NOTICE

All drawings located at the end of the document.

BACKGROUND GEOCHEMICAL CHARACTERIZATION REPORT

U.S. DEPARTMENT OF ENERGY

Rocky Flats Plant
Golden, Colorado

9 OCTOBER 1989

Rockwell International
Aerospace Operations
Rocky Flats Plant

Volume I - Text

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1 0 INTRODUCTION

1 1 BACKGROUND

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

Preliminary hydrogeological and hydrogeochemical characterizations of the entire Rocky Flats Facility were performed in 1986 as part of the initial ER site characterization Results of that investigation are presented in the RCRA Part B Permit Application for the Rocky Flats Plant Analysis of these data has identified four priority areas which are the most probable sources of environmental contamination, with each area containing several sites The priority areas are the 881 Hillside Area, the 903 Pad Area, the Mound Area, and the East Trenches Area

Remedial investigation and feasibility study plans for the priority areas were submitted to EPA and CDH in February 1987 Draft remedial investigations (RI) and feasibility study (FS) reports for the high priority sites (881 Hillside Area) were submitted to EPA and CDH in March 1988 Phase I field activities were completed in the 903 Pad, Mound and East Trenches Areas during 1987, and a draft RI report was submitted to EPA and CDH in December 1987 A draft Phase II RI Work Plan for the 903 Pad, Mound and East Trenches Areas was submitted to EPA and CDH in June 1988 Owing to the tight schedules mandated by the Compliance Agreement, sufficient background characterization data have not been collected Therefore, the remedial investigation and feasibility study reports for the priority areas will be finalized using the background chemistry data developed in this report

1 2 PURPOSE

1 2 1 Overall Purpose

Representative background analytical data are necessary for meaningful interpretations of RCRA ground-water monitoring and CERCLA remedial investigation (soils, bedrock, surface water and ground water) analytical results Background data will assist in the evaluation of environmental degradation by determining naturally-occurring spatial and temporal variability of a constituent Background data can then be compared statistically with data from a downgradient site to determine the likelihood that a particular concentration of chemicals represents a release from the facility

This document presents the results of the characterization of background ground-water, surface water and sediment chemistry at the Rocky Flats Plant The tolerance intervals calculated for each parameter will be used for comparative purposes to detect releases to ground-water or surface water from RCRA and/or CERCLA sites

1 2 2 Monitoring Objectives

Specific objectives have been developed to achieve program goals Monitoring objectives are to determine

1) Average Conditions -- Central tendencies and variability over time (water) and space (stream sediment and water) at background and downgradient stations,

2) Regulatory Compliance -- Determine whether a release has occurred from a particular unit and whether a regulatory limit or standard, i e, CERCLA applicable or relevant and appropriate requirement (ARAR) or RCRA ground-water protection standard, is being exceeded at background or downgradient stations or RCRA compliance points, and

3) Changing Conditions -- Detect and measure trends at monitoring stations over time

1 3 GENERAL APPROACH

In order to develop representative background data that achieves the stated monitoring objectives, sufficient samples have been collected to characterize background variation spatially across the Rocky Flats area The current report is based on results of one round of ground water and sediment sampling and two rounds of surface water sampling Temporal variation of background values over time is also being characterized for ground water and surface water The background characterization will be revised to incorporate additional data as it becomes available In order to compare background and downgradient chemistry, background data is being obtained by using the same sampling and analytical procedures used to collect and analyze RCRA and CERCLA samples

The background data set will then be compared to downgradient data to identify samples which are significantly different from the background population For surface water and ground water, changes in constituent concentrations over time at a station will also be assessed to identify potential contaminant releases

SECTION 2 0

GEOLOGIC & HYDROLOGIC SETTING

2 1 REGIONAL GEOLOGY

This section describes the regional geology in the vicinity of the Rocky Flats Plant Section 2 2 describes the site specific geology and stratigraphy of the plant area and Section 2 3 discusses the site surface water hydrology

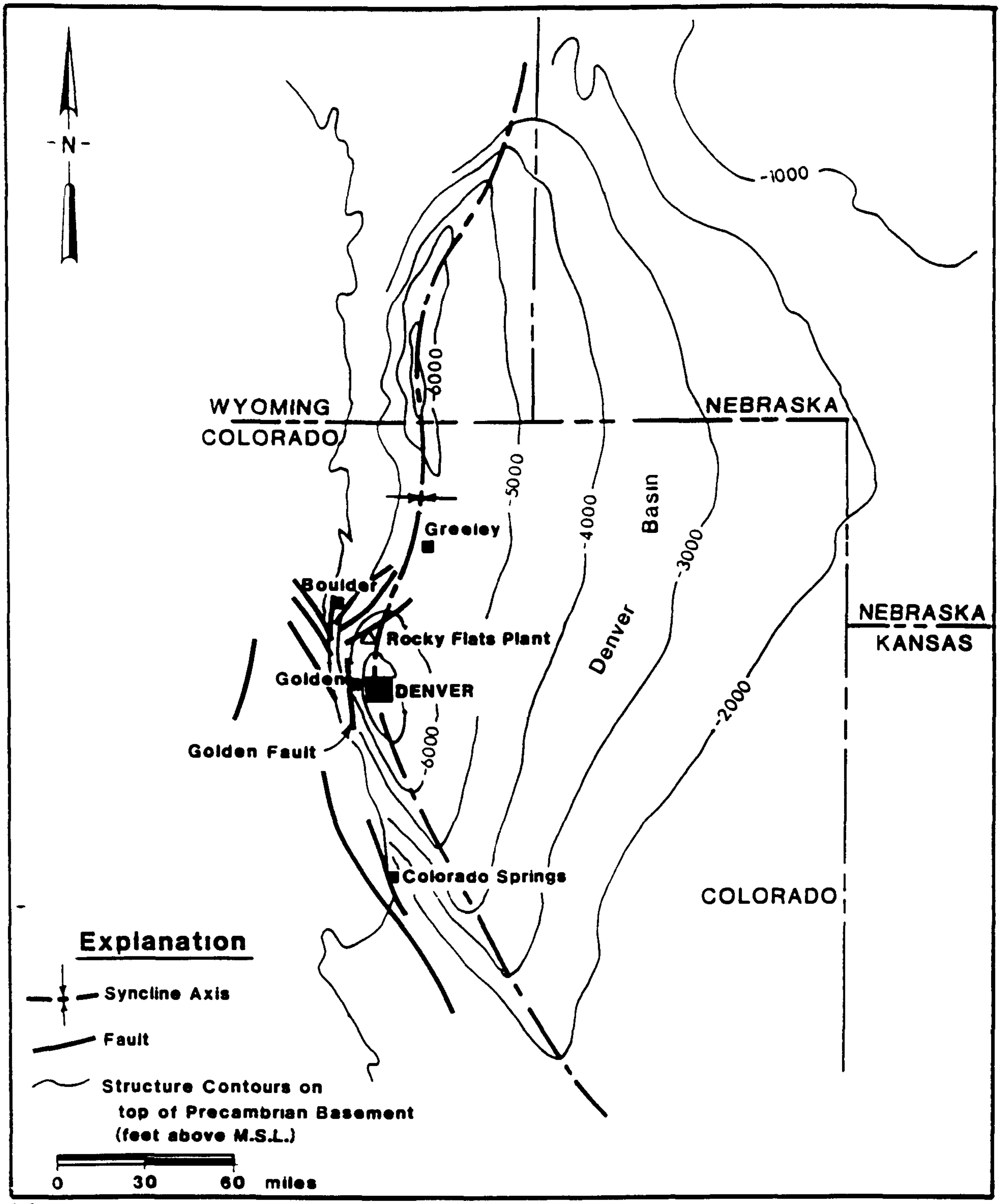
2 1 1 Geologic Setting

The Rocky Flats Plant is located on the northwestern flank of the Denver Basin and is underlain by approximately 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 2-1)

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 (Figure 2-2) Descriptions of the various units present beneath the Rocky Flats Plant are provided within this context

The Pierre Shale, consisting of shales and siltstones was deposited in an epicontinental sea during the late Cretaceous 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)

The Upper Cretaceous Arapahoe Formation was deposited on an erosional surface marking the end of deposition of the Laramie The Arapahoe Formation generally consists of



(after Rockwell International, 1986)

Figure 2.1: Structure of the Denver Basin

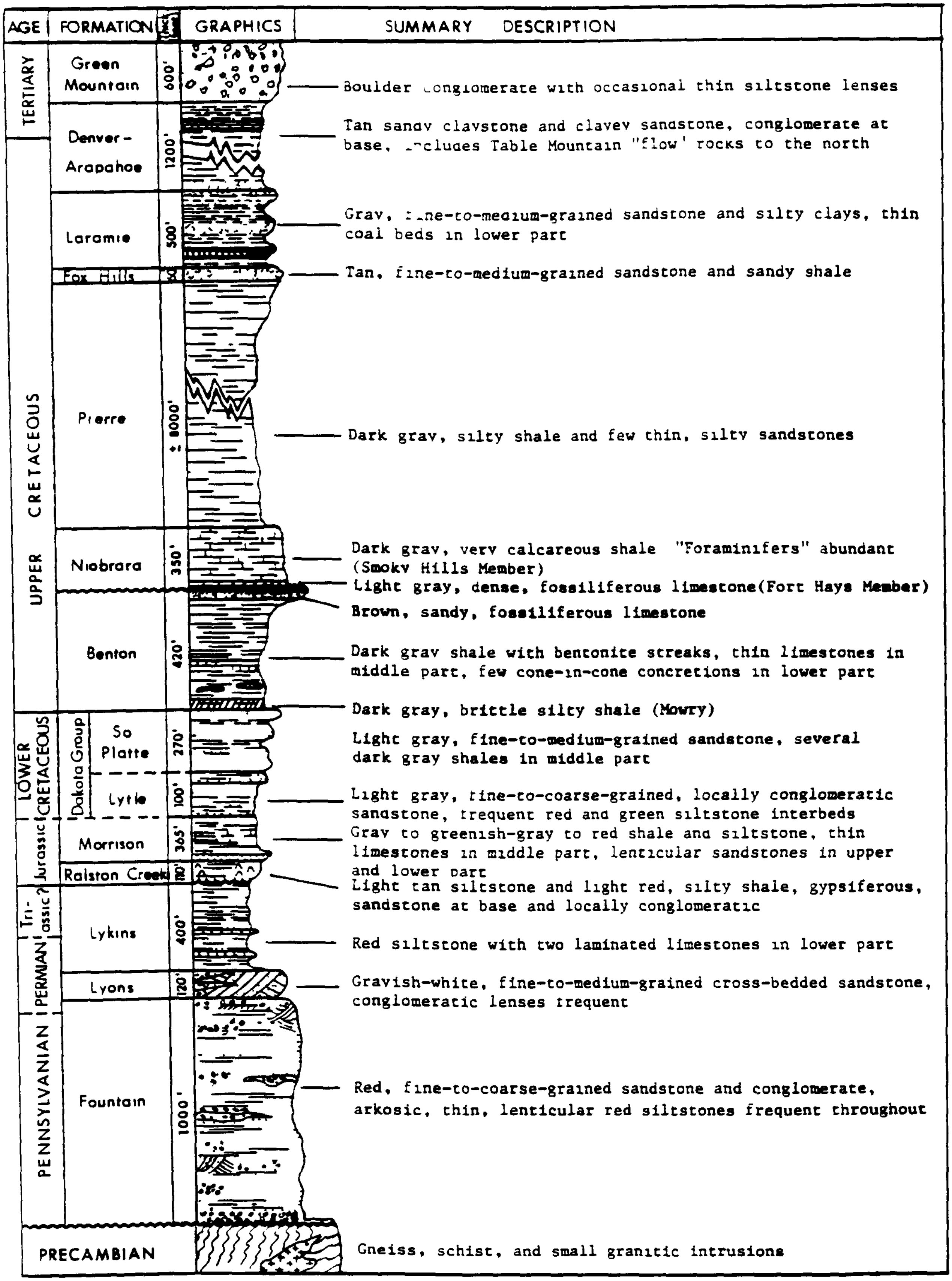


Figure 2.2. Generalized Stratigraphic Section, Golden-Morrison Area

(after LeRoy and Weimer, 1971)

interbedded claystones, siltstones and conglomerates (Robson and others, 1981a) 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)

Alluvial materials were deposited on top of a major erosional surface that developed in late Tertiary time 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 2-3) The topographic position of each alluvium is exhibited in Figure 2-4 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

2 1 2 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

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

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

Figure 2.3:
Surficial Alluvial Deposits in the Rocky Flats Area

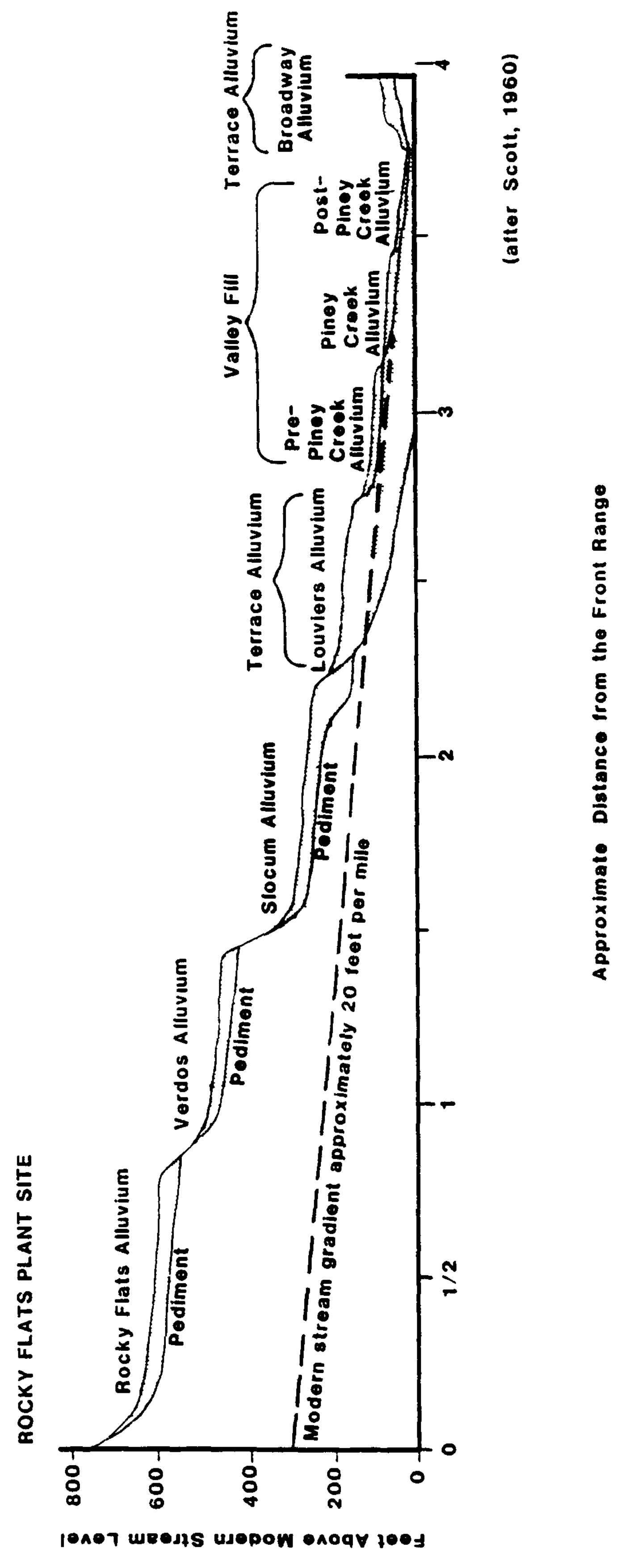


Figure 2.4:
Erosional Surfaces and Alluvial Deposits East of the Front Range, Colorado

more gentle, on the order of 7 to 15 degrees beneath the Plant itself (Rockwell International, 1986)

2 1 3 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 Formations and the Arapahoe Formation) These are discussed individually below

2 1 3 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 ditches, and surface water diversions (primarily through the Rocky Flats Alluvium) In addition, 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 irrigation Similarly, there are several monitoring wells at the plant which contain water during the spring months (April through June) which are dry in the late summer and fall

Ground-Water Flow Directions

Flow directions generally follow topography to the east and toward the drainages In addition, flow directions are primarily controlled by the configuration of the top of bedrock beneath surficial materials The ground water in the drainages flows generally 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 recharge the bedrock to a small extent

2 1 3 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 aquifers from deepest to shallowest are the Laramie-Fox Hills, the Arapahoe, the Denver, and the Dawson

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

Laramie-Fox Hills

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 sandstones from the overlying Arapahoe sandstones (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 surface waters Ground-water recharge from the overlying Araphoe to the Laramie-Fox Hills is negligible due to the thickness and low permeability of the upper Laramie claystone (Robson, 1984) Ground water discharges to pumping wells in the basin In the vicinity of Rocky Flats Plant ground-water flow in the Laramie-Fox Hills is generally from west to east (Robson and others, 1981b)

Arapahoe

The Arapahoe Aquifer is defined as the saturated portion of the Arapahoe Formation by 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, 1986)

There are two primary methods of recharge to the Arapahoe In outcrop and subcrop areas, it occurs from infiltration of incident precipitation and as infiltration of water from alluvial materials However, on a regional scale the primary recharge mechanism for the Arapahoe is leakage from the overlying Denver (Robson and others, 1981a)

Ground-water flow in the Arapahoe 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

2 2 SITE HYDROGEOLOGIC UNITS

Ground water at the RCRA/CERCLA sites at the Rocky Flats Plant occurs in surficial and bedrock materials Three major types of surficial materials have been identified at the Rocky Flats Plant The Present Landfill, Original Process Waste Lines, West Spray Field, Solar Evaporation Ponds, 903 Pad, Mound and East Trenches are situated on Rocky Flats Alluvium Colluvial materials are present in these areas as well as in the 881 Hillside Area Valley Fill Alluvium is present in drainages downgradient of the Landfill, 881 Hillside, and Solar Evaporation Ponds In order to gather background data from all medias from which investigative samples have been collected background surface water and stream sediment samples were also collected

2 2 1 Rocky Flats Alluvium

The Alluvium generally is described as a poorly sorted, unconsolidated deposit of gravel, cobbles and occasional boulders with clay, silt and sand matrixes Rocky Flats Alluvium primarily consists of quartzite and granitic gravels, pebbles, cobbles and boulders These components tend to be subangular to subrounded and range in grain size from trace fine-grained to primarily medium to coarse-grained Zones of clay and sand are frequently interbedded and interspersed throughout the gravels and cobbles Locally, the alluvium is cemented with calcium carbonate in the form of caliche

2 2 2 Colluvium

At the Rocky Flats Plant, colluvium collects on the sides and at the base of hills and slopes It is the product of mass wasting and downslope creep, commonly observed in and on the valley walls in the plant buffer zones These deposits are generally 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 In some cases clay layers with some silt, sand and gravel have been encountered during drilling in colluvial materials

Gravel common to the colluvium range from coarse to fine-grained Sand size particles primarily potassium feldspar in granite range from coarse to fine-grained, with occasional very fine grained intervals These constituents normally consist of granitic materials, lithic fragments and quartzose sand Also common to the colluvium is caliche

2 2 3 Valley Fill Alluvium

Valley Fill Alluvium occurs in the bottom of the present stream valleys around the plant Valley Fill Alluvium consists of reworked and redeposited alluvial and colluvial materials These deposits generally consist of granitic gravel, cobbles, and coarse pebbles, in a sandy silty matrix 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)

2 2 4 Bedrock Geology

The bedrock formations known to underlie the surficial material at the Rocky Flats Plant are the Arapahoe and Laramie Formations The contact between the two cannot be defined based on current information and therefore no definite differentiation between formations has been made There is no reason to expect geochemical differences in ground water from similar lithologies regardless of the formation they occur in

Weathered and unweathered claystones, siltstones and sandstones are the most common lithologies encountered in bedrock Claystones are described as massive and blocky, consolidated, and containing occasional sand, silt, and coal stringers At times the claystones were thinkly bedded, and highly fractured

Sandstones encountered are typically composed of moderately to well sorted, subrounded, very fine to medium-grained quartzose sand Most of the sandstones were encountered immediately below claystone and/or siltstone bodies Cementation is strong with silica/calcite being prominent with occasional calcareous cemented lenses noted Sandstones were thinly bedded with laminae of siltstones and claystones, and occasionally interspersed with lignite stringers

2 3 SITE SURFACE WATER HYDROLOGY

2 3 1 Natural Drainages

Three ephemeral streams drain the Rocky Flats Plant with flow from west to east (Figure 2-5) 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) The South Interceptor Ditch lies between the Plant and the southern drainage Woman Creek surface water The South Interceptor Ditch flows into Pond C-2 (see section 2 3 3) is tributary to the "C" Ponds Surface water runoff downstream of the interceptor ditch is tributary to Woman Creek, which flows eastward to Standley Lake An irrigation ditch headgate located east of Pond C-2 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

2 3 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 Dıtch delıvers water to Upper Church Lake and Great Western Reservoır (Cıty of Broomfıeld munıcıpal water storage) McKay Dıtch also supplıes water to Great Western Reservoır Kınnear Dıtch and Reservoır Co Dıtch dıverts water from Coal Creek and delıvers ıt to Standley Lake (munıcıpal water storage for the Cıty of Westmınster) vıa Woman Creek Woman Creek also delıvers water to Mower Reservoır Last Chance Dıtch flows south of the Plant and delıvers water to Rocky Flats Lake and Twın Lakes Smart Dıtch conveys water from Rocky Flats Lake to the east The South Boulder Dıversıon Canal runs along the western upgradıent edge of the Plant dıvertıng water from South Boulder Creek and delıverıng ıt to Ralston Reservoır (Cıty of Denver munıcıpal water storage)

2 3 3 Retentıon Ponds and Plant Dıscharges

A serıes of dams, retentıon ponds, dıversıon structures, and dıtches has been constructed at the Plant to control surface water and lımıt the potentıal for release of poor qualıty water The retentıon ponds are located ın the draınages of Walnut and Woman Creeks and are desıgnated the A, B, and C serıes ponds Dıscharges from the downstream pond ın each serıes are ın accordance wıth the Plant's Natıonal Pollutıon Dıscharge Elımınatıon System (NPDES) permıt

Ponds A-1 and A-2 are used only for spıll control, and North Walnut Creek stream flow ıs dıverted around them through an underground pıpe Pond A-3 receıves the North Walnut Creek stream flow and Plant runoff from the northern portıon of the Plant Pond A-4 ıs desıgned for surface water control and for addıtıonal storage capacıty for overflow from pond A-3

Fıve retentıon ponds are located along South Walnut Creek and are desıgnated 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 spıll control, whereas pond B-3 receıves treated effluent from the sanıtary sewage treatment plant Ponds B-4 and B-5 receıve surface runoff and occasıonally collect dıscharge from pond B-3 Pond B-5 receıves runoff from the central portıon of the Plant and ıs used for surface water control ın addıtıon to collectıon 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 The Central Avenue Ditch which runs eastward along Central Avenue discharges to Pond B-5

Another retention pond is located on the unnamed northern tributary of Walnut Creek, downstream of the present landfill 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 NPDES 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

3 0 SAMPLING PROGRAM

This section describes the sampling locations and data collection techniques employed during the background ground water and surface water geochemical characterization The rationale for sampling locations is presented below In addition, methodologies for borehole geophysics, monitor well installation, well development, water sampling, and sediment sampling are discussed below followed by a brief discussion of laboratory analytical methods

3 1 SAMPLING LOCATIONS

Presented below is a discussion of the monitor well and sampling locations selected for the background water quality characterization Fifty monitoring wells were installed during this program and nine stations were selected for collection of surface water samples (Plate 1) In order to identify changes in site water chemistry due to Plant operations, background water quality conditions in each unit have been established

Rocky Flats Alluvium Ground Water

Alluvial ground water was characterized by installing and sampling alluvial wells in eight borings used for characterization of the Rocky Flats Alluvium (Wells 01-89A, 02-89, 03-89, 04-89, 05-89, 06-89, 07-89, and 08-89) Well 55-86 serves as the ninth background alluvial well (Plate 1) The wells were installed in two different areas of the Plant Buffer Zone to account for spatial variability of alluvial ground-water quality Wells 55-86, 01-89A, 02-89, 03-89, and 04-89 were installed in the southwest portion of the buffer zone where there are no waste sites/units This area exhibits similar lithologies to the West Spray Field Wells 05-89, 06-89, 07-89, and 08-89 were installed in the northern buffer zone sidegradient of the Plant where there are also no waste sites/units This area was chosen due to expected similarities in lithology and saturated thicknesses to those at the Solar Evaporation Ponds, 903 Pad, Mound, and East Trenches Areas based on its similar topographic position

In addition to the above alluvial background wells, one well cluster was installed in the Rocky Flats Alluvium at the location where the greatest saturated thickness was encountered The purpose of this cluster is to evaluate geochemical stratification of alluvial ground-water quality west of the plant, where alluvium exceeds 90 feet in depth This will aid in the interpretation of potential impacts on ground-water quality from the West Spray Field The well cluster consists of three wells constructed on the basis of the static water levels recorded in the area Well 04-89 was screened over the entire saturated thickness of the Rocky Flats Alluvium (9 87 to 54 45 feet below ground surface) Well 48-89 located approximately 15 feet west of 04-89 and was screened over the bottom ten feet of saturated alluvium (43 01 to 52 48 feet below ground surface) and Well 47-89, installed approximately 15 feet east of 04-89, was screened from ten feet above to ten feet below the water level (3 0 to 22 51 feet below ground surface)

Colluvial Ground Water

In order to characterize colluvial ground-water quality, ten wells were installed in colluvial materials They were installed in various areas of the Plant buffer zone to account for spatial variability Wells 09-89, 10-89, 11-89, 12-89, 13-89, and 46-89 were installed in the north buffer, whereas Wells 14-89, 15-89, 16-89, and 50-89 were installed in the south buffer zone (Plate 1) There are no waste sites/units in either of these areas

Valley Fill Alluvium Ground Water

Characterization of valley fill ground water quality was accomplished by installing nine wells in valley fill materials (Plate 1) Wells 18-89, 19-89, 19-89, 20-89, and 21-89 were installed at four locations along the Rock Creek drainage to investigate ground-water quality changes along the length of the drainage To account for spatial variability of ground-water quality between drainages five additional wells in the Woman Creek drainage and other unnamed drainages in the south buffer (22-89, 23-89, 24-89, 25-89, and 26-89) were installed None of the above areas have been impacted by waste sites/units

Bedrock Ground Water

Data for the characterization of background bedrock ground-water quality were collected by installing 21 monitoring wells screened in bedrock These wells were drilled in various areas of the Plant buffer zone to account for spatial variability in bedrock ground-water quality (Plate 1)

Eleven bedrock wells were completed in the northern buffer zone Five of the eleven wells (27-89BR, 28-89BR, 29-89BR, 30-89BR, and 31-89BR) were installed adjacent to the sidegradient northern alluvial wells and were completed in weathered claystone The remaining six wells (32-89BR, 33-89BR, 34-89BR, 35-89BR, 36-89BR, and 38-89BR) were completed in unweathered sandstones

Ten bedrock wells were installed in the southern buffer zone Three were completed in unweathered sandstones (Wells 37-89BR, 41-89BR, and 43-89BR), five were completed in shallow, weathered claystone (Wells 39-89BR, 40-89BR, 42-89BR, 44-89BR, and 45-89BR, and two (17-89BR and 49-89BR) were completed in weathered sandstones

Surface Water

Nine surface water monitoring locations were selected as background stations (Plate 1 and Table 3-1) One station (SW-107) is located on Woman Creek drainage upstream of all

Table 3-1

Surface Water Stations
for
Rockwell (Rocky Flats)

Station Number	Northing * Coordinate (ft)	Easting * Coordinate (ft)	Ground Surface Elev (ft)
SW004	45162.18	22668 42	5721 20
SW005	40095 64	16442 91	5973 00
SW006	37119 25	12275 44	6129 00
SW007	35270.77	11107 42	6184.70
SW041	33890 00	16820 00	5995 00
SW080	33104 05	17902 55	6042 10
SW104	32376 51	18188 09	6062 40
SW107	34187 74	14780 90	6054 30
SW108	44323 08	22971 45	5838 60

* Rocky Flats Plant Coordinates

sites/units Three stations (SW-41, SW-80, and SW-104) are positioned within tributaries entering Woman Creek from the southwest Station SW-07 is situated in a tributary of Walnut Creek and stations SW-06, SW-05, SW-108, and SW-04 are located along the Rock Creek drainage These locations were chosen to gather an array of surface water samples which are representative of background conditions

Stream Sediment

Background stream sediment chemistry was evaluated by sampling nine sediment monitoring locations for subsequent chemical analyses (Plate 1 and Table 3-2) These stations are paired with the background surface water stations described above Stations SED-20, SED-21, SED-22, and SED-23 are located in the Rock Creek drainage, station SED-04 is located in Walnut Creek, and stations SED-16, SED-17, SED-18, and SED-19 are located in Woman Creek These sites have been selected as locations representative of lithologies present in the drainages on the plant site where impacts from sites/units are not anticipated

3 2 SAMPLING AND DATA COLLECTION

Field sampling and data collection followed the January 1989 ER Program Standard Operating Procedures (SOPs) for Rocky Flats Plant and in the Background Hydrogeochemical Characterization and Monitoring Plan (Rockwell International, 1989) Presented below are discussions of data collection methods utilized for the development of the background characterization

The drilling techniques and monitor well construction materials and methods were consistent with those outlined in the Background Hydrogeochemical Characterization and Monitoring Plan with few exceptions (Rockwell International, 1989) Hollow stem augers were

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Table 3-2

Sediment Station
for
Rockwell (Rocky Flats)

Station Number	Northing* Coordinate (ft)	Easting * Coordinate (ft)	State Northing (ft)	State Easting (ft)	Ground Surface Elev (ft)
SED04	35270 77	11107 42	748221 4350	2074221 8155	6184 70
SED16	34187 74	14780 90	747150 8123	2077897 9173	6054 30
SED17	34024 23	17138 39	746995 1229	2080255 3286	5980.50
SED18	33110 94	17897 74	746084 5755	2081017 4903	6041 40
SED19	32376 51	18188 09	745351 2988	2081310 1946	6062 40
SED20	40107 07	16453 06	753074 1130	2079550 1018	5972 70
SED21	44323 08	22971 45	757310 5398	2086052 8730	5838 60
SED22	45162 18	22668 42	758148 4163	2085747 1517	5721 20
SED23	37119 25	12275 44	750073 2885	2075383 4367	6129 00

* Rocky Flats Plant Coordinates

used to advance the boreholes through the surficial materials and weathered bedrock where possible, and materials were continuously sampled through the augers with the Mobile moss system (wireline and split tube samplers) In areas where coarse materials were encountered such as in the south-southwest buffers (borings for Wells 1-89A, 2-89, 3-89, 4-89, 44-89BR, 45-89BR, 47-89, 48-89, and 49-89BR), an air rotary downhole percussion hammer rig was used to advance the boring Bedrock was rotary drilled and continuously cored (size HX) and all lithologic samples were described, labeled, and packaged by a geologist in the field as described in the SOPs The log of borehole form for each of the background borings are presented in Appendix A and the details of each well construction are located in Appendix B The construction details for each well are summarized in Table 3-3

3 2 1 Borehole Geophysics

Borehole geophysics was utilized in this study to provide information pertinent to the selection of zones of completion for bedrock wells Table 3-4 summarizes the dates, well names, and types of borehole geophysical data acquired for background characterization Locations for the tabulated wells can be found on Plate 1 Appendix E provides a description of the borehole geophysical probes, the resulting well logs and individual overviews of borehole geophysical operations by well

The criteria for the zone of completion is the uppermost permeable zone which is at least three feet thick Consequently, analysis of well logs is oriented towards identifying zones of permeability Where geophysical evidence of permeability is not apparent, analysis is directed toward identifying sandstones and siltstones (based on geophysical data and lithologic descriptions), and quantitatively evaluating porosity and volume of clay (Vclay) Table 3-5 identifies borehole geophysical probes which proved useful in identifying completion zones in this study, and Table 3-6 compares zones of completion recommended by analysis of borehole logs with actual screened intervals The probes listed in Table 3-5 are recommended

Table 3-3

Well Data
for
Rockwell (Rocky Flats)

Well Number	Northing * Coordinate (ft)	Easting * Coordinate (ft)	State Northing (ft)	State Easting (ft)	Ground Surface Elev (ft)	Top of Casing Elev (ft)	Depth to Top of Screen	Depth to Bottom of Screen	Total Depth (ft)	Depth to Bedrock (ft)	Installed By	Geologic Strata of Complete
0189A	31600 11	15183 13	744565 1830	2078308 5787	6122 10	6124 15	10 09	49 60	51 35	49 80	KVA	Qrf
0189P	31599 94	15183 24	744565 0139	2078308 6909	6121 80	6123 76	28 58	37 95	38 26	48 50	RAC	Qrf
0289	31676 84	16017 21	744644 6478	2079142 1870	6105 90	6107 71	20 52	50 00	51 25	49 60	KVA	Qrf
0389	30794 80	15266 77	743760 3577	2078394 8564	6122 00	6124 00	9 50	49 00	50 30	48 50	KVA	Qrf
0489	30852 38	16077 58	743820 5973	2079205 2666	6105 90	6107 07	9 87	54 45	55 70	54 00	RTT	Qrf
0589	41857 55	20445 99	754837 3135	2083536 2087	5968 40	5970 17	11 86	31 57	33 31	30 00	KEM	Qrf
0689	42256 66	21069 70	755238 3808	2084158 4352	5960 10	5961 94	11 58	31 05	32 80	30 60	KEM	Qrf
0789	42781 02	21921 46	755765 4125	2085008.2449	5946 10	5948 08	9 07	28 50	30 47	28 00	KEM	Qrf
0889	43199 87	22617 22	756186 4527	2085702 4430	5936 10	5938 08	8 60	23 12	24 70	22 80	KVA	Qrf
0989	42275 09	24169 13	755267 0405	2087256 9935	5883 10	5885 15	3 48	7 83	9 60	7 50	KVA	Qc
1089	44655 14	23771 64	757645 1486	2086851 7585	5806.50	5808 41	20 36	34 80	36 50	34 00	RTT	Qc
1189	44616 73	20500 44	757595 9555	2083581 5337	5826 10	5827 80	14 73	23 90	26 11	23 40	JEM	Qc
1289	44092 75	22254 49	757077 9028	2085336 8530	5859 40	5861 20	5 58	9 96	11 64	7 00	JEM	Qc
1389	44426 56	23548 26	757415 8909	2086629.1867	5846 00	5847 68	4 38	8 76	10 50	8 20	JEM	Qc
1489	34321 96	22207 35	747309 5078	2085321 9781	5866 80	5868 83	13 16	22 60	24 45	22 30	KEM	Qc
1589	32873 07	18514 33	745848 8073	2081634 7119	6025 60	6027 67	6 55	21 00	22 65	20 50	RTT	Qc
1689	33804 66	20373 64	746786 2956	2083490 4539	5907 50	5909 55	3 85	13 30	15 00	13 50	RTT	Qc
1789BR	33364 04	18357 65	746339 1279	2081476 4480	6024 60	6026 49	13 50	22 90	24 60	7 50	RTT	Kss
1889	40124 54	16414 83	753091 4539	2079511 8166	5978 30	5980 06	3 00	12 47	14 22	12 50	KVA	Qvf
1989	40864 32	17161 65	753833 5008	2080256 0041	5939.50	5941 18	3 74	10 90	12 61	10 40	KVA	Qvf
2089	44414 51	20812 14	757394 8212	2083893 8232	5770 90	5772 83	3 43	12 90	14 65	12 40	KVA	Qvf
2189	45126 22	22633 57	758112 3563	2085712 4261	5723 60	5725 45	4 53	11 60	13 40	11 20	KVA	Qvf
2289	34264 35	15145 64	747228 6049	2078262 3035	6045.40	6047 07	2 55	3 28	5 85	2 80	KEM	Qvf
2389	31715 79	23104 08	744706 9744	2086227 0822	5832 30	5834 17	4 00	8 55	10 17	8 00	KVA	Qvf
2489	32824 94	26406 34	745826 7435	2089524 8098	5730 80	5733 16	5 92	10 52	12 10	10 20	KVA	Qvf
2589	32347 94	28146 31	745355 6090	2091265 9007	5686 20	5688 15	3 46	7 90	9 65	7 40	KVA	Qvf
2689	29260 92	30864 52	742278 3686	2093993 5910	5601 20	5602 93	4 61	7 00	8 90	6 60	KVA	Qvf
2789BR	41868 42	20466 34	754848 2491	2083556 5118	5968 00	5970 12	35 26	44 70	46 47	30 30	KEM	Kcl
2889BR	42258 71	21087 88	755240 4851	2084176 6034	5959 70	5961.59	35 00	44 47	46 00	30 10	KVA	Kcl

Table 3-3 (Continued)

Well Data
for
Rockwell (Rocky Flats)

Well Number	Northing* Coordinate (ft)	Easting* Coordinate (ft)	State Northing (ft)	State Easting (ft)	Ground Surface Elev (ft)	Top of Casing Elev (ft)	Depth to Top of Screen	Depth to Bottom of Screen	Total Depth (ft)	Depth to Bedrock (ft)	Installed By	Geologic Strata of Complete
2889BRA	42267 59	21087 28	755249 3607	2084175 9769	5959 80	0 00	0 00	0 00	0 00	0 00	KVA	
2989BR	42806 76	21964 89	755791 2887	2085051 5736	5945 70	5947 71	31 00	40 50	41 25	28 60	JEM	Kcl
3089BR	43221 96	22658 39	756208 6745	2085743 5243	5935 20	5937.07	29 70	39 16	40 94	24 30	KVA	Kcl
3189BR	43755 65	23487 29	756744 9537	2086570 4441	5920 50	5922 45	27 05	36 55	37 30	22 60	JEM	Kcl
3289BR	42792 37	21944 19	755776 8324	2085030 9263	5946 20	5948 28	134 15	138.59	140 84	26 70	RTT	Kss
3389BR	43211 47	22635 78	756198 1067	2085720 9611	5935 80	5937 69	107 00	111 43	113 90	28 40	RTT	Kss
3489BR	43740 80	23469 07	756730 0555	2086552 2860	5920 90	5922 78	125.97	130 42	132 70	23 70	RTT	Kss
3589BR	41904 59	24227 96	754896 8288	2087317 0381	5877 60	5879 29	106 50	112 90	115 23	1 60	KEM	Kss
3689BR	42344 56	25382 07	755340 4906	2088469 3930	5826 90	5828 86	81 10	95 33	97 62	3 70	KEM	Kss
3789BR	31688 14	23092 28	744679 3015	2086215 3718	5833 00	5835 18	84 40	88 49	90 95	10 50	JEM	Kss
3789BRA1	31700 57	23103 38	744691 7636	2086226 4290	5832 30	0.00	0 00	0 00	0 00	10 80	KVA	
3789BRA2	31710.60	23102 16	744701 7832	2086225 1733	5832 40	0 00	0 00	0 00	0 00	8 50	KVA	
3789P	31699 33	23098 54	744690 5072	2086221 5936	5832 30	5834 25	5 00	10.00	10 00	10 80	KVA	Qvf
3889BR	41797 90	23567 28	754787 9884	2086656 8840	5901 40	5902 82	105 50	109.95	112 22	2 90	JEM	Kss
3989BR	34321 35	22184 13	747308 8221	2085298 7662	5867.50	5869 56	27 90	37 57	39 14	22 90	KVA	Kcl
4089BR	32815 29	26451 93	745817 2440	2089570 4247	5730 60	5732 56	14 66	24 14	25 90	9 70	KVA	Kcl
4189BR	32799 24	26481 33	745801 2931	2089599 8741	5729 70	5731 85	75 50	82 87	86 25	8 40	JEM	Kss
4189BRA	32801 62	26472 01	745803 6441	2089590 5452	5729 80	0 00	0 00	0 00	0 00	10 40	KVA	
4289BR	33804.20	19330 97	746782 3900	2082448 0614	5967 90	5969 91	13 20	22 69	24 45	8 20	KVA	Kcl
4389BR	33819 62	19347 76	746797 8628	2082464 7930	5965 60	5967 31	41 24	45 67	48 00	10 30	RTT	Kss
4489BR	31726 76	23109 08	744717 9612	2086232 0415	5832 00	5833.90	15 18	25 00	26 30	10 00	KVA	Kcl
4589BR	32239 76	15235 37	745204 8392	2078358 6905	6115 80	6117 67	39 13	48 57	50 05	34 00	RIT	Kcl
4689	44664 12	23775 15	757654 1441	2086855 2290	5806 40	5808 46	6 87	16 30	18 00	32 30	RTT	Qc
4789	30851 28	16062 22	743819 4561	2079189 9129	6105 20	6107 25	3 00	22 51	23 75	0 00	SPC	Qrf
4889	30853 20	16092 40	743821 4683	2079220 0762	6104 80	6106 70	43 01	52.48	53 72	52 00	FSP	Qrf
4989BR	33357 04	18357 49	746332.1311	2081476 3079	6024 90	6026 87	36 04	45 50	46 75	6 50	EMH	Kss
5089	33374 00	18357 88	746349 0917	2081476 6474	6023 50	6026 06	2 80	6 70	8 50	6 20	RTT	Qc
5586	32259 45	15217 16	745260 8365	2078321 1160	6103 62	6105 81	3 55	36 39	36 39	35 50	TWG	Qrf

* Rocky Flats Coordinates

Table 3-4

SUMMARY OF BOREHOLE GEOPHYSICAL LOGGING AT BACKGROUND WELLS

Date	Well	Fluid Temp & Fluid Res	SP, IP, 16" & 64" Normal	Full Wave Form Sonic	Guard Res, Neut Den, GR	G-G Density, Caliper	EM-39 Ind.	Diplog	Comments
16 February 1989	33-89BR	X	X	X	X	X	X	X	Diplog not processed
7 March 1989	32-89BR	X	X	X	X	X	X		
9 March 1989	41-89BR	X	X	X	X	X	X		Purpose of logging run to provide sonic and density data on weathered claystone
13 March 1989	34-89BR	X	X	X	X	X	X		
23 March 1989	36-89BR	X	X	X	X	X	X		
4 April 1989	35-89BR	X	X	X	X	X	X		
13 April 1989	38-89BR	X	X	X	X	X	X		
19 April 1989	41-89BR	X	X	X	X	X	X		
25 April 1989	43-89BR	X	X	X	X	X	X		
28 April 1989	37-89BR	X	X	X	X	X	X		Total Depth of well at 67 ft No screened interval selected Well consequently deepened
11-12 May 1989	37-89BR	X	X	X	X	X	X		Total Depth of Well at 642 ft Entire well relogged

TABLE 3-5

BOREHOLE GEOPHYSICAL PROBES USEFUL IN IDENTIFYING COMPLETION ZONES

PROBE	OBJECT	COMMENT
Temperature	Identify permeable zones	Identifies changes in borehole fluid indicative of influx of formation water
Fluid Resistivity	Identify permeable zones	Identifies changes in borehole fluid indicative of influx of formation water
Caliper	Identify permeable zones	Identifies mudcake buildup indicative of fluid loss to the formation
Spontaneous Potential	Identify permeable zones	Sensitive to the salinity difference between the drilling fluid and formation water
Gamma-Gamma Density	Calculate porosity and volume clay	Porosity and Vclay calculations require Neutron Density data
Neutron Density	Calculate porosity and	Porosity and Vclay calculations require Gamma-Gamma Density data
Natural Gamma Ray	Identify sandstones	Not a good Vclay indicator at Rocky Flats Plant
Guard Resistivity	Identify sandstones	Best resistivity probe for locating resistive zones at RFP

Recommended logging runs for identification of completion zones

Run 1 Fluid Temperature and Fluid Resistivity

Run 2 Guard Resistivity, Neutron Density, Natural Gamma Ray

Run 3 Gamma-Gamma Density and Caliper

Run 4 Spontaneous Potential, Induced Potential, 16" & 64" Normal

Table 3-6

SUMMARY OF COMPLETION ZONES

WELL	SCREENED INTERVAL (Ft below Ground Level)	RECOMMENDED INTERVAL FROM BOREHOLE GEOPHYSICS (ft below Ground Level)	COMMENTS
32-89BR	134 15 - 138 59	134 0 - 138 65	
33-89BR	107 00 - 111 43	107 - 112	FR and FT deflection, flowing well
34-89BR	125 97 - 130 42	126 - 131 5	Mudcake build-up, SP deflection
35-89BR	106 50 - 112 90	106 5 - 111 8	
36-89BR	81 10 - 95 33	82 - 95	SP deflection
37-89BR	84 04 - 88 49	84 - 88 5	Mudcake build-up
38-89BR	105 50 - 109 95	105 5 - 109 5	Slight SP deflection
41-89BR	75 50 - 83 92	75 5 - 82 5	
41-89BRA	NOT SCREENED	NO RECOMMENDATION	Logged in alluvium
43-89BR	41 24 - 45 67	41 2 - 45 7	

Porosity estimated in Appendix E across all recommended intervals except for 33-89BR

FR = Fluid Resistivity Curve

FT = Fluid Temperature Curve

SP = Spontaneous Potential Curve

as the basis for any future suite of borehole geophysical logs run for the purpose of selecting completion zones Appendix E provides further discussion of the quantitative analysis of borehole geophysical logs, the results of these analyses, and composite logs correlating the lithology, well construction, and log curves In addition to providing for the selection of screened intervals, borehole geophysical logs can be used for correlation (Plates 4 through 9)

3 2 2 Geotechnical Sampling

To independently establish percentages of clay, silt, and sand, representative samples were taken from the cores over the screened intervals for selected background wells Gradation/Hydrometer analyses were prepared for these samples in accordance with ASTM procedure D422 Copies of the individual analyses are provided in Appendix F

In Table 3-7 the results of the Gradation/Hydrometer analyses are compared with the calculated volume of clay (Vclay) derived from borehole geophysical logs It should be noted that there are fundamental differences in these approaches to measuring the clay fraction Gradation/Hydrometer analysis properly characterizes the sand, silt, and clay fractions by grain size irrespective of mineralogy Vclay calculations as described in Appendix E estimates the clay fraction based on effect of clay minerals on the observed Gamma-Gamma Density and Neutron Density values irrespective of grain size The data for clay fraction presented in Table 3-7 is crossplotted in Figure 3-1 As evidenced in this crossplot, gradation/hydrometer analysis of clay fractions support the use of borehole geophysics as an estimator of volume of clay values for adjusted porosity calculations

3 2 3 Monitor Well Installation

All alluvial and colluvial wells were completed with four-inch diameter, Schedule 40 PVC casing and 0 01" slotted Schedule 40 PVC screen with the exception of colluvial well 11-

TABLE 3-7

RESULTS OF GRADATION/HYDROMETER ANALYSES WITH CORRESPONDING Vclay VALUES

Well	Sampled Interval (ft)	Gradation/Hydrometer Results (%) Sand	Silt	Clay	Vclay (fraction) Mean
32-89BR	134 0 - 137 2	17	50	33	35
32-89BR	185 0 - 192 0	18	44	38	48
34-89BR	126 0 - 130 0	55	28	17	0 21
35-89BR	106 0 - 112 0	24	48	28	0 44
36-89BR	80 2 - 95 1	9	45	46	0 50
37-89BR	84 0 - 89 0	23	50	27	0 43
38-89BR	105 5 - 108 4	27	41	32	0 27
41-89BR	76 2 - 77 0	53	32	15	0 26
41-89BR	74 9 - 84 0	15	53	32	0 40
43-89BR	41 13 - 45 67	4	60	36	0 39

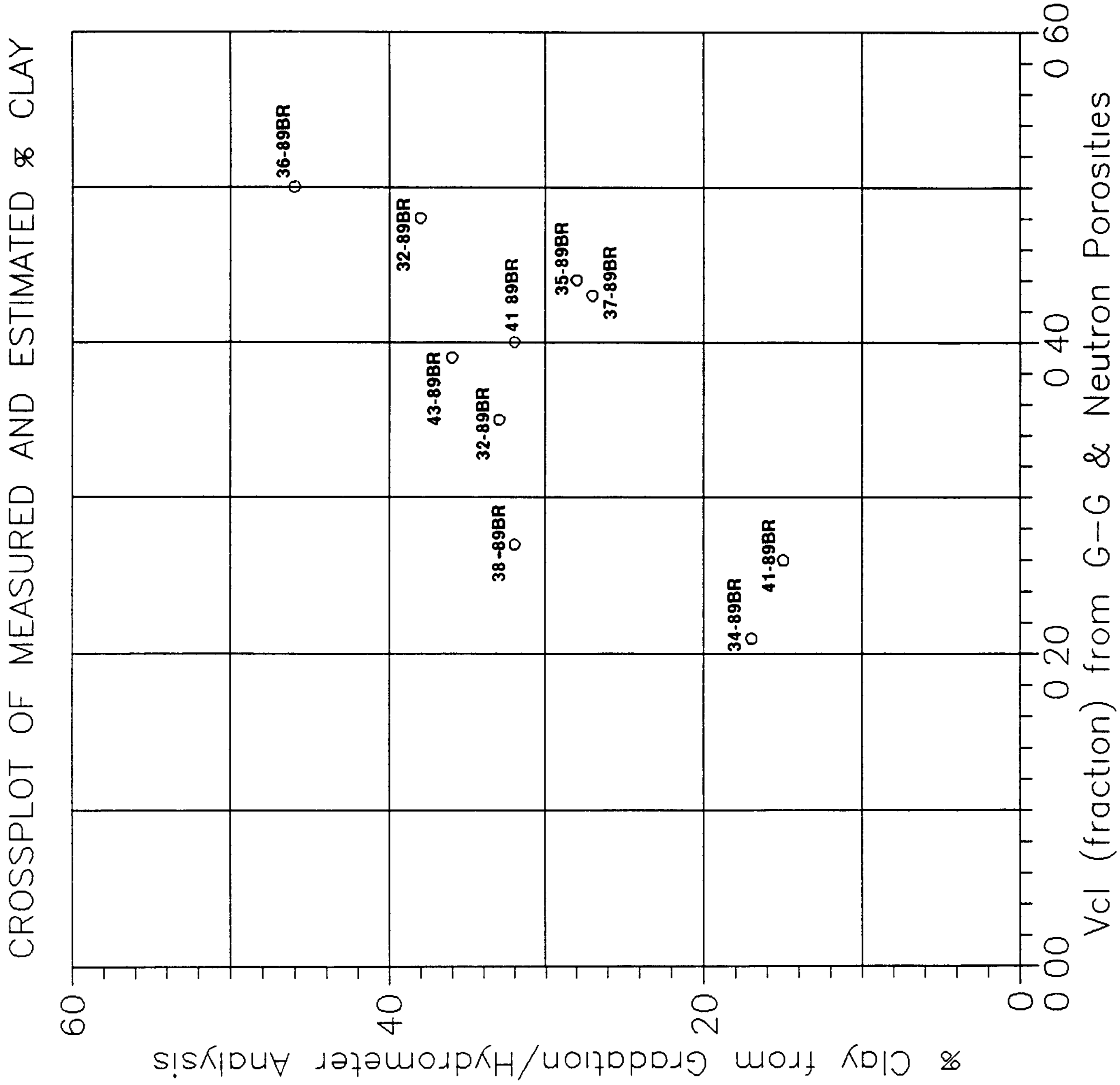
Sand has a grain diameter greater than 0 074 mm

Silt has a grain diameter greater than 0 004 mm and less than 0 074 mm

Clay has a grain diameter less than 0 004 mm

The mean of Vclay represents an average of Vclay estimated from Gamma-Gamma and Neutron Density measurements sampled at each tenth foot over the sampled interval

FIGURE 3-1


CROSSPLOT OF MEASURED AND ESTIMATED % CLAY
Vcl (fraction) from G–G & Neutron Porosities
% Clay from Gradation/Hydrometer Analysis
0 00
0 20
0 40
0 60
0 0
20
40
60
36-89BR
32-89BR
35-89BR
37-89BR
41 89BR
43-89BR
32-89BR
38-89BR
41-89BR
34-89BR

89 Hole instability at this location necessitated building the well inside the augers, therefore, the well was completed with two-inch Schedule 80 PVC Figure 3-2 illustrates the typical alluvial well design and annulus materials for Rocky Flats Alluvium, colluvium, and valley fill wells All background wells completed in surficial materials were screened over the entire alluvial saturated thickness (0 5 feet below the bedrock contact to a point above the water level encountered during drilling or observed in nearby wells installed in similar materials)

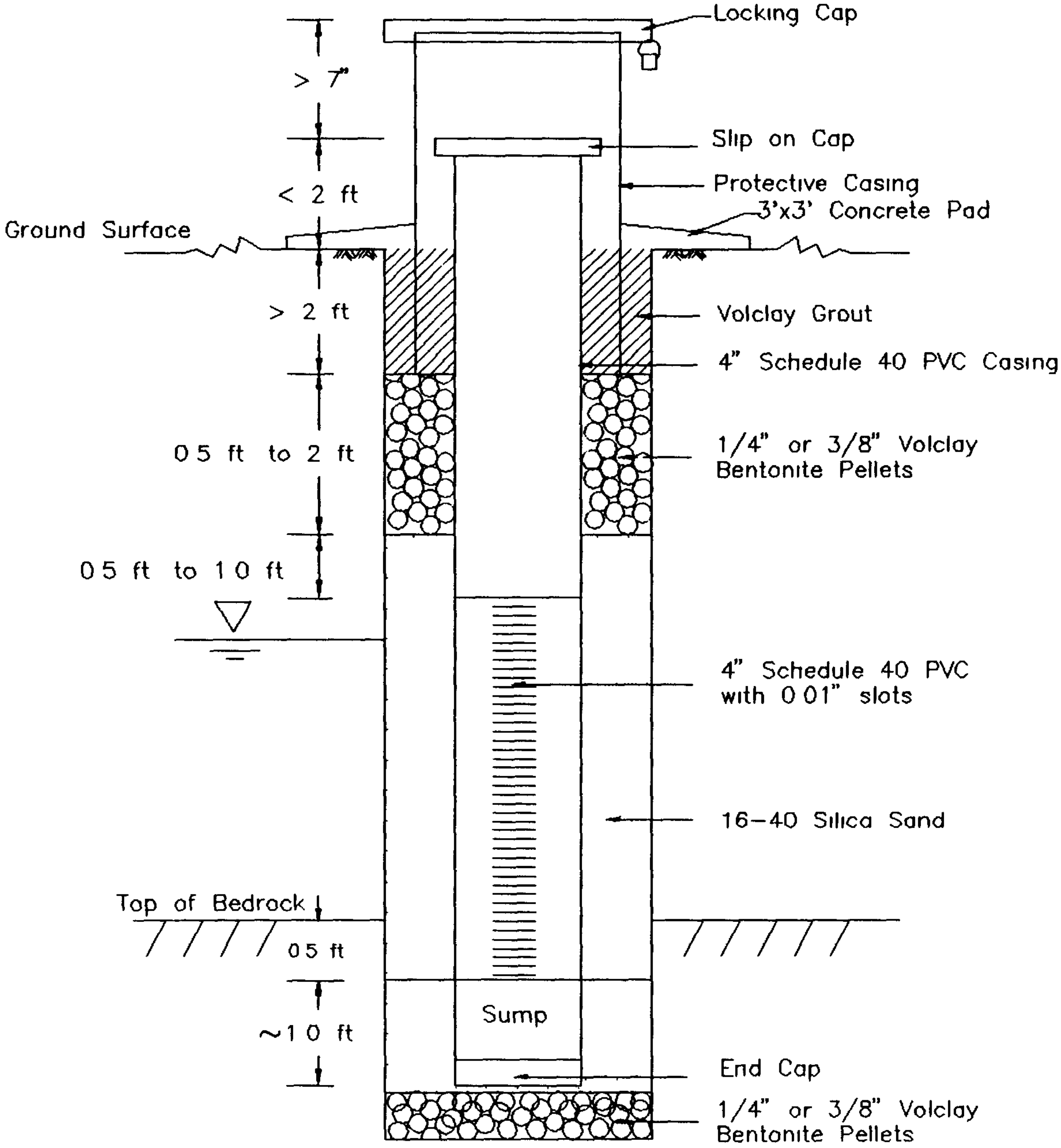
Three different types of bedrock wells were installed during the background characterization The shallow, weathered claystone bedrock wells were augered to total depth and constructed as described above with few exceptions Wells 27-89BR, 29-89BR, and 31-89BR were reamed with large diameter augers to total depth and the wells were constructed within the augers This was done where hole stability was a problem The remainder of the wells were built open hole The wells were screened from approximately five feet below the contact to fifteen feet below the contact with the exception of well 29-89BR in which the screen began 1 4 feet below the contact (Figure 3-3)

Two weathered sandstone wells were installed during this program Well 17-89BR was constructed to screen the upper ten feet of a weathered sandstone encountered at 13 5 feet below ground surface whereas well 49-89BR was constructed to monitor the bottom ten feet of the same sandstone unit In both cases, hole instability warranted constructing the well within large diameter augers or drill pipe The well construction materials used were the same as those described above for weathered claystone wells

The third type of bedrock wells were completed in unweathered sandstone referred to below as deep bedrock wells All deep bedrock wells were completed with two-inch diameter Schedule 80 PVC and 0 01" slotted Schedule 80 PVC The boring was advanced with hollow

FIGURE 3-2

TYPICAL ALLUVIAL MONITOR WELL CONSTRUCTION



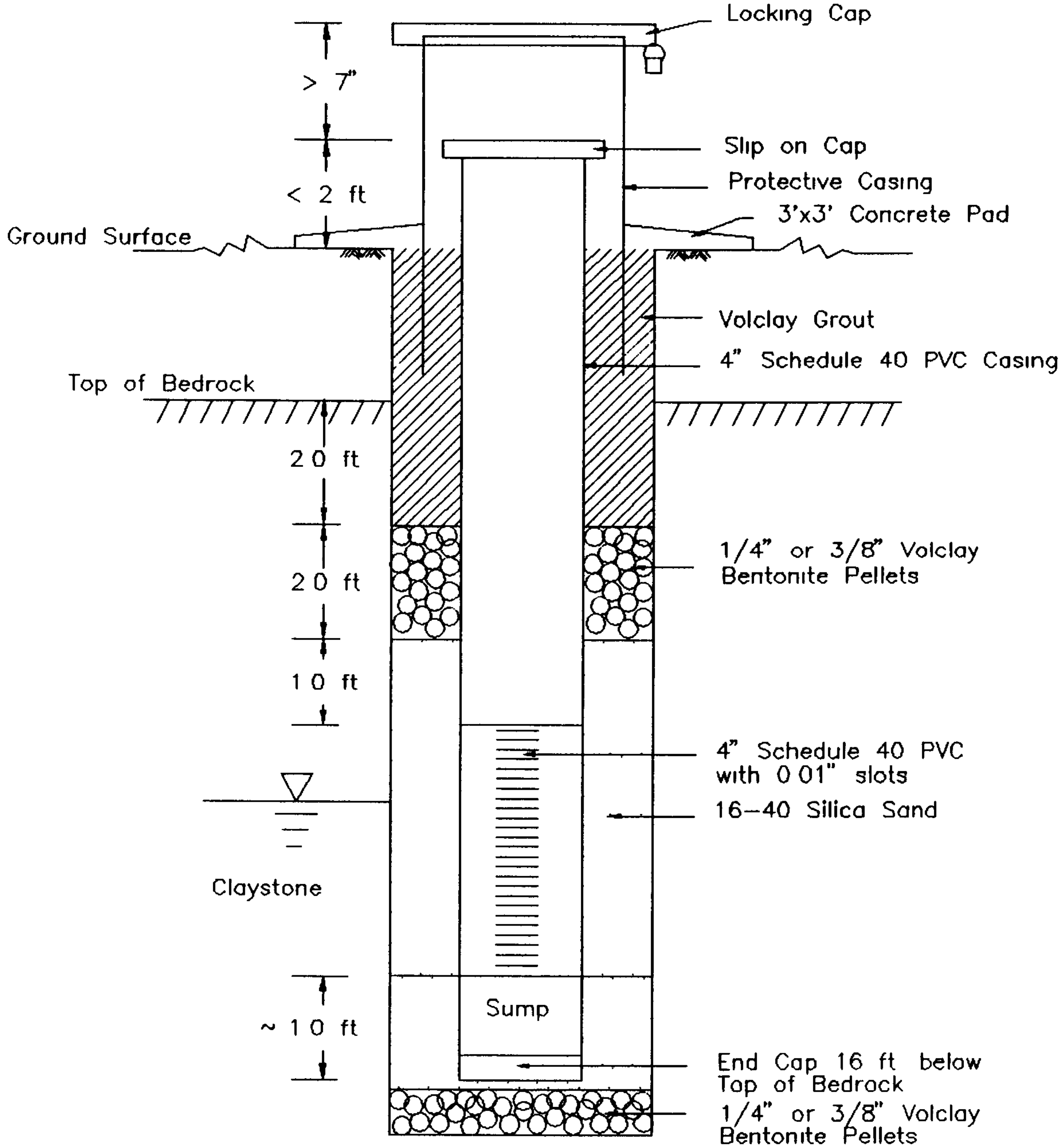
NOT TO SCALE

R33003-092989 MB

FIGURE 3-3

TYPICAL SHALLOW BEDROCK WELL CONSTRUCTION

(WEATHERED CLAYSTONE)



NOT TO SCALE

R33004–092889 MB

stem augers through surficial materials and into slightly weathered bedrock and steel surface casing was installed The remainder of the hole was then rotary cored to total depth The annular materials used were the same as those described above except two-foot sumps were installed at the base of the screen and Portland Type I cement was used instead of Volclay Grout (Figure 3-4)

3 2 4 Well Development

All monitoring wells were developed subsequent to well completion and prior to ground water sampling or aquifer testing The purpose of development is to remove fine materials from the sand pack to facilitate hydraulic communication between the screened formation and the monitor well

The well development procedures used during the background characterization field activities were consistent with those outlined in the Background Hydrogeochemical Characterization and Monitoring Plan and the ER Program Standard Operating Procedures with two exceptions The Geological Society of America Rock Color Chart was used the majority of the time in place of the turbidimeter suggested in the background plan to gage turbidity and color of the development water In addition, the attempt to add tap water to some monitoring wells to the top of the sand pack was not always successful It was apparent in some instances that water added to the wells in the southwest buffer was lost to the formation almost immediately Several attempts were made at each location before the procedure was abandoned

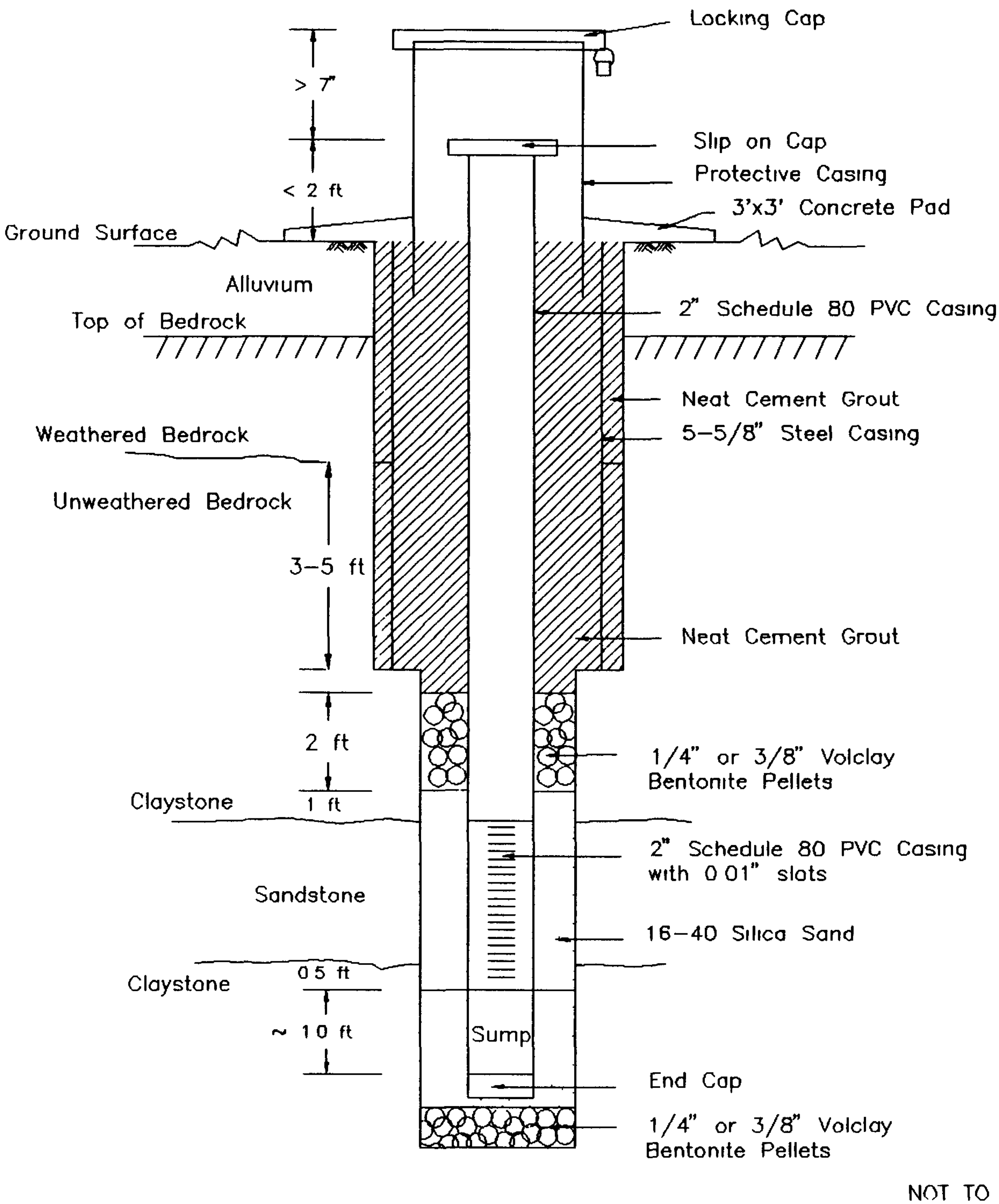
3 2 5 Ground-Water Sampling

Results of the first round (Round 1) of ground-water samples are presented in this report Subsequent sampling events will be evaluated in future reports Round 1 began on April 4, 1989 and was completed on July 17, 1989 A total of 35 samples were collected from

FIGURE 3-4

TYPICAL DEEP BEDROCK MONITOR WELL CONSTRUCTION

(UNWEATHERED SANDSTONE)



R33005-092889 MB

the 51 background monitoring wells and fifteen wells were dry (Table 3-8) As shown in Table 3-8, eight colluvial wells, one Valley Fill Alluvium well, six weathered claystone wells, and one unweathered sandstone well were determined dry during Round 1 sampling A well was considered dry if the water level in the well was below the base of the screen prior to the pre-sample purge Well 38-89BR was not sampled because a pump was lost in the well while attempting the presample purge The pump was unretrievable and therefore the well was subsequently sealed awaiting abandonment The samples were analyzed for the parameters listed in Table 3-9 Full suites of samples were collected from each of the background wells sampled TCL organics were not expected in background ground-water and therefore were not included in the parameter list

Ground-water sampling activities were performed in accordance with the SOPs and the background plan This includes the procedures for equipment decontamination, presample purging, water level measurements, field water quality measurements, sample collection, sample preservation, and sample shipping Ground-water samples were analyzed in the field for pH, conductivity, and temperature (Table 3-8) and with the exception of major ions and tritium samples, all samples were filtered and preserved in the field

Prior to presample purging of each well, a water level measurement was obtained This level was measured from the mark present on the north side of each well The static water level recorded on each lithologic log reflects the measurement of the depth to water acquired during the Round 1 sampling effort (Table 3-10)

The field quality assurance/quality control program included two basic areas documentation of field activities (i e, decontamination procedures, sampling techniques, unusual occurrences, preservation of samples and the order in which samples were collected), and the routine collection and analysis of duplicates (designated by "D" following the sample number) and field (equipment) blanks (designated by "FB" following the sample number) Trip blanks were not required during the background sampling efforts since volatile organic

Table 3-8

BACKGROUND

GROUND WATER SAMPLE INFORMATION

	SAMPLE INFORMATION					FIELD PARAMETERS			LABORATORY ANALYTES							
WELL NUMBER	SAMPLE NUMBER	SAMPLE DATE	SHIPPING DATE	TURNAROUND DATE	CUSTODY SHEET NO	pH	CONDUCT (umhos/cm)	TEMP (deg C)	VOA	SEMI-VOA	PEST PCB	TOTAL METALS	DISS METALS	INORG	TOT RADS	DISS RADS
0189A	G01890689001	06/14/89	06/15/89	07/31/89	MJS061589001	6 60	140 0	11 0	N	N	N	N	R	R	N	Y
0289	G02890689001	06/14/89	06/15/89	07/31/89	MJS061589001	6 70	160 0	11 5	N	N	N	N	R	R	N	Y
0389	G03890689001	06/14/89	06/16/89	08/01/89	MJS061689001	7 40	380 0	11 5	N	N	N	N	R	R	N	Y
0489	G04890689001	06/15/89	06/15/89	07/31/89	MJS061589001	7 00	210 0	13 0	N	N	N	N	R	R	N	Y
0589	G05890689001	06/07/89	06/08/89	07/24/89	MJS060789001	7 00	150 0	10 5	N	N	N	N	Y	R	N	Y
0689	G06890689001	06/07/89	06/08/89	07/24/89	MJS060789001	7 20	200 0	11 0	N	N	N	N	Y	R	N	Y
0789	G07890689001	06/06/89	06/07/89	07/23/89	MJS060689001	7 40	220 0	11 0	N	N	N	N	Y	R	N	Y
0889	G08890689001	06/05/89	06/05/89	07/21/89	MJS060589001	8 60	205 0	12 2	N	N	N	N	R	R	N	Y
0989	DRY	04/19/89	/ /	/ /		N/A	N/A	N/A	N	N	N	N	N	N	N	N
1089	G10890589001FB	05/05/89	05/05/89	06/20/89	MJS050589001	N/A	N/A	N/A	N	N	N	N	R	N	N	Y
1089	G10890589001	05/05/89	05/05/89	06/20/89	MJS050489001	7 20	550 0	10 0	N	N	N	N	R	R	N	Y
1189	DRY	05/15/89	/ /	/ /		N/A	N/A	N/A	N	N	N	N	N	N	N	N
1289	DRY	05/15/89	/ /	/ /		N/A	N/A	N/A	N	N	N	N	N	N	N	N
1389	DRY	05/12/89	/ /	/ /		N/A	N/A	N/A	N	N	N	N	N	N	N	N

N - Not sampled for this group, Y - Sampled for this group, results not yet received, R - Results for this group received

Table 3-8 (Continued)

BACKGROUND

GROUND WATER SAMPLE INFORMATION

	SAMPLE INFORMATION					FIELD PARAMETERS			LABORATORY ANALYTES							
WELL NUMBER	SAMPLE NUMBER	SAMPLE DATE	SHIPPING DATE	TURNAROUND DATE	CUSTODY SHEET NO	pH	CONDUCT (umhos/cm)	TEMP (deg C)	VOA	SEMI-VOA	PEST PCB	TOTAL METALS	DISS METALS	INORG	TOT RADS	DISS RADS
1489	DRY	05/11/89	/ /	/ /		N/A	N/A	N/A	N	N	N	N	N	N	N	N
1589	G15890589001D	05/04/89	05/05/89	06/20/89	MJS050489001	7 10	340 0	9 0	N	N	N	N	R	R	N	Y
1589	G15890589001	05/04/89	05/05/89	06/20/89	MJS050489001	7 10	340 0	9 0	N	N	N	N	R	R	N	Y
1689	DRY	05/16/89	/ /	/ /		N/A	N/A	N/A	N	N	N	N	N	N	N	N
1789BR	G17890689001	06/05/89	06/05/89	07/21/89	MJS060589001	8 40	345 0	10 0	N	N	N	N	R	R	N	Y
1889	G18890489001	04/25/89	04/27/89	06/12/89	MJS042589001	7 00	130 0	10 0	N	N	N	N	R	R	N	Y
1989	G19890489001	04/25/89	04/27/89	06/12/89	MJS042589001	6 70	250 0	9 0	N	N	N	N	R	R	N	Y
2089	G20890489001D	04/24/89	04/27/89	06/12/89	MJS042489001	7 00	265 0	12 0	N	N	N	N	R	R	N	Y
2089	G20890489001FB	04/24/89	04/27/89	06/12/89	MJS042489001	N/A	N/A	N/A	N	N	N	N	R	N	N	Y
2089	G20890489001	04/24/89	04/27/89	06/12/89	MJS042489001	7 00	265 0	12 0	N	N	N	N	R	R	N	Y
2189	G21890489001	04/26/89	04/27/89	06/12/89	MJS042689004	7 30	265 0	11 0	N	N	N	N	R	R	N	Y
2289	G22890489001	04/27/89	04/28/89	06/13/89	MJS042789001	7 10	500 0	14 0	N	N	N	N	R	R	N	Y
2389	G23890489001	04/26/89	04/27/89	06/12/89	MJS042689001	7 50	370 0	10 0	N	N	N	N	R	R	N	Y
2489	G24890489001	04/27/89	04/28/89	06/13/89	MJS042789001	7 50	410 0	11 0	N	N	N	N	R	R	N	Y
2589	G25890489001	04/27/89	04/28/89	06/13/89	MJS042789001	7 50	475 0	9 0	N	N	N	N	R	R	N	Y

N - Not sampled for this group, Y - Sampled for this group, results not yet received, R - Results for this group received

Table 3-8 (Continued)

BACKGROUND

GROUND WATER SAMPLE INFORMATION

	SAMPLE INFORMATION					FIELD PARAMETERS			LABORATORY ANALYTES							
WELL NUMBER	SAMPLE NUMBER	SAMPLE DATE	SHIPPING DATE	TURNAROUND DATE	CUSTODY SHEET NO	pH	CONDUCT (umhos/cm)	TEMP (deg C)	VOA	SEMI-VOA	PEST PCB	TOTAL METALS	DISS METALS	INORG	TOT RADS	DISS RADS
2689	DRY	05/10/89	/ /	/ /		N/A	N/A	N/A	N	N	N	N	N	N	N	N
2789BR	DRY	05/24/89	/ /	/ /		N/A	N/A	N/A	N	N	N	N	N	N	N	N
2889BR	G28890689001	06/20/89	06/20/89	08/05/89	MJS062089001	8 00	400 0	15 0	N	N	N	N	R	R	N	Y
2989BR	DRY	05/25/89	/ /	/ /		N/A	N/A	N/A	N	N	N	N	N	N	N	N
3089BR	DRY	05/22/89	/ /	/ /		N/A	N/A	N/A	N	N	N	N	N	N	N	N
3189	G31890589001FB	05/25/89	05/25/89	07/10/89	MJS052589001	N/A	N/A	N/A	N	N	N	N	Y	N	N	Y
3189BR	G31890589001D	05/25/89	05/25/89	07/10/89	MJS052589001	7 80	230 0	11 0	N	N	N	N	Y	R	N	Y
3189BR	G31890589001	05/25/89	05/25/89	07/10/89	MJS052589001	7 80	230 0	11 0	N	N	N	N	Y	R	N	Y
3289BR	G32890689001	06/27/89	06/28/89	08/13/89	MJS062789001	10 00	260 0	12 0	N	N	N	N	Y	R	N	Y
3389BR	G33890789001	06/29/89	07/15/89	08/30/89	CSW071489001	9 80	340 0	20 0	N	N	N	N	Y	R	N	Y
3489BR	G34890689001	06/16/89	06/16/89	08/01/89	MJS061689001	9 00	320 0	13 0	N	N	N	N	R	R	N	Y
3589BR	G35890789001	07/06/89	08/10/89	09/25/89	CSW080989001	9 70	1000 0	17 0	N	N	N	N	Y	R	N	Y
3689BR	G36890689001	06/27/89	06/28/89	08/13/89	MJS062789001	10 40	1800 0	12 0	N	N	N	N	Y	R	N	Y
3789BR	G37890689001	06/23/89	06/23/89	08/08/89	DEJ062389001	9 00	760 0	21 0	N	N	N	N	Y	R	N	Y

N - Not sampled for this group, Y - Sampled for this group, results not yet received, R - Results for this group received

Table 3-8 (Continued)

BACKGROUND

GROUND WATER SAMPLE INFORMATION

	SAMPLE INFORMATION					FIELD PARAMETERS			LABORATORY ANALYTES							
WELL NUMBER	SAMPLE NUMBER	SAMPLE DATE	SHIPPING DATE	TURNAROUND DATE	CUSTODY SHEET NO	pH	CONDUCT (umhos/cm)	TEMP (deg C)	VOA	SEMI-VOA	PEST PCB	TOTAL METALS	DISS METALS	INORG	TOT RADS	DISS RADS
3989BR	DRY	05/24/89	/ /	/ /		N/A	N/A	N/A	N	N	N	N	N	N	N	N
4089BR	DRY	05/22/89	/ /	/ /		N/A	N/A	N/A	N	N	N	N	N	N	N	N
4189BR	G41890689001	06/23/89	06/23/89	08/08/89	DEJ062389001	8 90	890 0	21 0	N	N	N	N	Y	R	N	Y
4289BR	DRY	05/24/89	/ /	/ /		N/A	N/A	N/A	N	N	N	N	N	N	N	N
4389BR	DRY	06/23/89	/ /	/ /		N/A	N/A	N/A	N	N	N	N	N	N	N	N
4489BR	G44890589001	05/31/89	05/31/89	07/16/89	DEJ053189001	7 30	570 0	12 0	N	N	N	N	R	R	N	Y
4589BR	G45890689001	06/21/89	06/23/89	08/08/89	DEJ062189001	8 10	325 0	23 0	N	N	N	N	R	R	N	Y
4689	DRY	05/05/89	/ /	/ /		N/A	N/A	N/A	N	N	N	N	N	N	N	N
4789	G47890689001	06/14/89	06/15/89	07/31/89	MJS061589001	7 50	340 0	11 0	N	N	N	N	R	R	N	Y
4889	G48890689001	06/15/89	06/16/89	08/01/89	MJS061689001	7 00	190 0	13 0	N	N	N	N	R	R	N	Y
4989	G49890689001FB	06/14/89	06/14/89	07/30/89	WWB061489001	N/A	N/A	N/A	N	N	N	N	R	N	N	Y
4989BR	G49890689001D	06/14/89	06/14/89	07/30/89	WWB061489001	7 00	250 0	9 0	N	N	N	N	R	R	N	Y
4989BR	G49890689001	06/14/89	06/14/89	07/30/89	WWB061489001	7 00	250 0	9 0	N	N	N	N	R	R	N	Y
5089	DRY	05/17/89	/ /	/ /		N/A	N/A	N/A	N	N	N	N	N	N	N	N

N - Not sampled for this group, Y - Sampled for this group, results not yet received, R - Results for this group received

Table 3-8 (Continued)

BACKGROUND

GROUND WATER SAMPLE INFORMATION

	SAMPLE INFORMATION					FIELD PARAMETERS			LABORATORY ANALYTES							
WELL NUMBER	SAMPLE NUMBER	SAMPLE DATE	SHIPPING DATE	TURNAROUND DATE	CUSTODY SHEET NO	pH	CONDUCT (umhos/cm)	TEMP (deg C)	VOA	SEMI-VOA	PEST PCB	TOTAL METALS	DISS METALS	INORG	TOT RADS	DISS RADS
5586	G55860689001	06/08/89	06/09/89	07/25/89	MJS060889001	7 10	180 0	11 0	N	N	N	N	Y	R	N	Y

N Not sampled for this group, Y - Sampled for this group, results not yet received, R - Results for this group received

TABLE 3-9

BACKGROUND GROUND-WATER AND SURFACE WATER SAMPLING PARAMETERS

FIELD PARAMETERS

pH
Specific Conductance
Temperature
Dissolved Oxygen*

INDICATORS

Total Dissolved Solids
Total Suspended Solids*
pH

METALS**

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

TABLE 3-9 (CONTINUED)

BACKGROUND GROUND-WATER AND SURFACE WATER SAMPLING PARAMETERS

ANIONS

Carbonate
Bicarbonate
Chloride
Sulfate
Nitrate (as N)
Cyanide

RADIONUCLIDES

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

* For surface water samples only

** Analysis for total and dissolved metals for surface water Analysis for total (Rounds 1 and 2) and dissolved (Round 1 only) radionuclides (except trituim) on surface water Analysis for dissolved metals and radionuclides (except tritium) only for ground water Analysis for total tritium only in surface water and ground water

*** Decision tree If the Gross Alpha value is ≥ 5 pCi/l then the sample is analyzed for RA 226,228

Table 3-10

Water Level Data
for
Rockwell (Rocky Flats)

Well Number	Date	Water Dpth Below TOC (ft)
0189A	06/14/89	23 75
0289	06/14/89	15 40
0389	06/14/89	21 05
0489	06/15/89	9 90
0589	06/07/89	21 70
0689	06/07/89	23 75
0789	06/06/89	21 10
0889	06/05/89	20 89
0989	04/19/89	1 00
1089	05/04/89	7 32
1189	05/15/89	1 00
1289	05/15/89	1 00
1389	05/12/89	1 00
1489	05/11/89	1 00
1589	05/04/89	3.30
1689	05/16/89	1 00
1789BR	06/05/89	8 69
1889	04/25/89	3 00
1989	04/25/89	5 95
2089	04/24/89	8 95
2189	04/26/89	5.41
2289	04/27/89	3 96
2389	04/26/89	6 86
2489	04/27/89	5 83
2589	04/27/89	4 18
2689	05/10/89	-1 00
2789BR	05/24/89	1 00
2889BR	06/19/89	39 95
2989BR	05/25/89	1 00
3089BR	05/22/89	1 00
3189BR	05/24/89	20 87
3289BR	06/27/89	138 85
3389BR	06/29/89	110 15
3489BR	06/16/89	78 90
3589BR	07/06/89	112 25
3689BR	06/27/89	90 70
3789BR	06/23/89	13 67
3989BR	05/24/89	1 00
4089BR	05/22/89	-1.00
4189BR	06/23/89	41 26
4289BR	05/24/89	-1 00
4389BR	06/23/89	-1 00
4489BR	05/31/89	10 48
4589BR	06/21/89	47 67
4689	05/04/89	1.00
4789	06/14/89	7 00
4889	06/15/89	9 40
4989BR	06/14/89	11 30
5089	05/17/89	1 00
5586	06/08/89	15 62

samples were not being collected One duplicate sample and one field blank sample were collected and analyzed for every 20 investigative ground-water samples collected (Table 3-8)

3 2 6 Slug and Pumping Tests

Slug and pumping tests were performed on the background wells to determine hydraulic conductivities and transmissivities and their variations within the different geological formations on the Rocky Flats Plant These same formations underlie the RCRA/CERCLA units of concern at the site, and the results of these tests will help characterize the flow patterns in those critical areas Slug tests were attempted on all background wells unless the saturated thickness of the water column was less than four feet

Within Appendices C-1 and D-1 are the revised Standard Operating Procedures (SOP) 3 2 and 3 4 (July 1989) which were generally followed during aquifer testing Any deviations from the SOPs are discussed below along with a generalized discussion of the methods used for analyzing the data

The SOP for slug testing states that the measured water level must be within 0 1 ft of the water level before sampling if a test was conducted on the well that had recently been water sampled or developed It was observed that natural fluctuations in the water level could be much greater than 0 1 ft, therefore, if the well appeared to be near equilibrium after waiting several days to a week after the disturbance, slug testing was performed

The SOP also suggests installation of the pressure transducer at least 2 ft above the bottom of the well Generally the transducer was installed in the well at least 2 ft above the bottom of the well, however, several wells had insufficient water to perform a slug test, therefore in several wells (Wells 08-89, 19-89, 20-89, 24-89, 25-89 and 46-89) the transducer was placed closer to the bottom than 2 ft

ER Program SOPs for aquifer pumping tests suggest establishing the barometric efficiency of the aquifer Pretest water levels were monitored at the test site before performing the test, and barometric pressure data were obtained from Rockwell International, Environmental Management (Wanda Busby, personal communication, 1989) Barometric pressure only affects the water levels in the confined aquifers (Stallman, 1983), thus Pump Tests 37-89BR and 49-89BR could possibly be affected However, either of these tests do not fall into the category of long-term pumping tests, and the barometric pressure data was not used to evaluate the pumping test values

Optimum pumping rates for each monitor well should be determined before the test begins in that longer tests produce more definitive results Optimum pumping rates were generally very low (less than 0 0625 gal,min) because of the low hydraulic conductivities of the formations If fact, in the case of 10-89 and 37-89BR, no pump is designed to pump at a sufficiently low flow rate Peristaltic pumps produce low flow rates but they can not lift the water up above approximately 20 feet at this atmospheric pressure Bladder pumps would also produce low flow rates, however the surge and fill rhythm does not produce a constant flow rate over short periods of time An attempt was made to reduce the back pressure on the Johnson-Keck pump by melting holes in the polyethylene tubing adjacent to the pump outlet below the water surface Lower flow rates and longer pump tests would have provided more optimum data to evaluate, however hardware for obtaining these ow constant flow rates is not available with current technology

Finally, the SOP suggests that one simple test for determining the adequacy of data is to compare the log time to drawdown for the most distant observation well and to plot a straight line on the semilog graph paper Test durations were generally so short that the straight line part of the curve, when the aquifer is approaching equilibrium with the constant discharge, was never reached in the pumping well

3 2 7 Surface Water Sampling

Surface water samples were collected from nine designated background stations (Table 3-12) Analytical data from the first two rounds of sampling are included in this report The first round of samples was collected from 2/24/89 to 3/2/89 and all nine stations were sampled The second round of samples was collected on 5/8/89 through 6/1/89 and two stations (SW-80 and SW-04) were dry Additional rounds are being collected to evaluate seasonal variations in the surface water chemistry

Laboratory analyses on background surface water samples consisted of the parameters listed in Table 3-9 Surface water samples were analyzed in the field for pH, conductivity, temperature, and dissolved oxygen (Table 3-12) All samples requiring filtration were filtered in the field, and all samples were preserved in the field where necessary All surface water sampling and stream flow measurements followed the procedures outlined in the SOPs Duplicate and field blank samples were collected at a rate of 10%

Stream flow measurements were taken at each sampling location where the water was flowing The flow measurements were taken with a Baski Cutthroat Flume when possible and alternative methods as described in the SOPs were used when necessary Table 3-13 lists the calculated stream flow measurements for the stations with obtainable flows

TABLE 3-11

BACKGROUND MONITOR WELL PAIRS SELECTED FOR PUMPING TESTS

Well Cluster	General Locations	Comment
01-89A 01-89P	In the Buffer Zone to the Southwest of the plant	Rocky Flats Alluvium well pair will characterize alluvium
04-89 47-89 48-89	In the Buffer Zone to the southwest of the plant	Fully screened alluvial well with two partially screened wells nearby Will characterize alluvium
49-89 BR 17-89 BR	South of the plant area and Woman Creek	Two wells though to be screened in the same sand Will test for interconnected sands
10-89 46-89	Northern edge of Buffer Zone	In slump block - may not provide representative results
37-89 BR	In Buffer Zone to the southeast of the plant	Bedrock well with piezometer completed in alluvium Will test for vertical connection between bedrock and alluvium

Table 3-12

BACKGROUND

SURFACE WATER SAMPLE INFORMATION

SAMPLE INFORMATION						FIELD PARAMETERS				LABORATORY ANALYTES								
STATION NUMBER	SAMPLE NUMBER	SAMPLE DATE	SHIPPING DATE	TURNAROUND DATE	CUSTODY SHEET NO	pH	CONDUCT (umhos/cm)	TEMP (deg C)	D O (mg/l)	VOA	SEMI-VOA	PEST PCB	HERB	TOT METS	DIS MET	INORG	TOT RADS	DISS RADS
SW04	SW004001	03/02/89	03/02/89	04/17/89	MJS030289003	6 50	210 00	3 0	70 0	N	N	N	N	Y	Y	R	R	R
SW04	DRY	05/30/89	/ /	/ /		N/A	N/A	N/A	N/A	N	N	N	N	N	N	N	N	N
SW05	SW05001	02/28/89	02/28/89	04/15/89	KMM022889003	6 28	150 00	2 7	40 0	N	N	N	N	R	R	R	R	R
SW05	SW005002	05/30/89	05/30/89	07/15/89	WWB053089001	7 20	70 00	12 0	3 4	N	N	N	N	R	R	R	Y	N
SW06	SW06001	02/24/89	02/24/89	04/11/89	KMM022489001	6 45	60 00	4 0	3 1	N	N	N	N	R	R	R	R	R
SW06	SW06001D	02/24/89	02/24/89	04/11/89	KMM022489001	6 45	60 00	4 0	3 1	N	N	N	N	R	R	R	R	R
SW06	SW06001FB	02/24/89	02/24/89	04/11/89	KMM022489001	N/A	N/A	N/A	N/A	N	N	N	N	R	R	N	R	R
SW06	SW006002	05/31/89	05/31/89	07/16/89	SAS053189001	7 00	90 00	14 0	4 5	N	N	N	N	R	R	R	Y	N
SW07	SW07001	02/27/89	02/28/89	04/15/89	KMM022789003	6 40	130 00	5 0	13 0	N	N	N	N	Y	Y	R	R	R
SW07	SW007002	05/31/89	05/31/89	07/16/89	SAS053189001	6 50	285 00	15 0	5 9	N	N	N	N	R	R	R	Y	N
SW104	SW104001	03/02/89	03/02/89	04/17/89	MJS030289003	5 90	410 00	1 0	30 0	N	N	N	N	R	R	R	R	R
SW107	SW107001	02/28/89	02/28/89	04/15/89	KMM0222789003	5 60	190 00	0 5	53 0	N	N	N	N	R	R	R	R	R
SW107	SW107002	05/26/89	05/26/89	07/11/89	WWB052689001	7 50	192 00	21 0	3 2	N	N	N	N	R	R	R	Y	N
SW108	SW108001	03/02/89	03/02/89	04/17/89	MJS030289003	5 80	285 00	1 0	74 0	N	N	N	N	R	R	R	R	R
SW108	SW108002	05/30/89	05/30/89	07/15/89	WWB053089001	7 40	300 00	13 0	0 0	N	N	N	N	R	R	R	Y	N
SW108	SW108002D	05/30/89	05/30/89	07/15/89	WWB053089001	7 40	300 00	13 0	0 0	N	N	N	N	R	R	R	Y	N
SW108	SW108002FB	05/30/89	05/30/89	07/15/89	WWB053089001	N/A	N/A	N/A	N/A	N	N	N	N	R	R	N	Y	N
SW41	SW41001	03/01/89	03/01/89	04/16/89	MJS030189002	5 00	200 00	0 5	55 0	N	N	N	N	R	R	R	R	R
SW41	SW041002	05/26/89	05/26/89	07/11/89	WWB052689001	6 80	165 00	19 0	0 0	N	N	N	N	R	R	R	Y	N

N - Not sampled for this group, Y - Sampled for this group, results not yet received, R - Results for this group received

Table 3-12 (Continued)

BACKGROUND

SURFACE WATER SAMPLE INFORMATION

	SAMPLE INFORMATION					FIELD PARAMETERS				LABORATORY ANALYTES								
STATION NUMBER	SAMPLE NUMBER	SAMPLE DATE	SHIPPING DATE	TURNAROUND DATE	CUSTODY SHEET NO	pH	CONDUCT (umhos/cm)	TEMP (deg C)	D O (mg/l)	VOA	SEMI-VOA	PEST PCB	HERB	TOT METS	DIS MET	INORG	TOT RADS	DISS RADS
SW80	SW080001	03/01/89	03/01/89	04/16/89	MJS030189002	6 00	160 00	0 6	38 0	N	N	N	N	R	R	R	R	R
SW80	DRY	05/24/89	/ /	/ /		N/A	N/A	N/A	N/A	N	N	N	N	N	N	N	N	N

N - Not sampled for this group, Y - Sampled for this group, results not yet received, R - Results for this group received

Table 3-13

Surface Water Flow
for
Rockwell (Rocky Flats)

STATION NUMBER	DATE MEASURED	FLOW* RATE
SW004	03/02/89	0 37
SW004	06/15/89	0 01
SW005	02/28/89	0 04
SW005	05/30/89	0 03
SW007	02/27/89	0 02
SW041	03/01/89	11 81
SW107	02/28/89	0 57
SW107	05/26/89	0 01

* Flow rates converted to cubic feet per second (cfs)

3 2 8 Stream Sediment Sampling

Stream sediment samples were collected from each of the nine background surface water sampling locations One round of sampling took place between 2/21/89 and 2/24/89 A total of nine samples were collected (Table 3-14) The background sediment samples were analyzed for the parameters listed in Table 3-15 and the collection of these samples were consistent with the procedures outlined in the SOPs

3 3 LABORATORY ANALYTICAL METHODS

Laboratory analyses of ground-water, and surface water samples were performed following the Contract Laboratory Program protocols for the Inorganic Target Analyte List Details of laboratory analyses for these and other constituents were presented in the January 1989 QA/QC Plan

Table 3-14

BACKGROUND

SEDIMENT SAMPLE INFORMATION

	SAMPLE INFORMATION					LABORATORY ANALYTES						
STATION NUMBER	SAMPLE NUMBER	SAMPLE DATE	SHIPPING DATE	TURNAROUND DATE	CUSTODY SHEET NO	VOA	SEMI-VOA	PEST PCB	HERB	TOTAL METALS	INORGAN	TOT RADS
SD004	SED04001	02/21/89	02/22/89	04/09/89	KMM022189001	N	N	N	N	R	R	R
SD004	SED04001D	02/21/89	02/22/89	04/09/89	KMM022189001	N	N	N	N	R	R	R
SD016	SED16001	02/23/89	02/23/89	04/10/89	MJS022389001	N	N	N	N	R	R	R
SD017	SED17001	02/23/89	02/23/89	04/10/89	KMM022389001	N	N	N	N	R	R	R
SD018	SED18001	02/23/89	02/23/89	04/10/89	MJS022389001	N	N	N	N	R	R	R
SD019	SED19001	02/23/89	02/23/89	04/10/89	MJS022389001	N	N	N	N	R	R	R
SD020	SED20001	02/22/89	02/22/89	04/09/89	RCC022289001	N	N	N	N	R	R	R
SD021	SED21001	02/22/89	02/22/89	04/09/89	RCC022289001	N	N	N	N	R	R	R
SD022	SED22001	02/22/89	02/22/89	04/09/89	RRC022289001	N	N	N	N	R	R	R
SD022	SED22001FB	02/22/89	02/22/89	04/09/89	RRC022289002	N	N	N	N	R	N	R
SD023	SED23001	02/21/89	02/22/89	04/09/89	KMM022189001	N	N	N	N	R	R	R

N - Not sampled for this group, Y - Sampled for this group, results not yet received, R - Results for this group received

TABLE 3-15

BACKGROUND SEDIMENT SAMPLING PARAMETERS

METALS

CLP Target Analyte List
Cesium
Lithium
Molybdenum
Strontium
Tin

INORGANICS

Nitrate (as N)
pH
% solids

RADIONUCLIDES

Gross Alpha
Gross Beta
Uranium 233, 234, 235, 238
Plutonium 239, 240
Americium 241
Strontium 89,90
Cesium 137
Tritium
Radium 226, 228

SECTION 4.0

BACKGROUND GEOLOGIC CHARACTERIZATION

The results of the hydrogeologic characterization of background areas of Rocky Flats Plant are presented in the following subsections Cross sections through background areas were constructed to illustrate the relationship between the hydrogeologic units In addition, aquifer testing results from the background wells are discussed below

4 1 ROCKY FLATS ALLUVIUM

Cross sections A-A' and B-B' (Plate 2) exhibit the variation in thickness of the Rocky Flats Alluvium across the background areas of the plant A fence diagram (Plate 3) was also constructed using wells 1-89A, 2-89, 3-89, and 4-89 to illustrate the facies relationships within the Rocky Flats Alluvium

As illustrated in cross-section B-B', sand intervals in the alluvium range in thickness from 0 5 feet (34-89BR) to 28 0 feet (03-89) and caliche/calcareous zones range in thickness from 0 5 feet (33-89BR) to 5 0 feet (32-89BR) In well pair 27-89BR and 28-89BR, the Rocky Flats Alluvium is 29 0 and 28 0 feet thick, respectively Both wells penetrated silty clay and clayey silt lenses up to 30 feet thick, however, these wells are approximately 750 feet and therefore it is difficult to correlate stringers within the alluvium It is evident from this cross-section and the lithologic logs from the wells that the alluvium is thinning from west to east, and is consistently fining downward Wells 32-89BR and 33-89BR are 805 feet apart and cannot be correlated Well 30-89BR exhibits a thin clayey to silty sand lens (6 3 - 24 3') that does not appear in 33-89BR

The fence diagram (Plate 3) shows cut and fill sequences characteristic of braided stream deposits in the Rocky Flats Alluvium Stratigraphic pinch-outs are also common in the alluvium It should be noted how gravel, and sand and gravel lenses between 1-89A, 2-89/BH02-89 come and go before reaching 3-89 and 4-89

Ground water occurs under unconfined conditions within the Quaternary Rocky Flats Alluvium at the Rocky Flats Plant In general, ground-water flow is from west to east through the Rocky Flats Alluvium, subtly reflecting the topography toward ephemeral streams

Ten wells were completed in the Rocky Flats Alluvium, all of which had sufficient water to perform slug tests The range of hydraulic conductivity observed in this aquifer was 3 0 x 10^{-2} cm/sec in Well 48-89 to 1 2 x 10^{-7} cm/sec in Well 47-89, with the average of the slug (slug out) tests at 2 4 x 10^{-3} cm/sec (Table 4-1) Transmissivities ranged between 9 3 cm^2/sec in Well 04-89 and 1 9 x 10^{-4} cm^2/sec in Well 47-89, with an average transmissivity of 2 9 cm^2/sec The saturated thickness of the materials ranged from 120 cm to 1500 cm with an average thickness of 808 cm Slug tests were analyzed using the method of Bouwer and Rice (1976) and Bouwer (1989)

Two pump tests were performed in the Rocky Flats Alluvium during the current study, Well Clusters 01-89A/01-89P and 04-89/47-89/48-89 The pumping test results correspond fairly well with the results of the slug tests

Wells 01-89A and 01-89P were both completed in the Rocky Flats Alluvium The results of the pumping test using the Boulton method (1963) showed the pumping Well 01-89A to have a transmissivity of 1 0 x 10^{-1} cm^2/sec and hydraulic conductivity of 1 2 x 10^{-4} cm/sec Piezometer 01-89P showed some response to the pumping test with transmissivity calculated to be 4 6 x 10^{-1} cm^2/sec, hydraulic conductivity of 5 5 x 10^{-4} cm/sec, and storativity of 0 016 (Table 4-2)

Wells 04-89, 47-89 and 48-89 were all completed in the Rocky Flats Alluvium The pumping well 04-89 is fully penetrating, while the two observation are only partially screened, Well 47-89 is screened in the upper part of the Rocky Flats Alluvium, while Well 48-89 is screened in the lower part The purpose of this test was to characterize the alluvium The results of the pumping test using the Boulton method (1963) showed the pumping Well 04-89 to have transmissivity of 1 7 cm^2/sec and hydraulic conductivity of 1 3 x 10^{-3} cm/sec TABLE

TABLE 4-1

SLUG TEST ANALYSIS RESULTS
ROCKY FLATS ALLUVIUM

Well Number	Slug In or Bail Out	Hydraulic Conductivity (cm/sec)	Transmissivity (cm^2/sec)	Aquifer Thickness (cm)	Water Above Top of Screened Interval
01-89A	In	5 8x10^{-5}	5 1x10^{-2}	893	Below
	Out	7 0x10^{-5}	6 3x10^{-2}		
02-89	In	7 6x10^{-4}	8 3x10^{-1}	1075	Above
	Out	7 6x10^{-4}	8 1x10^{-1}		
03-89	In	1 3x10^{-4}	1 2x10^{-1}	886	Below
	Out	1 8x10^{-4}	1 9x10^{-1}		
04-89	In	7 0x10^{-4}	9 3	1394	Above
	Out	5 8x10^{-4}	8 3		
05-89	In	3 0x10^{-3}	9 3x10^{-1}	320	Below
	Out	1 2x10^{-3}	3 9x10^{-1}		
06-89	In	3 7x10^{-4}	1 0x10^{-1}	278	Below
	Out	4 3x10^{-4}	1 2x10^{-1}		
	In Dup	3 7x10^{-4}	9 3x10^{-2}	276	Below
	Out Dup	3 7x10^{-4}	1 0x10^{-1}		
07-89	In	8 2x10^{-4}	2 2x10^{-1}	274	Below
	Out	8 5x10^{-4}	2 3x10^{-1}		
08-89	In	5 2x10^{-4}	6 2x10^{-2}	120	Below
	Out	4 0x10^{-4}	4 7x10^{-2}		
	In Dup	5 2x10^{-4}	6 2x10^{-2}	120	Below
	Out Dup	4 9x10^{-4}	5 9x10^{-2}		
47-89	In	2 2x10^{-7}	3 3x10^{-4}	1500	Below
	Out	1 2x10^{-7}	1 9x10^{-4}		
48-89	In	3 0x10^{-2}	41 8	1338	Above
	Out	1 4x10^{-2}	18 6		

TABLE 4-2
ROCKY FLATS ALLUVIUM

PUMPING TEST RESULTS

WELL NO	T CM^2/SEC	K CM/SEC	S	METHOD	COMMENTS
01-89A	1 0x10^{-1}	1 2x10^{-4}	*	Boulton, 1963	Unconfined
01-89P	4 6x10^{-1}	5 5x10^{-4}	0 016	Boulton, 1963	Unconfined
04-89	1 7	1 3x10^{-3}	*	Boulton, 1963	Unconfined
47-89	---	---	---		No Response
48-89	2 7	2 0x10^{-3}	0 019	Boulton, 1963	Unconfined

* Storativity (S) cannot be calculated with pumping well data

Observation Well 47-89, screened in the upper portion of the Rocky Flats Alluvium, showed no response to pumping in Well 04-89 Observation Well 48-89, screened in the lower portion of the alluvium, did respond to the pumping test Analysis using the Boulton method (1963) showed Well 48-89 to have transmissivity of 2 7 cm^2/sec, hydraulic conductivity of 2 0 x 10^{-3} cm/sec and storativity of 0 019 (Table 4-2)

4 2 COLLUVIUM

Cross section A-A' (Plate 2) illustrates the position of the colluvium at the Rocky Flats Plant Wells 09-89 and 35-89BR on the most eastern portion of the line show variable thickness due to erosion and depositional sequences The colluvium is 0 8 feet thick in 35-89BR and 2 25 feet thick in 09-89 As exhibited on section A-A', Wells 49-89BR, 43-89BR, 16-89 and 39-89BR encountered colluvium The colluvium is thickest in Well 39-89BR (24 0 feet)

Ground water occurs under unconfined conditions within the Quarternary colluvium Ten wells were completed in the colluvium, however, seven of these wells had insufficient water within the casing to perform a slug test Tests performed on the remaining 3 wells showed that hydraulic conductivity ranged from 2 5 x 10^{-3} cm/sec in Well 46-89 to 9 1 x 10^{-6} cm/sec in Well 10-89, with an average hydraulic conductivity of 9 1 x 10^{-4} cm/sec based on slug (slug out) tests (Table 4-3) Transmissivities of the Colluvium ranged between 1 6 cm^2/sec in Well 46-89 and 8 1 x 10^{-3} cm^2/sec in Well 10-89 The average transmissivity of the colluvium based on the slug out tests is 5 8 x 10^{-1} cm^2/sec The saturated thickness of the colluvium ranged from 548 cm to 869 cm, with an average thickness of 679 cm Slug tests were analyzed using the method of Bouwer and Rice (1976) and Bouwer (1989)

One pump test was performed in the Quaternary Colluvium during the current study at Well Cluster 10-89/46-89 Both wells were installed in a slump block of colluvium and this test was performed to test the interconnectedness of the two wells During pumping test 1A, a pumping rate of 0 52 gpm was used and during test 1B a rate of 0 23 gpm was maintained Using the Boulton method (1963), pumping Well 10-89 had a transmissivity of 1 4 x 10^{-2}

TABLE 4-3
SLUG TEST ANALYSIS RESULTS
COLLUVIUM

Well Number	Slug In or Baıl Out	Hydraulıc Conductıvıty (cm/sec)	Transmıssıvıty (cm^2/sec)	Aquıfer Thıckness (cm)	Water Above Top of Screened Interval
10-89	In	9 1x10^{-6}	8 1x10^{-3}	869	Above
	Out	9 5x10^{-6}	8 2x10^{-3}		
15-89	In	2 9x10^{-4}	1 6x10^{-1}	548	Above
	Out	3 0x10^{-4}	1 7x10^{-1}		
46-89	In	1 7x10^{-3}	1 0	621	Below
	Out	2 5x10^{-3}	1 6		

/cm^2/sec and hydraulic conductivity of 1 9 x 10^{-5} cm/sec for Test 1A, and had a transmissivity of 1 6 x 10^{-2} cm^2/sec and hydraulic conductivity of 2 2 x 10^{-5} cm/sec for Test 1B (Table 4-4) Observation Well 46-89 showed no response to pumping in Well 10-89, thus these two screened intervals are probably not connected, and storativity could not be calculated accurately

4 3 VALLEY FILL ALLUVIUM

The thickness of the valley fill materials in the background areas ranges from 4 4 feet in 25-89 to 9 4 feet in both 44-89BR and 20-89 (Plate 2) Correlations can be made of silty sand and gravel layers between wells 24-89 and 40-89BR West of these wells (23-89 and 44-89BR) silty clay stringers can be correlated, however, there is a small (4 0 feet) silty sand lense in 44-89BR that was not as thick, (2 0 feet) in 23-89, which may give evidence for channeling This lense cannot be correlated to the eastern most wells due to distance and irregularity of deposition

Ground water occurs under unconfined conditions within the Quarternary Valley Fill Alluvium Nine wells were completed in the Valley Fill Alluvium, three of which contained insufficient water to perform a slug test Hydraulic conductivities ranged between 2 3 x 10^{-2} cm/sec in Well 21-89 and 9 4 x 10^{-5} cm/sec in Well 18-89 (Table 4-5) The average hydraulic conductivity of the slug (slug out) tests is 5 5 x 10^{-3} cm/sec The range of transmissivities observed in the Valley Fill Alluvium background wells was between 5 5 cm^2/sec in Well 21-89 and 1 9 x 10^{-25} cm^2/sec in Well 19-89, with an average transmisivity of 1 2 cm^2/sec The saturated thickness of the Valley Fill Alluvium ranged from 160 cm to 342 cm, with an average aquifer thickness of 223 cm Slug tests were analyzed using the method of Bouwer and Rice (1976) and Bouwer (1989)

No pumping tests were attempted in the Valley Fill Alluvium

TABLE 4-4
COLLUVIUM

PUMPING TEST RESULTS

T WELL NO	K FT^2/SEC	S FT/SEC		METHOD	COMMENTS
10-89 1A	1 4x10^{-2}	1 9x10^{-5}	*	Boulton, 1963	Unconfined
1B	1 6x10^{-2}	2 2x10^{-5}	*	Boulton, 1963	
46-89	---	---	---		No Response

* Storativity (S) cannot be calculated with pumping well data

TABLE 4-5

SLUG TEST ANALYSIS RESULTS
VALLEY FILL ALLUVIUM

Well Number	Slug In or Bail Out	Hydraulic Conductivity (cm/sec)	Transmissivity (cm^2/sec)	Aquifer Thickness (cm)	Water Above Top of Screened Interval
18-89	In	2 3x10^{-4}	7 8x10^{-2}	342	Above
	Out	2 3x10^{-4}	7 5x10^{-2}		
19-89	In	1 4x10^{-4}	2 8x10^{-2}	193	Below
	Out	9 4x10^{-5}	1 9x10^{-2}		
20-89	In	7 6x10^{-3}	1 2	160	Below
	Out	1 0x10^{-2}	1 6		
	In Dup	7 3x10^{-3}	1 2	160	Below
	Out Dup	9 8x10^{-3}	1 5		
21-89	In	2 3x10^{-2}	6 1	273	Above
	Out	Transducer Moved During Slug Removal			
	In Dup	2 0x10^{-2}	5 5	273	Above
	Out Dup	1 9x10^{-3}	5 1		
24-89	In	2 8x10^{-3}	5 6x10^{-1}	200	Above
	Out	2 2x10^{-3}	4 5x10^{-1}		
25-89	In	1 2x10^{-3}	2 0x10^{-1}	168	Above
	Out	1 5x10^{-3}	2 6x10^{-1}		

4 4 BEDROCK

4 4 1 Bedrock Claystone

Claystones were the most common lithologies encountered immediately below the Quaternary/Cretaceous contact, illustrated in cross section A-A' (Plate 2) Claystones in the background area are described as massive and blocky, consolidated and containing occasional sand, silt and coal stringers At times the claystones were thickly bedded and highly fractured

Directly below the surficial material weathered bedrock was encountered Weathering is related to influx and filtration of groundwater percolating through the overlying materials and into the underlying bedrock unit In some cases weathering was prevalent to depths of 38 5 feet below ground surface, (29-89BR) Weathered claystone was typically pale olive (10 Y 6/2), light olive gray (5 Y 6/1) and pale to moderate yellowish brown (10 YR 6/2 and 10 YR 5/4) Along with staining and mottling, dark yellowish orange (10 YR 6/6) occasional iron-oxide nodules and concretions were observed Calcium carbonate deposits were also noted within the weathered claystone (40-89BR) Well 37-89BR located in the south buffer zone encountered highly weathered claystone to 24 0 feet In contrast, Well 36-89BR in the north buffer zone was fractured to 46 0 feet Most cases would also show that fracturing occurred during high stress, and influx of water movement added to the extent of weathering Trace to some silt and very fine-grained sand laminae are also common in the weathered claystone as well as lignite stringers and carbonaceous infilling in the form of plant fossils (27-89BR, 35-89BR, 34-89BR, 33-89BR and 32-89BR)

Unweathered claystone is typically dark gray (N 3/0) to yellowish gray (5 Y 7/2) and occasionally mottled Wells 36-89BR and 37-89BR show fracturing to depths of 46 0 feet and 24 0 feet respectively Most of the shallow fractures are filled with calcareous material and iron-stained implying water movement and fracturing becomes less predominant with depth

Ground water is very limited within the Cretaceous weathered claystone Nine of the ten wells completed in the weathered claystone had insufficient water to be slug tested or never fully stabilized after sampling, and only one of the ten was actually available for slug testing (Well 44-89BR) Ground water occurs under unconfined conditions within the Cretaceous weathered claystone The static water level was above the top of the screened interval in Well 44-89BR, therefore both the slug in and slug out data are valid (Bouwer, 1989) Hydraulic conductivity values for this well ranged between 1 8 x 10^{-4} cm/sec and 3 4 x 10^{-5} cm/sec (Table 4-6) Transmissivity ranged between 9 3 x 10^{-3} cm^2/sec and 6 2 x 10^{-3} cm^2/sec Saturated thickness of Well 44-89BR was 183 cm

4 2 2 Bedrock Sandstone

Cross section A-A' (Plate 2), shows a sandstone lense correlated between 49-89BR and 43-89BR and 16-89 It does appear to pinch out towards the west and thins to the east On the same section, a separate sandstone lense was encountered in 43-89BR This also pinches out to the west, and was not found in 49-89BR Bedrock lenses (claystone, silty claystone and sandstone) are seen as shallow dipping beds (3° - 4° as illustrated on section A-A' Occasionally interspersed were very fine to fine-grained sands, as well as wood fragments, carbonaceous material and chart and siderite nodules

Bedrock Wells 32-89, 33-89, 34-89, 35-89, 36-89 and 38-89BR are completed in bedrock sandstones with some interbedded siltstone intervals Sandstones ranged from 1 3 (35-89BR) to 14 9 (36-89BR) Unweathered sandstone was encountered in 35-89BR, varying from medium gray (N 5/0) to medium dark gray (N 4/0) General composition consisted of very fine (2 5 - 1 5 phi) to fine and medium-grained (2 0 - 1 0 phi) quartzose sand Silty sandstone was common as well as silty sandstone/sandstone interbeds and laminae In Well 35-89BR, the contact between sandstone and claystone beds was abrupt at 128 0 feet exhibiting a gentle dip of 10°

TABLE 4-6

SLUG TEST ANALYSIS RESULTS
WEATHERED CLAYSTONE

Well Number	Slug In or Bail Out	Hydraulic Conductivity (cm/sec)	Transmissivity (cm^2/sec)	Aquifer Thickness (cm)	Water Above Top of Screened Interval
44-89BR	In	$3.4x10^{-5}$	$6.2x10^{-3}$	183	Above
	Out	$1.8x10^{-4}$	$9.3x10^{-3}$		

Ground water occurs under confined conditions within the Cretaceous sandstone Eleven wells were completed in Cretaceous sandstone, only four of which were successfully slug tested Well 43-89BR had insufficient water to perform a slug test Wells 33-89BR and 35-89BR required many visits to obtain enough water for a complete suite of water quality samples, and it was decided not to perform these two tests due to time constraints of Round 2 sampling Wells 32-89BR and 41-89BR were recharging during the attempted slug test or were giving spurious, unusable data Well 34-89BR and a second attempt of testing Well 41-89BR resulted in loss of the data during downloading to a PC computer due to static loss A Well Wizard Pump became stuck in Well 38-89BR during ground-water sampling and prior to slug testing Hydraulic conductivity ranged from 2 4 x 10^{-3} cm/sec in Well 49-89BR to 8 2 x 10^{-8} cm/sec in Well 36-89BR, with an average hydraulic conductivity of 7 3 x 10^{-4} cm/sec using the Cooper, Bredehoeft and Papadopulos (1967) and Papadopulos, Bredehoelft and Cooper (1973) slug out methods Transmissivities ranged from 8 9 x 10^{-1} cm^2/sec in Well 49-89BR to 3 5 x 10^{-5} cm^2/sec in Well 36-89BR The average transmissivity was 2 7 x 10^{-1} cm^2/sec using Cooper, Bredehoeft and Papadopulos (1967) and Papadopulos, Bredehoeft and Cooper (1973) slug out methods Considering the low recharge rate of the untested wells (Wells 32-89BR, 33-89BR, 35-89BR, 41-89BR, and 43-89BR) the average hydraulic conductivity and transmissivity of the Cretaceous sandstone is probably toward the lower end of the ranges Saturated thickness of the Cretaceous sandstone ranged between 122 cm to 430 cm with an average thickness of 329 cm (Table 4-7)

Two pump tests were perfromed in the Cretaceous Sandstone during the current study, Well Clusters 37-89BR/37-89P and 49-89BR/17-89BR The values of transmissivities and hydraulic conductivities calculated for pumping tests correspond fairly well with the values computed for slug tests

Well 37-89BR was completed in unweathered sandstone and Well 37-89P was completed in alluvium One of the purposes of performing this pump test was to analyze the vertical connection between alluvium and bedrock Piezometer 37-89P showed no response to pumping in Well 37-89BR, thus no storativity value can be calculated accurately Using the Theis

TABLE 4-7
SLUG TEST ANALYSIS RESULTS
SANDSTONE

Well Number	Slug In or Bail Out	Hydraulic Conductivity (cm/sec)	Transmissivity (cm^2/sec)	Aquifer Thickness (cm)	Water Above Top of Screened Interval
17-89BR	In (B&R)	2 3x10^{-4}	8 6x10^{-2}	366	Above
	Out (B&R)	2 3x10^{-4}	8 2x10^{-2}		
	In	6 1x10^{-4}	2 2x10^{-1}	366	Above
	Out	6 1x10^{-4}	2 2x10^{-1}		
36-89BR	In	8 2x10^{-8}	3 5x10^{-5}	430	Above
	Out	1 5x10^{-7}	6 3x10^{-5}		
37-89BR	In	9 8x10^{-6}	1 2x10^{-3}	122	Above
	Out	1 1x10^{-5}	1 3x10^{-3}		
49-89BR	In	2 4x10^{-3}	8 9x10^{-1}	366	Above
	Out	2 3x10^{-3}	8 4x10^{-1}		

(B&R) - Analyzed by Bouwer & Rice, 1976 Method - all the rest were analyzed using Cooper, Bredehoeft apadopulos, 1967, 1973 method (1935), transmissivity of Well 37-89BR was calculated at 2 7 x 10^{-2} cm^2/sec and hydraulic conductivity at 2 2 x 10^{-4} cm/sec (Table 4-8)

Wells 49-89BR and 17-89BR were completed in weathered sandstone These two wells are thought to be screened in the same sand, and this test investigated the connection between sands It was determined by the pumping test data that Well 49-89BR was screened in a leaky-confined aquifer Three different methods were used to analyse the pumping test data, the Hantush and Jacob method (1955), the Cooper and Jacob method (1946) and the Theis recovery method (1935) Transmissivity for Well 49-89BR using these methods was determined to be 1 1 x 10^{-1} cm^2/sec, 3 5 x 10^{-1} cm^2/sec and 3 9 x 10^{-1} cm^2/sec, respectively (Table 4-8) Hydraulic conductivity was calculated to be 3 1 x 10^{-4} cm/sec, 9 5 x 10^{-4} cm/sec and 1 1 x 10^{-3} cm/sec, respectively Observation Well 17-89BR showed good response to the pumping of Well 49-89BR and was analyzed using Theis method (1935), Cooper and Jacob method (1946) and Theis recovery method (1935) Transmissivity was determined to be 2 0 cm^2/sec, 4 4 cm^2/sec and 2 7 cm^2/sec, respectively Hydraulic conductivity was determined to be 5 2 x 10^{-3} cm/sec, 1 2 x 10^{-2} cm/sec and 7 3 x 10^{-3} cm/sec, respectively Storativity was determined to be 1 25 using the Theis method, an unreasonable value, and 0 35 using the Cooper and Jacob method

ER Prgoram SOPs for aquifer pumping tests suggest establishing the barometric efficiency of the aquifer Pretest water levels were monitored at the test site before performing the test, and barometric pressure data were obtained from Rockwell International, Environmental Management (Wanda Busby, personal communication, 1989) Barometric pressure only affects the water levels in the confined aquifers (Stallman, 1983), thus Pump Tests 37-89BR and 49-89BR could possibly be affected However, either of these tests do not fall into the category of long-term pumping tests, and the barometric pressure data was not used to evaluate the pumping test values

Optimum pumping rates for each monitor well should be determined before the test begins in that longer tests produce more definitive results Optimum pumping rates were generally very low (less than 0 0625 gal/min) because of the low hydraulic conductivities of

TABLE 4-8
SANDSTONE

PUMPING TEST RESULTS

T WELL NO	K CM^2/SEC	S CM/SEC		METHOD	COMMENTS
49-89BR	1 1x10^{-1}	3 1x10^{-4}	*	Hantush-Jacob, 1955	Leaky Confined
	3 5x10^{-1}	9 5x10^{-4}	*	Cooper-Jacob, 1946	
	3 9x10^{-1}	1 1x10^{-3}	*	Theis Recovery, 1935	
17-89BR	2 0	5 2x10^{-3}	1 25**	Theis, 1935	
	4 4	1 2x10^{-2}	0 35	Cooper-Jacob, 1946	
	2 7	7 3x10^{-3}	---	Theis Recovery, 1935	
37-89BR	2 7x10^{-2}	2 2x10^{-4}	*	Theis, 1935	Confined Jacob & Recovery Plot Appears unusable
37-89P	---	---	---		No Response

* Storativity (S) cannot be calculated with pumping well data

** Impossible Result!

the formations In fact, in the case of 10-89 and 37-89BR, no pump is designed to pump at a sufficiently low flow rate Peristaltic pumps produce low flow rates but they can not lift the water up above approximately 20 feet at this atmospheric pressure Bladder pumps would also produce low flow rates, however the surge and fill rhythm does not produce a constant flow rate over short periods of time An attempt was made to reduce the back pressure on the Johnson-Keck pump by melting holes in the polyethylene tubing adjacent to the pump outlet below the water surface Lower flow rates and longer pump tests would have provided more optimum data to evaluate, however hardware for obtaining these low constant flow rates is not available with current technology

Finally, the SOP suggests that one simple test for determining the adequacy of data is to compare the log time to drawdown for the most distant observation well and to plot a straight line on the semilog graph paper Test durations were generally so short that the straight line part of the curve, when the aquifer is approaching equilibrium with the constant discharge, was never reached in the pumping well

SECTION 5.0

5 1 DATA QUALITY

5 2 CHEMICAL RESULTS STATISTICAL COMPARISON

5 2 1 Introduction

In order to develop representative background data, sufficient samples have been collected to characterize background variation spatially across the Rocky Flats area Temporal variation of background values over time will also be characterized, and the results reported when sufficient data is available In order to compare background and downgradient chemistry, background data was (and will be) obtained by using the same sampling and analytical procedures used to collect and analyze RCRA and CERCLA samples

Concentrations of chemicals in ground water and surface water can be highly variable in space and time due to various interacting factors, e g , rainfall, runoff, watershed size, soil characteristics, hydrogeology, geochemistry, recharge and discharge areas, channel size, flow rates, and others Concentrations of chemicals in surficial and bedrock materials can also show high spatial variability due to hydrologic, lithologic and geochemical factors Therefore, the underlying premise of this analysis is that background chemistry is considered a random statistical distribution of concentration levels, rather than a single concentration (Doctor, Gilbert, and Kinnison, 1986)

In this section, the background data set is compared to downgradient data to identify samples which are significantly different from the background population The approach used follows the recommendations of Doctor, Gilbert, and Kinnison (1986), Loftis, Harris, and Montgomery (1987), Gilbert (1987), and EPA facilities

The tolerance interval approach discussed here meets the following statistical design criteria

- The data required by the statistical test is readily obtainable

- The test is relatively easy to perform and interpret

- The test is applicable to a number of indicator parameters representing classes of chemicals

- The test is robust or reasonably robust, so that small or moderate departures from the statistical assumptions inherent in the data (e g, normality, homogeneity of variance, independence) do not appreciably affect the test performance

- The test is capable of treating non-detected values

- The test is reliable so it can be used in decision-making

A tolerance interval defines, with a specified probability, a range of values that contain a discrete percentage of the population Downgradient stations whose concentrations fall outside the tolerance interval may indicate an impact to ground water has occurred

In order to obtain reliable results, both a high level of confidence (P = 95%) and a high percentage of the population within the interval (p = 95%) have been chosen as statistical parameters The number of sampling stations in the background area determines the width of the tolerance interval, i e , the more background stations, the narrower the interval and the more likely it will be that contamination in downgradient locations will be detected Nine background stations have been established in order to obtain a 95 percent interval (95% of population within the one-sided interval) with a tolerance factor of three at the 95%

confidence level, i e, the upper limit of the tolerance interval is the mean plus three standard deviations of the sample population The tolerance limits identified in this report will be used to assess contamination at RCRA regulated units and CERCLA areas The RCRA assessment will be reported in the Annual RCRA Ground-Water Monitoring Report, and the CERCLA assessments documented in the various Remedial Investigation reports and plans

5 2 2 Tolerance Interval Calculation

5 2 2 1 Method

The lower and upper limits of a normal population tolerance interval were computed as follows

$L_1 = \bar{x} - Ks$ and

$L_2 = \bar{x} + Ks$

Where

$\bar{x}$ = mean of sample population of size n,
s = standard deviation of the sample population, and
K = the normal tolerance factor [dependent on p, P, n (the number of samples), and on whether the interval is one- or two-sided]

The values for K are selected from Table 5-1

Many Inorganic Target Analyte List constituents will be undetected in both background and downgradient wells Special procedures are thus needed to compute the mean and standard deviation of a population when a significant number of the observations are below the detection limit The technique for calculation of the mean and standard deviation of such data was developed by Cohen (1961) and is used here assuming the data are normally distributed The Cohen procedure is as follows (Doctor, Gilbert, Kinnison, 1986)

Let

n = the total number of observations for a constituent,
k = number of actual measurements out of n (not non-detects), and
x_o = the detection limit of the constituent

TABLE 5-1

TOLERANCE FACTORS FOR NOMAL TOLERANCE LIMITS FOR 95% POPULATION AT 95% CONFIDENCE

n	Two-Sided	One-Sided
2	37 67	
3	9 916	7 655
4	6 370	5 145
5	5 079	4 202
6	4 414	3 707
7	4 007	3 399
8	3 732	3 188
9	3 532	3 031
10	3 379	2 911
11	3 259	2 815
12	3 162	2 736
13	3 081	2 670
14	3 012	2 614
15	2 954	2 566
16	2 903	2 523
17	2 858	2 486
18	2 819	2 453
19	2 784	2 423
20	2 752	2 396
21	2 723	2 371
22	2 697	2 350
23	2 673	2 329
24	2 651	2 309
25	2 631	2 292
26	2 612	
27	2 595	
28	2 579	
29	2 554	
30	2 549	2 220
35	2 490	2 166
40	2 445	2 126
45		2 092
50	2 379	2 065
60	2 333	
80	2 272	
100	2 233	
200	2 143	
500	2 070	
1000	2 036	
inf	1 960	

Then

1) Compute $h = (n-k)/n$ (the proportion of measurements below the detection limit),

2) Compute x_u = (Sum of x_i for $i = 1$ to $k)/k$

3) Compute s_u^2 = (Sum of $(x_i - x_u)^2$ for $i = 1$ to $k)/k$

4) Compute $t = s_u^2/(x_u - x_o)^2$,

5) Obtain an estimate of lambda from Table 5-2 using h and t,

6) Estimate the mean and variance of the population from which the censored data set was drawn by computing

7) $x = x_u - (\text{lambda})(x_u - x_o)$,

8) $s = [s_u^2 + (\text{lambda})(x_u - x_o)^2]^{1/2}$

5 2 2 2 Calculation of Tolerance Intervals using the Rocky Flats Database

The computer database used for Rocky Flats data is the Environmental Data Management System (EDMS) developed by WESTON in 1987 This database has the capability of accessing up to ten files simultaneously and generating reports from those files This capability has been utilized for calculation of the tolerance intervals in this report A program designed to access analytical data from the database and to perform required calculations has been developed In addition, database files which incorporate data for tolerance factors (Table 5-1) and mean and variance for non-detects (Table 5-2) have been established

After its development, the program to calculate tolerance intervals was exhaustively tested for accuracy Selected tolerance intervals were manually computed to verify the computer program computation Also, it was determined that the value for t occasionally exceeded 1 00 In order to determine the effect of this on the tolerance intervals of lambda (Table 5-2) were estimated by extrapolation for t values greater than 1 00 Use of estimated lambda values or t > 1 00 did not significantly change the tolerance interval relative to the tolerance interval completed by selecting lambda assuming t = 1 00 Consequently, the program has been designed to default the 1 00 for all values of t which exceed 1 00

Table 5-2

Values of λ for Estimating the Mean and Variance of a Normal Distribution when ND Values are Present

τ \ h	01	.02	.03	04	.05	.06	.07	.08	0.9	.10	.15	.20	h / τ
00	.010100	.020400	.030902	.041583	.052507	.063627	.074953	.086488	.09824	.11020	.17342	.24268	.00
.05	010551	.021294	.032225	.043350	.054670	.066189	.077909	.089834	.10197	.11431	.17935	.25033	.05
.10	010950	.022082	.033398	.044902	.056596	.068483	.080568	.092852	.10534	.11804	.18479	.25741	.10
.15	011310	.022798	.034466	.046318	.058356	.070586	.083009	.095629	.10845	.12148	.18985	.26405	.15
.20	.011642	.023459	.035453	.047629	.059990	.072539	.085280	.098216	.11135	.12469	.19460	.27031	.20
.25	.011952	024076	.036377	.048858	.061522	.074372	.087413	.10065	.11408	.12772	.19910	.27626	.25
.30	.012243	.024658	.037249	.050018	.062969	.076106	.089433	.10295	.11667	.13059	.20338	.28193	.30
35	012520	.025211	.038077	051120	.064345	.077756	.091355	.10515	.11914	.13333	.20747	.28737	.35
40	.012784	.025738	.038866	.052173	.065660	.079332	.093193	.10725	.12150	.13595	.21139	.29260	.40
.45	013036	.026243	039624	.053182	.066921	.080845	.094958	.10926	.12377	.13847	.21517	.29765	.45
50	.013279	.026728	.040352	054153	.068135	.082301	.096657	.11121	.12595	.14090	.21882	.30253	.50
55	013513	027196	041054	055089	069306	.083708	098298	.11308	.12806	.14325	.22235	.30725	.55
60	013739	.027649	.021733	055995	.070439	.085068	.099887	.11490	.13011	.14552	22578	.31184	.60
65	013958	028087	042391	056874	071538	.086388	.10143	.11666	.13209	14773	.22910	.31630	.65
70	.014171	.028513	.043030	057726	.072605	.087670	.10292	.11837	.13402	.14987	23234	.32065	.70
75	014378	.028927	.043652	058556	.073643	.088917	.10438	.12004	.13590	.15196	.23550	.32489	.75
80	.014579	.029330	.044258	.059364	.074655	.090133	.10580	.12167	.13773	.15400	.23858	.32903	.80
.85	.014775	.029723	.044848	.060153	.075642	.091319	.10719	.12325	.13952	.15599	.24158	.33307	.85
.90	.014967	.030107	.045425	.060923	.076606	.092477	.10854	.12480	.14126	.15793	.24452	.33703	.90
.95	015154	.030483	.045989	.061676	.077549	.093611	.10987	.12632	.14297	.15983	.24740	.34091	.95
1.00	.015338	.030850	.046540	.062413	.078471	.094720	.11116	.12780	.14465	.16170	.25022	.34471	1.00

τ \ h	25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.80	.90	h / τ
.00	.31862	.4021	.4941	.5961	.7096	.8368	.9808	1.145	1.336	1.561	2.176	3.283	.00
.05	.32793	.4130	.5066	.6101	.7252	.8540	.9994	1.166	1.358	1.585	2.203	3.314	.05
.10	.33662	.4233	.5184	.6234	.7400	.8703	1.017	1.185	1.379	1.608	2.229	3.345	.10
.15	.34480	4330	.5296	.6361	.7542	.8860	1.035	1.204	1.400	1.630	2.255	3.376	.15
.20	.35255	.4422	.5403	.6483	.7678	.9012	1.051	1.222	1.419	1.651	2.280	3.405	.20
.25	.35993	.4510	.5506	.6600	.7810	.9158	1.067	1.240	1.439	1.672	2.305	3.435	.25
.30	.36700	.4595	.5604	.6713	.7937	.9300	1.083	1.257	1.457	1.693	2.329	3.464	.30
.35	.37379	.4676	.5699	.6821	.8060	.9437	1.098	1.274	1.476	1.713	2.353	3.492	.35
.40	.38033	.4755	.5791	.6927	.8169	.9570	1.113	1.290	1.494	1.732	2.376	3.520	.40
.45	.38665	.4831	.5880	.7029	.8295	.9700	1.127	1.306	1.511	1.751	2.399	3.547	.45
.50	.39276	.4904	.5967	.7129	.8408	.9826	1.141	1.321	1.528	1.770	2.421	3.575	.50
.55	.39870	.4976	.6051	.7225	.8517	.9950	1.155	1.337	1.545	1.788	2.443	3.601	.55
.60	.40447	.5045	.6133	.7320	.8625	1.007	1.169	1.351	1.561	1.806	2.465	3.628	.60
.65	.41008	.5114	.6213	.7412	.8729	1.019	1.182	1.366	1.557	1.824	2.486	3.654	.65
.70	.41555	.5180	.6291	.7502	.8832	1.030	1.195	1.380	1.593	1.841	2.507	3.679	.70
.75	.42090	.5245	.6367	.7590	.8932	1.042	1.207	1.394	1.608	1.858	2.528	3.705	.75
.80	.42612	.5308	.6441	.7676	.9031	1.053	1.220	1.408	1.624	1.875	2.548	3.730	.80
.85	.43122	.5370	.6515	.7761	.9127	1.064	1.232	1.422	1.639	1.892	2.568	3.754	.85
.90	.43622	.5430	.6586	.7844	.9222	1.074	1.244	1.435	1.653	1.908	2.588	3.779	.90
.95	.44112	.5490	.6656	.7925	.9314	1.085	1.255	1.448	1.668	1.924	2.607	3.803	.95
1.00	.44592	5548	.6724	.8005	.9406	1.095	1.267	1.461	1.682	1.940	2.626	3.827	1.00

The following sections provide the tolerance intervals for the analytes in the various media and formations, and provide a discussion of their characteristics These characteristics are described through a comparative analysis of tolerance interval widths, for different ground-water types percentage of non-detected values, and the magnitude of the mean concentration To the extent possible, the presumed geochemical basis for the differences is advanced

5 2 3 Rocky Flats Alluvial Water Quality

5 2 4 Colluvial Water Quality

5 2 5 Valley Fill Water Quality

5 2 6 Bedrock Water Quality

5 2 7 Surface Water Quality

5 2 8 Sediment Quality

5 2 9 Summary

The summary provides a discussion of whether the chemical characteristics of alluvial, colluvial, and bedrock ground waters are significantly different from each other

TABLE 5-3
INORGANIC COMPOUND TOLERANCE INTERVALS
FOR 1989 BACKGROUND SEDIMENTS
ALL CONCENTRATIONS IN mg/kg (PHUNITS for pH)

Analyte	Lower Interval	Upper Interval
Nitrate-Nitrite as N	0 000	0 000
pH	5 79	8 63

SECTION 6.0

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NOTICE

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Document # 000371

Titled: Plate 1, 1989 Background Surface Water, Sediment, Borehole, Monitor Well Locations, and Cross-Section Location Lines

Fiche location: A-SW-M27

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Titled: Plate 2 ' Background Geochemical Characterization Report, Cross Sections A-A', and B-B'

Fiche location: A-SW-M27

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Titled: Plate 3' Background Geochemical Characterization Report Fence Diagram

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Document # 000371

Titled: Plate #4 : Wells 32-89BR, 33-89BR, 34-89BR

NEUTRON - DENSITY COMPARISON

Fiche location: A-SW - M28

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Document # 000371

Titled: Plate # 5 : Wells 32-89BR, 33-89BR, 34-89BR Guard Resistivity - IP Comparison

Fiche location: A-SW-M28

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Document # 000371

Titled: Plate #6 ' Wells 32-89BR, 33-89BR, 34-89 BR

DELTA-T - AMPLITUDE COMPARISON

Fiche location: A-SW-M28

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Document # 000371

Titled: Plate #7: Wells 38-89BR, 35-89BR, 36-89BR

NEUTRON - DENSITY COMPARISON

Fiche location: A-SW-M28

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Document # 000371

Titled: Plate # 8 : Wells 38-89BR, 35-89BR, 36-89BR

GUARD RESISTIVITY - IP COMPARISON

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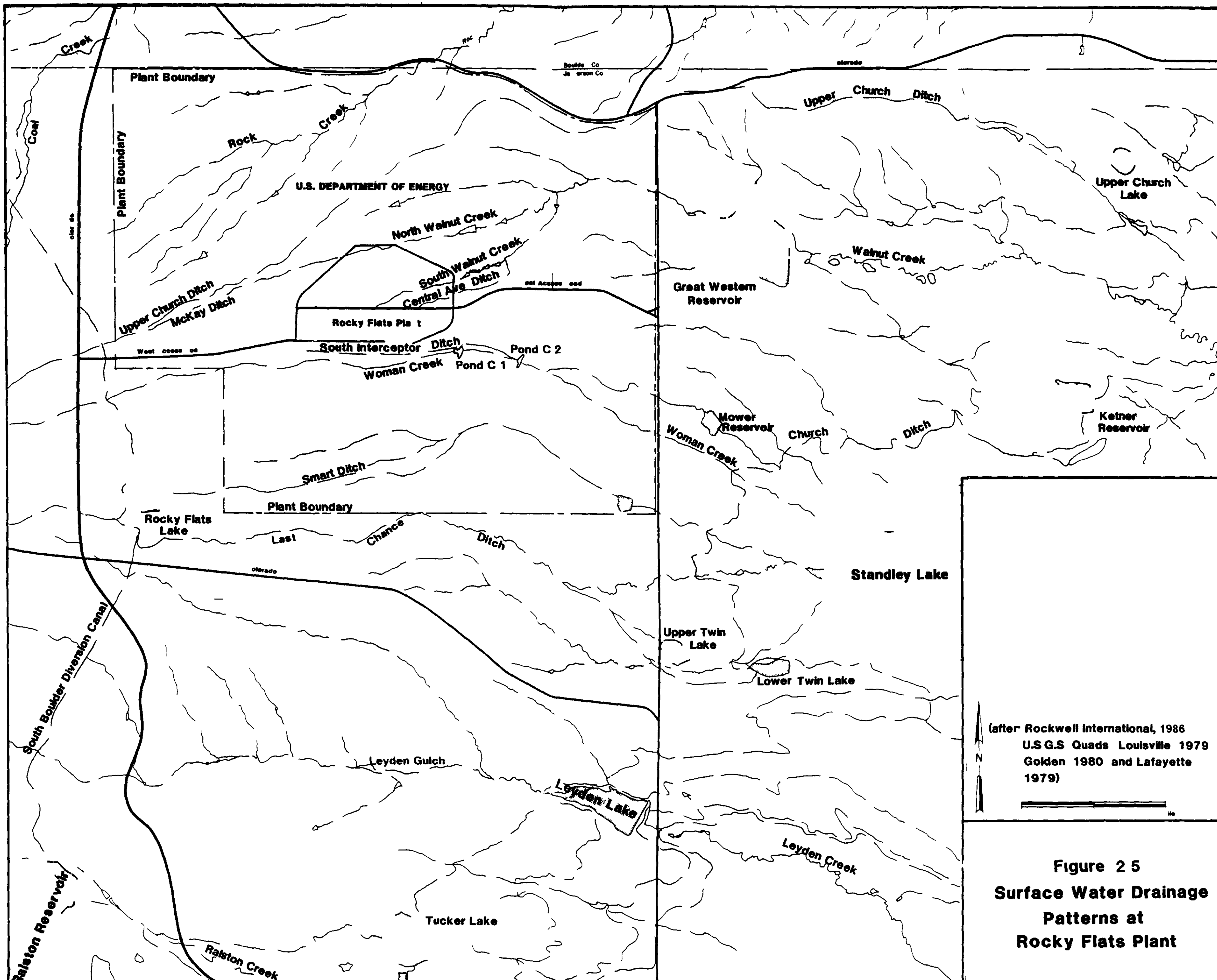
Document # 000371

Titled: Plate 9' Wells 38-89BR, 35-89BR, 36-89BR

DELTA • T - AMPLITUDE COMPARISON

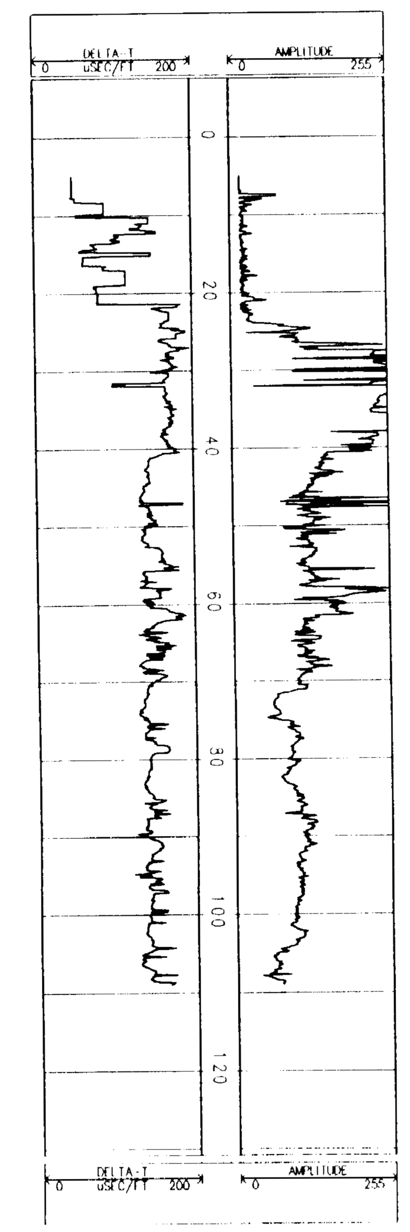
Fiche location: A-SW-M28



(after Rockwell International, 1986
U.S G.S Quads Louisville 1979
Golden 1980 and Lafayette
1979)

Figure 2 5
Surface Water Drainage Patterns at Rocky Flats Plant

WELL 38-89BR



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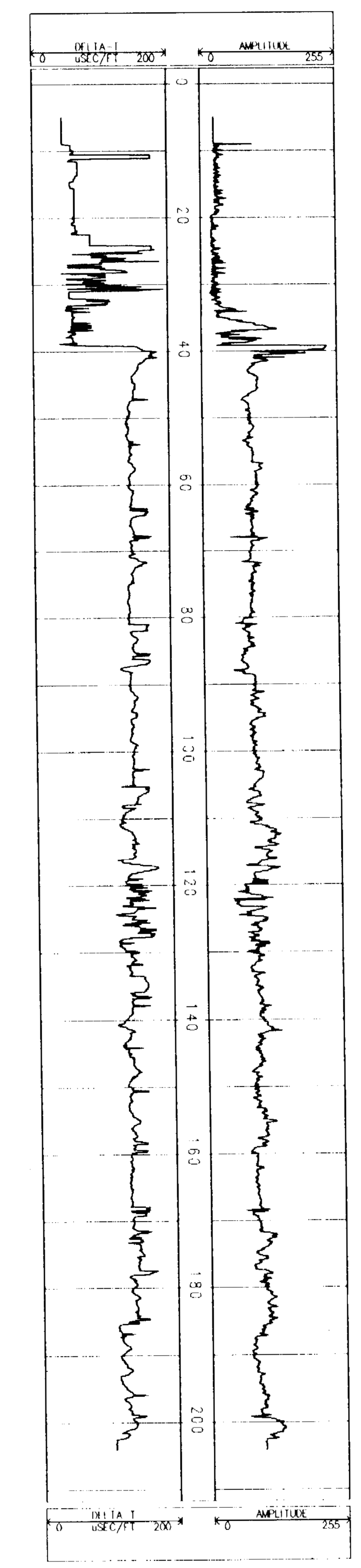

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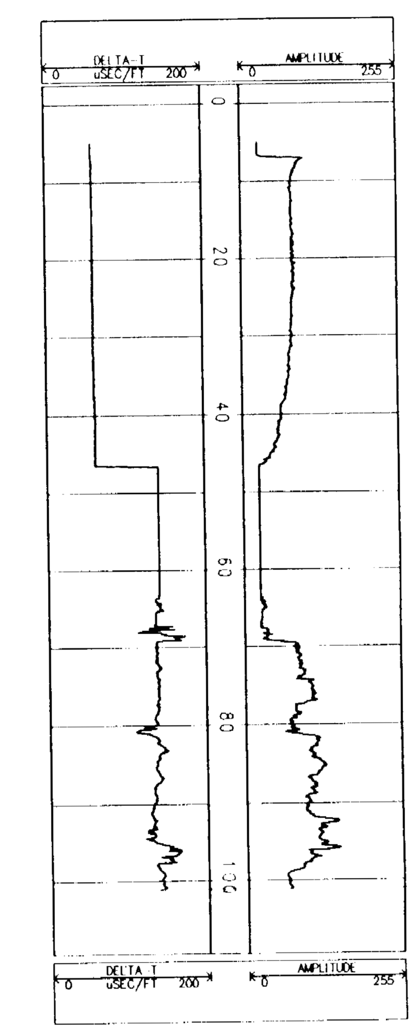


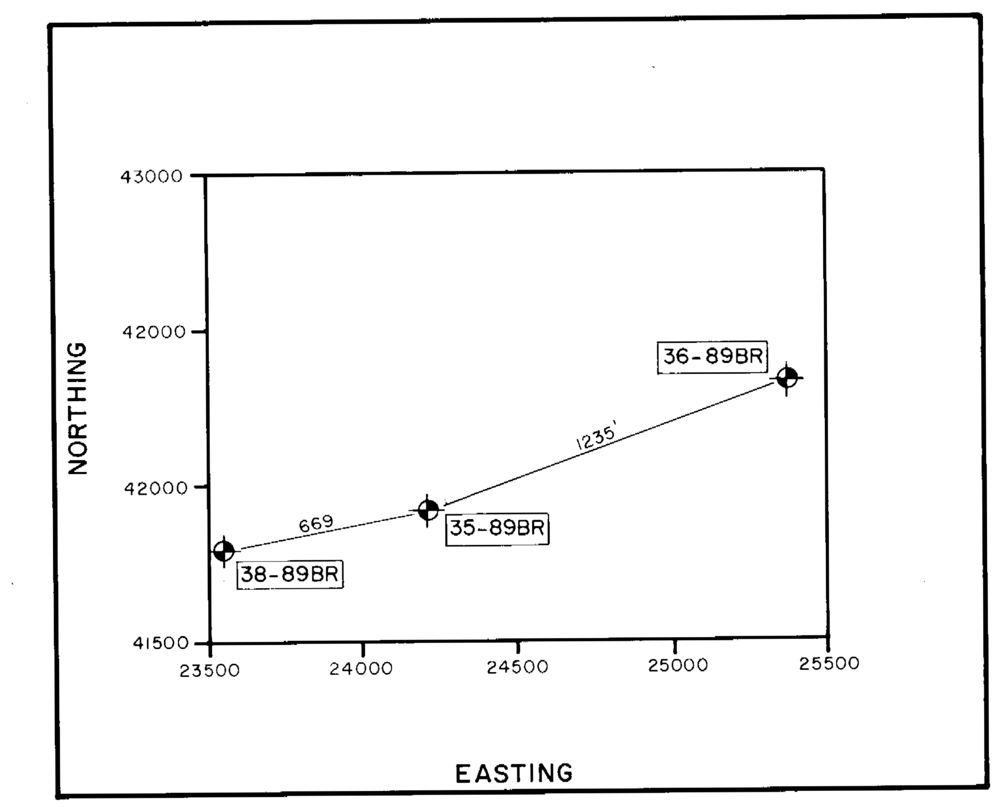


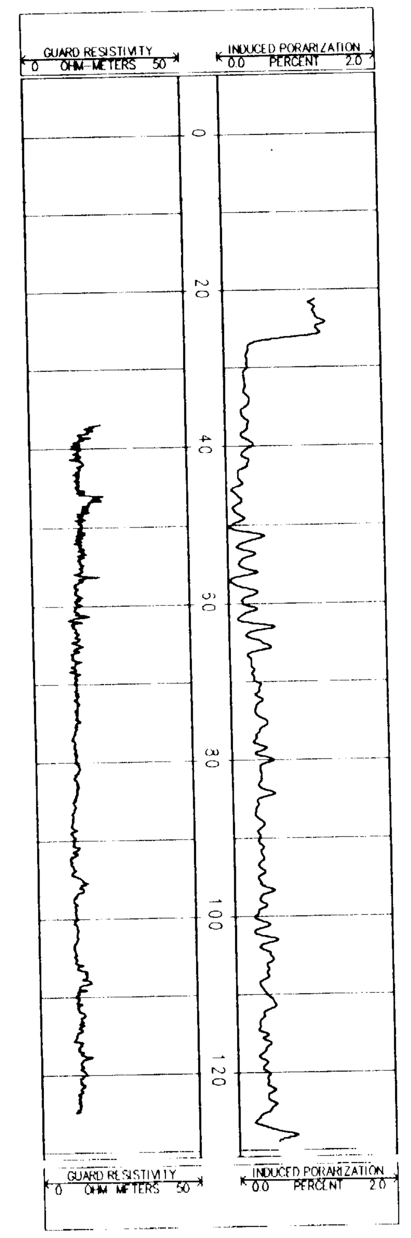
PLATE NO. 9

ROCKWELL INTERNATIONAL
ROCKY FLATS PLANT - GOLDEN, COLORADO
WELLS 38-89BR, 35-89BR, 36-89BR
DELTA·T - AMPLITUDE COMPARISON

ENGINEERS: Roy F. Weston
Lakewood, Colorado

COLOG INC.
Golden, Colorado

WELL 38-89BR



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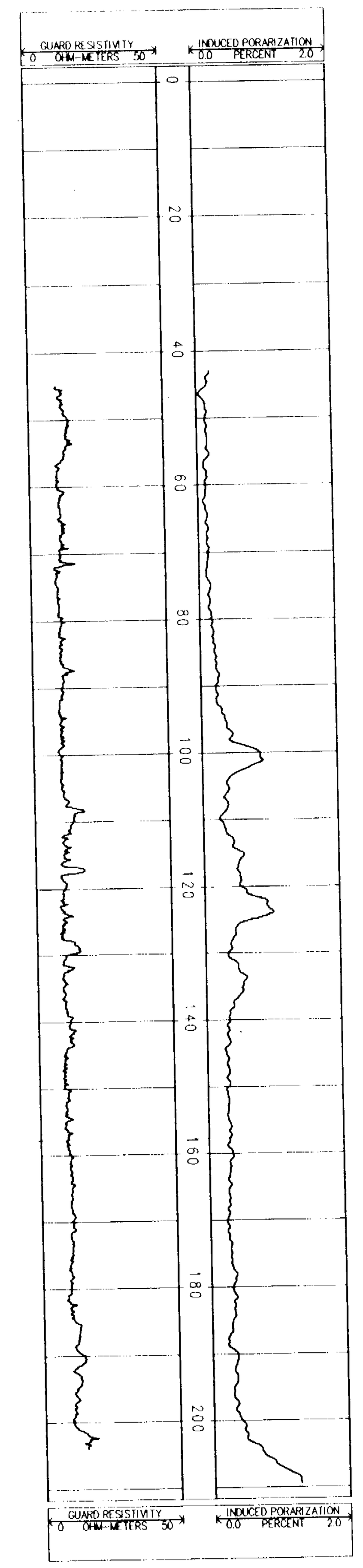

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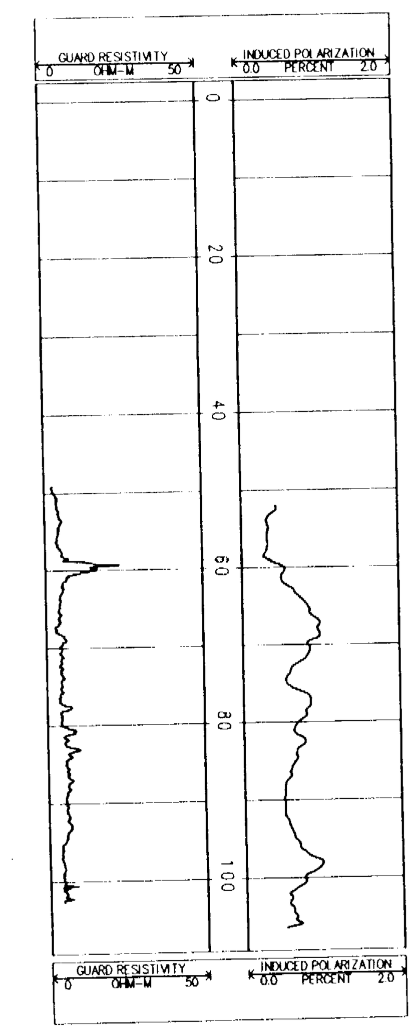


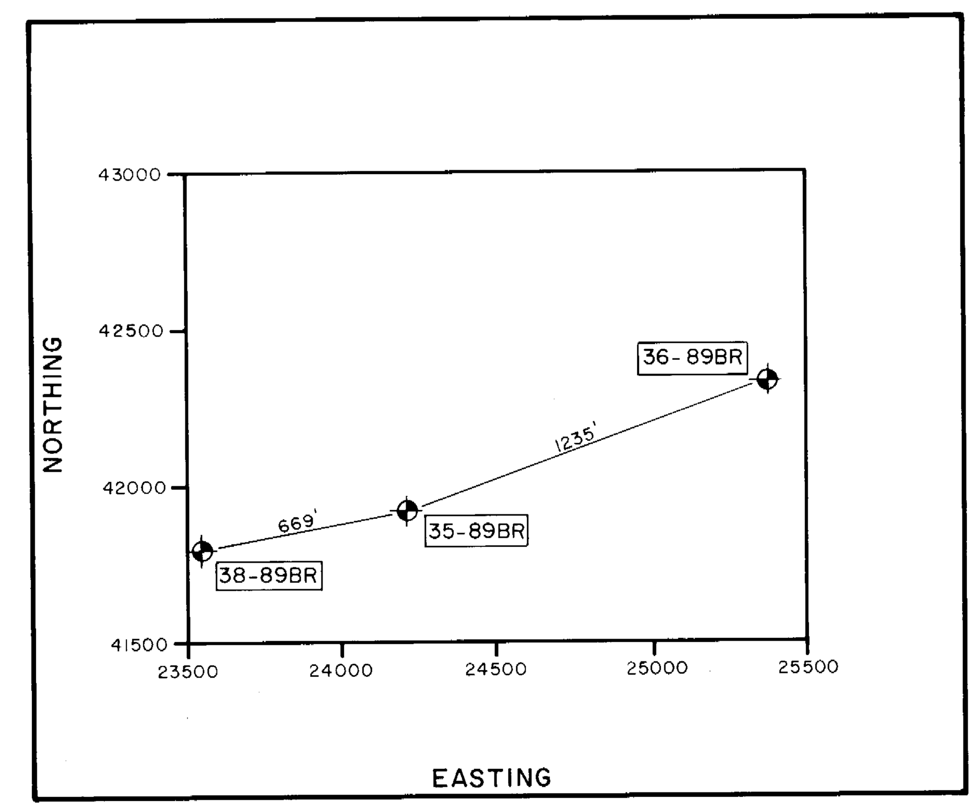


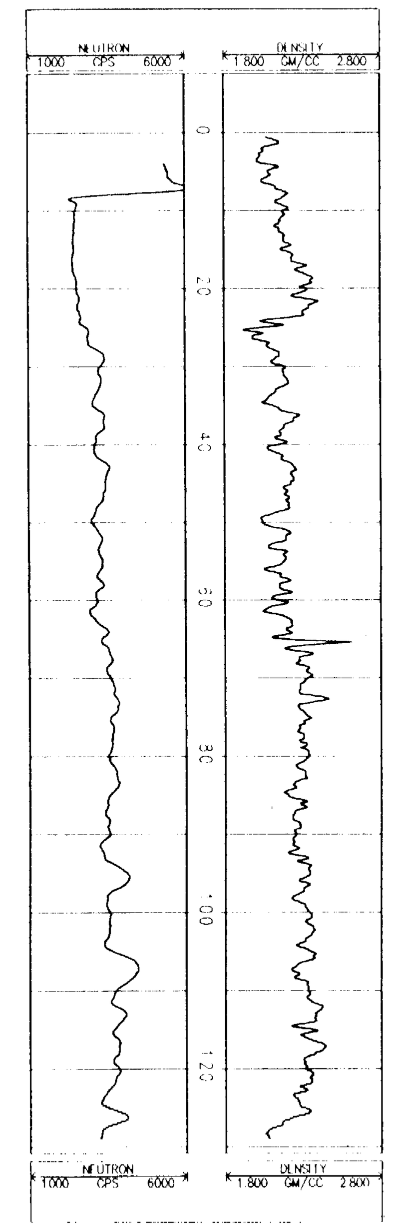
PLATE NO. 8

ROCKWELL INTERNATIONAL
ROCKY FLATS PLANT - GOLDEN, COLORADO
WELLS 38-89BR, 35-89BR, 36-89BR
GUARD RESISTIVITY - I.P. COMPARISON

ENGINEERS: Roy F. Weston
Lakewood, Colorado

COLOG INC.
Golden, Colorado

WELL 38-89BR



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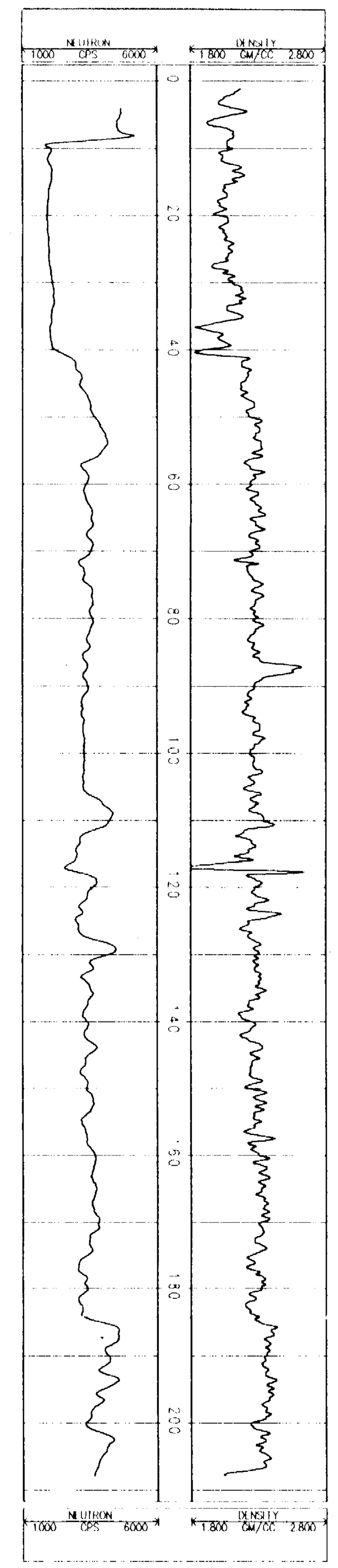

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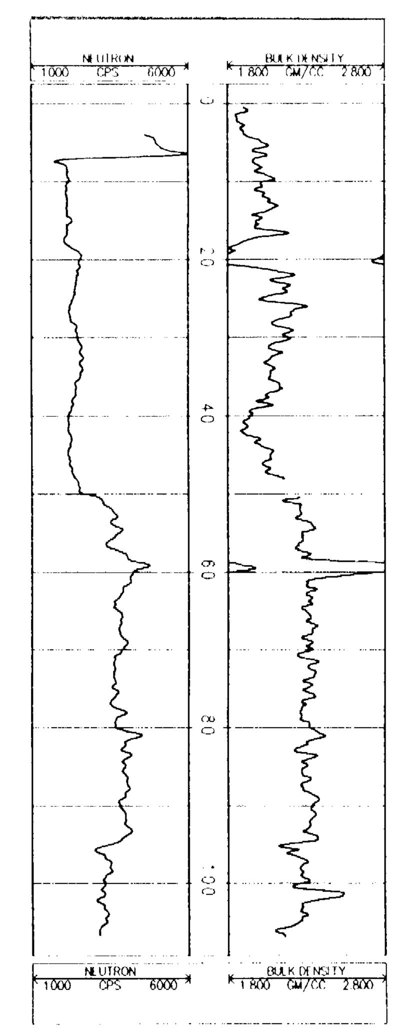


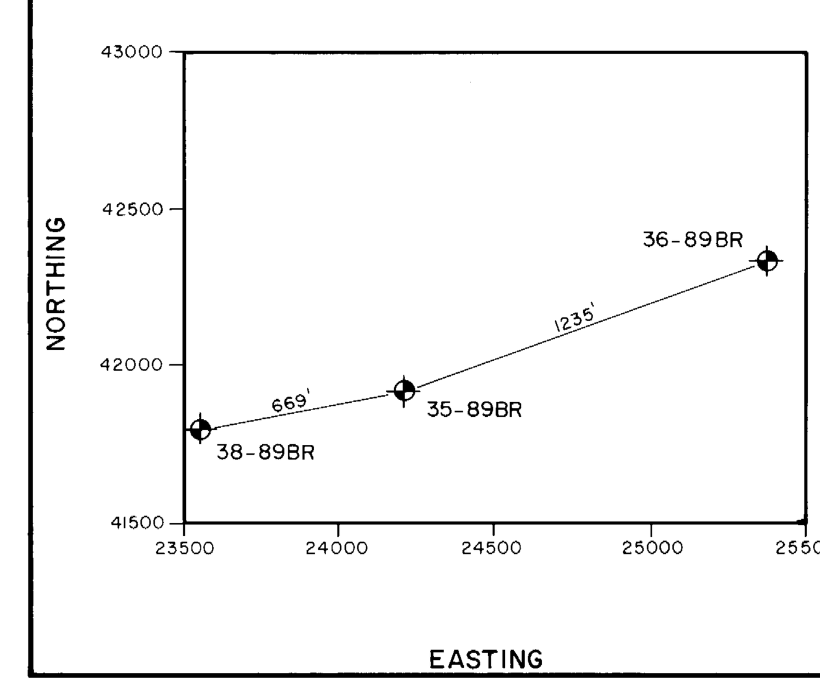


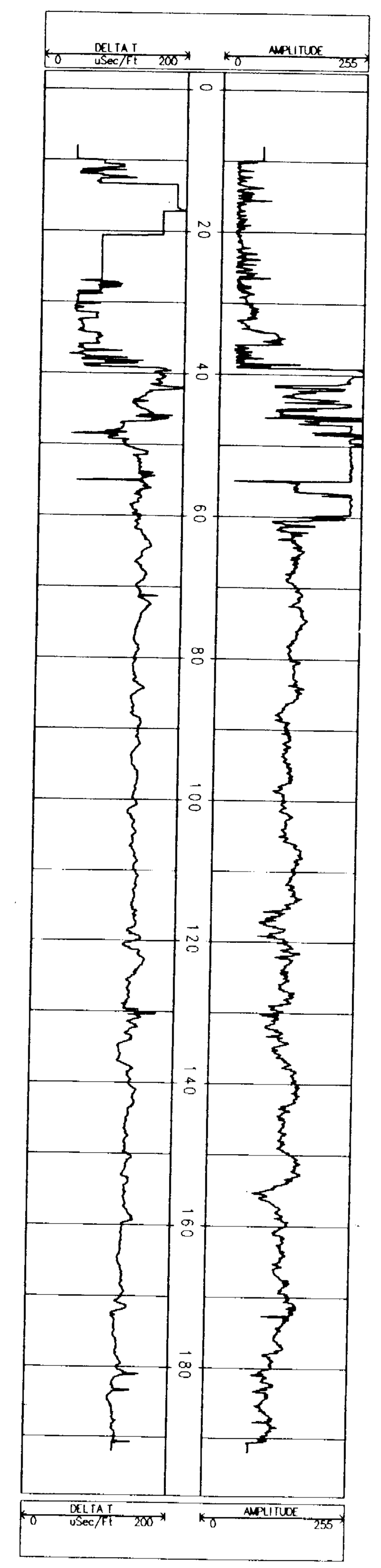
PLATE NO. 7

ROCKWELL INTERNATIONAL
ROCKY FLATS PLANT - GOLDEN, COLORADO
WELLS 38-89BR, 35-89BR, 36-89BR
NEUTRON - DENSITY COMPARISON

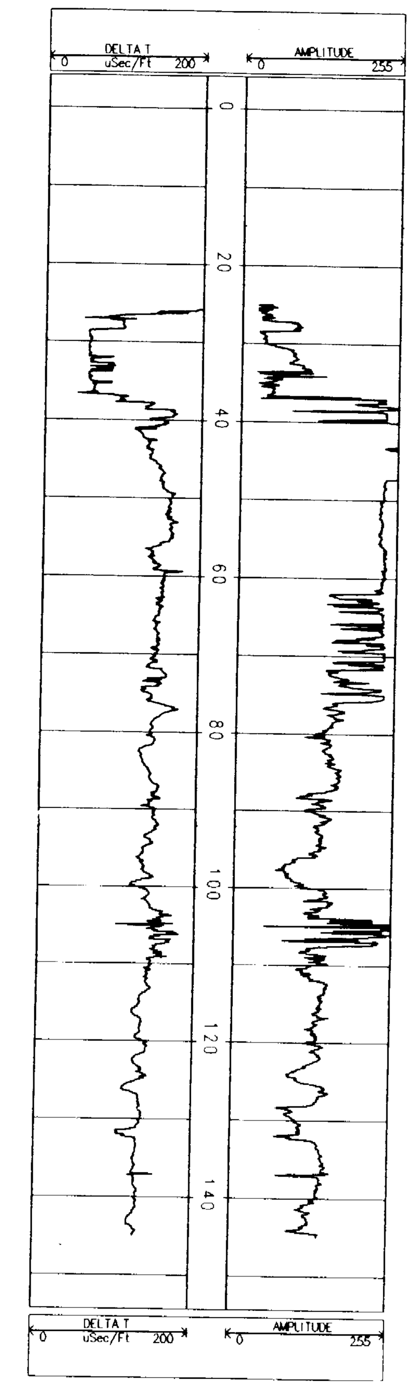
ENGINEERS: Roy F. Weston
Lakewood, Colorado

COLOG INC.
Golden, Colorado

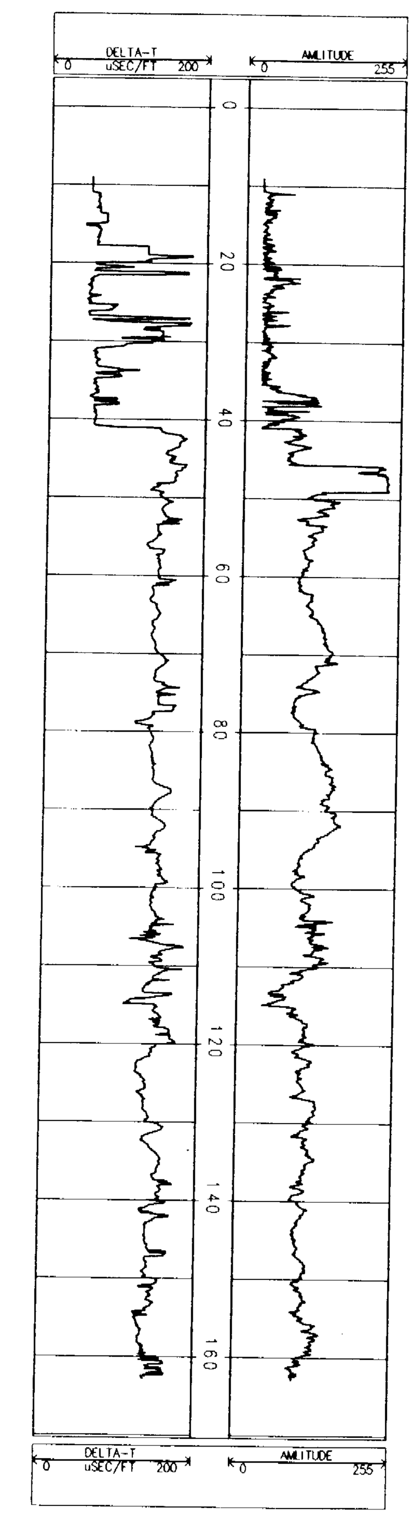
WELL 32-89BR



WELL 33-89BR



WELL 34-89BR



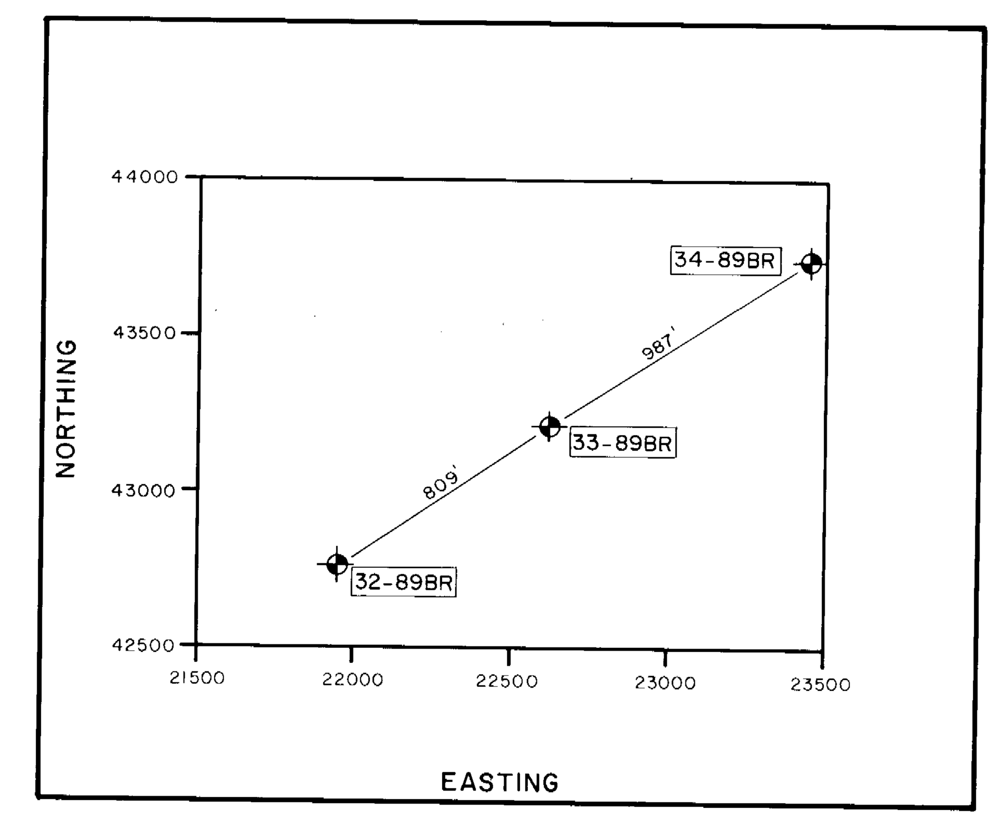


PLATE NO. 6

ROCKWELL INTERNATIONAL
ROCKY FLATS PLANT - GOLDEN, COLORADO
WELLS 32-89BR, 33-89BR, 34-89BR
DELTA-T - AMPLITUDE COMPARISON

ENGINEERS: Roy F. Weston
Lakewood, Colorado

COLOG INC.
Golden, Colorado

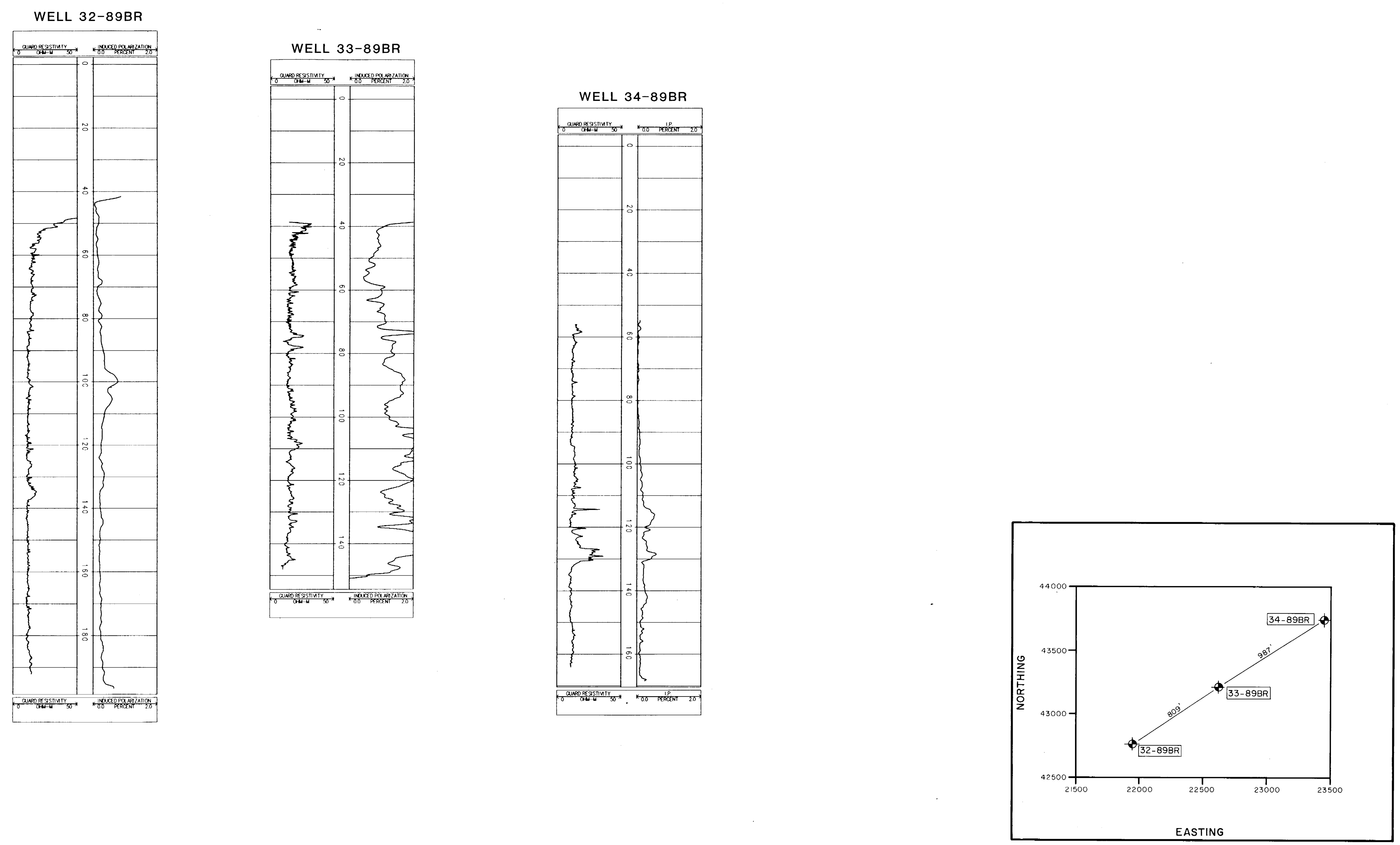


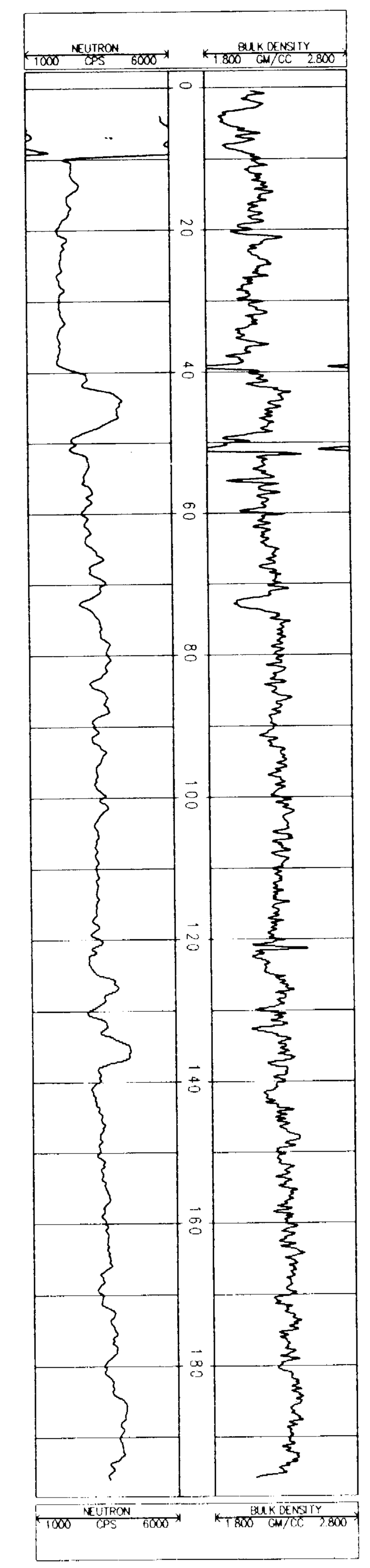
PLATE NO. 5

ROCKWELL INTERNATIONAL
ROCKY FLATS PLANT - GOLDEN, COLORADO
WELLS 32-89BR, 33-89BR, 34-89BR
GUARD RESISTIVITY - I.P. COMPARISON

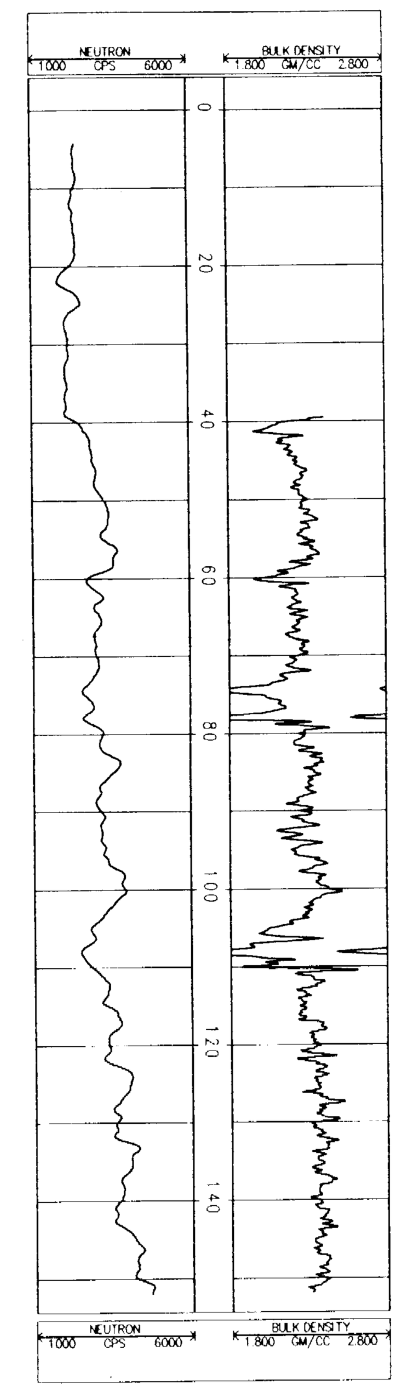
ENGINEERS: Roy F. Weston
Lakewood, Colorado

COLOG INC.
Golden, Colorado

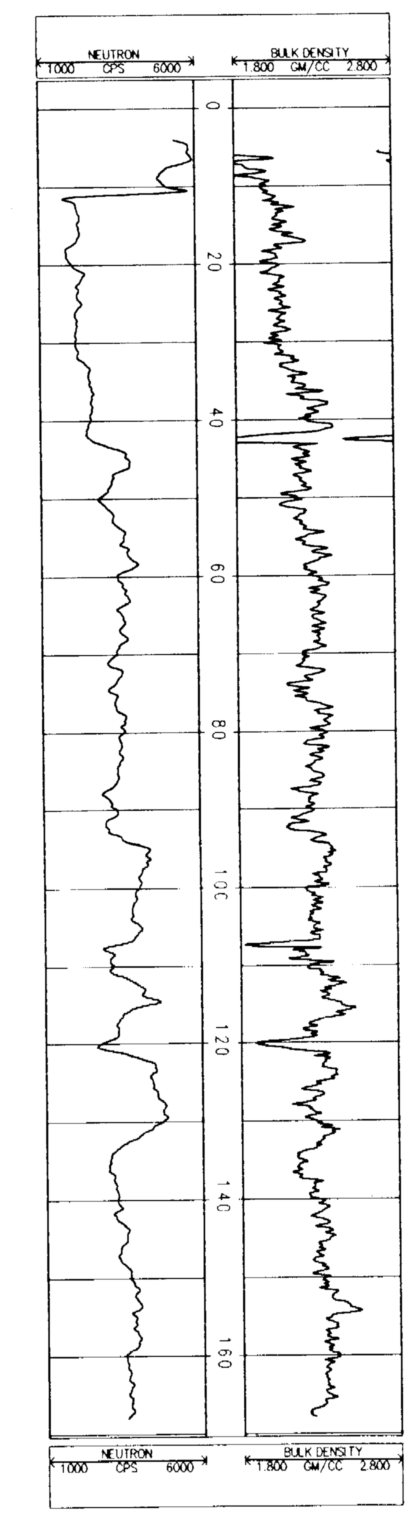
WELL 32-89BR



WELL 33-89BR



WELL 34-89BR



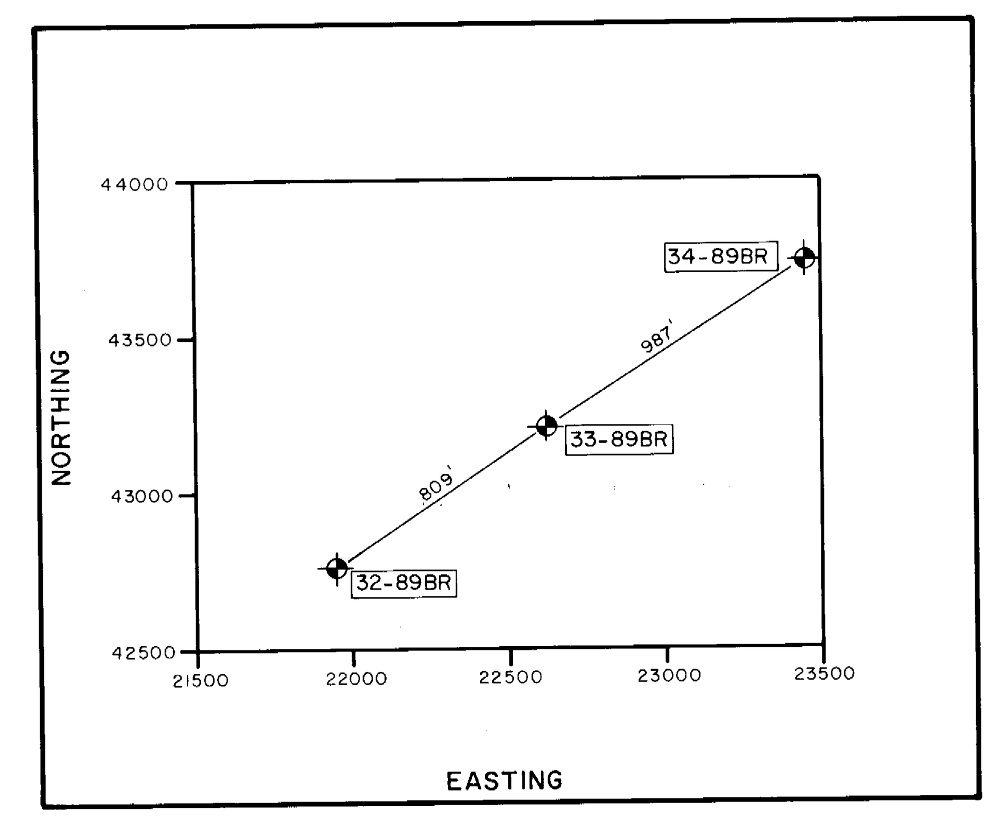
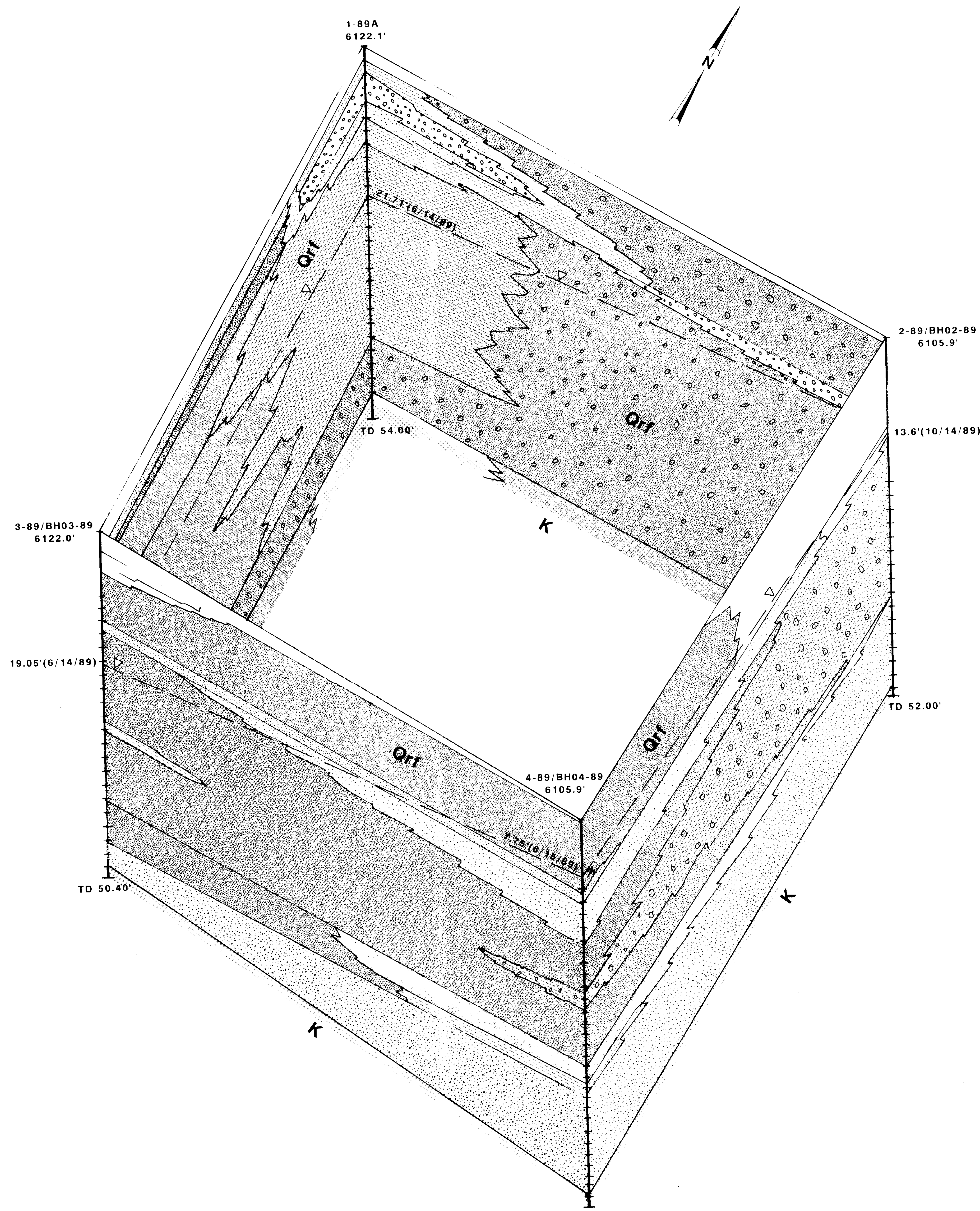


PLATE NO. 4

ROCKWELL INTERNATIONAL
ROCKY FLATS PLANT - GOLDEN, COLORADO
WELLS 32-89BR, 33-89BR, 34-89BR
NEUTRON - DENSITY COMPARISON

ENGINEERS: Roy F. Weston
Lakewood, Colorado

COLOG INC.
Golden, Colorado



EXPLANATION

2-87/BH3-87 — Well/Borehole Identification
5930.56' — Ground Surface Elevation (Surveyed)

Water Level (Measured / /)
Geologic Contact (Querried where inferred. Dashed where approximately located.)
Screened Interval

TD 16.00' — Total Depth Drilled

QUATERNARY
- **Qt** — Terrace
- **Qd** — Disturbed Ground
- **Qc** — Colluvium
- **Qrf** — Rocky Flats Alluvium
- **Qal** — Alluvium

CRETACEOUS
- **K** — Undiferentiated Cretaceous Claystone
- **Kss** — Undiferentiated Cretaceous Sandstone

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

10'
5'
0'
0' 50' 100'
SCALE

Vertical Exaggeration 10x

WESTON
MANAGERS DESIGNERS/CONSULTANTS

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Suite 600
Lakewood, Colorado 80228
(303) 980-6800

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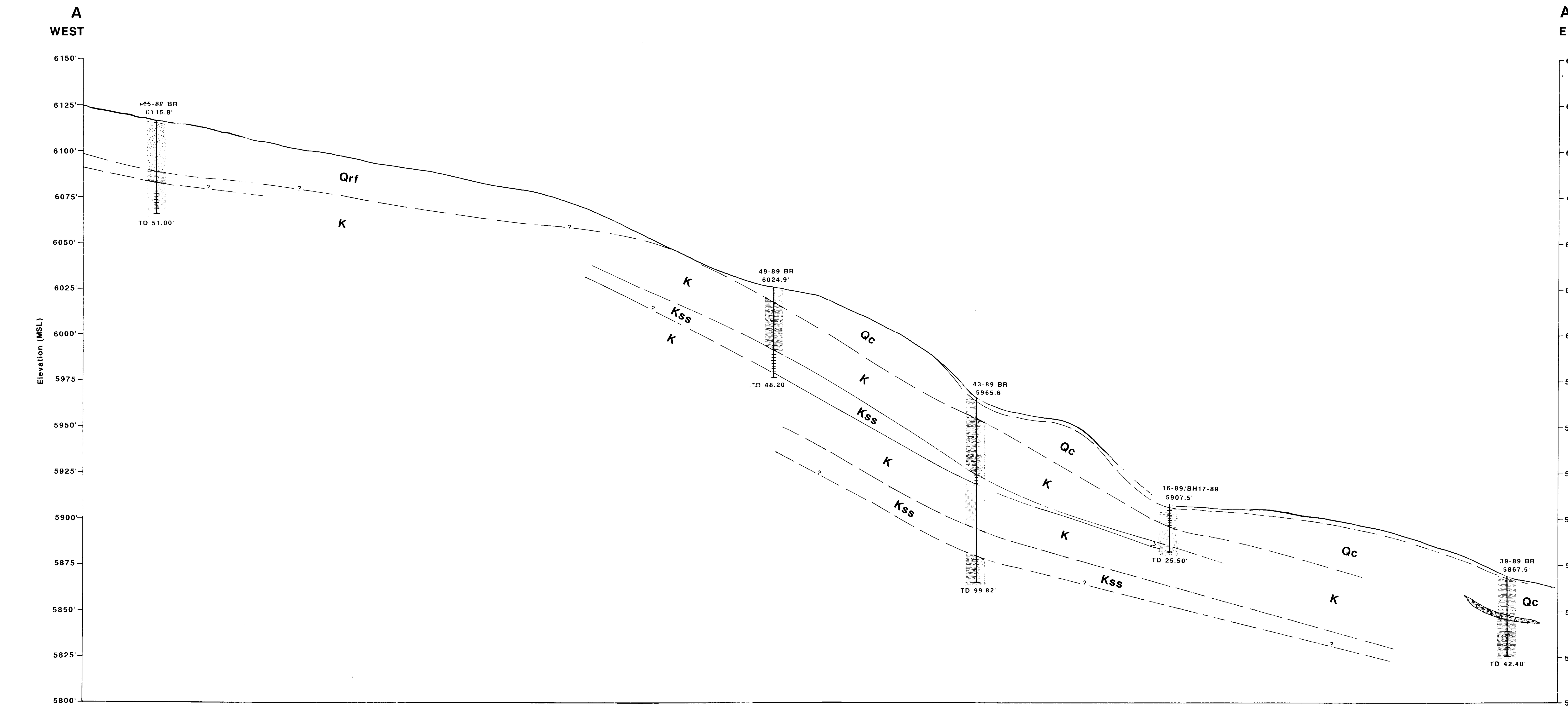
Rocky Flats Plant
Golden, Colorado

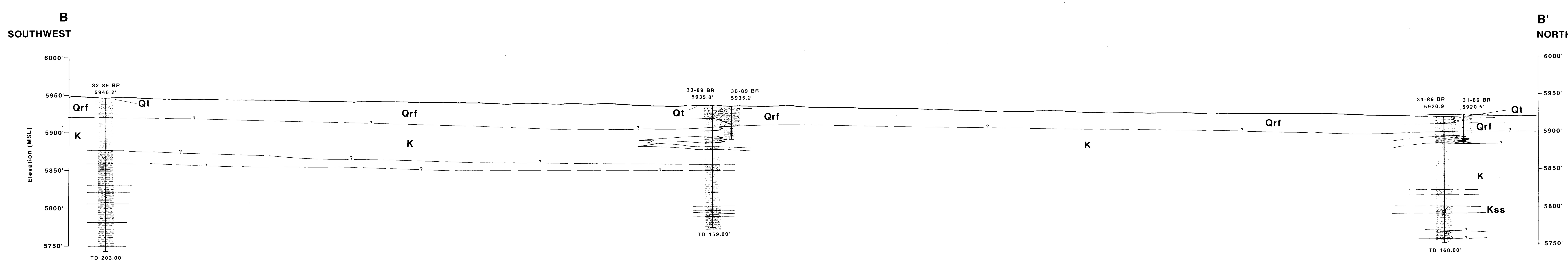
Plate 3

Background Geochemical Characterization Report

FENCE DIAGRAM

October, 1989





Vertical Exaggeration 10x

SCALE (A-A'): 25' vertical, 250' horizontal

SCALE (B-B'): 50' vertical, 50' horizontal

EXPLANATION

32-89 BR	Well/Borehole Identification
5946.2'	Ground Surface Elevation (Surveyed)
▽	Water Level (Measured / /)
— —	Geologic Contact (Querried where inferred. Dashed where approximately located.)
	Screened Interval
TD 203.00'	Total Depth Drilled
	QUATERNARY
Qt	Terrace
Qd	Disturbed Ground
Qc	Colluvium
Qrf	Rocky Flats Alluvium
Qal	Alluvium
	CRETACEOUS
K	Undiferentiated Cretaceous Claystone
Kss	Undiferentiated Cretaceous Sandstone
	Clay
	Clayey Sand or Sandy Clay
	Cobbles and/or Gravel
	Sand and Sandstone
	Sand and Gravel
	Silt or Siltstone
	Claystone

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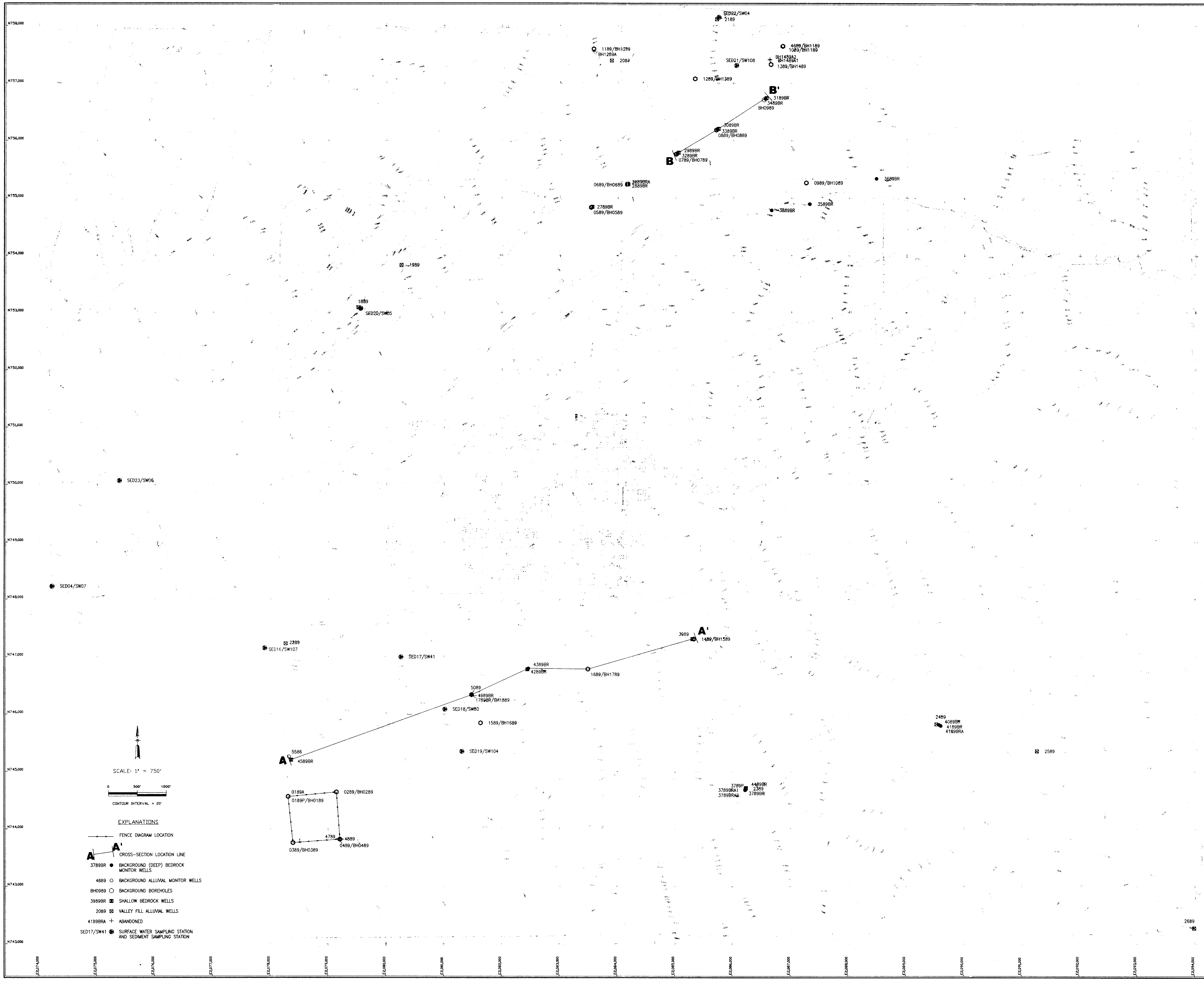
Rocky Flats Plant
Golden, Colorado

Plate 2

Background Geochemical Characterization Report

CROSS SECTIONS A-A' and B-B'

October, 1989



NO.	DATE	REVISION

WESTON
MANAGERS DESIGNERS/CONSULTANTS
215 UNION BOULEVARD
SUITE 600
LAKEWOOD, CO 80228
(303) 980-6800

ROCKWELL INTERNATIONAL
Rocky Flats Plant
Golden, Colorado

Plate 1

1989 BACKGROUND SURFACE WATER, SEDIMENT, BOREHOLE, MONITOR WELL LOCATIONS, AND CROSS-SECTION LOCATION LINES

RF750A-092889/A3

OCTOBER 9, 1989