ROCKWELL INTERNATIONAL
NORTH AMERICAN SPACE OPERATIONS
ROCKY FLATS PLANT

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

Volume I

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1.0 EXECUTIVE SUMMARY

This report presents the results of the remedial investigation of the 903 Pad, Mound, and East Trenches Areas at the Rocky Flats Plant, Golden, Colorado. The objectives of the remedial investigation are to verify the existence and location of the waste disposal sites, to characterize the sites, to evaluate the nature and extent of contamination, and to develop data needed for feasibility studies of remedial alternatives as appropriate.

The Rocky Flats Plant is a Department of Energy (DOE) facility manufacturing components for nuclear weapons and has been in operation since 1951. The Plant fabricates components from plutonium, uranium, beryllium, and stainless steel. Production activities include metal fabrication, machining, and assembly. Both radioactive and nonradioactive wastes are generated in the process. Current waste handling practices involve on-site and off-site recycling of hazardous materials and off-site disposal of solid radioactive materials at another DOE facility. However, both storage and disposal of hazardous and radioactive wastes occurred onsite in the past. Preliminary assessments under the DOE Comprehensive Environmental Assessment and Response Program (CEARP) identified some of the past on-site storage and disposal locations as potential sources of environmental contamination.

CEARP investigations at Rocky Flats Plant have been integrated with other RCRA and CERCLA issues pursuant to the Compliance Agreement signed by representatives of the DOE, the U.S. Environmental Protection Agency (EPA) and the State of Colorado (Colorado Department of Health) on July 31, 1986. The Compliance Agreement addresses hazardous and radioactive mixed waste management at Rocky

Flats Plant. The CEARP Phase 1 Installation Assessment for Rocky Flats Plant included analyses 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. CEARP Phase 1 identified a number of sites that could potentially have adverse impacts on the environment. Data collected during preparation of the RCRA Part B Operating Permit Application identified several additional potential sites. All of these potential sites at Rocky Flats Plant were designated as RCRA solid waste management units (SWMUs), and assigned an identification number.

Hydrogeological and hydrogeochemical characterization on an installation-wide basis was performed at Rocky Flats in 1986 as part of the initial CEARP Phase 2 site characterization. Results of that investigation are presented in the RCRA Part B Permit Application for Rocky Flats Plant. Analysis of these data has identified four areas which are the most probable sources of environmental contamination, with each area containing several sites. These areas are the 881 Hillside Area, the 903 Pad Area, the Mound Area, and the East Trenches Area. A CEARP Phase 2 remedial investigation report for high priority sites at the 881 Hillside Area was submitted to the Colorado Department of Health and EPA on July 1, 1987.

The CEARP remedial investigation of the eleven sites comprising the 903 Pad, Mound, and East Trenches Areas began in March 1987. The investigation consisted of the preparation of detailed topographic maps, radiometric and organic vapor screening surveys, surface geophysical surveys, a soil gas survey, a boring and well completion program, soil sampling, and ground and surface water sampling. A brief summary of the findings at each site is presented below:

903 PAD AREA

1) SWMUs 112, 155, 109, and 140: These SWMUs are all in the vicinity of the 903 drum storage site (SWMU 112). Chlorinated solvents occur in the ground water which appear to be released from multiple sources [903 drum storage site (SWMU 112), the reactive metal destruction site (SWMU 140), and Trench T-2 (SWMU 109)]. All of these sites, as well as the 903 lip site (SWMU 155), have plutonium contaminated surficial soils. Acetone and bis(2-ethylhexyl)phthalate also appear to be contaminants of the soil.

MOUND AREA

2) SWMU 108: Trench T-1 at the Mound Area contains drums filled with depleted uranium chips coated with small amounts of lathe coolant. Surficial soils were found to be contaminated with plutonium, and to a lesser extent, americium.

3) SWMUs 153 and 154: At SWMUs 153 (oil burn pit No. 2) and 154 (pallet burn site), with the exception of acetone, volatiles were either not detected in the soils or were detected at low levels. Acetone concentrations in the blanks and soils were of similar magnitude suggesting acetone is probably a lab contaminant.

4) SWMU 113: The Mound site, located northeast of Trench T-1 (SWMU 108), was a uranium, beryllium, and lathe coolant drum storage area. Soils in this area may be contaminated with bis(2-ethylhexyl)phthalate, and ground water is contaminated with chlorinated solvents.

EAST TRENCHES AREA

5) SWMU 110: Trench T-3 at the East Trenches contains sewage sludge and flattened drums contaminated with plutonium, uranium, and probably lathe coolant. This is a potential source for the alluvial ground water contamination (chlorinated solvents) in this area. Surficial soils are contaminated with plutonium.

6) SWMUs 111.1, 111.7, and 111.8: Trenches T-4, T-10, and T-11 contain sewage sludge, uranium, and plutonium contaminated planks from the solar ponds and flattened drums contaminated with uranium, plutonium, and probably lathe coolant. These trenches are a potential source for the alluvial ground-water contamination (chlorinated solvents) in this area.

7) SWMUs 111.2-111.6: Trenches T-5 through T-9 contain uranium and plutonium contaminated flattened drums. Soils are contaminated with chlorinated solvents and possibly acetone. Surficial soil is contaminated

with plutonium. These trenches are a potential source for the alluvial ground-water contamination (chlorinated solvents) in this area.

Ground water occurs in both alluvial and bedrock materials beneath all of the sites. Alluvial ground water flow is generally from west to east following the buried topography of the claystone bedrock. Bedrock highs in the East Trenches Area divert alluvial ground water to the northeast following a paleovalley or diverts it toward the edges (north and south) of the Rocky Flats terrace. Ground water flowing toward the terrace edges emerges as seeps and springs at the contact between the alluvium and claystone bedrock (contact seeps). Most of this water 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 creeks.

The majority of ground-water flow in the Arapahoe Formation is from west to east occurring in the lenticular 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. There is a strong downward gradient between ground water in surficial materials and bedrock.

The highest concentrations of volatile organics in alluvial ground water were found at wells 1-71, 2-71, 1-74, 42-86, 3-74, and 15-87. The highest concentrations of 1,1-dichloroethene (1,1-DCE) (673 ug/l), 1,2-dichloroethane (1,2-DCA) (400 ug/l), trans-1,2-dichloroethene (t-1,2-DCE) (364 ug/l), and trichloroethene (TCE) (26,000 ug/l) were reported in well 2-71, located within the 903 Pad Area. Also within the 903 Pad Area, the highest concentrations of chloroform ($CHCl_3$) (1,525 ug/l at well 1-

71) and 1,1,1-trichloroethane (1,1,1-TCA) (2,892 ug/l at well 1-71) were reported for alluvial ground water. High concentrations of volatile organics were found in the Mound Area in well 1-74. Concentrations of PCE were reported as high as 528,000 ug/l. This is the highest PCE concentration reported for alluvial ground water at the Plant. However, concentrations of PCE at this well have been as low as nondetectable (most recent sample) and typically have been in the range of 10,000 to 100,000 ug/l. Another potential source of VOCs is at the East Trenches Area in the vicinity of wells 3-74 and 42-86. The highest concentration of carbon tetrachloride (CCl_4) was observed at this location (4,835 ug/l at well 42-86); however, concentrations of VOCs are generally lower than those observed in alluvial ground water at the 903 Pad and Mound Areas. It should be noted that these reported maximum concentrations of VOCs are considered qualitative data because the laboratory performing the analyses did not meet all QA/QC requirements. (See Appendix G and Section 5.0 for further discussion). Samples collected subsequently and split with another laboratory indicate concentrations are considerably lower than reported here.

It appears volatilization, adsorption, or dilution have reduced VOC concentrations to non-detectable levels as alluvial ground water migrates to the east and toward the drainages. VOCs have not been detected at well 39-86 (South Walnut Creek drainage) or at wells 67-86 and 66-86 (Woman Creek drainage) located east of the potential sources. VOC contamination does not extend farther downgradient than well 41-86, just east of the East Trenches, and well 29-87 southeast of the 903 Pad Area. VOC contamination at these locations is only suspected as VOCs occur at low levels or are otherwise not detected (well 41-86), or the presence of VOCs is uncertain because duplicate samples do not show detectable VOC concentrations (well 29-87).

Ground-water samples collected during late 1986 from well 2-71 contained elevated levels of plutonium [32(3) pCi/l], americium [4.4(2.3) pCi/l], uranium-234 [30(3) pCi/l], and uranium-238 [33(5) pCi/l]. These are the highest levels of plutonium and americium ever reported for a well at the Plant. Therefore, an attempt was made to resample the well as soon as these results were available (November 1986), but the well was dry in November 1986 and could not be resampled to verify the reported values. The highest plutonium and americium concentrations ever reported for well 2-71 during 1980-1985 were <0.08 pCi/l and 0.16 ± 0.08 pCi/l, respectively, and plutonium and americium concentrations were within background levels during 1987. The only other ground-water data that indicated elevated radionuclides were for well 42-86 during late 1986 {U-234 [9.8(1.1) pCi/l] and U-238 [11(1) pCi/l]} and for well 40-86 during second quarter 1987 [Am 1(0.73) pCi/l), U-234 10(2) pCi/l]. All other ground-water samples collected at these wells have not shown radionuclide concentrations above estimated background levels. It is tentatively concluded that radionuclide contamination of ground water does not exist; however, further sampling and analysis is required for confirmation.

Bedrock ground water is contaminated with VOCs southeast of the 903 Pad Area at well 11-87BR, 12-87BR, and 14-87BR. Maximum concentrations of VOCs are PCE (43 ug/l), TCE (3,570 ug/l), CCl_4 (560 ug/l), and $CHCl_3$ (71 ug/l). The downgradient extent of contamination in the ground water of these bedrock sandstones is unknown. However, hydraulic conductivity and gradient data suggest a maximum travel distance of 2250 (feet using a maximum calculated gradient of 0.09 ft/ft) if the sandstones are continuous. Additional drilling is required to determine the extent and continuity of these sandstones.

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. Most of these samples were found to contain VOCs. The most contaminated samples appear to be located just north of the Mound Area and south of the 903 Pad Area. Maximum concentrations of TCE, PCE, 1,1-DCE, $CHCl_3$, CCl_4, and 1,1,1-TCA in the upper South Walnut Creek drainage north of the Mound Area were 62, 73, 133, 40, 605, and 33 ug/l, respectively. Other VOCs were not detected. Maximum concentrations of TCE, PCE, 1,1-DCE, $CHCl_3$, and CCl_4 in the seeps just southeast of the 903 Pad were 40, 65, 140, 84, and 1005 ug/l, respectively. However, the samples collected farther downstream on Woman Creek and South Walnut Creek showed no VOC contamination. For example, no VOCs were detected in surface water samples from the South Interceptor Ditch (Sample SW-30), Pond C-1 (Sample SW-29), Pond B-5 (Sample SW-B5) and South Walnut Creek (sample SW-25). VOCs were also not present in seeps just northwest of Pond C-2. All sampling stations are located downstream of the 903 Pad, Mound, and East Trenches Areas. The VOC contamination of surface water appears to be localized in the immediate vicinity of the 903 Pad and Mound Areas.

High plutonium and americium concentrations found in the seeps southeast of the 903 Pad represent particulate forms of these radionuclides originating from contaminated soils at the surface. This is concluded because ground water apparently is not contaminated with radionuclides; the seeps represent surfacing ground water; and the seep samples were not filtered prior to analysis and contained substantial suspended solids. As discussed below, plutonium contamination of surface soils exists in the vicinity of these seeps. It should be noted that none of the surface water samples were filtered, which facilitates comparison of the data.

Soils at the surface of the 903 Pad, Mound, and East Trenches Areas are contaminated with plutonium and americium. Maximum plutonium and americium concentrations in composite soil samples from drilling cores taken at ground surface were 180(10) pCi/g and 22(6) pCi/g. These concentrations occurred in soils at the 903 Pad Area. Concentrations of these radionuclides were generally two orders of magnitude less at the Mound and East Trenches Areas but nevertheless elevated above the estimated background levels of 0.10(0.20) pCi/gm and 0.28(0.16) pCi/gm for plutonium and americium, respectively. Windblown dust from the 903 drum storage site is the suspected source of surface contamination at the Mound and East Trenches Areas.

Ambient air monitoring for radionuclides and Criteria Pollutants (total suspended particulates, ozone, sulfur dioxide, carbon monoxide, nitrogen dioxide and lead) during the past ten years and during the remedial investigation indicate that air quality is not degraded by operations at the Plant. In addition, an ambient air survey during the remedial investigation did not detect any volatile organics emanating from the areas.

Biota at the Plant have been identified, classified, and studied with respect to plutonium uptake. No endangered species exist at the Plant, and no population-level effects due to plutonium were found.

Currently, neither ground water, surface water, nor air carries contaminants from the 903 Pad, Mound, and East Trenches Areas to the property boundary. Therefore, there is no immediate public health threat.

2.0 INTRODUCTION

A comprehensive, phased program of site characterization, remedial investigations, feasibility studies, and remedial/corrective actions is in progress at the Rocky Flats Plant. These investigations are pursuant to the U.S. Department of Energy (DOE) Comprehensive Environmental Assessment and Response Program (CEARP) and a Compliance Agreement finalized by representatives of DOE, the U.S. Environmental Protection Agency (EPA) and the State of Colorado (CDH) on July 31, 1986. The Agreement addresses hazardous and radioactive mixed waste management at the Rocky Flats Plant. The program developed by DOE, EPA, and CDH in response to the Agreement addresses RCRA and CERCLA issues and has been integrated with CEARP investigations.

CEARP is being implemented in five phases. CEARP Phase 1 (Installation Assessment) has already been completed at Rocky Flats Plant. CEARP Phase 1 evaluated compliance with environmental laws and ascertained the magnitude of potential environmental concerns. CEARP Phase 2 (Monitoring Plans and Remedial Investigations) will complete the environmental evaluation of potential environmental concerns identified in CEARP Phase 1, and plan and carry out sampling programs to understand potential contaminant sources and environmental pathways. CEARP Phase 3 (Feasibility Studies) will develop remedial action plans to mitigate environmental problems identified as needing correction in CEARP Phase 2. CEARP Phases 2 and 3 are currently in progress for priority sites at Rocky Flats Plant. CEARP Phase 4 (Remedial/Corrective Action) will design and implement the site-specific remedial actions selected on the basis of CEARP Phase 3 feasibility studies. CEARP Phase 5 (Compliance and Verification) will implement monitoring and performance assessment of remedial action and will verify and document the adequacy of remedial actions carried out under CEARP Phase 4.

CEARP Phase 2 consists of CEARP Phase 2a, Monitoring Plans, and CEARP Phase 2b, Remedial Investigations. CEARP uses a three-tiered approach in preparing monitoring plans: the CEARP Generic Monitoring Plan (CGMP, DOE, 1986a), the Installation Generic Monitoring Plan (IGMP, DOE, 1987a), and Site Specific Monitoring Plans/Remedial Investigation Plans (SSMP/RIFS). Each monitoring plan typically consists of five parts: Synopsis, Sampling Plan, Technical Data Management Plan, Health and Safety Plan, and Quality Assurance/Quality Control Plan.

Installation and site specific monitoring plans were submitted to EPA and CDH in February 1987 (DOE, 1987a and 1987b). The IGMP is the Rocky Flats Plant Comprehensive Source and Plume Characterization Plan, and the SSMP is the Remedial Investigation (RI) Work Plan for the high-priority sites (881 Hillside Area) and other priority sites including the 903 Pad, Mound, and East Trenches Areas.

2.1 REPORT OVERVIEW

This report describes the remedial investigations performed at the 903 Pad, Mound, and East Trenches Areas. Also presented are interpretations and conclusions from the resulting data and an assessment of public health and environmental concerns.

The report begins with site background information. Presented in this introduction are site locations and descriptions, results of previous investigations, the nature and extent of problems at these sites, objectives of this remedial investigation, and a description of remedial investigation field activities. The introduction is followed by a regional setting chapter (Section 3.0) which describes demography, land use, climatology, physiography, soils and geology, hydrogeology, and water resources in the vicinity of Rocky Flats Plant.

Following the introduction and regional setting chapters is the waste source characterization. This chapter (Section 4.0) is organized by area (903 Pad, Mound, and East Trenches). Each site within these areas is characterized based on remedial investigation results and previous studies. The location and extent of soil contamination is also presented for each site of interest.

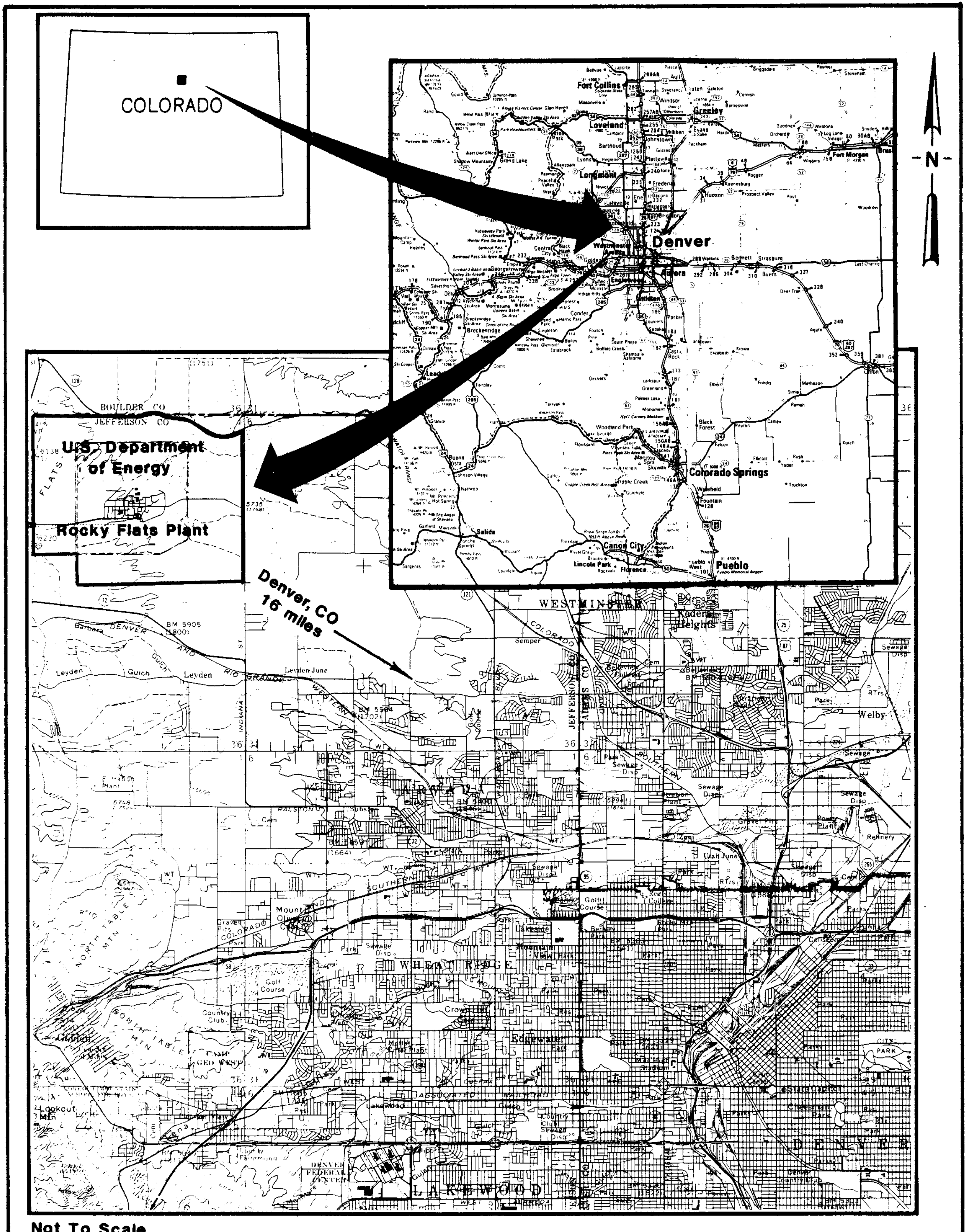
After describing the waste sources, a chapter is devoted to each potential contaminant pathway. Section 5.0 discusses the site geologic setting, characterizes ground-water flow paths, and discusses the extent of ground-water contamination resulting from each area. Section 6.0 characterizes the surface water pathway. Presented are descriptions of surface water flow paths, surface water quality, sediment chemistry, and flood potential. Section 7.0 characterizes the air pathway based on sampling results, and Section 8.0 describes site biota. The remedial investigation report concludes by addressing public health and environmental concerns (Section 9.0).

Appendices A through I contain remedial investigation supporting data. Excerpts from the RI Work Plan Sampling Plan pertaining to the 903 Pad, Mound, and East Trenches Areas are presented in Appendix A, and Appendices B and C contain results of geophysical and soil gas surveys, respectively. Appendix D presents a description of and rationale for the remedial investigation drilling program. Drilling, soil sampling, and ground-water sampling procedures are also discussed in Appendix D. Resulting hydrogeologic and analytical data are presented in Appendices E and F, respectively. Appendix G contains quality assurance/quality control (QA/QC) documentation for field and laboratory activities. Appendix H contains biota information, and Appendix I contains air quality data.

2.2 SITE LOCATIONS AND DESCRIPTIONS

The Rocky Flats Plant is located in northern Jefferson County, Colorado, approximately 16 miles northwest of Denver (Figure 2-1). 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 2-2).

This remedial investigation report addresses the 903 Pad, Mound, and East Trenches Areas located on the east side of the Rocky Flats Plant security area. These areas were selected because of their suspected relationship to ground-water contamination (DOE, 1987b). Several sites are included in each area because of their physical proximity to each other. Figure 2-3 shows the locations of each area and presents the site locations within each area as defined in Appendix I



Not To Scale

Figure 2-1: Location of Rocky Flats Plant

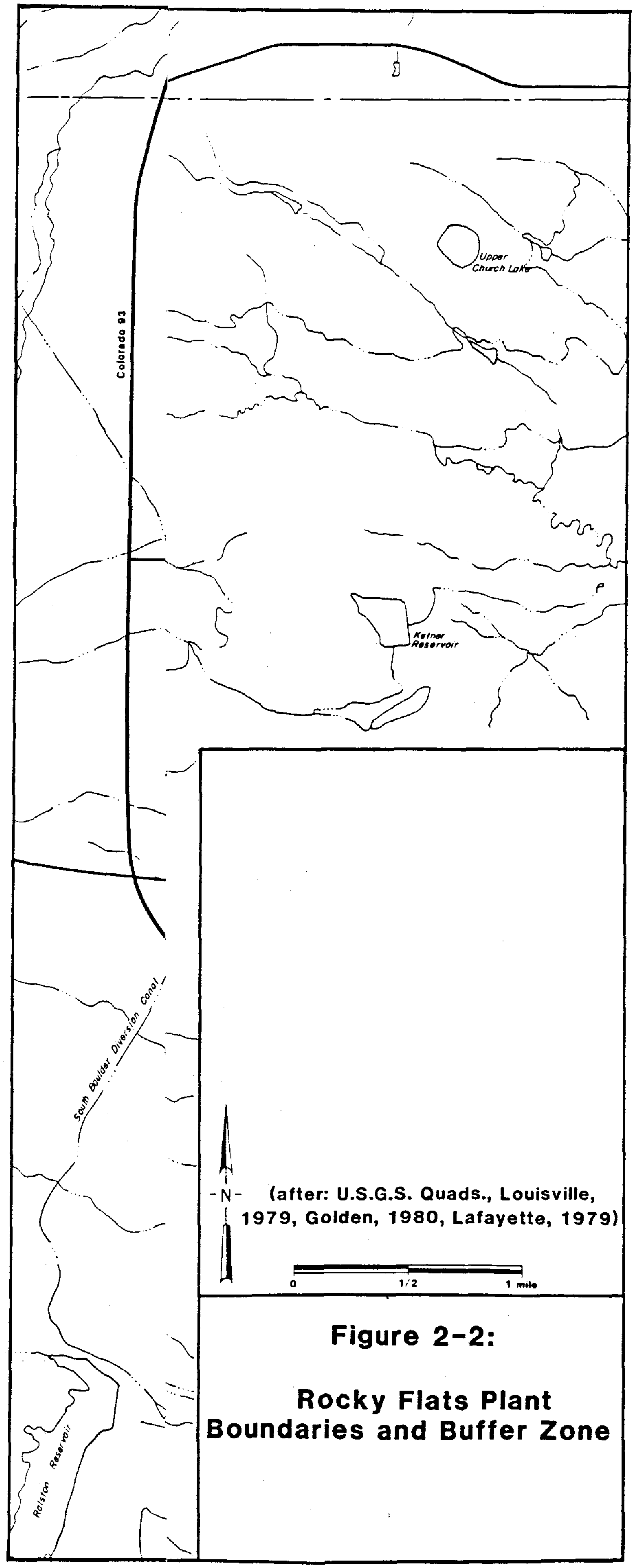


Figure 2-2:

Rocky Flats Plant Boundaries and Buffer Zone

[3004 (u) Waste Management Units] of the RCRA Part B Operating Permit Application (Rockwell International, 1986a). A complete list of solid waste management units at the Plant is presented in Appendix 1 of the RCRA Part B Operating Permit Application (Rockwell International, 1986a). These solid waste management units are divided into three categories. The first category includes those hazardous waste management units which will continue to operate and require a RCRA operating permit. The second category includes those hazardous waste management units that are being closed under RCRA interim status regulations and require a Post Closure Care Permit. The third category includes those inactive waste management units that are identified under Section 3004(u) of RCRA. Another class of sites is regulated only under CERCLA. These CERCLA sites contain only radioactive wastes. For ease in referencing these units and sites, and in accordance with RCRA terminology, each site is designated a Solid Waste Management Unit (SWMU) and assigned a reference number. No distinction is made in this report between RCRA and CERCLA sites. A base map and a tabulation of all SWMUs cross-referenced to the CEARP Phase 1 report is contained within the IGMP Monitoring Plan for Rocky Flats Plant (DOE, 1987a).

The site descriptions presented in the following sections are taken from the Rocky Flats Plant CEARP Phase I Report (DOE, 1986b) and the RCRA Part B Operating Permit Application (Rockwell International, 1986a). These descriptions are based on historical records, aerial photography review, and interviews with Plant personnel. Further characterization of each site based on this remedial investigation is presented in Chapter 4, "Waste Source Characterization".

2.2.1 903 Pad Area

Five sites are located within the 903 Pad Area. These sites are:

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

Presented below are descriptions of each of these sites.

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

The 903 drum storage site is located south of Central Avenue and west of the East Guard Gate. The site was used from 1958 to 1967 to store drums containing radioactively contaminated used machine cutting oil. Up to 5,240 drums were stored at this site during its use.

Approximately 3,570 drums contained oils and solvents contaminated with plutonium, and the balance were contaminated with uranium. Most of the drums contained lathe coolant consisting of mineral oil and carbon tetrachloride (CCl_4) in varying proportions. However, an unknown number of drums contained hydraulic oils, vacuum pump oils, trichloroethene (TCE), tetrachloroethene (PCE), silicone oils, and acetone (Rockwell International, 1986a). Ethanolamine was also added to new drums after 1959 to reduce the drum corrosion rate.

Removal of the drums from the storage area began in 1967. The older drums and those containing plutonium were removed first. The last known drum of contaminated liquid was removed in June 1968. The liquids from the drums were solidified and all materials were repackaged and shipped out of state to a DOE disposal facility (Rockwell International, 1986a).

After the drums were removed, efforts were undertaken to scrape and move the plutonium-contaminated soil into a relatively small area, cover it with fill material, and top it with an asphalt containment cover. This remedial action was completed in November 1969. An estimated 5,000 gallons of liquid leaked into the soil during use of the drum storage site. The liquid was estimated to contain 86 grams of plutonium (Rockwell International, 1986a).

903 Lip Site (SWMU Ref. No. 155)

During drum removal and cleanup activities associated with the 903 drum storage site, winds redistributed plutonium beyond the pad to the south and east. Approximately 1.0 Curie (Ci) of plutonium was deposited between the pad and the perimeter security fence. The most contaminated area is immediately adjacent to the pad to the south and southeast. Partial cleanup of this area, referred to as the 903 lip site, occurred in 1978 when about 4.7 million pounds (lbs) of contaminated soil containing 0.56 Ci plutonium were removed, packaged, and shipped off site as radioactive waste (Rockwell International, 1986a). Radioactive contamination is still present at the 903 lip site in the surficial soils.

Trench T-2 (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 (ft) wide by 200 ft long by 5 ft deep (Rockwell International, 1986a).

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

The reactive metals 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 (DOE, 1986b). Approximately 400 to 500 pounds of metallic lithium were destroyed on the ground surface in this area and the residues buried. Small quantities of other reactive metals (sodium, calcium, and magnesium) and some solvents were also destroyed at this location (Rockwell International, 1986a).

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. Various gases were detoxified using commercial neutralization processes. After neutralization, glassware used in the process was triple-rinsed, crushed, and deposited in the present landfill. The neutralized gases released to the environment during detoxification are no longer detectable (DOE, 1986b).

2.2.2 Mound Area

The Mound Area is composed of four sites. These are:

- Mound Site (SWMU Ref. No. 113);
- Trench T-1 (SWMU Ref. No. 108);
- Oil Burn Pit No. 2 (SWMU Ref. No. 153); and
- Pallet Burn Site (SWMU Ref. No. 154).

These sites are described individually below.

Mound Site (SWMU Ref. No. 113)

The mound site, located north of Central Avenue immediately west of the East Guard Gate, contained approximately 1,405 drums filled with depleted uranium and beryllium wastes. The wastes were mostly solid; however, some drums were filled with lathe coolant, and some drums may have contained "Perclene" (brand name of a solvent believed to be PCE). Cleanup of the mound area site was accomplished in 1970, and the materials removed were packaged and shipped to an offsite DOE facility as radioactive waste. Subsequent surficial soil sampling in the vicinity of the excavated mound site indicated 0.8 to 112.5 disintegrations per minute per gram (dpm/g) alpha activity. This radioactive contamination was thought to have come from the 903 drum storage site rather that from the mound area site (Rockwell International, 1986a).

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

Burial trench T-1 is also located just north of Central Avenue and immediately west of the Plant security area East Guard Gate. The estimated dimensions of Trench T-1 are 15 feet wide by 200 feet long by 5 feet deep

(Rockwell International, 1986a). The trench was used from 1952 until 1962 and contains approximately 125 drums filled with depleted uranium chips coated with small amounts of lathe coolant. Trench T-1 was covered with about 2 feet of soil, and the corners were marked (Rockwell International, 1986a). Two drums were uncovered during weed cutting in 1982, and the contents of one of the drums were sampled. The drum contained an oily sludge with 4.3 picocuries per gram (pCi/g) of plutonium and 1.2 microcuries per gram (mCi/g) of uranium (DOE, 1986b).

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

Oil burn pit No. 2 was located west of the mound area site and north of Trench T-1. The pit was actually two parallel trenches which were used in 1957 and from 1961 to 1965 to burn 1,083 drums of oil containing uranium (Rockwell International, 1986a). The residues from the burning operations and some flattened drums were covered with backfill. The pit was subsequently cleaned up and removed during the 1970s. Cleanup operations required the excavation of a hole approximately five feet deep (Rockwell International, 1986a).

Pallet Burn Site (SWMU Ref. No. 154)

An area southwest of oil burn pit No. 2 was reportedly used to destroy wooden pallets in 1965. The types of hazardous substances or radionuclides that may have been spilled on these pallets is unknown. This site was cleaned up and removed in the 1970s (DOE, 1986b).

2.2.3 East Trenches Area

The East Trenches Area consists of nine burial trenches (Trenches T-3 through T-11) located just east of the East Guard Gate. Trenches T-3, T-4, T-10, and T-11 are north of the east access road, and trenches T-5 through T-9 are south of the east access road.

The trenches were used from 1954 to 1968 for disposal of depleted uranium, flattened depleted uranium and plutonium-contaminated drums, and sanitary sewage sludge. Each trench is approximately 50 x 300 feet. Trench T-3 (SWMU Ref. No. 110) received radioactively contaminated flattened drums and substantial quantities of sanitary sewage sludge. The drums placed in Trenches T-4 through T-11 (SWMU Ref. No. 111) had radioactivity ranging from 800 to 8,000 dpm/g. Trenches T-4 and T-11 also contain some uranium and plutonium-contaminated planks from the solar evaporation ponds and sanitary sewage sludge. The trenches are covered with soil (DOE, 1986b).

2.3 PREVIOUS INVESTIGATIONS

A series of investigations has been conducted at the Plant to characterize ground water, surface water, soils, air quality, and biota. These programs include:

1) Several drilling programs beginning in 1961 that resulted in approximately 60 monitor wells by 1985;

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

3) Environmental, ecological, and public health studies which culminated in an Environmental Impact Statement (DOE, 1980);

4) An integrative report on ground-water hydrology using data from 1961 to 1985 (Hydro-Search, Inc., 1985);

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

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

7) A review of historical waste disposal practices and prioritization of disposal sites based on reported waste disposal practices and on ground-water quality, geophysical, and soil gas data (Rockwell International, 1986b and DOE, 1986b);

8) An initial Phase II site characterization including surface water monitoring and sampling, sediment sampling, and installation of 69 new monitor wells at the Plant (Rockwell International, 1986a, 1986d, and 1986e);

9) A remedial investigation of high priority sites at the 881 Hillside Area performed in 1987 (Rockwell International, 1987b); and

10) Environmental monitoring programs addressing air, surface water, ground water, and soils (Rockwell International, 1975-1985, 1986g, and 1987a).

Although none of the above investigations was specific to the 903 Pad, Mound, and East Trenches Areas, several monitor wells have been installed in these areas as part of Plant-wide investigations. Surface water, soil, and air samples have also been collected at these areas as part of various investigations. Presented below is a summary of previous investigations and a brief characterization of each pathway at the 903 Pad, Mound, and East Trenches Areas. Impacts to these pathways from each area as perceived prior to this RI are discussed in Section 2.4.

2.3.1 Ground-Water Pathway

Geologic information was collected prior to Plant construction in the early 1950s, and the ground-water pathway has been monitored since 1960. The initial Phase II site characterization performed in 1986 involved the installation of 69 new wells to monitor both alluvial and bedrock ground-water quality. This work, coupled with earlier investigations (Hurr, 1976; Hydro-Search, Inc., 1985), has characterized the Plant-wide hydrogeology and the site-specific hydrogeology of the solar evaporation ponds. The results of the initial site characterization are presented in Rockwell International (1986a) and summarized in the RI Work Plan (DOE, 1987b). Additional ground-water pathway information was collected as outlined in the Work Plan (DOE, 1987b). Plate 2-1 shows all monitor well locations at Rocky Flats Plant.

Ground water occurs in both surficial and bedrock materials at the 903 Pad, Mound, and East Trenches Areas. The major source of recharge is infiltration of incident precipitation into the surficial materials, although seepage from ditches also contributes to recharge. Most of the infiltrated water flows in surficial materials toward the drainages on top of the low permeability Arapahoe Formation claystones.

Some of the water in the Rocky Flats Alluvium emerges as seeps and springs at the contact between the alluvium and bedrock (contact seeps), most of which is consumed by evapotranspiration. In addition, some of the water is carried in the colluvium to the valley fill alluvium, where it either flows down-valley in the alluvium, is consumed by evapotranspiration, or discharges to streams. During the driest periods of the year, evapotranspiration dominates the shallow flow system, and there is no flow in some areas of the colluvium and valley fill alluvium.

Ground water in the surficial materials also enters the bedrock flow system by leakage through the claystones to the sandstones (very small quantity flows) or by direct recharge to sandstone units where sandstones subcrop beneath the soils. Water in the Arapahoe Formation flows generally to the east at a gradient of about 0.03 (Hurr, 1976).

2.3.2 Surface Water Pathway

The surface water pathway at Rocky Flats Plant has been characterized by Hurr (1976) and Rockwell International (1986h). Considerable work has also been done characterizing surface water and sediment chemistry in downstream reservoirs. Additional surface water and sediment data were collected during the initial site characterization at Rocky Flats Plant (Rockwell International, 1986a). Additional site-specific surface water information was collected as part of this RI at the 903 Pad, Mound, and East Trenches Areas. This section describes surface water flow at the Plant. Included is a description of natural drainages, ponds, ditches, and diversions.

Three intermittent streams drain the Rocky Flats Plant site with flow generally from west to east (Figure 2-2). Rock Creek drains the northwestern corner and flows to the northeast in the buffer zone to its off-site confluence with Coal Creek. Woman Creek drains the southern portion of the Plant and flows eastward to Standley Lake. Surface water flow to the south from the 903

Pad and East Trenches Areas is received by the South Interceptor Ditch and routed to pond C-2, which is isolated from Woman Creek. North and South Walnut Creeks and an unnamed tributary drain the remainder of the site. Surface water from the Mound Area and the northern East Trenches Area drains into South Walnut Creek. The three forks of Walnut Creek join in the buffer zone (approximately 0.7 miles downstream of the eastern edge of the Plant security area) and flow to Great Western Reservoir approximately one mile east of the confluence of the forks.

A series of dams, retention ponds, diversion structures, and ditches has been constructed at the Plant to control surface water and limit the potential for release of poor quality water. These structures and flow systems are described briefly below.

A series of retention ponds is located in the drainages of Walnut and Woman Creeks. The ponds are designated as the A, B, and C series ponds. Discharges from the downstream pond in each series are in accordance with the Plant's National Pollution Discharge Elimination System (NPDES) permit. Ponds A-1 and A-2 are used only for spill control, and North Walnut Creek stream flow is diverted around them through an underground pipe. Pond A-3 receives the North Walnut Creek stream flow and Plant runoff from the northern portion of the Plant site. Pond A-4 is designed for surface water control and for additional storage capacity for overflow from pond A-3. None of the remedial investigation areas drain into North Walnut Creek.

Five retention ponds are located along South Walnut Creek and are designated as B-1, B-2, B-3, B-4, and B-5, from west to east. The Mound Area and northern East Trenches Area drain into South Walnut Creek near the eastern Plant security fence, upstream of the B-series ponds. Ponds B-1 and B-2 are reserved for spill control, whereas pond B-3 receives effluent from the sanitary sewage treatment plant. Ponds B-4 and B-5 receive surface runoff and occasionally collect discharge from pond B-3. Pond B-5 receives runoff from the central portion of the Plant site and is used for surface water control in addition to collection of overflow from pond B-4.

The two C series ponds, C-1 and C-2, are located along Woman Creek, south and east of the Plant, respectively. Pond C-1 receives stream flow from Woman Creek. This flow is diverted around pond C-2 into the Woman Creek channel downstream. Pond C-2 is isolated from Woman Creek and receives surface runoff from the South Interceptor Ditch along the southern portion of the Plant site. Water in pond C-2 is discharged to Woman Creek in accordance with the Plant NPDES permit.

There are many runoff control ditches in the general vicinity of the Plant. The largest of these is the Central Avenue Ditch which runs eastward along Central Avenue and discharges to South Walnut Creek (Pond B-5). The Central Avenue Ditch crosses the center of the Mound Area and the northern portion of the East Trenches Area. The other major runoff control ditch is the South Interceptor Ditch which isolates runoff from the south side of the Plant from Woman Creek. Surface water runoff from the 903 Pad Area and the southern East Trenches Area flows south to the South Interceptor Ditch. The ditch extends from the old landfill to pond C-2, and Woman Creek is diverted around pond C-2 by a diversion structure just upstream of the pond.

2.3.3 Air Pathway

Air pathway studies at Rocky Flats Plant are performed continuously and reported annually in Annual Environmental Monitoring Reports (Rockwell International, 1975-1985, 1986g, and 1987a). In addition, the air pathway was further characterized by Rockwell International (1986f) in the "Rocky Flats Plant Radioecology and Airborne Pathway Summary Report".

Air samplers for routine ambient air monitoring at the Plant are located at various locations on and off Plant site. This ambient air program monitors only radionuclides. Conventional air quality parameters are monitored on site at a dedicated location inside the perimeter security gate west of the East Guard Gate.

The Plant Radioactive Ambient Air Monitoring Program (RAAMP) is comprised of 51 high-volume particulate air samplers which operate continuously. Twenty-three (23) of the 51 air samplers are within or directly adjacent to the Plant security area (on-site samplers), and 14 are located around the Plant property boundary (perimeter samplers) (Figure 2-4). An additional 14 samplers (community samplers) are located in neighboring towns (Figure 2-5).

Data collected at Rocky Flats Plant indicate a low potential for significant human exposure to radioactive and nonradioactive airborne emissions from the Plant. All perimeter and community ambient air samplers have recorded mean annual plutonium concentrations at less than 0.4% of the Derived Concentration Guide (DCG), which is based on the DOE interim standard dose limit for all pathways of 0.1 rem/yr for a 50-year committed effective dose equivalent (Rockwell International, 1986g). This level is indistinguishable from fallout.

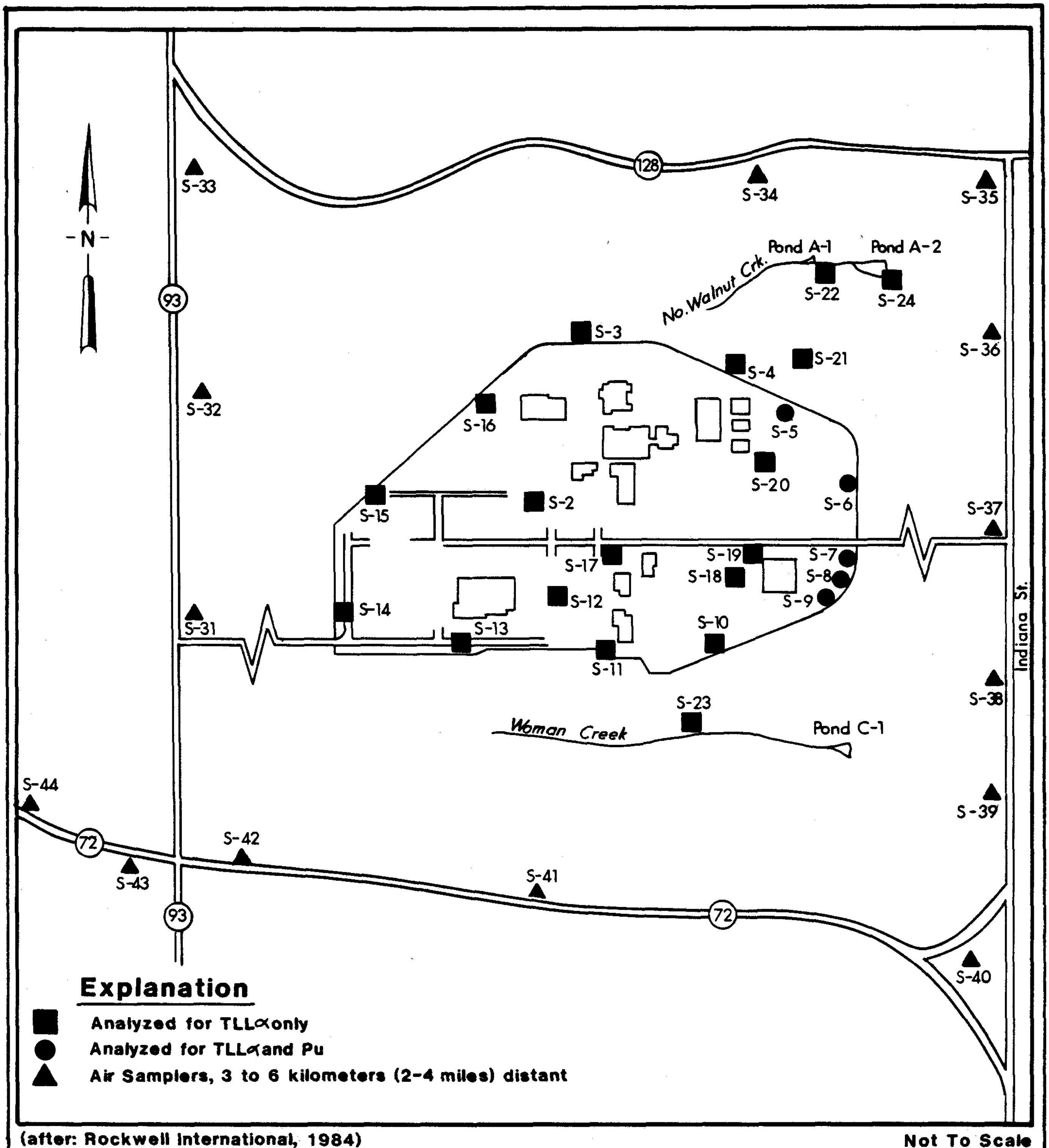
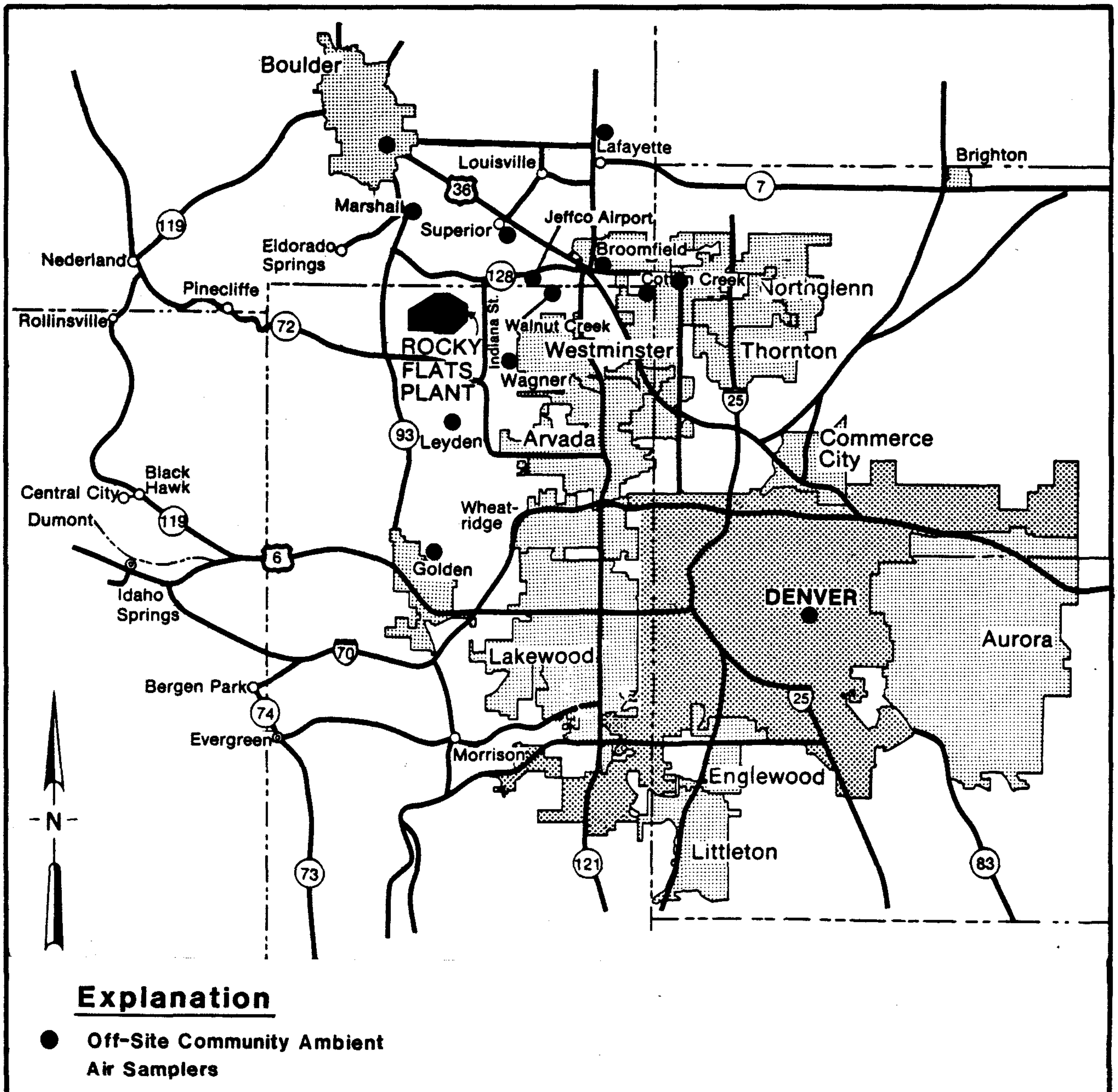


Figure 2-4:
Location of On-Site and Plant Perimeter Ambient Air Samplers



(after: Rockwell International, 1984)

Not To Scale

Figure 2-5:
Location of Off-Site Community Ambient Air Samplers

3.0 REGIONAL SETTING AND SITE FEATURES

This section presents the regional setting of Rocky Flats Plant and the 903 Pad, Mound, and East Trenches Areas. Included are sections on demography, land use, natural resources, climatology, and water resources in the vicinity of Rocky Flats Plant. Also presented is a section on soils, geology, and hydrogeology. This section is divided into a discussion of regional (Denver Basin) geology and local Rocky Flats geology. Site specific discussions of geology and hydrogeology at the 903 Pad, Mound, and East Trenches areas are presented in Section 5.0.

3.1 DEMOGRAPHY

Rocky Flats Plant is located in northern Jefferson County, Colorado; approximately 50 percent of the area within ten miles of the Plant is within Jefferson County. The remainder of the area within ten miles of the Plant 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, and several new housing subdivisions are located within a few miles of the Plant. One subdivision is located south of the Jefferson County Airport, and several are located southeast of the Plant.

A demographic study using 1980 census data (Rockwell International, 1985) shows that approximately 1.8 million people lived within 50 miles of the Plant in 1980. This was projected to increase to 3.5 million people by the year 2000. Approximately 9,500 people lived within 5 miles of the Plant in 1980, with a route for employees. The junction of Highway 17 and Colorado 72 southeast of the Plant carried about 3,800 cars daily during 1978. The D&RGW Railroad, which is about two miles south of the Plant, is the main line west from Denver. Several trains a day use this line to haul freight, coal, and passengers (DOE, 1980). A spur of the D&RGW rail line enters the Plant from the southwest.

Some of the land adjacent to the Plant is zoned for industrial development. Industrial facilities within five miles of the Plant 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 Jeffco 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 produce crops, raise beef cattle, supply milk, and breed and train horses. According to 1977 Colorado Agricultural Statistics, 14,000 acres of crops were planted in 1976 in Jefferson County (total land area of approximately 475,000 acres), and 56,200 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 9,500 head of cattle, 200 pigs, and 400 sheep in Jefferson County and 34,000 head of cattle, 2,300 pigs, and 6,500 sheep in Boulder County in 1976 (DOE, 1980).

The closest park and recreational area is the Standley Lake area, which is approximately five miles east of the Plant. Boating, picnicking, and limited overnight camping are permitted. Several other small parks are present in communities within ten miles of the Plant. The closest major park is Golden Gate Canyon State Park located approximately 15 miles to the southwest. This park provides 8,400 acres of general camping and outdoor recreation. Other national and state parks are located in the mountains west of the Plant, but all are more than fifteen miles away.

3.3 NATURAL RESOURCES

Rocky Flats Plant is located along the southwest trending Colorado Mineral Belt that extends from the northeastern plains, across the central Front Range, and into the southwest mountains of Colorado. Mineral resources in the vicinity of the Plant include sand and gravel, crushed rock, clay, coal, and uranium (Van Horn, 1972). Oil and natural gas resources are also present to the north and east of the Plant in Boulder, Weld, and Adams Counties. Several mining and quarry operations are also currently active or have been active in the past; these activities are described below.

3.3.1 Aggregate Resources

Extensive deposits of sand and gravel from the Rocky Flats Alluvium are a source of aggregate at the Plant which is suitable for concrete and mineral aggregate. There are currently sand and gravel pits operating about one mile southwest and approximately one-half mile west of the Plant. Several quarries have extracted rock from the Precambrian metamorphics and the Tertiary igneous rock exposed in the Golden Quadrangle for use as concrete aggregate, riprap, and road material. Rock is presently being quarried from the Ralston Dike about four miles southwest of the Plant.

Clay mined from the Laramie Formation and the Pierre Shale (west of the Plant) from Coal Creek south to Golden is used for brick, tile, and sewer pipe. Three pits in clay and claystone beds of the steeply dipping lower part of the Laramie Formation are presently being mined. Clay from the upper part of the Pierre Shale was mined and treated to form a lightweight aggregate at the facility operated by the Idealite Cement Company near the northwest corner of the Plant. The Idealite operation closed in 1976 (DOE, 1980).

3.3.2 Coal Resources

Sub-bituminous coal occurs in several lenticular bodies in the lower part of the Laramie Formation. This coal has been mined in the Golden Quadrangle south of the Plant and from the Louisville Quadrangle north of the Plant. No mining has occurred since 1950, and few sizeable areas remain where coal is of sufficient thickness and quality to justify mining (Spencer, 1961).

3.3.3 Uranium Resources

Uranium has been mined at the Schwartzwalder uranium mine about four miles southwest of the Plant. The mine has been the largest producer of vein-type uranium ore in Colorado and ranks among the six largest of this type in the United States. Ore shipments have yielded more than 11.5 million pounds of uranium (DOE, 1980).

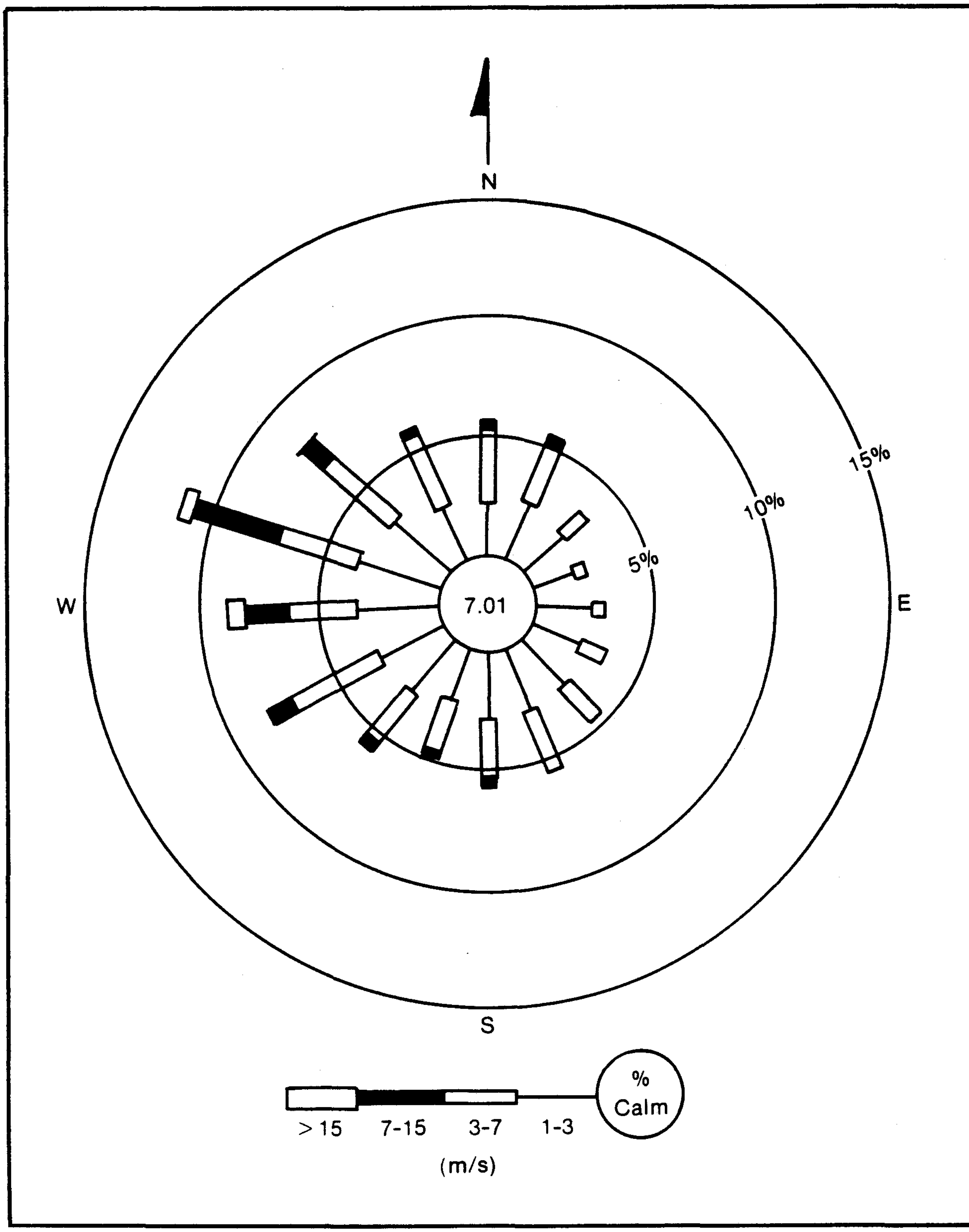
3.3.4 Oil and Gas Resources

Oil and natural gas activity near Rocky Flats Plant includes oil field developments, pipeline, and production operations. The closest major oil and gas fields are in northwest Adams County (Jackpot and Spindle Fields), and a smaller field occurs in east central Boulder County (Boulder Field). A natural gas pipeline that originates in Wyoming and proceeds across eastern Colorado into Oklahoma is located approximately ten miles north of the Plant in southern Boulder County. Local natural gas pipelines cross the south side of the Rocky Flats Plant. The nearest refinery operation is the Conoco Refinery located in Commerce City about 20 miles east of the Plant. A north-south oriented oil pipeline feeds into the refinery from fields in northeastern Colorado and southeastern Wyoming (Donaldson and MacMillan, 1980).

3.4 CLIMATOLOGY

The area surrounding the Rocky Flats Plant has a semiarid climate typical of the Rocky Mountain region. However, the elevation of the Plant and the nearby slopes of the Front Range slightly modify the regional climate.

Winds at Rocky Flats Plant, although variable, are predominantly westerly and northwesterly. Stronger winds occur during the winter, and the area occasionally experiences Chinook winds with gusts up to 100 miles per hour because of its location near the Front Range (DOE, 1980). Figure 3-2 shows the wind direction, frequency, and average velocity for each direction as recorded in 1985.



(after: Rockwell International, 1987a)

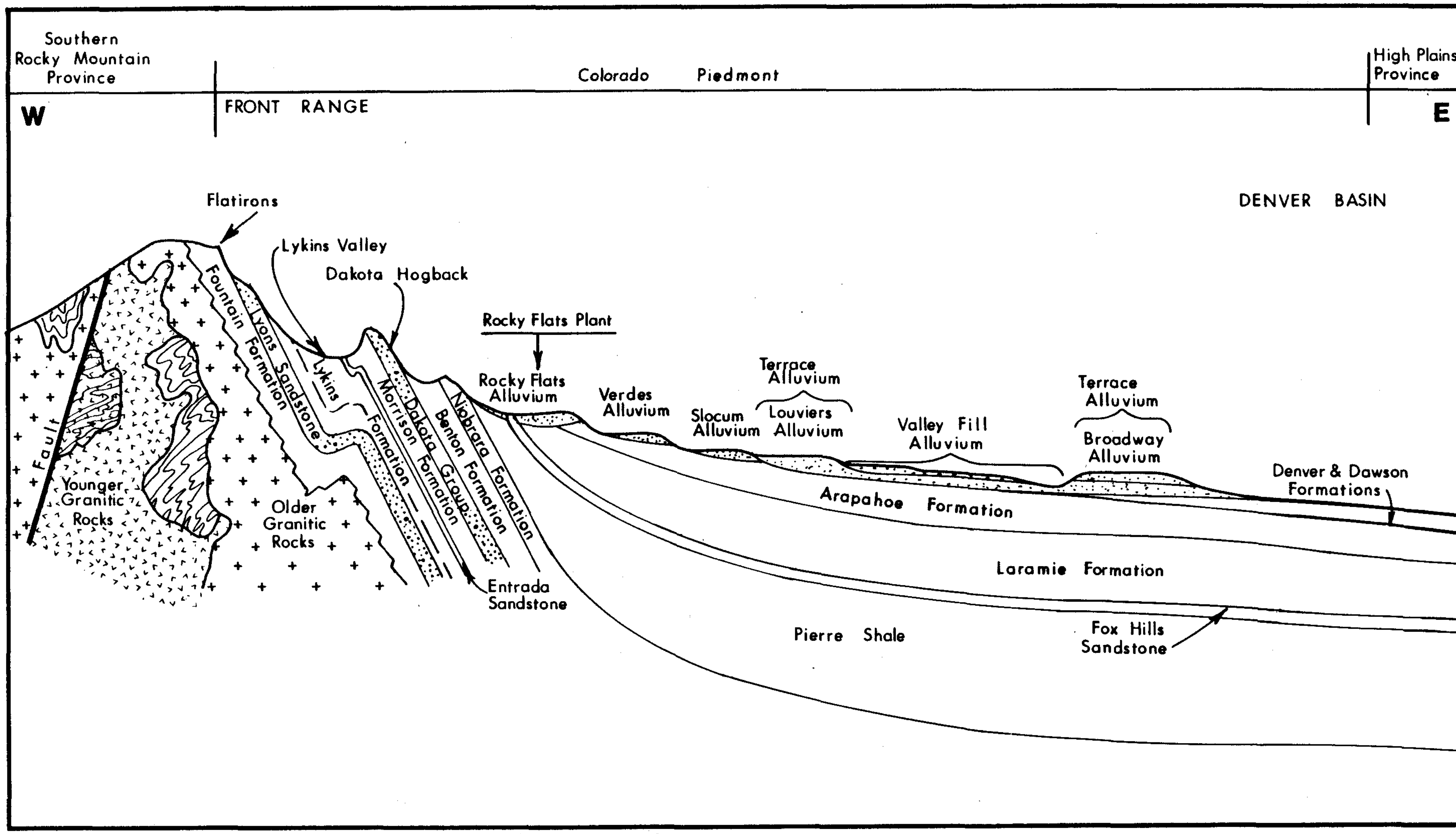
Figure 3-2:
1986 Annual Wind Rose for the Rocky Flats Plant

Temperatures are moderate; extremely warm or cold weather is usually of short duration. On the average, daily summer temperatures range from 55 to 85 degrees Fahrenheit (F) and winter temperatures range from 20 to 45 degrees F. Temperature extremes recorded at the Plant have ranged from 102 degrees F on July 12, 1971 to -26 degrees F on January 12, 1963. The 24-year average maximum temperature for the period 1952 to 1976 was 76 degrees F, the average minimum was 22 degrees F, and the average annual mean was 50 degrees F. Average relative humidity was 46 percent (DOE, 1980).

Average annual precipitation at the Plant is 15 inches. Approximately 40 percent of the precipitation falls during the spring season, much of it as snow. Thunderstorms from June to August account for an additional 30 percent of precipitation. Autumn and winter are drier seasons, accounting for 19 and 11 percent of the annual precipitation, respectively. Snowfall averages 85 inches per year, generally occurring between October and May (DOE, 1980 and Rockwell International, 1986a).

3.5 PHYSIOGRAPHY

The Rocky Flats Plant is located at an elevation of approximately 6,000 feet above mean sea level. The site is on the western margin of the Colorado Piedmont section of the Great Plains Physiographic Province (Fenneman, 1931). The Colorado Piedmont ranges in elevation from 4,000 feet on the east to 7,000 feet on the west. The Piedmont merges to the east with the High Plains section of the Great Plains Province and is terminated abruptly on the west by the Front Range section of the Southern Rocky Mountain Province (Figure 3-3).



(after: Boulder County Planning Commission, 1983 and Scott, 1960)

Not To Scale

Figure 3-3:
Generalized East-West Cross Section
Front Range to Denver Basin

The Colorado Piedmont is an area of dissected topography and denudation where Tertiary strata underlying the High Plains have been almost completely removed. In a regional context, the piedmont represents an old erosional surface along the eastern margin of the Rocky Mountains. It is underlain by gently dipping sedimentary rocks (Paleozoic to Cenozoic in age), which are abruptly upturned at the Front Range to form hogback ridges parallel to the mountain front. The piedmont surface is broadly rolling and slopes gently to the east with a topographic relief of only several hundred feet. This relief is due both to resistant bedrock units that locally rise above the surrounding landscape and to the presence of incised stream valleys. Major stream valleys which transect the piedmont from west to east have their origin in the Front Range. Small local valleys have developed as tributaries to these major streams within the piedmont. In the area of the Plant, a series of Quaternary pediments have been eroded across this gently rolling surface (Fenneman, 1931 and DOE, 1980).

The eastern margin of the Front Range a few miles west of the Plant is characterized by a narrow zone of hogback ridges and flatirons formed by steeply east-dipping Mesozoic strata (such as the Dakota Sandstone and the Fountain Formation). Less resistant sedimentary units were removed by erosion (Figure 3-3). The Front Range reaches elevations of 12,000 to 14,000 feet above mean sea level 15 miles farther west. The range itself is broad and underlain by resistant gneiss, schist and granitic rocks of Precambrian age. The resistant nature of these rocks has restricted stream erosion so that deep, narrow canyons have developed in the Front Range.

Several pediments have been eroded across both hard and soft bedrock in the area of the Plant during Quaternary time (Scott, 1963). The Rocky Flats pediment is the most extensive of these, forming a broad flat surface south of Coal Creek. The broad pediments and more narrow terraces are covered by thin alluvial deposits of ancient streams draining eastward into the Great Plains. The sequence of pediments reflects repetitive physical processes associated with cyclic changes in climate. Each erosional surface and stratigraphic sequence deposited on it probably represents a single glacial cycle. The oldest and highest pediment, the Subsummit Surface (Scott, 1960), truncates the hogback ridges of the Front Range. Three successively younger pediments, veneered by alluvial gravels, extend eastward from the mountain front. Erosion of valleys into the pediments followed each depositional cycle so that, near the mountain front, stratigraphically younger geologic units occur at topographically lower elevations as narrow terrace deposits along the streams. From oldest to youngest, the three pre-Wisconsin deposits are the Rocky Flats Alluvium, the Verdos Alluvium and the Slocum Alluvium (Scott, 1965). A series of Wisconsin and post-Wisconsin terrace deposits are present at lower elevations along streams that have incised the older pediments (east of the Plant). These alluvial deposits are described in Section 3.6.5, Surficial Geology.

The Rocky Flats Plant is located on a relatively flat surface of Rocky Flats Alluvium. The pediment surface and overlying alluvium (generally 10 to 50 feet thick, although the alluvium is as much as 100 feet thick west of the Plant) have been eroded by Walnut Creek on the north and Woman Creek on the south so that terraces along these streams range in height from 50 to 150 feet. The grade of the gently eastward-sloping, dissected Rocky Flats Alluvium surface varies from 0.7 percent at the Plant to approximately 2 percent just east of the Plant.

3.6 REGIONAL HYDROGEOLOGIC SETTING

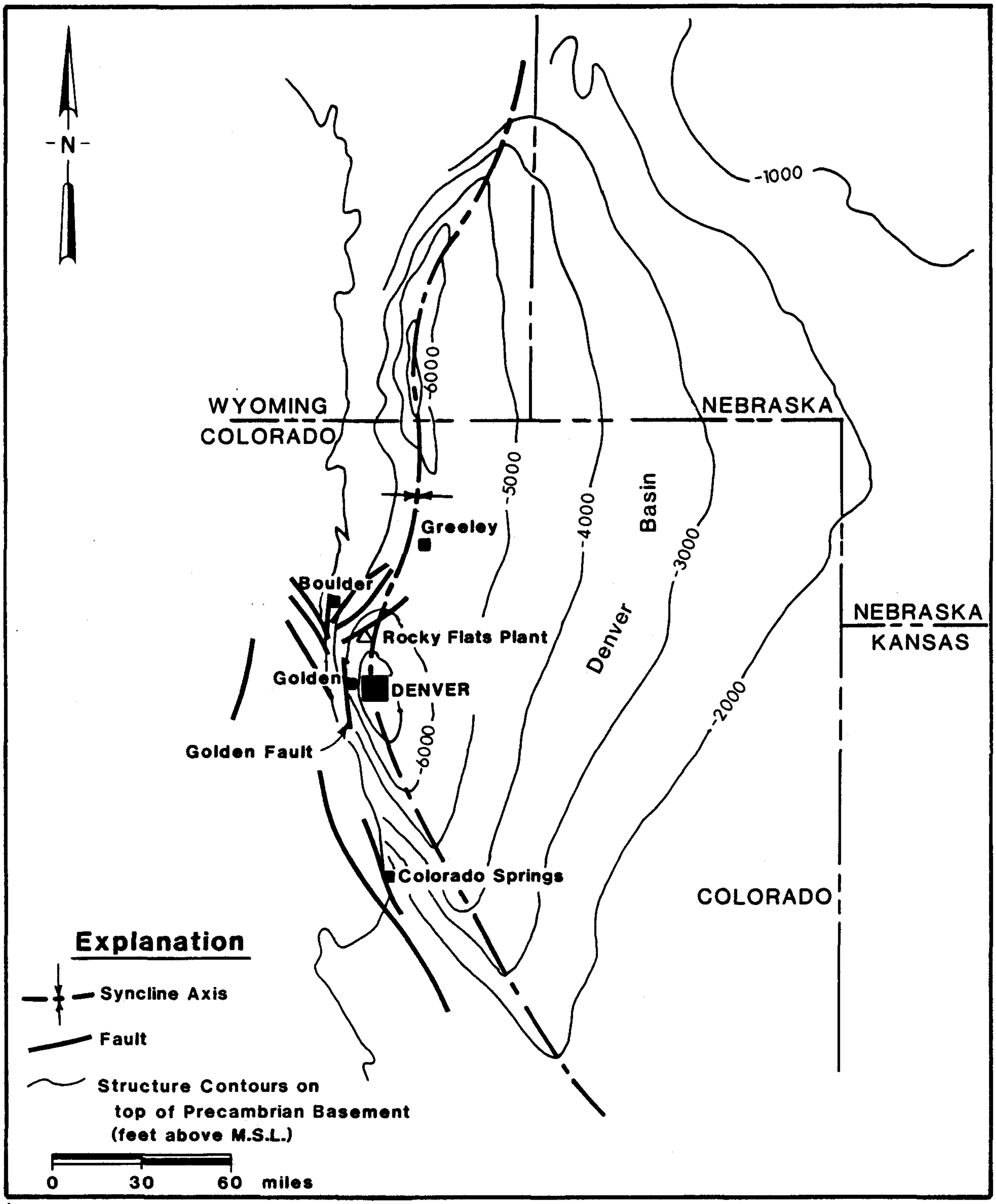
3.6.1 Geologic and Stratigraphic History

This section describes the regional geologic and stratigraphic history in the vicinity of the Plant, including the Denver Basin. Section 5.0 describes the site specific geology and stratigraphy of the Plant and study areas.

The Rocky Flats Plant is located on the northwestern flank of the Denver Basin and is underlain by about 12,000 feet of Paleozoic and Mesozoic sedimentary rocks (Hurr, 1976). The Denver Basin is an asymmetric syncline that formed during the Late Cretaceous Laramide Orogeny. The western limb of the basin dips steeply to the east, and the eastern limb dips gently to the west (Figure 3-4).

The geologic history of northeastern Colorado involves several episodes of mountain building and oceanic transgression and regression, resulting in the deposition of thousands of feet of sedimentary rock on top of the Precambrian basement. This section describes the geologic history beginning with Precambrian time. Geologic descriptions of the various units are provided within this context. More detailed descriptions of the units present on site are provided in Section 5.0.

Early Precambrian tectonic, metamorphic, and plutonic igneous activity created a complex fabric in the basement rock of Colorado (Grose, 1972). The Precambrian units were covered by marine and continental sedimentation during the lower Paleozoic (carbonate and siliciclastic rock units were deposited unconformably on the Precambrian basement). Most of these units were later eroded by multiple Paleozoic diastrophisms, thus removing Cambrian to Mississippian rocks from the



(after: Rockwell International, 1986a)

Figure 3-4: Structure of the Denver Basin

Denver Basin area (Kent, 1972). Middle Pennsylvanian orogenic activity formed the Ancestral Rockies, and the Fountain Formation was deposited unconformably on the uplifted Precambrian basement.

The sedimentary stratigraphic section in the vicinity of the Plant begins with the Fountain Formation (Figure 3-5), unconformably overlying the Precambrian metamorphics and dipping steeply to the east. The Fountain Formation contains coarse clastics derived from the erosion of the Ancestral Rockies and deposited as alluvial fans along the edge of the sea (Martin, 1965). The Fountain Formation is overlain by units resulting from sea transgressive and regressive sequences. The result was nonmarine sedimentation that occurred in northeastern Colorado from the Triassic to early Cretaceous. This sedimentation deposited a sequence of aeolian, fluvial-deltaic, and lacustrine units known as the Lyons, Lykins, Ralston Creek, Morrison, and Dakota Formations (Figure 3-5) (Kent, 1972).

The Pierre Shale, consisting of more than 5,600 feet of shales and siltstones, was deposited in the final phases of oceanic sedimentation. The sedimentation resulted from the last oceanic transgression occurring 100 million years ago during the late Cretaceous. This transgression formed an epicontinental sea called the Cretaceous Seaway that covered the eastern portions of New Mexico, Colorado, and Wyoming.

Following deposition of the Pierre, the ocean began to regress and deposition of the Upper Cretaceous Fox Hills and Laramie Formations occurred. These formations contain sandstones, siltstones, claystones, and coals deposited in fluvial-deltaic and lacustrine environments (Weimer, 1973). Deposition of the Laramie was influenced and then stopped by the Laramide Orogeny, a major mountain building

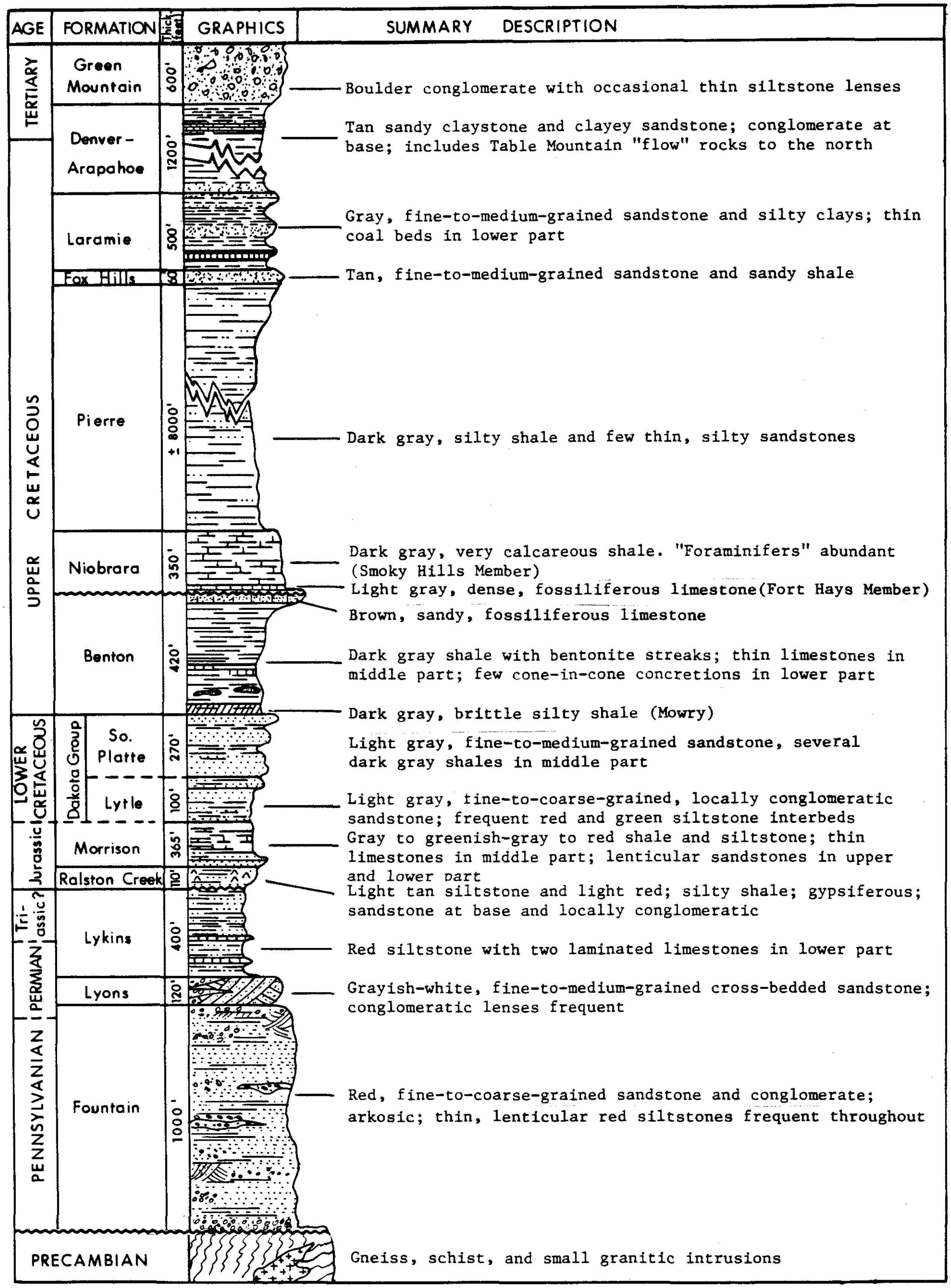


Figure 3-5: Generalized Stratigraphic Section, Golden-Morrison Area

(after: LeRoy and Weimer, 1971)

event that began in the late Cretaceous and caused uplift of the Colorado Front Range Mountains and the eastward tilting of the Denver Basin.

The Upper Cretaceous Arapahoe Formation was deposited on an erosional surface marking the end of deposition of the Laramie. Major uplift of the Front Range and downwarp of the Denver Basin continued during deposition of the Arapahoe Formation. Coarse pebble conglomerate lenses deposited in alluvial fans frequently occur in the Lower Arapahoe; however, conglomerate lenses were not found at the site. Claystone and sandstone units flank and top the alluvial fan deposits (Weimer, 1973).

The Denver Formation, deposited above the Arapahoe, resulted from volcanism associated with the Laramide Orogeny. This formation contains a variety of lithologies (siltstones, arkoses, conglomerates) up to 600 feet thick (Robson, 1984).

The Dawson Formation was deposited above the Denver in a similar geologic environment during the late Cretaceous and early Tertiary. Robinson (1972) described the Dawson Formation as a stratigraphic equivalent to the Denver Formation in southern portions of the Denver Basin. However, Robson (1984) mapped the Dawson as a separate, younger (Tertiary) formation occurring above the Denver. The Dawson is up to 600 feet thick and consists of conglomerates, sandstones, and shales (Robson, 1984).

The Tertiary Green Mountain Conglomerate was deposited unconformably on the Denver Formation, and consists of conglomerates, sandstones, siltstones, and claystones deposited by a local fluvial system that occurred only in the Golden, Colorado, area. This unit is only found capping Green Mountain, approximately 15 miles south of Rocky Flats Plant (Costa and Bilodeau, 1982).

The Rocky Flats Alluvium was deposited on top of a major erosional surface that developed in late Tertiary time. Before deposition of the Rocky Flats Alluvium, both the Dawson and Denver Formations were completely removed by erosion. The Green Mountain Conglomerate may never have been deposited at the site, but if it was, it also was removed by erosion. The Rocky Flats Alluvium contains boulders, cobbles, gravels, sands, silts, and clays deposited in alluvial fans at the base of the Colorado Front Range Mountains (Hurr, 1976).

Following deposition of the Rocky Flats Alluvium, the material was partially removed by erosion and the resulting drainages repeatedly infilled with more recent sediments. The Verdos Alluvium and the younger Slocum Alluvium are the result of drainage infilling in association with glacial activity. Similar processes are occurring now with an active valley fill alluvium in the stream channels and a recent but stable terrace above the valley fill.

3.6.2 Plant Bedrock Geology

Bedrock units mapped at the Plant during the 1986 initial site characterization consist of the Laramie and Arapahoe Formations (Figure 3-6). Because of the thickness (750 to 800 feet) and low permeability of the Upper Laramie, it is considered to be the base of the hydrologic system which could be affected by Plant operations. The Upper Laramie and overlying Arapahoe Formations are described below.

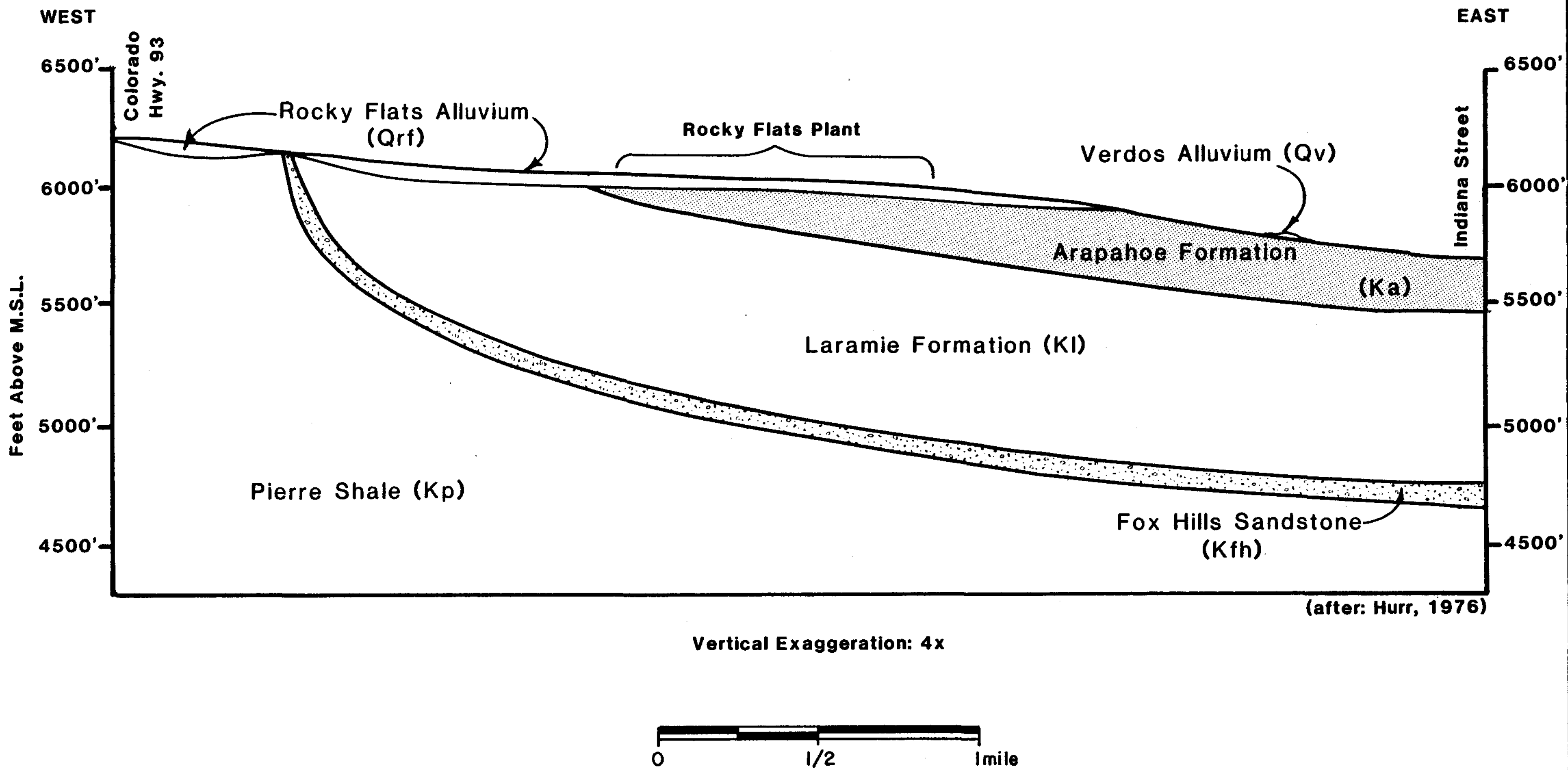


Figure 3-6: Generalized Cross Section of Rocky Flats Plant

Laramie Formation

The Laramie Formation is a fluvial sequence of sandstones, siltstones, claystones, and coals, which is subdivided into two major lithologic units: a lower sandstone unit and an upper claystone unit. The lower sandstone unit is exposed in clay pits west of the plant, and the upper claystone unit was observed in outcrop and in cores of several 1986 monitor wells west of the Plant. The descriptions presented below are taken from Rockwell International (1986a).

> Lower Sandstone Unit: The lower sandstone unit consists of light to medium gray, very fine- to medium-grained, well sorted, subrounded to subangular quartzose sand with up to 25% lithic fragments. Sandstones are typically fair to poorly indurated and cemented with silica. Individual sandstone beds are 5 to 15 feet thick and are interbedded with white to light gray claystones. The claystones are organic-rich and kaolinitic and have been mined from the clay pits west of the plant. Individual claystone beds are 10 to 15 feet thick. Sedimentary structures observed in outcrop include planar, angular, and trough crossbeds, load structures, fluid escape structures, and ripple marks. Plant fossil casts and molds of branches, stems, and leaves are concentrated along bedding planes. The contact between the lower sandstone unit and the upper claystone unit is gradational and was selected where thick sandstone beds and kaolinite-rich claystones are less abundant.
>
> Upper Claystone Unit: The upper claystone unit consists primarily of dark olive gray (5 Y 2/1) (GSA Rock Color Chart), poorly indurated claystones. Upper Laramie claystones generally weather to a light olive gray (5 Y 4/1) and may have dark yellowish orange (10 YR 6/6) iron staining along bedding planes and secondary fractures. These claystones appear quite similar to Arapahoe claystones in outcrop.
>
> Thin sandstone lenses (less than three feet thick) also occur in the upper Laramie. These sandstones are typically yellowish gray (5 Y 8/1), fine- to very fine-grained, well sorted, subangular, and calcareous. Core data (well 50-86) indicate that thin beds of white,

kaolinite-rich claystone typical of the Lower Laramie occur in the Upper Laramie as well.

The contact between the Upper Laramie claystones and the Lower Arapahoe sandstones is gradational and was selected using core data. The contact was picked below the first Arapahoe sandstone greater than five feet thick (Rockwell International, 1986a).

Arapahoe Formation

The Arapahoe Formation consists of fluvial claystones with interbedded lenticular sandstones and siltstones. Contacts between these lithologies are both sharp and gradational. The claystones are olive gray (5 Y3/2) to dark gray (N 3/0), poorly indurated, silty, and contain up to 15 percent organic material. Weathering has penetrated to depths ranging from 10 to 40 feet below the base of surficial materials. The weathered claystone is light olive gray, blocky, slightly fractured, and has iron staining as mottles and along bedding planes and fractures (Rockwell International, 1986a).

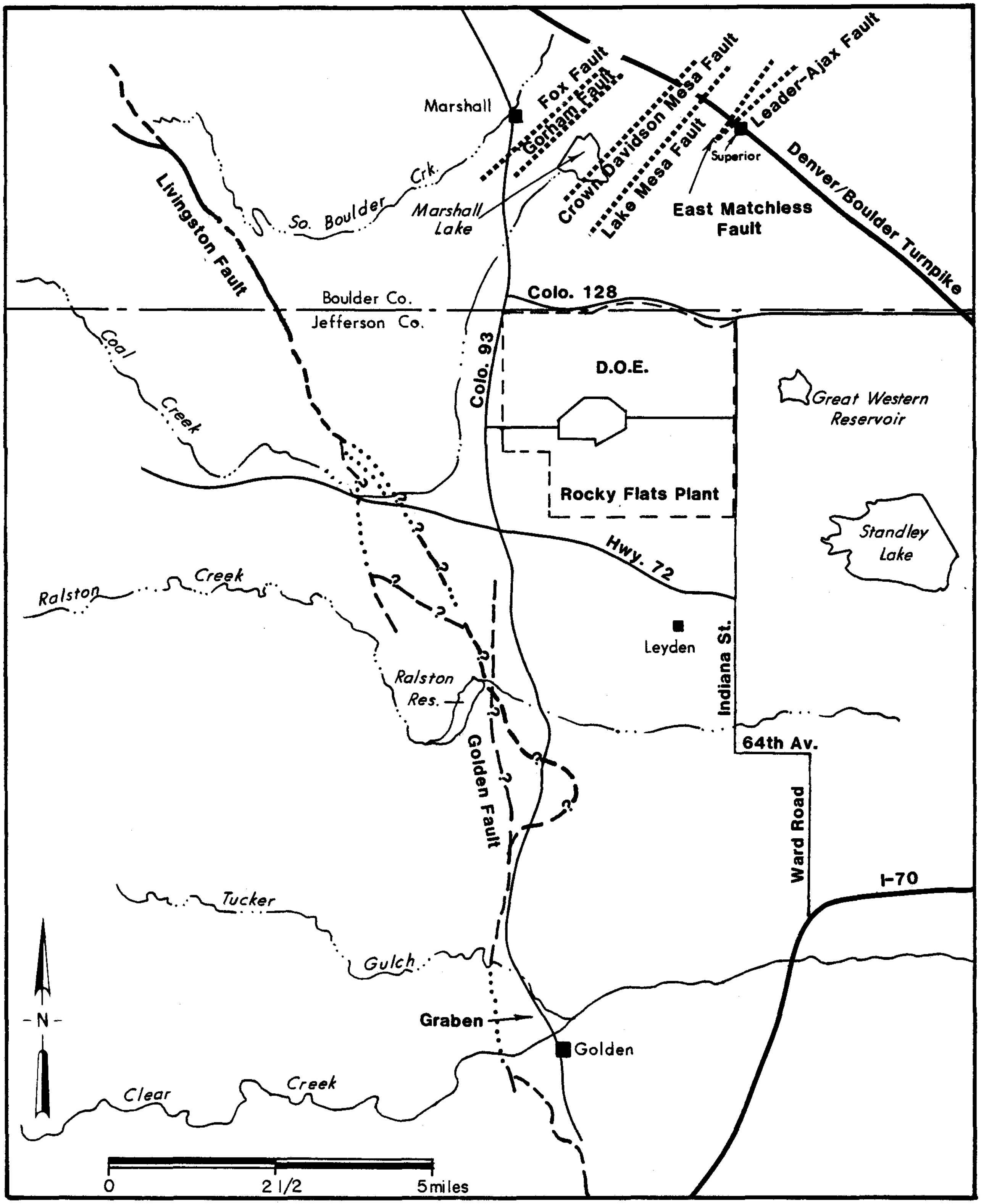
Sandstones in the Arapahoe Formation are light gray (N 6/0) to yellowish gray (5 YR 8/1), very fine- to medium-grained, with approximately 15 percent silt and clay. The sandstones are lenticular, discontinuous, and stratigraphically complex. The sand grains are subangular to subrounded and are predominantly quartzose with 10 percent lithic fragments. The sandstones are poorly to moderately cemented and exhibit ripple marks, load casts, and planar, angular, and trough crossbedding. Arapahoe Formation siltstones exhibit the same coloration, constituents, bedding characteristics, and sedimentary structures as the sandstones; however, they consist predominantly of silt-sized particles (Rockwell International, 1986a).

3.6.3 Regional Bedrock Structure

The general geologic structure of the area is north-striking sedimentary beds with dips to the east away from the Front Range Monocline. Dips are quite steep west of the Plant in the Fox Hills Sandstone and Laramie Formation (on the order of 50 degrees or greater). These units are flanked on the west by Precambrian terrain of the Front Range Uplift and on the east by gently dipping sedimentary beds of the Denver Basin. However, because the axis of the monocline onto the Front Range appears to be inclined to the east, dips become rapidly more gentle, on the order of 7 to 15 degrees beneath the Plant itself (Rockwell International, 1986a). A major bounding fault between the Front Range and the Denver Basin, the Golden Fault, runs north-south several miles west of the Plant at the mountain front (Figure 3-7).

The majority of the displacement on the Golden Fault, the uplift of the Front Range and subsidence of the Denver Basin, occurred during the late Cretaceous to early Eocene Laramide Orogeny about 40 to 70 million years ago (Martin, 1965). Erosion during the Laramide Orogeny is believed to have kept pace with uplift and the Front Range probably never stood very high above the Denver Basin during the orogeny. By the late Eocene, an erosional surface of the low relief covered much of the Rocky Mountain Region.

The present rugged topography to the west of the Rocky Flats Plant is the result of Post-Laramide tectonics and erosion. About 5,000 to 10,000 feet of uplift has taken place in the Rocky Mountain Region since the early Miocene about 25 million years ago. Late Tertiary block faulting is believed to have accompanied the regional uplift as indicated by apparent displacements of the late Eocene erosional



(after: Van Horn, 1972, Sheridan and others, 1967, Wells, 1967, and Spencer, 1961)

Figure 3-7: Fault Locations Between Golden and Marshall, Colorado (excluding Eggleston Fault)

surface (Scott, 1975 and Epis and Chapin, 1975). There is some evidence that block faulting has continued into the Quaternary (Scott, 1970; Whitkind, 1976; and Kirkham and Rogers, 1981).

In 1981, extensive studies were done to evaluate the Quaternary history of the Golden Fault and other faults at the Rocky Flats Plant and vicinity (Dames and Moore, 1981). The Golden Fault studies did not produce any evidence of tectonic activity along the Golden Fault within the past 500,000 years, and the fault does not have surficial expressions characteristic of geologically young fault zones.

Hurr (1976) showed a fault crossing the eastern edge of the Plant, based on a series of bedding irregularities that appeared to be an extension of the previously mapped Eggleston Fault (northwest of the site). Further investigations of the feature (Dames and Moore, 1981) revealed that it is probably a penecontemporaneous growth fault attributed to slumping of the unconsolidated Arapahoe Formation before burial and lithification. The Denver Basin has been tectonically stable for about 28 million years with the exception of a series of earthquakes associated with waste injection at the Rocky Mountain Arsenal in the 1960s and possible surface rupture on the Golden Fault approximately 600,000 years ago (Kirkham and Rogers, 1981).

3.6.4 Regional Ground-Water Hydrology

The Denver ground-water basin underlies a 6,700 square mile area extending from the Front Range on the west to near Limon, Colorado on the east and from Greeley on the north to Colorado Springs on the south. The four major bedrock aquifers occurring in the basin from deepest to shallowest are the Laramie-Fox Hills Aquifer, the Arapahoe Aquifer, the Denver Aquifer, and the Dawson Aquifer. The

Pierre Shale underlies these units and is considered the base of the bedrock aquifer system due to its great thickness (up to 8000 feet) and its low permeability (Robson and others, 1981a).

Presented below are discussions of the two Denver Basin bedrock aquifers which occur beneath Rocky Flats Plant - the Laramie-Fox Hills Aquifer and the Arapahoe Aquifer. The Denver and Dawson Aquifers do not occur in the immediate vicinity of Rocky Flats Plant.

Laramie-Fox Hills Aquifer

The Laramie-Fox Hills Aquifer is composed of the upper sandstone and siltstone units of the Fox Hills Formation and the lower sandstone units of the Laramie Formation. The thickness of the aquifer ranges from zero near the aquifer boundaries to 200 to 300 feet near the center of the basin. The upper Laramie coals and claystones separate the Laramie-Fox Hills Aquifer from the overlying Arapahoe Aquifer (Robson and others, 1981b).

There are three primary methods of ground-water recharge to the Laramie-Fox Hills Aquifer. In outcrop and subcrop areas recharge occurs as infiltration of incident precipitation and as infiltration from shallow alluvial aquifers. In the central part of the basin recharge occurs as leakage through the upper Laramie Formation from overlying bedrock aquifers (Robson and others, 1981b). The Laramie-Fox Hills outcrops in clay pits west of the Plant are recharge areas of the aquifer.

On a regional scale ground-water in the Laramie-Fox Hills Aquifer flows from outcrop recharge areas toward the center of the basin and discharges to remote stream valleys. In addition, ground water discharges to pumping wells in the basin (Robson and others, 1981b). In the vicinity of Rocky Flats Plant ground-water flow is generally from the west to the east.

Arapahoe Aquifer

The Arapahoe Aquifer is defined as the saturated portion of the Arapahoe Formation by Robson and others (1981a). The Arapahoe Formation consists of a 400 to 700 foot thick sequence of interbedded claystones, siltstones, sandstones, and conglomerates with claystones and shale being more prominent in the northern third of the basin (Robson and others, 1981a). Individual sandstone beds are commonly lens shaped and range from a few inches to 30 to 40 feet in thickness (Robson and others, 1981a). Beneath the Plant the majority of ground-water flow in the Arapahoe is in the lenticular sandstones contained within the claystones (Rockwell International, 1986a).

Recharge to the Arapahoe Aquifer occurs by the same mechanisms as those described for the Laramie-Fox Hills Aquifer. In outcrop and subcrop areas it occurs from infiltration of incident precipitation and as infiltration of water from shallow alluvial aquifers. However, on a regional scale the primary recharge mechanism for the Arapahoe Aquifer is leakage from the overlying Denver Aquifer (Robson and others, 1981a).

Ground-water flow in the Arapahoe Aquifer is from recharge areas at the edges of the basin toward discharge areas along incised stream valleys. Ground-water is also discharged to pumping wells (Robson and others, 1981a). Ground-water flow in the vicinity of Rocky Flats Plant is from west to east toward the area of regional discharge along the South Platte River.

3.6.5 Plant Surficial Geology

There are six distinct Quaternary unconsolidated units of surficial materials in the vicinity of the Plant: Rocky Flats Alluvium, Verdos Alluvium, Slocum Alluvium, terrace alluviums, valley fill alluvium, and colluvium (Figure 3-8).

The Rocky Flats Alluvium is topographically the highest and the oldest of the alluvial deposits. The alluvium unconformably overlies the Laramie and Arapahoe Formations in the vicinity of the Plant. The deposit is a series of laterally coalescing alluvial fans deposited by streams (Hurr, 1976). The fans were deposited on an erosional surface cut into the bedrock units, including channelization around the hogbacks of the lower Laramie.

The alluvium consists of sand, clay, silt, gravel, cobble, and occasional boulder deposits. Locally, the alluvium is cemented with calcium carbonate in the form of caliche. Color of the alluvium is pale to dark yellowish brown. The sands range from very fine-grained to medium-grained and poorly to moderately sorted. The thickness of the alluvium is variable due to deposition on an erosional surface and recent erosional processes. The alluvium is thickest to the west of the Plant, where less has been eroded, and thinnest to the east of the Plant (Rockwell International, 1986a).

Various alluvial deposits occur topographically below the Rocky Flats Alluvium in the drainages and include the Verdos, Slocum, terrace, and valley fill alluviums and colluvium (Figure 3-9). These deposits are primarily composed of

YEARS before present	EPOCH	GLACIAL SEQUENCE	DEPOSIT				
1000	HOLOCENE	Gannett Peak Stade	"Valley Fill"	post-Piney Creek Alluvium	young alluvial fan	colluvium and landslides	loess and eolian sand
2000		Interstade		(Soil)			
3000		Temple Lake Stade		Piney Creek Alluvium			
5000		"Altithermal Interval"		(Soil) pre-Piney Creek Alluvium			
12,000	PLEISTOCENE	WISCONSIN: Pinedale Glaciation	Terrace Alluvium	(Soil) Broadway Alluvium	old alluvial fan		
60,000		WISCONSIN: Bull Lake Glaciation		Louviers Alluvium			
130,000					?		
250,000		Sangamon Interglaciation / ILLINOIAN		(Soil) Slocum Alluvium	?	?	
600,000		Yarmouth Interglaciation / KANSAN		(Soil) Verdos Alluvium	?	?	
1,000,000		Aftonian Interglaciation / NEBRASKAN		(Soil) Rocky Flats Alluvium	?	?	
1,500,000	Pleistocene or Pliocene			Pre-Rocky Flats Alluvium	?	?	

(after: Van Horn, 1976, and Scott, 1965)

Figure 3-8: Surficial Alluvial Deposits in the Rocky Flats Area

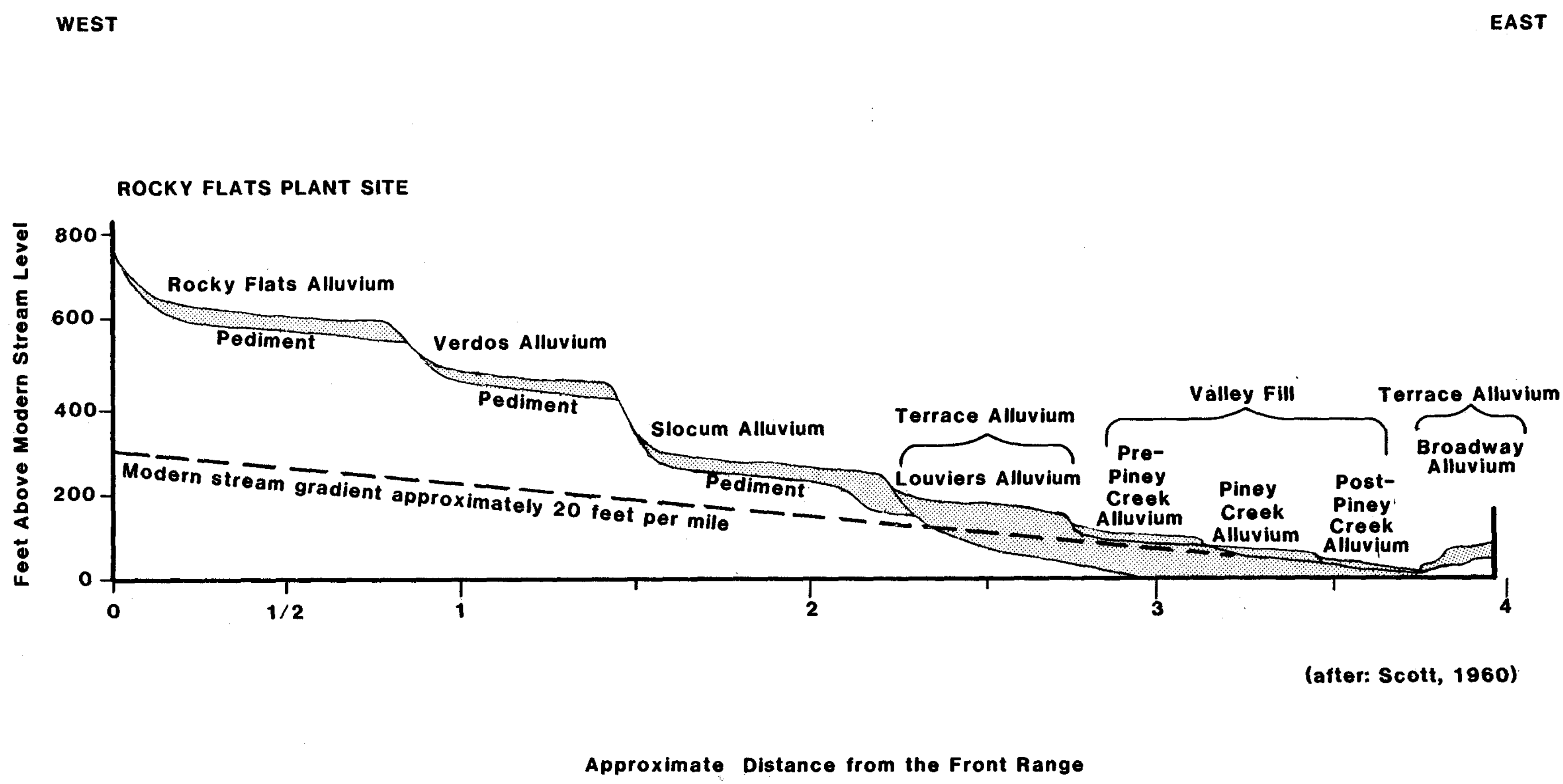


Figure 3-9:
Erosional Surfaces and Alluvial Deposits East of the Front Range, Colorado

reworked Rocky Flats Alluvium with the addition of some bedrock material. Each unit is described below.

The Verdos Alluvium occupies a topographic position about 0 to 100 feet below the adjacent top of the Rocky Flats Alluvium. The Verdos was deposited around the periphery of the present extent of the Rocky Flats Alluvium as fans and channel filling derived by erosion of the older Rocky Flats Alluvium. The maximum thickness is about 40 feet, occurring as terraces in valleys east of the Plant. The alluvium consists of unsorted gravels, sands, and clays similar to the Rocky Flats Alluvium, but the material is whitish gray in color (Rockwell International, 1986a).

The Slocum Alluvium is a poorly sorted gravel deposit containing much sand, silt, and clay derived from erosion of bedrock and the older gravel deposits. The formation has a maximum thickness in the vicinity of the Plant of about 20 feet, but is commonly 5 to 10 feet thick. It occupies a topographic position of about 150 to 300 feet below the top of the Rocky Flats Alluvium, and occurs downslope of the Verdos Alluvium in valleys east of the Plant site (Rockwell International, 1986a).

Locally, two Wisconsin-age terraces are associated with the present drainages. The terrace alluvium occurs 5 to 35 feet above recent valley floors. The alluvium is comprised of gravels, sands, and clays, derived from bedrock and reworking of older alluvial deposits. The terrace alluvium can rarely occur up to 30 feet in thickness; however, the thickness is usually around 5 feet. The alluvium occurs in valleys surrounding the Plant (Rockwell International, 1986a).

Valley fill alluvium occurs in the bottom of the present stream valleys around the Plant. The valley fill ranges from dark-brown, sandy, clayey silt to moderately sorted cobbles and small boulders, recently reworked from previously deposited alluviums. The valley fill along streams which head on the Rocky Flats Alluvium and have not yet cut through to bedrock tends to be coarse and have little or no fine material. However, where the valley fill is deposited on bedrock, 0.5 to 2 feet of cobbly sand and gravel commonly is overlain by several feet of sandy, clayey silt (Rockwell International, 1986a). Subsequent erosion and deposition locally may have added more sand, gravel and cobbles on top of the silt, or cut through the valley fill to expose bedrock along the channel bottom (Hurr, 1976).

Colluvium, produced by mass wasting and downslope creep, collects on the sides and at the base of hills and slopes. These deposits are poorly sorted mixtures of soil and debris from bedrock clay and sand mixed with gravel and cobbles derived from the older Rocky Flats Alluvium. The colluvium consists predominantly of clay with common occurrences of sandy clay and gravel. Color is yellowish brown to dusky brown and caliche is common locally. The thickness of the colluvium ranges from 3 to 22 feet (Rockwell International, 1986a).

3.7 WATER RESOURCES

3.7.1 Surface Water Resources

Surface waters in the vicinity of the Plant supply water to two reservoirs used for municipal water supply and recharge aquifers used for domestic water supply. There are six streams in the general area (Figure 3-10): North Walnut Creek, South Walnut Creek, Woman Creek, Coal Creek, Rock Creek, and Leyden Gulch. All of the streams are ephemeral i.e., they only flow in response to precipitation events (Hurr, 1976).

In addition to the natural flows, there are six ditches in the general vicinity of the Plant. The Church, McKay, and Kinnear Ditch and Reservoir Co. Ditches (diversions of Coal Creek) cross the Plant. Church Ditch delivers water to Upper Church Lake and Great Western Reservoir (City of Broomfield municipal water storage). McKay Ditch also supplies water to Great Western Reservoir. Kinnear Ditch and Reservoir Co. Ditch diverts water from Coal Creek and delivers it to Standley Lake (municipal water storage for the City of Westminster) via Woman Creek. Woman Creek also delivers water to Mower Reservoir. Last Chance Ditch flows south of the Plant and delivers water to Rocky Flats Lake and Twin Lakes. Smart Ditch takes water from Rocky Flats Lake and transports it out of the area to the east. The South Boulder Diversion Canal runs along the west edge of the Plant diverting water from South Boulder Creek and delivering it to Ralston Reservoir (City of Denver municipal water storage).

3.7.2 Ground-Water Resources

Usable ground water occurs in both the Laramie-Fox Hills and Arapahoe Aquifers. The Laramie-Fox Hills subcrops west of the Plant but has little potential for use in the general area because of its great depth (approximately 750 to 800 feet deeper than the Arapahoe). Various sandstones in the Arapahoe Aquifer are used for irrigation, livestock watering, and domestic purposes east of the Plant. Water wells within three miles of the Plant are listed in Table 9-1 and discussed in Section 9.0.

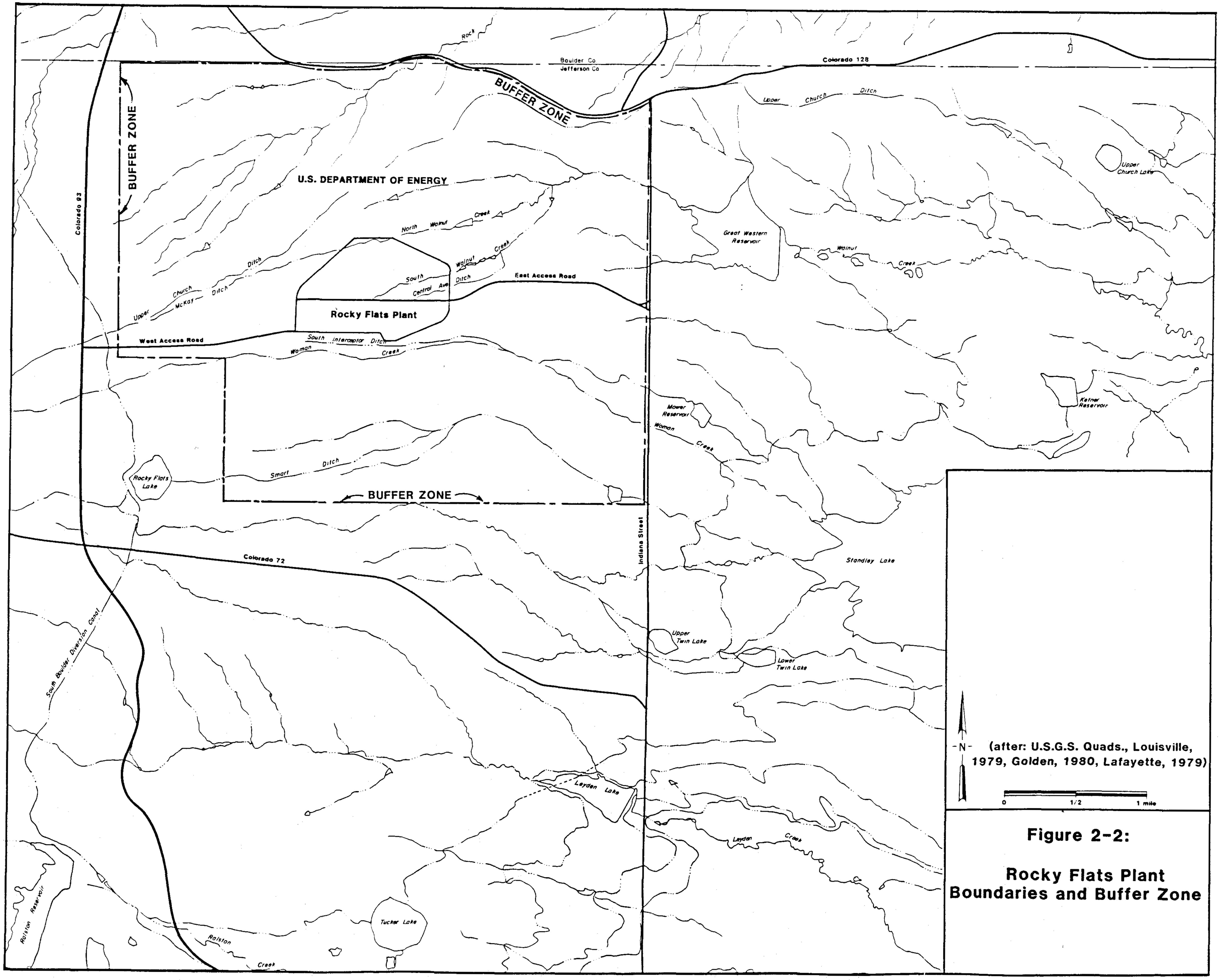
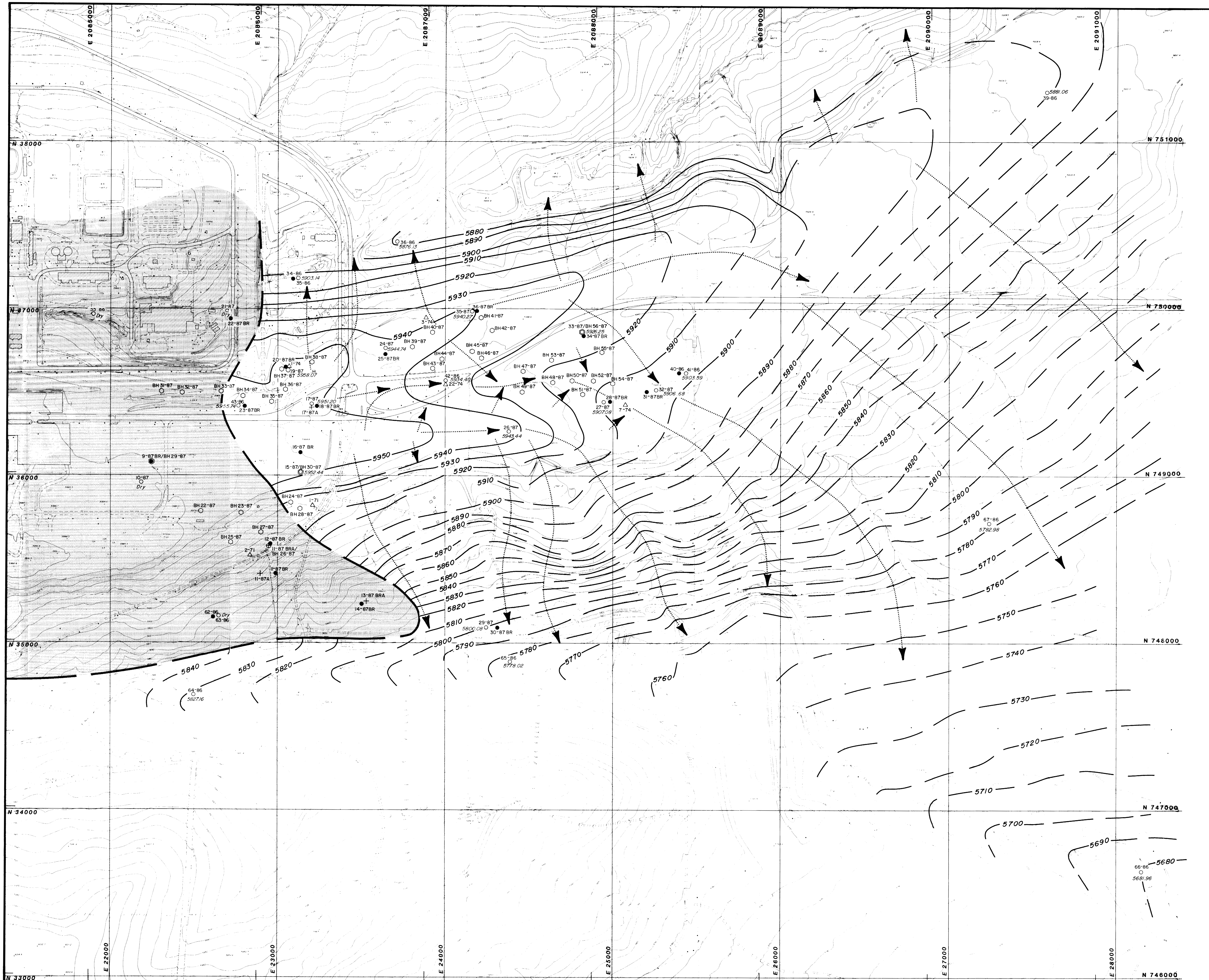


Figure 2-2:

Rocky Flats Plant Boundaries and Buffer Zone



EXPLANATION

5900 — Contour of Potentiometric Surface in Saturated Alluvium (Feet Above M.S.L.)

Contour Interval 10'

Approximate Area of Unsaturated Surficial Material

Flow Direction

○ 4-87 Alluvial Monitor Well

● 5-87BR Bedrock Monitor Well

△ 1-74 Pre-1986 Monitor Well

+ 7-87 BRA Abandoned Hole

⬡ BH 11-87 Borehole

-N-

Contour Interval = 2'
Scale: 1" = 200'
200' 0' 200' 400'

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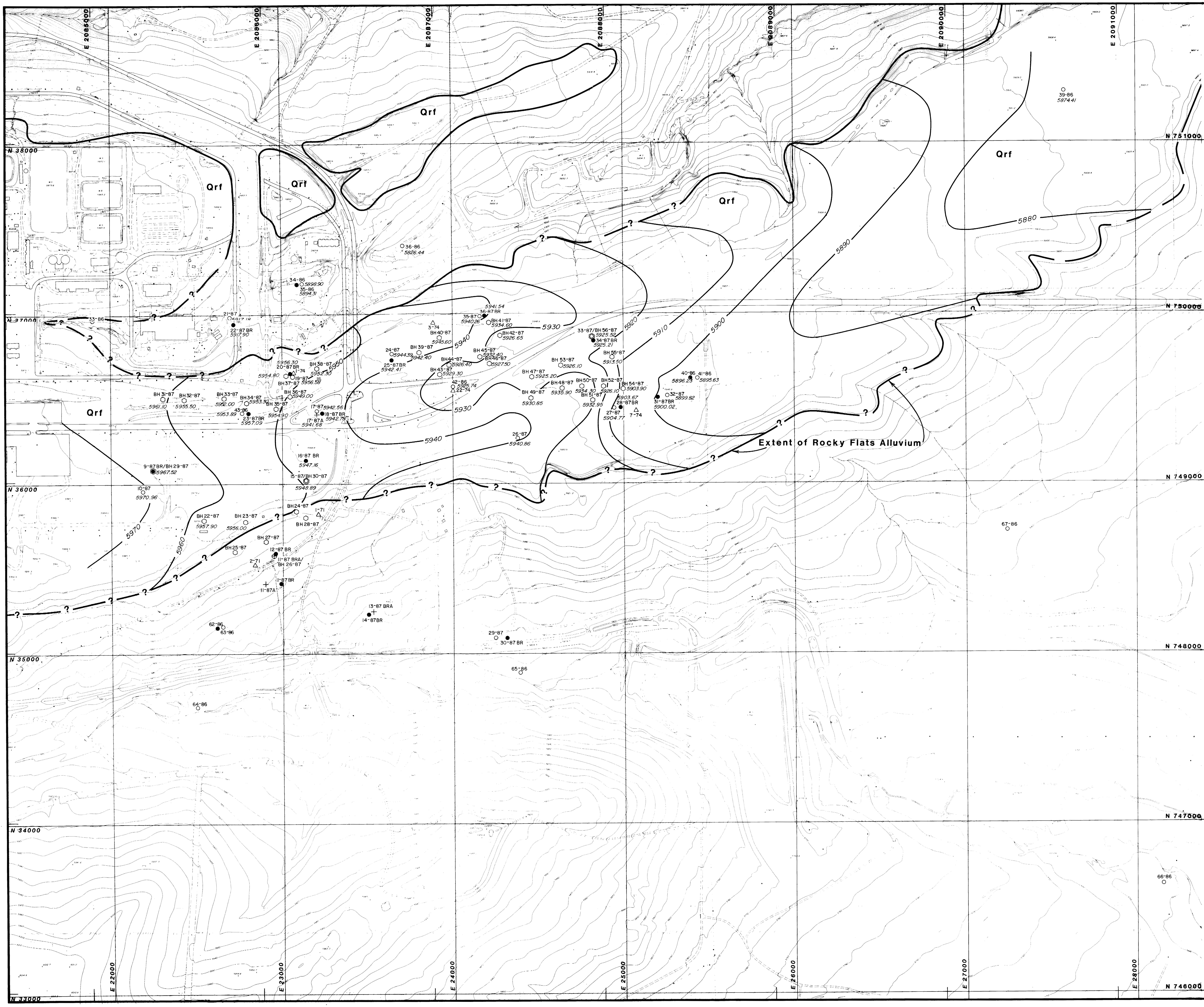
Plate 5-7

903 Pad, Mound, East Trenches Areas

ELEVATION OF POTENTIOMETRIC SURFACE IN SURFICIAL MATERIALS

December 31, 1987



EXPLANATION

Contact

Dashed where approximately located, queried where inferred.

5900 — Top of Bedrock Elevation (feet above M.S.L.) Contour Interval = 10'

○ 4-87 Alluvial Monitor Well

● 5-87BR Bedrock Monitor Well

△ 1-74 Pre-1986 Monitor Well

+ 7-87 BRA Abandoned Hole

⬡ BH 11-87 Borehole

N

Contour Interval = 2'
Scale: 1" = 200'
200' 0' 200' 400'

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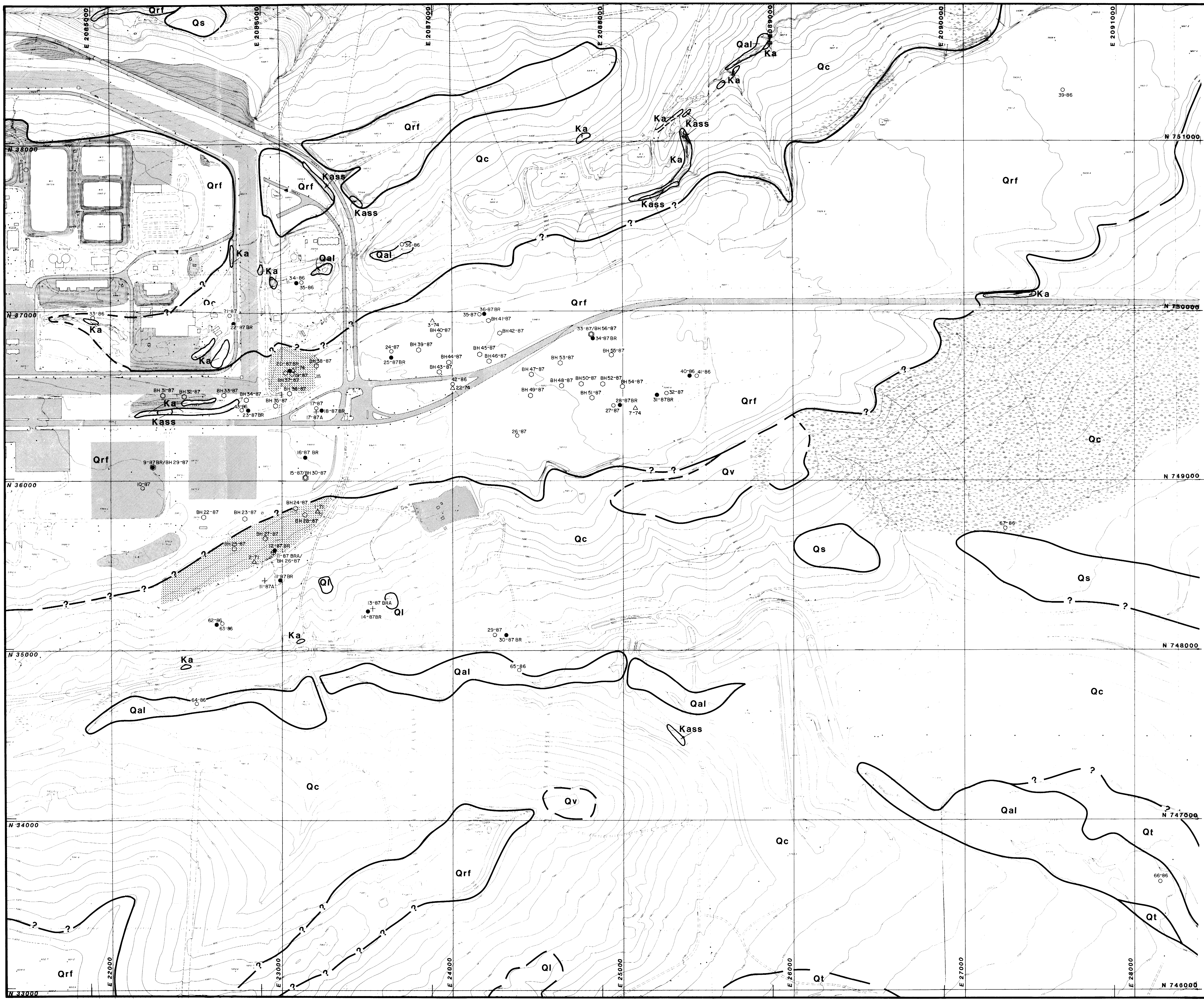
Plate 5-2

903 Pad, Mound, East Trenches Areas

TOP OF BEDROCK ELEVATION
BENEATH ROCKY FLATS ALLUVIUM

December 31, 1987



EXPLANATION

Contact

Dashed where approximately located, queried where inferred.

- Artificial Fill
- Phreatophytes
- 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

- ○ 4-87 — Alluvial Monitor Well
- ● 5-87BR — Bedrock Monitor Well
- △ 1-74 — Pre-1986 Monitor Well
- + 7-87 BRA — Abandoned Hole
- ⬡ BH 11-87 — Borehole

N

Contour interval = 2'
Scale: 1" = 200'
200' 0' 200' 400'

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Plate 5-1
903 Pad, Mound, East Trenches Areas
SURFICIAL GEOLOGY

December 31, 1987

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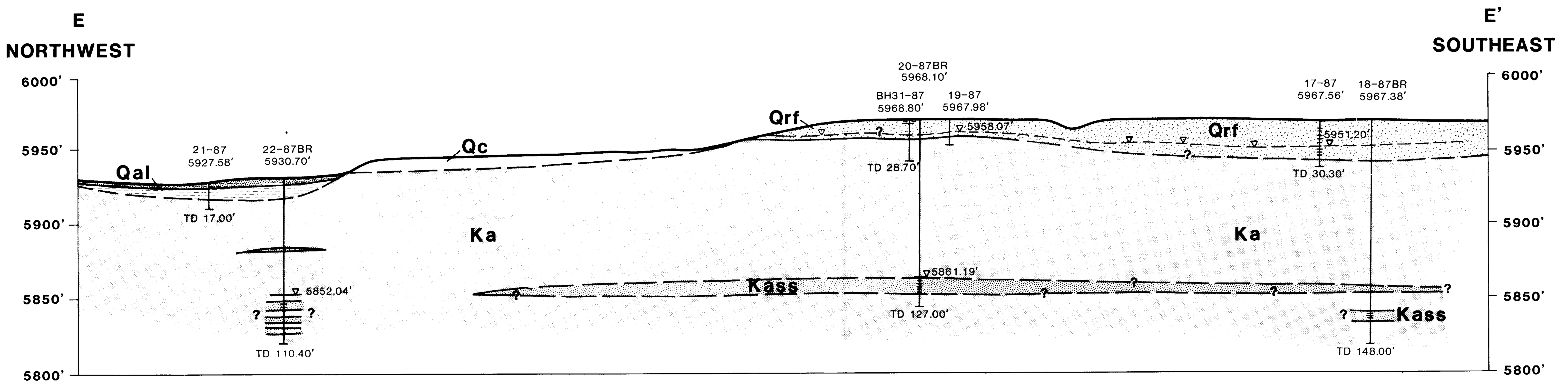
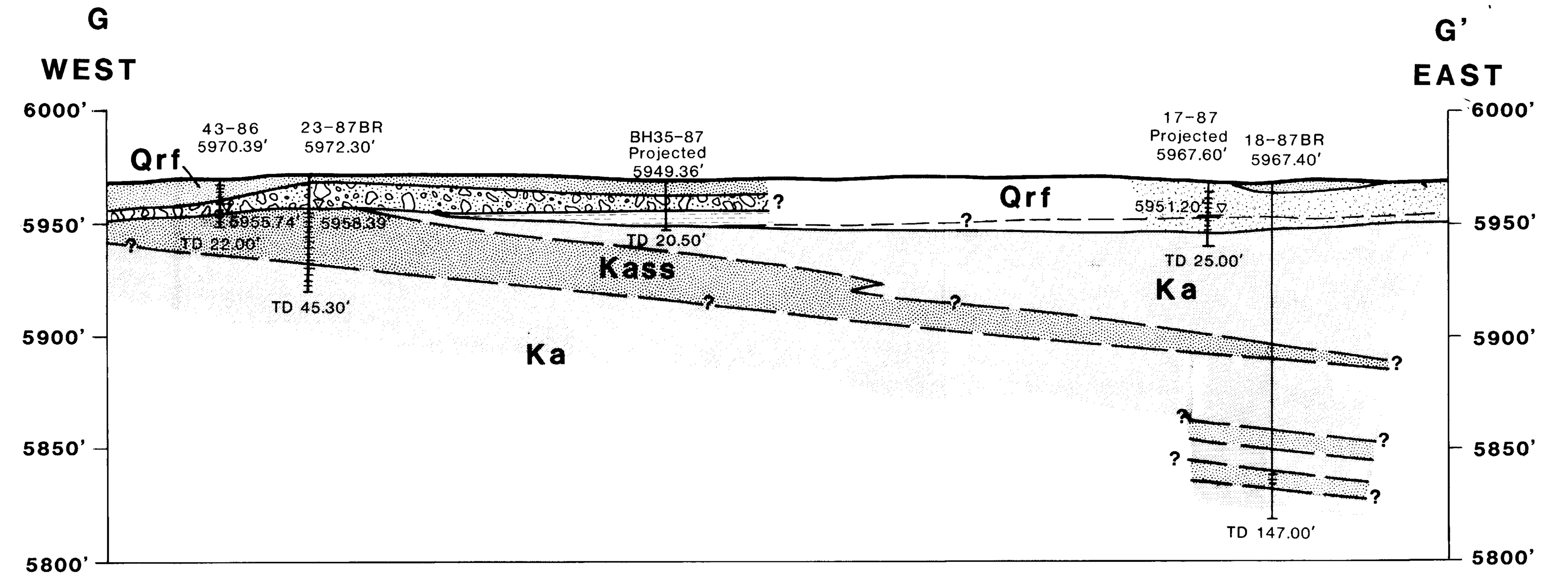
Plate 5-3

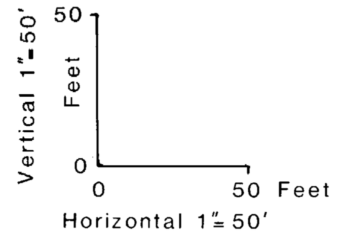
903 Pad, Mound, East Trenches Areas

CROSS SECTIONS A-A', B-B', C-C', AND D-D'

December 31, 1987







SCALE

EXPLANATION

2-87/BH3-87	Well/Borehole Identification
Prjtd.	Projected
5930.56'	Ground Surface Elevation (Surveyed)
∇	Water Level (Measured 12/1/87)
— —	Geologic Contact (Dashed Where Inferred)
	Screened Interval
TD 16.00'	Total Depth Drilled

QUATERNARY

- Qd Disturbed Ground
- Qc Colluvium
- Qrf Rocky Flats Alluvium
- Qal Alluvium

CRETACEOUS

- Ka Arapahoe Formation (Claystone)
- Kass Arapahoe Formation (Sandstone)

- Clay
- Clayey Sand or Sandy Clay
- Cobbles and/or Gravel
- Sand and Sandstone
- Sand and Gravel
- Silt or Siltstone
- Claystone

NOTE: Geology inferred between data points see plate 4-1 for cross section locations.

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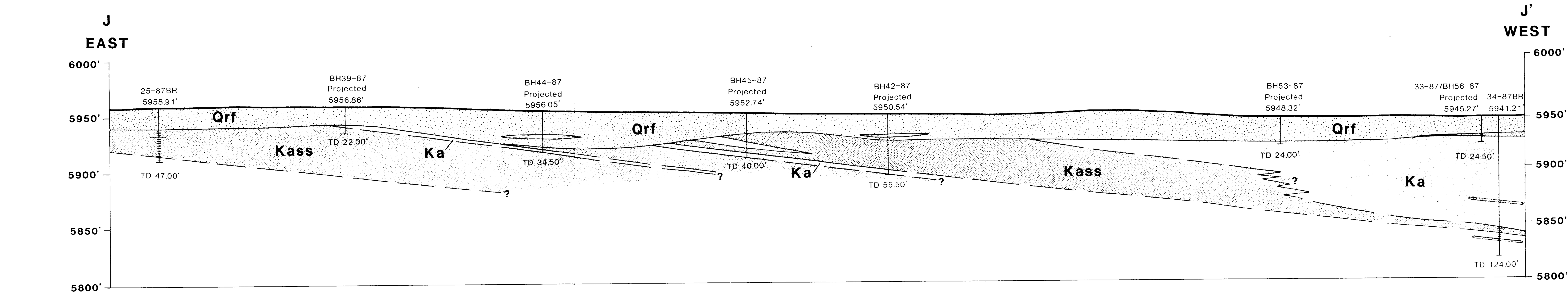
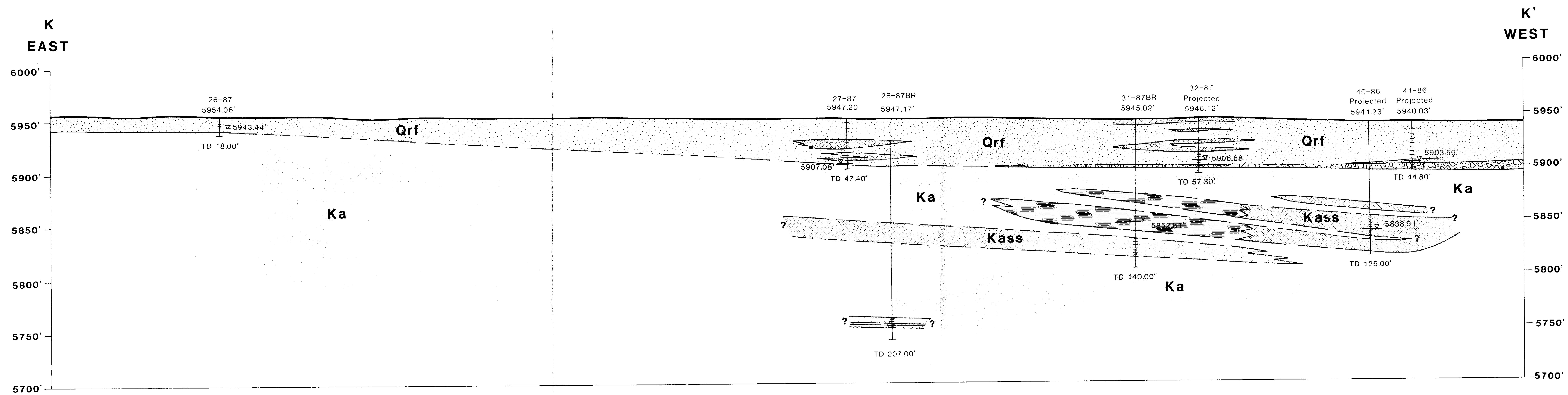
Plate 5-4

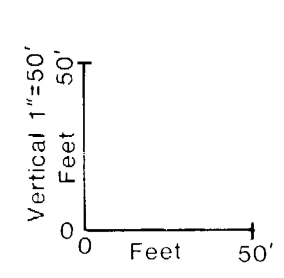
903 Pad, Mound, East Trenches Areas

CROSS SECTIONS E-E', F-F', AND G-G'

December 31, 1987







SCALE

EXPLANATION

2-87/BH3-87	Well/Borehole Identification
Prjtd.	Projected
5930.56'	Ground Surface Elevvation (Surveyed)
▽	Water Level (Measured 12/1/87)
— —	Geologic Contact (Dashed Where Inferred)
‡	Screened Interval
TD 16.00'	Total Depth Drilled

NOTE: Geology inferred between data points.
see Plate 4-1 for cross section locations.

QUATERNARY

- Qd Disturbed Ground
- Qc Colluvium
- Qrf Rocky Flats Alluvium
- Qal Alluvium

CRETACEOUS

- Ka Arapahoe Formation (Claystone)
- Kass Arapahoe Formation (Sandstone)

- Clay
- Clayey Sand or Sandy Clay
- Cobbles and/or Gravel
- Sand and Sandstone
- Sand and Gravel
- Silt or Siltstone
- Claystone

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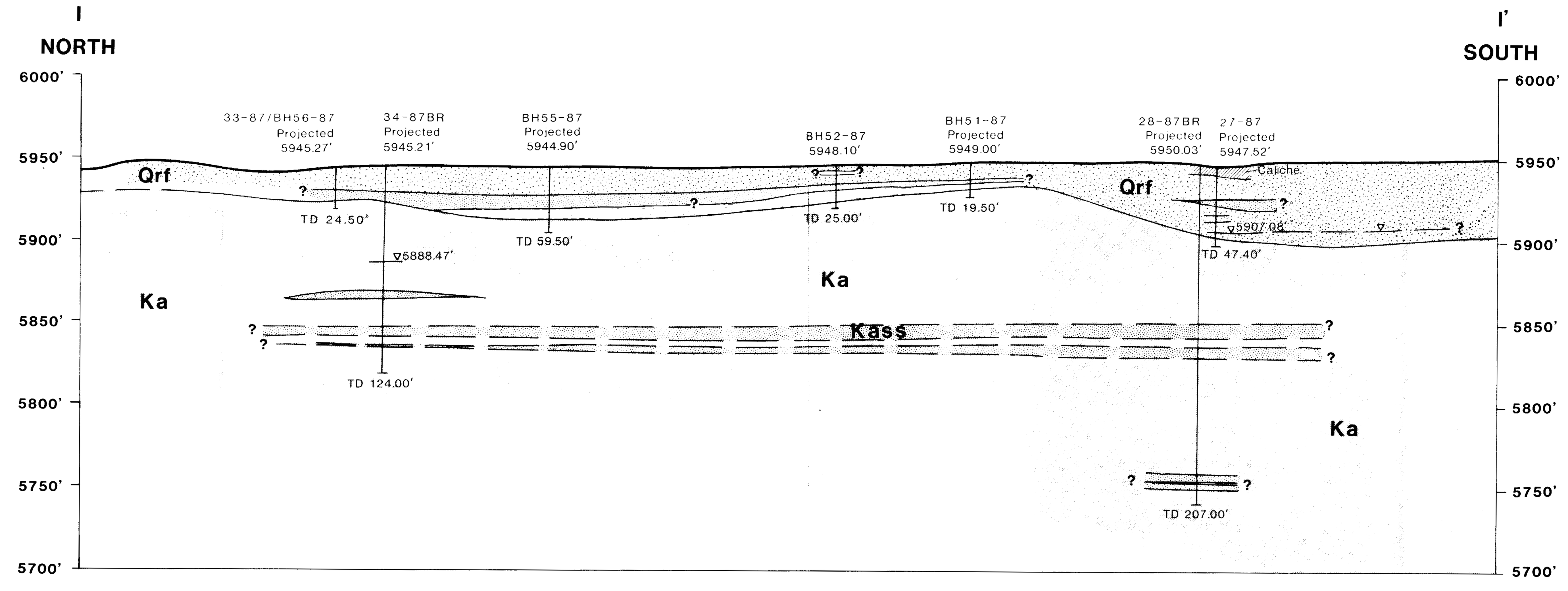
Plate 5-6

903 Pad, Mound, East Trenches Areas

CROSS SECTIONS J-J', AND K-K'

December 31, 1987



Vertical 1" = 50'
Horizontal 1" = 50'
SCALE

EXPLANATION

2-87/BH3-87	Well/Borehole Identification
Prjtd.	Projected
5930.56'	Ground Surface Elevation (Surveyed)
▽	Water Level (Measured 12/1/87)
— —	Geologic Contact (Dashed Where Inferred)
≡	Screened Interval
TD 16.00'	Total Depth Drilled

NOTE: Geology inferred between data points, see Plate 4-1 for cross section locations.

QUATERNARY

- Qd Disturbed Ground
- Qc Colluvium
- Qrf Rocky Flats Alluvium
- Qal Alluvium

CRETACEOUS

- Ka Arapahoe Formation (Claystone)
- Kass Arapahoe Formation (Sandstone)

- Clay
- Clayey Sand or Sandy Clay
- Cobbles and/or Gravel
- Sand and Sandstone
- Sand and Gravel
- Silt or Siltstone
- Claystone

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Plate 5-5
903 Pad, Mound, East Trenches Areas
CROSS SECTIONS H-H', AND I-I'

December 31, 1987

Error

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