PRESENT LANDFILL

HYDROGEOLOGIC CHARACTERIZATION REPORT

ROCKY FLATS PLANT

GOLDEN, COLORADO

JULY 1, 1988

Prepared for:

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TABLE OF CONTENTS

TABLE OF CONTENTS
(CONTINUED)

TABLE OF CONTENTS
(CONTINUED)

LIST OF PLATES

LIST OF TABLES

LIST OF TABLES
(CONTINUED)

LIST OF FIGURES

SECTION 2

INTRODUCTION

This report presents a geologic and hydrogeologic characterization of the Present Landfill. The landfill at the Rocky Flats Plant was first identified as a RCRA regulated unit in the fall of 1986 when the facility Part B application was in preparation. At that time, it was determined that certain waste streams being disposed at the landfill were RCRA hazardous wastes. Shortly thereafter, it was determined that continued disposal of hazardous wastes at the landfill would cease. Hence, a closure plan for interim status closure of the landfill is required pursuant to Part 265 of the Colorado State Hazardous Waste Regulations (6 CCR) and Title 40, Part 265 of the Code of Federal Regulations (40 CFR). The goal of the closure plan is to meet closure performance standards as follows:

- The owner or operator must close the facility in a manner that: a) minimizes the need for further maintenance; and b) controls, minimizes or eliminates, to the extent necessary, to protect human health and the environment, post-closure escape of hazardous waste constituents, leachate, contaminated rainfall, or waste decomposition products to the ground or surface waters or to the atmosphere (6 CCR and 40 CFR 265.111).

- The owner or operator must provide a detailed description of the steps needed to remove or decontaminate all hazardous waste residues and contaminated containment system components, equipment, structures, and soils during partial and final closure including, but not limited to, procedures for cleaning equipment and removing contaminated soils, methods for sampling and testing surrounding soils, and criteria for determining the extent of decontamination necessary to satisfy the closure performance standard [6 CCR at 40 CFR 265.112(b)(4)].

- The owner or operator must provide a detailed description of other activities necessary during partial and final closure period to ensure that all partial and final closure satisfy the closure performance standards, including, but not limited to, ground-water monitoring,

leachate collection, and run-on and run-off control [6 CCR and 40 CFR 265.112(b)(5)].

- During the partial and final closure periods, all contaminated equipment, structures and soil must be properly disposed of, or decontaminated unless specified otherwise in 265.228 or 265.310 (6 CCR and 40 CFR 265.114).

- If the owner or operator does not remove all the impoundment materials (standing liquids, waste and waste residues, liners, underlying and surrounding contaminated soil), he must close the impoundment and provide post-closure care as for a landfill under Subpart G (6 CCR and 40 CFR 265.110-265.120 and 265.310; 6 CCR and 40 CFR 265.228 (a,b,c)).

- At final closure of the landfill or upon closure of any cell, the owner or operator must cover the landfill or cell with a final cover designed and constructed to provide long-term minimization of migration of liquids through the closed landfill; function with minimum maintenance; promote drainage and minimize erosion or abrasion of the cover; accommodate settling and subsidence so that the covers' integrity is maintained; and have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present (6 CCR and 40 CFR 265.310).

A closure plan was submitted on November 28, 1986, for the landfill as part of the RCRA Post Closure Care Permit Application for the Rocky Flats Plant (Rockwell International, 1986a). It was prepared in accordance with 6 CCR and 40 CFR 265. Interpretations and conclusions incorporated in this report supersede those in the 1986 Post Closure Care Permit Application.

2.1 REPORT OVERVIEW

This report provides results of the 1986 and 1987 site characterization investigation performed at the Present Landfill at Rocky Flats Plant. Historical aerial photographs and previous investigations were also sources of information for this report.

Presented in this introduction are site location and description, objectives of this study, and a summary of previous investigation results. The introduction is followed by a regional setting chapter (Section 3) which describes climatology, physiography, geology, ground-water hydrology, and surface water hydrology in the vicinity of Rocky Flats Plant. Section 4 describes the site hydrogeology, including site geologic setting, ground-water flow paths, and water quality. Section 5 characterizes the surface water pathway including descriptions of surface water flow and surface water chemistry.

Appendices A through D contain supporting data. The sampling plan for the 1987 field work is presented in Appendix A. Appendices B and C contain the hydrogeologic data and analytical data, respectively. Finally, Appendix D contains historical analytical data.

2.2 SITE LOCATION AND DESCRIPTION

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 site characterization report addresses the Present Landfill located on the north side of the Rocky Flats Plant (Figure 2-2). This site was identified as a regulated unit because materials contaminated with listed hazardous wastes were disposed at the landfill.

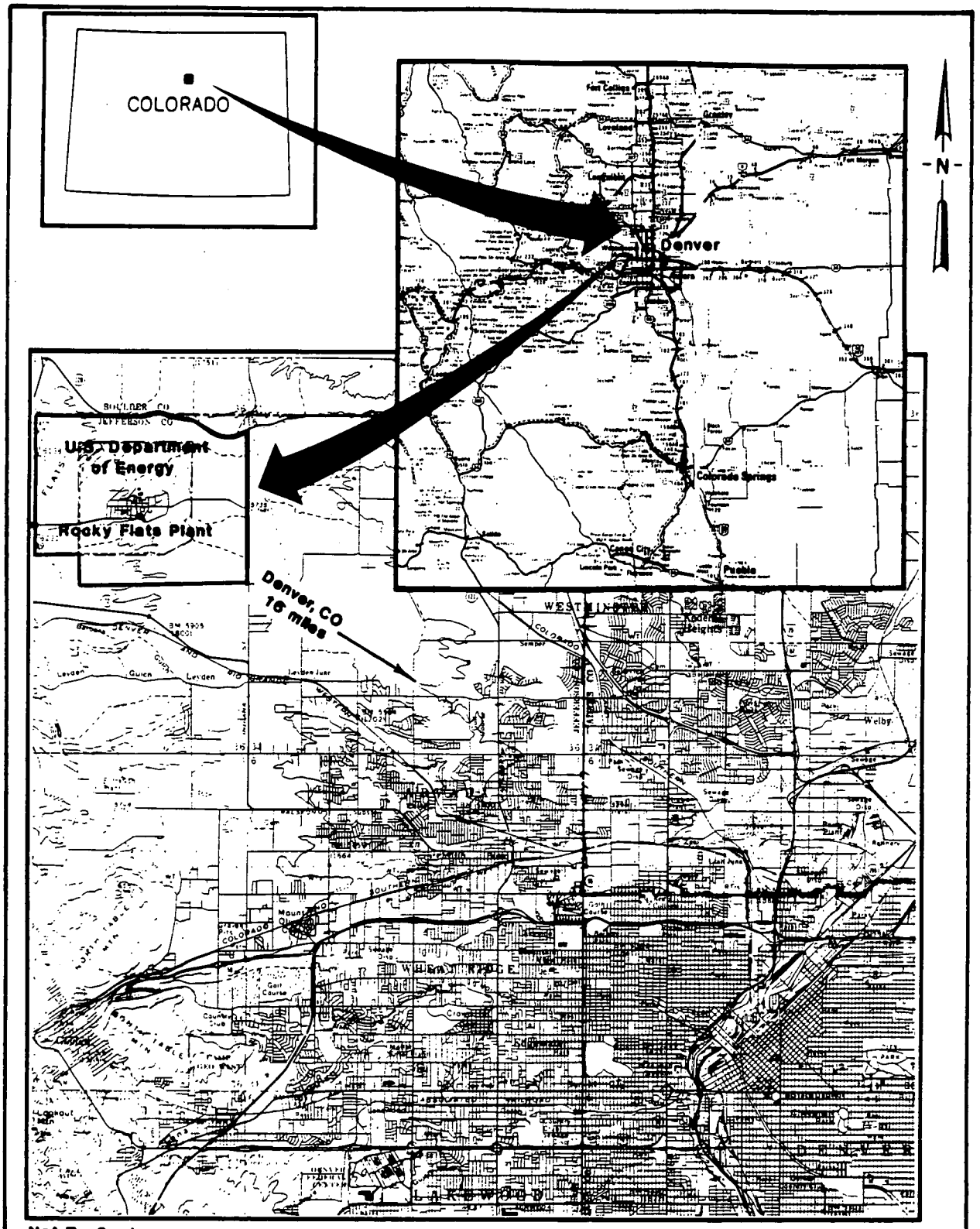


Figure 2-1: Location of Rocky Flats Plant

The Present Landfill was placed in operation on August 14, 1968 after a study determined that a landfill operation would be the most efficient and economical means to dispose of the Plant nonradioactive solid waste. A number of available sites within the Plant's boundaries were evaluated. The site selected is located on the western end of an unnamed tributary to North Walnut Creek. The west end of this unnamed tributary to North Walnut Creek was filled, with on-site soils from a borrow area, to a depth of 5 feet across the width of the channel. Aerial photographs from August, 1969, show that landfill operations had commenced by that time.

In 1974, the landfill had expanded in surface area to approximately 300,000 square feet. Two geotechnical studies were undertaken for the future expansion of the landfill including the construction of two pond embankments east of the landfill and ground-water, surface water, and leachate collection systems. The pond embankments and collections systems were constructed in 1974 (Figure 2-3).

The west pond (Pond No. 1) embankment was constructed approximately 500 feet east of the 1974 position of the landfill's advancing face. The east pond (Pond No. 2) embankment was constructed approximately 1,000 feet east of the west pond embankment. A cutoff trench, set in bedrock, was constructed in the east pond embankment to reduce seepage through the embankment foundation. The embankments and ponds were built to collect and evaporate ground water, surface water, and leachate from the collection systems.

The collection systems consist of a surface water interceptor ditch and a combined leachate and ground-water interceptor system. The surface water interceptor ditch was constructed around the exterior of the landfill to direct surface

water run-off from outside of the ditch around the landfill. The ditch is V-shaped and approximately three feet deep with steep side slopes (Figure 2-4).

In 1977, another geotechnical study (Lord, 1977) was conducted for the expansion of the landfill and for the location of a new borrow area north of the landfill. The field investigation consisted of drilling seventeen test borings; ten at the proposed landfill extension site, five in the proposed borrow area, and two in the existing borrow area.

The west embankment and pond were removed in 1981 to allow eastward expansion of the landfill. Between 1977 and 1981, the leachate collection system was covered with waste as the landfill expanded beyond the limits of the system. Two slurry trenches were constructed in 1981 extending eastward from the ends of the north and south ground-water interceptor ditches. These slurry trenches vary in depth from 10 to 25 feet and were designed to be seated in bedrock. The leachate pond (Pond No. 1) can no longer be seen on aerial photographs beginning in the year 1982.

Since beginning operations in 1968, the landfill has occupied a total volume of approximately 120,000 cubic yards based on aerial photographs and geotechnical studies; (Colorado Aerial Photo Service 1968, 1970, 1972, 1974-1985; U. S. Geol. Survey, 1971; Scharf & Assoc., 1986; Agricultural Stabilization and Conservation Service, 1969; Woodward-Clevenger, 1974; Zeff et al., 1974; and Lord, 1977). Of the 120,000 cubic yards, approximately 17,000 cubic yards are estimated to be soil utilized as cover. The volume of covers is based on two 6-inch layers extending over an area approximately 230,000 square feet. The total volume, as of November 1986, of

compacted waste was estimated to be 103,000 cubic yards (Rockwell International, 1986a).

2.3 OBJECTIVES

The objectives of this study are to characterize site geology, hydrology, and the extent of contamination. This information will be used to support closure activities and develop post closure care and monitoring programs. Post closure care activities and monitoring programs are presented in the Post Closure Care Permit Application. Specifically, it is the objective of this study to evaluate the effectiveness of the ground-water intercept system, the leachate collection system, and the slurry trenches. In addition, an evaluation of the ground-water quality and hydrogeology are presented along with recommendations for additional field work.

2.4 SUMMARY OF PREVIOUS INVESTIGATIONS

A series of investigations have been conducted at the Plant to characterize ground water, surface water, and soils. A summary of investigations performed at the Present Landfill is presented below.

Two geotechnical investigations (Woodward-Clevenger, 1974; and Zeff et al., 1974) were conducted for the 1974 expansion of the Present Landfill. Woodward-Clevenger drilled 47 test holes in the existing landfill. In addition, a total of six boreholes were drilled in three other sites to examine their suitability for landfill construction. The study concluded that all but one location was acceptable for landfill expansion/construction and that a ground-water monitoring system should be installed.

The geotechnical investigation undertaken by Zeff et al., (1974) proposed renovation plans for the existing landfill. Plans were developed to construct an impervious ring around the landfill to intercept and divert ground and surface water away from the landfill. In addition, structures were designed to sample and impound all drainage effluent from the landfill. The Zeff et al. (1974) proposals were implemented in 1974.

Another geotechnical study was conducted in 1977 by Lord and Associates. This report discussed the suitability of the claystone bedrock to serve as the landfill liner. The claystone bedrock was determined adequate to serve as a liner, and the overburden materials were determined adequate for daily landfill cover.

Hydro-Search, Inc. (1985) presented a hydrogeologic characterization of the Rocky Flats Plant. This report describes the hydrogeologic and ground-water quality conditions at the Plant based on data existing at the time. The ground-water monitoring system was described and evaluated, and recommendations were made for a new monitoring program.

In 1986, R.L. Henry (Rockwell International) submitted a report summarizing trends observed in the surface water monitoring at Rocky Flats Plant. The report discusses the surface water control system (SWCS) completed in 1980, which is designed to divert flow around Plant site and collect surface runoff and store it temporarily for monitoring before discharge. Henry also discusses non-radioactive and radioactive trends in the surface water quality.

Chen and Associates (Rockwell International, 1986a) prepared a closure plan for the Present Landfill at Rocky Flats Plant. This plan describes the construction and operation procedures at the landfill including disposal policies and procedures;

the leachate collection system; waste inventory; treatment and disposal of solid waste and hazardous waste; and collection, removal, and treatment of leachate.

Chen and Associates (Rockwell International, 1986b) also prepared a preliminary prioritization of sites at Rocky Flats Plant. The prioritization of sites was based on review of previous investigations and historical aerial photographs. The Present Landfill was considered a priority site at that time.

Four ground-water monitoring wells, two upgradient and two downgradient of the landfill, were installed in 1986 according to the procedures outlined in Rockwell International (1986c). These wells were installed to characterize the hydrogeology in the vicinity of the landfill and to evaluate whether the landfill pond was an imminent threat to the public or the environment. The work plan for the 1986 field program is presented in Rockwell International (1986d), and Plate 2-1 presents monitor well locations at Rocky Flats Plant.

Tracer Research (1986) conducted a shallow soil-gas investigation at the Rocky Flats Plant. Ninety-five soil-gas and shallow ground-water samples were collected and analyzed. Another soil-gas survey was performed in 1987 by Chen and Associates using the Petrex method. Two grids were set up around the Present Landfill on 120 foot centers. A total of 140 samples were collected from these areas.

In 1987, seventeen additional ground-water monitoring wells were installed for characterization of the Present Landfill. Sixteen alluvial wells and one bedrock well were installed.

Rockwell International (1975, 1976, 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986e, and 1987a) are annual environmental monitoring reports. These

reports summarize annual monitoring, data collection, analyses, and evaluations of programs at the facility.

NOTICE

This document (or documents) is oversized for 16mm microfilming, but is available in its entirety on the 35mm fiche card referenced below:

Document # 000292

Titled: Plate 2-1: Monitor Well Locations

Fiche location: A-SW-M13

SECTION 1

CONCLUSIONS AND RECOMMENDATIONS

Hydrogeologic investigation results of the Present Landfill suggest landfill may not be completely isolated from ground water exterior to the landfill by the ground-water intercept system. However, ground-water quality impacts from the landfill are within natural variations observed in ground-water in the vicinity of the landfill.

Hydraulic assessments for specific areas on the west, north, and south sides of the ground-water intercept system indicate ground water does not migrate into the landfill at all locations along intercept system. However, water balance calculations indicate ground water inflow probably occurs around the landfill. The intersection of the ground-water intercept system and the slurry walls may be the location of this inflow.

Based upon an examination of alluvial water quality data from wells within and surrounding the landfill it appears the landfill may be contributing calcium, bicarbonate, and to a lesser extent sodium, sulfate, iron, manganese, and strontium to the ground water. However, ground water to the north of the north slurry wall (presumably not influenced by the landfill) has similar concentrations of these analytes. This implies that even if the landfill contributes these constituents to the ground water, the resulting concentrations are within natural variations for the area. With respect to the public health significance of the water quality directly downgradient of the landfill (well 42-87), only iron (0.40 mg/l) and manganese (0.57 mg/l) exceed the ground-water quality criteria (0.3 and 0.05 mg/l, respectively).

However, manganese also exceeds the criterion (maximum concentration of 0.63 mg/l) in upgradient ground water, and it is not elevated with respect to upgradient conditions.

It is concluded that the landfill does not alter alluvial ground-water quality relative to the natural variations in the vicinity of the landfill and relative to public health-based water quality criteria. High salt concentrations further down the drainage (wells 6-86 and 5-86) appear to result from another yet unidentified and presumably natural source.

Bedrock ground-water quality is conjectured to be influenced largely by mineral dissolution within the sandstones and claystone. High salt concentrations observed in bedrock wells are not seen in alluvial ground water within the landfill.

An impermeable cap will be placed on the Present Landfill area during closure to eliminate precipitation infiltration. This cap will aid in removing water currently present by reducing recharge to the landfill. However, the effectiveness of this plan is dependent upon the ability of the in-place ground-water collection system to effectively divert ground water away from the landfill. Therefore, the following future actions are recommended to evaluate the performance of the collection system. These activities will be completed within one year.

1) Well 59-87 should be abandoned because the borehole penetrates the clay surface seal of the ground-water/leachate collection system. This well should be replaced by another alluvial monitoring well located approximately 80 feet northeast of well 59-87 along cross-section line E-E'. This new well will allow continued monitoring of water levels within the landfill waste.

2) An addition alluvial monitoring well will be installed approximately 100 feet north of well 72-87. By installing this well, a well pair will be established straddling the south slurry trench . Single hole pump tests will then be performed on well 68-87 and the proposed new well, with 67-87 and 72-87 serving as the observation wells during these tests. The

effectiveness of the slurry trenches will then be assessed based on the response of these observation wells to the pumped wells.

3) A bedrock monitor well will be installed adjacent to well 64-87 and completed in the sandstone unit subcropping in this area. An additional bedrock well will also be installed approximately 350 feet east of well 64-87 and completed in the same sandstone unit. This sandstone should be encountered approximately 43 feet below ground surface based on a seven degree easterly dip. A comparison can then be made between bedrock water quality inside and outside of the Present Landfill.

4) Single hole pump tests should be conducted in wells 63-87, 64-87, and the replacement well for 59-87 with wells 62-87, 65-87, and 58-87 serving as the observation wells, respectively. These tests will serve to establish if a hydraulic connection exists between alluvial ground-water inside and outside of the landfill at these locations.

5) The valves present along the ground-water collection system outside pipe drain will be exposed to determine where the water is being diverted.

6) The areas where the north and south slurry trenches are keyed into the outside pipe drain will be uncovered and examined to determine if a blockage of the drain occurred during this constriction.

7) Monthly monitoring of ground-water levels within the landfill will continue to establish seasonal variations in water levels.

Additional bedrock monitoring well be installed and field tests will also be performed to further characterize the bedrock hydrogeology at the Present Landfill. The following recommendations are provided to meet this objective.

1) An additional bedrock monitor well will be installed approximately 170 feet east of well 8-86 to verify the sandstone unit subcrop beneath the landfill pond. The unit should be encountered at approximately one to five feet below ground surface and should extend to a depth of approximately 21 feet below ground surface. The lithology of this sandstone will be compared to the description of the completion sandstone of 41-87BR to verify the correlation.

2) A bedrock well will be installed approximately 75 feet east of well 72-87 (along Cross-section line C-C') to verify the thickness of the subcropping sandstone present in wells 70-87 and 72-87. The subcropping sandstone should be encountered at approximately eight feet below ground surface. The borehole will fully penetrate the sandstone unit to determine the thickness of the bed, and the well will be screened across the entire sandstone thickness.

3) Two additional bedrock monitor wells will be installed near well 41-87BR. One of these wells will be completed in the uppermost sandstone unit encountered in 41-87BR (approximately 33 feet below ground surface). The second well will be completed in the middle sand found in 41-87BR approximately 48 feet below ground surface. These additional wells will help formulate an assessment of the bedrock ground-water quality leaving the present landfill area.

4) Slug tests will be conducted in all newly installed wells as well as in wells 40-87 and 42-87 to determine the hydraulic conductivity of the valley fill alluvium.

Finally, additional sampling programs for both surface water and ground water are recommended for continued monitoring as follows.

1) Continue sampling and measuring flow rates of leachate discharging from the landfill toe to assess water quality and water balance.

2) Monitor spray rates from the landfill pond.

3) Continue monitoring flow rates and water quality from the ground-water interceptor outlets.

4) Conduct a full year of ground-water sampling to confirm analytical results.

5) Conduct quarterly sampling and flow measurements at surface water stations LFP,SW13, SW14, and SW15 (Plate 5-1) to evaluate temporal variations in water quality and flow rates.

SECTION 3

REGIONAL SETTING

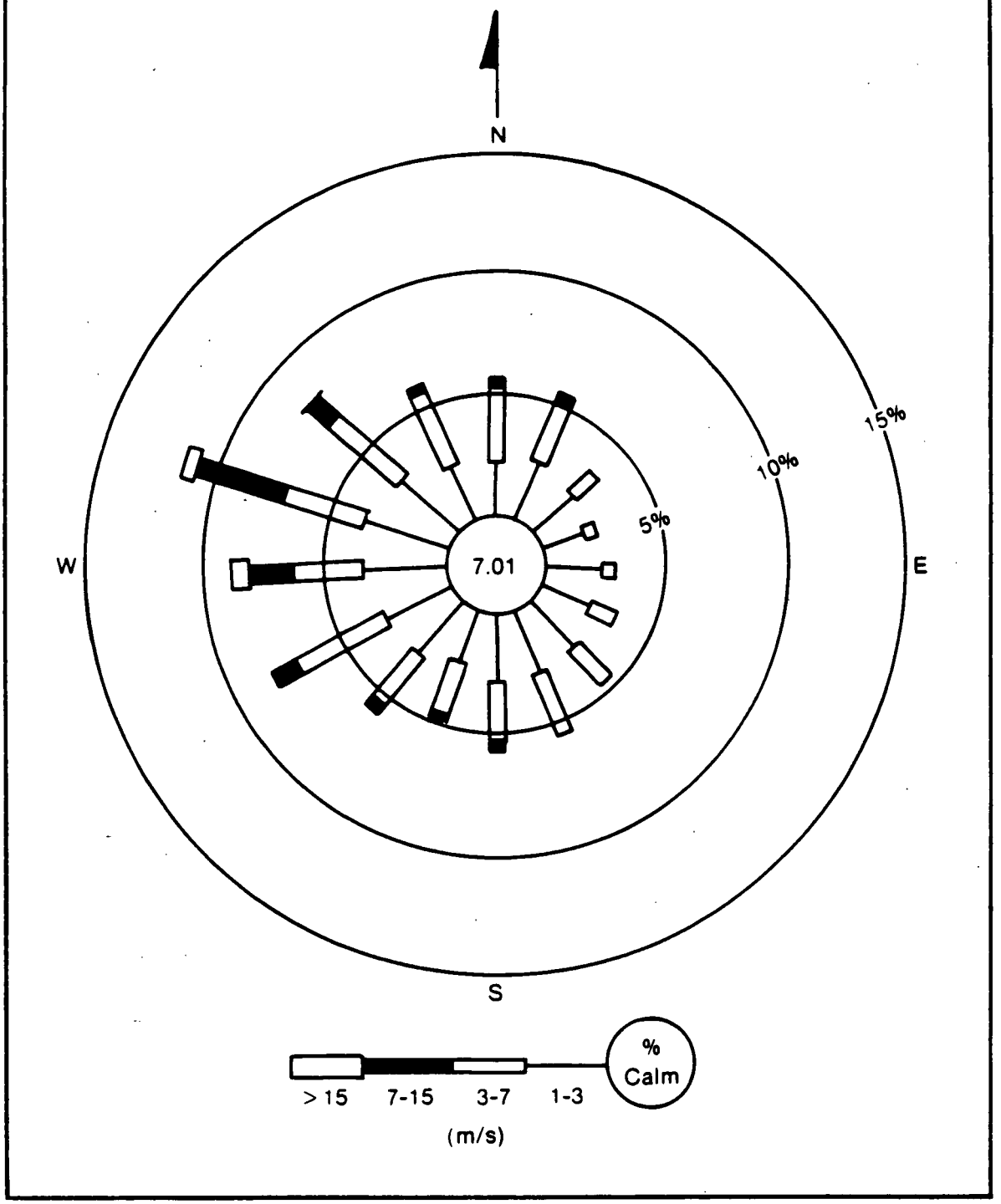
This section presents the regional setting of Rocky Flats Plant, including discussions of climatology, physiography, geology, ground-water hydrology, and surface water hydrology. Site-specific discussions of hydrogeology and surface water hydrology at the Present Landfill are presented in Sections 4.0 and 5.0, respectively.

3.1 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 from the west-northwest. 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 3-1 shows the wind direction, frequency, and average velocity for each direction as recorded in 1985.

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 daily average maximum temperature for the period 1952 to 1976 was 76 degrees F, the daily average minimum



(after: Rockwell International, 1987a)

Figure 3-1:

1986 Annual Wind Rose for the Rocky Flats Plant

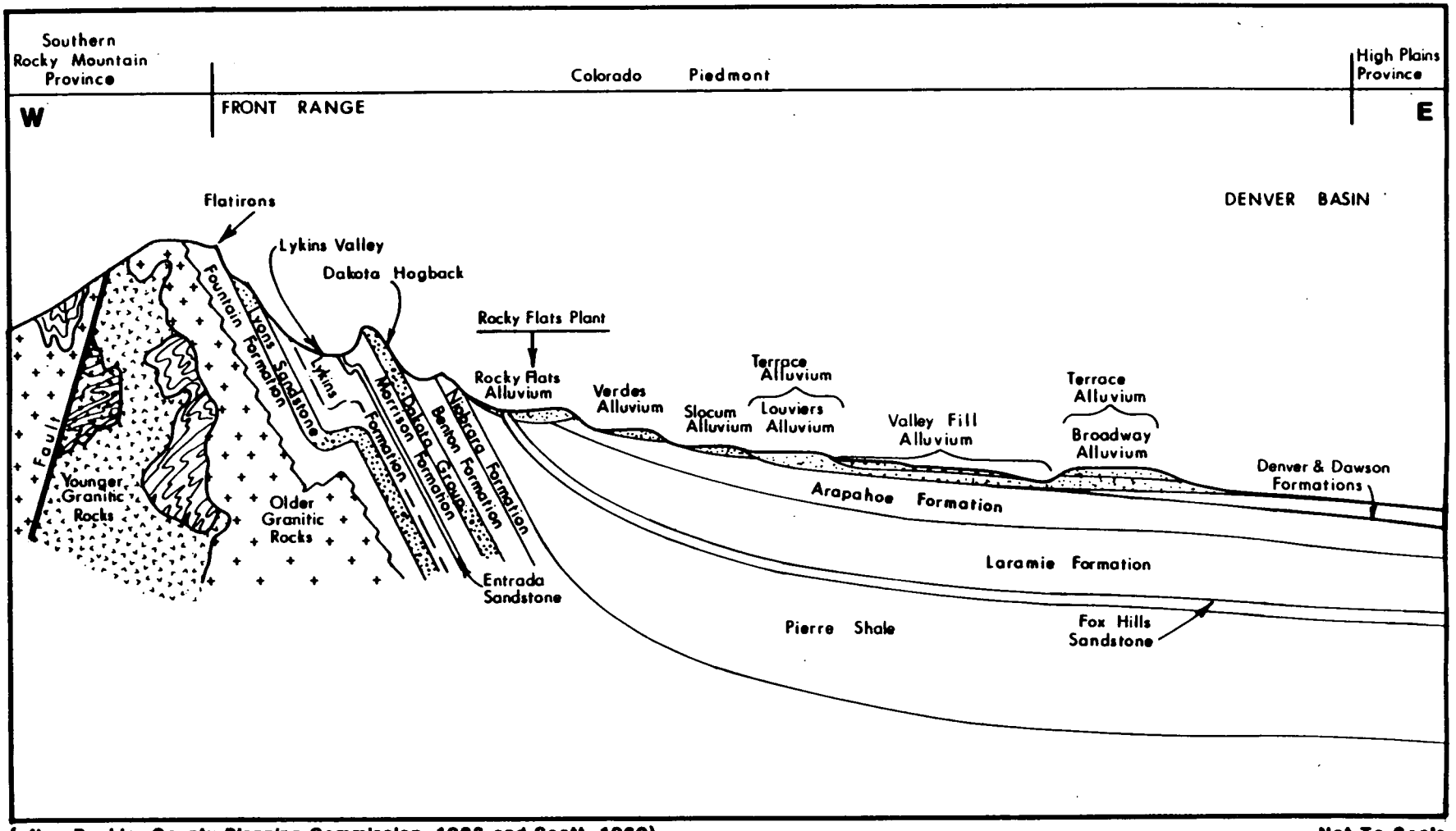
was 22 degrees F, and the average annual mean was 50 degrees F. Average relative humidity was 46 percent (DOE, 1980).

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 the 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).

3.2 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 3-2).

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



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

Not To Scale

Figure 3-2:
Generalized East-West Cross Section
Front Range to Denver Basin

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 (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 3-2). 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 3.3.3, 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.

3.3 REGIONAL GEOLOGY

3.3.1 Geologic and Stratigraphic History

This section describes the regional geologic and stratigraphic history in the vicinity of the Plant, including the Denver Basin. Section 4.0 describes the site specific geology and stratigraphy of the Present Landfill.

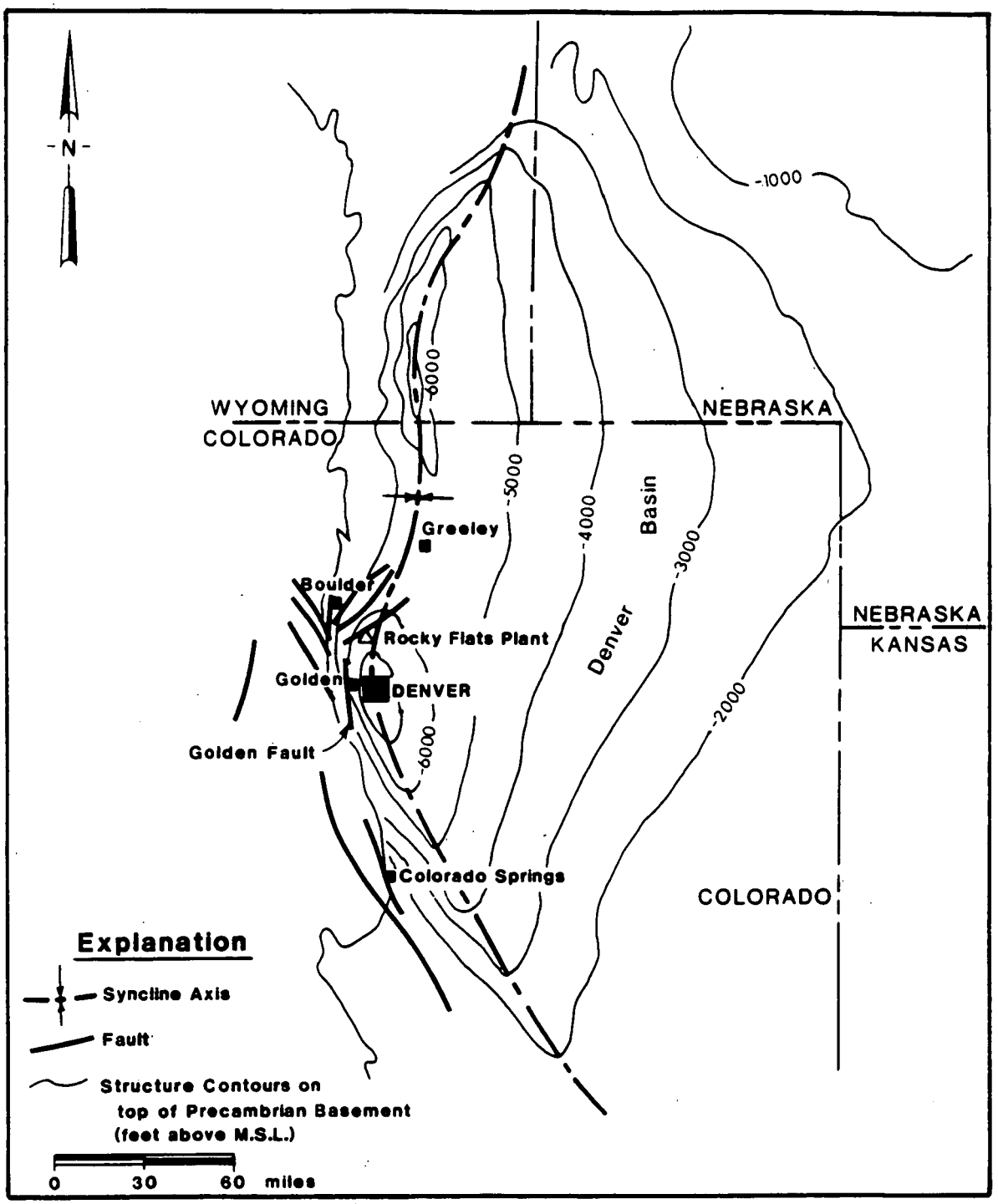
The Rocky Flats Plant is located on the northwestern flank of the Denver Basin and is underlain by about 12,000 feet of Paleozoic and Mesozoic sedimentary

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 3-3).

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 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 (Figure 3-4). The Fountain Formation contains coarse clastics derived from the erosion of the Ancestral Rockies and deposited as alluvial fans along a continental margin (Martin, 1965). 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



(after: Rockwell International, 1986a)

Figure 3-3: Structure of the Denver Basin

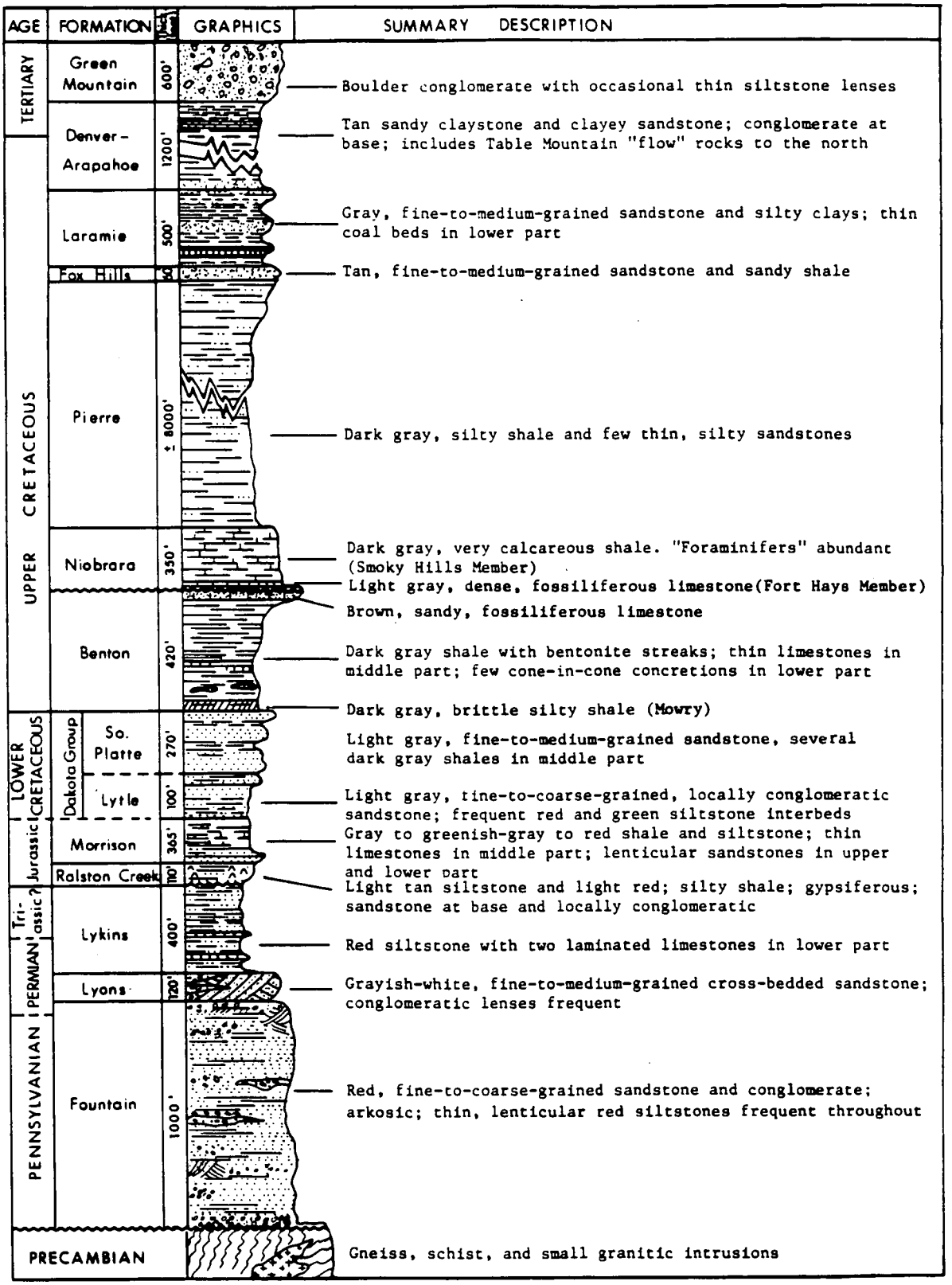


Figure 3-4: Generalized Stratigraphic Section, Golden-Morrison Area

(after: LeRoy and Weimer, 1971)

known as the Lyons, Lykins, Ralston Creek, Morrison, and Dakota Formations (Figure 3-4) (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 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 commonly occur in the Lower Arapahoe; however, conglomerate lenses have not been found at Rocky Flats Plant. Claystone and sandstone units flank and top the alluvial fan deposits (Weimer, 1973).

The Denver Formation was deposited above the Arapahoe and is over 600 feet thick. This formation contains a variety of lithologies including siltstones, arkoses, conglomerates, and basalt flows (near Golden, Colorado) (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 associated 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.

3.3.2 Plant Bedrock Geology

Bedrock units mapped at the Plant consist of the Laramie and Arapahoe Formations (Rockwell International, 1986a). These are shown in cross section in Figure 3-5. 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 (Hurr, 1976). The Upper Laramie and overlying Arapahoe Formations are described below.

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

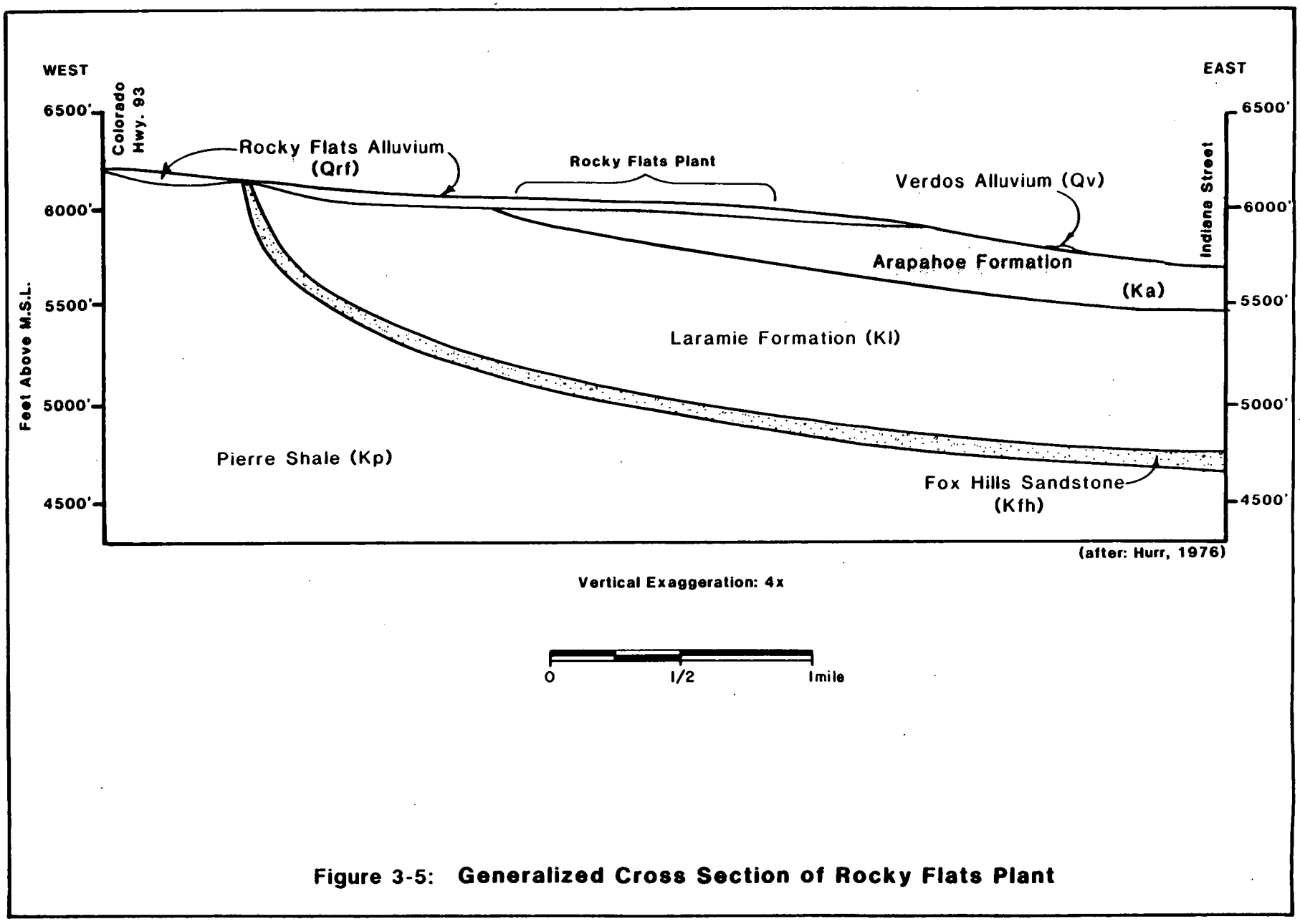


Figure 3-5: Generalized Cross Section of Rocky Flats Plant

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). This is consistent with the stratigraphic horizon picked as the base of the Arapahoe Formation at Rocky Flats Plant by Hurr (1976, 1985).

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 from 10 to 40 feet into bedrock. 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).

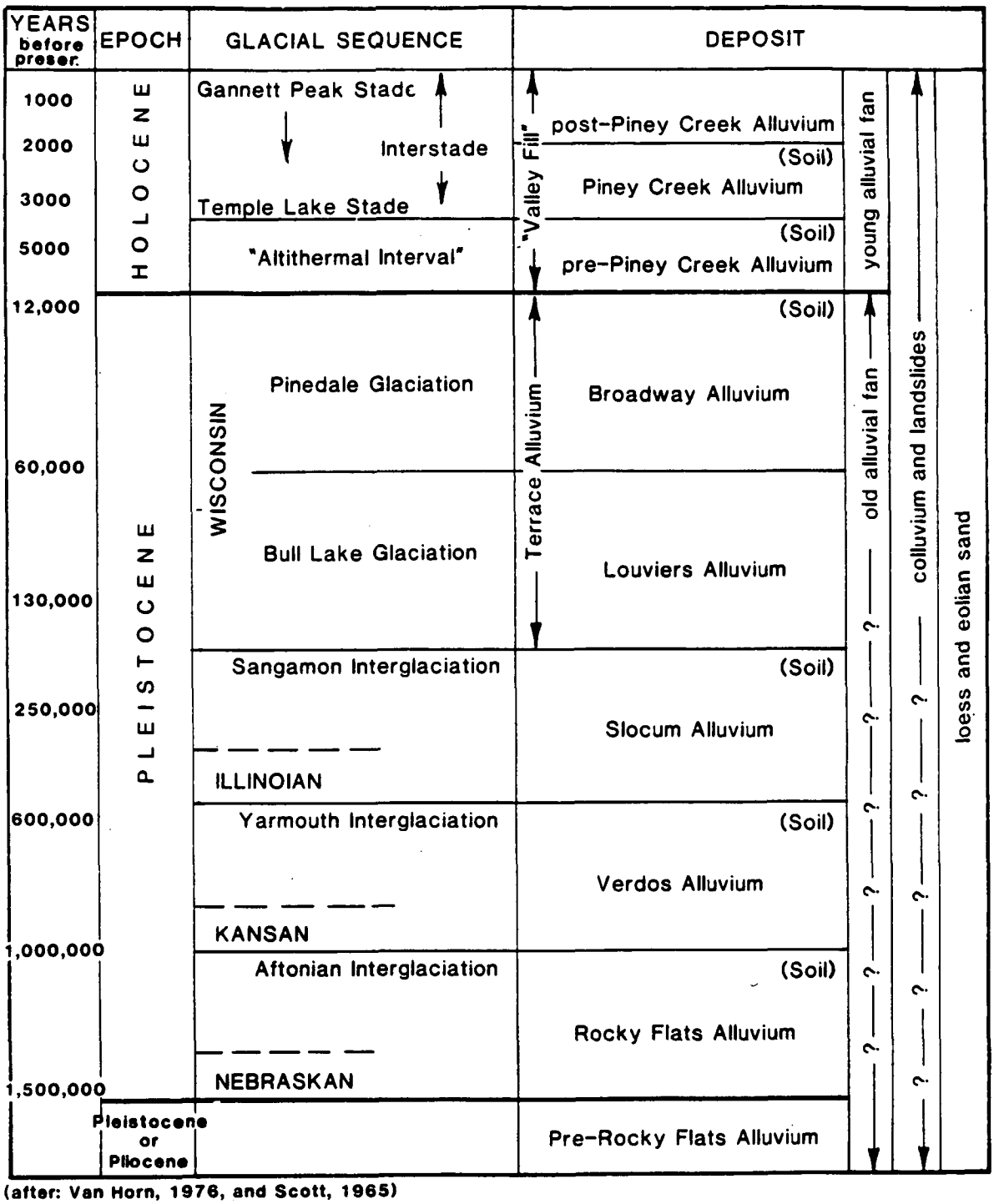
3.3.3 Plant Surficial Geology

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 3-6).

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 3-7). These deposits are primarily composed of reworked Rocky Flats Alluvium with the addition of some bedrock material. Each unit is described below.



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

Figure 3-6:
Surficial Alluvial Deposits in the Rocky Flats Area

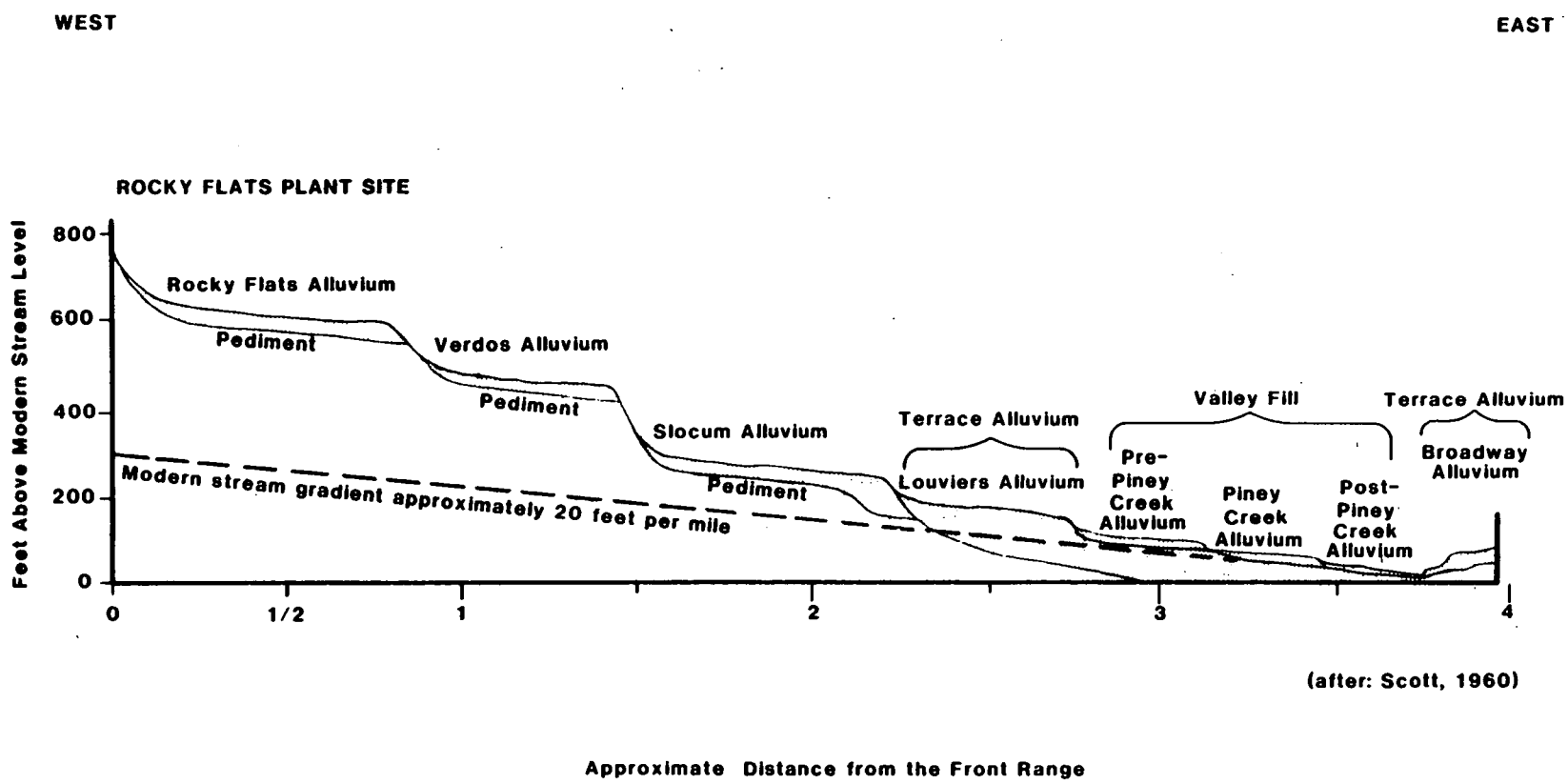


Figure 3-7:
Erosional Surfaces and Alluvial Deposits East of the Front Range, Colorado

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).

3.3.4 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 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).

3.4 REGIONAL GROUND-WATER HYDROLOGY

There are two hydraulically connected ground-water systems at the Rocky Flats Plant. These systems occur in the surficial material (Rocky Flats Alluvium, colluvium, and valley fill material) and the underlying bedrock formations (Laramie-Fox Hills Aquifer and the Arapahoe Aquifer). These are discussed individually below.

3.4.1 Unconfined Surficial Flow Systems

Recharge/Discharge Conditions

The shallow ground-water flow system occurs in the Rocky Flats Alluvium and other surficial materials under unconfined conditions. The alluvium is recharged by infiltration of incident precipitation, irrigation, and surface water diversion canals (primarily through the Rocky Flats Alluvium). In addition, the retention ponds in the various drainages recharge the valley fill alluvium.

The shallow system appears to be quite dynamic, with large water level changes in response to seasonal and other stresses. Hurr (1976) describes the rapid response of water levels in wells completed in the Rocky Flats Alluvium to surface flows in the irrigation ditches. Similarly, between mid-April and September 1986, the

water levels in wells 1-86 and 4-86 at the eastern property boundary (completed in most recent valley fill) dropped more than four to eight feet, respectively. These wells were dry in September, and there was no water exiting the Plant as ground-water flow in the valley fill alluvium in either Woman or Walnut Creek.

Ground-Water Flow Directions

Flow directions follow topography to the east and toward the drainages. In addition, flow directions are controlled by the configuration of the top of bedrock beneath surficial materials. The ground water in the drainages flows to the east in the valley fill materials and discharges as subsurface flow across the eastern Plant boundary during some portions of the year. In addition, water in all of the surficial materials recharges the bedrock.

3.4.2 Bedrock Flow Systems

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 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 Denver Basin 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).

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).

There are two primary methods of recharge to the Arapahoe 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.

3.4.3 Ground-Water Use

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.

3.5 SURFACE WATER HYDROLOGY

3.5.1 Natural Drainages

Three ephemeral streams drain the Rocky Flats Plant with flow generally from west to east (Figure 3-8). Rock Creek drains the northwestern corner and flows to the northeast in the buffer zone to its off-site confluence with Coal Creek.

A topographic divide bisects the Plant. The divide trends east-west and lies slightly south of Central Avenue (the approximate center line of the Plant site). An interceptor ditch lies between the Plant and the southern drainage Woman Creek. The South Interceptor Ditch is tributary to the "C" Ponds. Surface runoff downstream of the interceptor ditch is tributary to Woman Creek, which flows eastward to Standley Lake. An irrigation ditch headgate located in the northeast quarter of the northwest quarter diverts water from Woman Creek and conveys it to a small reservoir known as Mower Reservoir. North and South Walnut Creeks and an unnamed tributary drain the remainder of the Plant. These 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.

3.5.2 Ditches and Diversions

The Church and McKay ditches cross the northern portion of the Plant. Both carry water diverted from Coal Creek to Great Western Reservoir. A diversion structure has been built in North Walnut Creek upstream of the Plant to divert McKay ditch out of the drainage. The ditches parallel each other north of the

Present Landfill and enter the Walnut Creek drainage downstream of the confluence of the north and south forks.

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 western upgradient edge of the Plant diverting water from South Boulder Creek and delivering it to Ralston Reservoir (City of Denver municipal water storage).

3.5.3 Retention Ponds and Plant Discharges

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.

The ponds are located in the drainages of Walnut and Woman Creeks and are designated 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. Pond A-4 is designed for surface water control and for additional storage capacity for overflow from pond A-3.

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. Ponds B-1 and B-2 are reserved for spill control, whereas pond B-3 receives treated 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 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 receives surface runoff from the South Interceptor Ditch along the southern portion of the Plant. 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 generally 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 other major runoff control ditch is the South Interceptor Ditch which prevents runoff from the south side of the Plant from entering Woman Creek. The ditch discharges to pond C-2, and Woman Creek is diverted around pond C-2 by a diversion structure just upstream of the pond.

Another retention pond is located on the unnamed northern tributary of Walnut Creek, downstream of the Present Landfill (see Section 2.1). Following water quality analyses, the water from the landfill pond is spray irrigated onto an area south of the landfill but upstream of the pond.

The permit requires monitoring of specific parameters at seven discharge points. The permitted discharges are:

Discharge	Location
001	Pond B-3
002	Pond A-3
003	Reverse Osmosis Pilot Plant
004	Reverse Osmosis Plant
005	Pond A-4
006	Pond B-5
007	Pond C-2

The discharges from the ponds are regularly monitored to document compliance with NPDES permit requirements. In addition to NPDES monitoring requirements, all discharges are monitored for plutonium, americium, uranium, and tritium concentrations.

SECTION 4

SITE HYDROGEOLOGY

4.1 SITE GEOLOGY

Presented below are hydrogeologic and ground-water quality data collected during the Present Landfill investigations conducted in 1986 and 1987 as well as from previous investigations. The section begins with a detailed description of the surficial (4.1.1) and bedrock (4.1.2) geology including lithologies, thicknesses, and extent of materials found at the landfill. Ground-water hydrology and water quality data are discussed in Section 4.2.1 and 4.2.2 for surficial and bedrock flow systems, respectively.

Information for the discussion was obtained from previous studies, aerial photographs, 21 monitoring well borehole logs, and field mapping. Plate 2-1 shows the locations of all monitoring wells at the Rocky Flats Plant, and Plate 4-1 presents monitoring well locations at the Present Landfill. Geologic logs and well completion data sheets for the wells at the landfill are presented in Appendix B, and analytical data are presented in Appendixes C (recent data) and D (historical data).

4.1.1 Surficial Geology

Surficial materials in the landfill area consist of the Rocky Flats Alluvium, colluvium, valley fill alluvium, and artificial fill or disturbed ground which unconformably overlie the bedrock units. In addition, there are a few isolated exposures of claystone bedrock located along the side slopes of the drainage. Plate 4-2 presents the distribution of surficial materials based on interpretation of aerial

photographs, field mapping, and borehole logs. The landfill is located on the western end of the unnamed tributary to North Walnut Creek. Rocky Flats Alluvium caps the top of the slopes on the north and south sides of the tributary while colluvium (slope wash) covers the hillsides down to the tributary. Artificial fill or disturbed surficial materials are present within the boundaries of the landfill; along major man-made drainage ways surrounding the landfill; and northwest of the landfill. Valley fill alluvium is present along the unnamed tributary channel.

4.1.1.1 Rocky Flats Alluvium

The Quaternary Rocky Flats Alluvium is the oldest and topographically highest alluvial deposit at the Rocky Flats Plant. It is Nebraskan in age (Scott, 1965) and is situated at an elevation of approximately 5,950 to 6,000 feet above mean sea level at the landfill area. The Rocky Flats Alluvium is a series of coalescing alluvial fans deposited by braided streams (Hurr, 1976). The erosional surface (pediment) on which the alluvium was deposited slopes gently eastward truncating the Arapahoe Formation at the landfill area.

After deposition of the Rocky Flats Alluvium, eastward flowing streams began dissecting the deposit by headward erosion and lateral planation. All of the alluvium was eroded from the unnamed tributary, and colluvium and valley fill alluvium were subsequently deposited along the slopes and in the unnamed tributary drainage, respectively.

The Rocky Flats Alluvium in the landfill area is described as a generally poorly sorted, unconsolidated deposit of clay, silt, sand, gravel, and cobbles. Colors of the alluvium range from light yellow (10 YR 5/4) (Geological Society of America

Rock-Color Chart, 1984] to dark brown (10 YR 4/2). In addition shades of various oranges, olives, grays, and pinks are interspersed throughout. Occasional reddish brown (10 YR 4/6) oxide staining is present. The grain size of the quartz and granitic sand encountered ranges from very fine to coarse-grained (3.0 Ø - 0.5 Ø on the Wentworth Scale). Quartzite and granitic gravels, pebbles, and cobbles, found throughout the area in thin (less than one inch) to moderately thick (greater than one foot) layers, are subangular to subrounded, indicative of materials transported short distances. They range in size from 0.25 mm to 4.75 mm with no one size being predominant. The Rocky Flats alluvium ranges between 6.5 (72-87) and 27.2 feet thick (60-87) with an average thickness of approximately 18.0 feet where undisturbed. Lenses of sand, gravel, and clay within the Rocky Flats Alluvium can be correlated between wells in close proximity to each other. Depositional features such as cut and fill sequences (Cross section E-E'), stratigraphic pinch-outs (Cross sections D-D' and E-E'), and lateral stratigraphic variations are evident in the cross sections (Plate 4-6).. These features are characteristic of braided stream deposits associated with alluvial fans and reflect the dynamic nature of the depositional environment.

4.1.1.2 Colluvium

Colluvial materials are present on the slopes descending to the unnamed tributary (Plate 4-2); however, only wells 7-86 and 8-86 penetrated colluvium in the vicinity of the landfill. Colluvium consists predominantly of clay with common occurrences of sandy clay and gravel layers. Colluvial clay is typically poorly consolidated and ranges from yellowish brown (10 YR 5/4) to dusky brown (5 YR 2/2) in color. The sandy intervals contain moderate yellowish brown (10 YR 5/4) to

dark yellowish brown (10 YR 4/2) colors, and vary from very fine-grained to coarse-grained (4.0 Ø to 0.0 Ø), rounded to subangular quartzite sand.

4.1.1.3 Valley Fill Alluvium

The most recent deposit in the landfill area is the valley fill alluvium along the unnamed tributary channel. This alluvium is derived from reworked and redeposited older alluviums and bedrock material. Valley fill thickness ranges from 4 feet (5-86) to 8.0 feet (40-87) in the landfill area. The valley fill materials generally become finer-grained downstream of the landfill. Alluvial deposits in well 42-87 are described as predominantly gravel with abundant cobbles and pebbles, whereas well 5-86, further downgradient of the landfill in the unnamed tributary, encountered predominantly very fine-grained sand and gravels with occasional cobbles.

The unconsolidated valley fill consists of poorly sorted sand, gravel, and pebbles in a silty clay matrix. Colors range from brown (5 YR 5/6) to grayish orange pink (5 YR 7/2) with areas of gray brown (5 YR 3/2) to yellow brown (10 YR 5/4). Quartzite, granite, and schistose gravels are generally angular to subangular and unsorted.

4.1.1.4 Disturbed Ground

There are two types of disturbed ground at the landfill. The first is derived from excavations of Church Ditch located northwest of the landfill and ground associated with the building of the dam across the tributary. The core of the east pond embankment was constructed of compacted clay and claystones with the outer shell being composed of clayey sands, gravels, and cobbles. These materials were

taken from borrow areas. The disturbed ground in the Church Ditch area likely consists of reworked Rocky Flats Alluvium.

The second type of disturbed ground consists of the material comprising the landfill itself. It is described as a mixture of clay, gravel, coarse sand, asphalt fragments, wire, plastics, surgical gloves, wood particles, and other materials associated with landfilling activities. Cross-sections A-A',B-B', C-C', D-D', and E-E' (Plates 4-4, 4-5, and 4-6) show landfill areas as disturbed ground underlain by Rocky Flats alluvium (wells 61-87, 62-87, 63-87, 64-87, and 65-87). Thicknesses of the fill material where drilled ranged from approximately 1.5 feet to approximately 27 feet in the center of the landfill (Woodward-Clevenger, 1974). Fill thicknesses are greater in the center of the landfill according to the test holes drilled by Woodward-Clevenger in 1974. Cross-sections D-D' and E-E' show the landfill leachate collection/ground-water diversion system which has been included in the surficial geology map as disturbed ground.

4.1.2 Bedrock Geology

The Cretaceous Arapahoe Formation underlies surficial materials at the Present Landfill. Six wells were completed in various zones of the bedrock during the 1986 and 1987 drilling programs. The Arapahoe Formation beneath the landfill consists of claystone and interbedded sandstones and siltstones with a thin isolated shale layer encountered in well 8-86. The Arapahoe Formation was deposited by meandering streams flowing generally west to east off the Front Range. Sandstones were deposited as braided stream channel deposits and overbank splays. Claystones were deposited in back swamp and floodplain areas. Leaf fossils, black organic

matter, and wood fragments were encountered within the claystones during drilling at the landfill. Contacts between various lithologies are both gradational and sharp.

4.1.2.1 Arapahoe Formation Claystones

Claystone was the most frequently encountered lithology of the Arapahoe Formation immediately below the Quaternary/Cretaceous contact (Cross-sections A-A' through E-E'; Plates 4-4, 4-5, and 4-6). Claystones are described as massive and blocky containing occasional thin laminae and interbeds of sands and silt.

Weathered bedrock was encountered directly beneath surficial materials in all of the monitoring wells and test holes drilled during previous investigations. Weathering penetrates approximately 2 feet (well 6-86) to 11 feet (well 9-86) into bedrock. The weathered claystones generally range from pale yellowish brown (10 YR 6/2) to light olive gray (5 YR 5/6), and are moderately oxide stained, blocky and layered. Stains may also occur as brown and red mottling. Iron oxide concretions along with sporadic caliche and abundant black organic fragments were noted in the zone. A few fractures were noted in the core from well 41-87 at depths of 9.5-12 feet.

Unweathered claystone is typically dark gray (N, 3/0) to yellowish gray (5 Y 7/2) and has little mottling. Vertical to subvertical fracturing in claystone was noted in the core from well 9-86 between 42 and 60.5 feet, and again from 79.0 to 84.0 feet below ground surface. These fractures were lined with dark yellowish orange (10 YR 6/6) to dusky purple (5 P 2/2) limonite staining.

Both weathered and unweathered claystone contains horizons of very fine silt and sand. Typical silt and sand horizons range in color from brownish gray (5 YR 4/1) to dark yellowish orange (10 YR 6/6).

4.1.2.2 Arapahoe Formation Sandstones

Bedrock wells 8-86, 9-86, and 41-87BR are completed in Arapahoe Formation sandstones. In addition wells 58-87, 64-87, 65-87, 70-87, and 72-87 encountered shallow or subcropping bedrock sandstones. These sandstones are generally composed of moderately to well sorted, subrounded to rounded, very fine- to medium-grained quartz sand. Cementation increases with depth as weathering decreases. Sandstone bed thicknesses ranged from approximately 2.5 feet in well 8-86 to 20 feet in well 41-87. The sandstone in wells 41-87 and 9-86 are homogeneous and contain thin beds and laminae of fine silt and clay. Crossbedding was also noted in 9-86. The sandstone color ranged from light gray (N 7/0) in well 65-87 to olive black (5 Y 2/1) in well 41-87, which contained some organics (fossilized) at approximately 68.0 feet and again between 86.0 and 90.0 feet.

Weathered sandstone is lithologically similar to unweathered sandstone. In well 64-87 it was dark yellowish orange (10 YR 6/6) to light brown (5 YR 5/6) from approximately 24.5 feet to 28 feet below ground surface and weakly cemented.

Siltstones were encountered in the Arapahoe Formation associated with the sandstones as gradational units of silty sandstone or sandy siltstone. Well 9-86 encountered relatively homogeneous layers of unweathered siltstone at 89.0 to 122.0 feet and again at 139.0 to 144.0 feet. They are described as dark gray (N 3/0) to greenish gray (5 G 6/1), clayey, trace very fine-grained sand, very carbonaceous, and slightly calcareous with woody fragments and convoluted bedding.

Subcropping sandstones were encountered during drilling at well locations 65-87, 72-87, and 70-87 (Cross sections F-F' and C-C'). Subcropping is defined as

consolidated sandstone directly underlying the unconsolidated surficial material. Subcropping sandstones were not fully penetrated during the drilling of 70-87 and 72-87; therefore, the thickness of the unit cannot be determined at this time. The sandstones are described as weathered, weakly cemented, varying in color from light gray (N 7/0) to moderate brown (5 YR 4/4) with pale yellowish browns (10 YR 6/2). Sand was generally fine-grained (3.5-2.5 Ø), subrounded to rounded, poorly to moderately sorted, moderately iron oxide stained, massive and blocky.

Cross-section C-C' depicts the subcropping sandstones in wells 70-87 and 72-87 as interconnected based on their lithologic descriptions and physical proximity to one another. Plate 4-3 shows the estimated areal extent beneath the alluvium of subcropping sandstones associated with these two wells based on a 3.5 foot thick unit and a seven degree easterly dip and the relatively flat topography capping the slope. This is only an estimate since neither borehole (70-87 or 72-87) fully penetrated the sandstone unit. The seven degree dip is based on the correlation of the sandstone unit encountered in wells 9-87 and 16-87 in the 903 Pad Area. These sandstone units were correlated on the basis of similar lithologies and therefore a seven degree dip was established (Rockwell International, 1987b).

A second, smaller subcropping sandstone area is associated with wells 64-87 and 65-87. Approximately 3.2 feet of subcropping sandstone was encountered at well 65-87 while well location 64-87 contains a weathered clayey sandstone at a depth of approximately one foot below the Quaternary/Cretaceous contact. These sandstones are similar with the exception of color; 64-87 is dark yellowish orange (10 YR 6/6) to light brown (5 YR 5/6) while 65-87 varies from light gray (N 6/0) to moderate brown (5 YR 4/4).

A few correlations between sandstones of the Arapahoe Formation can be made when an easterly dip of seven degrees is applied. Three sandstone units were encountered during the drilling of well 41-87BR (A-A'). The upper sandstone (32.5 to 53.0 feet below ground surface) appears to subcrop underneath the present landfill pond. The second sandstone unit (64.7 to 73.5 feet below ground surface) pinches out up dip. The lowest sandstone unit (79.6 to 101.0 feet below ground surface) connects with the uppermost sandstone encountered in well 8-85 and probably pinches out dip because the bed appears to be thinning up dip. In addition, the lowermost sandstone encountered in 8-86 (59.5 to 63.6 feet below ground surface) correlates with the subcropping sandstone found during the drilling of 65-87.

4.2 GROUND-WATER HYDROLOGY

Ground water occurs in surficial materials (Rocky Flats Alluvium, colluvium, valley fill alluvium, and disturbed ground) and in Arapahoe sandstones and claystones at the Present Landfill. These two hydraulically connected flow systems are discussed separately below.

4.2.1 Ground-water System in Surficial Materials

Ground water is present in surficial materials at the Present Landfill under unconfined conditions.

4.2.1.1 Recharge/Discharge Conditions

Recharge to the water table occurs as infiltration of incident precipitation and from localized spraying of water from the landfill pond. In addition, intermittent

recharge occurs as infiltration from ditches and creeks and possibly as seepage from the landfill pond along the eastern embankment.

Discharge from the water table occurs as evapotranspiration and as seepage into the landfill pond, creeks, and springs. In addition, ground water is discharged from the surficial ground-water system into the underlying bedrock ground-water system.

The surficial ground-water flow system is quite dynamic, with large water level changes occurring in response to precipitation events and to stream and ditch flow. Hurr (1976) describes the rapid response of water levels in wells completed in Rocky Flats Alluvium to surface flows in irrigation ditches.

There are also seasonal variations in the saturated thickness of the surficial materials. Hydrographs showing saturated thickness over time are found for most wells in Appendix B. In general, water-level data for wells completed in Rocky Flats Alluvium, valley fill, and disturbed ground are available from September 1986 for the 1986 wells. Data are available as early as August 1987 for 1987 wells, although for most of these wells recorded data begins in January 1988. In view of the limited amount of data available for many wells, full analysis of seasonal variations in saturated thickness is not possible at this time.

There are three wells completed downgradient of the Present Landfill (wells 7-86, 40-87 in valley fill alluvium, and 42-87 in colluvium). Well 7-86 is adjacent to the landfill pond, and wells 40-87 and 42-87 are downstream of the pond. Saturated thickness in each of these wells has never been in excess of 5 feet, and all of the wells were dry part of the year.

Most of the wells completed in Rocky Flats Alluvium at the Present Landfill were installed in the fall of 1987. Therefore only limited water level data are available for these wells. Water level data are available for over a full year for the two 1986 wells completed in Rocky Flats Alluvium at the landfill (10-86 and 45-86). Both of these wells are upgradient of the landfill.

The hydrograph of well 10-86 indicates that the saturated thickness varies sinusoidally. The maximum saturated thickness occurs during April and May, and the minimum occurs in December. The hydrograph of well 45-86 is in rough agreement, although the minimum occurs in October.

4.2.1.2 Ground-water Flow

Natural ground-water flow in the vicinity of the Present Landfill is eastward through the Rocky Flats Alluvium following topography toward ephemeral streams (Plate 4-7 and 4-8). In the vicinity of the landfill the ground-water intercept system is designed to divert the natural ground-water flow around the landfill; however, this diversion does not appear to be working effectively at all locations. Other diversions may also occur due to the presence of slurry trenches, although this cannot be conclusively stated at this time. Within the landfill, ground-water flow generally follows topography from west to east toward the landfill pond.

Leachate/Ground-water Collection System

-- Design

In order to control ground-water flow around the landfill, a two-part leachate and ground-water collection system was constructed in 1974. This system was

designed to collect and divert ground-water around the outside of the landfill and to collect leachate generated in the landfill.

As shown on Plate 4-1, the two-part system is approximately 24 feet in width at its base. The design drawings show the leachate collection trench (shown on Plate 4-1 as "landfill trench") approximately 12 feet in width at the bottom with side slopes of 2:1. A five-foot thick gravel blanket was placed in the bottom of the system to facilitate grater flow of leachate collected in the system. The collection system was constructed by excavating a trench around the perimeter of the solid wastes to depths of 10 to 25 feet. The ground-water collection portion of the system is located on the exterior of the excavation and is separated from the leachate collection portion of the system by a 4.5-foot wide zone of clayey soil (clayey silt/sandy clay). The clayey soil zone was designed to be extended 2 feet into bedrock in order to prevent ground-water flows into the landfill. An 8-inch perforated pipe is located on the outside of the wall immediately above the bedrock contact. Ground water flows into the pipe drain and is diverted around the landfill. A series of valves determine the discharge area for the flow. Review of the aerial photographs shows the location of the installed interceptor ditch. In addition, the Present Landfill pond (Pond No. 2) and leachate pond (Pond No. 1) are seen for the first time on aerial photographs from 1975.

Field reconnaissance, a review of the borehole logs, topographic maps, and previous reports has shown that the landfill wastes bury the leachate collection system and extend beyond the system (Rockwell International, 1986a). Therefore, leachate generated outside the landfill trench would be collected by the ground-water collection system. In addition, the clay cutoff wall no longer extends to the surface of the landfill; therefore, water could enter the landfill if high enough.

No conclusive evidence has been uncovered to verify that the clay surface seal (liner) extends into bedrock as specified in the construction diagrams. The lithologic logs for the 1986 and 1987 boreholes encountered bedrock at approximately 25 feet below ground surface. Design cross sections indicate that the cutoff wall and trench invert do not always penetrate bedrock. Appendix I of the Landfill Closure Plan contain profiles of the landfill trench. As shown in Drawing Number 27317-2 in Appendix I, the trench may not extend into bedrock in one area on the southwest side of the landfill.

-- Conclusions

The following conclusions regarding the effectiveness of the leachate/ground-water intercept system have been made based on water level and ground-water quality data:

1) The ground-water intercept system is diverting ground-water away from the west end of the landfill along cross section E-E';

2) the ground-water intercept is not diverting ground-water away from the north and south sides of the landfill along cross section D-D';

3) The clay barrier is holding degraded ground water in the landfill along the west and north sides;

4) The clay barrier is ineffective on the south side of the landfill and is allowing contaminated ground water to leave the landfill;

5) The leachate collection system appears to function intermittently on the north side of the landfill.

The efficiency of the ground-water intercept system at the west end of the landfill is displayed in Cross section E-E' (Plate 4-6). Three wells (10-86, 58-87, and 59-87) are screened in the Rocky Flats Alluvium west of the ground-water intercept.

The water level in well 59-87 (immediately adjacent to the intercept) is lower that those in wells 10-86 and 58-87 indicating the ground-water intercept is accepting ground water at this location. No conclusion can be drawn as to the effectiveness of the leachate collection system at this location as there is no well east of 59-87 and the intercept system.

In contrast, the water table profiles in Cross section D-D' (Plate 4-6) indicate ground-water is not effectively draining into the system at the north and south ends of the cross section. There is no appreciable difference in water levels across the ground-water intercept system.

A comparison of water levels through time along the northern end of cross section D-D' suggests the clay liner and leachate collection system work intermittently. Figure 4-1 presents water levels for wells along Cross section E-E' plotted by date. Water levels in well 63-87 (inside the landfill) track those in wells 60-87, 61-87, and 62-87 (outside the landfill and intercept system) for three of the four months of available data. However, in January 1988, well 63-87 is dry, while water levels outside the landfill remain relatively constant. This indicates the clay liner is acting as a hydraulic barrier, and the leachate collection system is draining intermittently. In addition, water levels in well 62-87 (outside the interceptor system) have remained below the top of the clay liner estimated at an elevation of 5,980 feet. This further supports the contention that the barrier is effectively separating ground water inside the landfill from ground water outside the landfill.

It should be noted that the above conclusions are drawn on a total of four water levels per well. Because the only significant discrepancy occurs in the first month of sampling,

Figure 4-1
Elevation of Water Table for Wells 60-87 through 63-87
(Landfill)

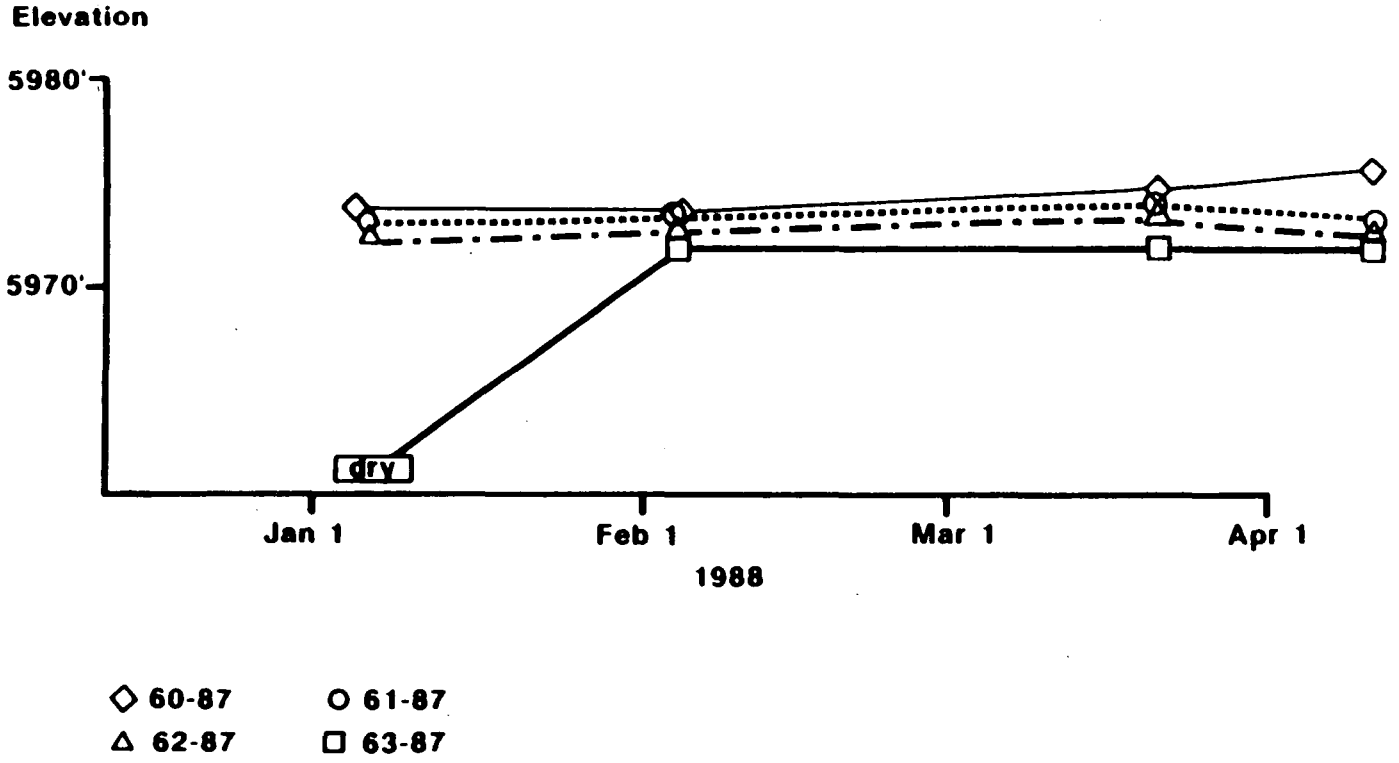
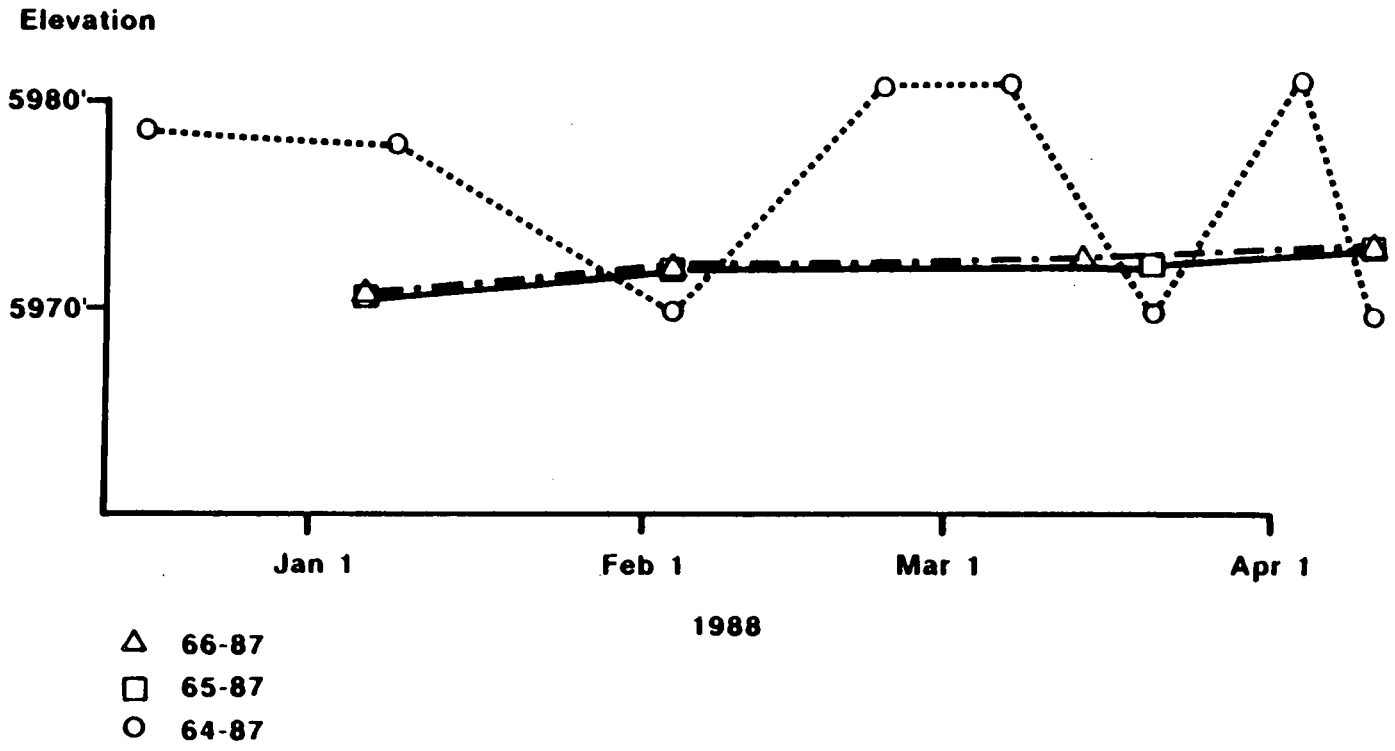


Figure 4-2

Elevation of Water Table for Wells 64-87 through 66-87

(Landfill)



the possibility exists that this is due to an initially poor well development in 63-87; however, this is not documented.

Based on water levels in wells along the southern end of Cross section D-D', the clay liner and leachate collection system at this location are not functioning properly. Figure 4-2 presents water levels through time along this cross section. Water levels in well 64-87 (inside the landfill) fluctuated up to ten feet over the four month period, while water levels in wells 65-87 and 66-87 (outside the landfill) remained constant. In fact, water levels in well 64-87 exceeded those in wells 65-87 and 66-87 during January, March, and April, 1988, when water levels in 64-87 reached elevations of 5979.83, 5980.43, and 5980.63, creating the potential for ground-water flow out of the landfill toward the south. As shown in Cross section D-D', well 65-87 intersected the top of the clay liner. This clay liner is associated with the clay encountered 2.5 feet below ground surface in this well. This places the elevation of the clay liner at this location at 5980.58 feet. This suggests that water elevations at well 64-87 will not exceed approximately 5981 feet in elevation because at this elevation water within the landfill will overspill the clay liner and discharge to the south across the clay liner. Ground-water quality data, as discussed in Section 4.2.1.6, support the conclusion that alluvial ground-water has spilled over the clay liner and exited the landfill at this location.

Slurry Trenches

A slurry trench is a curtain of low permeability material initially emplaced in trenches as a slurry. The purpose is to impede the flow of ground water. A description of the slurry trenches installed north and south of the landfill pond (Plate

4-1) is provided in Section 2.2 of the Landfill Closure Plan. Design drawings for the slurry trenches are presented in Appendix I of this closure plan.

The location of the north and south slurry trenches are shown in Plate 4-1. The well pair 67-87 and 68-87 straddle the north slurry trench. In Table 4-1, water-surface elevations for well pair 67-87 and 68-87 are listed. Except for January 1988, the difference between water elevations is slight. Determination of the degree of hydraulic continuity existing across the north slurry trench will require a pump test at some future date.

As shown in Plate 4-1, wells do not straddle the south slurry trench. Consequently, no evaluation of the south slurry trench can be made. Well 70-87 located upgrade and south of the south slurry trench is dry January through March 1988, but has a saturated thickness of 6.82 feet in April. Ground-water flow in this locale is limited for part of the year by unsaturated conditions.

It should be noted that a subcropping sandstone was found in wells 72-87 and 70-87. A comparison of this sandstone subcrop in Plate 4-3 and the location of the south slurry trench in Plate 4-1 indicates that approximately 40 percent of the southern slurry trench is underlain by subcropping sandstone. This suggests that it is likely that some degree of hydraulic continuity may extend across the eastern end of the southern slurry trench when saturated alluvium is present.

4.2.1.3 Hydraulic Conductivity of Surficial Materials

Hydraulic conductivity values were developed for surficial materials from drawdown-recovery tests performed on 1986 wells during the initial site

TABLE 4-1

ROCKY FLATS PRESENT LANDFILL
WATER LEVEL SUMMARY

DATE	67-87 WATER SURFACE ELEVATION	68-87 SURFACE ELEVATION
01/06/88	5967.42	5960.51
02/04/88	5961.32	5961.21
03/21/88	5961.72	5961.51
04/11/88	5961.82	5962.11

characterization (Rockwell International, 1986a) and from slug tests performed on select 1987 wells during this remedial investigation. Drawdown-recovery tests were analyzed using the Residual Drawdown Plot (Driscoll, 1986) and the method of Bouwer (1978), and slug tests were analyzed by the method of Bouwer and Rice (1976). Results of these tests are summarized in Table 4-2. Test data and analyses are presented in Appendix B.

Hydraulic conductivity values for the Rocky Flats Alluvium range from 1.3 x 10^{-3} centimeters per second (cm/s) [1300 feet per year (ft/yr)] at well 60-87 to 1.6 x 10^{-5} cm/s (1.6 ft/yr) at well 58-87 with a geometric mean of 2.4 x 10^{-4} cm/s (240 ft/yr).

4.2.1.4 BASIS FOR GROUND-WATER QUALITY ASSESSMENT

This evaluation of chemical conditions is based on all data collected since 1986 when detailed ground-water investigations began at the Plant. Some of the 1986 wells have six quarters of analytical results, i.e., the last quarter of 1986 (initial site characterization results), four quarters of 1987, and the first quarter of 1988. Wells completed in 1987 have first quarter, 1988 analytical data only. Table 4-3 lists the analyses performed on ground-water samples, and Table 4-4 summarizes the availability of alluvial ground-water quality data used in this report. Analytical data are presented in Appendix C and summary tables for alluvial wells sample results are presented in Table 4-5.

TABLE 4-2

RESULTS OF HYDRAULIC CONDUCTIVITY TESTS OF SURFICIAL MATERIALS

Well No.	Formation	Lithology Screened	DRAWDOWN RECOVERY Test (cm/s)	SLUG TESTS (cm/s)
45-86	Q_{RF}	SAND AND POORLY SORTED GRAVEL	2.1×10^{-5}	
58-87	Q_{RF}	SAND, POORLY SORTED GRAVEL, AND CLAYEY SAND	1.6×10^{-5}	
60-87	Q_{RF}	SAND AND GRAVEL GRADING TO CLAYEY SAND AND CLAY		1.3×10^{-3}
61-87	Q_{RF}	SAND		9.9×10^{-4}
62-87	Q_{RF}	SAND AND GRAVEL, CLAYEY SAND,AND CLAY		6.2×10^{-4}
63-87	Q_{RF}	SAND AND GRAVEL, SANDY CLAY		6.7×10^{-4}
65-87	Q_{RF}/KA_{SS}	CLAYEY SAND, SANDSTONE		4.6×10^{-4}
66-87	Q_{RF}	SAND AND SANDY CLAY		1.8×10^{-4}
67-87	Q_{RF}	CLAYEY SAND		6.4×10^{-5}
71-87	Q_{RF}	CLAYEY SAND GRADING TO SANDY CLAY		6.6×10^{-4}

Q_{RF} = ROCKY FLATS ALLUVIUM
KA_{SS} = ARAPAHOE SANDSTONE

TABLE 4-3

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
- Cesium
- Chromium (total)
- Cobalt
- Copper
- Iron
- Lead
- Magnesium
- Manganese
- Mercury
- Molybdenum
- Nickel
- Potassium
- Selenium
- Silver
- Sodium
- Thallium
- Tin
- Vanadium
- Zinc

Chromium (hexavalent)
Lithium
Strontium

TABLE 4-3

GROUND-WATER AND SURFACE WATER SAMPLING PARAMETERS
(CONTINUED)

ANIONS
Carbonate
Bicarbonate
Chloride
Sulfate
Nitrate

ORGANICS
Hazardous Substances List - Volatiles***
Oil and Grease

RADIONUCLIDES
Gross Alpha
Gross Beta
Uranium 233, 234, 235, and 238
Americium 241
Plutonium 239
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, second, and third quarters of 1987, and all surface water samples were analyzed by the Rockwell 881 Laboratory for only 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 $CHCl_3$. Ground-water samples from fourth quarter 1987 and first quarter 1988 were analyzed for HSL volatiles with the exception of 2-chloroethylvinyl ether.

Table 4-4

GROUND WATER SAMPLE INFORMATION

LANDFILL ALLUVIAL WELLS

	SAMPLE INFORMATION			FIELD PARAMETERS			LABORATORY BATCH NUMBERS					
WELL NUMBER	NUMBER	DATE	TYPE	PH	CONDUCT (umho/cm)	TEMP (deg C)	VOLATILE ORGANICS	SEMI-VOL ORGANICS	PESTICIDES AND PCB'S	METALS	INORGANICS	RADIO-CHEMISTRY
0586	DRY	09/08/86										
0586	5-86-05-05-87	05/05/87	Routine	7.10	3500	1.0	0187-881-073	No Sample	No Sample	0187-881-073	0187-881-075	0187-881-075
0586	5-86-06-09-87	06/09/87	Routine	7.20	6260	12.6	0287-881-038	No Sample	No Sample	0287-881-038	0287-881-041	0287-881-038
0586	5-86-07-31-87	07/31/87	Routine	7.20	7480	16.5	Insufficient Sample	No Sample	No Sample	0387-881-069	0387-881-068	0387-881-046
0686	DRY	09/08/86										
0686	6-86-05-13-87	05/13/87	Routine	6.90	6650	11.9	0187-881-097	No Sample	No Sample	0187-881-097	0187-881-096	0187-881-118
0686	6-86-06-09-87	06/09/87	Routine	7.20	4380	11.3	0287-221-082	No Sample	No Sample	Insufficient Sample	Insufficient Sample	Insufficient Sample
0686	6-86-08-10-87	08/10/87	Routine	7.00	5660	16.0	0387-881-074	No Sample	No Sample	Insufficient Sample	Insufficient Sample	Insufficient Sample
0686	08-86-02-01-88	02/01/88	Routine				0188-881-020	No Sample	No Sample	Insufficient Sample	Insufficient Sample	Insufficient Sample
0786	DRY	09/29/86										
0786	DRY	08/10/87										
0786	07-86-02-01-88	02/01/88	Routine				0188-881-021	No Sample	No Sample	Insufficient Sample	Insufficient Sample	Insufficient Sample
1086	G1086108C0	10/16/86	Routine	6.60	205	15.5	8610-044-021	No Sample	No Sample	8610-044-032	8610-044-033	Insufficient Sample
1086	10-86-05-14-87	05/14/87	Routine	5.90	203	12.0	0187-881-100	No Sample	No Sample	0187-881-100	0187-881-103	0187-881-105
1086	10-86-06-15-87	06/15/87	Routine	7.50	164	13.9	0287-881-047	No Sample	No Sample	0287-881-047	0287-881-050	0287-881-047
1086	10-86-08-10-87	08/10/87	Routine	6.90	211	16.0	0387-881-076	No Sample	No Sample	0387-881-083	0387-881-081	0387-881-059
1086	10-86-12-15-87	12/15/87	Routine	5.80	154	11.0	0487-881-067	No Sample	No Sample	0487-881-061	0487-881-053	0487-881-056
1086	10-86-02-02-88	02/02/88	Routine	8.20	206	9.2	0188-881-015	No Sample	No Sample	0188-881-015	0188-881-015	0188-881-015
4087	DRY	08/10/87										
4087	DRY	02/01/88										
4287	GM4287	06/24/87	Routine				8706-079-0010	No Sample	No Sample	Insufficient Sample	Insufficient Sample	Insufficient Sample
4287	DRY	08/10/87										
4287	42-87-12-16-87	12/16/87	Routine				0487-881-072	No Sample	No Sample	Insufficient Sample	Insufficient Sample	Insufficient Sample
4287	42-87-02-04-88	02/04/88	Routine	7.00	701	5.0	0188-881-017	No Sample	No Sample	0188-881-017	0188-881-017	0188-881-017
4586	G4586108C0	10/16/86	Routine	6.70	240	12.0	8610-044-006	8610-055-002	8610-055-002	8610-044-007	8610-044-008	1000-000-287
4586	G458610862	10/16/86	Field Duplicate	6.70	220	12.0	8610-044-016	8610-055-004	8610-055-004	8610-044-017	8610-044-018	1000-000-289
4586	45-86-05-15-87	05/14/87	Routine	6.40	91	12.0	0187-881-098	No Sample	No Sample	0187-881-098	0187-881-106	0187-881-108
4586	45-86-06-12-87	06/12/87	Routine	6.50	114	14.7	0287-881-043	No Sample	No Sample	0287-881-043	0287-881-046	0287-881 043
4586	45-86-08-14-87	08/14/87	Routine	5.80	87	12.1	0387-881-084	No Sample	No Sample	0387-881-089	0387-881-087	0387-881-065
4586	45-86-09-30-87	09/30/87	Field Split				8710-006-0050	No Sample	No Sample	No Sample	No Sample	No Sample
4586	45-86-09-30-87	09/30/87	Routine	6.90	105	15.3	0487-881-001	No Sample	No Sample	0487-881-005	0487-881-001	0487-881-020
4586	45-86-10-01-87	10/01/87	Field Split				No Sample	No Sample	No Sample	No Sample	No Sample	0187-123-013
5887	58-87-01-23-88	01/23/88	Routine	8.10	342	10.0	0188-881-001	No Sample	No Sample	0188-881-001	0188-881-001	0188-881-001
5937	59-87-01-23-88	01/23/88	Routine	7.20	656	12.2	0188-881-002	No Sample	No Sample	0188-881-002	0188-881-002	0188-881-002

Table 4-4 (cont'd.)

GROUND WATER SAMPLE INFORMATION

LANDFILL ALLUVIAL WELLS

	SAMPLE INFORMATION			FIELD PARAMETERS			LABORATORY BATCH NUMBERS					
WELL NUMBER	NUMBER	DATE	TYPE	pH	CONDUCT (umho/cm)	TEMP (deg C)	VOLATILE ORGANICS	SEMI-VOL ORGANICS	PESTICIDES AND PCB'S	METALS	INORGANICS	RADIO-CHEMISTRY
6087	60-87-01-23-88	01/23/88	Routine	7.10	215	10.9	0188-881-003	No Sample	No Sample	0188-881-003	0188-881-003	0188 881-003
6187	61-87-01-27-88	01/27/88	Routine	7.50	170	13.3	0188-881 006	No Sample	No Sample	0188-881-006	0188-881-006	0188-881-006
6287	62-87-01-26-88	01/26/88	Routine	7.30	227	12.3	0188-881-004	No Sample	No Sample	0188-881-004	0188-881-004	0188-881-004
6387	63-87-01-27-88	01/27/88	Routine	7.00	624	13.4	0188-881-005	No Sample	No Sample	0188-881-005	0188-881-005	0188-881-005
6487	64-87-01-29-88	01/29/88	Routine	7.00	463	11.4	Insufficient Sample	No Sample	No Sample	0188-881-014	0188-881-014	0188-881-014
6587	65-87-01-28-88	01/28/88	Routine	7.20	685	13.3	0188-881-010	No Sample	No Sample	0188-881-010	0188-881-010	0188-881-010
6687	66-87-01-29-88	01/29/88	Routine	7.30	685	9.8	Insufficient Sample	No Sample	No Sample	0188-881-012	0188-881-012	0188 881 012
6787	67-87-01-28-88	01/28/88	Routine	7.00	390	10.8	0188-881-008	No Sample	No Sample	0188-881-008	0188-881-008	0188-881-008
6887	68-87-01-28-88	01/28/88	Routine	7.00	390	10.4	0188-881-009	No Sample	No Sample	0188-881-009	0188-881-009	0188-881-009
7087	DRY	02/03/88										
7187	71-87-01-29-88	01/29/88	Routine	7.50	564	7.8	Insufficient Sample	No Sample	No Sample	0188-881-013	0188-881-013	0188 881-013
7287	72-87-01-28-88	01/28/88	Routine	7.20	685	7.9	0188-881-011	No Sample	No Sample	0188-881-011	0188-881-011	0188-881-011

Table

Groundwater Volatile ...anic Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Chloro methane	Bromo methane	Vinyl Chloride	Chloro ethane	Methylene Chloride	Acetone	Carbon Disulfide	1,1-Dichloro ethene	1,1-Dichloro ethane	Trans-1,2 Dichloro ethene
Landfill Alluvial Wells Upgradient														
1086	G108610860	10/16/86		ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
1086	10-86-05-14-87	05/14/87	1	ug/l	NR	NR	NR	NR	NR	NR	NR	4 U	NR	4 U
1086	10-86-06-15-87	06/15/87	2	ug/l	NR	NR	NR	NR	NR	NR	NR	4 U	NR	4 U
1086	10-86-08-10-87	08/10/87	3	ug/l	NR	NR	NR	NR	NR	NR	NR	5 U	NR	5 U
1086	10-86-12-15-87	12/15/87	4	ug/l	10 U	10 U	10 U	10 U	9	10 U	5 U	5 U	5 U	5 U
1086	10-86-02-02-88	02/02/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
4586	G458610860	10/16/86		ug/l	10 U	10 U	10 U	10 U	5 U	15 B	5 U	5 U	5 U	5 U
4586	G458610862	10/16/86		ug/l	10 U	10 U	10 U	10 U	5 U	3 BJ	5 U	5 U	5 U	5 U
4586	45-86-05-15-87	05/14/87	1	ug/l	NR	NR	NR	NR	NR	NR	NR	4 U	NR	4 U
4586	45-86-06-12-87	06/12/87	2	ug/l	NR	NR	NR	NR	NR	NR	NR	4 U	NR	4 U
4586	45-86-08-14-87	08/14/87	3	ug/l	NR	NR	NR	NR	NR	NR	NR	5 U	NR	5 U
4586	45-86-09-30-87	09/30/87		ug/l	10 U	10 U	10 U	10 U	5 U	1 JB	5 U	5 U	5 U	5 U
4586	45-86-09-30-87	09/30/87	4	ug/l	NR	NR	NR	NR	NR	NR	NR	5 U	NR	5 U
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	13	5 U	5 U	5 U	5 U

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-5 (r 1.)

Groundwater Volatile ic Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr	Units	Chloroform	1,2 Dichloro ethane	2 Butanone	1,1,1-Trichloro ethane	Carbon tetra chloride	Vinyl Acetate	Bromo dichloro methane	1,2-Dichloro propane	Trans 1,3 Dichloro propene	Trichloro ethene
Landfill Alluvial Wells Upgradient														
1086	G1086108c0	10/16/86		ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
1086	10-86-05-14-87	05/14/87	1	ug/l	4 U	4 U	NR	4 U	4 U	NR	NR	NR	NR	4 U
1086	10-86-06-15-87	06/15/87	2	ug/l	4 U	4 U	NR	4 U	4 U	NR	NR	NR	NR	4 U
1086	10-86-08-10 87	08/10/87	3	ug/l	5 U	5 U	NR	5 U	5 U	NR	NR	NR	NR	5 U
1086	10-86-12-15 87	12/15/87	4	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
1086	10-86-02-02-88	02/02/88	1	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
4586	G4586108c0	10/16/86		ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
4586	G4586108c2	10/16/86		ug/l	5 U	5 U	6 J	5 U	5 U	10 U	5 U	5 U	5 U	5 U
4586	45-86-05-15-87	05/14/87	1	ug/l	4 U	4 U	NR	4 U	4 U	NR	NR	NR	NR	4 U
4586	45-86 06-12-87	06/12/87	2	ug/l	4 U	4 U	NR	4 U	4 U	NR	NR	NR	NR	4 U
4586	45-86-08-14-87	08/14/87	3	ug/l	5 U	5 U	NR	5 U	5 U	NR	NR	NR	NR	5 U
4586	45-86-09-30-87	09/30/87		ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
4586	45-86-09-30-87	09/30/87	4	ug/l	5 U	5 U	NR	5 U	5 U	NR	NR	NR	NR	5 U
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1	ug/l	5 U	5 U	10 U	5 U	8	10 U	5 U	5 U	5 U	5 U

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4- (Cont'd.)

Groundwater Volatile Organic Results for Landfill Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Dibromo chloro methane	1,1,2-Trichloro ethane	Benzene	cis-1,3 Dichloro propene	2 chloro ethylvinyl ether	Bromoform	4-Methyl-2-pentanone	2-Hexanone	Tetrachloro ethene	1,1,2,2-Tetrachloro ethane
Landfill Alluvial Wells Upgradient														
1086	G108610860	10/16/86		ug/l	5 U	5 U	5 U	5 U	10 U	5 U	10 U	10 U	5 U	5 U
1086	10-86-05-14-87	05/14/87	1	ug/l	NR	4 U	NR	NR	NR	NR	NR	NR	4 U	NR
1086	10-86-06-15-87	06/15/87	2	ug/l	NR	4 U	NR	NR	NR	NR	NR	NR	4 U	NR
1086	10-86-08-10-87	08/10/87	3	ug/l	NR	5 U	NR	NR	NR	NR	NR	NR	5 U	NR
1086	10-86-12-15-87	12/15/87	4	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
1086	10-86-02-02-88	02/02/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
4586	G458610860	10/16/86		ug/l	5 U	5 U	5 U	5 U	10 U	5 U	10 U	10 U	5 U	5 U
4586	G458610862	10/16/86		ug/l	5 U	5 U	5 U	5 U	10 U	5 U	10 U	10 U	5 U	5 U
4586	45-86-05-15-87	05/14/87	1	ug/l	NR	4 U	NR	NR	NR	NR	NR	NR	4 U	NR
4586	45-86-06-12-87	06/12/87	2	ug/l	NR	4 U	NR	NR	NR	NR	NR	NR	4 U	NR
4586	45-86-08-14-87	08/14/87	3	ug/l	NR	5 U	NR	NR	NR	NR	NR	NR	5 U	NR
4586	45-86-09-30-87	09/30/87		ug/l	5 U	5 U	5 U	5 U	10 U	5 U	10 U	10 U	5 U	5 U
4586	45-86-09-30-87	09/30/87	4	ug/l	NR	5 U	NR	NR	NR	NR	NR	NR	5 U	NR
4586	45-86 10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U

Notes: NR = Analyte not reported
NA = Insufficient water in well for analysis
U = Analyzed but not detected
J = Present below detection limit
B = Present in laboratory blank

Table 4-5 (1.)

Groundwater Volatile Organic Results for Landfill Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Toluene	Chloro benzene	Ethyl benzene	Styrene	Total Xylenes
Landfill Alluvial Wells Upgradient									
1086	G1086:10860	10/16/86		ug/l	5 U	5 U	5 U	5 U	5 U
1086	10-86-05-14-87	05/14/87	1	ug/l	NR	NR	NR	NR	NR
1086	10-86-06-15-87	06/15/87	2	ug/l	NR	NR	NR	NR	NR
1086	10-86-08-10-87	08/10/87	3	ug/l	NR	NR	NR	NR	NR
1086	10-86-12-15-87	12/15/87	4	ug/l	5 U	5 U	5 U	5 U	5 U
1086	10-86-02-02-88	02/02/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
4586	G4586:10860	10/16/86		ug/l	5 U	5 U	5 U	1 J	5 U
4586	G4586:10862	10/16/86		ug/l	5 U	5 U	5 U	2 J	5 U
4586	45-86-05-15-87	05/14/87	1	ug/l	NR	NR	NR	NR	NR
4586	45-86-06-12-87	06/12/87	2	ug/l	NR	NR	NR	NR	NR
4586	45-86-08-14-87	08/14/87	3	ug/l	NR	NR	NR	NR	NR
4586	45-86-09-30-87	09/30/87		ug/l	5 U	5 U	5 U	5 U	5 U
4586	45 86-09-30-87	09/30/87	4	ug/l	NR	NR	NR	NR	NR
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA
5887	58-87-01-23 88	01/23/88	1	ug/l	5 U	5 U	5 U	5 U	5 U

Notes: NR = Analyte not reported
NA = Insufficient water in well for analysis
U = Analyzed but not detected
J = Present below detection limit
B = Present in laboratory blank

Table ' ont'd.)

Groundwater Volatile .nic Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Chloro methane	Bromo methane	Vinyl Chloride	Chloro ethane	Methylene Chloride	Acetone	Carbon Disulfide	1,1-Dichloro ethene	1,1-Dichloro ethane	Trans 1,2 Dichloro ethene
Landfill Alluvial Wells Downgradient														
0586	DRY	09/08/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0586	5-86-05-05-87	05/05/87	1	ug/l	NR	NR	NR	NR	NR	NR	NR	4 U	NR	4 U
0586	5-86-06-09-87	06/09/87	2	ug/l	NR	NR	NR	NR	NR	NR	NR	4 U	NR	4 U
0586	5-86-07-31-87	07/31/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0786	DRY	09/29/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0786	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0786	07-86-02-01-88	02/01/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
4087	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4087	DRY	02/01/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4287	GW4287	06/24/87	2	ug/l	10 U	10 U	10 U	10 U	5 U	2L B	5 U	5 U	5 U	5 U
4287	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4287	42-87-12-16-87	12/16/87	4	ug/l	10 U	10 U	10 U	10 U	12	10 U	5 U	5 U	5 U	5 U
4287	42-87-02-04-88	02/04/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
5987	59-87-01-23-88	01/23/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
6087	60-87-01-23-88	01/23/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
6187	61-87-01-27-88	01/27/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
6287	62-87-01-26-88	01/26/88	1	ug/l	10 U	10 U	10 U	10 U	6	10 U	5 U	5 U	5 U	5 U
0686	DRY	09/08/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0686	6-86-05-13-87	05/13/87	1	ug/l	NR	NR	NR	NR	NR	NR	NR	4 U	NR	4 U
0686	6-86-06-09-87	06/09/87	2	ug/l	NR	NR	NR	NR	NR	NR	NR	4 U	NR	4 U
0686	6-86-08-10-87	08/10/87	3	ug/l	NR	NR	NR	NR	NR	NR	NR	5 U	NR	5 U
0686	08-86-02-01-88	02/01/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
6387	63-87-01-27-88	01/27/88	1	ug/l	10 U	10 U	10 U.	10 U	5 U	10 U	5 U	5 U	5 U	5 U
6487	64-87-01-29-88	01/29/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6587	65-87-01-28-88	01/28/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
6687	66-87-01-29-88	01/29/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6787	67-87-01-28-88	01/28/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
6887	68-87-01-28-88	01/28/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
7087	DRY	02/03/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7187	71-87-01-29-88	01/29/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7287	72-87-01-28-88	01/28/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
0486	DRY	08/28/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0486	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: NR = Analyte not reported
NA = Insufficient water in well for analysis
U = Analyzed but not detected
J = Present below detection limit
B = Present in laboratory blank

Table 4 (Cont'd.)

Groundwater Volatile Organic Results for Landfill Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Chloroform	1,2-Dichloroethane	2-Butanone	1,1,1 Trichloroethane	Carbon Tetrachloride	Vinyl Acetate	Bromodichloromethane	1,2-Dichloropropane	Trans 1,3 Dichloropropene	Trichloroethene
Landfill Alluvial Wells Downgradient														
0586	DRY	09/08/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0586	5-86-05-05-87	05/05/87	1	ug/l	4 U	4 U	NR	4 U	4 U	NR	NR	NR	NR	4 U
0586	5-86-06-09-87	06/09/87	2	ug/l	4 U	4 U	NR	4 U	4 U	NR	NR	NR	NR	4 U
0586	5-86-07-31-87	07/31/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0786	DRY	09/29/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0786	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0786	07-86-02-01-88	02/01/88	1	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
4087	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4087	DRY	02/01/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4287	GW4287	06/24/87	2	ug/l	5 U	5 U	2.0 J	5 U	5 U	10 U	5 U	5 U	5 U	5 U
4287	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4287	42-87-12-16-87	12/16/87	4	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
4287	42-87-02-04-88	02/04/88	1	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
5987	59-87-01-23-88	01/23/88	1	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
6087	60-87-01-23-88	01/23/88	1	ug/l	5 U	5 U	10 U	5 U	6	10 U	5 U	5 U	5 U	5 U
6187	61-87-01-27-88	01/27/88	1	ug/l	5 U	5 U	10 U	5 U	7	10 U	5 U	5 U	5 U	5 U
6287	62-87-01-26-88	01/26/88	1	ug/l	5 U	5 U	10 U	5 U	8	10 U	5 U	5 U	5 U	5 U
0686	DRY	09/08/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0686	6-86-05-13-87	05/13/87	1	ug/l	4 U	4 U	NR	4 U	4 U	NR	NR	NR	NR	4 U
0686	6-86-06-09-87	06/09/87	2	ug/l	4 U	4 U	NR	4 U	4 U	NR	NR	NR	NR	4 U
0686	6-86-08-10-87	08/10/87	3	ug/l	5 U	5 U	NR	5 U	5 U	NR	NR	NR	NR	5 U
0686	08-86-02-01-88	02/01/88	1	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
6387	63-87-01-27-88	01/27/88	1	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
6487	64-87-01-29-88	01/29/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6587	65-87-01-28-88	01/28/88	1	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
6687	66-87-01-29-88	01/29/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6787	67-87-01-28-88	01/28/88	1	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
6887	68-87-01-28-88	01/28/88	1	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
7087	DRY	02/03/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7187	71-87-01-29-88	01/29/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7287	72-87-01-28-88	01/28/88	1	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	17
0486	DRY	08/28/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0486	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: NR = Analyte not reported
NA = Insufficient water in well for analysis
U = Analyzed but not detected
J = Present below detection limit
B = Present in laboratory blank

Table 4-[illegible] t'd.)

Groundwater Volatile [illegible]anic Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr	Units	Dibromo chloro methane	1,1,2 Trichloro ethane	Benzene	cis-1,3-Dichloro propene	2-Chloro ethylvinyl ether	Bromoform	4-Methyl-2-pentanone	2-Hexanone	Tetrachloro ethene	1,1,2,2-Tetrachloro ethane
Landfill Alluvial Wells Downgradient														
0586	DRY	09/08/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0586	5-86-05-05-87	05/05/87	1	ug/l	NR	4 U	NR	NR	NR	NR	NR	NR	4 U	NR
0586	5-86-06-09-87	06/09/87	2	ug/l	NR	4 U	NR	NR	NR	NR	NR	NR	4 U	NR
0586	5-86-07-31-87	07/31/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0786	DRY	09/29/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0786	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0786	07-86-02-01-88	02/01/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
4087	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4087	DRY	02/01/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4287	GW4287	06/24/87	2	ug/l	5 U	5 U	5 U	5 U	10 U	5 U	10 U	10 U	5 U	5 U
4287	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4287	42-87-12-16-87	12/16/87	4	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
4287	42-87-02-04-88	02/04/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
5987	59-87-01-23-88	01/23/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
6087	60-87-01-23-88	01/23/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
6187	61-87-01-27-88	01/27/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
6287	62-87-01-26-88	01/26/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
0686	DRY	09/08/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0686	6-86-05-13-87	05/13/87	1	ug/l	NR	4 U	NR	NR	NR	NR	NR	NR	4 U	NR
0686	6-86-06-09-87	06/09/87	2	ug/l	NR	4 U	NR	NR	NR	NR	NR	NR	4 U	NR
0686	6-86-08-10-87	08/10/87	3	ug/l	NR	5 U	NR	NR	NR	NR	NR	NR	5 U	NR
0686	08-86-02-01-88	02/01/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
6387	63-87-01-27-88	01/27/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
6487	64-87-01-29-88	01/29/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6587	65-87-01-28-88	01/28/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
6687	66-87-01-29-88	01/29/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6787	67-87-01-28-88	01/28/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
6887	68-87-01-28-88	01/28/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
7087	DRY	02/03/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7187	71-87-01-29-88	01/29/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7287	72-87-01-28-88	01/28/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
0486	DRY	08/28/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0486	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-5 / d.)

Groundwater Volatile .nic Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Toluene	Chloro benzene	Ethyl benzene	Styrene	Total Xylenes
Landfill Alluvial Wells Downgradient									
0586	DRY	09/08/86			NA	NA	NA	NA	NA
0586	5-86-05-05-87	05/05/87	1	ug/l	NR	NR	NR	NR	NR
0586	5-86-06-09-87	06/09/87	2	ug/l	NR	NR	NR	NR	NR
0586	5-86-07-31 37	07/31/87	3		NA	NA	NA	NA	NA
0786	DRY	09/29/86			NA	NA	NA	NA	NA
0786	DRY	08/10/87	3		NA	NA	NA	NA	NA
0786	07-86-02-01-88	02/01/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
4087	DRY	08/10/87	3		NA	NA	NA	NA	NA
4087	DRY	02/01/88	1		NA	NA	NA	NA	NA
4287	GW4287	06/24/87	2	ug/l	5 U	5 U	5 U	5 U	5 U
4287	DRY	08/10/87	3		NA	NA	NA	NA	NA
4287	42-87-12-16-87	12/16/87	4	ug/l	5 U	5 U	5 U	5 U	5 U
4287	42-87-02-04-88	02/04/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
5987	59-87-01-23-88	01/23/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
6087	60-87-01-23-88	01/23/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
6187	61-87-01-27-88	01/27/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
6287	62-87-01-26-88	01/26/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
0686	DRY	09/08/86			NA	NA	NA	NA	NA
0686	6-86-05-13-87	05/13/87	1	ug/l	NR	NR	NR	NR	NR
0686	6-86-06-09-87	06/09/87	2	ug/l	NR	NR	NR	NR	NR
0686	6-86-08-10-87	08/10/87	3	ug/l	NR	NR	NR	NR	NR
0686	06-86-02-01-88	02/01/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
6387	63-87-01-27-88	01/27/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
6487	64-87-01-29-88	01/29/88	1		NA	NA	NA	NA	NA
6587	65-87-01-28-88	01/28/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
6687	66-87-01-29-88	01/29/88	1		NA	NA	NA	NA	NA
6787	67 87-01-28-88	01/28/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
6887	68-87-01-28-88	01/28/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
7087	DRY	02/03/88	1		NA	NA	NA	NA	NA
7187	71-87-01 29-88	01/29/88	1		NA	NA	NA	NA	NA
7287	72-87-01-28-88	01/28/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
0486	DRY	08/28/86			NA	NA	NA	NA	NA
0486	DRY	08/10/87	3		NA	NA	NA	NA	NA

Notes: NR = Analyte not reported
NA = Insufficient water in well for analysis
U = Analyzed but not detected
J = Present below detection limit
B = Present in laboratory blank

Table 4- nt'd.)

Groundwater Semivolati rganic Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Phenol	bis(2-Chloro ethyl)Ether	2-Chloro phenol	1,3-Dichloro benzene	1,4-Dichloro benzene	Benzyl Alcohol	1,2-Dichloro benzene	2-Methyl phenol	bis(2-Chloro isopropyl) Ether	4 Methyl phenol
Landfill Alluvial Wells Upgradient														
1086	G108610860	10/16/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-05-14-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-06-15-87	06/15/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-08-10-87	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-12-15-87	12/15/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-02-02-88	02/02/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	G458610860	10/16/86		ug/l	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
4586	G458610862	10/16/86		ug/l	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
4586	45-86-05-15-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-06-12-87	06/12/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-08-14-87	08/14/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: NR = Analyte not reported
NA = Insufficient water in well for analysis
U = Analyzed but not detected
J = Present below detection limit
B = Present in laboratory blank

Table 4-5 (1.)

Groundwater Semivolatile Organic Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	N Nitroso-di-n-propylamine	Hexachloro ethane	Nitro benzene	Isophorone	2-Nitro phenol	2,4 Dimethyl phenol	Benzoic Acid	bis(2-Chloro ethoxy) Methane	2,4-Dichloro phenol	1,2,4-Trichloro benzene
Landfill Alluvial Wells Upgradient														
1086	G108610860	10/16/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-05-14-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-06-15-87	06/15/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-08-10-87	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-12-15-87	12/15/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-02-02-88	02/02/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	G45861086O	10/16/86		ug/l	10 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U
4586	G458610862	10/16/86		ug/l	10 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	10 U	10 U
4586	45-86-05-15-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-06-12-87	06/12/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-08-14-87	08/14/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4- nt'd.)

Groundwater Semivolati. ganic Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Napthalene	4-Chloro aniline	Hexachloror butadiene	4-Chloro-3-methyl phenol	2-Methyl naphthalene	Hexachloro cyclo pentadiene	2,4,6-Trichloro phenol	2,4,5-Trichloro phenol	2-Chloro naphthalene	2-Nitro aniline
Landfill Alluvial Wells Upgradient														
1086	G108610860	10/16/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-05-14-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-06-15-87	06/15/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-08-10-87	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-12-15-87	12/15/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-02-02-88	02/02/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	G458610860	10/16/86		ug/l	10 U	10 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	50 U
4586	G458610862	10/16/86		ug/l	10 U	10 U	10 U	10 U	10 U	10 U	10 U	50 U	10 U	50 U
4586	45-86-05-15-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-06-12-87	06/12/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-08-14-87	08/14/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: NR = Analyte not reported
NA = Insufficient water in well for analysis
U = Analyzed but not detected
J = Present below detection limit
B = Present in laboratory blank

Table 4-F (cont'd.)

Groundwater Semivolatile Organic Results for Landfill Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Dimethyl Phthalate	Ace naphthylene	3-Nitro aniline	Ace naphthene	2,4-Dinitro phenol	4-Nitro phenol	Dibenzo furan	2,4-Dinitro toluene	2,6-Dinitro toluene	Diethyl phthalate
Landfill Alluvial Wells Upgradient														
1086	G10861086O	10/16/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-05-14-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-06-15-87	06/15/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-08-10-87	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10 86-12-15-87	12/15/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-02-02 88	02/02/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	G4586108&0	10/16/86		ug/l	10 U	10 U	50 U	10 U	50 U	50 U	10 U	10 U	10 U	10 U
4586	G4586108&2	10/16/86		ug/l	10 U	10 U	50 U	10 U	50 U	50 U	10 U	10 U	10 U	10 U
4586	45-86-05-15-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-06-12 87	06/12/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-08-14-87	08/14/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-5 (cont'd.)

Groundwater Semivolatile Organic Results for Landfill Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	4-Chloro phenyl-phenylether	Fluorene	4-Nitro aniline	4,6-Dinitro-2-methyl phenol	N-Nitrosodi phenylamine	4-Bromophenyl-phenylether	Hexachloro benzene	Pentachloro phenol	Phenanthrene	Anthracene
Landfill Alluvial Wells Upgradient														
1086	G108610860	10/16/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-05-14-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-06-15-87	06/15/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-08-10-87	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-12-15-87	12/15/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-02-02-88	02/02/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	G458610860	10/16/86		ug/l	10 U	10 U	50 U	50 U	10 U	10 U	10 U	50 U	10 U	10 U
4586	G458610862	10/16/86		ug/l	10 U	10 U	50 U	50 U	10 U	10 U	10 U	50 U	10 U	10 U
4586	45-86-05-15-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-06-12-87	06/12/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-08-14-87	08/14/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: NR = Analyte not reported
NA = Insufficient water in well for analysis
U = Analyzed but not detected
J = Present below detection limit
B = Present in laboratory blank

Table (ont'd.)

Groundwater Semivolatile ganic Results for Landfill Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	di-n-Butyl Phthalate	Fluoranthene	Pyrene	Butyl Benzyl Phthalate	3,3'-Dichloro benzidine	Benzo(a) Anthracene	bis(2-Ethylhexyl) Phthalate	Chrysene	di-n-Octyl Phthalate	Benzo(b) Fluoranthene
Landfill Alluvial Wells Upgradient														
1086	G108610860	10/16/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-05-14-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-06-15-87	06/15/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-08-10-87	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-12-15-87	12/15/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-02-02 88	02/02/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	G458610860	10/16/86		ug/l	4 JB	10 U	10 U	1 J	20 U	10 U	7 JB	10 U	10 U	10 U
4586	G458610862	10/16/86		ug/l	4 JB	10 U	10 U	10 U	20 U	10 U	4 JB	10 U	10 U	10 U
4586	45-86-05-15-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-06-12-87	06/12/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-08-14 87	08/14/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-5 1.)

Groundwater Semivolatile Organic Results for Landfill Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Benzo(b.) Fluoranthene	Benzo(a) Pyrene	Indeno (1,2,3-cd) Pyrene	Dibenz(a,h) Anthracene	Benzo(g,h,i) Perylene
Landfill Alluvial Wells Upgradient									
1086	G108610860	10/16/86			NA	NA	NA	NA	NA
1086	10-86-05-14-87	05/14/87	1		NA	NA	NA	NA	NA
1086	10-86 06-15-87	06/15/87	2		NA	NA	NA	NA	NA
1086	10-86-08-10-87	08/10/87	3		NA	NA	NA	NA	NA
1086	10-86-12-15-87	12/15/87	4		NA	NA	NA	NA	NA
1086	10-86-02-02-88	02/02/88	1		NA	NA	NA	NA	NA
4586	G458610860	10/16/86		ug/l	10 U	10 U	10 U	10 U	10 U
4586	G458610862	10/16/86		ug/l	10 U	10 U	10 U	10 U	10 U
4586	45-86-05-15-87	05/14/87	1		NA	NA	NA	NA	NA
4586	45-86-06-12-87	06/12/87	2		NA	NA	NA	NA	NA
4586	45-86-08-14-87	08/14/87	3		NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87			NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4		NA	NA	NA	NA	NA
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1		NA	NA	NA	NA	NA

Notes: NR = Analyte not reported
NA = Insufficient water in well for analysis
U = Analyzed but not detected
J = Present below detection limit
B = Present in laboratory blank

Table 4 nt'd.)

Groundwater Ra..ochemistry Results

for Regulated Units at Rocky Flats Plant

Well Number	Field Sample Number	Date Sampled	Qtr.	Gross Alpha	Gross Beta	Uranium 233, 234	Uranium 235	Uranium 238	Strontium 89, 90	Plutonium 239, 240
Landfill Alluvial Wells Upgradient										
1086	G108610860	10/16/86		NA	NA	NA	NA	NA	NA	NA
1086	10-86-05-14-87	05/14/87	1	35 +/- 31 pci/l	68 +/- 5 pci/l	1.1 +/- 1.5 pci/l	.01 +/- .40 pci/l	4.3 +/- 1.9 pci/l	9.3 pci/l	.13 +/- .74 pci/l
1086	10-86-06-15-87	06/15/87	2	249 +/- 15 pci/l	171 +/- 35 pci/l	0.22 +/- 0.61 pci/l	0.0 +/- 0.29 pci/l	0.05 +/- 0.38 pci/l	1.6 pci/l	0.0 +/ 0.64 pci/l
1086	10-86-08-10 87	08/10/87	3	69 +/- 33 pci/l	62 +/- 45 pci/l	0.4 +/- 1.3 pci/l	2.6 +/- 0.9 pci/l	4.5 +/- 1.5 pci/l	2.7 pci/l	.32 +/- .61 pci/l
1086	10-86-12-15-87	12/15/87	4	29 +/- 8 pci/l	35 +/- 13 pci/l	.11 +/- .09 pci/l	0.00 +/- .02 pci/l	.02 +/- .07 pci/l	<1.0 pci/l	0 00 +/- .15 pci/l
1086	10-86-02-02-88	02/02/88	1	2 +/- 4 pci/l	-9 +/- 11 pci/l	6.3 +/- 0.6 pci/l	0.24 +/- 0.09 pci/l	5.1 +/- 0.5 pci/l	NR	0.00 +/- 0.32 pci/l
4586	G45861086O	10/16/86		200 +/- 80 pci/l	140 +/- 30 pci/l	11 +/- 1 pci/l	NR	10 +/- 1 pci/l	NR	0.13 +/- 0.21 pci/l
4586	G45861086Z	10/16/86		190 +/- 100 pci/l	250 +/- 40 pci/l	15 +/- 2 pci/l	NR	1t +/- 2 pci/l	NR	-0.02 +/- 0.08 pci/l
4586	45-86-05-15-87	05/14/87	1	55 +/- 21 pc/l	23 +/- 15 pc/l	1.5 +/- 1.1 pc/l	.28 +/- .49 pc/l	1.0 +/- 0.9 pc/l	1.61 pc/l	4.7 +/- 1.8 pc/l
4586	45-86-06-12-87	06/12/87	2	0 +/- 0 pci/l	18 +/- 21 pci/l	0.0 +/- 0.59 pci/l	0.0 +/- 0.36 pci/l	0.0 +/- 0.35 pci/l	1.0 pci/l	0.0 +/- 0.68 pci/l
4586	45-86-08-14-87	08/14/87	3	25 +/- 24 pci/l	27 +/- 41 pci/l	2.0 +/- 1.5 pci/l	0.2 +/- 0.6 pci/l	9.8 +/- 2.3 pci/l	2.1 pci/l	.10 +/- .86 pci/l
4586	45-86-09-30-87	09/30/87		NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4	21 +/- 5 pci/l	26 +/- 10 pci/l	0.00 +/- 0.06 pci/l	0.00 +/- 0.03 pci/l	0.02 +/- 0.96 pci/l	<1.0 pci/l	0 00 +/- 0.09 pci/l
4586	45-86-10-01-87	10/01/87	4	NR	NR	0.099 +/- 0.174 pci/l	NR	0.085 +/- 0.053 pci/l	NR	0.106 +/- 0.062 pci/l
5887	58-87-01-23-88	01/23/88	1	9 +/- c pci/l	3 +/- 12 pci/l	0.49 +/- 0.23 pci/l	0.07 +/- 0.07 pci/l	0.48 +/- 0.20 pci/l	NR	0.00 +/- 0.27 pci/l

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis

Table ont'd.)
Groundwater R hemistry Results

for Regulated Units at Rocky Flats Plant

Well Number	Field Sample Number	Date Sampled	Qtr.	Americium 241	Cesium 137	Tritium
Landfill Alluvial Wells Upgradient						
1086	G108610860	10/16/86		NA	NA	NA
1086	10-86-05-14-87	05/14/87	1	0.0 +/- 1.5 pc/l	NR	<110 pc/l
1086	10-86-06-15-87	06/15/87	2	0.0 +/- 1.3 pci/l	NR	<110 pci/l
1086	10-86-08-10-87	08/10/87	3	0.0 +/- 1.4 pci/l	NR	<540 pci/l
1086	10-86-12-15-87	12/15/87	4	0.00 +/- .10 pci/l	NR	<220 pci/l
1086	10-86-02-02-88	02/02/88	1	NR	NR	<210 pci/l
4586	G458610860	10/16/86		0.03 +/- 0.07 pci/l	NR	0.10 +/- 0.22 pci/ml
4586	G458610862	10/16/86		-0.01 +/- 0.03 pci/l	NR	0.13 +/- 0.22 pci/ml
4586	45-86-05-15-87	05/14/87	1	0.0 +/- 1.4 pc/l	NR	<110 pc/l
4586	45-86-06-12-87	06/12/87	2	0.0 +/- 1.5 pci/l	NR	330 pci/l
4586	45-86-08-14-87	08/14/87	3	.69 +/- .91 pci/l	NR	<535 pci/l
4586	45-86-09-30-87	09/30/87		NA	NA	NA
4586	45-86-09-30-87	09/30/87	4	0.00 +/- 0.44 pci/l	NR	<460 pci/l
4586	45 86 10-01 87	10/01/87	4	-0.019 +/- 0.036 pci/l	NR	NA
5887	58-87-01-23-88	01/23/88	1	0.00 +/- 0.44 pci/l	NR	210 pci/l

Notes: NR = Analyte not reported
NA = Insufficient water in well for analysis

Table ont'd.)
Groundwater R. chemistry Results

for Regulated Units at Rocky Flats Plant

Well Number	Field Sample Number	Date Sampled	Qtr.	Gross Alpha	Gross Beta	Uranium 233, 234	Uranium 235	Uranium 238	Strontium 89, 90	Plutonium 239, 240
Landfill Alluvial Wells (Downgradient										
0586	DRY	09/08/86		NA	NA	NA	NA	NA	NA	NA
0586	5-86-05-05-87	05/05/87	1	126 +/- 102 pc/l	79 +/- 2[illegible] pc/l	.79 +/- .09 pc/l	1.6 +/- 0.9 pc/l	.49 +/- .06 pc/l	<0.6 pc/l	0.7 +/- 1.1 pci/l
0586	5-86-06-09-87	06/09/87	2	NR	NR	NR	NR	NR	NR	0.0 +/- 0.6 pci/l
0586	5-86-07-31-87	07/31/87	3	NR	NR	NR	NR	NR	NR	-.32 +/- .97
0786	DRY	09/29/86		NA	NA	NA	NA	NA	NA	NA
0786	DRY	08/10/87	3	NA	NA	NA	NA	NA	NA	NA
0786	07-86-02-01-88	02/01/88	1	NA	NA	NA	NA	NA	NA	NA
4087	DRY	08/10/87	3	NA	NA	NA	NA	NA	NA	NA
4087	DRY	02/01/88	1	NA	NA	NA	NA	NA	NA	NA
4287	GW4287	06/24/87	2	NA	NA	NA	NA	NA	NA	NA
4287	DRY	08/10/87	3	NA	NA	NA	NA	NA	NA	NA
4287	42-87-12-16-87	12/16/87	4	NA	NA	NA	NA	NA	NA	NA
4287	42-87-02-04-88	02/04/88	1	8 +/- 5 pci/l	5 +/- 13 pci/l	0.08 +/- 0.11 pci/l	0.02 +/- 0.07 pci/l	0.00 +/- 0.09 pci/l	NR	0.02 +/- 0.24 pci/l
5987	59-87-01-23-88	01/23/88	1	14 +/- 7 pci/l	5 +/- 12 pci/l	5.3 +/- 0.6 pci/l	0.22 +/- 0.10 pci/l	4.4 +/- 0.6 pci/l	NR	0.00 +/- 0.24 pci/l
6087	60-87-01-23-88	01/23/88	1	10 +/- 8 pci/l	-9 +/- 12 pci/l	0.60 +/- 0.11 pci/l	0.00 +/- 0.05 pci/l	0.01 +/- 0.09 pci/l	NR	0.00 +/- 0.27 pci/l
6187	61-87-01-27-88	01/27/88	1	0 +/- 7 pci/l	-4 +/- 11 pci/l	0.00 +/- 0.07 pci/l	0.01 +/- 0.05 pci/l	0.08 +/- 0.08 pci/l	NR	0.00 +/- 0.24 pci/l
6287	62-87-01-26-88	01/26/88	1	8 +/- 6 pci/l	1 +/- 12 pci/l	0.01 +/- 0.10 pci/l	0.02 +/- 0.05 pci/l	0.01 +/- 0.08 pci/l	NR	0.01 +/- 0.19 pci/l
0686	DRY	09/08/86		NA	NA	NA	NA	NA	NA	NA
0686	6-86-05-13-87	05/13/87	1	NR	NR	NR	NR	NR	NR	0.0 +/- 0.8 pci/l
0686	6-86-06-09-87	06/09/87	2	NA	NA	NA	NA	NA	NA	NA
0686	6-86-08-10-87	08/10/87	3	NA	NA	NA	NA	NA	NA	NA
0686	08-86-02-01-88	02/01/88	1	NA	NA	NA	NA	NA	NA	NA
6387	63-87-01-27-88	01/27/88	1	17 +/- 7 pci/l	8 +/- 15 pci/l	4.6 +/- 0.4 pci/l	0.18 +/- 0.07 pci/l	5.6 +/- 0.3 pci/l	NR	0.21 +/- 0.22 pci/l
6487	64-87-01-29-88	01/29/88	1	2 +/- 4 pci/l	16 +/- 11 pci/l	0.62 +/- 0.37 pci/l	0.02 +/- 0.11 pci/l	0.84 +/- 0.44 pci/l	NR	0.00 +/- 0.40 pci/l
6587	65-87-01-28-88	01/28/88	1	10 +/- 6 pci/l	8 +/- 11 pci/l	5.4 +/- 1.9 pci/l	0.27 +/- 0.39 pci/l	4.3 +/- 1.6 pci/l	NR	0.01 +/- 0.14 pci/l
6687	66-87-01-29-88	01/29/88	1	2 +/- 4 pci/l	15 +/- 11 pci/l	0.80 +/- 0.16 pci/l	0.01 +/- 0.04 pci/l	0.50 +/- 0.13 pci/l	NR	0.01 +/- 0.18 pci/l
6787	67-87-01-28-88	01/28/88	1	19 +/- 7 pci/l	3 +/- 13 pci/l	0.57 +/- 0.18 pci/l	0.00 +/- 0.05 pci/l	0.48 +/- 0.13 pci/l	NR	0.02 +/- 0.14 pci/l
6887	68-87-01-28-88	01/28/88	1	1 +/- 4 pci/l	-1 +/- 12 pci/l	0.05 +/- 0.10 pci/l	0.00 +/- 0.04 pci/l	0.16 +/- 0.10 pci/l	NR	0.00 +/- 0.16 pci/l
7087	DRY	02/03/88	1	NA	NA	NA	NA	NA	NA	NA
7187	71-87-01-29-88	01/29/88	1	5 +/- 5 pci/l	17 +/- 10 pci/l	0.22 +/- 0.13 pci/l	0.07 +/- 0.08 pci/l	0.08 +/- 0.10 pci/l	NR	0.00 +/- 0.15 pci/l
7287	72-87-01-28-88	01/28/88	1	6 +/- 5 pci/l	-3 +/- 13 pci/l	5.8 +/- 0.9 pci/l	0.27 +/- 0.15 pci/l	4.2 +/- 0.7 pci/l	NR	0.00 +/- 0.19 pci/l
0486	DRY	08/28/86		NA	NA	NA	NA	NA	NA	NA
0486	DRY	08/10/87	3	NA	NA	NA	NA	NA	NA	NA

Notes: NR = Analyte not reported
NA = Insufficient water in well for analysis

Table 4-' ıt'd.)

Groundwater R. hemistry Results

for Regulated Units at Rocky Flats Plant

Well Number	Field Sample Number	Date Sampled	Qtr.	Americium 241	Cesium 137	Tritium
Landfill Alluvial Wells Downgradient						
0586	DRY	09/08/86		NA	NA	NA
0586	5-86-05-05-87	05/05/87	1	0.0 +/- 1.3 pc/l	NR	120 pc/l
0586	5-86-06-09-87	06/09/87	2	NR	NR	NR
0586	5-86-07-31-87	07/31/87	3	NR	NR	<540 pci/l
0786	DRY	09/29/86		NA	NA	NA
0786	DRY	08/10/87	3	NA	NA	NA
0786	07-86-02-01-88	02/01/88	1	NA	NA	NA
4087	DRY	08/10/87	3	NA	NA	NA
4087	DRY	02/01/88	1	NA	NA	NA
4287	GW4287	06/24/87	2	NA	NA	NA
4287	DRY	08/10/87	3	NA	NA	NA
4287	42-87-12-16-87	12/16/87	4	NA	NA	NA
4287	42-87-02-04-88	02/04/88	1	NR	NR	<220 pci/l
5987	59-87-01-23-88	01/23/88	1	0.00 +/- 0.14 pci/l	NR	<220 pci/l
6087	60-87-01-23-88	01/23/88	1	0.00 +/- 0.10 pci/l	NR	<220 pci/l
6187	61-87-01-27-88	01/27/88	1	0.02 +/- 0.10 pci/l	NR	<220 pci/l
6287	62-87-01-26-88	01/26/88	1	0.00 +/- 0.16 pci/l	NR	<220 pci/l
0686	DRY	09/08/86		NA	NA	NA
0686	6-86-05-13-87	05/13/87	1	NR	NR	NR
0686	6-86-06-09-87	06/09/87	2	NA	NA	NA
0686	6-86-08-10-87	08/10/87	3	NA	NA	NA
0686	06-86-02-01-88	02/01/88	1	NA	NA	NA
6387	63-87-01-27-88	01/27/88	1	0.00 +/- 0.24 pci/l	NR	1900 +/- 100 pci/l
6487	64-87-01-29-88	01/29/88	1	0.00 +/- 0.71 pci/l	NR	<210 pci/l
6587	65-87-01-28-88	01/28/88	1	0.00 +/- 0.50 pci/l	NR	<210 pci/l
6687	66-87-01-29-88	01/29/88	1	0.00 +/- 0.50 pci/l	NR	<210 pci/l
6787	67-87-01-28-88	01/28/88	1	0.03 +/- 0.06 pci/l	NR	<220 pci/l
6887	68-87-01-28-88	01/28/88	1	0.00 +/- 0.09 pci/l	NR	<220 pci/l
7087	DRY	02/03/88	1	NA	NA	NA
7187	71-87-01-29-88	01/29/88	1	0.00 +/- 0.69 pci/l	NR	<210 pci/l
7287	72-87-01-28-88	01/28/88	1	0.00 +/- 0.11 pci/l	NR	<210 pci/l
0486	DRY	08/28/86		NA	NA	NA
0486	DRY	06/10/87	3	NA	NA	NA

Notes: NR = Analyte not reported
NA = Insufficient water in well for analysis

Table 4-F t'd.)

Groundwater Inorga. - Results for Landfill Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	CO3:		HCO2-		Chloride		Sulfate		pH	Fluoride	Nitrate- Nitrite Nitrogen	
Landfill Alluvial Wells Upgradient															
1086	G1086108c0	10/16/86		66	mg/l	16	mg/l	4.3	mg/l	17	mg/l	NR	NR	NR	
1086	10-86-05-14-87	05/14/87	1	NR		30 0	mg/l	c.30	mg/l	42.0	mg/l	NR	NR	3.40	mg/l
1086	10 86-06-15-87	06/15/87	2	NR		27 5	mg/l	4 91	mg/l	40 0	mg/l	NR	NR	4.50	mg/l
1086	10 86-08-10-87	08/10/87	3	NR		30.2	mg/l	72.0	mg/l	3c.0	mg/l	NR	NR	4.95	mg/l
1086	10-86-12-15 87	12/15/87	4	NR		47 1	mg/l	2.91	mg/l	49.0	mg/l	NR	NR	3 94	mg/l
1086	10-86-02-02-88	02/02/88	1	NR		40.5	mg/l	3.02	mg/l	23.8	mg/l	NR	NR	3.37	mg/l
4586	G4586108c0	10/16/86		110	mg/l	12	mg/l	c.1	mg/l	14	mg/l	NR	NR	NR	
4586	G4586108c2	10/16/86		5 U	mg/l	4.9	mg/l	5.9	mg/l	13	mg/l	NR	NR	NR	
4586	45-8c-05-15-87	05/14/87	1	NR		22.0	mg/l	4.90	mg/l	24.5	mg/l	NR	NR	0 5c	mg/l
4586	45-86-06-12-87	06/12/87	2	NR		18.4	mg/l	9.30	mg/l	19 0	mg/l	NR	NR	0.51	mg/l
4586	45-86-08-14 87	08/14/87	3	NR		39 1	mg/l	6.39	mg/l	14.5	mg/l	NR	NR	0.75	mg/l
4586	45-86-09-30-87	09/30/87		NA		NA		NA		NA		NA	NA	NA	
4586	45-86-09-30-87	09/30/87	4	NR		45.1	mg/l	c.5	mg/l	17 5	mg/l	NR	NR	1.02	mg/l
4586	45-86-10-01-87	10/01/87	4	NA		NA		NA		NA		NA	NA	NA	
5887	58-87-01-23-88	01/23/88	1	NR		97.3	mg/l	12.8	mg/l	34.2	mg/l	NR	NR	3 38	mg/l

Notes: NR = Analyte not reported
NA = Insufficient water in well for analysis
U = Analyzed but not detected
J = Present below detection limit
B = Present in laboratory blank

Table 4 (cont'd.)

Groundwater Inorg Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Sulfide	Phosphate	Cyanide, Total	Hexavalent Chromium (Free)	Total Dissolved Solids	Suspended Solids	% Solids
Landfill Alluvial Wells Upgradient										
1086	G1086108610	10/16/86		NR	NR	0.01 U mg/l	NR	140 mg/l	NR	NR
1086	10-86-05-14-87	05/14/87	1	NR	NR	1.0 U mg/l	NR	145 mg/l	NR	NR
1086	10-86-06-15-87	06/15/87	2	NR	NR	1.0 U mg/l	NR	161 mg/l	NR	NR
1086	10-86-08-10-87	08/10/87	3	NR	NR	1 U mg/l	NR	125 mg/l	NR	NR
1086	10-86-12-15-87	12/15/87	4	NR	NR	NR	NR	134 mg/l	NR	NR
1086	10-86-02-02-88	02/02/88	1	NR	NR	NR	NR	131 mg/l	NR	NR
4586	G4586108610	10/16/86		NR	NR	0.01 U mg/l	NR	180 mg/l	NR	NR
4586	G4586108612	10/16/86		NR	NR	0.01 U mg/l	NR	160 mg/l	NR	NR
4586	45-86-05-15-87	05/14/87	1	NR	NR	1.0 U mg/l	NR	143 mg/l	NR	NR
4586	45-86-06-12-87	06/12/87	2	NR	NR	1.0 U mg/l	NR	92.0 mg/l	NR	NR
4586	45-86-08-14-87	08/14/87	3	NR	NR	1 U mg/l	NR	124 mg/l	NR	NR
4586	45-86-09-30-87	09/30/87		NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4	NR	NR	NR	NR	125 mg/l	NR	NR
4586	45-86-10-01-87	10/01/87	4	NA	NA	NA	NA	NA	NA	NA
5887	58 87-01-23-88	01/23/88	1	NR	NR	NR	NR	233 mg/l	NR	NR

Notes: NR = Analyte not reported
NA = Insufficient water in well for analysis
U = Analyzed but not detected
J = Present below detection limit
B = Present in laboratory blank

Table 4-[illegible] t'd.)

Groundwater Inorg Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	CO3=	HCO3-	Chloride	Sulfate	pH	Fluoride	Nitrate-Nitrite-Nitrogen
Landfill Alluvial Wells Downgradient										
0586	DRY	09/08/86		NA	NA	NA	NA	NA	NA	NA
0586	5-86-05-05-87	05/05/87	1	NR	366 mg/l	150 mg/l	1780 mg/l	NR	NR	2.75 mg/l
0586	5-86-06-09-87	06/09/87	2	NR	388 mg/l	264 mg/l	725 mg/l	NR	NR	1.26 mg/l
0586	5-86-07-31-87	07/31/87	3	NR	459 mg/l	270 mg/l	4600 mg/l	NR	NR	1.20 mg/l
0786	DRY	09/29/86		NA	NA	NA	NA	NA	NA	NA
0786	DRY	08/10/87	3	NA	NA	NA	NA	NA	NA	NA
0786	07-86-02-01-88	02/01/88	1	NA	NA	NA	NA	NA	NA	NA
4087	DRY	08/10/87	3	NA	NA	NA	NA	NA	NA	NA
4087	DRY	02/01/88	1	NA	NA	NA	NA	NA	NA	NA
4287	GW4287	06/24/87	2	NA	NA	NA	NA	NA	NA	NA
4287	DRY	08/10/87	3	NA	NA	NA	NA	NA	NA	NA
4287	42-87-12-16-87	12/16/87	4	NA	NA	NA	NA	NA	NA	NA
4287	42-87-02-04-88	02/04/88	1	NR	259 mg/l	13.9 mg/l	74.2 mg/l	NR	NR	0.02 U mg/l
5987	59-87-01-23 88	01/23/88	1	NR	306 mg/l	24.3 mg/l	31.8 mg/l	NR	NR	0.02 U mg/l
6087	60-87-01-23-88	01/23/88	1	NR	75.7 mg/l	4.33 mg/l	57.1 mg/l	NR	NR	2.62 mg/l
6187	61-87-01-27-88	01/27/88	1	NR	88.0 mg/l	2.87 mg/l	59.2 mg/l	NR	NR	2.58 mg/l
6287	62-87-01-26-88	01/26/88	1	NR	75.4 mg/l	3.89 mg/l	35.0 mg/l	NR	NR	2.55 mg/l
0686	DRY	09/08/86		NA	NA	NA	NA	NA	NA	NA
0686	6-86-05-13-87	05/13/87	1	NR	227 mg/l	826 mg/l	1710 mg/l	NR	NR	0.44 mg/l
0686	6-86-06-09-87	06/09/87	2	NA	NA	NA	NA	NA	NA	NA
0686	6-86-08-10-87	08/10/87	3	NA	NA	NA	NA	NA	NA	NA
0686	08-86-02-01-88	02/01/88	1	NA	NA	NA	NA	NA	NA	NA
6387	63-87-01-27-88	01/27/88	1	NR	392 mg/l	26.3 mg/l	54.5 mg/l	NR	NR	0.02 U mg/l
6487	64-87-01-29-88	01/29/88	1	NR	179 mg/l	19.9 mg/l	8.4 mg/l	NR	NR	0.02 mg/l
6587	65-87-01-28-88	01/28/88	1	NR	208 mg/l	6.38 mg/l	153 mg/l	NR	NR	2.00 mg/l
6687	66-87-01-29-88	01/29/88	1	NR	127 mg/l	4.50 mg/l	29.0 mg/l	NR	NR	3.22 mg/l
6787	67-87-01-28-88	01/28/88	1	NR	101 mg/l	4.32 mg/l	39.8 mg/l	NR	NR	1.81 mg/l
6887	68-87-01-28-88	01/28/88	1	NR	107 mg/l	5.03 mg/l	139 mg/l	NR	NR	2.12 mg/l
7087	DRY	02/03/88	1	NA	NA	NA	NA	NA	NA	NA
7187	71-87-01-29-88	01/29/88	1	NR	219 mg/l	2.15 mg/l	67.0 mg/l	NR	NR	1.02 mg/l
7287	72-87-01-28-88	01/28/88	1	NR	276 mg/l	8.42 mg/l	90.4 mg/l	NR	NR	0.33 mg/l
0486	DRY	08/28/86		NA	NA	NA	NA	NA	NA	NA
0486	DRY	08/10/87	3	NA	NA	NA	NA	NA	NA	NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
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B : Present in laboratory blank

Table 4-f t'd.)

Groundwater Inorg Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Sulfide	Phosphate	Cyanide, Total	Hexavalent Chromium (Cric)	Total Dissolved Solids	Suspended Solids	% Solids
Landfill Alluvial Wells Downgradient										
0586	DRY	09/08/86		NA	NA	NA	NA	NA	NA	NA
0586	5-86-05-05-87	05/05/87	1	NR	NR	1.0 U ug/l	NR	3517 ug/l	NR	NR
0586	5-86-06-09-87	06/09/87	2	NR	NR	1.0 U ug/l	NR	7363 ug/l	NR	NR
0586	5-86-07-31-87	07/31/87	3	NR	NR	1 U ug/l	NR	6747 ug/l	NR	NR
0786	DRY	09/29/86		NA	NA	NA	NA	NA	NA	NA
0786	DRY	08/10/87	3	NA	NA	NA	NA	NA	NA	NA
0786	07-86-02-01-88	02/01/88	1	NA	NA	NA	NA	NA	NA	NA
4087	DRY	08/10/87	3	NA	NA	NA	NA	NA	NA	NA
4087	DRY	02/01/88	1	NA	NA	NA	NA	NA	NA	NA
4287	GW4287	06/24/87	2	NA	NA	NA	NA	NA	NA	NA
4287	DRY	08/10/87	3	NA	NA	NA	NA	NA	NA	NA
4287	42-87-12-16-87	12/16/87	4	NA	NA	NA	NA	NA	NA	NA
4287	42-87-02-04-88	02/04/88	1	NR	NR	NR	NR	355 ug/l	NR	NR
5987	59-87-01-23 88	01/23/88	1	NR	NR	NR	NR	406 ug/l	NR	NR
6087	60-87-01-23 88	01/23/88	1	NR	NR	NR	NR	160 ug/l	NR	NR
6187	61-87-01-27 88	01/27/88	1	NR	NR	NR	NR	153 ug/l	NR	NR
6287	62-87-01-26-88	01/26/88	1	NR	NR	NR	NR	154 ug/l	NR	NR
0686	DRY	09/08/86		NA	NA	NA	NA	NA	NA	NA
0686	6-86-05-13 87	05/13/87	1	NR	NR	1.0 U ug/l	NR	4542 ug/l	NR	NR
0686	6-86-06-09-87	06/09/87	2	NA	NA	NA	NA	NA	NA	NA
0686	6-86-08-10-87	08/10/87	3	NA	NA	NA	NA	NA	NA	NA
0686	08-86-02-01-88	02/01/88	1	NA	NA	NA	NA	NA	NA	NA
6387	63 87-01-27-88	01/27/88	1	NR	NR	NR	NR	519 ug/l	NR	NR
6487	64-87-01-29-88	01/29/88	1	NR	NR	NR	NR	255 ug/l	NR	NR
6587	65-87-01-28-88	01/28/88	1	NR	NR	NR	NR	491 ug/l	NR	NR
6687	66-87-01-29-88	01/29/88	1	NR	NR	NR	NR	405 ug/l	NR	NR
6787	67-87-01-28-88	01/28/88	1	NR	NR	NR	NR	191 ug/l	NR	NR
6887	68-87-01-28-88	01/28/88	1	NR	NR	NR	NR	226 ug/l	NR	NR
7087	DRY	02/03/88	1	NA	NA	NA	NA	NA	NA	NA
7187	71-87-01-29-88	01/29/88	1	NR	NR	NR	NR	262 ug/l	NR	NR
7287	72-87-01-28 88	01/28/88	1	NR	NR	NR	NR	395 ug/l	NR	NR
0486	DRY	08/28/86		NA	NA	NA	NA	NA	NA	NA
0486	DRY	08/10/87	3	NA	NA	NA	NA	NA	NA	NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-5 (Cont'd.)

Groundwater Meta... esults for Landfill Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Silver (Ag), total	Aluminum (Al), total	Arsenic (As), total	Barium (Ba), total	Beryllium (Be), total	Calcium (Ca), total	Cadmium (Cd), total	Cobalt (Co), total	Chromium (Cr), total	Cesium (Cs), total
Landfill Alluvial Wells Upgradient														
1086	G10861086O	10/16/86		mg/l	0.019	36.6	0.002 U	0.340	0.026	22.1	0.005 U	0.050 U	0.010	0.150 U
1086	10-86-05-14-87	05/14/87	1	mg/l	0.0076 U	0.1323	0.01 U	0.0326	0.005 U	25.6217	0.005 U	0.0220 U	0.0100 U	0.2 U
1086	10-86-06-15-87	06/15/87	2	mg/l	0.0076 U	0.0290 U	0.01 U	0.0330	0.005 U	20.1122	0.005 U	0.0220 U	0.0105	0.2 U
1086	10-86-08-10-87	08/10/87	3	mg/l	0.0076 U	0.0320	0.005 U	0.0805	0.005 U	20.5573	0.001 U	0.0220 U	0.0188	0.02 U
1086	10-86-12-15-87	12/15/87	4	mg/l	0.0076 U	0.1504	0.005 U	0.0838	0.005 U	16.1526	0.0008 J	0.0220 U	0.0100 U	0.02 U
1086	10-86-02-02-88	02/02/88	1	mg/l	0.0076 U	0.0290 U	0.005 U	0.0722	0.005 U	17.0330	0.001 U	0.0220 U	0.0214	0.02 U
4586	G4586108600	10/16/86		mg/l	0.010 U	0.480	0.002 U	0.160	0.011	26.2	0.005 U	0.050 U	0.010 U	0.150 U
4586	G4586108620	10/16/86		mg/l	0.010 U	0.550	0.002 U	0.150	0.007	25.5	0.005 U	0.050 U	0.010 U	0.150 U
4586	45-86-05-15-87	05/14/87	1	mg/l	0.0076 U	0.1786	0.0100 U	0.0308	0.005 U	11.5612	0.0050 U	0.0220 U	0.0100 U	0.2 U
4586	45-86-06-12-87	06/12/87	2	mg/l	0.0076 U	0.0405	0.01 U	0.0265	0.005 U	9.0966	0.005 U	0.0220 U	0.0100 U	0.2 U
4586	45-86-08-14-87	08/14/87	3	mg/l	0.0076 U	0.0727	0.005 U	0.0615	0.005 U	10.0692	0.001 U	0.0220 U	0.0115	0.02 U
4586	45-86-09-30-87	09/30/87			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4	mg/l	0.0076 U	0.0336	0.005 U	0.0556	0.005 U	12.8262	0.001 U	0.0220 U	0.0100 U	0.02 U
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1	mg/l	0.0085	0.0443	0.005 U	0.1067	0.005 U	27.8264	0.001 U	0.0220 U	0.0191	0.02 U

Notes: NR = Analyte not reported
NA = Insufficient water in well for analysis
U = Analyzed but not detected
J = Present below detection limit
B = Present in laboratory blank

Table 4-' it'd.)

Groundwater Meta. esults for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Copper (Cu), total	Iron (Fe), total	Mercury (Hg), total	Potassium (K), total	Lithium (Li), total	Magnesium (Mg), total	Manganese (Mn), total	Molybdenum (Mo), total	Sodium (Na), total	Nickel (Ni), total
Landfill Alluvial Wells Upgradient														
1086	G108610860	10/16/86		mg/l	0.024	28.2	0.00056	12.9	NR	7.88	0.634	0.100 U	12.2	0.040 U
1086	10-86-05-14-87	05/14/87	1	mg/l	0.0063 U	0.04c9	0.0002 U	5.0 U	NR	4 9c38	0.1339	0.0220 U	13.2611	0.0370 U
1086	10-86-06-15-87	06/15/87	2	mg/l	0.0080	0.0481	0.0002 U	5.0 U	NR	3.7433	0.1113	0.0220 U	9.7672	0.0370 U
1086	10-86-08-10-87	08/10/87	3	mg/l	0.0063 U	0.0640	0.0002 U	5.9	NR	4.0182	0.0979	0.0220 U	13.7014	0.0370 U
1086	10-86-12-15-87	12/15/87	4	mg/l	0.0086	0.1329	0.0002 U	0.9	0.1 U	3 4896	0.0901	0.0220 U	12.9361	0.0370 U
1086	10-86-02-02-88	02/02/88	1	mg/l	0.0070	0.0868	0.0002 U	0.6	0.1 U	3.2011	0.0835	0.0220 U	9.9138	0.0693
4586	G458610860	10/16/86		mg/l	0.020 U	0.252	0.00021	0.623	NR	5.90	0.079	0.100 U	13.4	0.040 U
4586	G458610862	10/16/86		mg/l	0.020 U	0.242	0.0016	0.540	NR	5.40	0.091	0 100 U	13.9	0.040 U
4586	45-86-05-15-87	05/14/87	1	mg/l	0.0063 U	0.0948	0.0002 U	5.0 U	NR	2 6072	0.0141	0.0220 U	7.3332	0.0370 U
4586	45-86-06-12-87	06/12/87	2	mg/l	0.0063 U	0.0311	0.0002 U	5.0 U	NR	2.1295	0.0051 U	0.0220 U	6 5707	0.0370 U
4586	45-86-08-14-87	08/14/87	3	mg/l	0.0068 U	0.0495	0.0002 U	0.6	NR	2 3749	0.0062	0 0220 U	10.7756	0.0370 U
4586	45-86-09-30-87	09/30/87			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4	mg/l	0.0063 U	0.0143	0.0002 U	0.63 J	0.1 U	3 2390	0.0051 U	0.0220 U	10 8467	0.0370 U
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1	mg/l	0.0437	0.0999	0.0002	5.2	0.1 U	5 4896	0.5217	0.0220 U	24.6325	0.1425

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
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B : Present in laboratory blank

Table 4· nt'd.)

Groundwater Metal esults for Landfill Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Lead (Pb), total	Antimony (Sb), total	Selenium (Se), total	Strontium (Sr), total	Thallium (Tl), total	Vanadium (V), total	Zinc (Zn), total
Landfill Alluvial Wells Upgradient											
1086	G108610860	10/16/86		ug/l	0.005 U	0.050 U	0 002 U	0.238	0.010 U	0.057	0.055
1086	10-86-05-14 87	05/14/87	1	ug/l	0.005 U	0.0600 U	0.0050 U	0.1292	0.01 U	0 0240 U	0.02 U
1086	10 86-06-15-87	06/15/87	2	ug/l	0.009	0.06 U	0.005 U	0.1014	0 01 U	0.0240 U	0.0295
1086	10-86-08-10-87	08/10/87	3	ug/l	0.005 U	0.02 U	0.005 U	0.1145	0.01 U	0.0240 U	0.0581
1086	10-86-12-15-87	12/15/87	4	ug/l	0.004 J	0.02 U	0 005 U	0.0975	0.01 U	0 0240 U	0.0200 U
1086	10-86-02-02-88	02/02/88	1	ug/l	0.005 U	0.02 U	0 005 U	0.0971	0.01 U	0 0292	0.0884
4586	G4586108&0	10/16/86		ug/l	0.005 U	0.050 U	0.002 U	0.190	0.010 U	0.025 U	0.006
4586	G4586108&2	10/16/86		ug/l	0.005 U	0.050 U	0.002 U	0.193	0.010 U	0.025 U	0.005 U
4586	45-86-05-15-87	05/14/87	1	ug/l	0.0050 U	0.06 U	0.005 U	0.0633	0.0100 U	0.0240 U	0.02 U
4586	45-86 06-12-87	06/12/87	2	ug/l	0.011	0.06 U	0.005 U	0.0550	0.01 U	0.0240 U	0.0200 U
4586	45-86-08-14-87	08/14/87	3	ug/l	0.005 U	0.02 U,	0.005 U	0.0617	0.01 U	0 0240 U	0.0498
4586	45-86-09-30-87	09/30/87			NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4	ug/l	0.002 J	0.011 J	0 005 U	0.0847	0.01 U	0.0334	0.0200 U
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1	ug/l	0.005 U	0.02 U	0.005 U	0.2275	0.01 U	0.0240 U	0.4270

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-5 (cont'd.)

Groundwater Meta sults for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Silver (Ag), total	Aluminum (Al), total	Arsenic (As), total	Barium (Ba), total	Beryllium (Be), total	Calcium (Ca), total	Cadmium (Cd), total	Colbalt (Co), total	Chromium (Cr), total	Cesium (Cs), total
Landfill Alluvial Wells Downgradient														
0586	DRY	09/08/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0586	5-86-05-05-87	05/05/87	1	mg/l	0.0076 U	0.0290 U	0.01 U	0.0416	0.005 U	325.9938	0.005 U	0.0220 U	0.0100 U	0.2 U
0586	5-86-06-09-87	06/09/87	2	mg/l	0.0076 U	0.4102	0.01 U	0.0758	0.005 U	31.6307	0.005 U	0.0220 U	0.0120	0.2 U
0586	5-86-07-31-87	07/31/87	3	mg/l	0.0076 U	0.0372	0.005 U	0.0656	0.005 U	475.0916	0.001 U	0.0220 U	0.0100 U	0.02 U
0786	DRY	09/29/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0786	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0786	07-86-02-01-88	02/01/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4087	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4087	DRY	02/01/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4287	GW4287	06/24/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4287	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4287	42-87-12-16-87	12/16/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4287	42-87-02-04-88	02/04/88	1	mg/l	0.0076 U	0.0463	0.005 U	0.1437	0.005 U	31.3661	0.001 U	0.0220 U	0.0100 U	0.02 U
5987	59-87-01-23-88	01/23/88	1	mg/l	0.0076 U	0.0737	0.005 U	0.2532	0.005 U	78.5587	0.001	0.0220 U	0.0154	0.02 U
6087	60-87-01-23-88	01/23/88	1	mg/l	0.0076 U	0.0769	0.005 U	0.1434	0.005 U	26.9666	0.001 U	0.0220 U	0.0100 U	0.02 U
6187	61-87-01-27-88	01/27/88	1	mg/l	0.0076 U	0.1453	0.005 U	0.1307	0.005 U	24.2757	0.001 U	0.0220 U	0.0282	0.02 U
6287	62-87-01-26-88	01/26/88	1	mg/l	0.0076 U	0.1130	0.005 U	0.1538	0.005 U	26.8479	0.001 U	0.0220 U	0.0193	0.02 U
0686	DRY	09/08/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0686	6-86-05-13-87	05/13/87	1	mg/l	0.0076 U	0.0554	0.01 U	0.0463	0.005 U	443.5891	0.005 U	0.0220 U	0.0100 U	0.2 U
0686	6-86-06-09-87	06/09/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0686	6-86-08-10-87	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0686	08-86-02-01-88	02/01/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6387	63-87 01-27-88	01/27/88	1	mg/l	0.0076 U	0.0506	0.005 U	0.2462	0 005 U	122 5689	0.001 U	0.0220 U	0.0296	0.02 U
6487	64-87-01-29-88	01/29/88	1	mg/l	0.0085	0.0353	0.005 U	0.1826	0.005 U	47.2474	0.001 U	0.0313	0.0136	0.02 U
6587	65-87-01-28-88	01/28/88	1	mg/l	0.0076 U	0.0346	0.005 U	0.1291	0.005 U	74 4528	0.001 U	0.0220 U	0.0131	0.02 U
6687	66-87-01-29-88	01/29/88	1	mg/l	0.0076 U	0.0769	0.005 U	0.1020	0.005 U	34 0248	0.001 U	0.0220 U	0.0236	0.02 U
6787	67-87-01-28-88	01/28/88	1	mg/l	0.0076 U	0.0290 U	0.005 U	0.1034	0.005 U	40 1314	0.001	0.0220 U	0.0114	0.02 U
6887	68-87-01-28-88	01/28/88	1	mg/l	0.0076 U	0.0290	0.005 U	0.1528	0.005 U	32.4063	0.001 U	0.0220 U	0.0100 U	0.02 U
7087	DRY	02/03/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7187	71-87-01-29-88	01/29/88	1	mg/l	0.0076 U	0.0308	0.005 U	0.0841	0.005 U	71.2977	0.001 U	0.0220 U	0.0135	0.02 U
7287	72-87-01-28-88	01/28/88	1	mg/l	0.0076 U	0.0516	0.005 U	0.1574	0.005 U	88.9694	0.001 U	0.0220 U	0.0111	0.02 U
0486	DRY	08/28/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0486	DRY	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4- (Cont'd.)

Groundwater Metals Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Copper (Cu), total		Iron (Fe), total		Mercury (Hg), total		Potassium (K), total		Lithium (Li), total		Magnesium (Mg), total		Manganese (Mn), total		Molybdenum (Mo), total		Sodium (Na), total		Nickel (Ni), total	
Landfill Alluvial Wells Downgradient																								
0586	DRY	09/08/86				NA		NA		NA		NA		NA		NA		NA		NA		NA		NA
0586	5-86-05-05-87	05/05/87	1	mg/l	0.0799		0.0069	U	0.0002	U	5.0			NR	264.1889		0.0624		0.0220	U	720.3239		0.1912	
0586	5-86-06-09-87	06/09/87	2	mg/l	0.0063	U	0.4246		0.0002	U	5.7			NR	6.4399		0.0234		0.0220	U	21.7350		0.0370	U
0586	5-86-07-31-87	07/31/87	3	mg/l	0.0154		0.0069	U	0.0002	U	3.1			NR	291.7351		0.0479		0.0291		1179.3182		0.1751	
0786	DRY	09/29/86				NA		NA		NA		NA		NA		NA		NA		NA		NA		NA
0786	DRY	08/10/87	3			NA		NA		NA		NA		NA		NA		NA		NA		NA		NA
0786	07-86-02-01-88	02/01/88	1			NA		NA		NA		NA		NA		NA		NA		NA		NA		NA
4087	DRY	08/10/87	3			NA		NA		NA		NA		NA		NA		NA		NA		NA		NA
4087	DRY	02/01/88	1			NA		NA		NA		NA		NA		NA		NA		NA		NA		NA
4287	GW4287	06/24/87	2			NA		NA		NA		NA		NA		NA		NA		NA		NA		NA
4287	DRY	08/10/87	3			NA		NA		NA		NA		NA		NA		NA		NA		NA		NA
4287	42-87-12-16-87	12/16/87	4			NA		NA		NA		NA		NA		NA		NA		NA		NA		NA
4287	42-87-02-04-88	02/04/88	1	mg/l	0.0065		0.4066		0.0002	U	9.4		0.05	J	12.9761		0.5674		0.0220	U	52.5685		0.0370	U
5987	59-87-01-23-88	01/23/88	1	mg/l	0.0154		0.1716		0.0002	U	11		0.1	U	14.8116		2.1310		0.0220	U	31.5072		0.2035	
6087	60-87-01-23-88	01/23/88	1	mg/l	0.0365		0.0813		0.0002	U	1.0		0.1	U	4.7603		0.5136		0.0220	U	14.1688		0.0370	U
6187	61-87-01-27-88	01/27/88	1	mg/l	0.0085		0.1863		0.0002	U	2.1		0.1	U	4.5329		0.2702		0.0220	U	14.9011		0.0370	U
6287	62-87-01-26-88	01/26/88	1	mg/l	0.0118		0.1015		0.0002	U	3.0		0.1	U	4.8600		0.4100		0.0220	U	13.4639		0.0416	
0686	DRY	09/08/86				NA		NA		NA		NA		NA		NA		NA		NA		NA		NA
0686	6-86-05-13-87	05/13/87	1	mg/l	0.0063	U	0.0069	U	0.0002	U	10.9			NR	177.7157		1.2989		0.0220	U	801.8515		1.4027	
0686	6-86-06-09-87	06/09/87	2			NA		NA		NA		NA		NA		NA		NA		NA		NA		NA
0686	6-86-08-10-87	08/10/87	3			NA		NA		NA		NA		NA		NA		NA		NA		NA		NA
0686	08-86-02-01-88	02/01/88	1			NA		NA		NA		NA		NA		NA		NA		NA		NA		NA
6387	63-87-01-27-88	01/27/88	1	mg/l	0.0105		0.1137		0.0002	U	3.8		0.1	U	15.3287		0.6425		0.0220	U	33.6016		0.0370	U
6487	64-87-01-29-88	01/29/88	1	mg/l	0.0568		0.0471		0.0002	U	4.2		0.1	U	8.2194		1.2001		0.3551		18.7309		0.0444	
6587	65-87-01-28-88	01/28/88	1	mg/l	0.0063	U	0.0401		0.0002	U	6.2		0.1	U	13.2047		1.0484		0.0220	U	71.3146		0.0370	U
6687	66-87-01-29-88	01/29/88	1	mg/l	0.0545		0.1182		0.0002		6.1		0.1	U	7.2507		0.1784		0.0299		94.6908		0.1863	
6787	67-87-01-28-88	01/28/88	1	mg/l	0.0063	U	0.0419		0.0002	U	4.9		0.1	U	5.5284		0.6670		0.0220	U	17.3672		0.0748	
6887	68-87-01-28-88	01/28/88	1	mg/l	0.0063	U	0.9498		0.0002	U	3.0		0.1	U	5.3604		1.6145		0.0220	U	19.3733		0.0370	
7087	DRY	02/03/88	1			NA		NA		NA		NA		NA		NA		NA		NA		NA		NA
7187	71-87-01-29-88	01/29/88	1	mg/l	0.0070		0.0344		0.0002		1.7		0.1	U	9.3802		0.0590		0.0220	U	9.5292		0.0370	U
7287	72-87-01-28-88	01/28/88	1	mg/l	0.0069		0.0344		0.0002	U	3.1		0.1	U	16.7782		0.5105		0.0220	U	23.4236		0.0370	U
0486	DRY	08/28/86				NA		NA		NA		NA		NA		NA		NA		NA		NA		NA
0486	DRY	08/10/87	3			NA		NA		NA		NA		NA		NA		NA		NA		NA		NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table (ont'd.)

Groundwater Metals Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Lead (Pb), total		Antimony (Sb), total		Selenium (Se), total		Strontium (Sr), total		Thallium (Tl), total		Vanadium (V), total		Zinc (Zn), total	
Landfill Alluvial Wells Downgradient																		
0586	DRY	09/08/86				NA		NA		NA		NA		NA		NA		NA
0586	5-86-05-05-87	05/05/87	1	ug/l	0.005	U	0.0600	U	0.011		5.2430		0.01	U	0 0240	U	0.02	U
0586	5-86-06-09-87	06/09/87	2	ug/l	0.005	U	0.06	U	0.005	U	0.1721		0.01	U	0.0240	U	0.0236	
0586	5-86-07-31-87	07/31/87	3	ug/l	0.005		0.007	J	0.009		9.4688		0.01	U	0.0240	U	0.0212	
0786	DRY	09/29/86				NA		NA		NA		NA		NA		NA		NA
0786	DRY	08/10/87	3			NA		NA		NA		NA		NA		NA		NA
0786	07-86-02-01-88	02/01/88	1			NA		NA		NA		NA		NA		NA		NA
4087	DRY	08/10/87	3			NA		NA		NA		NA		NA		NA		NA
4087	DRY	02/01/88	1			NA		NA		NA		NA		NA		NA		NA
4287	GW4287	06/24/87	2			NA		NA		NA		NA		NA		NA		NA
4287	DRY	08/10/87	3			NA		NA		NA		NA		NA		NA		NA
4287	42-87-12-16-87	12/16/87	4			NA		NA		NA		NA		NA		NA		NA
4287	42-87-02-04-88	02/04/88	1	ug/l	0.005	U	0.02	U	0.005	U	1.2777		0.01	U	0 0240	U	0.0352	
5987	59-87-01-25-88	01/25/88	1	ug/l	0.010		0.02	U	0.002	J	0.6235		0.01	U	0 0240	U	0.5840	
6087	60-87-01-25-88	01/25/88	1	ug/l	0.005	U	0.02	U	0.005	U	0.1399		0.01	U	0 0240	U	0.2418	
6187	61-87-01-27-88	01/27/88	1	ug/l	0.005	U	0 02	U	0.005	U	0.1619		0.01	U	0.0264		0.0755	
6287	62-87-01-26-88	01/26/88	1	ug/l	0.005	U	0.02	U	0.005	U	0.1716		0.01	U	0.0240	U	0.0714	
0686	DRY	09/08/86				NA		NA		NA		NA		NA		NA		NA
0686	6-86-05-13-87	05/13/87	1	ug/l	0.005	U	0 0600	U	0.089		5.1181		0.01	U	0.0240	U	0.02	U
0686	6-86-06-09-87	06/09/87	2			NA		NA		NA		NA		NA		NA		NA
0686	6-86-08-10-87	08/10/87	3			NA		NA		NA		NA		NA		NA		NA
0686	08-86-02-01-88	02/01/88	1			NA		NA		NA		NA		NA		NA		NA
6387	63-87-01-27-88	01/27/88	1	ug/l	0.005	U	0.02	U	0.005	U	0.6899		0.01	U	0.0240	U	0.0608	
6487	64-87-01-29-88	01/29/88	1	ug/l	0.005	U	0.02	U	0.005	U	0.3320		0.01	U	0.0572		0.0486	
6587	65-87-01-28-88	01/28/88	1	ug/l	0.005	U	0.02	U	0.005	U	0.5041		0.01	U	0.0240	U	0.0598	
6687	66-87-01-29-88	01/29/88	1	ug/l	0.005	U	0.02	U	0.005	U	0.3011		0.01	U	0.1004		0.4714	
6787	67-87-01-28-88	01/28/88	1	ug/l	0.005	U	0.02	U	0.005	U	0.2425		0.01	U	0.0240	U	0.1893	
6887	68-87-01-28-88	01/28/88	1	ug/l	0.005	U	0.02	U	0.005	U	0.1964		0.01	U	0.0240	U	0.1062	
7087	DRY	02/03/88	1			NA		NA		NA		NA		NA		NA		NA
7187	71-87-01-29-88	01/29/88	1	ug/l	0.005	U	0.02	U	0.005	U	0.4217		0.01	U	0.0364		0.0572	
7287	72-87-01-28-88	01/28/88	1	ug/l	0.005	U	0.02	U	0.005	U	0.5986		0.01	U	0.0240	U	0.0353	
0486	DRY	08/28/86				NA		NA		NA		NA		NA		NA		NA
0486	DRY	08/10/87	3			NA		NA		NA		NA		NA		NA		NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-5 (cont'd.)

Groundwater Pesticide and PCB Results for Landfill Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Alpha-BHC	Beta-BHC	Delta-BHC	Gamma-BHC	Heptachlor	Aldrin	Heptachlor Epoxide	Endosulfan I	Dieldrin	4,4'-DDT
Landfill Alluvial Wells Upgradient														
1086	G108610860	10/16/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-05-14-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-06-15-87	06/15/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-08-10-87	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-12-15-87	12/15/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-02-02-88	02/02/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	G458610860	10/16/86		ug/l	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.1 U	0.1 U
4586	G4586108C2	10/16/86		ug/l	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.1 U	0.1 U
4586	45-86-05-15-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-06-12-87	06/12/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-08-14-87	08/14/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4- nt'd.)

Groundwater Pestici[illegible]B Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Endrin	Endosulfan II	4,4'-DDD	Endosulfan Sulfate	4,4'-DDT	Methoxychlor	Endrin Ketone	Chlordane	Toxaphene	Aroclor-1016
Landfill Alluvial Wells Upgradient														
1086	G108610860	10/16/86			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-05-14-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-06-15-87	06/15/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-08-10-87	08/10/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-12-15-87	12/15/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1086	10-86-02-02-88	02/02/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	G458610860	10/16/86		ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.5 U	0.1 U	0.5 U	1 U	0.5 U
4586	G458610862	10/16/86		ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.5 U	0.1 U	0.5 U	1 U	0.5 U
4586	45-86-05-15-87	05/14/87	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-06-12-87	06/12/87	2		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-08-14-87	08/14/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5887	SB 87-01-23-88	01/23/88	1		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: NR = Analyte not reported
NA = Insufficient water in well for analysis
U = Analyzed but not detected
J = Present below detection limit
B = Present in laboratory blank

Table 4-5 (1.)

Groundwater Pesticic CB Results for Landfill

Alluvial Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Aroclor-1221	Aroclor-1232	Aroclor-1242	Aroclor-1248	Aroclor-1254	Aroclor-1260
Landfill Alluvial Wells Upgradient										
1086	6108610860	10/16/86			NA	NA	NA	NA	NA	NA
1086	10-86-05-14-87	05/14/87	1		NA	NA	NA	NA	NA	NA
1086	10-86-06-15-87	06/15/87	2		NA	NA	NA	NA	NA	NA
1086	10-86-08-10-87	08/10/87	3		NA	NA	NA	NA	NA	NA
1086	10-86-12-15-87	12/15/87	4		NA	NA	NA	NA	NA	NA
1086	10-86-02-02-88	02/02/88	1		NA	NA	NA	NA	NA	NA
4586	6458610860	10/16/86		ug/l	0.5 U	0.5 U	0.5 U	0.5 U	1 U	1 U
4586	6458610862	10/16/86		ug/l	0.5 U	0.5 U	0.5 U	0.5 U	1 U	1 U
4586	45-86-05-15-87	05/14/87	1		NA	NA	NA	NA	NA	NA
4586	45-86-06-12-87	06/12/87	2		NA	NA	NA	NA	NA	NA
4586	45-86-08-14-87	08/14/87	3		NA	NA	NA	NA	NA	NA
4586	45-86-09-30-87	09/30/87			NA	NA	NA	NA	NA	NA
4586	45 86-09-30-87	09/30/87	4		NA	NA	NA	NA	NA	NA
4586	45-86-10-01-87	10/01/87	4		NA	NA	NA	NA	NA	NA
5887	58-87-01-23-88	01/23/88	1		NA	NA	NA	NA	NA	NA

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

During the 1986 drilling program, two ground-water monitor well pairs were installed at the Present Landfill. One pair consisting of one alluvial well (10-86) and one bedrock well (9-86) were placed upgradient of the landfill. The second well pair was placed downgradient of the landfill (bedrock well 8-86 and alluvial well 7-86) to monitor ground-water quality. Additional alluvial wells, 6-86 and 5-86, are located downgradient of the landfill in the unnamed tributary of North Walnut Creek.

In 1987, additional wells were installed to characterize the landfill and determine the effectiveness of the collection systems described in Section 4.2.1.2. An additional upgradient alluvial well was installed immediately west of the landfill (58-87). Eight wells were placed across the landfill collection system (59-87, 60-87, 61-87, 62-87, 63-87, 64-87, 65-87, and 66-87). Wells 67-87, 68-87, and 71-87 were positioned to monitor the effectiveness of the north slurry trench, whereas, wells 70-87 and 72-87 were installed to determine the effectiveness of the south slurry trench. Three wells were installed downgradient of the landfill pond embankment to monitor ground-water quality leaving the landfill area (alluvial wells 40-87 and 42-87 and bedrock well 41-87BR).

Two new alluvial wells, 40-87 and 70-87, were dry during the first quarter, 1988 sampling effort, therefore, no analytical data are available at this time. Three additional wells, 64-87, 66-87, and 71-87, were sampled for volatile organic compounds (VOC); however, the holding times expired before the samples were analyzed. Therefore, no VOC data are available for these three wells.

-- Establishment of Ground-Water Quality Criteria

The upgradient ground-water chemistry will be the basis for assessing impacts to ground water from the landfill. Table 4-6 provides the analyte concentration ranges observed in ground water at alluvial and bedrock wells located immediately upgradient of the landfill. As shown in the table, some unusually high analyte concentrations seen in the data set have not been considered in establishing the upgradient analyte concentration ranges. These high values are considered outliers that are likely not representative of upgradient alluvial ground-water chemistry.

The assessment provided here is qualitative in nature, its purpose being the identification of obvious impacts of the landfill on ground-water quality. The reader is referred to Section E of the Post Closure Care Permit Application for a discussion of proposed monitoring to achieve compliance with 40 CFR 265, Subpart F. Although the current monitoring program at the landfill was not designed specifically to satisfy RCRA requirements, many of the analytes measured are those required for routine monitoring under 265.92(b), and assessment monitoring under 265.93(a). Parameters for routine monitoring included in the monitoring program are the Safe Drinking Water Act (SDWA) metals, chloride, iron, manganese, sodium, sulfate, pH, and specific conductance. Assessment monitoring parameters are Appendix VIII hazardous waste constituents expected in the unit. Many of the HSL volatiles are Appendix VIII hazardous waste constituents that could have been disposed of and released from the facility. The radionuclides, although not Appendix VIII hazardous constituents, have been analyzed because they may be possible constituents of waste disposed at the landfill. Other parameters analyzed are for general inorganic characterization of the ground water.

TABLE 4-6

UPGRADIENT GROUND-WATER CHEMISTRY* AND GROUND-WATER QUALITY CRITERIA

Parameter	Upgradient Alluvial Ground-Water Chemistry Concentration Range (mg/l)	Upgradient Bedrock** Ground-Water Chemistry Concentration Range (mg/l)	Ground-Water Quality Criteria
METALS			
+ Silver (Ag)	.0076U-.019[1]	.0076U	.05
Aluminum (Al)	.029U-.179	.029U-.055	5
+ Arsenic (As)	.01U	.01U-.015	.05
+ Barium (Ba)	.026-.340	.028-.160	1
++ Beryllium (Be)	.005U-.026	.005U	.1
+ Cadmium (Cd)	.005U	.005U	.01
Cobalt (Co)	.05U	.022U	.05
+ Chromium (Cr)	.01U-.02	.01U-.02	.05**
Cesium (Cs)	0.2U	.2U	NA
Copper (Cu)	.020U-.044[2]	.02U-.026	1
Iron (Fe)	.031-.252	.013-.227	.3
• Mercury (Hg)	.0002U-.0016	.0002U-.0002	.002
Lithium (Li)	.1U	.1U	2.5
Manganese (Mn)	.005U-.634	.013-.034	.05
Molybdenum (Mo)	.1U	.1U	.1
++ Nickel (Ni)	.037U-.142	.037U	.2
• Lead (Pb)	.005U-.011	.005U-.025	.05
++ Antimony (Sb)	.06U	.06U	NA
+ Selenium (Se)	.005U	.005U	.01
Strontium (Sr)	.06-.24	.18-.28	NA
++ Thallium (Tl)	.01U	.01U	NA
Vanadium (V)	.025U-.057	.025U-.030	.1
Zinc	.02U-.43	.02U-.24	5
MAJOR IONS			
Calcium	9-28	21-26	NA
Magnesium	2-8	5-6	NA
Potassium	5U-13	5U	NA
Sodium	7-25[3]	53-72	NA
Chloride	4-14	8-13[5]	250
Sulfate	13-49	3-15	250
Bicarbonate	18-97	172-205	NA
Nitrate-N	0.5-5	.2U	10
Cyanide	1U	1U	NA
Total Dissolved Solids	92-233	217-350	400

TABLE 4-6
(CONTINUED)

UPGRADIENT GROUND-WATER CHEMISTRY* AND GROUND-WATER QUALITY CRITERIA

E

Parameter	Upgradient Alluvial Ground-Water Chemistry Concentration Range (mg/l)	Upgradient Bedrock Ground-Water Chemistry Concentration Range (mg/l)	Ground-Water Quality Criteria
RADIONUCLIDES (pCi/l)			
Gross Alpha	<MDA - 249(15)	<MDA - 160(100)	15
Gross Beta	<MDA - 250(40)	<MDA - 220(60)	50
Plutonium 239, 240	<MDA - .106(.062)	<MDA	40
Americium 241	<MDA	<MDA	4 ***
Uranium 233, 234	<MDA - 15(2)	<MDA - 3.0(.5)	40***
Uranium 238	<MDA - 16(2)	<MDA - 5.3(2)	40
Strontium 89, 90	<MDA - 9.3	<MDA****-1.03	8
Tritium	<MDA - 330	<MDA	20,000

1 eliminating 36.6 mg/l as an outlier
2 eliminating 28.2 mg/l as an outlier
3 eliminating 72 mg/l as an outlier
4 eliminating 4.7 (1.8) pCi/l as an outlier
5 eliminating 151 mg/l as an outlier

* Based on data from wells 10-86, 45-86, and 58-87 for alluvial ground water and well 9-86 for bedrock ground water.
** Not available.
*** Total uranium.
**** MDA--Maximum Detectable Activity.
+ SDWA Metal
+ Appendix VIII hazardous constituent that is not an SDWA metal.

A ground-water protection standard is not defined for interim status regulated units under 40 CFR 265; however, regulations at 40 CFR 264, Subpart F, have been used as a framework to examine the ground-water quality at the landfill. The ground-water protection standard defined at 40 CFR 264.94 specifies background levels for hazardous constituents or SDWA drinking water standards for the SDWA metals (which are also hazardous constituents). The SDWA drinking water standards, as well as standards for other metals, inorganics, and radionuclides which are not hazardous constituents are shown in Table 4-6. The concentrations for major ions and non-SDWA metals are the Colorado Department of Health (CDH) ground-water standards for protection of human health (or protection of agriculture if human health standards are not available). Because the ground water in the vicinity of the landfill has not been classified by the State, these standards are not enforceable. The plutonium and americium concentrations are proposed drinking water standards (51 FR 34859). The uranium concentration is a CDH surface water standard [5 CCR 1002-8, Section 3.8.5(3)]. All other radionuclide standards are SDWA maximum contaminant levels. These analyte concentrations have been termed ground-water quality criteria, and are used only to preliminarily assess the public health significance of the ground-water quality.

-- General Observations

As shown in Appendix C, with few exceptions, HSL volatiles did not occur above detection limits. The only exceptions are the random occurrences of low concentrations [generally less than 10 milligrams per liter (ug/l)] of methylene chloride, acetone, methylethyl ketone, and carbon tetrachloride(CCL_4) in both upgradient and downgradient wells. For any single well, the occurrences are

infrequent, the balance of the data showing the analytes non-detectable. Therefore, organic contamination is not an issue at the Present Landfill and is not discussed further.

With the exception of tritium, all radionuclide concentrations in ground water downgradient of the landfill were within ranges established for upgradient conditions. At well 63-87, located within the landfill, tritium was 1900(100) picoCuries (pCi/l), whereas upgradient ground-water tritium concentrations are below the minimum detectable activity (220 pCi/l). This tritium concentration likely reflects the known historical disposal of tritium in the landfill. The concentration is, however, below the proposed ground-water quality criterion. Tritium does not occur above the MDA elsewhere in ground water downgradient of the landfill.

As discussed in the next section, upgradient gross alpha, gross beta, and strontium 90 concentrations exceed the proposed ground-water quality criteria. This only occurs for gross alpha in downgradient ground-water, and occurs infrequently and at concentrations near the proposed ground-water quality criterion (15 pCi/l). These are the only findings with respect to radionuclides at the Present Landfill, and therefore, radionuclide concentrations downgradient of the landfill are not discussed further.

4.2.1.5 UPGRADIENT ALLUVIAL GROUND-WATER QUALITY

Major Ion Chemistry

All major ion concentrations are below the ground-water quality criteria. The concentration ranges suggest variability exists generally on the order of a factor of two or three.

Metals

With the exception of manganese, trace metal concentrations in upgradient alluvial ground water are below the proposed ground-water quality criteria. Manganese, at times, exceeds the proposed ground-water quality criteria by a factor of ten. Concentrations can vary considerably over time for many of the metals.

Radionuclides

The radionuclide concentrations in the upgradient alluvial ground water are below the proposed ground-water quality criteria except for gross alpha, gross beta, and strontium 90. Concentrations of gross alpha range from less than the MDA to 249(15) pCi/l. Gross beta concentrations range from less than the MDA to 250(40) pCi/l. Strontium 90 was 9.3 pCi/l in well 10-86. The proposed ground-water quality criteria for gross alpha, gross beta, and strontium 90 are 15, 50, and 8 pCi/l, respectively.

4.2.1.6 ALLUVIAL GROUND-WATER QUALITY ADJACENT TO LANDFILL

Major Ion Chemistry

Well 59-87 is located at the western extent of the landfill. The well penetrates the intervening clay of the leachate/ground-water collection system and is completed in both the Rocky Flats Alluvium (below the clay) and fill material (above the clay). Although at the time of sampling, ground water occurred below the clay liner, the possible presence of trash even further west toward the surface water intercept ditch, and the fact that a conduit now exists between the fill and alluvium, makes it

difficult to assign this well as upgradient of the landfill. Indeed, it appears the ground water at this location may be impacted by the landfill. Analyte concentrations above the upgradient ranges include calcium (78 mg/l), magnesium (14 mg/l), sodium (32 mg/l), bicarbonate (306 mg/l), chloride (24 mg/l), total dissolved solids (406 mg/l), manganese (2.13 mg/l), nickel (0.20 mg/l), strontium (0.62 mg/l), and zinc (0.58 mg/l). Of these analytes, calcium, bicarbonate, total dissolved solids, strontium, and manganese are most elevated (factor of 2-4 higher) relative to upgradient conditions and appear to best represent indicators of a ground-water quality change at the landfill. Total dissolved solids and manganese exceed the proposed ground-water quality criteria (400 mg/l and 0.05 mg/l, respectively). However, manganese concentrations in upgradient ground water also exceed the ground-water quality criteria.

Well 63-87 is located at the north-central edge of the landfill and is within the landfill. Ground-water quality at this location is similar to that observed at well 59-87. Except for nickel, zinc, and chloride, the same analytes exceed the upgradient concentration ranges. Again, calcium (123 mg/l), bicarbonate (392 mg/l), total dissolved solids (519 mg/l), and strontium (0.69 mg/l) significantly exceed the concentrations in upgradient alluvial ground water. Total dissolved solids exceed the ground-water quality criterion at this location.

At wells 62-87, 61-87, and 60-87, each located progressively further north and outside the landfill, ground water appears to represent upgradient conditions. Only sulfate in wells 60-87 (57 mg/l) and 61-87 (59 mg/l) exceeded the upper limit of the upgradient range (49 mg/l). This is likely not a significant difference. This information supports the hydrogeologic findings that the hydraulic gradient at this location is into the landfill and that the clay barrier appears to function.

At well 64-87, located at the south-central edge of the landfill and within the landfill, elevated concentrations of calcium (47 mg/l), chloride (20 mg/l), bicarbonate (179 mg/l), total dissolved solids (255 mg/l), copper (0.057 mg/l), manganese (1.20 mg/l), molybdenum (0.35 mg/l), and strontium (0.33 mg/l) occur. However, in this case, only bicarbonate and molybdenum are significantly elevated. The molybdenum exceeds the proposed ground-water quality criterion (0.1 mg/l); however, this is the only occurrence of elevated molybdenum downgradient of or within the landfill. The significance of this finding is unknown at this time.

At wells 65-87 and 66-87, located progressively further south and outside the landfill, ground water contains higher concentrations of salts and trace metals. Analytes exceeding upgradient concentrations at wells 65-87 and 66-87 are calcium (74 and 34 mg/l), sodium (71 and 95 mg/l), magnesium [13 mg/l (65-87 only)], bicarbonate (208 and 127 mg/l), sulfate [153 mg/l (65-87 only)], total dissolved solids (491 and 405 mg/l), manganese [1.05 mg/l (65-87 only)], copper [0.054 mg/l (66-87 only)], nickel [0.186 mg/l (66-87 only)], strontium (0.50 and 0.30 mg/l), vanadium [0.10 mg/l (66-87 only)], and zinc [0.47 mg/l (66-87 only)]. This data supports the hydrogeologic finding that the hydraulic gradient is away from the landfill at this location. Analytes exceeding the proposed ground-water quality criteria are total dissolved solids and manganese.

East of the landfill in the vicinity of the slurry trenches are wells 71-87, 67-87, 68-87 (north slurry wall), and wells 70-87 and 72-87 (south slurry wall). In general, total dissolved solids (range 191-395 mg/l), bicarbonate (range 101-276 mg/l), sulfate (range 67-139 mg/l), and calcium (range 32-89 mg/l) in all these wells exceed the upgradient alluvial ground-water concentrations. Strontium is only elevated in wells 71-87 and 72-87 which are outside the slurry walls (0.42 and 0.60 mg/l, respectively).

Manganese is only elevated in wells 67-87 and 68-87 which straddle the slurry wall (0.67 and 1.61 mg/l, respectively). Ground water at well 68-87 also contains elevated iron (0.95 mg/l). Well 70-87 was dry. Predicted ground-water flow directions do not support a landfill impact on ground-water quality at wells 67-87 and 71-87. At these locations, ground-water flow is from the north and east. This suggests that the observed concentrations of salts, strontium, and manganese may represent natural spatial variations in ground-water quality. On the contrary, ground water is predicted to flow, at times, south from the landfill at well 64-87 toward wells 65-87 and 66-87, which could proceed east toward well 72-87. Regardless, the observed water quality at well 72-87 does not appear unusual relative to the ground water to the north, which is presumably unimpacted. Iron and manganese are the only analytes which exceed the proposed ground-water quality criteria.

4.2.1.7 Downgradient Alluvial Ground-Water Chemistry

Wells 7-86, 40-87, 42-87, 6-86, and 5-86 are located progressively downgradient of the landfill. Well 7-86 is usually dry, and only organic data exist for this well. Well 40-87 is also dry. Analytes exceeding upgradient concentration ranges for wells 42-87, 6-86, and 5-86 are as follows:

Analyte	Concentration (mg/l)		
	Well 42-87	Well 6-86	Well 5-86
Calcium	71	444	32-473
Magnesium	13	180	6.5-292
Sodium	53	301	22-1179
Bicarbonate	259	227	366-459
Sulfate	75	1710	725-4600
Chloride	14	826	150-270
Iron	.40	.007	.0070-.42
Manganese	.56	1.3	.023-.062
Strontium	1.28	5.12	.17-9.5
Nickel	.037	1.40	.04-.19
Total Dissolved Solids	355	4542	3517-7363

The analyte concentrations observed at well 42-87 may indicate an impact from the landfill; however, as discussed in the previous section, the observed concentrations may be due to natural variations in ground-water chemistry. Iron and manganese exceed the ground-water quality criteria. Iron occurs at high concentrations at well 68-87 but not within landfill (wells 63-87 and 64-87). The limited data makes it difficult to draw conclusions with respect to iron as a contaminant of the landfill. As previously mentioned, the manganese concentration also exceeds the ground-water quality criterion in upgradient ground water and ground water to the north.

The concentrations of analytes at wells 6-86 and 5-86 do not indicate a release from the landfill. These high levels of contamination are not seen within the landfill ground water or immediately downgradient of the landfill (42-87). The implication is another source of high total dissolved solids water exists downgradient of the landfill. As no SWMUs are known to be located downgradient of the landfill, this source may be due to natural saline mineral dissolution.

4.2.2 Bedrock Ground-Water Flow System

4.2.2.1 Recharge Conditions

Ground-water flow in the Arapahoe Formation occurs within sandstones, siltstones, and claystones. Ground-water recharge to the Arapahoe Formation occurs as infiltration of alluvial ground water.

Seasonal variations in saturated thickness are shown in the hydrographs for wells 8-86, 9-86, and 41-87 (Appendix B). The smallest saturated thickness occur from

June through September. There is a downward gradient between ground water in surficial materials and bedrock. This has been demonstrated previously at the Plant (Hurr, 1976, and Rockwell International, 1986a, 1988a). Table 4-7 presents vertical hydraulic gradients calculated for alluvial/bedrock well pairs 7-86 and 8-86 (bedrock well), 10-86 and 9-86 (bedrock well), and 40-87 and 41-87BR. Calculated vertical gradients range from about 0.2 to 0.5.

4.2.2.2 Ground-Water Flow Directions

Ground-water flow within individual sandstones is from west to east at an average gradient of 0.09 ft/ft based on wells completed in the same sandstones at the 903 Pad and East Trenches Areas (Rockwell International, 1987b) and on regional data (Robson and others, 1981a). None of the existing bedrock wells at the Present Landfill are completed in the same sandstone. Therefore, a site-specific horizontal gradient cannot be calculated for Arapahoe sandstone.

4.2.2.3 Hydraulic Conductivities

Hydraulic conductivity values for Arapahoe sandstones were estimated from drawdown-recovery tests performed in 1986, a slug test performed in 1987, and packer tests performed in 1986 and 1987. Tables 4-8 and 4-9 summarize the results of these tests. Data, analyses, and results of each test are provided in Appendix C.

Hydraulic conductivity values in sandstones from drawdown recovery, slug, and packer tests are in good agreement. The hydraulic conductivities in sandstones vary from 4×10^{-8} cm/s to 3.1×10^{-7} cm/s. This is in the range of the hydraulic conductivity calculated for siltstones.

TABLE 4-7

VERTICAL GRADIENTS

Well	Elevation of Potentiometric Surface	Water Level Difference (ft)	Elevation of Saturated Interval Midpoint	Elevation of Saturated Interval	Separator Thickness (ft)	Downview Vertical Gradient
7-86	5920.76		5920.40-5917.66	5919.21		
		18.89				
					56.83	0.33
8-86	5901.87		5864.73-5860.02	5862.38		
10-86	5987.93		5991.73-5971.24	5979.59		
		20.09			113.32	0.18
9-86	5967.84		5872.66-5859.88	5866.27		
40-87	5879.39		5884.19-5881.23	5880.31		
		38.44			85.03	0.45
41-87	5840.95		5801.57-5788.99	5795.28		

Potentiometric Surface Values Based on April 11, 1988 measurements

TABLE 4-8

RESULTS OF PACKER TESTS IN ARAPAHOE FORMATION

Well No.	Interval (ft)	Lithology	1st P 1/3 (cm/s)	P 2/3 (cm/s)	2nd P 1/3 (cm/s)	Geometric mean (cm/s)
8-86	33.50 - 43.53	Claystone	6.90×10^{-6}	5.06×10^{-6}	3.10×10^{-6}	4.8×10^{-6}
	43.50 - 53.53	Claystone	Aborted	2.1×10^{-7}	Aborted	2.1×10^{-7}
	53.50 - 63.53	Claystone	1.13×10^{-6}	3.0×10^{-8}	Aborted	1.8×10^{-7}
		Claystone		Geometric mean for 8-86:		5.7×10^{-7}
9-86	87.64 - 97.67	Siltstone	-	1.0×10^{-8}	-	1.0×10^{-8}
	97.87 - 107.70	Siltstone	6.0×10^{-8}	3.0×10^{-8}	Aborted	4.0×10^{-8}
	107.70 - 117.93	Siltstone	-	1.0×10^{-8}	-	1.0×10^{-8}
	121.00 - 131.03	Sandstone	1.9×10^{-7}	4.0×10^{-8}	-	9.0×10^{-8}
	135.00 - 145.03	Sandstone/Siltstone				
		Siltstone		Geometric mean for 9-86:		2.0×10^{-8}
		Sandstone		Geometric mean for 9-86:		9.0×10^{-8}
41-87BR	20.85 - 30.50	Claystone	5.7×10^{-7}	1.71×10^{-6}	9.9×10^{-7}	9.9×10^{-7}
	32.50 - 42.15	Sandstone	3.5×10^{-7}	1.0×10^{-7}	2.0×10^{-8}	9.0×10^{-8}
	41.55 - 51.20	Sandstone	9.0×10^{-7}	2.46×10^{-6}	1.75×10^{-6}	1.6×10^{-6}
	53.05 - 62.70	Claystone	2.0×10^{-7}	3.9×10^{-7}	1.0×10^{-7}	2.0×10^{-7}
	62.70 - 72.35	Sandstone	4.2×10^{-7}	6.6×10^{-7}	1.70×10^{-7}	3.6×10^{-7}
	73.35 - 82.00	Claystone	9.1×10^{-7}	2.58×10^{-6}	-	1.5×10^{-6}
	82.00 - 91.65	Sandstone	5.7×10^{-7}	5.0×10^{-8}	-	1.7×10^{-7}
		Claystone		Geometric mean for 41-87BR:		6.7×10^{-7}
		Sandstone		Geometric mean for 41-87BR:		6.7×10^{-7}

TABLE 4-9

RESULTS OF HYDRAULIC TESTS IN BEDROCK

Well No.	Lithology	Drawdown Recovery Test (cm/s)	Slug Test (cm/s)	Packer Test (cm/s)
8-86	Claystone	-	-	5.7×10^{-7}
	Sandstone	7×10^{-8}		
9-86	Siltstone	-	-	2.0×10^{-8}
	Sandstone	4×10^{-8}		9.0×10^{-8}
41-87BR	Claystone	-	-	6.7×10^{-7}
	Sandstone	-	2.78×10^{-8}	3.1×10^{-7}

2×10^{-8} cm/s, and actually less than the range of the hydraulic conductivity for the claystone, 5.7×10^{-7} to 6.7×10^{-7} cm/s.

This very low hydraulic conductivity in the sandstones may explain why the downward gradient from the surficial flow system to the bedrock flow system in the landfill area is not greater than 0.2 to 0.5 ft/ft. This low hydraulic conductivity impairs the ability of the sandstones underlying the landfill area to discharge downdip.

4.2.2.4 Bedrock Ground-Water Quality

Three bedrock monitor wells were installed to monitor bedrock ground-water quality. Well 9-86 is located immediately west of the landfill; 8-86 is located immediately east of the landfill; and 41-87BR is downgradient of the landfill embankment in an unnamed tributary of North Walnut Creek. Table 4-10 summarizes the availability of bedrock ground-water quality data used in this report.

4.2.2.5 Upgradient Bedrock Ground-Water Chemistry

Major Ions

Upgradient bedrock ground-water chemistry is similar to upgradient alluvial ground-water chemistry except for some of the major ions (Table 4-11). Bedrock ground water has higher sodium, bicarbonate, and total dissolved solids relative to alluvial ground water. The ground-water protection criteria for major ions is not exceeded in upgradient bedrock ground water.

Table 4-10

GROUND WATER SAMPLE INFORMATION

LANDFILL BEDROCK WELLS

	SAMPLE INFORMATION			FIELD PARAMETERS			LABORATORY BATCH NUMBERS					
WELL NUMBER	NUMBER	DATE	TYPE	pH	CONDUCT (umho/cm)	TEMP (deg C)	VOLATILE ORGANICS	SEMI-VOL ORGANICS	PESTICIDES AND PCB'S	METALS	INORGANICS	RADIO-CHEMISTRY
0886	G088&118&0	11/13/8&	Routine	11.85	2&00	9.5	8&11-027-023	No Sample	No Sample	8&11-027-024	8&11-027-025	1000-000-240
0886	8-86-04-13-87	04/13/87	Routine				0187-881-053	No Sample	No Sample	0187-881-053	0187-881-054	0187-881-054
0886	8-86 06-11-87	06/11/87	Routine	10.20	5&9	12.0	0287-881 044	No Sample	No Sample	0287-881-044	0287-881-065	0287-881-044
0886	8-86-08-12 87	08/12/87	Routine	9.80	515	15.0	0387-881 078	No Sample	No Sample	0387-881-086	0387-881-082	Insufficient Sample
0886	8-86-12-16-87	12/16/87	Routine	10.50	540	9.6	0487-881 0&8	No Sample	No Sample	0487-881-056	0487-881-054	0487-881-058
0886	08-8&-02-04-88	02/04/88	Routine	9.30	477	9.7	0188-881-019	No Sample	No Sample	0188-881-019	0188-881-019	0188-881 019
0986	G098&108&0	10/21/8&	Routine	8.20	410	[illegible]	8&11 004 00&	No Sample	No Sample	8&11-004-007	8&11 004-008	1000 000 240
0986	9-86-05-14-87	05/14/87	Routine	7.40	398	14.0	0187-881-099	No Sample	No Sample	0187-881-099	0187-881-102	0187-881 104
0986	9-86-06-15-87	06/15/87	Routine	7.90	396	14.5	0287-881-046	No Sample	No Sample	0287-881-046	0287-881-049	0287-881 046
0986	9-86-08-12-87	08/12/87	Routine	8.00	395	17.2	0387-881-077	No Sample	No Sample	0387-881-084	0387-881-083	0387 881 060
0986	9-86-01-18 88	01/18/88	Routine	7.60	546	9.6	0487 881-102	No Sample	No Sample	0487-881-124	0487-881-083	0487-881 083
0986	09-86-02-04-88	02/04/88	Routine	8.40	400	10.1	0188 881-018	No Sample	No Sample	0188-881-018	0188-881-018	0188-881 018
4187	41-87-09-21 87	09/21/87	Routine				0&87-881-010	No Sample	No Sample		0&87-881-010	
4187	41-87-09 21-87	09/21/87	Routine				8709-078-0150	No Sample	No Sample	Insufficient Sample	Insufficient Sample	Insufficient Sample
4187	41-87-12-17-87	12/17/87	Routine	6.80	2940	9.6	0487-881-071	No Sample	No Sample	0487-881-060		0487-881-057
4187	41 87 02-03-88	02/03/88	Routine	7.70	30&0	10.1	0188-881-01&	No Sample	No Sample	0188-881-016	0188-881-01&	0188 881-01&

Metals

Metal concentrations in upgradient bedrock ground water are similar to upgradient alluvial ground water. However, unlike alluvial ground water, manganese concentrations do not exceed the proposed ground-water protection standard.

Radionuclides

As with upgradient alluvial ground water, gross alpha and gross beta exceed the proposed ground-water quality criteria in upgradient bedrock ground water. Concentrations for gross alpha and gross beta are as high as 160(100) and 220(60) pCi/l, respectively, while the standards are 15 and 50 pCi/l, respectively.

Table 4

Groundwater Volatile Organic Results for Landfill

Bedrock Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Chloro methane	Bromo methane	Vinyl Chloride	Chloro ethane	Methylene Chloride	Acetone	Carbon Disulfide	1,1-Dichloro ethene	1,1-Dichloro ethane	Trans-1,2 Dichloro ethene
Landfill Bedrock Wells Upgradient														
0986	G0986108c0	10/31/86		ug/l	10 U	10 U	10 U	10 U	5 U	2 JB	5 U	5 U	5 U	5 U
0986	9-86-05-14-87	05/14/87	1	ug/l	NR	NR	NR	NR	NR	NR	NR	4 U	NR	4 U
0986	9-86-06-15-87	06/15/87	2	ug/l	NR	NR	NR	NR	NR	NR	NR	4 U	NR	4 U
0986	9-86-08-12-87	08/12/87	3	ug/l	NR	NR	NR	NR	NR	NR	NR	5 U	NR	5 U
0986	9-86-01-18-88	01/18/88	4	ug/l	10 U	10 U	10 U	10 U	c	10 U	5 U	5 U	5 U	5 U
0986	09-86-02-04-88	02/04/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
Landfill Bedrock Wells Downgradient														
4187	41-87-09-21-87	09/21/87	3	ug/l	NR	NR	NR	NR	NR	NR	NR	5 U	NR	5 U
4187	41-87-09-21-87	09/21/87	3	ug/l	10 U	10 U	10 U	10 U	5 U	6 JB	5 U	5 U	5 U	5 U
4187	41-87-12-17-87	12/17/87	4	ug/l	10 U	10 U	10 U	10 U	10	10 U	5 U	5 U	5 U	5 U
4187	41-87-02-03-88	02/03/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U
0886	G0886118c0	11/13/86		ug/l	10 U	10 U	10 U	10 U	5 U	84	5 U	5 U	5 U	5 U
0886	8-86-04-13-87	04/13/87	1	ug/l	NR	NR	NR	NR	NR	NR	NR	4 U	NR	4 U
0886	8-86-06-11-87	06/11/87	2	ug/l	NR	NR	NR	NR	NR	NR	NR	4 U	NR	4 U
0886	8-86-08-12-87	08/12/87	3	ug/l	NR	NR	NR	NR	NR	NR	NR	5 U	NR	5 U
0886	8-86-12-16-87	12/16/87	4	ug/l	10 U	10 U	10 U	10 U	12	4 J	5 U	5 U	5 U	5 U
0886	08-86-02-04-88	02/04/88	1	ug/l	10 U	10 U	10 U	10 U	5 U	10 U	5 U	5 U	5 U	5 U

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
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B : Present in laboratory blank

Table 4-11 (.)

Groundwater Volatile Organic Results for Landfill

Bedrock Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Chloroform	1,2-Dichloro ethane	2 Butanone	1,1,1-Trichloro ethane	Carbon tetra chloride	Vinyl Acetate	Bromo dichloro methane	1,2-Dichloro propane	Trans-1,3-Dichloro propene	Trichloro ethene
Landfill Bedrock Wells Upgradient														
0986	G0986108&0	10/31/86		ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
0986	9-86-05-14-87	05/14/87	1	ug/l	4 U	4 U	NR	4 U	4 U	NR	NR	NR	NR	4 U
0986	9-86-06-15-87	06/15/87	2	ug/l	4 U	4 U	NR	4 U	4 U	NR	NR	NR	NR	4 U
0986	9-86-08-12-87	08/12/87	3	ug/l	5 U	5 U	NR	5 U	5 U	NR	NR	NR	NR	5 U
0986	9-86-01-18-88	01/18/88	4	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
0986	09-86-02-04-88	02/04/88	1	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
Landfill Bedrock Wells Downgradient														
4187	41-87-09-21-87	09/21/87	3	ug/l	5 U	5 U	NR	5 U	5 U	NR	NR	NR	NR	5 U
4187	41-87-09-21-87	09/21/87	3	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
4187	41-87-12-17-87	12/17/87	4	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
4187	41-87-02-03-88	02/03/88	1	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
0886	G0886118&0	11/13/86		ug/l	5 U	5 U	12 B	5 U	5 U	10 U	5 U	5 U	5 U	5 U
0886	8-86-04-13-87	04/13/87	1	ug/l	4 U	4 U	NR	4 U	4 U	NR	NR	NR	NR	4 U
0886	8-86-06-11-87	06/11/87	2	ug/l	4 U	4 U	NR	4 U	4 U	NR	NR	NR	NR	4 U
0886	8-86-08-12-87	08/12/87	3	ug/l	5 U	5 U	NR	5 U	5 U	NR	NR	NR	NR	5 U
0886	8-86-12-16-87	12/16/87	4	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U
0886	08-86-02-04-88	02/04/88	1	ug/l	5 U	5 U	10 U	5 U	5 U	10 U	5 U	5 U	5 U	5 U

Notes: NR = Analyte not reported
NA = Insufficient water in well for analysis
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B = Present in laboratory blank

Table 4-11 (Cont'd.)

Groundwater Volatile Organic Results for Landfill

Bedrock Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Dibromo chloro methane	1,1,2-Trichloro ethane	Benzene	cis-1,3 Dichloro propene	2-Chloro ethylvinyl ether	Bromoform	4-Methyl-2-pentanone	2-Hexanone	Tetrachloro ethene	1,1,2,2 Tetrachloro ethane
Landfill Bedrock Wells Upgradient														
0986	G098610860	10/31/86		ug/l	5 U	5 U	5 U	5 U	10 U	5 U	10 U	10 U	5 U	5 U
0986	9-86-05-14-87	05/14/87	1	ug/l	NR	4 U	NR	NR	NR	NR	NR	NR	4 U	NR
0986	9-86-06-15-87	06/15/87	2	ug/l	NR	4 U	NR	NR	NR	NR	NR	NR	4 U	NR
0986	9-86-08-12-87	08/12/87	3	ug/l	NR	5 U	NR	NR	NR	NR	NR	NR	5 U	NR
0986	9-86-01-18-88	01/18/88	4	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
0986	09-86-02-04-88	02/04/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
Landfill Bedrock Wells Downgradient														
4187	41-87-09-21-87	09/21/87	3	ug/l	NR	5 U	NR	NR	NR	NR	NR	NR	5 U	NR
4187	41-87-09-21-87	09/21/87	3	ug/l	5 U	5 U	5 U	5 U	10 U	5 U	10 U	10 U	5 U	5 U
4187	41-87-12-17-87	12/17/87	4	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
4187	41-87-02-03-88	02/03/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
0886	G088611860	11/13/86		ug/l	5 U	5 U	5 U	5 U	10 U	5 U	10 U	10 U	5 U	5 U
0886	8-86-04-13-87	04/13/87	1	ug/l	NR	4 U	NR	NR	NR	NR	NR	NR	4 U	NR
0886	8-86-06-11-87	06/11/87	2	ug/l	NR	4 U	NR	NR	NR	NR	NR	NR	4 U	NR
0886	8-86-08-12-87	08/12/87	3	ug/l	NR	5 U	NR	NR	NR	NR	NR	NR	5 U	NR
0886	8-86-12-16-87	12/16/87	4	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U
0886	08-86-02-04-88	02/04/88	1	ug/l	5 U	5 U	5 U	5 U	NR	5 U	10 U	10 U	5 U	5 U

Notes: NR = Analyte not reported
NA = Insufficient water in well for analysis
U = Analyzed but not detected
J = Present below detection limit
B = Present in laboratory blank

Table 4-11 1.)

Groundwater Volatile Organic Results for Landfill

Bedrock Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Toluene	Chloro benzene	Ethyl benzene	Styrene	Total Xylenes
Landfill Bedrock Wells Upgradient									
0986	C098610860	10/31/86		ug/l	5 U	5 U	5 U	5 U	5 U
0986	9-86-05-14-87	05/14/87	1	ug/l	NR	NR	NR	NR	NR
0986	9-86-06-15-87	06/15/87	2	ug/l	NR	NR	NR	NR	NR
0986	9-86-08-12-87	08/12/87	3	ug/l	NR	NR	NR	NR	NR
0986	9-86-01-18-88	01/18/88	4	ug/l	5 U	5 U	5 U	5 U	5 U
0986	09-86-02-04-88	02/04/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
Landfill Bedrock Wells Downgradient									
4187	41-87-09-21-87	09/21/87	3	ug/l	NR	NR	NR	NR	NR
4187	41-87-09-21-87	09/21/87	3	ug/l	5 U	5 U	5 U	5 U	5 U
4187	41-87-12-17-87	12/17/87	4	ug/l	5 U	5 U	5 U	5 U	5 U
4187	41-87-02-03-88	02/03/88	1	ug/l	5 U	5 U	5 U	5 U	5 U
0886	C088611860	11/13/86		ug/l	5 U	5 U	5 U	5 U	5 U
0886	8-86-04-13-87	04/13/87	1	ug/l	NR	NR	NR	NR	NR
0886	8-86-06-11-87	06/11/87	2	ug/l	NR	NR	NR	NR	NR
0886	8 86-08-12-87	08/12/87	3	ug/l	NR	NR	NR	NR	NR
0886	8-86-12-16-87	12/16/87	4	ug/l	5 U	5 U	5 U	5 U	5 U
0886	08-86-02-04-88	02/04/88	1	ug/l	5 U	5 U	5 U	5 U	5 U

Notes: NR : Analyte not reported
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Table 4-11 'd.)

Groundwater Ra. .emistry Results

for Regulated Units at Rocky Flats Plant

Well Number	Field Sample Number	Date Sampled	Qtr.	Gross Alpha	Gross Beta	Uranium 233, 234	Uranium 235	Uranium 238	Strontium 89, 90	Plutonium 239, 240
Landfill Bedrock Wells Upgradient										
0986	G098610860	10/31/86		160 +/- 100 pci/l	220 +/- 60 pci/l	0.04 +/- 0.25 pci/l	NR	-0.18 +/- 0.35 pci/l	NR	0.39 +/- 0.79 pci/l
0986	9-86-05-14-87	05/14/87	1	5 +/- 0 pc/l	0 +/- 9 pc/l	1.8 +/- 1.4 pc/l	.85 +/- .74 pc/l	.28 +/- .97 pc/l	1.03 pc/l	0.6 +/- 1.2 pc/l
0986	9-86-06-15-87	06/15/87	2	45 +/- 21 pci/l	67 +/- 6 pci/l	2.2 +/- 1.0 pci/l	0.0 +/- 0.26 pci/l	0.32 +/- 0.5 pci/l	<1.0 pci/l	0.0 +/- 0.65 pci/l
0986	9-86-08-12-87	08/12/87	3	12 +/- 20 pci/l	12 +/- 39 pci/l	1.9 +/- 1.5 pci/l	-0.2 +/- 0.2 pci/l	5.3 +/- 2.0 pci/l	<1.0 pci/l	-0.3 +/- 1.4 pci/l
0986	9-86-01-18-88	01/18/88	4	2 +/- 5 pci/l	-1 +/- 11 pci/l	2.0 +/- 0.5 pci/l	.06 +/- .10 pci/l	.98 +/- .28 pci/l	<1.0 pci/l	0.00 +/- .14 pci/l
0986	09-86-02-04-88	02/04/88	1	1 +/- 5 pci/l	-4 +/- 11 pci/l	1.1 +/- 0.24 pci/l	0.09 +/- 0.07 pci/l	0.24 +/- 0.12 pci/l	NR	0.0 +/- 0.58 pci/l
Landfill Bedrock Wells Downgradient										
4187	41-87-09 21-87	09/21/87	3	NA	NA	NA	NA	NA	NA	NA
4187	41-87-09-21 87	09/21/87	3	NA	NA	NA	NA	NA	NA	NA
4187	41-87-12-17-87	12/17/87	4	109 +/- 22 pci/l	122 +/- 15 pci/l	NR	NR	NR	.1.0 pci/l	0.00 +/- .14 pci/l
4187	41-87-02-03-88	02/03/88	1	3 +/- 6 pci/l	-4 +/- 13 pci/l	0.26 +/- 0.18 pci/l	0.01 +/- 0.06 pci/l	0.15 +/- 0.17 pci/l	NR	0.0 +/- 2.0 pci/l
0886	G0886118&0	11/13/86		1& +/- 41 pci/l	&1 +/- 90 pci/l	-0.09 +/- 0.44 pci/l	NR	-0.3 +/- 1.8 pci/l	NR	-1.0 +/- 1.6 pci/l
0886	8-86-04-13-87	04/13/87	1	8 +/- 4 pc/l	21 +/- 12 pc/l	0.0 +/- .45 pc/l	0.0 +/- .41 pc/l	0.0 +/- .75 pc/l	<0.6 pc/l	.21 +/- .85 pc/l
0886	8-86-06-11 87	06/11/87	2	20 +/- 10 pci/l	51 +/- 45 pci/l	0.18 +/- 0.61 pci/l	0.26 +/- 0.45 pci/l	2.3 +/- 5.4 pci/l	1.3 pci/l	0.05 +/- 0.62 pci/l
0886	8-86-08-12-87	08/12/87	3	NA	NA	NA	NA	NA	NA	NA
0886	8-86-12-16-87	12/16/87	4	3 +/- 17 pci/l	4 +/- 11 pci/l	98 +/- .21 pci/l	.03 +/- .04 pci/l	.45 +/- .14 pci/l	<1.0 pci/l	0.00 +/- .16 pci/l
0886	08-86-02-04-88	02/04/88	1	3 +/- 5 pci/l	-7 +/- 12 pci/l	2.9 +/- 0.63 pci/l	0.08 +/- 0.12 pci/l	0.90 +/- 0.30 pci/l	NR	0.0 +/- 0.31 pci/l

Notes: NR = Analyte not reported
NA = Insufficient water in well for analysis

Table 4-1 (cont'd.)

Groundwater Radiochemistry Results

for Regulated Units at Rocky Flats Plant

Well Number	Field Sample Number	Date Sampled	Qtr.	Americium 241	Cesium 137	Tritium
Landfill Bedrock Wells Upgradient						
0986	G098610860	10/31/86		-0.17 +/- 0.34 pci/l	NR	0.05 +/- 0.21 pci/ml
0986	9-86-05-14-87	05/14/87	1	0.0 +/- 1.2 pc/l	NR	<110 pc/l
0986	9-86-06-15-87	06/15/87	2	0.0 +/- 1.2 pci/l	NR	<110 pci/l
0986	9-86-08-12-87	08/12/87	3	.19 +/- .29 pci/l	NR	<492 pci/l
0986	9 86-01-18-88	01/18/88	4	0.00 +/- .12 pci/l	NR	<220 pci/l
0986	09-86-02-04-88	02/04/88	1	NR	NR	<210 pci/l
Landfill Bedrock Wells Downgradient						
4187	41-87-09-21-87	09/21/87	3	NA	NA	NA
4187	41-87-09-21-87	09/21/87	3	NA	NA	NA
4187	41-87-12-17-87	12/17/87	4	0.00 +/- .32 pci/l	NR	<210 pci/l
4187	41-87-02-03-88	02/03/88	1	NR	NR	<210 pci/l
0886	G0886118c0	11/13/86		-0.44 +/- 0.79 pci/l	NR	0.01 +/- 0.23 pci/ml
0886	8-86-04-13-87	04/13/87	1	0.0 +/- 1.2 pc/l	NR	<110 pc/l
0886	8-86-06-11-87	06/11/87	2	0.0 +/- 1.2 pci/l	NR	<110 pci/l
0886	8-86-08-12-87	08/12/87	3	NA	NA	NA
0886	8-86-12-16-87	12/16/87	4	.02 +/- .10 pci/l	NR	<210 pci/l
0886	08-86-02-04-88	02/04/88	1	NR	NR	<210 pci/l

Notes: NR = Analyte not reported
NA = Insufficient water in well for analysis

Table 4-11 d.)

Groundwater Inorgan. Results for Landfill

Bedrock Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	$CO_3^{=}$	HCO_3^-	Chloride	Sulfate	pH	Fluoride	Nitrate-Nitrite-Nitrogen
Landfill Bedrock Wells Upgradient										
0986	G098610860	10/31/86		5 U mg/l	220 mg/l	11 mg/l	15 mg/l	NR	NR	NR
0986	9-86-05-14-87	05/14/87	1	NR	172 mg/l	13.2 mg/l	10.0 mg/l	NR	NR	0.20 U mg/l
0986	9-86-06-15-87	06/15/87	2	NR	192 mg/l	10.5 mg/l	7.80 mg/l	NR	NR	0.20 U mg/l
0986	9-86-08-12-87	08/12/87	3	NR	187 mg/l	10.5 mg/l	8.5 mg/l	NR	NR	0.20 U mg/l
0986	9-86-01-18-88	01/18/88	4	NR	201 mg/l	11.23 mg/l	10.3 mg/l	NR	NR	0.02 U mg/l
0986	09-86-02-04-88	02/04/88	1	NR	205 mg/l	8.44 mg/l	151 mg/l	NR	NR	0.02 U mg/l
Landfill Bedrock Wells Downgradient										
4187	41-87-09-21-87	09/21/87	3	NF	NF	NF	NF	NF	NF	NF
4187	41-87-09-21-87	09/21/87	3	NA	NA	NA	NA	NA	NA	NA
4187	41-87-12-17-87	12/17/87	4	NA	NA	NA	NA	NA	NA	NA
4187	41-87-02-03-88	02/03/88	1	NR	114 mg/l	928 mg/l	44.3 mg/l	NR	NR	0.02 U mg/l
0886	G088611860	11/13/86		450 mg/l	5 U mg/l	12 mg/l	101 mg/l	NR	NR	NR
0886	8-86-04-13-87	04/13/87	1	NR	21.4 mg/l	872 mg/l	200 mg/l	NR	NR	2.10 mg/l
0886	8-86-06-11-87	06/11/87	2	12.4 mg/l	36.6 mg/l	9.50 mg/l	225 mg/l	NR	NR	0.20 U mg/l
0886	8-86-08-12-87	08/12/87	3	NR	61.5 mg/l	9.7 mg/l	178 mg/l	NR	NR	NR
0886	8-86-12-16-87	12/16/87	4	NR	57.7 mg/l	7.93 mg/l	151 mg/l	NR	NR	1.47 mg/l
0886	08-86-02-04-88	02/04/88	1	NR	80.2 mg/l	8.19 mg/l	125 mg/l	NR	NR	0.34 mg/l

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
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Table 4-11 'd.)

Groundwater Inorga .esults for Landfill

Bedrock Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Sulfide	Phosphate	Cyanide, Total	Hexavalent Chromium (Cr+6)	Total Dissolved Solids	Suspended Solids	% Solids
Landfill Bedrock Wells Upgradient										
0986	G0986108&0	10/31/86		NR	NR	0.01 U mg/l	NR	350 mg/l	NR	NR
0986	9-86-05-14 87	05/14/87	1	NR	NR	1.0 U mg/l	NR	217 mg/l	NR	NR
0986	9-86-06-15-87	06/15/87	2	NR	NR	1.0 U mg/l	NR	255 mg/l	NR	NR
0986	9-86-08 12-87	08/12/87	3	NR	NR	1 U mg/l	NR	220 mg/l	NR	NR
0986	9-86-01-18-88	01/18/88	4	NR	NR	NR	NR	224 mg/l	NR	NR
0986	09-86-02-04-88	02/04/88	1	NR	NR	NR	NR	238 mg/l	NR	NR
Landfill Bedrock Wells Downgradient										
4187	41-87-09-21-87	09/21/87	3	NF	NF	NF	NF	NF	NF	NF
4187	41-87-09-21-87	09/21/87	3	NA	NA	NA	NA	NA	NA	NA
4187	41-87-12-17-87	12/17/87	4	NA	NA	NA	NA	NA	NA	NA
4187	41-87-02-03-88	02/03/88	1	NR	NR	NR	NR	1880 mg/l	NR	NR
0886	G0886118&0	11/13/86		NR	NR	0.005 U mg/l	NR	911 mg/l	NR	NR
0886	8-86-04-13-87	04/13/87	1	NR	NR	1.0 U mg/l	NR	402 mg/l	NR	NR
0886	8-86-06-11-87	06/11/87	2	NR	NR	1.0 U mg/l	NR	380 mg/l	NR	NR
0886	8-86-08-12-87	08/12/87	3	NR	NR	1 U mg/l	NR	358 mg/l	NR	NR
0886	8-86-12-16-87	12/16/87	4	NR	NR	NR	NR	330 mg/l	NR	NR
0886	08-86-02-04-88	02/04/88	1	NR	NR	NR	NR	307 mg/l	NR	NR

Notes: NR = Analyte not reported
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B = Present in laboratory blank

Table 4-11 'd.)

Groundwater Metals Results for Landfill Bedrock Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Silver (Ag), total	Aluminum (Al), total	Arsenic (As), total	Barium (Ba), total	Beryllium (Be), total	Calcium (Ca), total	Cadmium (Cd), total	Cobalt (Co), total	Chromium (Cr), total	Cesium (Cs), total
Landfill Bedrock Wells Upgradient														
0986	G098&10860	10/31/86		ug/l	0.010 U	0.100 U	0.010 U	0.160	0.005 U	21.1	0.005 U	0.025 U	0.010 U	0.150 U
0986	9-86-05-14-87	05/14/87	1	ug/l	0.0076 U	0.0421	0.01 U	0.0907	0.005 U	25.8270	0.005 U	0.0220 U	0.0100 U	0.2 U
0986	9 86-06-15-87	06/15/87	2	ug/l	0.0076 U	0.0290 U	0.01 U	0 0279	0.005 U	25.6395	0.005 U	0.0220 U	0.0100 U	0.2 U
0986	9-86-08-12-87	08/12/87	3	ug/l	0.0076 U	0.0487	0.004 J	0.1303	0.005 U	22 8456	0.0004 J	0.0220 U	0.0178	0.02 U
0986	9-86-01-18-88	01/18/88	4	ug/l	0.0076 U	0.0551	0.015	0.1323	0 005 U	24 6412	0.001 U	0.0220 U	0.0100 U	0.02 U
0986	09-8&-02-04-88	02/04/88	1	ug/l	0.0076 U	0.0290 U	0.005 U	0.10&7	0.005 U	21.8304	0.001 U	0.0220 U	0.0137	0.02 U
Landfill Bedrock Wells Downgradient														
4187	41-87-09-21-87	09/21/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4187	41-87-09-21-87	09/21/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4187	41-87-12-17-87	12/17/87	4	ug/l	0.0076 U	0 0&99	0.002 J	0.1815	0.005 U	9& 18&0	0.001 U	0.0220 U	0.0100 U	0.02 U
4187	41-87-02-03-88	02/03/88	1	ug/l	0.0076 U	0.0350	0.003 J	0.2899	0.005 U	96.0820	0.001	0.0220 U	0.0100 U	0.02 U
0886	G088&118&0	11/13/86		ug/l	0.009 U	0.380	0.010 U	0.156	0.005 U	91.5	0.005 U	0.025 U	0.010 U	0 150 U
0886	8-86-04-13-87	04/13/87	1	ug/l	0.0076 U	0.1209	0.01 U	0.0338	0.005 U	32 2310	0.005 U	0.0220 U	0.0100 U	0.2 U
0886	8-86-06-11-87	06/11/87	2	ug/l	0.0076 U	0.1254	0.01 U	0.0135	0.005 U	26.0747	0.005 U	0.0220 U	0.0100 U	0.2 U
0886	8-86-08-12-87	08/12/87	3	ug/l	0.0076 U	0.0730	0.01	0.0478	0.005 U	25.6007	0.001 U	0.0220 U	0.0103	0.02 U
0886	8-86-12-16-87	12/16/87	4	ug/l	0.0076 U	0.0722	0.007	0.0268	0.005 U	19.3936	0.001 U	0.0220 U	0.0100 U	0.02 U
0886	08-8&-02-04-88	02/04/88	1	ug/l	0.0076 U	0.0416	0.005 U	0.01&4	0.005 U	16.0180	0.001 U	0.0220 U	0.0100 U	0.02 U

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-1 t'd.)

Groundwater Metals Results for Landfill

Bedrock Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Copper (Cu), total	Iron (Fe), total	Mercury (Hg), total	Potassium (K), total	Lithium (Li), total	Magnesium (Mg), total	Manganese (Mn), total	Molybdenum (Mo), total	Sodium (Na), total	Nickel (Ni), total
Landfill Bedrock Wells Upgradient														
0986	G098610860	10/31/86		mg/l	0.020 U	0.075 U	0.0002 U	3.62	NR	5.25	0.028	0.100 U	60.7	0.020 U
0986	9-86-05-14-87	05/14/87	1	mg/l	0.0068	0.0207	0.0002 U	5.0 U	NR	6.1611	0.0127	0.0220 U	61.5676	0.0370 U
0986	9-86-06-15-87	06/15/87	2	mg/l	0.0063 U	0.0131	0.0002 U	5.0 U	NR	5.5015	0.0312	0.0220 U	60.6963	0.0370 U
0986	9-86-08-12-87	08/12/87	3	mg/l	0.0071	0.2267	0.0002 U	3.9	NR	5.1208	0.0212	0.0290	72.1450	0.0370 U
0986	9-86-01-18-88	01/18/88	4	mg/l	0.0257	0.0519	0.0002 U	3.6	0.1 U	5.6543	0.0338	0.0220 U	60.9950	0.0370 U
0986	09-86-02-04-88	02/04/88	1	mg/l	0.0063 U	0.0825	0.0002	3.5	0.1 U	5.4654	0.0236	0.0220 U	57.6813	0.0370 U
Landfill Bedrock Wells Downgradient														
4187	41-87-09-21-87	09/21/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4187	41-87-09-21-87	09/21/87	3		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4187	41-87-12-17-87	12/17/87	4	mg/l	0.0246	0.0532	0.0002 U	9.9	0.10	24.1295	0.0653	0.0456	4447.3764	0.0370 U
4187	41-87-02-03-88	02/03/88	1	mg/l	0.0063 U	0.0372	0.0002 U	8.6	0.13	25.5941	0.0821	0.0343	442.8450	0.0370 U
0886	G0886118c0	11/13/86		mg/l	0.020 U	0.094	0.0002 U	41.1	NR	1 U	0.016	0.133	177	0.020 U
0886	8-86-04-13-87	04/13/87	1	mg/l	0.00e3 U	0.0069 U	0.0002 U	10.0	NR	1.2284	0.0051 U	0.1247	101.4100	0.0370 U
0886	8-86-06-11-87	06/11/87	2	mg/l	0.0079	0.0447	0.0002 U	7.6	NR	0.3173	0.0051 U	0.1241	89.6748	0.0370 U
0886	8-86-08-12-87	08/12/87	3	mg/l	0.0074	0.0294	0.0002 U	5.9	NR	1.1104	0.0051 U	0.1332	88.3283	0.0370 U
0886	8-86-12-16-87	12/16/87	4	mg/l	0.0330	0.0384	0.0002 U	6.2	0.1 U	1.2793	0.0051 U	0.0732	78.2412	0.0370 U
0886	08-86-02-04-88	02/04/88	1	mg/l	0.0092	0.0320	0.0002 U	4.9	0.06 J	1.4480	0.0051 U	0.0410	71.9646	0.0370 U

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

Table 4-11 d.)

Groundwater Metals Results for Landfill

Bedrock Wells at Rockwell (Rocky Flats)

Well Number	Field Sample Number	Date Sampled	Qtr.	Units	Lead (Pb), total	Antimony (Sb), total	Selenium (Se), total	Strontium (Sr), total	Thallium (Tl), total	Vanadium (V), total	Zinc (Zn), total
Landfill Bedrock Wells Upgradient											
0986	G098610860	10/31/86		ug/l	0.025	0.060 U	0.005 U	0.175	0.010 U	0.025 U	0.020 U
0986	9-86-05-14-87	05/14/87	1	ug/l	0.005 U	0.0600 U	0.0050 U	0.2726	0.01 U	0.0240 U	0.02 U
0986	9-86-06-15-87	06/15/87	2	ug/l	0.015	0.06 U	0.005 U	0.2263	0.01 U	0.0295	0.0200 U
0986	9-86-08-12-87	08/12/87	3	ug/l	0.001 J	0.02 U	0.004	0.2387	0.01 U	0.0240 U	0.2433
0986	9-86-01-18-88	01/18/88	4	ug/l	0.002 J	0.02 U	0.002 J	0.2800	0.01 U	0.0240 U	0.0200 U
0986	09-86-02-04-88	02/04/88	1	ug/l	0.005 U	0.02 U	0.005 U	0.2572	0.01 U	0.0240 U	0.0423
Landfill Bedrock Wells Downgradient											
4187	41-87-09-21-87	09/21/87	3		NA	NA	NA	NA	NA	NA	NA
4187	41-87-09-21-87	09/21/87	3		NA	NA	NA	NA	NA	NA	NA
4187	41-87-12-17-87	12/17/87	4	ug/l	0.005 U	0.02 U	0.005	1.3371	0.01 U	0.0240 U	0.0242
4187	41-87-02 03 88	02/03/88	1	ug/l	0.005 U	0.02 U	0.004 J	1.3304	0.01 U	0.0240 U	0.0263
0886	G0886118c0	11/13/86		ug/l	0.005 U	0.060 U	0.010	1.310	0.010 U	0.025 U	0.029
0886	8-86-04-13-87	04/13/87	1	ug/l	0.005 U	0.0600 U	0.006	0.3843	0.01 U	0.0324	0.02
0886	8-86-06-11-87	06/11/87	2	ug/l	0.008	0.06 U	0.005 U	0.3013	0.01 U	0.0333	0.0200 U
0886	8-86-08-12-87	08/12/87	3	ug/l	0.005 U	0.02 U	0.005 U	0.2818	0.01 U	0.0240 U	0.0200 U
0886	8-86-12-16-87	12/16/87	4	ug/l	0.005 U	0.02 U	0.006	0.2535	0.01 U	0.0240 U	0.0200 U
0886	08-86-02-04-88	02/04/88	1	ug/l	0.005 U	0.02 U	0.005 U	0.1896	0.01 U	0.0240 U	0.0200 U

Notes: NR : Analyte not reported
NA : Insufficient water in well for analysis
U : Analyzed but not detected
J : Present below detection limit
B : Present in laboratory blank

4.2.2.6 DOWNGRADIENT BEDROCK GROUND-WATER CHEMISTRY

Well 8-86, at the west end of the landfill pond, and well 41-87 at the toe of the landfill pond embankment, are the two downgradient bedrock wells. Analyte concentrations in ground water at these wells exceed the upgradient conditions as shown below:

Analyte	Upgradient Range (mg/l)	Concentration Ranges (mg/l) 8-86	41-87
Calcium	21-26	16-91	96
Magnesium	5-6	-*	24-26
Sodium	58-72	72-177	443
Chloride	8-13	8-872	928
Sulfate	8-15	101-225	44
Nitrate	.20	.20-2.1	-
Total Dissolved Solids	217-350	307-911	1880
Aluminum	.0290-.055	.042-.380	.035-.070
Manganese	.013-.034	-	.065-.082
Molybdenum	.10	.04-.13	-
Selenium	.0050	.0050-.010	-
Strontium	.18-.28	.19-1.31	1.33-1.34

* - indicated, upgradient concentration not exceeded

Relative to the ground water at well 9-86 (upgradient), the ground water at wells 8-86 and 41-87 is particularly enriched (more so at 41-87 than 8-86) in calcium, magnesium, sodium, chloride, and strontium. These high concentrations are not observed in alluvial ground water within, adjacent, or immediately downgradient of the landfill. Although it is possible the sandstones in 8-86 and 41-87 subcrop beneath the landfill (Cross Section A-A') and thus are recharged by alluvial ground water in this vicinity, it is likely the quality of the ground water in the sandstones at these wells simply reflects dissolution of minerals within the sandstone and claystone. The higher salt concentration at 41-87 relative to 8-86 could be explained by the somewhat

longer contact time and resulting mineral dissolution of water moving from the alluvium to well 41-87. The observed lower concentrations of salts in well 9-86 may be due to lower mineral content within the sandstone and claystone in this vicinity. It is concluded that the apparent "degradation" of bedrock ground water downgradient of the landfill is not related to releases from the landfill.

4.2.2.7 GROUND-WATER QUALITY SUMMARY

Examination of water quality data for upgradient alluvial ground water and alluvial ground water within the landfill, adjacent to and south of the landfill, and immediately downgradient of the landfill, indicates the landfill may be contributing calcium, bicarbonate, and to a lesser extent sodium, sulfate, iron, manganese, and strontium to the ground water. However, ground water to the north of the north slurry wall which is not influenced by the landfill has similar concentrations of these analytes. This implies that even if the landfill contributes these constituents to the ground water, the resulting concentrations are within natural variations for the area. With respect to the public health significance of the water quality directly downgradient of the landfill (42-87), only iron (0.40 mg/l) and manganese (0.57 mg/l) exceed the ground-water quality criteria (0.3 and 0.05 mg/l, respectively). However, manganese also exceeds the criteria (maximum concentration of 0.63 mg/l) in upgradient ground water.

It is concluded that any impacts the landfill has on alluvial ground water do not alter the quality to any significant extent relative to the natural variations in quality observed in the vicinity of the landfill and relative to public health-based water quality criteria. High salt concentrations further down the drainage (wells 6-86

and 5-86) appear to result from another, yet unidentified and presumably natural source.

Bedrock ground-water quality is conjectured to be influenced largely by mineral dissolution within the sandstones and claystone, as the high salt concentrations observed are not seen in alluvial ground water within the landfill.

4.3 PERFORMANCE OF PROPOSED CAP AND LEACHATE SYSTEM

The performance of the proposed cap and leachate system is dependent not only on its design characteristics, but also on the effectiveness of the intercept and slurry trenches in already place.

4.3.1 Effectiveness of the Ground-Water Intercept, Clay Liner and Slurry Trenches

Section 4.2.1.2 of this text discussed the effectiveness of the leachate/ground-water collection system (including the clay liner) and of the slurry trenches. In this section a water balance approach is used to evaluate the effectiveness of the ground-water intercept/clay liner and the slurry trenches in isolating the landfill from the alluvial ground-water flow system. If the intercept/slurry wall does isolate the landfill, rates of recharge from precipitation should approximate rates of discharge into the bedrock and into the landfill pond.

Conclusion

It appears from water balance calculations that the ground-water intercept and slurry trenches are not completely effective in isolating the landfill from the alluvial ground-water flow system.

Estimated recharge rates for the landfill from incident precipitation vary from 24,000 to 152,000 cubic feet per year. The range is a function of precipitation rate and percentage of precipitation estimated to recharge the water table.

Estimated discharge rates for the landfill vary from 187,000 to 392,000 cubic feet per year. Actual discharge rates may be higher because ground-water flow in the alluvial toe of the landfill was not estimated.

Recharge

Table 4-12 lists the annual rainfall at the Rocky Flats Plant for the years 1953 through 1987. The 35-year average annual precipitation is 15.15 inches; the maximum recorded annual precipitation is 24.67 inches in 1969; and the minimum is 7.76 inches in 1954.

A large fraction of this precipitation is lost as runoff and as evapotranspiration. The percentage of annual precipitation that recharges the ground-water system is quite low. Table 4-13 (after Gutentag, et al., 1984) compiles these values for the unconfined High Plains Aquifer in Colorado. With reference to this table, it is estimated that 5 to 10 percent of annual precipitation recharges the ground-water flow system within the landfill.

The volume of ground-water recharge resulting from incident precipitation is the product of the annual precipitation, the percent of resulting recharge (as a fraction), and the landfill area. The landfill area within the ground-water intercept and slurry trenches is approximately 740,000 square feet. Recharge rates for the historical rates of precipitation are listed in Table 4-14.

TABLE 4-12

ANNUAL RAINFALL AT THE ROCKY FLATS PLANT

Year	Rainfall	Year	Rainfall
1953	11.26	1971	14.30
1954	7.76	1972	14.78
1955	14.77	1973	21.55
1956	13.42	1974	13.73
1957	22.67	1975	12.22
1958	18.07	1976	13.51
1959	19.65	1977	8.73
1960	13.72	1978	13.53
1961	16.08	1979	19.14
1962	8.26	1980	12.96
1963	12.23	1981	13.24
1964	8.79	1982	17.95
1965	18.87	1983	21.62
1966	10.24	1984	11.32
1967	22.54	1985	14.23
1968	12.71	1986	15.13
1969	24.67	1987	18.17
1970	18.56		

35-Year Average Annual Rainfall: 15.15 inches (1.26 feet; 38.5 cm)
Maximum Recorded Annual Rainfall: 24.67 inches (1969)
Minimum Recorded Annual Rainfall: 7.76 inches (1954)

Data for years 1953-1976 from DOE, 1980, Table 2.3.6-6.
Data for years 1977-1987 from rainfall measured at Building 774--Rocky Flats.

TABLE 4-13

RECHARGE ESTIMATES FOR THE HIGH PLAINS AQUIFER

State	Recharge		Reference	Remarks
	In inches per year	In percentage of mean annual precipitation		
Colorado	0.80 to 0.95	5	McGovern and Coffin (1963)	Northern High Plains, water-budget method
	0.95	5	McGovern (1964)	Washington County, water-budget method
	0.82	5	Reddell (1967)	Northern High Plains, county averages range from 0.15 (Kiowa) to 1.45 inches per year (Yuma), computer-model analysis
	4.0	23	Longenbaugh and Krishnamurthi (1975)	Washington County, sandy soils, computer-model analysis
	0.59	2	Kapple and others (1977)	Cheyenne and Kiowa Counties, computer-model analysis

TABLE 4-14

EXPECTED RECHARGE (ft^3) TO LANDFILL AREA (inches)

		Annual Precipitation		
		Min	Avg	Max
		7.76	15.15	24.67
Percent of precipitation that recharges ground-water system	5%	276,000	539,000	878,000
	10%	426,000	832,000	1,354,000

Discharge

Ground water within the landfill is discharged by eastward flow into the landfill pond, by seepage into the bedrock, and by possible, intermittent southward flow across the clay liner.

The possibility of intermittent southward flow across the clay liner is discussed in Section 4.2.1.2. There is insufficient documentation on this flow to estimate annual discharge rates.

Ground water discharge to bedrock can be estimated from Darcy's equation:

$$Q = K\ A\ (dh/dL)$$

Where: K = hydraulic conductivity
A = cross sectional area of flow
dh/dL = hydraulic gradient

As discussed in Section 4.2.2.1, there is a downward gradient between ground water in surficial materials and bedrock. Calculated vertical gradients in the landfill area range from 0.2 to 0.5 (See Table 4-6).

The cross sectional flow area for downward flow into bedrock is the surface area of the landfill. This is approximately 740,000 square feet.

Hydraulic conductivities for the bedrock formations are summarized in Table 4-8. Because claystone underlies most of the landfill, a hydraulic conductivity representative of claystone is used. Two hydraulic conductivities for claystone are available: 5.7×10^{-7} cm/s from well 8-86; and 6.7×10^{-7} cm/s from well 41-87BR. The geometric mean of these values is 6.2×10^{-7} cm/s. This is a measurement of the horizontal hydraulic conductivity. Freeze and Cherry (1979) state that in general

vertical permeabilities are less than horizontal, but that the ratio of horizontal to vertical hydraulic conductivities is usually less than three.

As shown below, estimate discharge into the bedrock formations vary from 32,000 to 237,000 cubic feet of water per year.

EXPECTED DISCHARGE (ft^3/yr) FROM LANDFILL

Hydraulic Conductivity (cm/s) (ft/ft)	Downward Hydraulic Gradient	
	.2	.5
6.2×10^{-7} |	95,000	237,000
2.1×10^{-7} |	32,000	80,000

Discharge from the landfill into the Landfill Pond is composed of two components. Ground-water flow along the thin alluvial toe at the base of the landfill, and surface water flow from seepage at the base of the landfill.

Because there is insufficient data to estimate a hydraulic gradient across the alluvial material at the base of the landfill, this rate of discharge cannot be estimated.

On June 16, 1988 the flow of the seepage was measured with a Baski Cutthroat flume. The measured flow rate was 2.2 gallons per minute. Although this landfill seepage is a recent phenomenon (first noticed in April, 1988), it is assumed this represents a stable discharge rate. Based on this rate, the landfill is discharging 155,000 cubic feet of water per year.

Total discharge of ground water from the landfill is estimated at a range of 187,000 to 392,000 cubic feet of ground water per year. Not included in either of these values is the unknown discharge within the alluvium at the base of the landfill.

4.3.2 Performance of the Proposed Cap

The primary function of the proposed cap will be a reduction in the recharge from incident precipitation. As discussed above, the estimated rate of recharge from incident precipitation ranges from 24,000 to 152,000 cubic feet per year. This will be reduced to the 1,000 cubic feet per year estimated in Section 4.2.8 of the closure plan.

While water levels can be expected to drop with the installation of the proposed cap, some water will remain in the landfill. As concluded in Section 4.3.1, the landfill is probably not hydraulically isolated from the alluvial ground-water flow system; therefore, a component ground-water recharge can be expected. Essential for keeping water levels low in the landfill is the ability to remove ground water from the eastern end.

4.3.3 Performance of the Proposed Leachate Collection System

The proposed leachate collection system is designed to collect leachate at the low end of the landfill at expected rates of less than one gallon per minute (Closure Plan, Section 5.2.4). Currently the seepage at the low of the landfill is discharging at 2.2 gallons per minute. This should be reduced with the installation of the proposed cap.

NOTICE

This document (or documents) is oversized for 16mm microfilming, but is available in its entirety on the 35mm fiche card referenced below:

Document # 000292

Titled: Plate 4-1: Landfill Area Monitor Well Locations and Collection Systems

Fiche location: A-SW-M13

NOTICE

This document (or documents) is oversized for 16mm microfilming, but is available in its entirety on the 35mm fiche card referenced below:

Document # 000292

Titled: Plate 4-2 : Landfill Area, Surficial Geology Map

Fiche location: A-SW-M13

NOTICE

This document (or documents) is oversized for 16mm microfilming, but is available in its entirety on the 35mm fiche card referenced below:

Document # 000292

Titled: Plate 4-3: Landfill Area Cross Section Location Lines and Subcropping Sandstone (Plain View) Map

Fiche location: A-SW-M13

NOTICE

This document (or documents) is oversized for 16mm microfilming, but is available in its entirety on the 35mm fiche card referenced below:

Document # 000292

Titled: Plate 4-4 : Landfill Area Cross Section A-A'

Fiche location: A-SW-M13

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Document # 000292

Titled: Plate 4-5: Landfill Area Cross Sections B-B', & C-C'

Fiche location: A-SW-M13

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Document # D00292

Titled: Plate 4-6: Landfill Area Cross Section D-D' & E-E'

Fiche location: A-SW-M14

NOTICE

This document (or documents) is oversized for 16mm microfilming, but is available in its entirety on the 35mm fiche card referenced below:

Document # 000292

Titled: Plate 4-7: Water Table Elevations at the Present Landfill for January 1988

Fiche location: A-SW-M14

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Document # 000292

Titled: Plate 4-8 : Water Table Elevation at the Present Landfill For APRIL 1988

Fiche location: A-SW-M14

SECTION 5

SURFACE WATER CHARACTERIZATION

The Present Landfill area is drained by an eastward flowing unnamed tributary to North Walnut Creek. A landfill retention pond, also known as the east pond, is located downstream of the Present Landfill on the unnamed tributary. The pond was designed to receive surface and subsurface flow from the landfill. The unnamed tributary joins North and South Walnut Creek approximately 0.7 miles downstream of the eastern edge of the Plant security area before flowing into Great Western Reservoir approximately one mile east of the confluence.

5.1 SURFACE WATER FLOW--UNNAMED TRIBUTARY TO WALNUT CREEK

During August 1986, as part of the initial Rocky Flats Plant site characterization (Rockwell, 1986a), flow rates were measured in all of the site natural drainages and ditches using either a portable cut-throat flume or the Parshall flumes used for NPDES monitoring. Surface water monitoring stations are shown on Plate 5-1. Flow rates were not measured during 1987 surface water sampling.

Three surface water stations were established on the unnamed tributary of Walnut Creek draining the area near the Present Landfill. These stations are SW-10 (upgradient of the landfill), SW-13 (upstream of the landfill retention pond), SW-14 (immediately downstream of the landfill retention pond), and SW-15 (immediately upstream of the confluence with North Walnut Creek). There was no flow in the tributary at these stations in late August 1986. Flow in the tributary is seasonal and

is dependent upon precipitation and ground-water flow. The landfill pond, however, was sampled.

The landfill pond is essentially recharged by ground water and surface runoff from the landfill located upgradient. The potentiometric surface maps (Plates 4-7 and 4-8) indicate flow from the landfill is in an easterly direction toward the landfill retention pond. The potentiometric surface maps also indicate the water table is at or near the retention pond water elevation.

Ground water at the north and south hillsides of the landfill above the pond locally flows toward the pond. Water loss from the retention pond consists of natural evaporation which is enhanced by spraying water through fog nozzles and spray irrigation over the pond and on the hill to the south of the pond. The pond does not directly discharge to the drainage downgradient.

5.2 WATER QUALITY

Surface water quality data collected to date consist of samples collected in August 1986 and September 1987 from the landfill pond (Table 5-1), and historical data (Appendix D). Historical data are discussed in Section 5.3. The 1986 and 1987 samples were analyzed for HSL volatile organics, semi-volatiles, pesticide/PCBs, major ion inorganics, metals, and radionuclides.

Background surface water quality at the Rocky Flats Plant has not been thoroughly characterized; however, for the purpose of characterizing surface water downgradient of the Solar Ponds, the chemistry of the surface water quality is compared to local alluvial groundwater quality and health based water quality

Table 5-1

SURFACE WATER SAMPLE INFORMATION

LANDFILL SURFACE WATER STATIONS

STATION NUMBER	SAMPLE INFORMATION			FIELD PARAMETERS			LABORATORY BATCH NUMBERS					
	NUMBER	DATE	TYPE	pH	CONDUCT (umho/cm)	TEMP (deg C)	VOLATILE ORGANICS	SEMI-VOL ORGANICS	PESTICIDES AND PCB'S	METALS	INORGANICS	RADIO-CHEMISTRY
SW03	SW03088600	08/20/86	Routine	6.80	350	20.0	8608-044-021	8608-064-004	8608-064-004	8608-044-022	8608-044-023	1000-000-369
SW13	DRY	08/11/86										
SW14	DRY	08/12/86										
SW15	DRY	08/12/86										
SWLFP	SWLFP08860	08/14/86	Routine	7.50	830	21.0	8608-029-025	8608-055-005	8608-055-005	8608-029-027	8608-029-028	1000-000-405

criteria. The water quality criteria examined are The Safe Drinking Water Act (SDWA) Maximum Contaminant Levels (MCLs), and the Colorado Department of Health (CDH) in-stream standards for tributaries to Great Western Reservoir. These surface water quality criteria are presented in Table 5-2. Where an MCL and an in-stream standard both exist for an analyte, it is noted that they are equivalent. It is further noted that a discharge to the drainage is necessary for these criteria to be considered enforceable. They are presented here merely to provide perspective for the water quality observed at the Rocky Flats Plant.

HSL volatile organics, semi-volatiles, and pesticide/PCBs were not detected in the 1986 and 1987 landfill pond samples. As shown in Table 5-3, radionuclide concentrations were detected but did not exceed the water quality criteria. The only trace metals exceeding the surface water quality criteria were manganese and iron. Total dissolved solids (TDS) also exceeded the surface water quality criterion. Elevated TDS, iron and manganese are typical of landfill leachate.

Table 5-3 also provides a comparison to surface water concentrations to ground-water alluvial concentrations upgradient of the landfill retention pond quality criteria. Ground-water chemistry is fully discussed in Section 4. The results of this comparison are discussed below.

The most notable difference between the water quality in the landfill pond and the ground water within the landfill is the relatively higher concentrations of magnesium, sodium, potassium, chloride, and TDS. This may be due to the leaching of these constituents from the soils south of the pond because of the spraying activities. Other analyte concentrations are similar in the pond and upgradient ground water. It would appear based on chemistry that interconnection of the ground

TABLE 5-2

SURFACE WATER QUALITY CRITERIA

METALS Analyte	CDH Water Quality Limited Standard (mg/l)	SDWA MCL (mg/l)	Water Quality Criteria (to be applied to Rocky Flats Plant site)
Aluminum	0.95		0.95 mg/l
Antimony			NS
Arsenic	0.05	0.05	0.05 mg/l
Barium	1.0	1.0	1.0 mg/l
Beryllium	0.1		0.1 mg/l
Cadmium	0.01	0.01	0.01 mg/l
Chromium III	0.05		0.05 mg/l
Chromium VI	0.05	0.05	0.05 mg/l
Cobalt			NS
Copper	1.0		1.0 mg/l
Lead	0.05	0.05	0.005 mg/l
Iron	0.3		0.3 mg/l
Manganese	0.05		0.05 mg/l
Mercury	0.002	0.002	0.002 mg/l
Molybdenum			NS
Nickel	0.05		0.05 mg/l
Selenium	0.01	0.01	0.01 mg/l
Silver	0.05	0.05	0.05 mg/l
Strontium			NS
Thallium	0.015		0.015 mg/l
Vanadium			NS
Zinc	5.0		5.0 mg/l

TABLE 5-2
(CONTINUED)

SURFACE WATER STANDARDS AND CRITERIA

RADIONUCLIDES Analyte	CDH Water Quality Limited Standard (mg/l)	SDWA MCL (mg/l)	Water Quality Criteria (to be applied to Rocky Flats Plant site)
Gross Alpha		15 pCi/l	15 pCi/l
Gross Beta		50 pCi/l	50 pCi/l
$Pu^{238, 239, 240}$		40 pCi/l*	40 pCi/l
Am^{241}		4 pCi/l*	4 pCi/l
H^{3}		20000 pCi/l	20000 pCi/l
Uranium total			40** pCi/l
Major Ions			
pH	6.5-9.0		6.5-9.0
Nitrate	10.0		10.0 mg/l
Chloride	250		250 mg/l
Sulfate	250		250 mg/l
Cyanide (total)	0.200		0.200 mg/l
TDS		500***	500*** mg/l

* Proposed value in drinking water yielding a risk equal to that from a dose rate of 4 mrem/yr. September 30, 1986 (51FR34859).

** CDH Water Quality Standard for Surface Water [5CCR 1002-8, Section 3.8.5(3)]

*** SDWA Secondary Maximum Concentration Limit (SMCL)

NS = No standard

TABLE 5-3

ANALYTE CONCENTRATIONS IN LANDFILL POND COMPARED TO SURFACE WATER CRITERIA AND UPGRADIENT GROUND WATER CHEMISTRY

Analyte	Surface Water Concentration Range •	Upgradient Ground Water Concentration Range ••	Surface Water Quality Criteria
METALS (mg/l)			
Silver	<0.01	<0.01	0.05
Aluminum	0.120-0.704	.029-.051	0.95
Arsenic	<0.01	<0.005	0.05
Barium	<0.1-.58	0.15-0.25	1.00
Beryllium	<0.005	<0.005	0.1
Cadmium	<0.005	<0.001	0.01
Cobalt	<0.05	<0.02-.03	NS
Chromium	0.011-0.019	<0.01-.03	0.05
Cesium	<0.2	<0.02	NS
Copper	<0.02	<0.006-.057	1.0
Iron	<0.03-2.3	0.047-.950	0.3
Mercury	<0.0002-0.00063	<0.0002	0.002
Mangenese	0.06-0.42	.64-1.6	0.05
Molybdenum	<0.1	<0.02-.36	NS
Nickel	<0.04	<.037-.044	0.05
Lead	<0.005	<0.005	0.005
Antimony	<0.05	<0.02	NS
Selenium	<0.005	<0.005	0.01
Strontium	0.4-1.05	.20-.69	NS
Thallium	<0.01	<0.01	0.015
Vanadium	<0.024	<0.024	NS
Zinc	<0.02-.89	.05-.11	5.0
MAJOR IONS (mg/l)			
Calcium	40-100	32-123	NS
Magnesium	21-75	5-15	NS
Sodium	75-226	19-33	NS
Potassium	9-68	3-4	NS
Chloride	91-124	5-26	250
Sulfate	8-52	8-139	250
Bicarbonate	190-402	107-392	NS
Nitrate	<0.2	<0.02-2.12	10
TDS	533-1082	226-519	500

TABLE 5-3 continued

ANALYTE CONCENTRATIONS IN LANDFILL POND COMPARED TO SURFACE WATER CRITERIA AND UPGRADIENT GROUND WATER CHEMISTRY

Analyte	Surface Water Concentration Range *	Upgradient Ground Water Concentration Range **	Surface Water Quality Criteria
RADIONUCLIDES (pCi/l)			
Gross Alpha	0(7)-23(11)	1(4)-17(7)	15
Gross Beta	11(5)-27(22)	-1(12)-16(11)	50
Plutonium	0.00(.97)-0.02(.05)	0.00(.16)-.21(.22)	40
Uranium 233 + 234	0.0(2.0)-1.1(.2)	0.05(.10)-4.6(.4)	40
Uranium 238	0.00(.55)-1.0(.2)	0.16(.10)-3.6(.3)	40
Americium	0.00(.51)-0.04(.04)	0.00(.09)-0.00(.71)	4
Tritium	110(220)-440	<220-1900	20,000

* Based on August 1986 and September 1987 data
** Based on January 1988 data for wells 63-87, 64-87, and 68-87

water and surface water exists. Further, the potentiometric surface map indicates the water table is at or near the retention pond elevation, and movement of ground water from the landfill is toward the retention pond.

5.3 Summary of Historical Water Quality Data

Appendix D presents historical chemical data for the west and east landfill ponds, landfill seepage, and the ground-water intercept system. The west landfill pond was removed in 1981 to allow eastward expansion of the landfill and was subsequently filled with waste. The east landfill pond is the pond that exists today.

5.3.1 Landfill Ponds

Comparison of the gross alpha, gross beta, tritium, nitrate, pH, total organic carbon (TOC), conductivity, chemical oxygen demand (COD), metals, and TDS data that exist for the west and east ponds show the water quality to be similar. This suggests that the leachate/ground water that entered the west pond also entered the east pond. It is noted that both gross alpha and gross beta exceeded, at times, the water quality criteria in both ponds. Also tritium, at times, was elevated (on the order of 1,000 pCi/l) which would appear to be related to the known disposal of tritium in the landfill. As shown in Table 5-4, tritium concentrations in the west pond during the years 1974 through 1977 are higher than in subsequent years (they are nevertheless below the surface water quality criterion). Gross alpha, gross beta, and tritium were lower during the 1986 sampling of the east pond relative to the historical data. There are inadequate data to interpret the significance of this finding; however, in general there are no apparent historical trends in water quality for the east landfill pond (or west landfill pond with the exception of tritium). The absence of a trend also applies to metal concentrations in both ponds. Lastly, the

TABLE 5-4

TRITIUM ANALYSES - LANDFILL POND NO. 1*

	1974 (pCi/l)	1975 (pCi/l)	1976 (pCi/l)	1977 (pCi/l)
January	-	1143	1740	1365
February	-	1429	1733	922
March	7922	1837	1323	1303
April	-	924	1431	1113
May	-	1445	1121	-
June	5875	984	1172	-
July	4797	1520	1378	-
August	3724	1258	1305	-
September	5056	1777	1143	-
October	3304	1762	869	-
November	1800	1553	1005	-
December	-	1542	1067	-

* Landfill Pond No. 1 = West Pond; Data reproduced verbatim from a file of historical data. Source unknown.

TDS, gross alpha, gross beta, metal, and nitrate concentrations are similar to those observed for ground water within the landfill. It is concluded that future changes in water quality of the east pond or ground water within the landfill are unlikely based on this data.

5.3.2 Landfill Seepage

It would appear that "seepage" from the landfill contained higher metal concentrations and possibly volatile organic compounds that are not observed in the west pond, east pond, or ground water within the landfill. Table 5-5, constructed from a 1973 Dow Chemical Lab report on what was termed "landfill seepage", shows the presence of freon, chloroform, chlorothene, carbon tetrachloride, trichloroethene, and tetrachloroethene. The seepage also contained high concentrations of calcium, magnesium, sodium manganese, and iron relative to that observed in the west or east ponds, or the ground water within the landfill. It would appear this seepage is a concentrated leachate that ultimately mixed with runoff and ground water in the west (and east) ponds producing the water quality seen in the ponds. However, the VOC's have never been observed in the ponds or ground water at the landfill.

As discussed in Section 4, the most significant water quality change in ground water within the landfill is elevated calcium, bicarbonate, iron, and manganese. The seepage has these same characteristics but these compounds are at considerably higher concentrations than observed in the ground water within the landfill. It is conjectured that in the early 1970's there was less water within the landfill and thus current landfill ground water chemical conditions reflect a mixture of ground water and this "leachate".

TABLE 5-5

SANITARY LANDFILL SEEPAGE
CHEMICAL CHARACTERISTICS*

ANALYTE	CONCENTRATION (mg/l)
ORGANICS	
Freon	1.2
Chloroform	0.1
Chloroethene	0.05
Carbon Tetrachloride	0.005
Trichloroethylene	0.50
Perchloroethylene	0.05
Pesticides	0.001
METALS	
Silver	0.005
Aluminum	0.4
Barium	<1
Cadmium	0.001
Cobalt	0.018
Chromium	<0.005
Copper	0.06
Iron	60
Mercury	<0.001
Manganese	3.4
Molybdenum	1.0
Nickel	0.06
Lead	0.008
Antimony	<0.01
Selenium	<0.01
Tin	<0.05
Thallium	<0.0025
Vanadium	<1.0
Zinc	0.061
MAJOR IONS	
Calcium	400
Magnesium	125
Sodium	205
Potassium	8.5
Sulfate	12
Chloride	4.8
Bicarbonate	1670
Total Solids	2400

* Source = Dow Chemical Laboratory Report M73-1752, 01/14/73

5.3.3 Ground-Water Intercept System

Historical gross alpha, tritium, and nitrate data exist for ground water discharging from the north and south ground-water intercept systems (data coded as the north and south landfill bypass). Concentrations of gross alpha and tritium are similar to the concentrations observed for ground water within the landfill. Nitrate concentrations in ground water from the north intercept system (on the order of 3-4 mg/l) are similar to ground water within the landfill; however, nitrate concentrations in ground water for the south interceptor system are higher (on the order of 6-10 mg/l). It is not known why elevated nitrates occur in ground water of the south intercept system but do not occur within the landfill. As discussed in Section 4, ground-water quality within the landfill, which is ostensibly impacted by the landfill, is within the ground-water quality variations observed in the general area. Therefore, this limited data do not provide additional useful information to interpret whether the ground-water intercept system is functioning.

NOTICE

This document (or documents) is oversized for 16mm microfilming, but is available in its entirety on the 35mm fiche card referenced below:

Document # 000292

Titled: Plate 5-1; Surface Water and Sediment Monitoring Locations

Fiche location: A-SW-M14

SECTION 6

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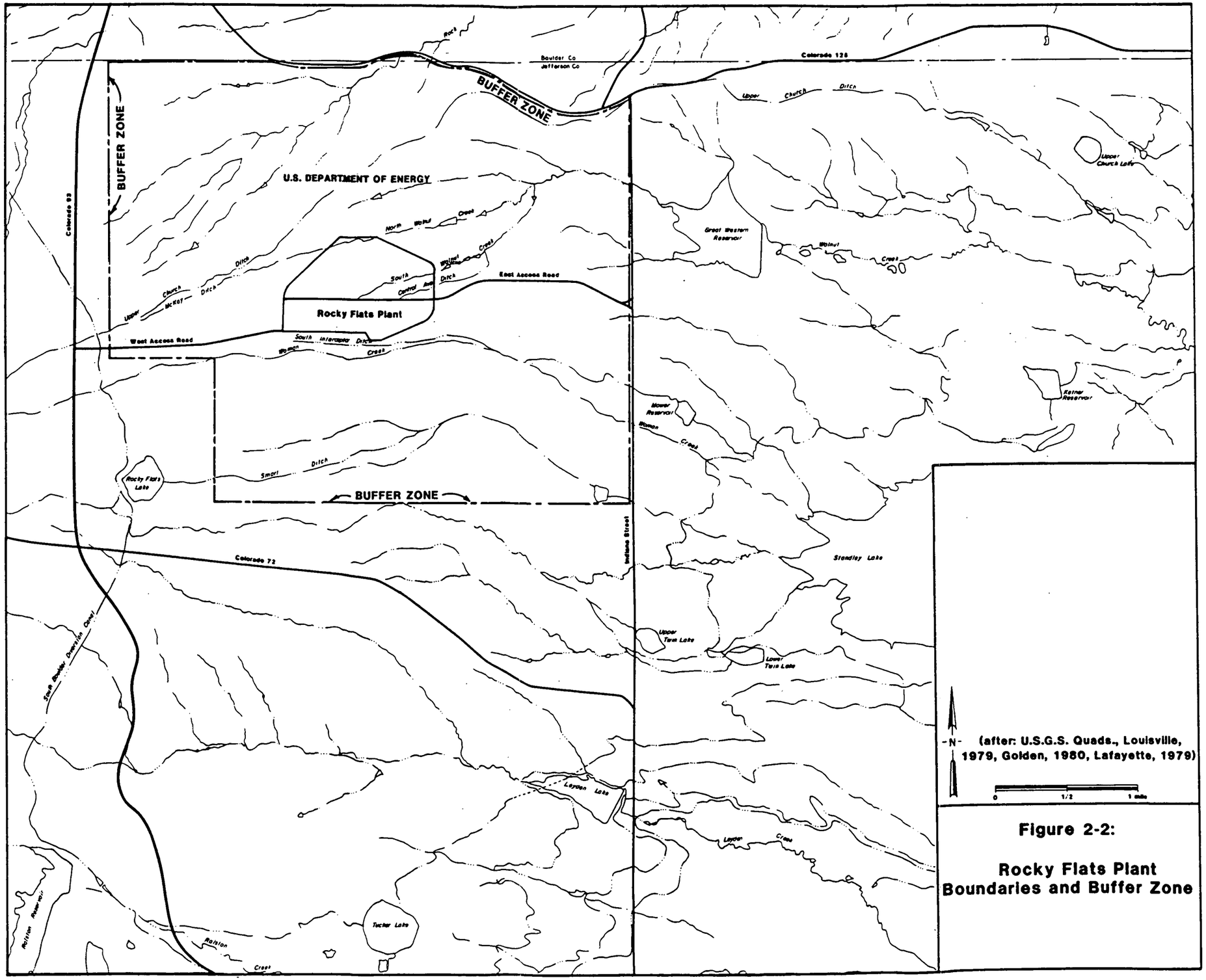
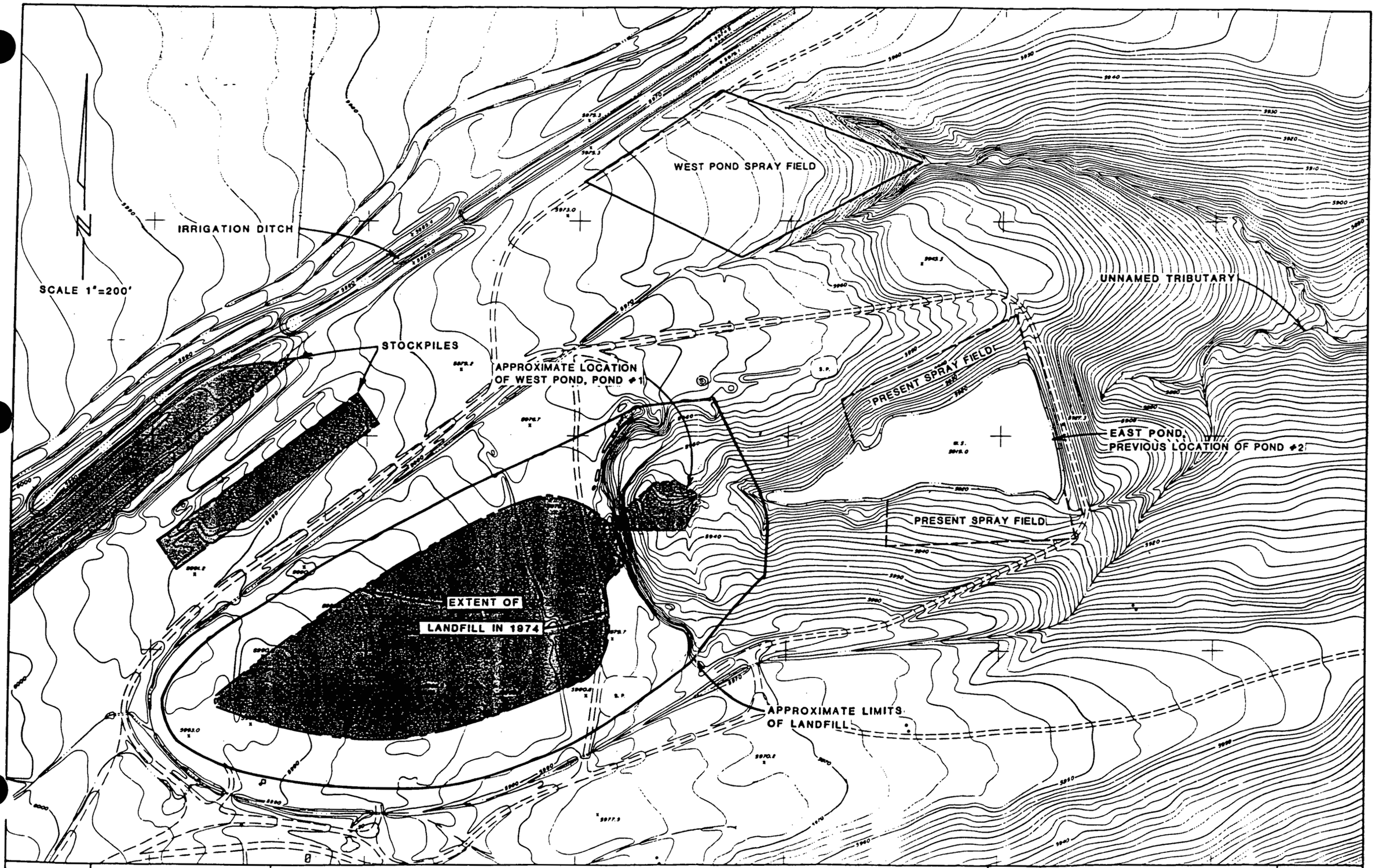
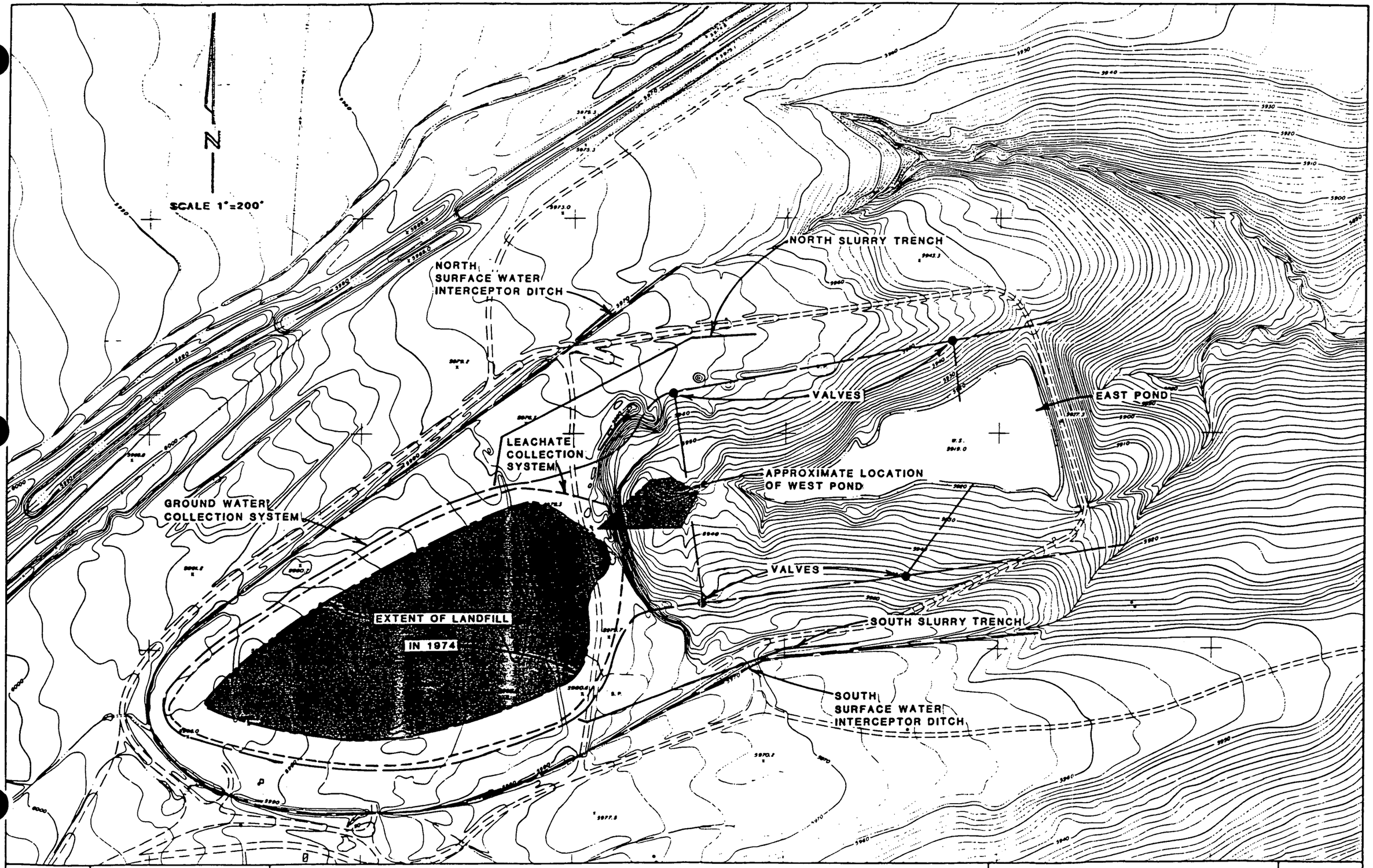


Figure 2-2:

Rocky Flats Plant Boundaries and Buffer Zone



6 032 88	Chen & Associates		PRESENT LANDFILL SITE MAP	Fig. 2-3



6 032 88	Chen & Associates		PRESENT LANDFILL COLLECTION SYSTEMS	Fig. 2-4

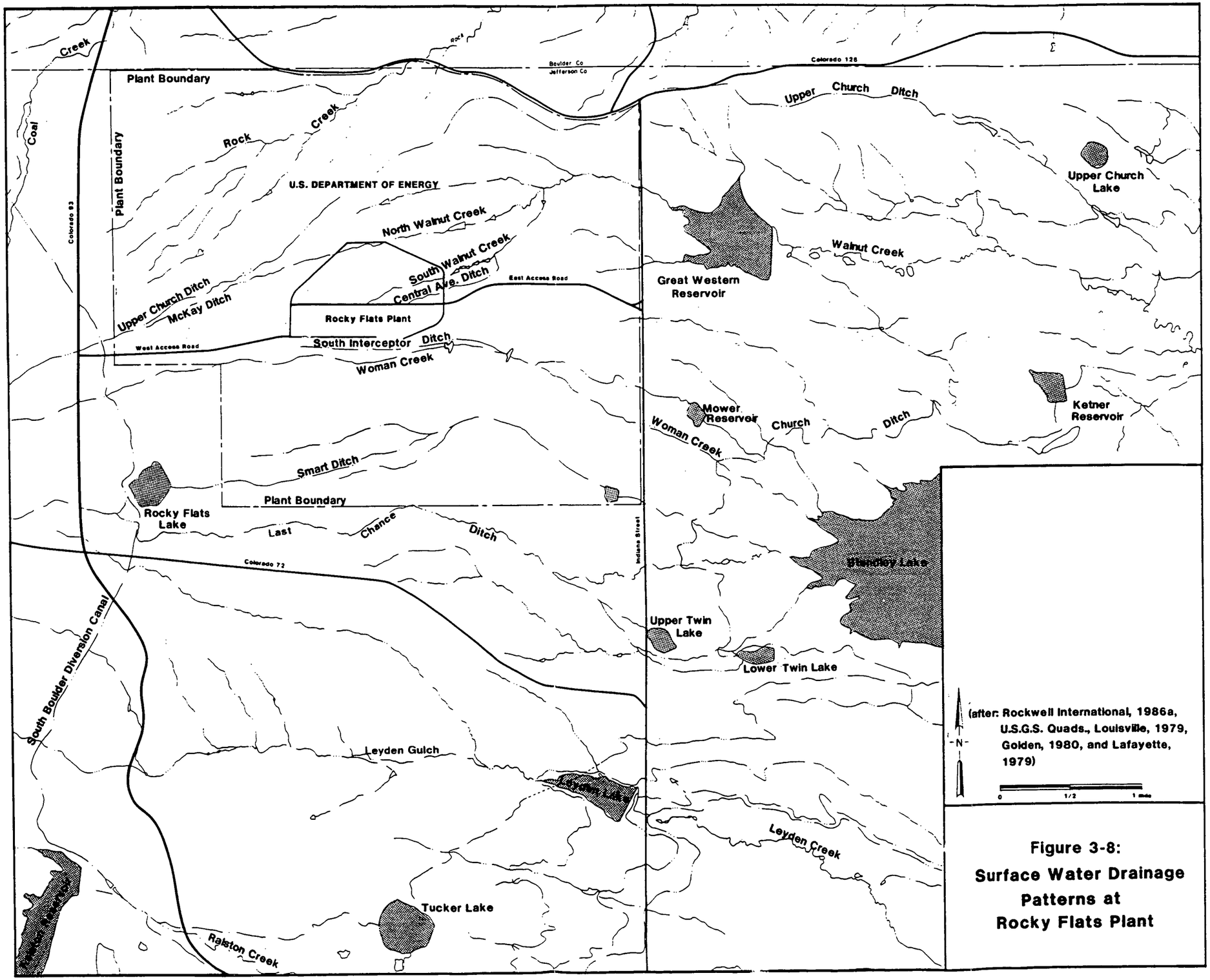


Figure 3-8:
Surface Water Drainage Patterns at Rocky Flats Plant

Resource Conservation and Recovery Act

Post-Closure Care Permit Application

For U.S.D.O.E.-Rocky Flats Plant
Hazardous & Radioactive Mixed Wastes

CO7890010526

5 October 1988

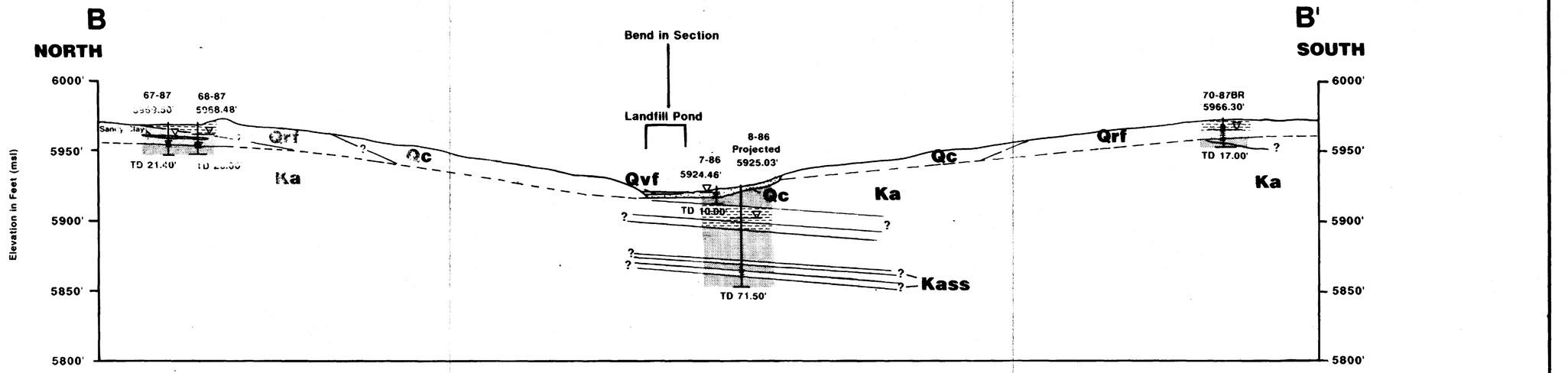
Volume X

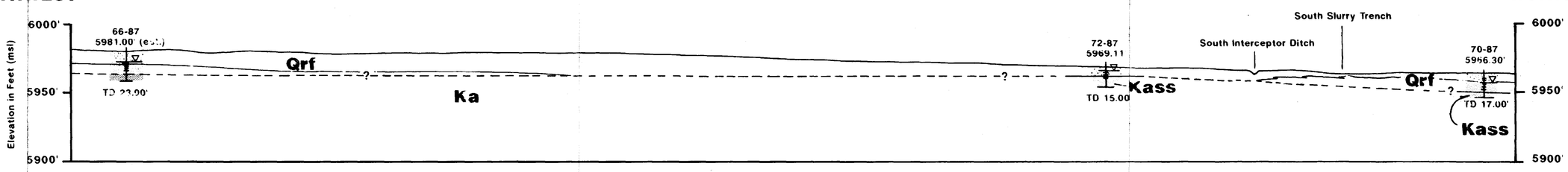
[redacted]

ADMIN RECORD

REVIEWED FOR CLASSIFICATION/UCNI
By
Date 4/1/92

A-SW-000292





EXPLANATION

Scale

50 feet — 0 — 50 feet

No Vertical Exaggeration

41-87
5931.56'
TD 110.00'

Well Identification
Ground Surface Elevation (Surveyed)
Water Level (Measured 4/11/88)
Geologic Contact (dashed where inferred)
Screened Interval
Total Depth Drilled

QUATERNARY

- Qc — Colluvium
- Qd — Disturbed Ground
- Qrf — Rocky Flats Alluvium
- Qvf — Valley Fill Alluvium

CRETACEOUS

- Ka — Arapahoe Formation (Claystone)
- Kass — Arapahoe Formation (Sandstone & Siltstone)

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

NOTE: 1986 Well locations resurveyed during 1988.
This plate reflects new locations and elevations.

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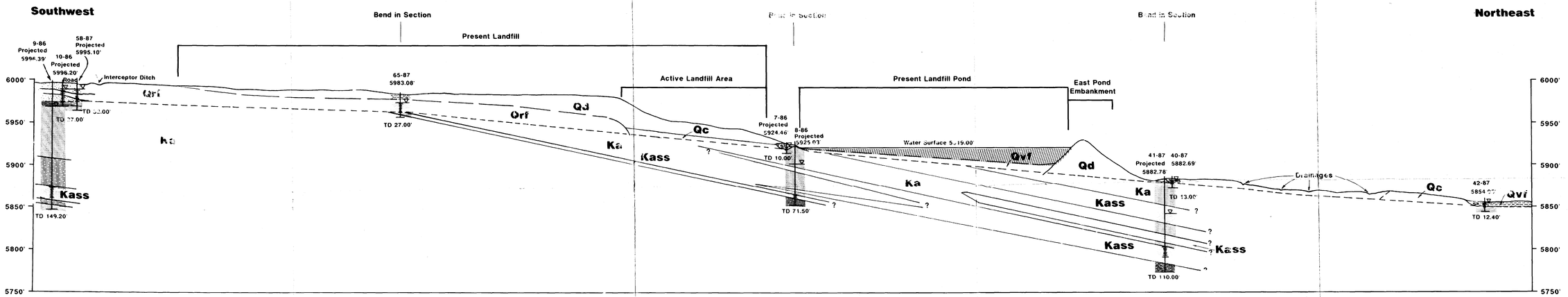
ROCKWELL INTERNATIONAL
Rocky Flats Plant
Golden, Colorado

Plate 4-5

Landfill Area

CROSS SECTIONS B-B' & C-C'

July, 1988



EXPLANATION

Scale
50 feet
0
100 feet
Vertical Exaggeration 2X

41-87
5931.56'
TD 110.00'

Well Identification
Ground Surface Elevation (Surveyed)
Water Level (Measured 4 11 88)
Geologic Contact (dashed where inferred)
Screened Interval
Total Depth Drilled

QUATERNARY
- Qc Colluvium
- Qd Disturbed Ground
- Qrf Rocky Flats Alluvium
- Qvf Valley Fill Alluvium

CRETACEOUS
- Ka Arapahoe Formation (Claystone)
- Kass Arapahoe Formation (Sandstone & Siltstone)

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

NOTE: 1986 Well locations resurveyed during 1988.
This plate reflects new locations and elevations.

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ROCKWELL INTERNATIONAL
Rocky Flats Plant
Golden, Colorado

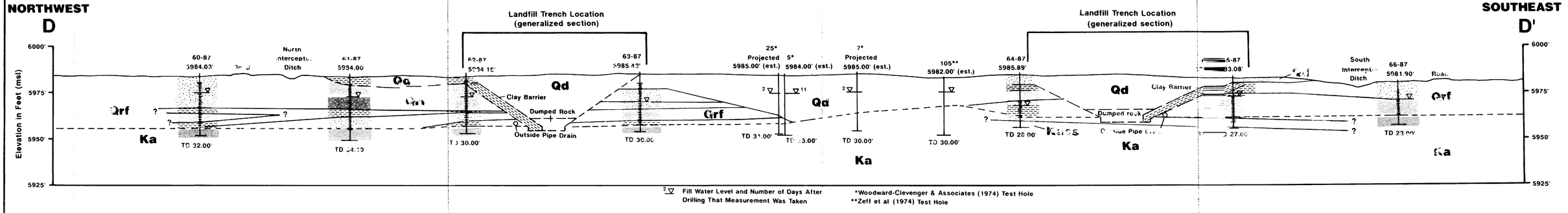
Plate 4-4

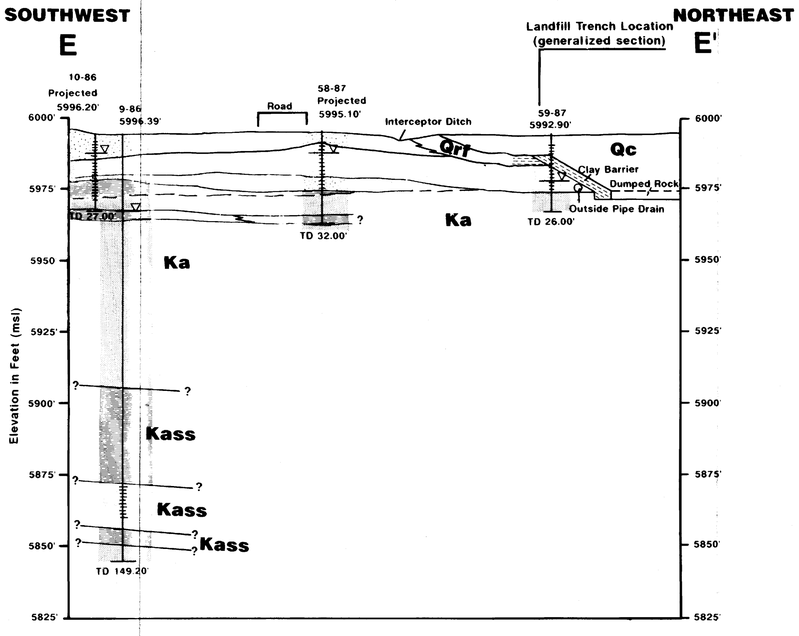
Landfill Area

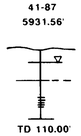
CROSS SECTION A-A'

July, 1988

SW-A-000292





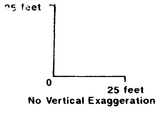


41-87 Well Identification
5931.56' Ground Surface Elevation (Surveyed)
Water Level (Measured 4/11/88)
Geologic Contact (dashed where inferred)
Screened Interval
TD 110.00' Total Depth Drilled

QUATERNARY
- Qc Colluvium
- Qd Disturbed Ground
- Qrf Rocky Flats Alluvium
- Qvf Valley Fill Alluvium

CRETACEOUS
- Ka Arapahoe Formation (Claystone)
- Kass Arapahoe Formation (Sandstone & Siltstone)

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



NOTE: 1986 Well locations resurveyed during 1988.
This plate reflects new locations and elevations.

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Plate 4-6

Landfill Area

CROSS SECTION D-D' &E-E'

July, 1988

SW-A-000292

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(303)-988-6802

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ROCKY FLATS PLANT
GOLDEN, COLORADO

PLATE 4-7:

WATER TABLE ELEVATIONS AT THE PRESENT LANDFILL FOR JANUARY 1988

CONTOUR INTERVAL = 10 FT

SCALE 1 INCH = 100 FT

28 JUNE 1988

EXPLANATION

- 1086 ⊙ 14.17 — MONITOR WELL LOCATION, WELL IDENTIFICATION, AND ELEVATION OF WATER TABLE (FEET ABOVE MSL).
- △ — ELEVATION OF EPHEMERAL STREAM
- □ — WATER SURFACE ELEVATION
- 5000 — LINES OF EQUAL WATER TABLE ELEVATION (FEET ABOVE MSL).
- HATCHURE LINES INDICATE FLOW DIRECTION.
- **Areas of Unsaturated Surficial Materials**

SW-A-000290

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(303)-980-6800

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ROCKY FLATS PLANT
GOLDEN, COLORADO

PLATE 4-8:

WATER TABLE ELEVATIONS AT THE PRESENT LANDFILL FOR APRIL 1988

CONTOUR INTERVAL = 10 FT
SCALE 1 INCH = 100 FT
28 JUNE 1988

EXPLANATION

1086 ○ 15.2 — MONITOR WELL LOCATION, WELL IDENTIFICATION, AND ELEVATION OF WATER TABLE (FEET ABOVE MSL).

△ — ELEVATION OF EPHEMERAL STREAM

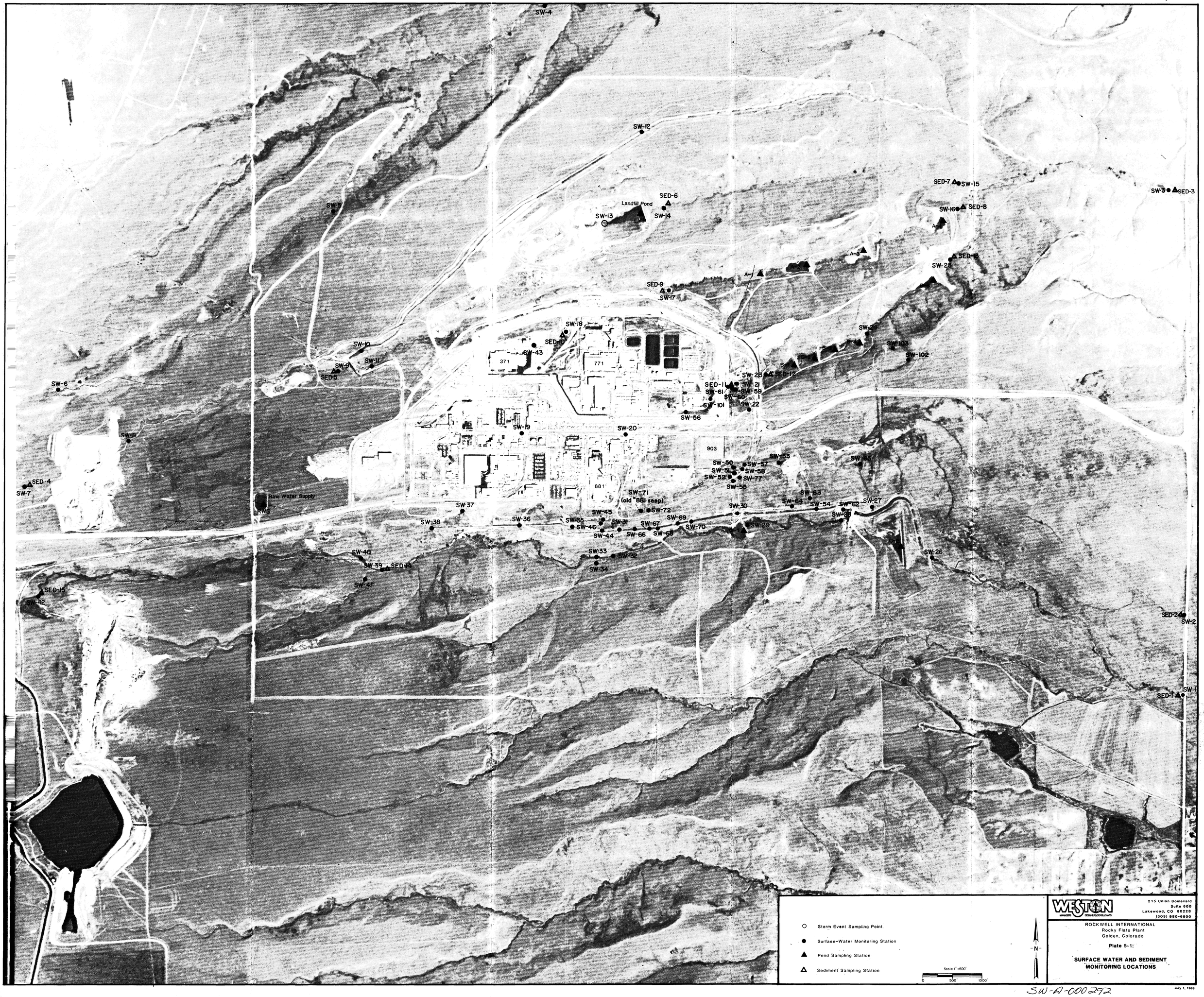
□ — WATER SURFACE ELEVATION

5000 — LINES OF EQUAL WATER TABLE ELEVATION (FEET ABOVE MSL).

HATCHURE LINES INDICATE FLOW DIRECTION.

Areas of Unsaturated Surficial Materials

SW-A-000292


SW-4
SW-12
SED-6
Landfill Pond
SW-13
SW-14
SED-7
SW-15
SW-3
SED-3
SW-16
SED-8
SW-1
A-3
SED-13
SW-28
SED-9
SW-17
SW-18
SED-10
SW-43
SW-10
SW-11
SW-9
SED-5
SW-6
SW-8
SW-29
SW-103
SW-102
SED-12
SW-21
SW-59
SW-60
SW-101
SW-22
SW-56
SED-11
SW-61
SW-19
SW-20
371
771
903
881
SW-50
SW-57
SW-51
SW-58
SW-52
SW-77
SW-55
SW-53
SW-54
SW-63
SW-64
SW-62
SW-27
SW-30
SW-23
SW-71
(old "881 seep)
SW-72
SW-45
SW-46
SW-44
SW-31
SW-67
SW-66
SW-68
SW-69
SW-70
SW-37
SW-38
SW-36
SW-35
SW-40
SW-39
SED-14
SW-41
SW-33
SW-32
SW-34
SED-4
SW-7
Raw Water Supply
RWS
SED-15
SW-42
SW-26
SED-2
SW-2
SED-1
SW-5
Storm Event Sampling Point
Surface-Water Monitoring Station
Pond Sampling Station
Sediment Sampling Station
Scale 1"=500'
0
500'
1000'
N
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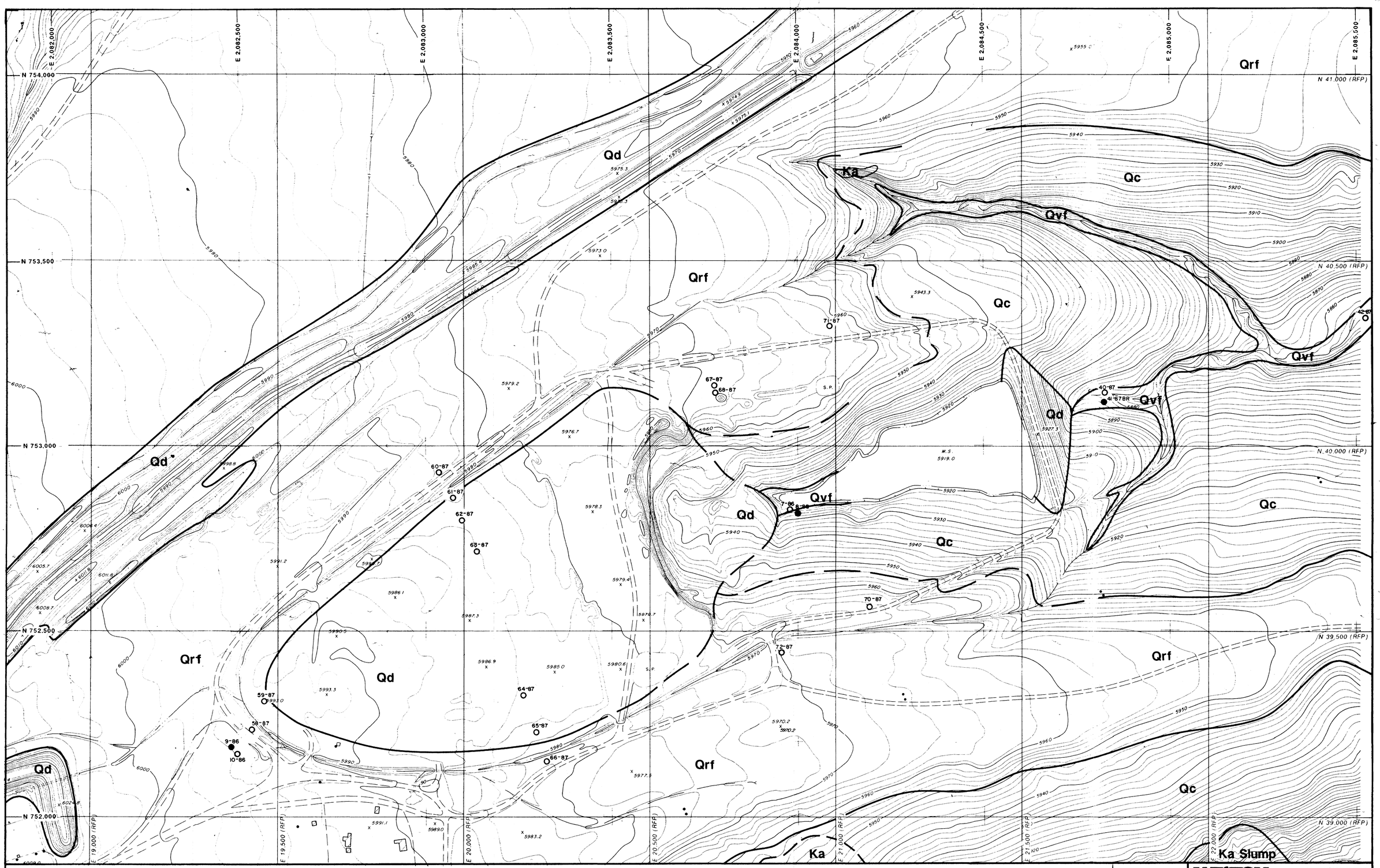
Rocky Flats Plant
Golden, Colorado
Plate 5-1:
SURFACE WATER AND SEDIMENT
MONITORING LOCATIONS
July 1, 1988

SW-A-000292



EXPLANATION

- 64-87 — Alluvial Monitor Well
- 65-87BR — Bedrock Monitor Well
- Borehole Locations

Cretaceous

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

Quarternary

- Qaf — Artificial Fill
- Qc — Colluvium
- Qd — Disturbed Ground
- Qrf — Rocky Flats Alluvium
- Qvf — Valley Fill Alluvium

-N-

Scale: 1"=100'

100 0 100

Contour interval = 2 feet

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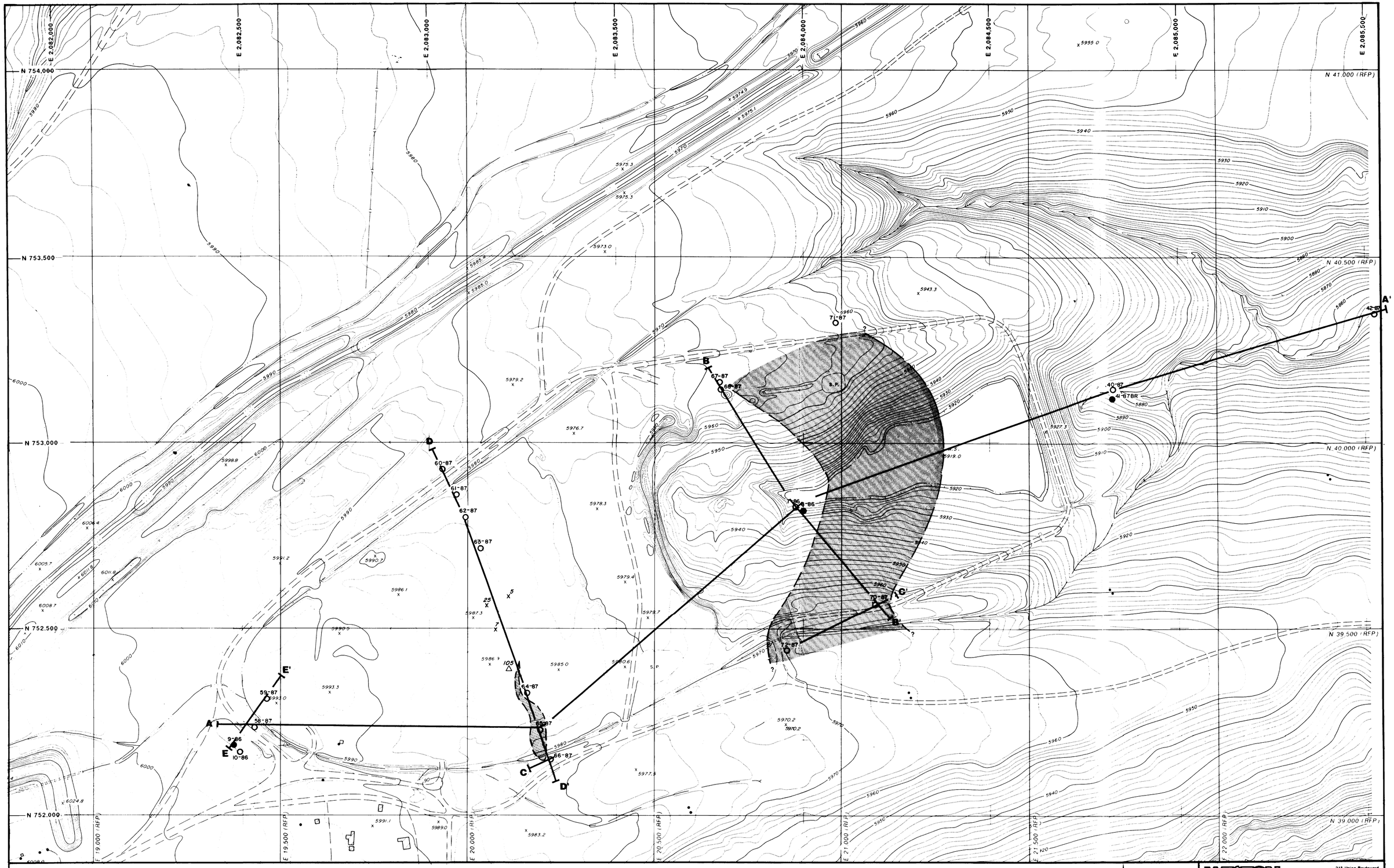
Plate 4-2

Landfill Area
SURFICIAL GEOLOGY MAP

July, 1988

SW-A-000292



EXPLANATION

- 64-87 — Alluvial Monitor Well
- 9-86 — Bedrock Monitor Well
- 7 — Woodward-Clevenger and Associates (1974) Test Hole
- 105 — Zeff et al, (1974) Test Hole
- Line of Section
- Subcropping Sandstone (estimated extent)

N

Scale: 1"=100'

100 0 100

Contour Interval = 2 feet

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Golden, Colorado

Plate 4-3

Landfill Area

CROSS SECTION LOCATION LINES AND SUBCROPPING SANDSTONE (Plan View) MAP

July 1987

E 2,082,000 E 2,082,500 E 2,083,000 E 2,083,500 E 2,084,000 E 2,084,500 E 2,085,000 E 2,085,500

N 754,000 N 753,500 N 753,000 N 752,500 N 752,000

N 41,000 (RFP) N 40,500 (RFP) N 40,000 (RFP) N 39,500 (RFP) N 39,000 (RFP)

E 19,000 (RFP) E 19,500 (RFP) E 20,000 (RFP) E 20,500 (RFP) E 21,000 (RFP) E 21,500 (RFP) E 22,000 (RFP)

North Slurry Trench

South Slurry Trench

Approximate Location of West Pond (removed in 1981)

Outlet-inside pipe drain

Interceptor Ditch 3' deep

Approximate Limits of Present Landfill

Center Line of Trench

Landfill Extent (1974)

Top Of Trench

Outside Pipe Drain

Bop Of Trench

Valves

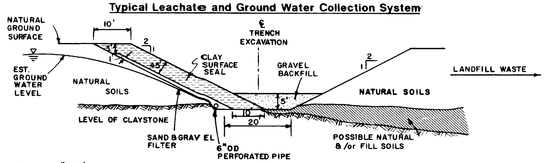
W.S. 5919.0

60-87 61-87 62-87 63-87 64-87 65-87 66-87 67-87 68-87 69-87 70-87 71-87 72-87 7-86 8-86 9-86 10-86 40-87 41-87BR 42-87

D D' E E'

10' 10' 10' 2:1 2:1 2:1

Typical Leachate and Ground Water Collection System



SCALE : 1"=20'

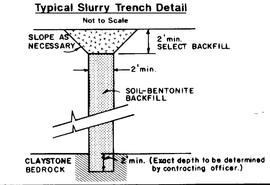
Reference: Rockwell International, 1986, closure Plan, Present Landfill

EXPLANATION

- 64-87 — Alluvial Monitor Well
- 65-87BR — Bedrock Monitor Well
- Borehole Locations
- Line of Section
- Interceptor Ditch
- Trench
- 6" OD Perforated Pipe
- Valves
- Center Line of Trench
- Present Landfill Limit
- 1974 Landfill Limit
- Location of West Pond (removed in 1981)

Typical Slurry Trench Detail

Not to Scale



N

Scale: 1"=100'

100 0 100

Contour Interval = 2 feet

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Plate 4-1

Landfill Area
MONITOR WELL LOCATIONS AND COLLECTION SYSTEMS

July, 1988

SW-A-000292

NOTICE

THIS FILE CONTAINS

DRAWINGS WHOSE

CONDITION AND / OR SIZE

PREVENTED THEM FROM

BEING SCANNED.