", Volume II, Environmental Evaluation Manual (U. S. EPA, 1989d) as part of the 903 Pad, Mound and East Trenches Areas Phase II RI. The scope of the investigation will include the collection of vegetation, small mammals, arthropods, and aquatic life for determining if bio-accumulation is occurring. The radioecology study, (Rocky Flats Plant Radioecology and Airborne Pathway Summary Report (Rockwell International, 1986f), the Final Environmental Impact Statement (U.S. DOE, 1980), the soils and surface water chemical data, and biological parameters collected during this environmental evaluation will be utilized to assess both the current and future ecological impacts from Operable Unit No. 2.

Field and laboratory activities will be necessary to determine what effect contaminants at the 903 Pad, Mound and East Trenches Areas are having on the area's flora and fauna. These activities may include field assessments, toxicity testing, and biomarkers.

Aquatic and terrestrial field surveys will provide detailed assessments of ecological effects. A field survey for aquatic invertebrates in South Walnut Creek will be conducted in order to determine if these organisms have been adversely affected by contaminants at this site. The survey will include relative abundance, species richness, community organization, and biomass. The upper reaches of North Walnut Creek will serve as a "control" for comparison with results from the South Walnut Creek survey.

Toxicity tests will be conducted for the aquatic systems if the aquatic survey indicates an impact. The toxicity of environmental media can be estimated using two approaches: a a chemistry-based approach or toxicity-based approach. The chemistry-based approach will first be applied where chemical analyses of water, air, soil, or sediment will be compared to literature criteria to estimate toxicity. If this analysis fails to explain the contaminant impact on the biota, the toxicity based approach will be used. The toxicity-based approach involves the measurements of a biological effect associated with exposure to complex mixtures. For this study, toxicity testing will include acute and chronic toxicity methods for aqueous samples.

The concept of biomarkers is that selected endpoints (such as population-ecosystem density, diversity, or nutrient cycling) which are measured in individual organisms are typically comprised of biochemical or physiological responses that can provide sensitive indices of exposure or sublethal stress. The most direct biomarker to assess exposure is to measure tissue residues which is a key component of bio-accumulation. Biomarkers for sublethal stress include histopathology, determination of skeletal abnormalities, measurement of gas exchange in plants and other various measurements (i.e. enzymes). For this evaluation, toxicological endpoints for indicator or target species will be chosen based on a review of available laboratory toxicity tests providing quantitative data for species of concern, when available. In the absence of toxicological indices for the target species, toxicological endpoints will be derived using safety factors that reflect interspecies extrapolation, acute-to-chronic extrapolations, and added protection for endangered and/or threatened species. Procedures to be used for the field and laboratory activities are presented in the "Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference (U.S. EPA, 1989c).

In presenting the conclusions of the environmental evaluation for the 903 Pad, Mound and East Trenches Areas, the degree of success in meeting the overall objective of the evaluation will be discussed. Each conclusion will be presented along with items of evidence which would support or fail to support the conclusions and the uncertainty accompanying that conclusion. Any factors that limited or prevented development of definitive conclusions will also be described. Information will be provided to indicate the degree of confidence in the data that was used to assess the site and its contaminants.

4.1.7 Task 7 - Treatability Studies/Pilot Testing

This task includes efforts to prepare and conduct pilot and bench-scale treatability studies, and/or review data from recently conducted testing. These activities will serve to determine the operability, reliability, cost-effectiveness, and overall implementability of a particular remedial alternative. A comprehensive plan for treatability studies designed for remediation of waste sources soils and water at all operable units at Rocky Flats will be prepared and submitted to the regulatory agency in July 1990 in accordance with the draft IAG schedule. This section briefly discusses some of the work that has been conducted, is in progress, or is planned as part of this task. The treatability studies/pilot testing to be conducted or reviewed focus on removal of radionuclides from water (uranium) and soil (plutonium and americium). Many of the promising soil treatments for remediating radionuclide contaminated soils evaluated in Rocky Flats' laboratories during the late 1970's and early 1980's are currently being revisited. These technologies are generally directed toward substantially reducing the volume of contaminated soils, with the subsequent intention of disposing of a small remaining concentrated fraction of contaminated soil in a facility approved to receive radioactive wastes. Past investigations have included evaluations of dry screening, wet screening, scrubbing, ultrasonics, chemical oxidation, calcination, desliming, flotation, and heavy-liquid density separation. Treatment processes currently being evaluated include wet screening, scrubbing (vibratory and attrition), mineral jigs, and acid leaching. Wash solutions used in these processes can be treated to remove radioactivity and recycled back to the process. A few of these studies are discussed below.

Metal Adsorption on MRA

A biomass material called Metal Recovery Agent (MRA) has been developed by Advanced Mineral Technologies (AMT) of Golden, Colorado. According to AMT, this material can be used to remove metals from water. Laboratory- and pilot-scale testing and full-scale systems have proven that MRA is reliable at high metal concentrations. However, testing is necessary to determine the effectiveness of MRA in removing low concentrations of radionuclides from water. The potential benefits of this technology are:

- radionuclide removal would be accomplished without having to retreat the water or significantly change the pH;
- the MRA material can potentially be regenerated at Rocky Flats; and
- the possibility that all metal removal from ground water can be accomplished using one process.

Metal Adsorption on Activated Carbon

This study is intended to determine if radionuclides in contaminated ground water can be adsorbed onto granular activated carbon (GAC). Positive test results would enable GAC to be considered for removing volatile organic compounds and radioactive metals from ground water. Subsequently, GAC may be tested to determine its efficiency in removing non-radioactive metals from ground water. An additional benefit of this study is that it will determine the extent of radionuclide loading on carbon. If it is determined that radionuclides significantly load onto carbon, subsequent evaluations of GAC to remove volatile organics from ground water must include the cost of either an on-site GAC regeneration facility or the cost of shipping the loaded GAC to the Nevada Test Site for disposal.

Column Test (Ferrite) for Radionuclide Removal

A proven technology previously used at Rocky Flats for removing highly levels of plutonium from process waste and uranium from water is treatment with ferrite (magnetite).

The process requires ferrite to be added to a contaminated solution. With the pH in the 11 to 13 range, radionuclides adsorb to the ferrite. A flocculating agent is added to the slurry to improve settling and separation. The sludge settles to the bottom of the vessel, and is then removed and disposed, ferrite and all. The clean effluent remains. In this study, radionuclide contaminated water at a high pH is passed through a column filled with ferrite to determine the efficiency of radionuclide removal. The use of ferrite in a column will significantly reduce the amount of waste that must ultimately be handled. Once the ferrite is loaded with radionuclides, the column can be backflushed with a mild acid to remove the radionuclides, allowing reuse of the ferrite in the column. The concentrated metal contaminated stream would require further processing prior to disposal.

Mineral Jig Tests

The uses of a mineral jig to separate heavy metals (plutonium and americium) from coral was demonstrated at Johnston Atoll and at the Nevada Test Site using Rocky Flats soils.

The mineral jig would be the final stage in a three stage process intended to reduce the volume of plutonium contaminated soil by 75 to 85 percent. The first stage involves a soil washing technique which will reduce the total volume of contaminated soil by 60 to 70 percent. The second stage uses an attrition scrubbing technique to reduce the remaining volume of soil by an additional 25 to 30 percent. The third stage uses a mineral jig to reduce the volume of the remaining soil by an additional 10 to 15 percent.

The mineral jig process is the final stage of the most probable technology for reducing the volume of contaminated soil at the 903 Pad Area. A number of questions can be answered by performing laboratory-scale work. First, the radionuclide removal efficiency using a mineral jig on actual Rocky Flats soil would be evaluated more thoroughly than what was done in the previous study. Second, important data would be obtained in order to scale up the equipment for pilot- or full-scale application. Finally, this data could then be used to estimate equipment and operating costs for the chosen mineral jig system. These costs would be compared with the cost of disposing the contaminated soils off-site. The potential use of a mineral jig as a secondary treatment rather than a tertiary treatment may also be determined from this study.

Pilot-Scale Tests for Soil Decontamination

If the laboratory-scale study of soil washing and attrition scrubbing is successful, pilot-scale development work should be conducted to properly size equipment to meet production requirements. The lack of pilot-scale data supporting the use of this technology would make it virtually impossible to evaluate the use of a full-scale soil washing/attrition scrubbing/mineral jig system to decontaminate Rocky Flats soils to acceptable levels. A pilot-scale system would be designed and tested on the contaminated sites using actual contaminated soils. The draft treatability study plan to be completed in July 190 will present specific tasks and methods for the technologies proposed.

4.1.8 Task 8 - Remedial Investigation Report

A Draft Phase II RI Report will be prepared to consolidate and summarize the data obtained during Phase I and Phase II RI field work. This report will:

- Describe in detail the field activities which serve as a basis for the RI report. This will include any deviations from the work plan which occurred during implementation of the field investigation.
- Thoroughly discuss site physical conditions. This discussion will include surface features, meteorology, surface water hydrology, surficial geology, ground-water hydrology, demography and land use, and ecology. Bedrock geology discussions will not be presented in the Phase II RI Report but will be included in the Phase III RI Work Plan and resulting RI report.
- Present site characterization results discussing the nature and extent of contamination. The media to be addressed will include contaminant sources, soils, ground water, surface water, air, and biota.
- Discuss contaminant fate and transport. This discussion will include potential migration routes, contaminant persistence, and contaminant migration.

- Present a baseline risk assessment. The risk assessment will include human health and environmental evaluations.
- Present a summary and conclusions.

4.2 FEASIBILITY STUDY TASKS

At this time, a FS is planned for the 903 Pad, Mound, and East Trenches Areas to evaluate remedial alternatives for clean up of contaminated soils, ground water and surface water. Results of the Phase II RI and baseline risk assessment will indicate to what extent other remedial action is necessary for Operable Unit No. 2.

The FS process occurs in two phases. The first phase consists of developing and screening remedial alternatives, and the second phase includes a detailed analysis of alternatives (U.S. EPA, 1988a). Each of these two phases are discussed in the following sections.

4.2.1 Task 9 - Remedial Alternatives Development and Screening

The goal of this task is to identify and screen remedial alternatives. The work consists of four parts:

- Identifying remedial technologies;
- Screening remedial technologies;
- Developing remedial alternatives; and
- Screening remedial alternatives.

General response actions that may prove appropriate at the site were identified in Section 2.5. These general response actions were identified in order to determine data gaps to be addressed in RI activities. For each response action, potentially applicable remedial technologies were identified. These are also presented in Section 2.5. As the Phase II RI progresses, additional potentially applicable technologies may be determined.

During screening, the broad expanse of potentially applicable technology types will be narrowed by eliminating those technologies that are not technically implementable. Based on contaminant concentrations and other site-specific information contained in the Phase II RI, non-implementable technology types will be screened and eliminated from further consideration.

Technology process options will then be screened in order to select a representative process option for each technology type that is technically implementable. Process options are compared and eliminated based on their effectiveness relative to other processes within the same technology type. The screening is based on the volume of media to be treated, achievement of remediation goals, potential impacts on human health and the environment, and the proven performance and reliability of the option considering the contaminants and site characteristics. In addition to effectiveness, the process options will also be evaluated based on administrative feasibility and relative cost.

To develop alternatives, general response actions and the process options that are representative of the various technology types for each medium will be combined to form alternatives for the operable unit. In general, more than one response action is applicable to each medium. Response actions and process options will be assembled based primarily on medium-specific considerations and implementability. Descriptions of each alternative will be developed for inclusion in the FS report.

During alternative screening, the developed alternatives will be evaluated to ensure that they protect human health and welfare and the environment from each potential pathway of concern at the operable unit. Treatment rates will be identified, and the size and configuration of on-site extraction and treatment systems or containment structures will be developed. The time frame in which treatment, containment or removal goals can be achieved will be determined. Lastly, spatial requirements for treatment units, containment structures, staging of construction materials, excavated wastes, etc. will be determined. If there are off-site actions such as surface water discharge, a regulatory review will be conducted to determine permit and compliance requirements.

Alternatives will then be further defined to provide sufficient information to differentiate among alternatives with respect to effectiveness, implementability and cost. Each alternative will be evaluated to determine its effectiveness in protecting human health and the environment, and in reducing toxicity, mobility or volume of hazardous wastes or contaminated media. As a consequence of reducing the toxicity, mobility or volume, the inherent threats or risks associated with wastes are decreased.

Implementability is a measure of both the technical and administrative feasibility of constructing, operating and maintaining a remedial action alternative. It is used during screening to evaluate the combinations of process options with respect to the site-specific conditions. Technical feasibility refers to the ability to construct, reliably operate and comply with action-specific (technology-specific) requirements in order to complete the remedial action. Administrative feasibility refers to the ability to obtain required permits and approvals; to obtain the necessary services and capacity for treatment, storage and disposal of hazardous wastes; and to obtain essential equipment and technical expertise.

Cost estimates for screening will be derived from cost curves, generic unit costs, vendor information, conventional cost estimating guides and prior estimates made for Rocky Flats and similar sites, with modifications made for Rocky Flats Plant conditions. Absolute cost accuracy is not necessary. The cost estimates for the alternatives however, will have the same relative accuracy for comparison and screening. The cost estimating procedures used during screening are similar to those that will be used during the later detailed alternatives analysis. The later detailed analysis however, will receive more in-depth and detailed cost estimates of the components of each alternative. The screening cost estimates will include capital, operating, and maintenance costs. The operating and maintenance costs will be calculated for the lifetime of the treatment unit operation at the site. Present worth cost analysis will be used for alternatives in order to make the costs for the various alternatives comparable.

Alternatives with the most favorable results from the composite evaluation will be retained for further scrutiny during the detailed analysis. Not more than ten alternatives will be retained for detailed analysis (including containment and no action). At that time, it may be determined that additional site-specific information or technology-specific treatability studies are necessary for an objective detailed analysis. Also, it will be necessary to identify and verify the action-specific ARARs that each respective alternative will be required to meet.

4.2.2 Task 10 - Detailed Analysis of Remedial Alternatives

The detailed analysis is not a decision-making process, but it is the process of analyzing and comparing relevant information in order to select a remedial action. Each alternative will be assessed against nine evaluation criteria, and the assessments will be compared to identify the key tradeoffs among the alternatives. Assessment against the nine evaluation criteria is necessary for the FS and the subsequent Record of Decision (ROD)/Corrective Action Decision (CAD) to comply with the requirements of CERCLA/RCRA.

4.2.2.1 Alternative Analysis Against Nine Evaluation Criteria

Overall Protection of Human Health and the Environment

The alternatives will be individually analyzed to determine if the alternative provides adequate protection of human health and the environment. The protectiveness evaluation focuses on how the risks posed by each pathway are being eliminated, reduced or controlled by treatment, engineering or institutional measures.

Compliance with ARARs

Each alternative will be analyzed to determine whether it will comply with all state and federal ARARs that have been identified. The analysis will address compliance with chemical-specific, location-specific and action-specific ARARs. If an alternative will not comply with an ARAR, the FS report will present the basis for justifying a waiver.

Long-Term Effectiveness and Permanence

This criterion assesses the risks that are left at the site after the response objectives have been met. The risks associated with any remaining untreated wastes or treatment residuals will be evaluated. For each alternative, the magnitude of the residual risk, and the reliability and adequacy of the controls used to manage untreated wastes and treatment residuals will be addressed.

Reduction of Toxicity, Mobility or Volume Through Treatment

This criterion evaluates the statutory preference of selecting remedial actions that permanently reduce toxicity, mobility or volume of the hazardous materials. Factors evaluated for each alternative will include the proposed treatment process and the materials treated; the quantity of materials to be treated or destroyed, and how the primary hazardous threat will be addressed; the estimated degree of the reduction in toxicity, mobility or volume that will be achieved; the extent to which the treatment will be irreversible; the type and quantity of treatment residuals that will remain following treatment; and a determination if the alternative will comply with the statutory preference for treatment.

Short-Term Effectiveness

Short-term effectiveness refers to the effects an alternative may have during the construction and implementation phases until the cleanup objectives have been achieved.

Alternatives will be evaluated to determine the effects on human health and the environment during implementation. Each alternative will be assessed against the following factors: protection of the community and workers during the remedial action; environmental impacts; and the time required to achieve the remedial action objectives.

Implementability

This criterion assesses the technical and administrative feasibility of implementing an alternative, and the availability of the necessary services and materials. The following factors will be analyzed during the implementability assessment: the technical feasibility of construction and operation; the reliability of the technology; the practicability of employing additional remedial actions; the ability to monitor the effectiveness of the remedial action; administrative coordination with other offices and agencies; the availability of adequate off-site hazardous (or mixed) waste treatment, storage and disposal; and the availability of equipment, expertise and other services and materials.

Costs

An in-depth cost estimate will be conducted, and if necessary, a cost sensitivity analysis will be prepared to evaluate costing assumptions. Capital costs include direct construction costs and indirect non-construction costs and overhead costs. Operating and maintenance costs are incurred after construction in order to operate the remedial action on a continuous basis until the remedial action objectives have been achieved. FS cost estimates are expected to be within an accuracy range of minus 30 percent to plus 50 percent. If this accuracy cannot be achieved, it will be stated in the FS report.

A cost sensitivity analysis may be conducted to determine the effect that specific cost assumptions have on the total estimated cost of an alternative. The cost assumptions will be based on site-specific data, technological operating data, etc. although the assumptions will be subject to varying degrees of uncertainty depending on the accuracy of the data.

State Acceptance

This criterion addresses the state's administrative and technical issues and concerns with each of the alternatives.

Community Acceptance

Community acceptance addresses the public's concerns and issues with each of the alternatives.

4.2.2.2 Comparison of Alternatives

The FS report will contain a narrative discussion of each alternatives evaluation against the nine criteria. The narrative will describe how each alternative addresses the technical treatability issues, long-term and short-term effectiveness, costs, protection of human health and the environment, compliance with ARARs, etc. Once the alternatives have been described, a comparative analysis will be conducted to evaluate the relative performance of each alternative. The relative advantages and disadvantages of each alternative with respect to the other alternatives will be determined in order to assess the key tradeoffs that must be made in selecting a remedial action. A candidate alternative must generally attain the primary objectives of compliance with ARARs and overall protection of human health and the environment in order for it to be eligible for selection as the remedial action. A narrative discussion of the alternatives comparison describing the tradeoffs, and the benefits and detriments of each alternative in comparison to the others will be included in the FS report.

Following completion of the FS process, the results of the detailed alternatives comparison and risk management will be used as the rationale for selecting a preferred alternative and a remedial action. Although the purpose of the FS report and process is not to select a remedial action, it will present and evaluate the alternatives in sufficient detail in order to objectively consider all significant issues and select a feasible, cost-effective and defensible remedial action.

4.2.3 Task 11 - Feasibility Study Report

The FS Report will discuss and present the results of the feasibility study. The report will include sections describing site background; nature and extent of problem; results of the RI; risk assessment and environmental evaluation; identification, screening and detailed evaluation of remedial alternatives, and the recommended remedial actions. This task includes development of a Draft FS, a revised Draft FS that incorporates EPA and CDH comments, and preparation of a Final FS that incorporates public comments.

5.0 PHASE II RI FIELD SAMPLING PLAN

The overall objectives of the Phase II RI are source characterization and better definition of the nature and extent of alluvial ground-water and surface water contamination. Within these broad objectives, site specific data objectives and needs have been identified in Section 3.0. The purpose of this section is to provide a detailed field sampling plan which will realize these data objectives and needs.

5.1 SAMPLING LOCATIONS AND FREQUENCY

5.1.1 Source Characterization

Further source characterization is required for sites within Operable Unit No. 2. Boreholes will be drilled into SWMUs where access is feasible to characterize any waste materials remaining in place and to assess the maximum contaminant concentrations in soils directly beneath the sites. In addition, ground-water monitoring wells will be installed adjacent to some of the boreholes to characterize ground-water quality directly beneath the sites. This section discusses those wells and boreholes which will be drilled for source characterization. Wells to be drilled outside of SWMUs for characterizing the extent of contamination are discussed in Section 5.1.2. Table 5-1 provides an overview of all proposed Phase II RI boreholes and wells which are shown on Figure 5-1. All drilling, sampling, and well installation will follow the Rocky Flats Plant ER Program SOP.

Boreholes to be drilled into SWMUs will extend from the ground surface to the base of weathered bedrock. Continuous samples will be collected for geologic descriptions for the entire borehole depth. From this core, discrete samples will be submitted for laboratory chemical analyses every two feet from the ground surface to the water table. In addition, a discrete sample will be collected for chemical analysis at the water table. Core from saturated

TABLE 5-1

PROPOSED PHASE II ALLUVIAL WELLS AND BOREHOLES
903 PAD, MOUND, AND EAST TRENCHES AREAS

WELL OR BOREHOLE NO.	PURPOSE	ANTICIPATED MONITOR WELL TOTAL DEPTH (ft. below g.s)	ANTICIPATED SCREENED INTERVAL
1-90/BH0190	Adjacent to and upgradient (west) of 903 Pad.	15	5-15
2-90/BH0290	Ground-water quality beneath 903 Pad. Source characterization 903 Pad.	15	5-15
BH0390	Source Characterization 903 Pad	N/A	N/A
3-90/BH0490	Ground-water quality beneath 903 Pad. Source characterization 903 Pad.	15	5-15
4-90/BH0590	Ground-water quality downgradient (south) of 903 Pad. Soil characterization adjacent to 903 Pad.	15	5-15
5-90/BH0690	Ground-water quality downgradient (north) of 903 Pad. Soil characterization adjacent to 903 Pad.	20	5-20
BH0790	Source Characterization 903 Pad	N/A	N/A
6-90/BH0890	Ground-water quality beneath 903 Pad. Source characterization 903 Pad.	20	5-20
BH0990	Source Characterization 903 Pad	N/A	N/A
BH1090	Source Characterization 903 Pad	N/A	N/A
7-90/BH1190	Ground-water quality downgradient (east) of 903 Pad. Soil characterization adjacent to 903 Pad.	20	5-20
8-90/BH1290	Ground-water quality downgradient (east) of 903 Pad. Soil characterization adjacent to 903 Pad.	20	5-20
9-90/BH1390	Ground-water quality downgradient (south) of 903 Pad. Soil characterization adjacent to 903 Pad.	20	5-20
10-90/BH1490	Ground-water quality beneath Trench T-2. Source characterization Trench T-2.	10	5-10
BH1590	Source Characterization Trench T-2. Extent of soil contamination.	N/A	N/A
11-90/BH1690	Ground-water quality downgradient (south) of 903 Pad and upgradient of Trench T-2 (north) to differentiate between sources.	10	5-10
BH1790	Source Characterization Trench T-2. Extent of soil contamination.	N/A	N/A

TABLE 5-1
(continued)

PROPOSED PHASE II ALLUVIAL WELLS AND BOREHOLES
903 PAD, MOUND, AND EAST TRENCHES AREAS

WELL OR BOREHOLE NO.	PURPOSE	ANTICIPATED MONITOR WELL TOTAL DEPTH (ft. below g.s)	ANTICIPATED SCREENED INTERVAL
BH1890	Source Characterization Trench T-2. Extent of soil contamination.	N/A	N/A
12-90/BH1990	Ground-water quality downgradient south of Trench T-2. Extent of soil contamination.	10	5-10
BH2090	Source characterization Reactive Metal Destruction Site.	N/A	N/A
13-90/BH2190	Ground-water quality downgradient (south) of Reactive Metal Destruction Site.	10	5-10
BH2290	Source characterization Reactive Metal Destruction Site.	N/A	N/A
14-90/BH2390	Ground-water quality downgradient of Reactive Metal Destruction Site. Extent of soil contamination.	10	5-10
15-90/BH2490	Ground-water quality downgradient of 903 and Reactive Metal Destruction Site. Extent of soil contamination.	10	5-10
16-90/BH2590	Ground-water quality beneath Mound Site. Source characterization.	25	5-25
17-90/BH2690	Ground-water quality beneath Mound Site. Source characterization.	25	5-25
BH2790	Extent of soil contamination Mound Site.	N/A	N/A
BH2890	Investigation possible Pallet Burn Site location.	N/A	N/A
18-90/BH2990	Ground-water quality beneath Trench T-3. Source characterization.	20	10-20
19-90/BH3090	Ground-water quality beneath Trench T-4. Source characterization.	20	10-20
20-90/BH3190	Ground-water quality beneath Trench T-4. Source characterization.	25	10-25
21-90/BH3290	Ground-water quality beneath Trench T-11. Source characterization.	25	10-25
22-90/BH3390	Ground-water quality beneath Trench T-11. Source characterization.	25	10-25

TABLE 5-1
(continued)

PROPOSED PHASE II ALLUVIAL WELLS AND BOREHOLES
903 PAD, MOUND, AND EAST TRENCHES AREAS

WELL OR BOREHOLE NO.	PURPOSE	ANTICIPATED MONITOR WELL TOTAL DEPTH (ft. below g.s)	ANTICIPATED SCREENED INTERVAL
23-90/BH3490	Ground-water quality beneath Trench T-9. Source characterization.	40	10-40
24-90/BH3590	Ground-water quality beneath Trench T-5. Source characterization.	40	10-40
25-90/BH3690	Ground-water quality beneath Trench T-5. Source characterization.	40	10-40
26-90/BH3790	Ground-water quality beneath Trench T-6. Source characterization.	40	10-40
27-90/BH3890	Ground-water quality beneath Trench T-7. Source characterization.	40	10-40
28-90/BH3990	Ground-water quality beneath Trench T-7. Source characterization.	40	10-40
29-90/BH4090	Ground-water quality beneath Trench T-8. Source characterization.	40	10-40
30-90/BH4190	Ground-water quality beneath Trench T-8. Source characterization.	40	10-40
31-90	Volatile organic plume definition downgradient (east) of 903 Pad and Mound Areas.	15	5-15
32-90	Volatile organic plume downgradient (east) of 903 Pad and Mound Areas.	15	5-15
33-90	Volatile organic plume definition downgradient (east) of 903 Pad and Mound Areas.	15	5-15
34-90	Volatile organic plume definition downgradient (southeast) of 903 Pad. Extent of saturated colluvium.	10	5-10
35-90	Volatile organic plume definition downgradient (southeast) of 903 Pad. Extent of saturated colluvium.	10	5-10
36-90	Volatile organic plume definition downgradient (southeast) of 903 Pad. Extent of saturated colluvium.	10	5-10
37-90	Volatile organic plume definition downgradient (southeast) of 903 Pad. Extent of saturated colluvium.	10	5-10

TABLE 5-1
(continued)

PROPOSED PHASE II ALLUVIAL WELLS AND BOREHOLES
903 PAD, MOUND, AND EAST TRENCHES AREAS

WELL OR BOREHOLE NO.	PURPOSE	ANTICIPATED MONITOR WELL TOTAL DEPTH (ft. below g.s)	ANTICIPATED SCREENED INTERVAL
38-90	Volatile organic plume definition downgradient (south) of 903 Pad. Extent of saturated colluvium.	10	5-10
39-90	Volatile organic plume definition downgradient (southeast) of 903 Pad. Extent of saturated colluvium.	10	5-10
40-90	Volatile organic plume definition downgradient (south) of the 903 Pad Area. Ground water/surface water interaction at SID.	20	5-20
41-90	Volatile organic plume definition downgradient (southeast) of the 903 Pad Area. Ground water/surface water interaction at SID.	20	5-20
42-90	Volatile organic plume definition downgradient (southeast) of the 903 Pad Area. Ground water/surface water interaction at SID.	20	5-20
43-90	Determine extent of elevated inorganics in well 29-87. Ground-water/surface water interaction at SID.	20	5-20
44-90	Woman Creek valley fill alluvial ground water upgradient of 65-86.	10	5-10
45-90	Woman Creek Valley fill alluvial ground water downgradient of 65-86.	10	5-10
46-90	Ground water quality upgradient (west) of Operable Unit No. 2.	15	5-15
47-90	Ground-water quality and extent of saturation adjacent to possible Pallet Burn Site.	15	5-15
48-90	Ground-water quality downgradient (south) of Mound Site.	10	5-10
49-90	Ground-water quality downgradient (south) of Oil Burn Pit Site.	10	5-10
50-90	Ground-water quality downgradient of Trench T-1 and upgradient of Mound to differentiate between sources.	25	5-25
51-90	Ground-water quality upgradient of Trench T-1 and downgradient of the 903 Pad to differentiate between sources.	25	5-25

TABLE 5-1
(continued)

PROPOSED PHASE II ALLUVIAL WELLS AND BOREHOLES
903 PAD, MOUND, AND EAST TRENCHES AREAS

WELL OR BOREHOLE NO.	PURPOSE	ANTICIPATED MONITOR WELL TOTAL DEPTH (ft. below g.s)	ANTICIPATED SCREENED INTERVAL
52-90	Volatile organic plume definition downgradient (north) of Mound Area.	20	5-20
53-90	Volatile organic plume definition downgradient (north) of Mound Area.	10	5-10
54-90	Volatile organic plume definition downgradient (northeast) of Mound Area.	10	5-10
55-90	Volatile organic plume definition downgradient (east) of Mound Area.	20	5-20
56-90	Volatile organic plume definition downgradient (northeast) of Mound Area.	15	5-15
57-90	Volatile organic plume definition downgradient (north) of Trench T-3. Replace well 3-74.	10	5-10
58-90	Ground-water quality downgradient of Trench T-3 and upgradient of Trench T-4 to differentiate between sources.	10	5-10
59-90	Volatile organic plume definition downgradient (south) of Trench T-3.	15	5-15
60-90	Ground-water quality downgradient (south) of Trench T-4 and upgradient (north) of Trench T-11 to differentiate between sources.	15	5-15
61-90	Ground-water quality downgradient (south) and upgradient (north) Trench T-10 to differentiate between sources.	15	5-15
62-90	Volatile organic plume definition downgradient (south) of Trench T-10.	20	5-20
63-90	Volatile organic plume definition downgradient (south) of Trench T-11.	20	5-20
64-90	Ground-water quality upgradient of southern East Trenches	25	5-25
65-90	Ground-water quality downgradient (north) of Trench T-9.	30	5-30
66-90	Ground-water quality downgradient (south) of Trench T-9.	40	5-40
67-90	Ground-water quality downgradient (north) of Trench T-5.	40	5-40

TABLE 5-1
(continued)

PROPOSED PHASE II ALLUVIAL WELLS AND BOREHOLES
903 PAD, MOUND, AND EAST TRENCHES AREAS

WELL OR BOREHOLE NO.	PURPOSE	ANTICIPATED MONITOR WELL TOTAL DEPTH (ft. below g.s)	ANTICIPATED SCREENED INTERVAL
68-90	Ground-water quality downgradient (east) of Trenches T-5, T-6, and T-7. Evaluate influence of East Spray Field Sites on ground-water flow and quality.	40	5-40
69-90	Ground-water quality downgradient (south) of Trench T-7 and upgradient (north) of Trench T-8 to differentiate between sources.	40	5-40
70-90	Volatile organic plume definition downgradient (southeast) of East Trenches Area.	40	5-40
71-90	Volatile organic plume definition downgradient (southeast) of East Trenches Area.	40	5-40
72-90	Volatile organic plume definition downgradient (southeast) of East Trenches Area.	40	5-40
73-90	Volatile organic plume definition downgradient (southeast) of East Trenches Area.	40	5-40
74-90	Volatile organic plume definition downgradient (southeast) of East Trenches Area.	40	5-40
75-90	Evaluate influence of East Spray Field Sites on ground-water flow and quality.	40	5-40
76-90	Evaluate influence of East Spray Field Sites on ground-water flow and quality.	40	5-40
77-90	Ground-water quality southeast of East Trenches Area.	10	5-10
78-90	Volatile organic plume definition and extent of saturation downgradient (north) of East Trenches Area.	10	5-10
79-90	Volatile organic plume definition and extent of saturation downgradient (north) of East Trenches Area.	10	5-10
80-90	Volatile organic plume definition and extent of saturation downgradient (north) of East Trenches Area.	10	5-10
81-90	Volatile organic plume definition and extent of saturation downgradient (north) of East Trenches Area.	10	5-10

TABLE 5-1
(continued)

PROPOSED PHASE II ALLUVIAL WELLS AND BOREHOLES
903 PAD, MOUND, AND EAST TRENCHES AREAS

WELL OR BOREHOLE NO.	PURPOSE	ANTICIPATED MONITOR WELL TOTAL DEPTH (ft. below g.s)	ANTICIPATED SCREENED INTERVAL
82-90	Volatile organic plume definition and extent of saturation downgradient (north) of East Trenches Area.	10	5-10
83-90	Volatile organic plume definition and extent of saturation downgradient (north) of East Trenches Area.	10	5-10
84-90	Volatile organic plume definition and extent of saturation downgradient (north) of East Trenches Area.	10	5-10
85-90	Volatile organic plume definition and extent of saturation downgradient (north) of East Trenches Area.	20	5-20
86-90	Volatile organic plume definition and extent of saturation downgradient (north) of East Trenches Area.	40	5-40
87-90	Evaluate influence of East Spray Field Sites on ground-water flow and quality.	40	5-40
88-90	Evaluate influence of East Spray Field Sites on ground-water flow and quality.	40	5-40

	1989 WP	IAG	CONTRACT WCFS	1991 WP
Boreholes Only	11ea	45		
Primary Wells/Boreholes	30ea	138	41 Boreholes	
Primary Wells Only	58ea	183	88 well	113
			129 holes	
Secondary				
Total	98 holes 99			

88
31
57

IAG

surficial materials will not be submitted to the laboratory, as the presence of water in this zone will affect interpretation of chemical results. In order to prevent alluvial ground water from affecting weathered bedrock samples, surface casing will be grouted into the borehole through surficial materials. Subsequent to grout hardening, the borehole will then be advanced through weathered bedrock with continuous sampling. Discrete samples from the core will be submitted to the laboratory for chemical analysis from two feet immediately below the casing and every four feet thereafter to the base of weathering. To further characterize bedrock immediately beneath the sites, in-situ packer tests will be performed in the weathered bedrock where drilling conditions allow.

Alluvial ground-water monitoring wells will be installed adjacent to some boreholes to characterize ground-water quality directly beneath SWMUs. Wells will be drilled, sampled, and completed in accordance with the Rocky Flats ER Program SOP. Source characterization well locations are discussed in the following sections.

5.1.1.1 903 Pad Area

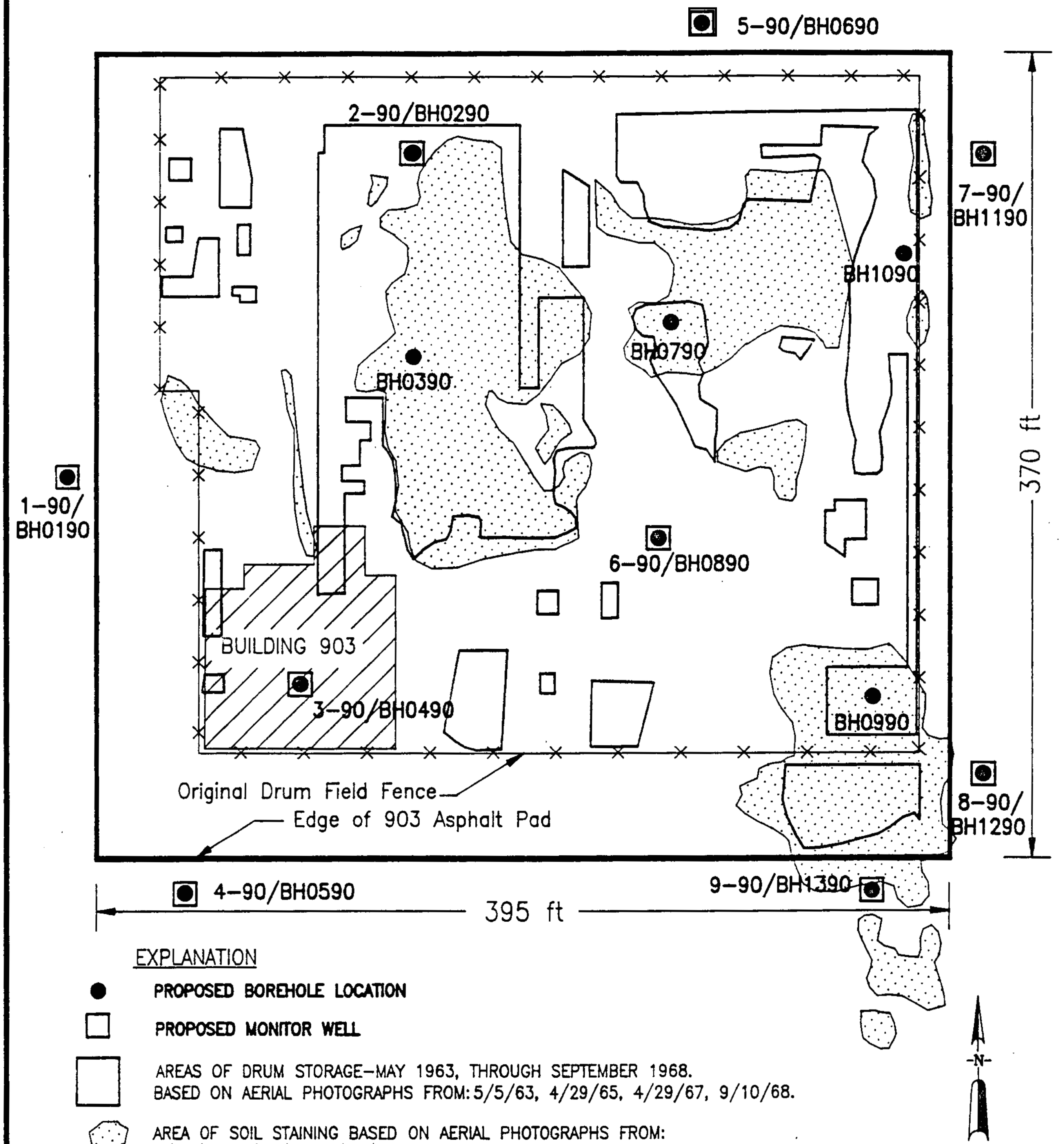
SWMUs of the 903 Pad Area are shown in Figure 1-5. Specific source sampling activities for sites within the 903 Pad Area are discussed below.

903 Drum Storage Site (SWMU Ref. No. 112)

In order to characterize the vertical and horizontal extent of radionuclide and solvent contamination beneath the 903 Pad, 13 boreholes (BH0190 through BH1390) are proposed within and adjacent to the site. These boreholes have been located in areas which contained drums as well as in areas which historically did not contain drums (Figure 5-2).

FIGURE 5-2

PROPOSED BOREHOLE AND MONITOR WELL LOCATIONS FOR THE 903 PAD DRUM STORAGE SITE



EXPLANATION

● **PROPOSED BOREHOLE LOCATION**

□ **PROPOSED MONITOR WELL**

AREAS OF DRUM STORAGE-MAY 1963, THROUGH SEPTEMBER 1968.
BASED ON AERIAL PHOTOGRAPHS FROM: 5/5/63, 4/29/65, 4/29/67, 9/10/68.

AREA OF SOIL STAINING BASED ON AERIAL PHOTOGRAPHS FROM:
4/29/67, 4/10/68, 5/24/69.

NOTE: BUILDING 903 LOCATION BASED ON AERIAL PHOTOGRAPHS FROM 4/10/68.

R33007 PJ-122189

In order to characterize the ground water beneath and adjacent to the 903 Pad, alluvial monitoring wells 1-90 through 9-90 will be installed adjacent to boreholes BH0190, BH0290, BH0490, BH0590, BH0690, BH0890, BH1190, BH1290, and BH1390, respectively.

903 Lip Site

Boreholes will not be drilled specifically for source characterization of the 903 Lip Site, as surficial radionuclides are the contaminants of concern. Therefore, surficial soil sampling and radionuclide analyses will be performed in the area. This sampling is discussed in Section 5.1.2.1.

Trench T-2 Site (SWMU Ref. No. 109)

One alluvial well/borehole (10-90/BH1490) will be drilled through the east end of Trench T-2 to characterize the contents and dimensions of the site (Figure 5-1). Barrels are known to be present at the west end of the trench, so no borehole will be drilled in this area. 10-90 will be completed as a colluvial monitoring well in order to sample ground water directly beneath this site.

In addition to well/borehole 10-90/BH1490, boreholes BH1590, BH1690, BH1790, BH1890, and BH19-90 will be drilled around Trench T-2 to verify its location and to evaluate the extent of soil contamination in the area. Colluvial monitoring wells 11-90 and 12-90 will be installed adjacent to boreholes BH1690 and BH1990, respectively, to monitor water quality upgradient and downgradient of Trench T-2.

Reactive Metal Destruction Site (SWMU Ref. No. 140)

Five boreholes (BH2089 through BH2490) will be drilled within the Reactive Metal Destruction Site to further characterize this source and the extent of soil contamination.

Boreholes BH2090, BH2190, and BH2290 will be drilled and sampled within the area disturbed by activities at this site. Boreholes BH2390 and BH2490 will be drilled and sampled at the downgradient edges of the site to verify the lack of disturbance in these areas. Colluvial monitoring wells 13-90, 14-90, and 15-90 will be completed adjacent to boreholes BH2190, BH2390 and BH2490, respectively, to monitor downgradient water quality (Figure 5-1).

5.1.1.2 Mound Area

SWMUs within the Mound Area are identified on Figure 1-5. Proposed well and borehole locations are shown on Figure 5-1 and summarized in Table 5-1. Details of source characterization activities planned for sites within the Mound Area are provided below.

Mound Site (SWMU Ref. No. 113)

Boreholes BH2590 and BH2690, are proposed within the revised boundaries of the Mound Site to characterize soils and any remaining wastes. Alluvial monitoring wells 16-90 and 17-90 will be completed adjacent to boreholes BH2690 and BH2790, respectively, to monitor ground-water quality beneath the site. In addition, borehole BH2790 will be drilled and sampled downgradient of the Mound Site adjacent to existing wells 1-74 and 19-87. This hole will serve to characterize the nature and extent of soil contamination possibly associated with the high levels of PCE and TCE detected in well 1-74.

Trench T-1 Site (SWMU Ref. No. 108)

No boreholes are proposed within Trench T-1 because of the ubiquitous presence of barrels. However, additional alluvial ground-water monitoring wells are proposed adjacent to the trench in Section 5.1.2.2.

Oil Burn Pit No. 2 Site (SWMU Ref. No. 153

This site was removed in the 1970's and its location is currently covered by the PSZ fence which is inaccessible for security purposes. Therefore, no additional boreholes are proposed for source characterization of this site. Additional monitor wells upgradient and downgradient of the Oil Burn Pit Site are discussed in Section 5.1.2.2.

Pallet Burn Site (SWMU Ref. No. 154)

The westernmost of the two possible locations for this site is located within the PSZ fence. As this area is inaccessible and boreholes were drilled adjacent to this site during the Phase I RI, no additional boreholes are proposed. However, an additional borehole (BH2890) will be drilled in the possible eastern location of the Pallet Burn Site identified from historical aerial photographs. This borehole will aid in verifying the location of SWMU 154.

5.1.1.3 East Trenches

As shown in Figure 1-5, SWMUs within the East Trenches are closely spaced and portions of the trenches are occupied by barrels. Location of boreholes and monitoring wells are presented in Figure 5-1 and summarized on Table 5-1.

The boreholes proposed within the East Trenches are located in portions of the trenches devoid of barrels. Boreholes within the trenches will provide not only waste and source characterization but also details on the construction of the trenches. Alluvial monitoring wells will be completed adjacent to all of the boreholes. These sampling locations are discussed below.

Five boreholes will be drilled through the northern trenches in areas not containing barrels. Borehole BH2990 will be drilled through the western end of Trench T-3 which is devoid of barrels, and boreholes BH3090 and BH3190 will be drilled through Trench T-4. Boreholes BH3290 and BH3390 will be drilled at the ends of Trench T-11 outside of the area containing barrels. Trench T-10 is filled with barrels; therefore, no boreholes will be drilled into this SWMU. Alluvial monitoring wells will be completed adjacent to all of the source characterization boreholes in the northern trenches (wells 18-90, 19-90, 20-90, 21-90, and 22-90).

Nine boreholes (BH3490 through BH4190) will be drilled and sampled in portions of the southern trenches devoid of barrels (Table 5-1). All of these boreholes will have alluvial monitoring wells completed adjacent to them to characterize alluvial ground-water quality immediately beneath the sites.

5.1.2 Nature and Extent of Contamination

In addition to source characterization, the Phase II RI will focus on additional soil, surficial materials, ground-water, surface water, and sediment sampling to further characterize the nature and extent of contamination in each of these media arising from the SWMUs. These sampling programs are outlined in detail below.

5.1.2.1 Surficial Soils

Plutonium was elevated above background levels in Phase I RI boreholes from several sites in the 903 Pad, Mound, and East Trenches Areas. However, radionuclide contamination is limited to the uppermost soil samples from each borehole. In order to characterize the vertical and horizontal extent of surficial soil plutonium contamination, surficial soil scrapes and vertical soil profiles will be collected in all three remedial investigation areas, and in the Plant areas (buffer zone) south and east of these areas to Indiana Street.

In addition to the RI activities, Rockwell conducts annual soil sampling to assess plutonium contamination in soils surrounding the 903 Drum Storage Site. The Rocky Flats Plant site soil sampling procedures are designed to assess total plutonium in the soil. A ten cm by ten cm frame is driven five cm into the soil, and material within the frame is collected. Ten subsamples are collected from an area approximately three meters by one meter. Samples are collected annually on one and two mile intervals from points located on 18 degree radii from Plant center. Soil is collected from approximately the same point each year. Figure 5-3 is a map showing soil plutonium concentrations at the sample points averaged over the years 1984-1987. Extensive sampling has also occurred off site. However, off-site soil sampling is outside the scope of this investigation, as off-site soil contamination is undergoing remedial action as a separate project.

In order to assess the extent of plutonium in surficial soils within Plant boundaries, soil samples will be collected across the area identified in Figure 5-4. This delineation is based on results depicted in Figure 5-3. Figure 5-4 was constructed by including all areas where soil plutonium concentrations are expected to exceed two dpm/g (approximately one pCi/g). This area consists of approximately 800 acres. The State of Colorado requires special techniques for construction lands with plutonium concentrations greater than two dpm/g of dry soil which is approximately equal to one pCi/g. To evaluate the soil plutonium values relative to this standard, the CDH sampling protocol will be used.

The CDH sampling protocol requires 25 subsamples to be composited within a 10-acre area to compose a soil sample. The 10-acre grids will be located as indicated on Figure 5-4. Grids will not be contiguous except near the 903 Pad. Lines of grids will be placed to define the southern and northern extent of contamination. Other grids will be used to confirm values from within the areas of concern. The northwest corner of each grid will be located by survey and identified with an appropriately marked steel post. Grids will be oriented on the cardinal compass directions. The 25 subsamples will be located with a handheld compass and tape measure using the northwest corner as the starting point.

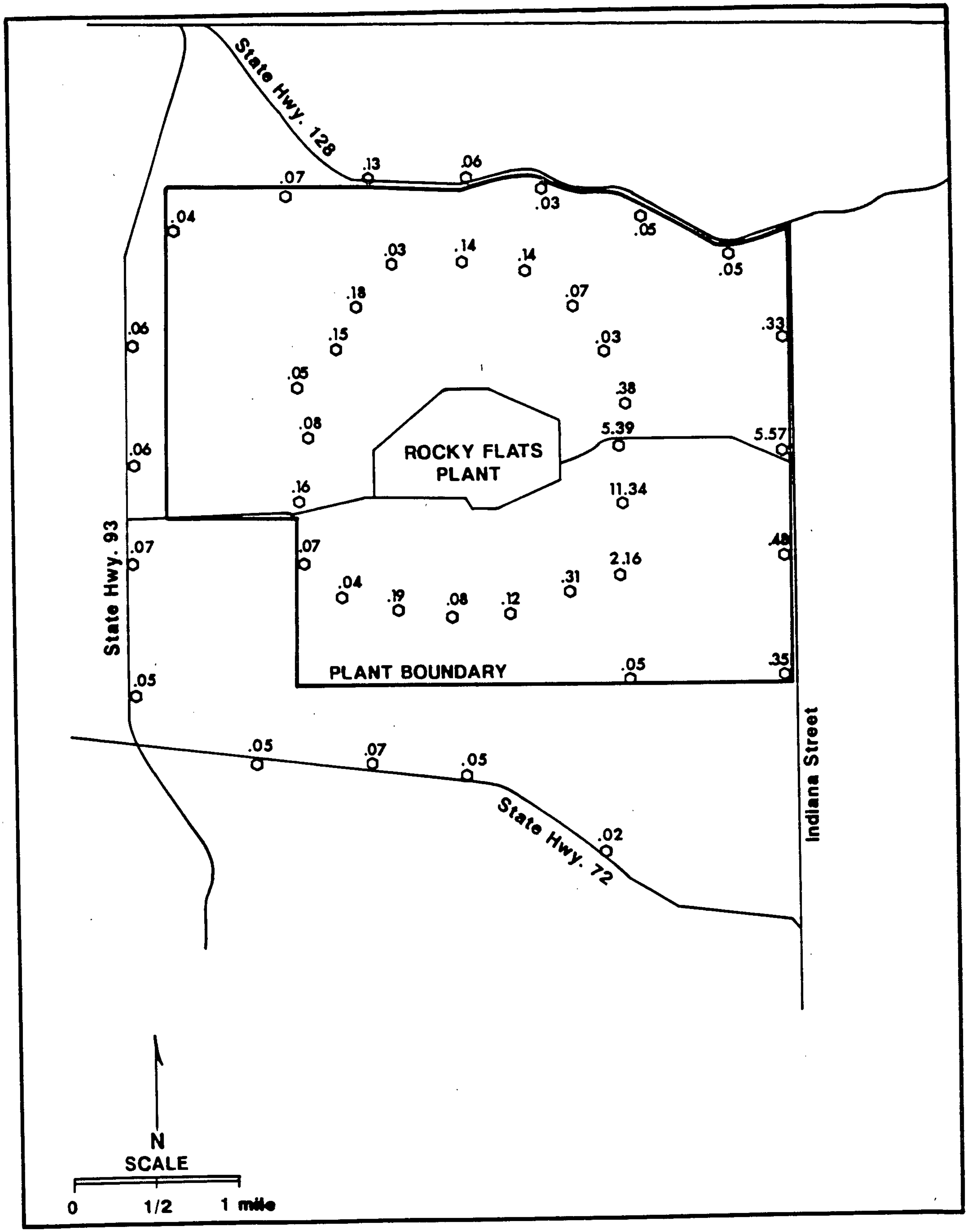


FIGURE 5-3
AVERAGE PLUTONIUM CONCENTRATIONS IN SOIL, 1984-1987
(Values in Picocuries per Gram)

In order to assess the vertical distribution of plutonium 239 + 240 and americium 241 in the soil profile, subsurface sampling will also be done at the locations shown on Figure 5-4. The 24 subsurface soil sampling locations will be placed at the center of the 10 acre plots to facilitate comparison of the data. Backhoe pits will be excavated at each of the indicated locations to a depth of one meter. A 1/8 inch surface scrape, 1/8 inch to 1 cm deep sample, and 1 cm to 5 cm deep sample will be taken. Samples will then be collected each 5 to 10 cm. Samples will be collected from the face of the pit, with all samples being collected within 50 cm of each other horizontally. The samples will be collected from the bottom upward to the surface and equipment will be decontaminated between collection of each sample.

5.1.2.2 Ground Water in Surficial Materials

Based on data collected during the Phase I investigation, volatile organics are present in alluvial and bedrock ground-water flow systems at the 903 Pad, Mound, and East Trenches Areas. The extent of contamination is not fully delineated, and additional monitor wells are needed to define the vertical and lateral extent of the organics. Potential major ion, trace metal, and radionuclide impacts to ground water were not well characterized in the Phase I RI report due to the lack of appropriate background ground-water quality data. Presented below are proposed monitoring well locations and rationale to further characterize ground-water flow and quality in surficial materials at the 903 Pad, Mound, and East Trenches. Bedrock monitoring wells will be proposed in the Phase III RI sampling plan scheduled for completion in 1990, subsequent to the seismic reflection program.

Based on initial sampling results and the Petrex soil gas survey, CCl_4, PCE, and TCE are the primary volatile organic contaminants found in the unconfined ground-water flow system as discussed in Section 2.0. However, the exact leading edge of the plumes are not well defined by the current network of monitoring wells.

903 Pad Area

A total of 27 new alluvial monitor wells will be completed within and downgradient of the 903 Pad Area excluding the three wells to be completed beneath the pad (2-90, 3-90, and 6-90). Table 5-1 presents the proposed wells, the objective of each well, and anticipated completion intervals, and well locations are presented on Figure 5-1.

Six new alluvial wells (1-90, 4-90, 5-90, 7-90, 8-90, and 9-90) are proposed immediately adjacent to the 903 Drum Storage Site to evaluate the extent of saturation, flow directions, and water quality in Rocky Flats Alluvium beneath the pad. Wells 10-90, 11-90, 12-90, 13-90, 14-90, and 15-90 will be drilled downgradient of the 903 Drum Storage Site, Trench T-2, and the Reactive Metal Destruction Site. Data from these wells will serve to differentiate between these three potential sources of volatile organics and to characterize unconfined ground-water flow southeast of the 903 Pad.

Thirteen new alluvial monitor wells are proposed to further define the lateral extent saturation, the potentiometric surface and volatile organics in the shallow ground-water system east and southeast of the 903 Pad Area (Figure 5-1). Three wells (31-90, 32-90 and 33-90) will be completed in Rocky Flats Alluvium east of the 903 Drum Storage Site to define the extent of volatile organics in alluvial ground water and to characterize alluvial ground-water flow. Likewise, alluvial wells 34-90, 35-90, 36-90, 37-90, 38-90, and 39-90 will be completed in colluvium southeast of the 903 Pad Area for plume delineation. Alluvial wells 40-90, 41-90, and 42-90 will be drilled along the northern berm of the South Interceptor Ditch and completed in the berm to monitor the quality of ground water adjacent to the ditch. Well 43-90 will be located on the southern berm of the ditch across from 29-90 to evaluate the elevated inorganics detected in well 29-87 and the relationship between the South Interceptor Ditch and alluvial ground-water flow and quality.

No volatile organics have been detected in Woman Creek valley fill alluvium downgradient of the 903 Pad Area in well 65-86. However, chloride, sulfate, and TDS appear elevated in this well. Two additional wells will be installed in the Woman Creek valley fill alluvium to better define the extent of this contamination and to further characterize the valley fill alluvium. Well 44-90 will be completed in alluvium west (upgradient) of 65-86 and east (downgradient) of Pond C-1, and well 45-90 will be drilled east (downgradient) of 65-86 but west (upgradient) of Pond C-2.

Mound Area

Several new alluvial monitor wells are proposed for the Mound Area. The current upgradient well (43-86) appears to be impacted by the 903 Drum Storage Site, so another upgradient alluvial well is needed. Well 46-90 will be installed in Rocky Flats Alluvium west of 43-86 and the 903 Pad Area to serve as an upgradient well.

Within the Mound Area, ten new alluvial wells will be installed to identify contaminant sources and to characterize the extent of ground-water contamination emanating from the area. Three of the ten well locations are designed to monitor ground water from the Pallet Burn Site and the Oil Burn Pit No. 2 Site. Well 47-90 will be installed adjacent to the Western Pallet Burn Site, and well 48-90 will be installed downgradient of the Oil Burn Pit No. 2 Site. These SWMUs locations are within the PSZ fence, so well installation downgradient of them is difficult. These wells will be placed as close as possible to the SWMUs. In addition, well 49-90 will be installed inside the PSZ fence to monitor ground water downgradient of these sites.

Seven wells will be located between and downgradient of Trench T-1 and the Mound Site to differentiate between these potential sources. Wells 50-90 and 51-90 will be installed adjacent to and downgradient of Trench T-1. Data from well 50-90, located between the trench and the Mound Site, will differentiate between sources. In addition, wells 52-90, 53-90, 54-90, 55-90, and 56-90 will be installed downgradient of the area to the north and east to delineate the extent of volatile organics in ground water.

East Trenches Area

Seven new alluvial wells will be drilled within the northern trench area to characterize ground-water quality and flow and to help differentiate which trenches are contaminant sources. Wells 57-90, 58-90, and 59-90 will be installed downgradient of Trench T-3 to the north, east, and south, respectively. These wells will assist in differentiating between Trenches T-3 and T-4 as the source of volatile organics in well 36-87. Wells 60-90 and 61-90 will be constructed between Trenches T-3/T-4 and T-11/T-10 in an attempt to differentiate the two groups of trenches as contaminant sources. Alluvial ground-water flow in this area is to the southeast toward Trenches T-10 and T-11. Wells 62-90 and 63-90 will be located southeast of Trenches T-11 and T-10 to further characterize the extent of volatile organics in alluvial ground water.

Seven new alluvial wells are proposed within the southern trenches, again, to help differentiate between these potential contaminant sources. Well 64-90 will be installed south of the northern trenches and west of the southern trenches to differentiate between these source areas. Wells 65-90 and 66-90 will be drilled adjacent to Trench T-9, and wells 67-90, 68-90, and 69-90 will bracket flow into and out of the group of Trenches T-5, T-6, and T-7. In addition, well 69-90, located downgradient of Trenches T-5, T-6, and T-7 and upgradient of Trench T-8 will help differentiate these sites as contaminant sources. Well 70-90 will be located downgradient (southeast) of Trench T-8.

Farther downgradient of the southern trenches, a line of alluvial wells will be placed to monitor ground-water flow and quality exiting the area via the paleochannel. These wells (71-90, 72-90, 73-90, 74-90, 75-90, and 76-90) will help delineate the southern and eastern extent of volatile organics in Rocky Flats alluvial ground water. Well 77-90 will be located south of this line of wells and will be completed in colluvium to further characterize hydrogeologic conditions in this area.

Downgradient of the East Trenches toward South Walnut Creek, seven new wells will be installed to evaluate saturated conditions and to monitor ground-water quality north of the Trenches (wells 78-90, 79-90, 80-90, 81-90, 82-90, 83-90, and 84-90). In addition, four alluvial wells will be constructed in Rocky Flats Alluvium east of the trenches and within the East Spray Fields (85-90, 86-90, 87-90 and 88-90) to characterize ground-water flow and quality in this area.

5.1.2.3 Surface Water and Sediments

Nineteen surface water stations were established south of the 903 Pad and East Trenches Areas in the Woman Creek drainage during the 1986 and 1987 investigations, and 12 stations were established north of the Mound and East Trenches Areas in the South Walnut Creek drainage. These 31 stations will also be sampled during the Phase II RI investigation. Figure 2-10 presents surface water monitoring locations in the area, and Table 5-2 presents the surface water stations to be sampled during the Phase II RI.

Sediment samples were taken in October 1989 at stations along South Walnut Creek as well as Woman Creek and the South Interceptor Ditch. The resulting data should suffice as confirmatory information regarding the concentrations of volatile organics, metals, other inorganics, and radionuclides in the sediments. For the Phase II RI, physical characteristics of the sediments (background and "downgradient") and the spatial distribution of the metal concentrations will be examined to assess the adequacy of the background sediment geochemical characterization and thus whether metals are contaminants in the sediments at the 903 Pad, Mound, and East Trenches Areas.

TABLE 5-2

SURFACE WATER SAMPLING STATIONS

SW-21
SW-22
SW-23
SW-24
SW-25
SW-26
SW-27
SW-28
SW-29
SW-30
SW-50
SW-51
SW-52
SW-53
SW-54
SW-55
SW-56
SW-57
SW-58
SW-59
SW-60
SW-61
SW-62
SW-63
SW-64
SW-65
SW-70
SW-77
SW-101
SW-102
SW-103

5.2 SAMPLE ANALYSIS

5.2.1 Borehole Soil Samples

5.2.1.1 Chemical Analysis

Soil samples will be collected from boreholes within and adjacent to SWMUs to characterize sources. All samples will be analyzed for the chemical parameters listed in Table 5-3 following CLP or the methods specified in the QA/QC plan. These parameters are essentially the same as those analyzed in the Phase I RI except that oil and grease and RCRA characteristics are eliminated. Oil and grease have not proven useful in determining extent of soil contamination, and RCRA hazardous waste characteristics have been within acceptable limits. The TCL list for organics and the TAL list for inorganics are nearly the same as the previously used HSL list for organics and inorganics.

5.2.1.2 Physical Analysis

The physical properties of on-site geologic materials will also be characterized to support the evaluation of remedial action alternatives. Bulk samples will be collected from continuous core of alluvial wells to characterize each of the materials found within the 903 Pad, Mound and East Trenches Areas. (Rocky Flats Alluvium, colluvium, valley fill alluvium, and weathered bedrock). Specifically, five samples of each material type will be submitted for grain size analyses (sieve and hydrometer analyses), Atterberg limits testing, and recompacted permeability testing to evaluate the variability of these parameters across the site.

5.2.2 Surficial Soil Samples

Soil samples for plutonium 239 + 240 and americium 241 will be collected from 57 10-acre plots near the 903 Pad, Mound, and East Trenches Areas and in the buffer zone to Indiana

TABLE 5-3

PHASE II RI
SOURCE SAMPLING PARAMETERS
SOIL AND WASTE SAMPLES

METALS

Target Analyte List - Metals

- Aluminum
- Antimony
- Arsenic
- Barium
- Beryllium
- Cadmium
- Calcium
- Chromium
- Cobalt
- Copper
- Iron
- Lead
- Magnesium
- Manganese
- Mercury
- Nickel
- Potassium
- Selenium
- Silver
- Sodium
- Thallium
- Vanadium
- Zinc

Other Metals

- Molybdenum
- Cesium
- Strontium
- Lithium
- Tin

INORGANICS

- pH
- Nitrate
- Percent Solids

ORGANICS

Target Compound List - Volatiles

- Chloromethane
- Bromomethane
- Vinyl Chloride
- Chloroethane
- Methylene Chloride
- Acetone
- Carbon Disulfide
- 1,1-Dichloroethene
- 1,1-Dichloroethane
- total 1,2-Dichloroethene
- Chloroform
- 1,2-Dichloroethane
- 2-Butanone
- 1,1,1-Trichloroethane
- Carbon Tetrachloride
- Vinyl Acetate
- Bromodichloromethane
- 1,1,2,2-Tetrachloroethane
- 1,2-Dichloropropane
- trans-1,2-Dichloropropene
- Trichloroethene

TABLE 5-3 (Continued)

PHASE II RI
SOURCE SAMPLING PARAMETERS
SOIL AND WASTE SAMPLES

ORGANICS (CONT.)

Target Compound List - Volatiles (Continued)

- Dibromochloromethane
- 1,1,2-Trichloroethane
- Benzene
- cis-1,3-Dichloropropene
- Bromoform
- 2-Hexanoe
- 4-Methyl-2-pentanone
- Tetrachloroethene
- Toluene
- Chlorobenzene
- Ethyl Benzene
- Styrene
- Total Xylenes
- 1,1-Dichloroethane

Target Compound List -- Semi-volatiles

- Phenol
- bis(2-Chloroethyl)ether
- 2-Chlorophenol
- 1,3-Dichlorobenzene
- 1,4-Dichlorobenzene
- Benzyl Alcohol
- 1,2-Dichlorobenzene
- 2-Methylphenol
- bis(2-Chloroisopropyl)ether
- 4-Methylphenol
- N-Nitroso-Dipropylamine
- Hexachloroethane
- Nitrobenzene
- Isophorone
- 2-Nitrophenol
- 2,4-Dimethylphenol
- Benzoic Acid
- bis(2-Chloroethoxy)methane
- 2,4-Dichlorophenol
- 1,2,4-Trichlorobenzene
- Naphthalene
- 4-Chloroaniline
- Hexachlorobutadiene
- 4-Chloro-3-methylphenol(para-chloro-meta-cresol)
- 2-Methylnaphthalene
- Hexachlorocyclopentadiene
- 2,4,6-Trichlorophenol
- 2,4,5-Trichlorophenol
- 2-Chloronaphthalene
- 2-Nitroaniline
- Dimethylphthalate
- Acenaphthylene
- 3-Nitroaniline
- Acenaphthene
- 2,4-Dinitrophenol
- 4-Nitrophenol
- Dibenzofuran
- 2,4-Dinitrotoluene
- 2,6-Dinitrotoluene

TABLE 5-3 (Continued)

PHASE II RI
SOURCE SAMPLING PARAMETERS
SOIL AND WASTE SAMPLES

ORGANICS (CONT.)

Target Compound List -- Semi-volatiles (continued)

- Diethylphthalate
- 4-Chlorophenyl Phenyl ether
- Fluorene
- 4-Nitroaniline
- 4,6-Dinitro-2-methylphenol
- N-nitrosodiphenylamine
- 4-Bromophenyl Phenyl ether
- Hexachlorobenzene
- Pentachlorophenol
- Phenanthrene
- Anthracene
- Di-n-butylphthalate
- Fluoranthene
- Pyrene
- Butyl Benzylphthalate
- 3,3'-Dichlorobenzidine
- Benzo(a)anthracene
- bis(2-ethylhexyl)phthalate
- Chrysene
- Di-n-octyl Phthalate
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Benzo(a)pyrene
- Indeno(1,2,3-cd)pyrene
- Dibenz(a,h)anthracene
- Benzo(g,h,i)perylene

Target Compound List -- Pesticides/PCBs

- alpha-BHC
- beta-BHC
- delta-BHC
- gamma-BHC (Lindane)
- Heptachlor
- Aldrin
- Heptachlor Epoxide
- Endosulfan I
- Dieldrin
- 4,4'-DDE
- Endrin
- Endosulfan II
- 4,4'-DDD
- Endosulfan Sulfate
- 4,4'-DDT
- Endrin Ketone
- Methoxychlor
- alpha-Chlordane
- gamma-Chlordane
- Toxaphene
- AROCLOR-1016
- AROCLOR-1221
- AROCLOR-1232
- AROCLOR-1242
- AROCLOR-1248
- AROCLOR-1254
- AROCLOR-1260

TABLE 5-3 (Continued)

PHASE I RI
SOURCE SAMPLING PARAMETERS
SOIL AND WASTE SAMPLES

RADIONUCLIDES

- Gross Alpha
- Gross Beta
- Uranium 233+234, 235 and 238
- Americium 241
- Plutonium 239+240
- Tritium
- Strontium 90, 89
- Cesium 137

NOTE: Select samples will be analyzed for constituents in 40 CFR 268 Table CCWE and Appendix III as well as organic matter content and BTU content.

Street following the CDH sampling protocol. In addition, vertical profiles of plutonium and americium will be developed at 24 sites in the same general area (Section 5.2.1.1). Samples will be collected every 5 to 10 cm to a depth of one meter in order to evaluate the vertical distribution of plutonium and americium.

5.2.3 Ground-Water Samples

Ground-water samples will be collected from all new and existing monitoring wells at the 903 Pad, Mound, and East Trenches Areas. Ground-water samples will be analyzed in the field for pH, conductivity, and temperature. With the exception of samples designated for organics, major ions, and tritium analyses, all samples will be filtered and preserved in the field. Organics, major ions, and tritium samples will not be filtered. Samples will be analyzed for the parameters listed in Table 5-4 during the first round of sampling after completion of 1990 wells. This parameter list may be reduced in subsequent sampling events if certain parameter groups are not detected or are not significantly above background levels.

5.2.4 Surface Water and Sediment Samples

Surface water samples will be analyzed in the field for pH, conductivity, temperature, and dissolved oxygen. Laboratory analyses of surface water samples will consist of the parameters listed in Table 5-5, and sediments will be analyzed for the parameters listed in Table 5-3. All samples requiring filtration will be filtered in the field, and all samples will be preserved in the field. Surface water sampling and stream flow measurements will follow the procedures described in the Rocky Flats ER Program SOP.

TABLE 5-4

PHASE II RI
GROUND-WATER SAMPLING PARAMETERS

FIELD PARAMETERS
- pH
- Specific Conductance
- Temperature

INDICATORS
- Total Dissolved Solids

DISSOLVED METALS
- Target Analyte List - Metals
  - Aluminum
  - Antimony
  - Arsenic
  - Barium
  - Beryllium
  - Cadmium
  - Calcium
  - Chromium
  - Cobalt
  - Copper
  - Iron
  - Lead
  - Magnesium
  - Manganese
  - Mercury
  - Nickel
  - Potassium
  - Selenium
  - Silver
  - Sodium
  - Thallium
  - Vanadium
  - Zinc
- Other Metals
  - Molybdenum
  - Strontium
  - Cesium
  - Lithium
  - Tin

ANIONS
- Carbonate
- Bicarbonate
- Chloride
- Sulfate
- Nitrate as N
- Cyanide

ORGANICS
- Target Compound List - Volatiles
  - Chloromethane
  - Bromomethane
  - Vinyl Chloride
  - Chloroethane
  - Methylene Chloride
  - Acetone
  - Carbon Disulfide
  - 1,1-Dichloroethene
  - 1,1-Dichloroethane
  - total 1,2-Dichloroethene
  - Chloroform

TABLE 5-4 (Continued)

PHASE II RI
GROUND-WATER SAMPLING PARAMETERS

ORGANICS (CONT.)

Target Compound List - Volatiles (Continued)

- 1,2-Dichloroethane
- 2-Butanone
- 1,1,1-Trichloroethane
- Carbon Tetrachloride
- Vinyl Acetate
- Bromodichloromethane
- 1,1,2,2-Tetrachloroethane
- 1,2-Dichloropropane
- trans-1,3-Dichloropropene
- Trichloroethene
- Dibromochloromethane
- 1,1,2-Trichloroethane
- Benzene
- cis-1,3-Dichloropropene
- Bromoform
- 2-Hexanone
- 4-Methyl-2-pentanone
- Tetrachloroethene
- Toluene
- Chlorobenzene
- Ethyl Benzene
- Styrene
- Total Xylenes

Target Compound List -- Semi-volatiles

- Phenol
- bis(2-Chloroethyl)ether
- 2-Chlorophenol
- 1,3-Dichlorobenzene
- 1,4-Dichlorobenzene
- Benzyl Alcohol
- 1,2-Dichlorobenzene
- 2-Methylphenol
- bis(2-Chloroisopropyl)ether
- 4-Methylphenol
- N-Nitroso-Dipropylamine
- Hexachloroethane
- Nitrobenzene
- Isophorone
- 2-Nitrophenol
- 2,4-Dimethylphenol
- Benzoic Acid
- bis(2-Chloroethoxy)methane
- 2,4-Dichlorophenol
- 1,2,4-Trichlorobenzene
- Naphthalene
- 4-Chloroaniline
- Hexachlorobutadiene
- 4-Chloro-3-methylphenol(para-chloro-meta-cresol)
- 2-Methylnaphthalene
- Hexachlorocyclopentadiene
- 2,4,6-Trichlorophenol
- 2,4,5-Trichlorophenol
- 2-Chloronaphthalene
- 2-Nitroaniline
- Dimethylphthalate
- Acenaphthylene

TABLE 5-4 (Continued)

PHASE II RI
GROUND-WATER SAMPLING PARAMETERS

ORGANICS (CONT.)

Target Compound List -- Semi-volatiles (Continued)

- 3-Nitroaniline
- Acenaphthene
- 2,4-Dinitrophenol
- 4-Nitrophenol
- Dibenzofuran
- 2,4-Dinitrotoluene
- 2,6-Dinitrotoluene
- Diethylphthalate
- 4-Chlorophenyl Phenyl ether
- Fluorene
- 4-Nitroaniline
- 4,6-Dinitro-2-methylphenol
- N-nitrosodiphenylamine
- 4-Bromophenyl Phenyl ether
- Hexachlorobenzene
- Pentachlorophenol
- Phenanthrene
- Anthracene
- Di-n-butylphthalate
- Fluoranthene
- Pyrene
- Butyl Benzylphthalate
- 3,3'-Dichlorobenzidine
- Benzo(a)anthracene
- bis(2-ethylhexyl)phthalate
- Chrysene
- Di-n-octyl Phthalate
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Benzo(a)pyrene
- Indeno(1,2,3-cd)pyrene
- Dibenz(a,h)anthracene
- Benzo(g,h,i)perylene

Target Compound List -- Pesticides/PCBs

- alpha-BHC
- beta-BHC
- delta-BHC
- gamma-BHC (Lindane)
- Heptachlor
- Aldrin
- Heptachlor Epoxide
- Endosulfan I
- Dieldrin
- 4,4'-DDE
- Endrin
- Endosulfan II
- 4,4'-DDD
- Endosulfan Sulfate
- 4,4'-DDT
- Endrin Ketone
- Methoxychlor
- alpha-Chlordane
- gamma-Chlordane
- Toxaphene
- AROCLOR-1016

TABLE 5-4 (Continued)

PHASE II RI
GROUND-WATER SAMPLING PARAMETERS

ORGANICS (CONT.)

Target Compound List -- Pesticides/PCBs (continued)

- AROCLOR-1221
- AROCLOR-1232
- AROCLOR-1242
- AROCLOR-1248
- AROCLOR-1254
- AROCLOR-1260

RADIONUCLIDES

- Gross Alpha — 70
- Gross Beta
- Uranium 233+234, 235, and 238 — 5 x 173
- Americium 241
- Plutonium 239+240
- Tritium — 100
- ~~Cesium 137~~
- Strontium 90 — 130
- Radium 226, 228 — 100

sum 1265

Preparation 35

Disposal 5

Packaging 300

$ 1305

$1605

Screening -
Alpha Beta - $.75 all sample
Gamma -

TABLE 5-5

PHASE II RI
SURFACE WATER SAMPLING PARAMETERS

FIELD PARAMETERS

- pH
- Specific Conductance
- Temperature
- Dissolved Oxygen

INDICATORS

- Total Dissolved Solids
- Total Suspended Solids

DISSOLVED AND TOTAL METALS

- Target Analyte List - Metals
  - Aluminum
  - Antimony
  - Arsenic
  - Barium
  - Beryllium
  - Cadmium
  - Calcium
  - Chromium
  - Cobalt
  - Copper
  - Iron
  - Lead
  - Magnesium
  - Manganese
  - Mercury
  - Nickel
  - Potassium
  - Selenium
  - Silver
  - Sodium
  - Thallium
  - Vanadium
  - Zinc
- Other Metals
  - Molybdenum
  - Strontium
  - Cesium
  - Lithium
  - Tin

ANIONS

- Carbonate
- Bicarbonate
- Chloride
- Sulfate
- Nitrate as N
- Cyanide

ORGANICS

- Target Compound List - Volatiles
  - Chloromethane
  - Bromomethane
  - Vinyl Chloride
  - Chloroethane
  - Methylene Chloride
  - Acetone
  - Carbon Disulfide
  - 1,1-Dichloroethene

TABLE 5-5 (Continued)

PHASE II RI
SURFACE WATER SAMPLING PARAMETERS

ORGANICS (CONT.)

Target Compound List - Volatiles (Continued)

- 1,1-Dichloroethane
- total 1,2-Dichloroethene
- Chloroform
- 1,2-Dichloroethane
- 2-Butanone
- 1,1,1-Trichloroethane
- Carbon Tetrachloride
- Vinyl Acetate
- Bromodichloromethane
- 1,1,2,2-Tetrachloroethane
- 1,2-Dichloropropane
- trans-1,3-Dichloropropene
- Trichloroethene
- Dibromochloromethane
- 1,1,2Trichloroethane
- Benzene
- cis-1,3-Dichloropropene
- Bromoform
- 2-Hexanone
- 4-Methyl-2-pentanone
- Tetrachloroethene
- Toluene
- Chlorobenzene
- Ethyl Benzene
- Styrene
- Total Xylenes

RADIONUCLIDES

- Gross Alpha (Filtered)
- Gross Beta (Filtered)
- Uranium 233+ 234, 235, and 238 (Filtered and Unfiltered)
- Americium 241 (Filtered and Unfiltered)
- Plutonium 239+240 (Filtered and Unfiltered)
- Tritium (Unfiltered)
- Cesium 137
- Radium 226, 228
- Strontium 90

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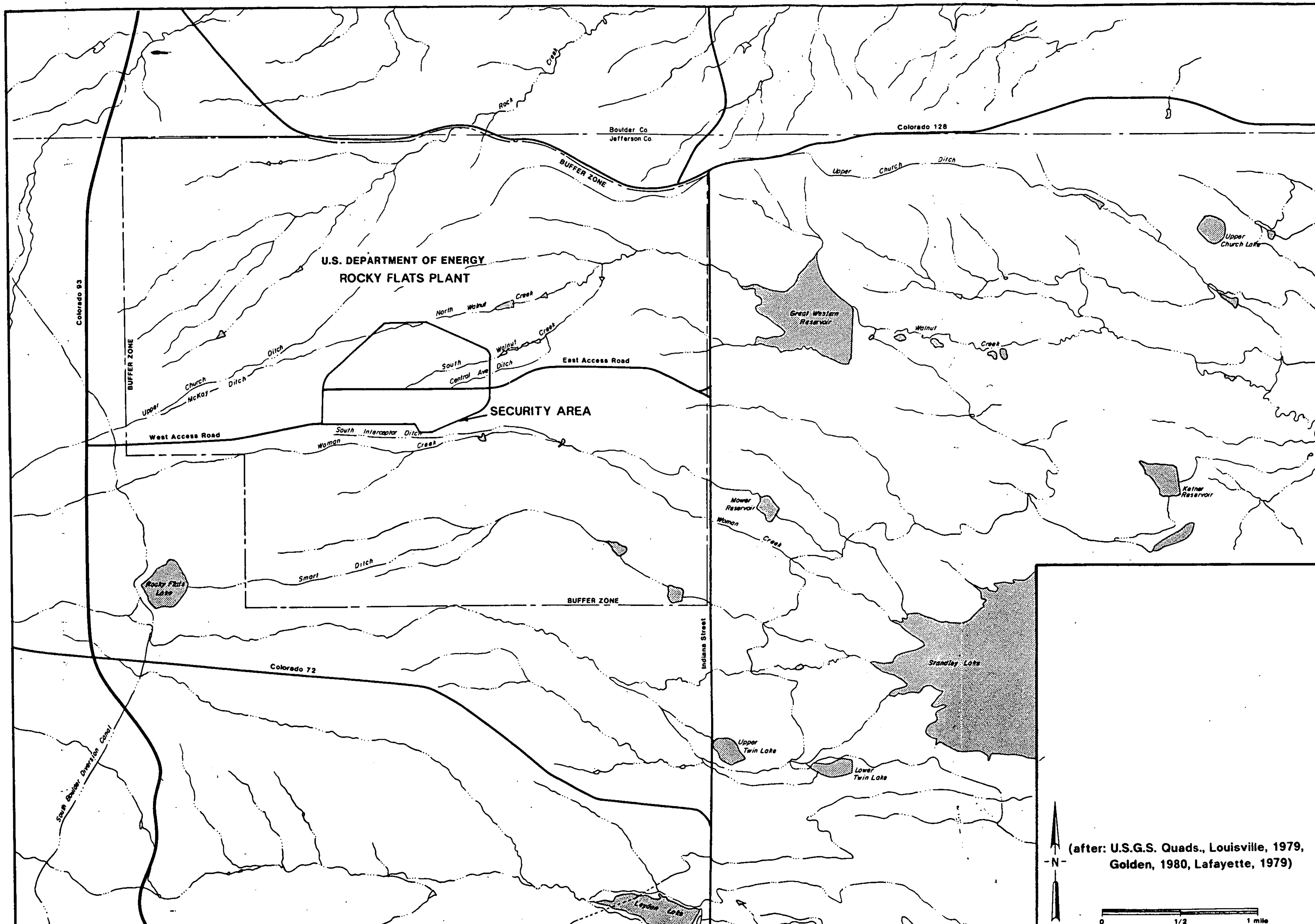
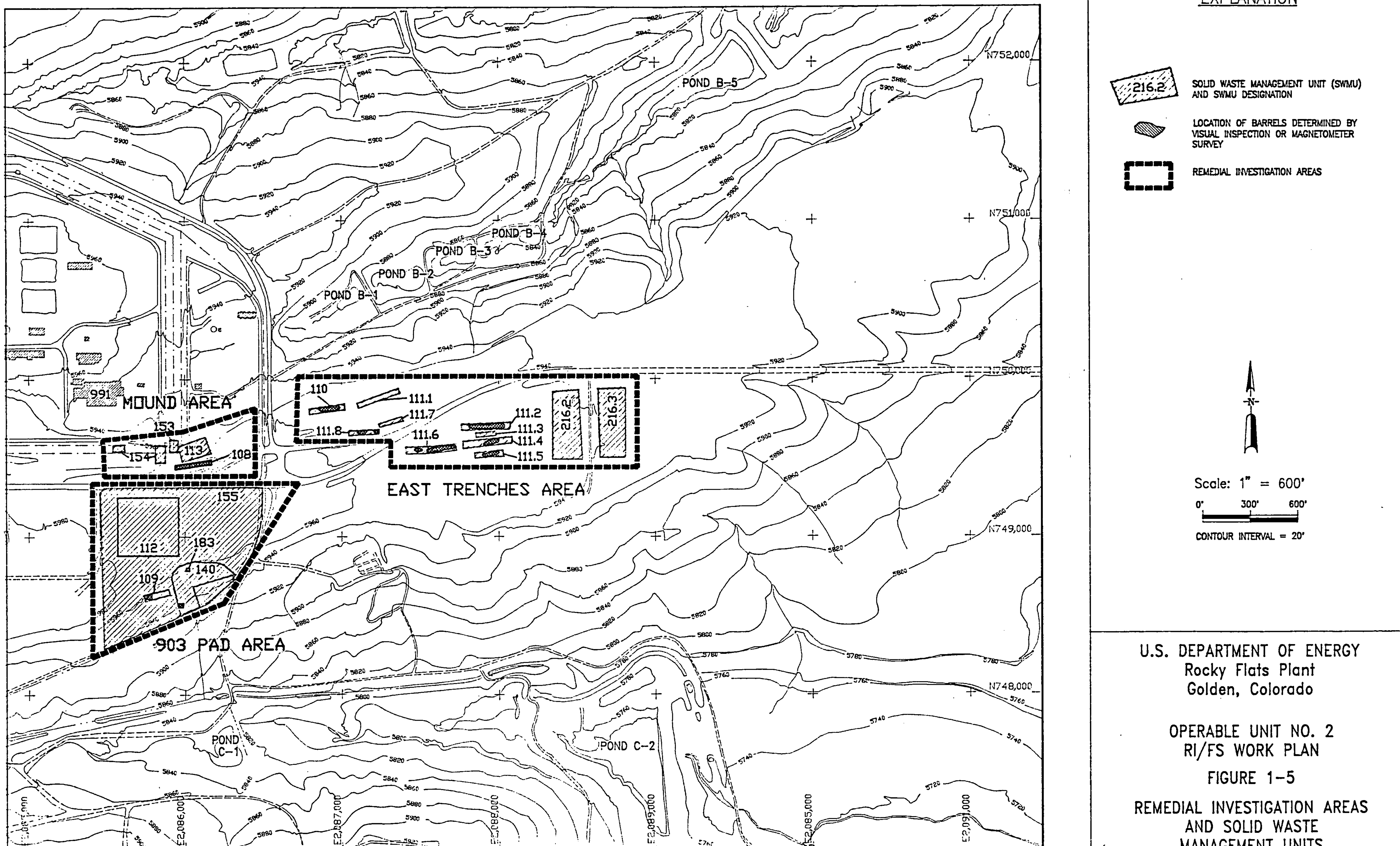


FIGURE 1-2

ROCKY FLATS PLANT BOUNDARIES AND BUFFER ZONE



U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

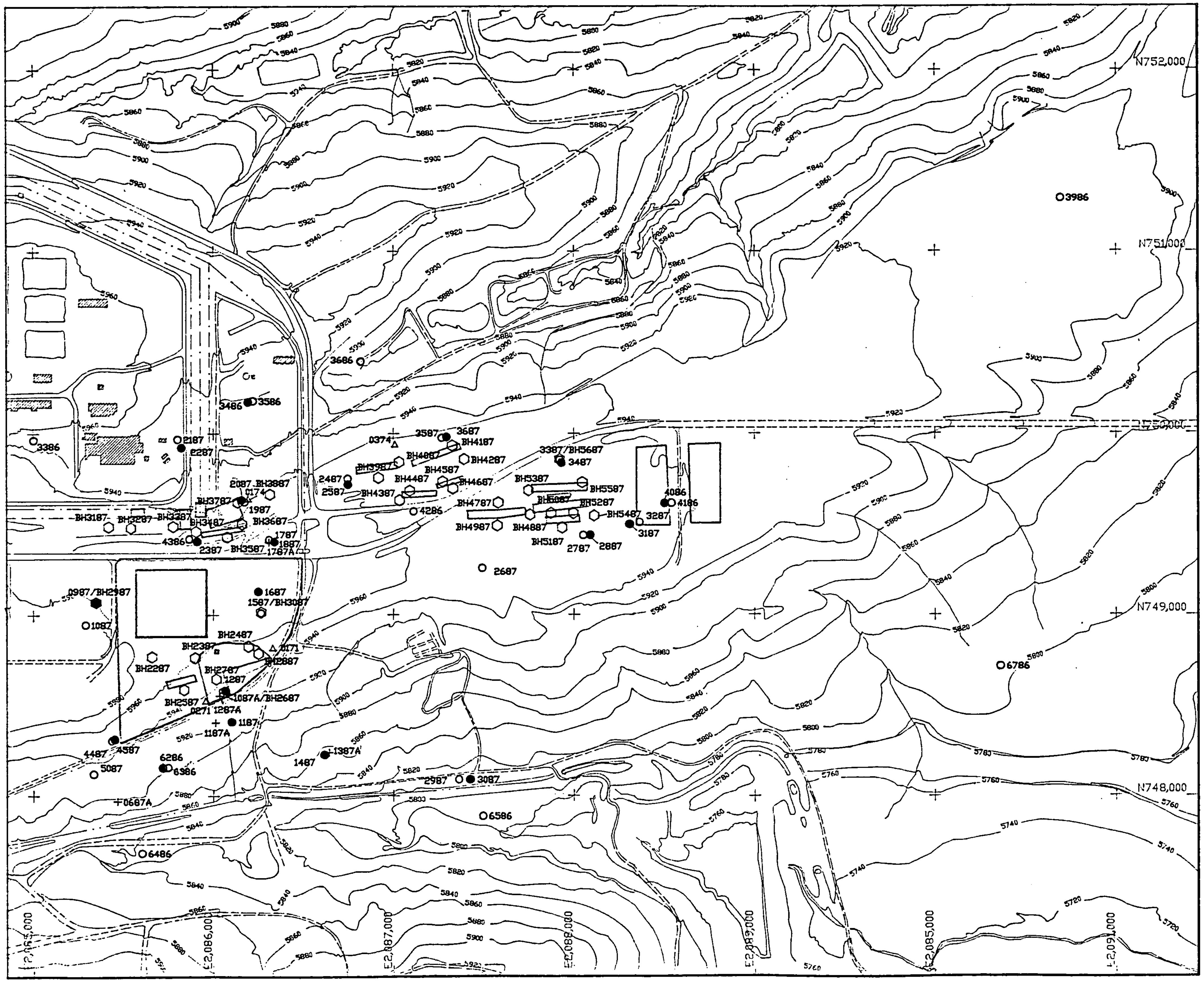
OPERABLE UNIT NO. 2
RI/FS WORK PLAN

FIGURE 1-5

REMEDIAL INVESTIGATION AREAS AND SOLID WASTE MANAGEMENT UNITS

December 1989

RF600A.MB-121889



EXPLANATION

▭	SOLID WASTE MANAGEMENT UNIT (SWMU) AND SWMU DESIGNATION
B217489 ●	BEDROCK MONITOR WELL
B213789 ○	ALLUVIAL MONITOR WELL
0392 △	PRE-1986 MONITOR WELL
B217389 +	ABANDONED HOLE
BH4987 ⬡	BOREHOLE

N

Scale: 1" = 600'

0' 300' 600'

CONTOUR INTERVAL = 20'

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

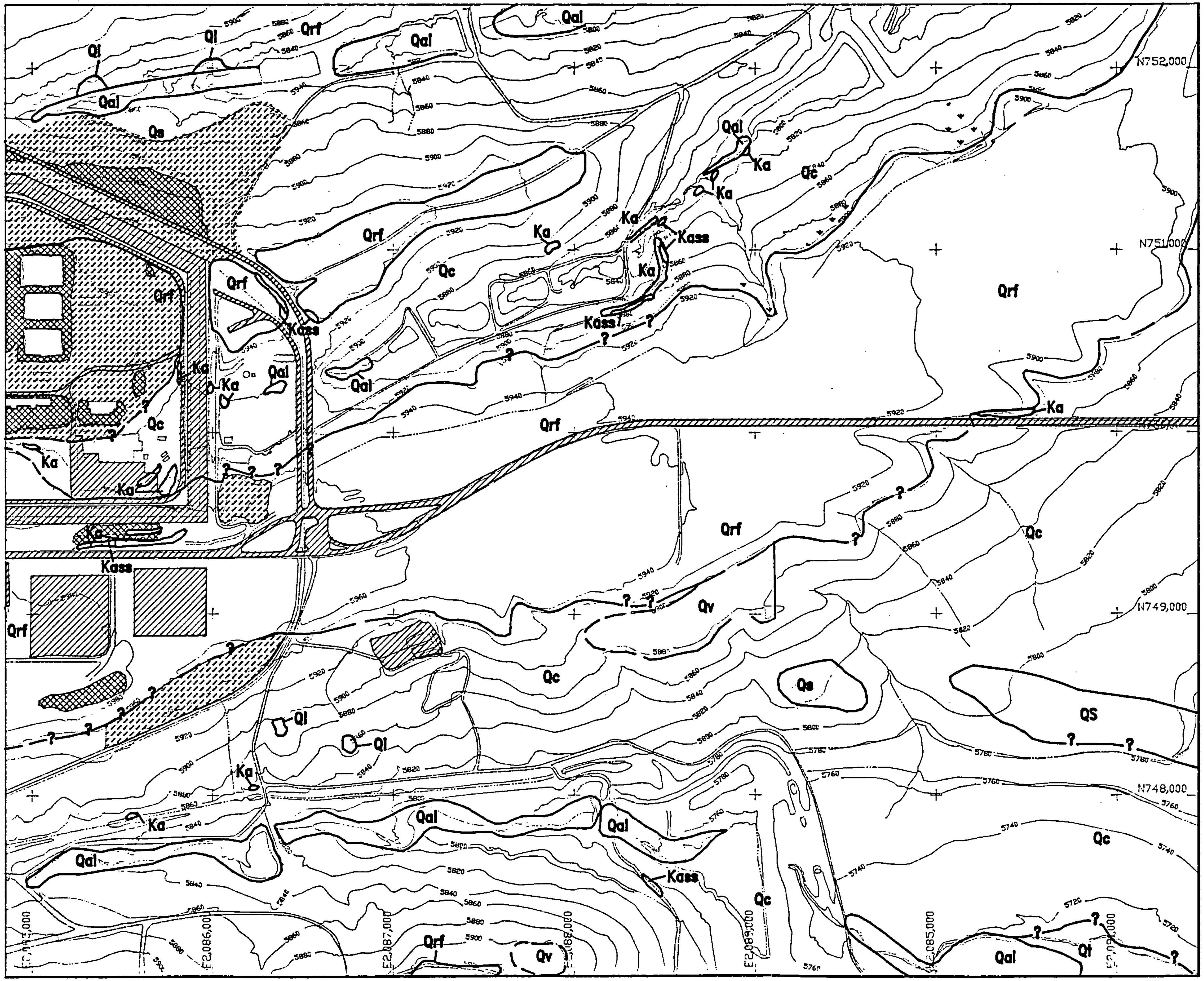
OPERABLE UNIT NO. 2
RI/FS WORK PLAN

FIGURE 2-1

PHASE I-REMEDIAL INVESTIGATION
MONITOR WELL AND
BOREHOLE LOCATIONS

December, 1989

RF6000.MB-121789



EXPLANATION

CONTACT
DASHED WHERE APPROXIMATELY LOCATED, QUERIED WHERE INFERRED.

ARTIFICIAL FILL

PAVEMENT OR GRAVEL

DISTURBED GROUND

QUATERNARY

- **Qal** RECENT VALLEY FILL
- **Ql** LANDSLIDE
- **Qc** COLLUVIUM
- **Qt** TERRACE ALLUVIUM
- **Qs** SLOCUM ALLUVIUM
- **Qv** VERDOS ALLUVIUM
- **Qrf** ROCKY FLATS ALLUVIUM

CRETACEOUS

- **Kass** ARAPAHOE FORMATION, SANDSTONE
- **Ka** ARAPAHOE FORMATION, CLAYSTONE

N

Scale: 1" = 600'

0' 300' 600'

CONTOUR INTERVAL = 20'

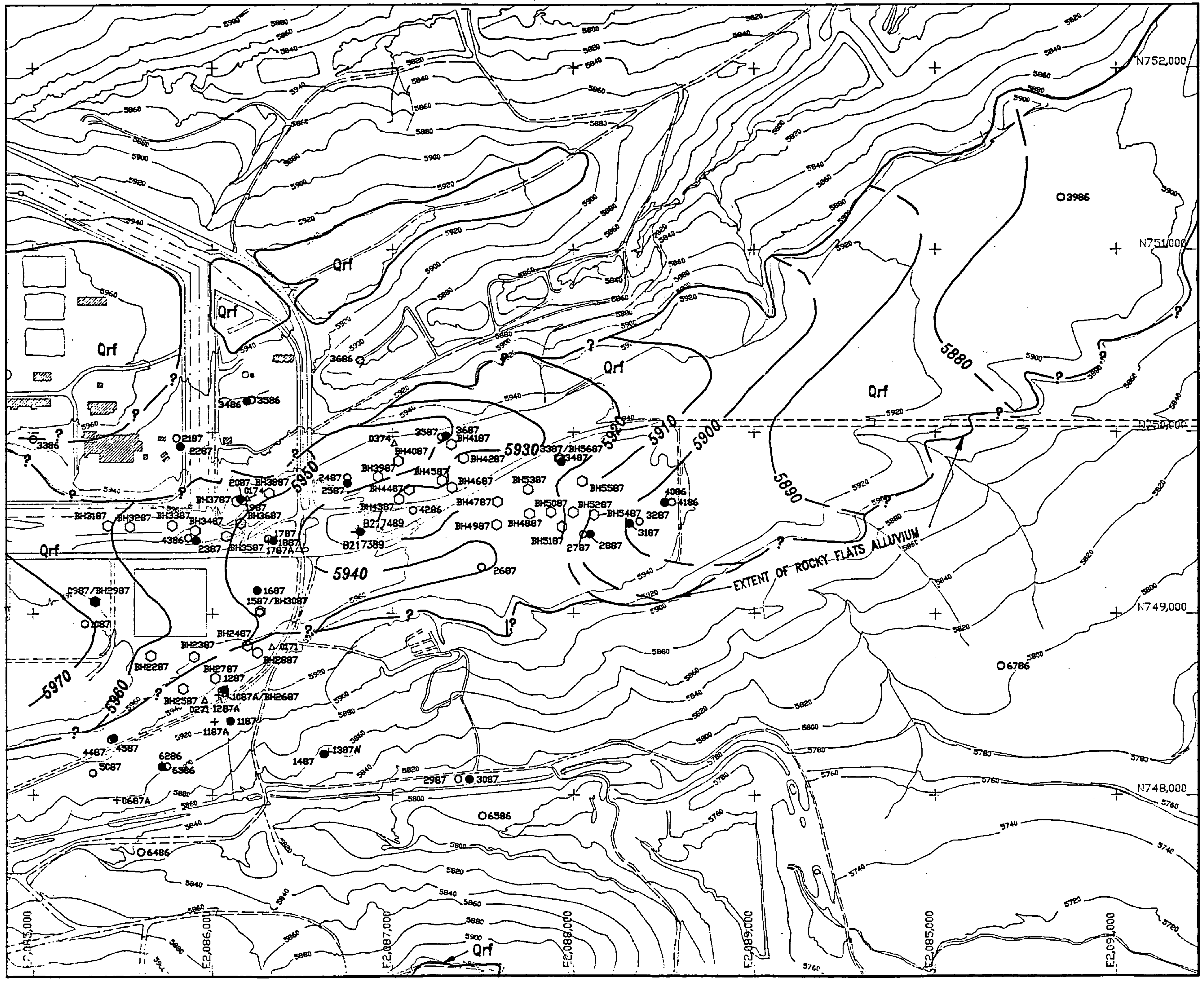
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

OPERABLE UNIT NO. 2
RI/FS WORK PLAN

FIGURE 2-2
SURFICIAL GEOLOGY

December, 1989

RF600J.MB-122089



EXPLANATION

CONTACT

DASHED WHERE APPROXIMATELY LOCATED, QUERIED WHERE INFERRED.

5900 — TOP OF BEDROCK ELEVATION (FEET ABOVE M.S.L.) CONTOUR INTERVAL = 10'

B217489	●	BEDROCK MONITOR WELL
B213789	○	ALLUVIAL MONITOR WELL
0392	△	PRE-1986 MONITOR WELL
B217389	+	ABANDONED HOLE
BH4987	⬡	BOREHOLE

N

Scale: 1" = 600'

0' 300' 600'

CONTOUR INTERVAL = 20'

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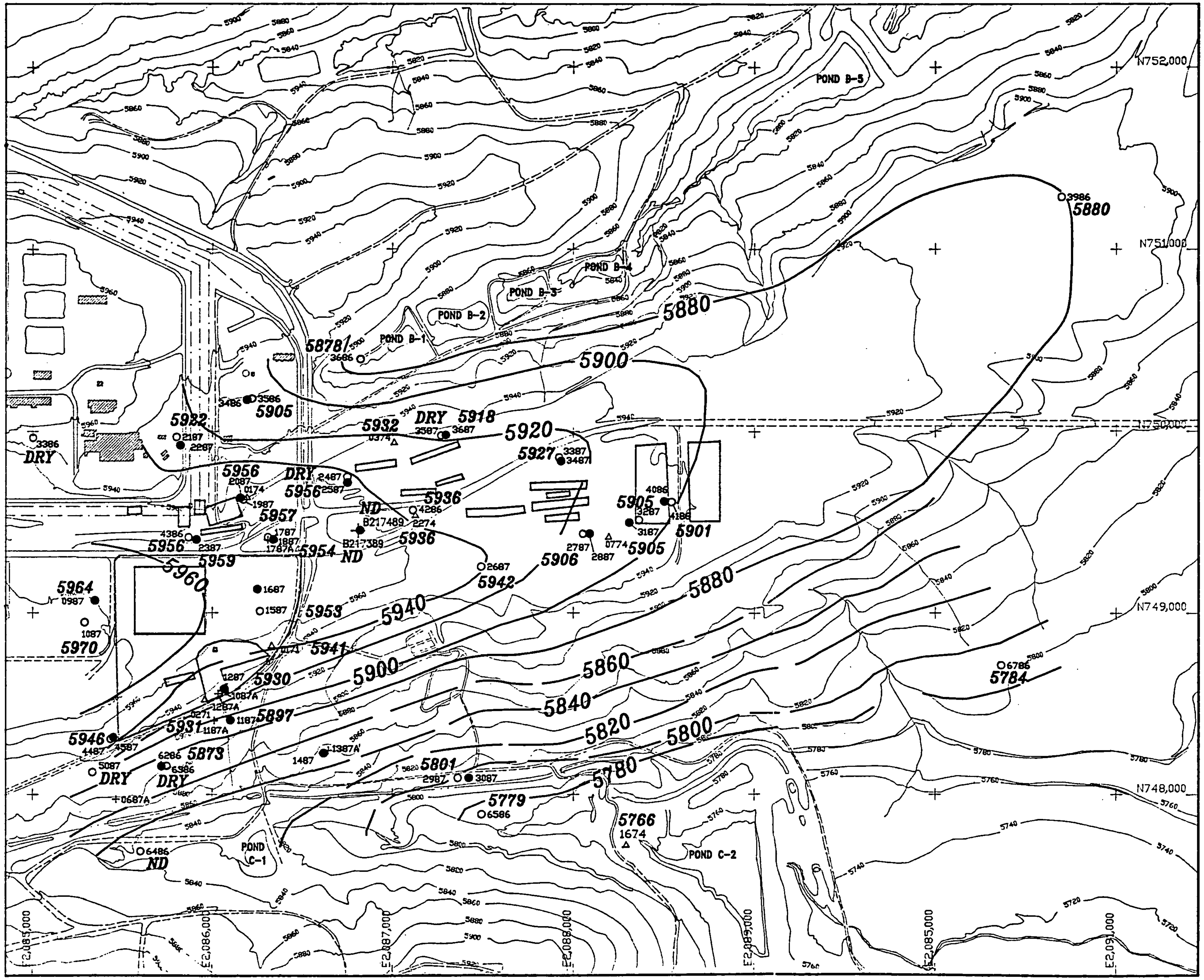
FIGURE 2-3

TOP OF BEDROCK ELEVATION
BENEATH ROCKY FLATS ALLUVIUM

December, 1989

RF600I.MB-121589



EXPLANATION

SOLID WASTE MANAGEMENT UNIT (SWMU)

5798 POTENTIOMETRIC SURFACE ELEVATION (feet above mean sea level)

ALL DATA BASED ON MEASUREMENTS MADE APRIL 4–8, 1988 INCLUSIVE

5860 LINE OF EQUAL POTENTIOMETRIC SURFACE ELEVATION (feet above mean sea level)—DASHED WHERE APPROXIMATELY LOCATED

ND NO DATA

B217489 ● BEDROCK MONITOR WELL

B213789 ○ ALLUVIAL MONITOR WELL

0382 △ PRE-1986 MONITOR WELL

B217389 + ABANDONED HOLE

N

Scale: 1" = 600'

0' 300' 600'

CONTOUR INTERVAL = 20'

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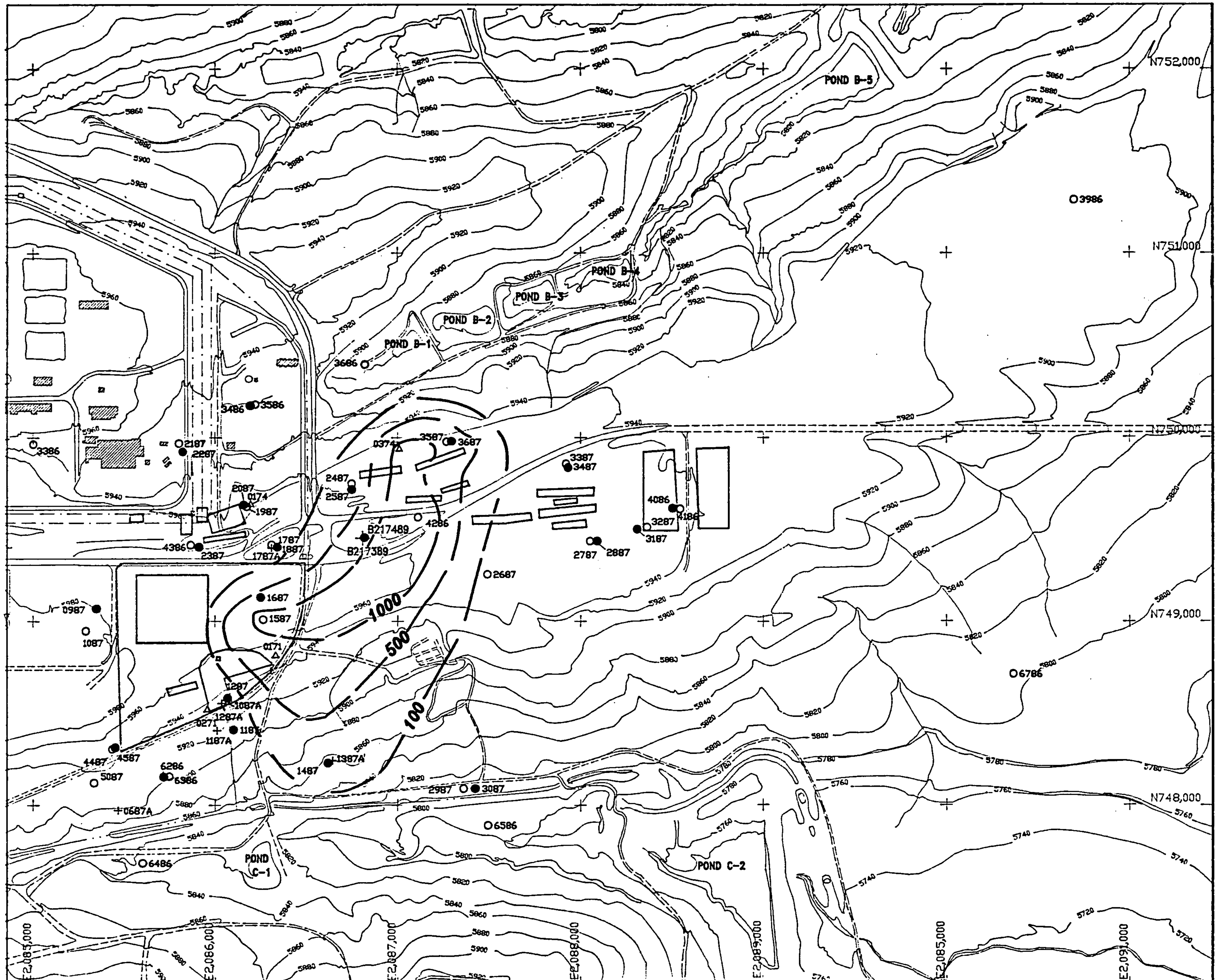
FIGURE 2-4

POTENTIOMETRIC SURFACE OF UNCONFINED GROUND-WATER FLOW SYSTEM

December, 1989

RF600R.MB-121889



EXPLANATION

SOLID WASTE MANAGEMENT UNIT (SWMU)

500 — LINE OF EQUAL CCl_4 CONCENTRATION (µg/l) DASHED WHERE APPROXIMATELY LOCATED

NOTE: DATA VALUES SHOWN ON TABLE 2-10

B217489 ● BEDROCK MONITOR WELL

B213789 ○ ALLUVIAL MONITOR WELL

0382 △ PRE-1986 MONITOR WELL

B217389 + ABANDONED HOLE

N

Scale: 1" = 600'

0' 300' 600'

CONTOUR INTERVAL = 20'

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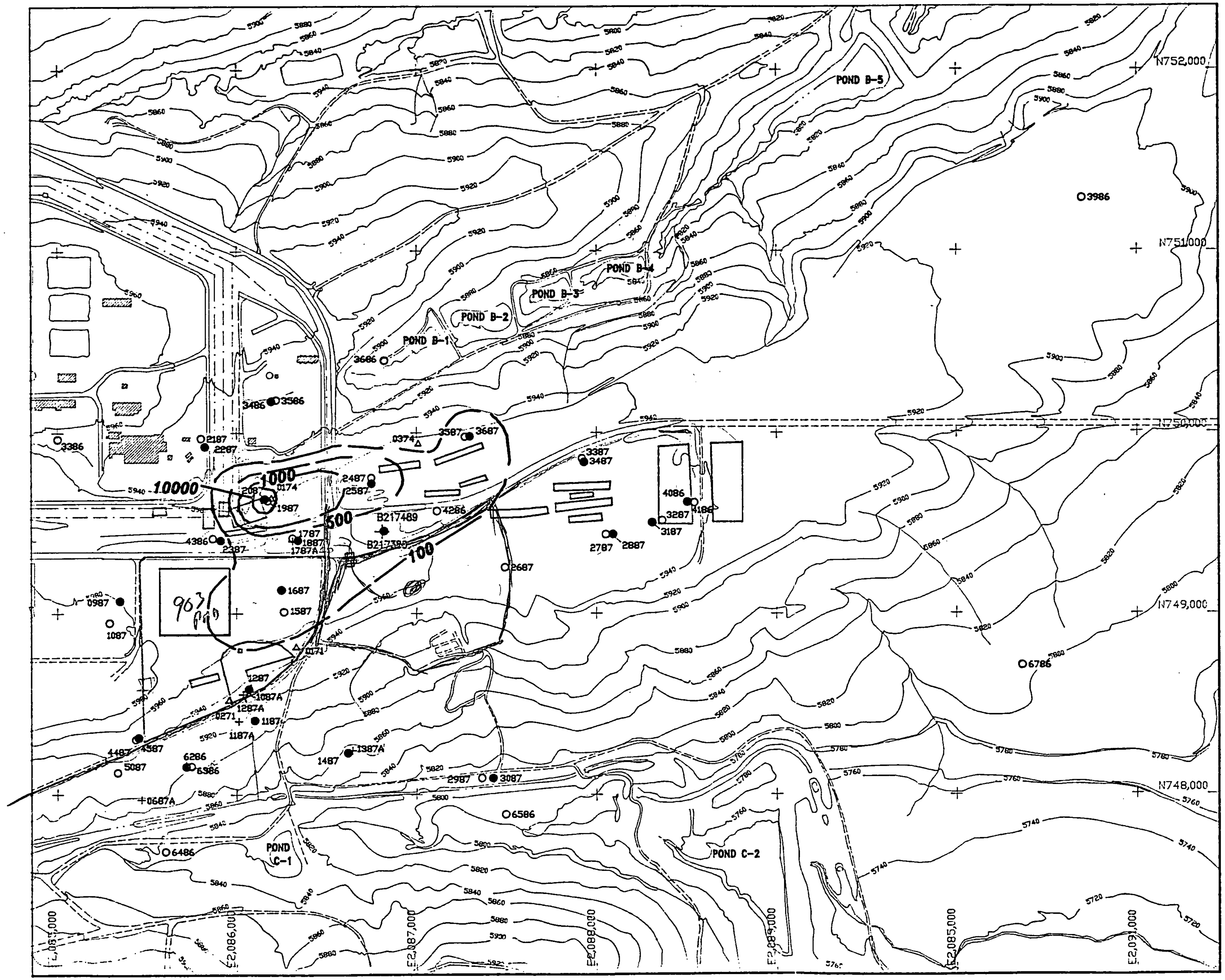
FIGURE 2-7

CARBON TETRACHLORIDE ISOPLETHS FOR THE UNCONFINED GROUND-WATER FLOW SYSTEM
Second Quarter 1989

December, 1989

RF600D.MB-121789



EXPLANATION

SOLID WASTE MANAGEMENT UNIT (SWMU) AND SWMU DESIGNATION

500 — LINE OF EQUAL PCE CONCENTRATION (µg/l) DASHED WHERE APPROXIMATELY LOCATED

NOTE: DATA VALUES SHOWN ON TABLE 2-10

B217489 ● BEDROCK MONITOR WELL

B213789 ○ ALLUVIAL MONITOR WELL

0382 △ PRE-1986 MONITOR WELL

B217389 + ABANDONED HOLE

N

Scale: 1" = 600'

0' 300' 600'

CONTOUR INTERVAL = 20'

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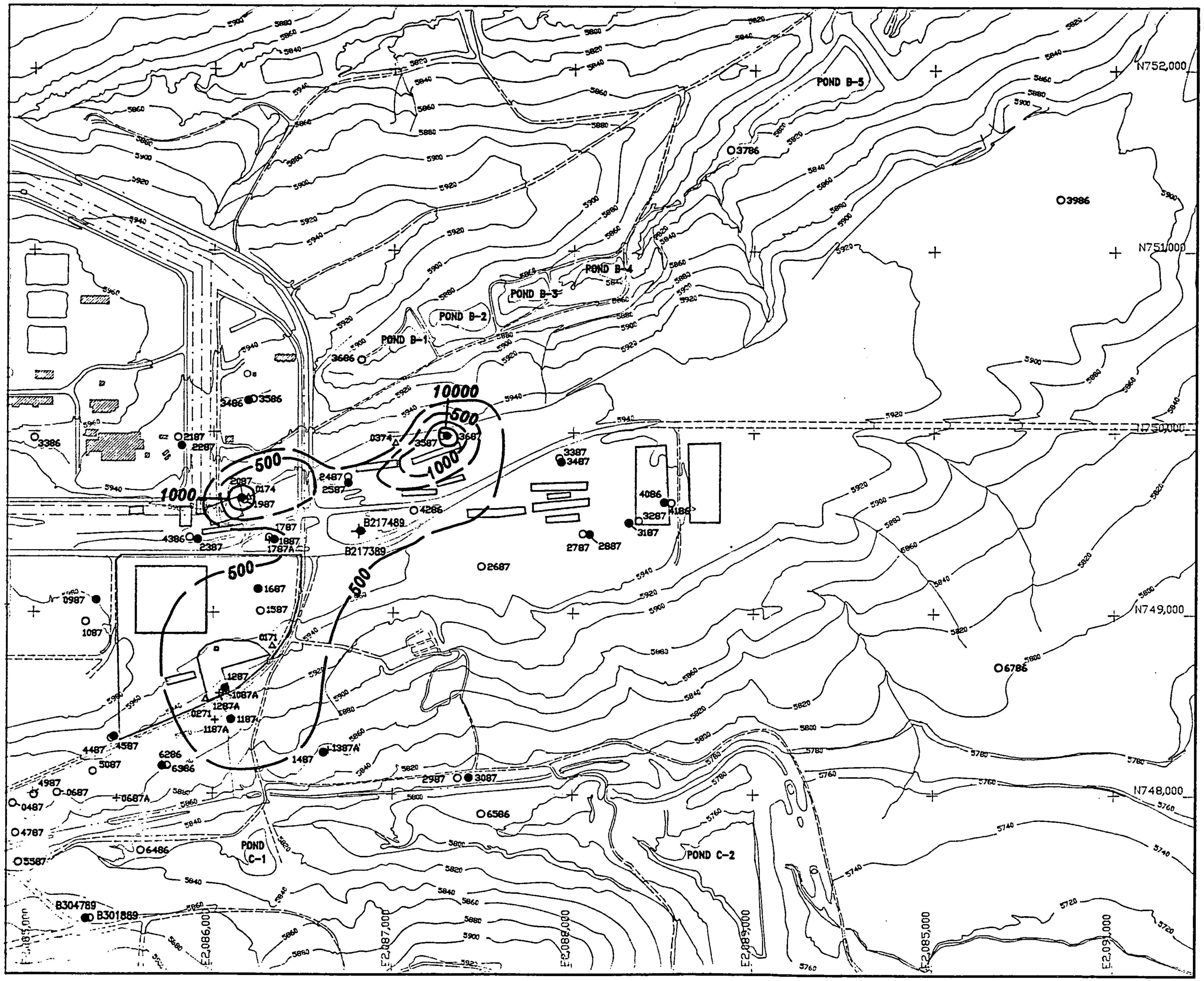
FIGURE 2-8

TETRACHLOROETHENE ISOPLETHS FOR THE UNCONFINED GROUND-WATER FLOW SYSTEM
Second Quarter 1989

December, 1989

RF600F.MB-121789



EXPLANATION

SOLID WASTE MANAGEMENT UNIT (SWMU)

500 — LINE OF EQUAL TCE CONCENTRATION (μg/l) DASHED WHERE APPROXIMATELY LOCATED

NOTE: DATA VALUES SHOWN ON TABLE 2-10

B217489 ● BEDROCK MONITOR WELL

B213789 ○ ALLUVIAL MONITOR WELL

0382 △ PRE-1986 MONITOR WELL

B217389 + ABANDONED HOLE

N

Scale: 1" = 600'

0' 300' 600'

CONTOUR INTERVAL = 20'

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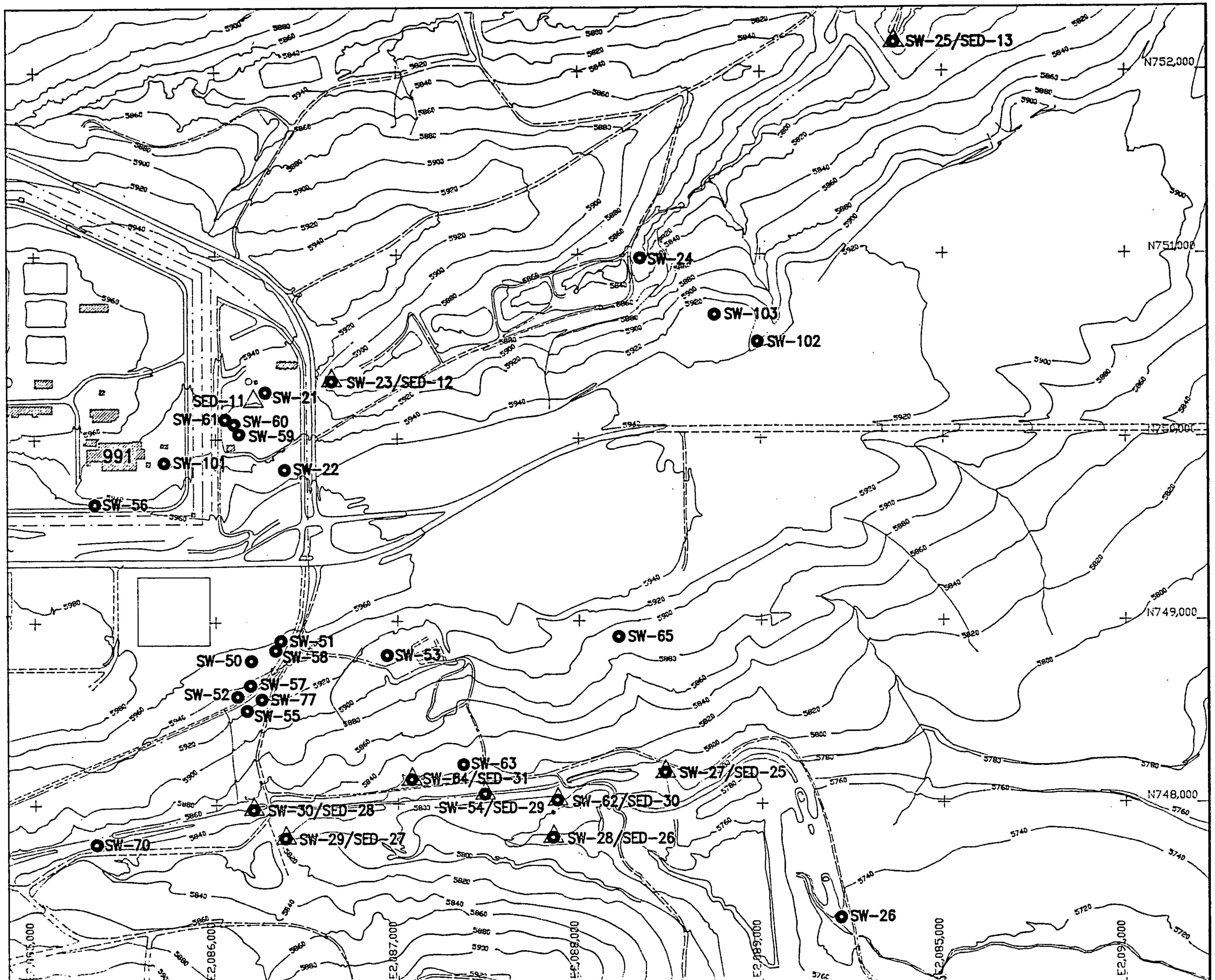
FIGURE 2-9

TRICHLOROETHENE ISOPLETHS
FOR THE UNCONFINED GROUND-WATER
FLOW SYSTEM
Second Quarter 1989

December, 1989

RF600H.NB-121789



EXPLANATION

SW-102 — SURFACE WATER MONITORING STATION

SED-11 — SEDIMENT SAMPLING STATION

N

Scale: 1" = 600'

0' 300' 600'

CONTOUR INTERVAL = 20'

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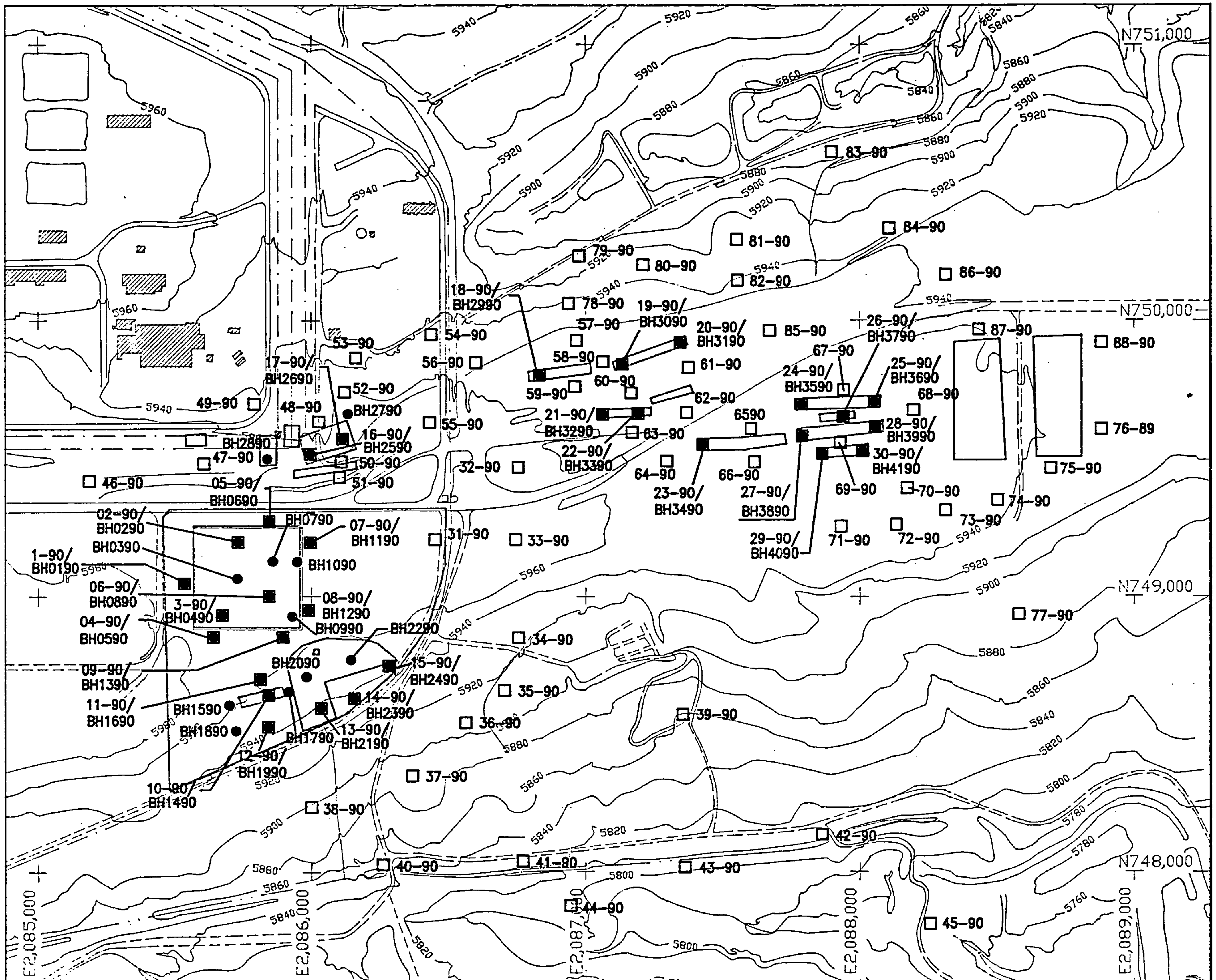
RI/FS WORK PLAN

FIGURE 2-10

SURFACE WATER AND SEDIMENT MONITORING STATIONS

December, 1989

RF600S.MB-122089



EXPLANATION

SOLID WASTE MANAGEMENT UNIT (SWMU) AND SWMU DESIGNATION

□ 77-90 PROPOSED MONITOR WELL

● BH1590 PROPOSED BOREHOLE

■ 18-90/ BH2990 PROPOSED MONITOR WELL AND BOREHOLE

N

Scale: 1" = 400'

0' 200' 400'

CONTOUR INTERVAL = 20'

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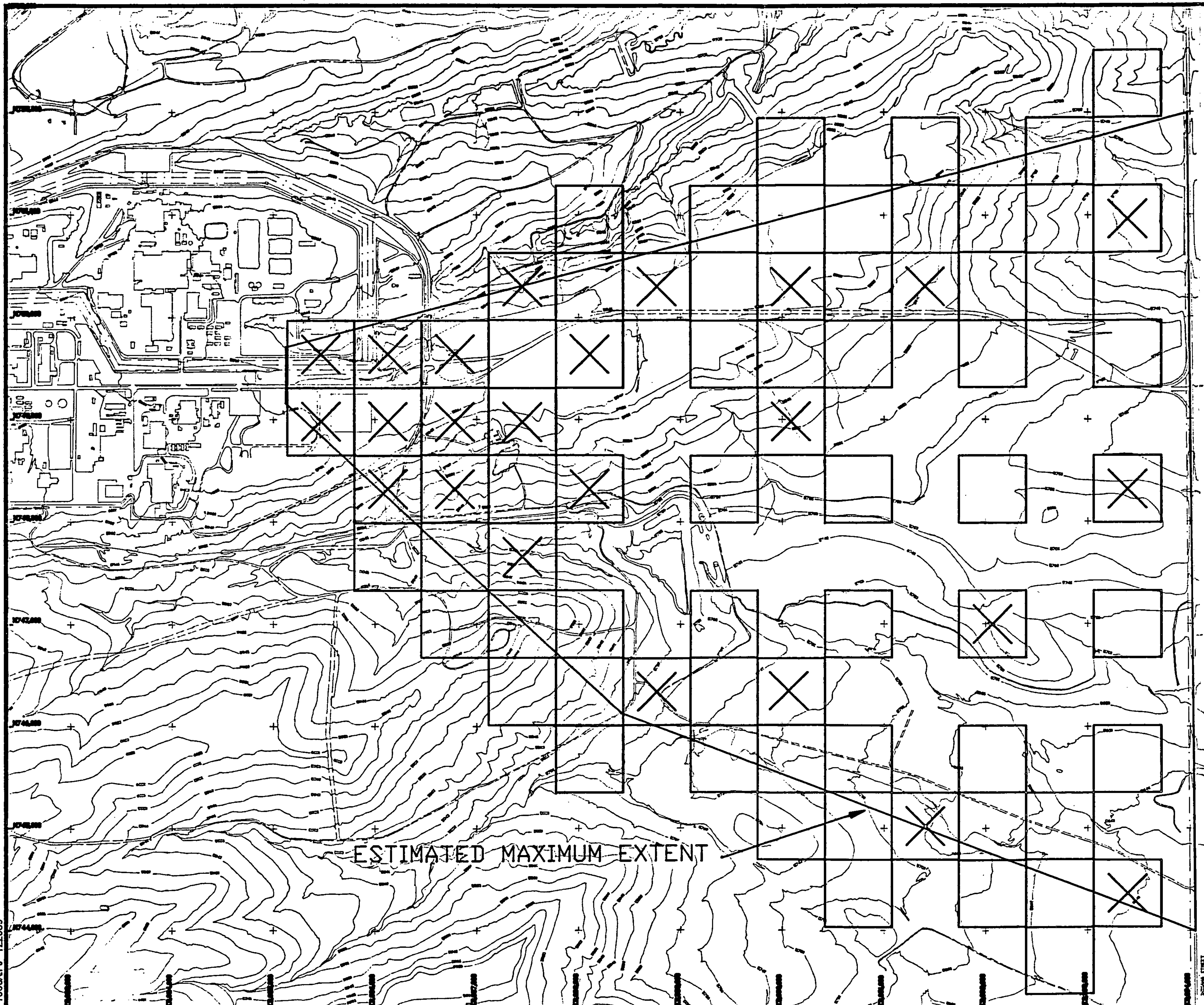
FIGURE 5-1

PHASE II-REMEDIAL INVESTIGATION
PROPOSED MONITOR WELL AND
BOREHOLE LOCATIONS

December 1989

RF400BPJ-122089



EXPLANATION

ESTIMATED MAXIMUM EXTENT OF SURFICIAL SOILS CONTAINING TWO dpm/g ACTIVITY BY CDH PROTOCOL

10 ACRE SAMPLING PLOT LOCATIONS

SOIL PROFILE SAMPLING LOCATIONS

N

1" = 1000'

0' 500' 1000'

CONTOUR INTERVAL = 20'

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FIGURE 5-4

SURFICIAL SOIL SAMPLING LOCATIONS

December 1989

RF1000A.PJ-122089