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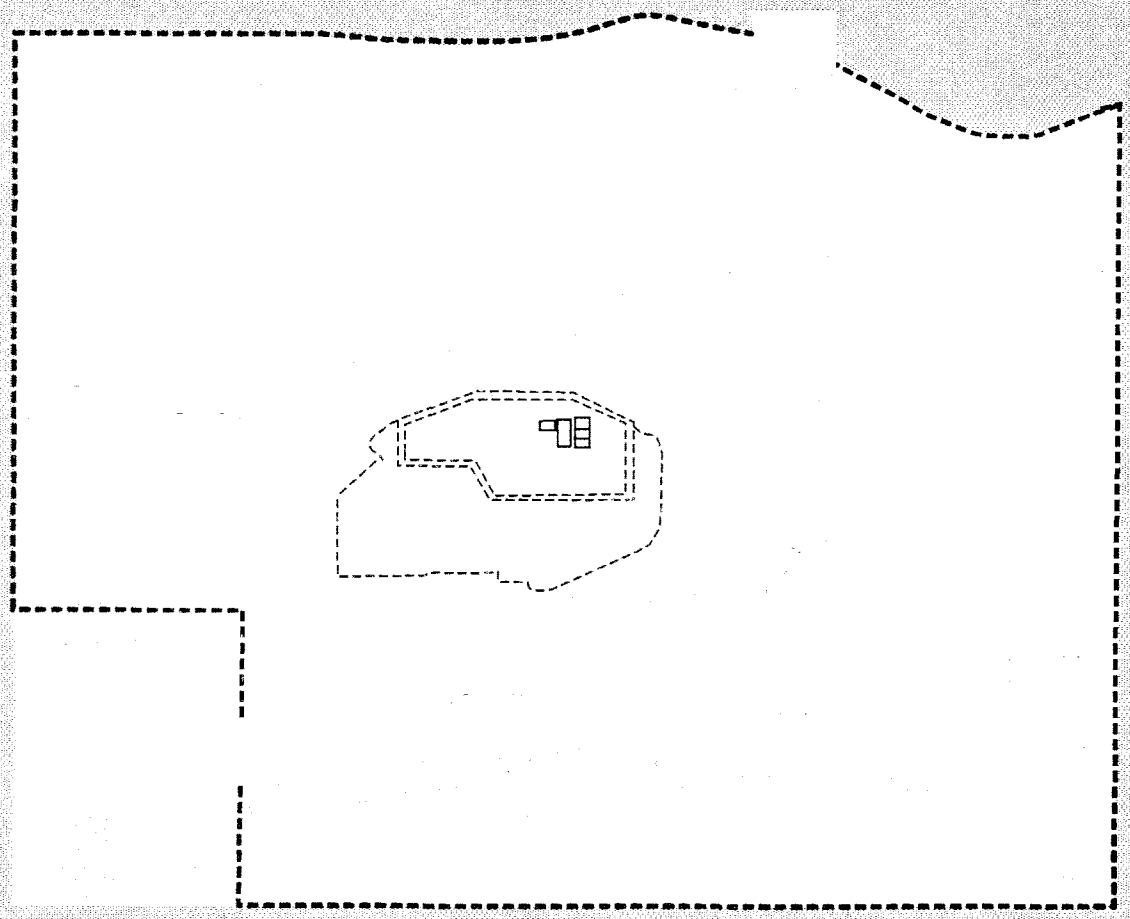
Groundwater Geochemistry Report for the Rocky Flats Environmental Technology Site

Volume III of the Sitewide Geoscience Characterization Study

Final Report
January 1995



EG&G ROCKY FLATS

Rocky Flats Environmental Technology Site
Golden, Colorado

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Groundwater Geochemistry Report for the Rocky Flats Environmental Technology Site

Volume III of the Sitewide Geoscience Characterization Study

January 5, 1995

EG&G Rocky Flats, Inc.
P.O. Box 464
Golden, Colorado 80402

EG&G ROCKY FLATS

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Appendix I Groundwater Contamination at Superfund Sites, Literature Summary

List of Acronyms, Abbreviations, and Symbols

AEC	Atomic Energy Commission
cdf	cumulative distribution function
CDPHE	Colorado Department of Public Health and Environment
CEC	cation exchange capacity
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
cm/sec	centimeters per second
D	deuterium
d	deuterium excess
DOE	U.S. Department of Energy
Eh	redox potential
EPA	U.S. Environmental Protection Agency
ERPD	Environmental Restoration Program Division
IAEA	International Atomic Energy Agency
IAP	ion-activity product
Ksp	equilibrium solubility product
LHSU	lower hydrostratigraphic unit
M	molarity (moles per liter of solution)
meq/L	milliequivalents per liter
mg/L	milligrams per liter
mmol/kg	millimoles per kilogram
NPL	National Priorities List

OU	operable unit
PCB	polychlorinated biphenyl
pCi/L	picocuries per liter
RCRA	Resource Conservation and Recovery Act
RFEDS	Rocky Flats Environmental Database System
RFETS	Rocky Flats Environmental Technology Site
SEM	scanning electron microscopy
SI	saturation index
SMOW	Standard Mean Ocean Water
SOP	standard operating procedure
SVOC	semivolatile organic compound
TAL	Target Analyte List
TCL	Target Compound List
TDS	total dissolved solids
TOC	total organic carbon
TSS	total suspended solids
TU	tritium unit
UHSU	upper hydrostratigraphic unit
VOC	volatile organic compound
WQCC	Water Quality Control Commission
XRD	x-ray diffraction
XRF	x-ray fluorescence
δ	per mil difference
°C	degrees Celsius
°F	degrees Fahrenheit

1. Executive Summary

The Groundwater Geochemistry Report was produced by the Environmental Restoration Program Division (ERPD) at the Rocky Flats Environmental Technology Site (RFETS or Rocky Flats site) as Volume III of the Sitewide Geoscience Characterization Study. The discussion of groundwater geochemistry complements and supports the Geologic Characterization Report (Volume I) and Hydrogeologic Characterization Report (Volume II) and provides the conceptual framework for discussions of groundwater quality related to other sitewide and operable unit (OU) investigations.

Geochemical data describing groundwater have been collected over many years at the Rocky Flats site, but a thorough analysis and interpretation of these data have been lacking. The main objectives of the groundwater geochemistry report were to: (1) assess analytical data available for groundwater samples collected from the site, (2) evaluate the chemistry of groundwater in the upper and lower hydrostratigraphic units, and (3) evaluate the evolutionary trends and spatial patterns in the chemistry of groundwater as it traverses the site.

These objectives were addressed through the evaluation of data collected from 1990 through the first quarter of 1994. Chemical analyses of groundwater from approximately 530 monitoring wells (some no longer sampled) were available for use in this report.

Groundwater from two hydrostratigraphic units, designated the upper and lower hydrostratigraphic units (UHSU and LHSU, respectively), has been routinely sampled and analyzed. Each of the units is composed of several hydraulically connected lithostratigraphic units. The UHSU consists of surficial deposits and weathered portions of the bedrock (Laramie and Arapahoe formations). Weathered-bedrock portions of the UHSU were defined using lithologic criteria developed for the Geologic Characterization and Hydrogeologic Characterization reports (Volumes I and II). The LHSU is composed of unweathered portions of the Arapahoe and Laramie formations and has generally lower permeabilities and hydraulic conductivities than the UHSU.

A variety of graphical methods, including Stiff and Piper diagrams, reveal that groundwaters from the two hydrostratigraphic units are generally distinguishable by their chemical characteristics. Groundwater within the UHSU is predominantly a calcium-bicarbonate water, whereas groundwater within the LHSU is more sodium rich than UHSU groundwater and more variable in its composition. The LHSU includes calcium-bicarbonate, sodium-bicarbonate, sodium-chloride, and sodium-sulfate water.

Four probable flow paths for UHSU groundwater were identified using sitewide potentiometric-surface maps from the Hydrogeologic Characterization Report (Volume II). Changes in groundwater chemistry along these flow paths are evident on ion-variation diagrams, Stiff plots, and Piper diagrams. Along the Rock Creek flow path (an area considered to be unaffected by plant activities), concentrations of total dissolved solids and the major ions increase, from initial to final wells, by approximately one order of magnitude in the direction of groundwater flow. Groundwater along the other three flow paths, including the flow path through the Industrial Area, shows similar changes in chemistry from the initial to the final wells. Locally, groundwater within the central Industrial Area shows some marked increases in the concentrations of major ions; however, groundwater at the terminus of the flow path shows a similar (or smaller) increase in the concentration of major ions, from initial to final wells, as that seen along the Rock Creek flow path. Dissolved uranium isotopes also increase in concentration along the Industrial Area flow path, but the ratio of uranium-233,234 to uranium-238 remains constant, between a value of one to two. Background values of this uranium ratio range between 1.19 and 2.43 for upgradient groundwater at the Rocky Flats Site.

Two distinct methods were used to identify patterns of spatial variation in groundwater chemistry. First, a geostatistical analysis method, kriging, was used to estimate the concentrations of selected analytes in groundwater between the available measuring points (monitoring wells). Ordinary kriging was used to create isoconcentration maps of 19 ions and water-quality parameters in UHSU groundwater. These maps show two general patterns of spatial variation: (1) increasing ion concentrations in groundwater from west to east across the site (in the direction of groundwater flow) and (2) greatest variability in ion concentrations within the Industrial Area and other areas of past waste generation, storage, and disposal. The geostatistical analysis demonstrates that there is a general spatial correlation to ion concentrations in the UHSU groundwater. The number of monitoring wells in the LHSU was not sufficient to permit kriging of analyte concentrations in that unit.

Isoconcentration-contour maps were also compiled by hand-contouring posted concentration data. In areas where well coverage is dense, these maps provide more realistic and accurate depictions of spatial distribution than the kriging output because they honor all of the actual concentration data and also take into account other information about groundwater flow (e.g., flow direction, aquifer continuity, etc.). The resultant isoconcentration-contour maps show the same general pattern of increasing ion concentration in the direction of groundwater flow as was evident from the kriging analysis. They also show areas where ion concentrations are elevated relative to background areas and aid in the interpretation of the kriging output.

The maps generated by ordinary kriging are best used to identify large-scale trends in the distribution of groundwater parameters. The sitewide kriging output should not be used, however, to define areas of groundwater contamination.

The results of an environmental-isotope study show that groundwaters from within surficial deposits and weathered bedrock of the UHSU are not distinguishable on the basis of their oxygen and hydrogen isotopic compositions, but UHSU groundwater is distinct from groundwater in the LHSU. LHSU groundwater generally has no detectable tritium (< 0.8 tritium units) and may be much older than groundwater from the UHSU (tritium contents from 0.8 to 3,703 tritium units). These results support current definitions of the UHSU and also suggest that a low-permeability layer separates the upper and lower hydrostratigraphic units. In addition, the stable-isotope compositions UHSU of groundwater ($\delta^{18}O$ = -19.2 to -10.1) confirm that the main source of recharge to the UHSU is precipitation ($\delta^{18}O$ = -29.2 to -7.3) but also indicate that some recharge originates from other sources, such as lakes, ponds, and isotopically distinct sources within the Industrial Area.

Two geochemical models, WATEQF and NETPATH, were used to evaluate and model changes in water chemistry along flow paths in the UHSU. The number of monitoring wells in the LHSU was not sufficient to permit modeling of groundwater evolution in that unit. Mineralogic data from the Geologic Characterization Report (Volume I) and analytical data describing groundwater chemistry at wells along the flow paths were used to constrain the models. The speciation of dissolved elements and the saturation indices for solid phases were calculated for groundwater using WATEQF. The results of WATEQF modeling are consistent with the mineralogic analyses of core samples from weathered bedrock.

WATEQF models indicate that the concentrations of metals present in UHSU groundwater are generally not in excess of their predicted concentrations resulting from interactions with the mineral phases present; however, groundwater at most locations is oversaturated with respect to several iron minerals. Naturally occurring mineral phases appear to control the concentrations of some dissolved metals, including barium, manganese, selenium, and strontium. In addition, the behavior of some species — especially trace metals — may be coupled to that of iron by coprecipitation or adsorption onto iron oxides and oxyhydroxides.

Mass-balance modeling of UHSU groundwater was performed using NETPATH. The model describes the chemical evolution of groundwater along a user-defined flow path, in terms of water/rock interactions. The NETPATH results indicate that realistic amounts of dissolution and precipitation of mineral phases along the groundwater flow path can explain the observed changes in the chemical composition of groundwater as it flows across the Rocky Flats site. Therefore, mixing with other solutions, such as a

contaminant-bearing solution, is not required to produce the increased concentrations of metals observed in groundwater from the eastern boundary of the site.

In summary:

1. Major-ion chemistry and stable-isotope data support the current flow-system concept of two hydrologically separate units: the UHSU and LHSU.

2. Spatial analysis of chemical data shows a general increase in analyte concentrations from west to east across the site.

3. The results of geochemical modeling are consistent with the natural chemical evolution of a groundwater as it moves along the flow path.

4. The data suggest that the sitewide evolution in groundwater chemistry can create an "upgradient bias" when the inorganic chemistry of upgradient background wells is compared to that of any downgradient well.

5. Although groundwater in some locations in and near the Industrial Area of the site shows the impact of local contamination, most contamination currently appears to be attenuated before groundwater reaches the eastern boundary of the site.

Results from the qualitative and quantitative evaluation of chemical and isotopic data, along with the initial modeling of sitewide groundwater, provide additional information that should be considered in weight-of-evidence discussions of groundwater contamination by metals and other inorganic analytes.

2. Introduction

The Groundwater Geochemistry Report was produced by the Environmental Restoration Program Division (ERPD) at Rocky Flats as Volume III of the Sitewide Geoscience Characterization Study. The report presents a comprehensive description of groundwater geochemistry at the U.S. Department of Energy's (DOE's) Rocky Flats Environmental Technology Site (Rocky Flats site). The discussion of groundwater geochemistry complements and supports the Geologic Characterization Report (Volume I) and Hydrogeologic Characterization Report (Volume II) and provides the conceptual framework for discussions of groundwater quality related to other sitewide and operable unit (OU) investigations.

2.1 Background

DOE's Rocky Flats site is located approximately 16 miles northwest of Denver, Colorado, in northern Jefferson County. The site occupies approximately 10 square miles; the site boundaries and features are illustrated in Figure 2-1. The site consists of an industrial complex of approximately 400 acres surrounded by a Buffer Zone of approximately 6,150 acres. Rocky Flats is a government-owned, contractor-operated facility that has been in operation since 1952. EG&G Rocky Flats, Inc. is currently the primary operating contractor.

Until January 1992, the Rocky Flats Plant was involved in manufacturing the plutonium component of nuclear weapons, reprocessing scrap metal and plutonium from dismantled weapons, conducting laboratory research on the properties of nuclear materials, and fabricating steel and beryllium components. In January 1992, the primary mission of the Rocky Flats site changed; the work force is now engaged in environmental restoration, waste management, decontamination and decommissioning, and economic development. In July 1994, the name of the Rocky Flats site was changed from Rocky Flats Plant to Rocky Flats Environmental Technology Site (RFETS or Rocky Flats site).

Wastes produced during plant operations included hazardous wastes, low-level and transuranic radioactive wastes, and mixed wastes. Historically, these wastes have been either disposed onsite, stored in containers onsite, or disposed offsite. As a result of these past practices, Rocky Flats was proposed for inclusion on the Superfund National Priorities List (NPL) in 1984 and was included on the NPL in the October 4, 1989 Federal Register. Cleanup is being conducted under the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). The U.S. Environmental Protection Agency (EPA) and the Colorado Department of Public Health and Environment

(CDPHE) are the regulatory agencies overseeing the assessment and cleanup activities at sixteen OUs on the site (refer to Figure 2-2 for map of OUs).

Of the 16 OUs, one (OU3, Offsite Areas) is located outside RFETS boundaries, one (OU15, Inside Building Areas) includes areas within buildings, and the remaining 14 are outside-of-building areas within RFETS boundaries. Table 2-1 summarizes the general locations of the OUs, and the locations of individual hazardous substance sites (IHSSs) associated with OUs 1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, and 16 are shown on Figure 2-2. Areas within these OUs are discussed throughout the following report.

Table 2-1
Operable Units at RFETS

Operable Unit Number	Description	Number of IHSSs
OU 1	881 Hillside	11
OU 2	903 Pad, Mound, and East Trenches	20
OU 3	Off-Site Releases	4
OU 4	Solar Evaporation Ponds	1
OU 5	Woman Creek	10
OU 6	Walnut Creek	20
OU 7	Present Landfill	2
OU 8	700 Area	38
OU 9	Original Process Waste Lines	1
OU 10	Other Outside Closures	19
OU 11	West Spray Field	1
OU 12	400/800 Area	12
OU 13	100 Area	15
OU 14	Radioactive Sites	9
OU 15	Inside Building Closures	8
OU 16	Low-Priority Sites	7

2.2 Groundwater Monitoring at the Rocky Flats Site

Groundwater at the Rocky Flats site has been monitored since 1954 (WWE, 1993). The monitoring system has grown from a small number of wells designed to detect leakage from the Solar Evaporation Ponds, to approximately 600 wells and piezometers. Monitoring wells have been added to the system over the years to meet

groundwater protection and monitoring requirements of specific federal and state environmental protection laws and DOE or Atomic Energy Commission (AEC) orders. During 1993, more than 400 active groundwater monitoring wells were sampled (EG&G, 1994a).

The current groundwater monitoring program is an amalgamation of several programs that address distinct regulatory-compliance or site-characterization objectives. Wells are classified as follows:

- RCRA
- CERCLA
- Background Characterization
- Boundary or Point-of-Compliance
- Special Purpose

Monitoring wells are generally sampled quarterly; CERCLA wells are commonly sampled more frequently to provide additional data for remedial investigations of the OUs. The analytical suite for groundwater samples consists of the following analytes and analyte groups: water-quality parameters, including nitrate/nitrite as nitrogen; Target Analyte List (TAL) standard and additional metals; gross alpha and gross beta and isotopes of uranium, plutonium, americium, tritium, cesium, radium, and strontium; Target Compound List (TCL) volatile organic compounds (VOCs); semivolatile organic compounds (SVOCs); polychlorinated biphenyls (PCBs)/pesticides; cyanide; and orthophosphate. A complete analyte list is presented in Appendix A.

2.3 Purpose and Scope of the Groundwater Geochemistry Report

Geochemical data describing groundwater have been collected over many years at the Rocky Flats site, but a thorough analysis and interpretation of these data have been lacking. A more thorough description of the natural variations in groundwater geochemistry is required to help distinguish naturally occurring chemical variations from those resulting from contamination related to past production and waste-storage activities at the site. The main objectives of the groundwater geochemistry investigation are to present and assess the large body of analytical data available for groundwater samples collected from the site, evaluate the chemistry of groundwater at the site, and evaluate the evolutionary trends in the chemistry of groundwater as it traverses the site. An overview of groundwater chemistry at the site will provide needed context for discussions of groundwater contamination at the individual OUs that are currently under investigation.

The Groundwater Geochemistry Report utilizes groundwater chemistry data for samples collected from 1990 through the first quarter of 1994 for approximately 530

monitoring wells (Plate 1). These samples were collected during sitewide and OU-specific monitoring and characterization programs. Using a variety of data-analysis and data-presentation methods, the report evaluates groundwater chemistry in the two uppermost hydrostratigraphic units, the spatial variations in groundwater chemistry, and variations in groundwater chemistry along flow paths across the site. The report also presents the stable-isotope compositions of groundwater and the results of geochemical modeling of water chemistry along flow paths. The geochemical models describe the natural evolution of groundwater along flow paths and will help to distinguish natural chemical variations from contamination in groundwater at each of the OUs under investigation.

The report includes brief descriptions of the geologic and hydrogeologic settings in Sections 3 and 4. Section 5 provides a description of the major-ion chemistry of groundwater. Section 6 presents the results of geostatistical analyses performed to identify spatial trends in groundwater composition. The results of an environmental-isotope study and its implications for hydrogeologic and hydrochemical models are presented in Section 7. Finally, the results of chemical-speciation and geochemical mass-balance modeling conducted using site-specific mineralogic and hydrochemical data are presented in Section 8.

3. Geologic Setting and Description of Geologic Units

The Rocky Flats site is located at an elevation of approximately 6,000 feet above mean sea level on the western margin of the Colorado Piedmont section of the Great Plains Physiographic Province. The piedmont merges to the east with the High Plains section of the Great Plains Province and is terminated abruptly on the west by the Front Range section of the Southern Rocky Mountain Province. Fault geometries along the Front Range change from east-directed thrusts near Golden to west-directed backthrusts north of Boulder. The Rocky Flats site is in a complex transition zone that contains both fault geometries. Geologic units present at the site include Quaternary surficial deposits, which unconformably overlie Cretaceous bedrock. Faults are interpreted to offset bedrock units (EG&G, 1995a), but their influence on groundwater flow has not been determined.

3.1 Physiography and Topography

The Colorado Piedmont is an area of dissected topography and denudation representing an old erosional surface along the eastern margin of the Rocky Mountains. The piedmont surface is broadly rolling and slopes gently to the east with a topographic relief of only several hundred feet. This relief is a result of both resistant bedrock units that locally rise above the surrounding landscape and the presence of incised stream valleys. Major stream valleys that transect the piedmont from west to east originate in the Front Range. Small local valleys have developed as tributaries to these major streams.

A few miles west of Rocky Flats, the eastern margin of the Front Range is characterized by a narrow belt of hogback ridges and flatirons formed by steeply east-dipping Mesozoic strata of the Dakota Group and the Paleozoic Fountain Formation. Less resistant sedimentary units were removed by erosion.

During the Quaternary, several pediments have been eroded across the bedrock surface at Rocky Flats (Scott, 1965). The Rocky Flats pediment is the most extensive of these, forming a broad flat surface south of Coal Creek. The broad pediments and more narrow terraces are now covered by alluvial deposits from ancient streams draining eastward into the Great Plains. The pediments have been locally dissected and reworked along several eastward-flowing streams including Rock Creek, Walnut Creek, and Woman Creek. Fluvial processes have formed moderately steep hillslopes adjacent to the stream drainages.

3.2 Lithology and Stratigraphy

Geologic units underlying the Rocky Flats site include unconsolidated surficial deposits and bedrock. A geologic map illustrating the distribution of the dominant surficial-deposit and bedrock units is included as Figure 3-1. A generalized stratigraphic section showing the vertical sequence of geologic units is included as Figure 3-2. Detailed descriptions of these units are provided in the Geologic Characterization Report (Volume I, EG&G, 1995a); more general summary descriptions are provided below.

3.2.1 Surficial Deposits

Approximately 99 percent of the Rocky Flats site is covered with surficial deposits that include artificial fill, colluvial, landslide, and alluvial deposits. Colluvial and landslide deposits are most extensive but are not shown on the geologic map (Figure 3-1) so that bedrock units could be shown. Surficial deposits range in thickness from 0 to 100 feet.

Artificial fill materials are present across the site and include road and railroad embankments, earth dams and other engineered fills, as well as compacted and uncompacted landfills and spoil piles along some of the irrigation ditches (Plate 4-1, EG&G, 1995a). The artificial deposits are commonly less than 10 feet thick, although some of the earth dams and landfills are greater than 30 feet thick. Most of these deposits are impermeable and restrict groundwater flow.

Colluvial deposits cover the steep hillslopes in the incised stream drainages (Plate 4-1, EG&G, 1995a). These middle Pleistocene to Holocene deposits were derived from older alluvial units and bedrock and were deposited by sheetwash and soil creep. Colluvial deposits range in thickness from 3 to 15 feet. Lithologically, the colluvium consists of silty sand, sandy silt, clayey silt, and silty clay with pebbles and cobbles. These deposits are typically poorly sorted and poorly stratified. Colluvial deposits are variably saturated, and colluvial groundwater tends to flow downslope following paleogullies developed on the bedrock surface.

Landslide deposits are present along the steep hillslopes in the incised drainages (Colton *et al.*, 1975; Colton and Holligan, 1977; Irvine, 1962 and 1963; Van Horn, 1954). These middle Pleistocene to Holocene deposits include earth flows, earth slumps, debris flows, debris slumps, rock-block slides, and complex landslides. These deposits range in thickness from 10 to 100 feet. Landslide scarps are present in all of the drainages in the map area and are most numerous in the Rock Creek drainage (refer to Plate 4-1, EG&G, 1995a). Landslides are commonly located downgradient from alluvial or bedrock groundwater discharge areas. Groundwater discharge increases the saturation within downgradient soils, leading to failure of the material.

Alluvial deposits have been mapped in flood plains, stream channels, and terraces along the drainages across the Rocky Flats site and include valley-fill alluvium, undifferentiated alluvium, and Rocky Flats Alluvium. Valley-fill alluvium includes the Pleistocene Louviers, Broadway, and pre-Piney Creek Alluvium and the Holocene Piney Creek and post-Piney Creek alluvial units. Valley-fill alluvium consists of channel and terrace deposits in and along most of the ephemeral streams that cross the site (Figure 3-1) (Plate 4-1, EG&G, 1995a). Valley-fill alluvium ranges in thickness from 10 to 40 feet and is variably saturated. The valley-fill alluvium is permeable and may provide preferential pathways for groundwater migration. Undifferentiated alluvial deposits, as shown in Figure 3-1, include the Pleistocene Slocum Alluvium and Verdos Alluvium of Shroba and Carrara (1994). These units form small remnants of pediment or terrace deposits primarily in the southeastern portion of the Rocky Flats site. The undifferentiated alluvial deposits range in thickness from 5 to 20 feet, but this unit is not a significant component of the hydrologic system on the site (EG&G, 1995b).

The Rocky Flats Alluvium caps the pediment at the Rocky Flats site. These Pleistocene sediments were deposited as alluvial fans along the eastern edge of the Front Range. Thickness of the Rocky Flats Alluvium ranges from 10 to 100 feet and is controlled by location within the fan (proximal or distal) and topography on the bedrock surface. Thicker deposits correspond to paleoscours, and thinner deposits occur along the crests of paleoridges. Groundwater flow within the Rocky Flats Alluvium is influenced by the topography of the underlying bedrock surface (paleotopography), the geometry and lithology of alluvial lithofacies, and the regional hydraulic gradient.

3.2.2 Bedrock Units

Bedrock units unconformably underlie the surficial deposits and consist of claystones, siltstones, and sandstones of the Upper Cretaceous Arapahoe Formation, Laramie Formation, Fox Hills Sandstone, and Pierre Shale (Figure 3-2). A preserved bedrock pediment exists between the major drainages of Rock Creek, Walnut Creek, and Woman Creek. The pediment surface is irregular (refer to Plate 4-4, EG&G, 1995a) as a result of earlier erosion.

Weathering of the upper part of the bedrock has occurred to various depths across the site and is dependent on the abundance of fractures, presence of root zones, elevation relative to the water table, and proximity to modern drainages. The degree of weathering and the thickness of the weathered zone influence groundwater flow in bedrock. These parameters are described in the Geologic and Hydrogeologic Characterization Reports, Volumes I and II of the Sitewide Geoscience Characterization Study (EG&G, 1995a and 1995b).

The Upper Cretaceous Arapahoe Formation is locally present at the Rocky Flats site. The thickness of the Arapahoe Formation, a fluvial deposit, ranges from 0 to 50 feet beneath the central portion of the site (EG&G, 1992a). The Arapahoe Sandstone, formerly referred to as the No. 1 Sandstone (EG&G, 1991), has a sharp basal contact, is fine- to coarse-grained and generally contains rip-up clasts near the base of the sandstone package. The fluvial sedimentary package fines upward into a clayey sandstone or sandy claystone. Channel sequences scoured into bedrock units of the Laramie Formation are laterally discontinuous at Rocky Flats. Arapahoe sandstones are pathways for groundwater flow, and in some areas of the site, they are in direct hydraulic communication with overlying alluvial units (EG&G, 1995a and 1994b). Arapahoe sandstones are described in the Geologic Characterization Report (EG&G, 1995a).

The Upper Cretaceous Laramie Formation is 600 to 800 feet thick and subcrops beneath the alluvial/bedrock unconformity across most of the Rocky Flats site. The upper Laramie Formation includes massively bedded claystone, very fine- to fine-grained silty to clayey sandstones and calcareous clayey siltstones. Sandstones and siltstones are laterally discontinuous and are less than 15 feet thick. Fracturing of claystones is common and fractured zones may provide pathways for groundwater flow. Fracturing of claystones typically occurs in association with relatively shallow weathering and possibly with faulting. Upper Laramie Formation sandstones have lower hydraulic conductivities than Arapahoe sandstones (EG&G, 1995b) and generally are not in hydraulic communication with the overlying alluvial deposits.

The Upper Cretaceous Fox Hills Sandstone is 90 to 140 feet thick and conformably underlies the Laramie Formation. This unit is composed of a fine-grained, friable sandstone. This sandstone, along with sandstones in the lower Laramie Formation, composes the Laramie/Fox Hills Aquifer.

3.3 Mineralogy of Bedrock Units

As part of the Geologic Characterization Report (EG&G, 1995a), mineralogical and petrographic analyses of drill-core samples from the Cretaceous bedrock were performed. Analyses of six samples from saturated portions of the bedrock were included to further describe the whole-rock and mineral compositions, secondary mineral phases, and the effects of water/rock interactions in bedrock that is in contact with groundwater. These analyses provided mineralogic data that could be used to constrain realistic geochemical models for water/rock interaction on the Rocky Flats site. This section summarizes the relevant results of the mineralogic analyses. More detailed descriptions and discussion of these results are provided in the Geologic Characterization Report (EG&G, 1995a).

Samples from drill cores collected at four wells located immediately south of Rock Creek—40391 (40.8 feet), 41892 (29.4 feet), 42192 (176 feet), and 42392 (110, 141.6, and 162 feet)—were analyzed. X-ray diffraction (XRD), x-ray fluorescence (XRF), scanning electron microscopy (SEM), and electron microprobe analyses were performed. A petrographic description and determinations of total organic carbon (TOC), cation exchange capacity (CEC), sesquioxides, bulk density, and porosity were also obtained.

XRD results identified the bulk and clay (<2-micron size fraction) mineral assemblages within the samples. The main component of the bulk samples is quartz, with lesser amounts of potassium feldspar, plagioclase, mica/illite, and kaolinite. In the clay-size fraction, which constitutes 2 to 7 percent of the total weight of the samples, the main components are mixed-layered illite/smectite and kaolinite, with minor amounts of illite, chlorite, and gibbsite. The mixed-layered illite/smectite contains approximately 10 to 15 percent illite. This low percentage of illite, together with an analysis of the x-ray diffractograms, indicates that many of the clay minerals are detrital in origin.

SEM analyses of six core samples (one each from 40391, 41892, and 42192 and three from 42392) also revealed a dominantly detrital mineral assemblage. With the exception of one sample, the morphologies of the clay minerals observed using the SEM indicate the minerals were deposited *in situ* rather than formed by diagenetic processes. The exception to this observation was in sample 40391 (40.8 feet), where authigenic kaolinite was observed adjacent to a potassium feldspar grain.

Potassium feldspar and quartz surfaces were rough and irregular and appeared weathered in the SEM micrographs. These surface features probably originated at the time of sediment transport/deposition, but ragged edges on some microcline grains may be indicative of continued "weathering" of the grains by water/rock interaction. Floccules of secondary iron-oxides/hydroxides were also present in the weathered bedrock. These appear to be uncompacted and may have precipitated from groundwater.

Petrographic descriptions of the same six samples (see above for description) support the XRD and SEM analyses. Quartz was reported as the main framework component, and clay was reported as the main non-framework component. Also present in minor abundances are potassium feldspar, plagioclase, mica, and lithic and micrite fragments. Authigenic carbonate cement was observed in the sample from 40391 (40.8 feet). Post-depositional features observed in thin section included slight sediment compaction and localized mineral dissolution in each of the samples.

The electron microprobe was used to identify the mineral phases present in each of the samples and to determine the composition of the more abundant phases such as

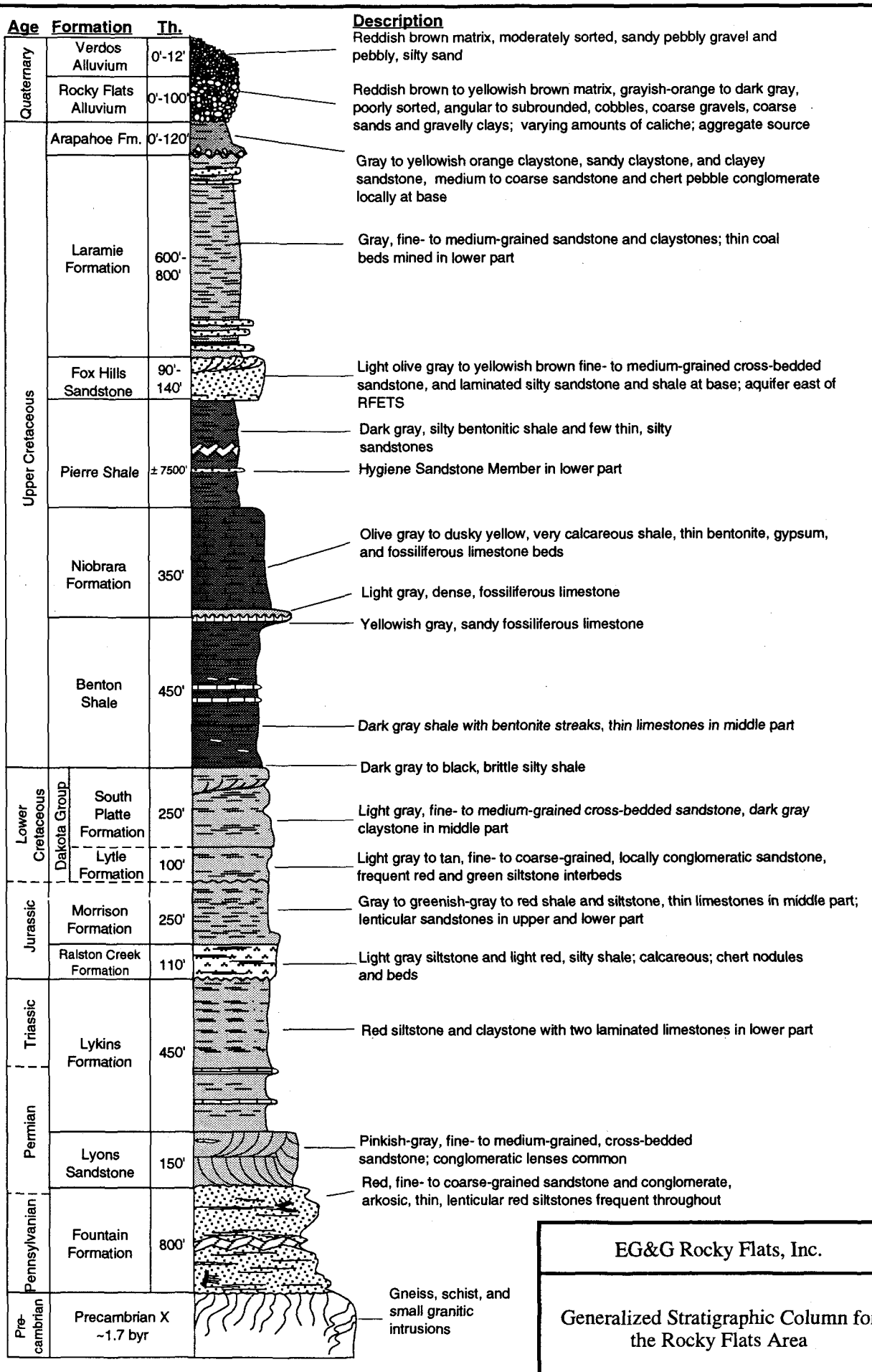
microcline, biotite, plagioclase (albite), siderite, and iron oxyhydroxides. These results are summarized in the Geologic Characterization Report (EG&G, 1995a). The semiquantitative analyses of microclines indicate that the microcline composition is not variable among the samples. Plagioclase feldspars are rare, and they are albitic (sodium rich) in composition. The major-oxide compositions of these minerals were used to model chemical interaction between bedrock and groundwater on the site (see Section 8).

3.4 Structural Geology

The tectonic framework of the Southern Rocky Mountain Province is dominated by Laramide structural features that include north-northwest- and west-trending basement-cored ranges flanked by asymmetric, elliptical basins. Many of the ranges are bounded by low-angle thrust faults dipping under the ranges and result in asymmetrical folds. Based on the fold asymmetry and vergence, these ranges reflect basin-directed slip. Other ranges are bounded by blind faults and flanked by monoclinal folds.

The Laramie/Fox Hills Aquifer was deformed during the Laramide orogeny when eastward translation of the Front Range formed a north-trending monoclinal fold (Figure 3-3). Bedrock units of the Fox Hills Sandstone and the Laramie Formation are inclined west of Rocky Flats along this fold. Figure 3-3 also shows conjugate thrusts and backthrusts, identified on the basis of deep-reflection seismic data, that appear to terminate along deeper detachment faults in the Pierre Shale (EG&G, 1993a). These detachments appear to develop as shallow, basement thrust faults in bedding planes in the lower Pierre Shale.

Shallower thrusts and backthrusts in the Cretaceous bedrock units are discussed in the Geologic Characterization Report (EG&G, 1995a) and may be conduits or barriers for groundwater migration.



Modified from LeRoy and Weimer (1971)

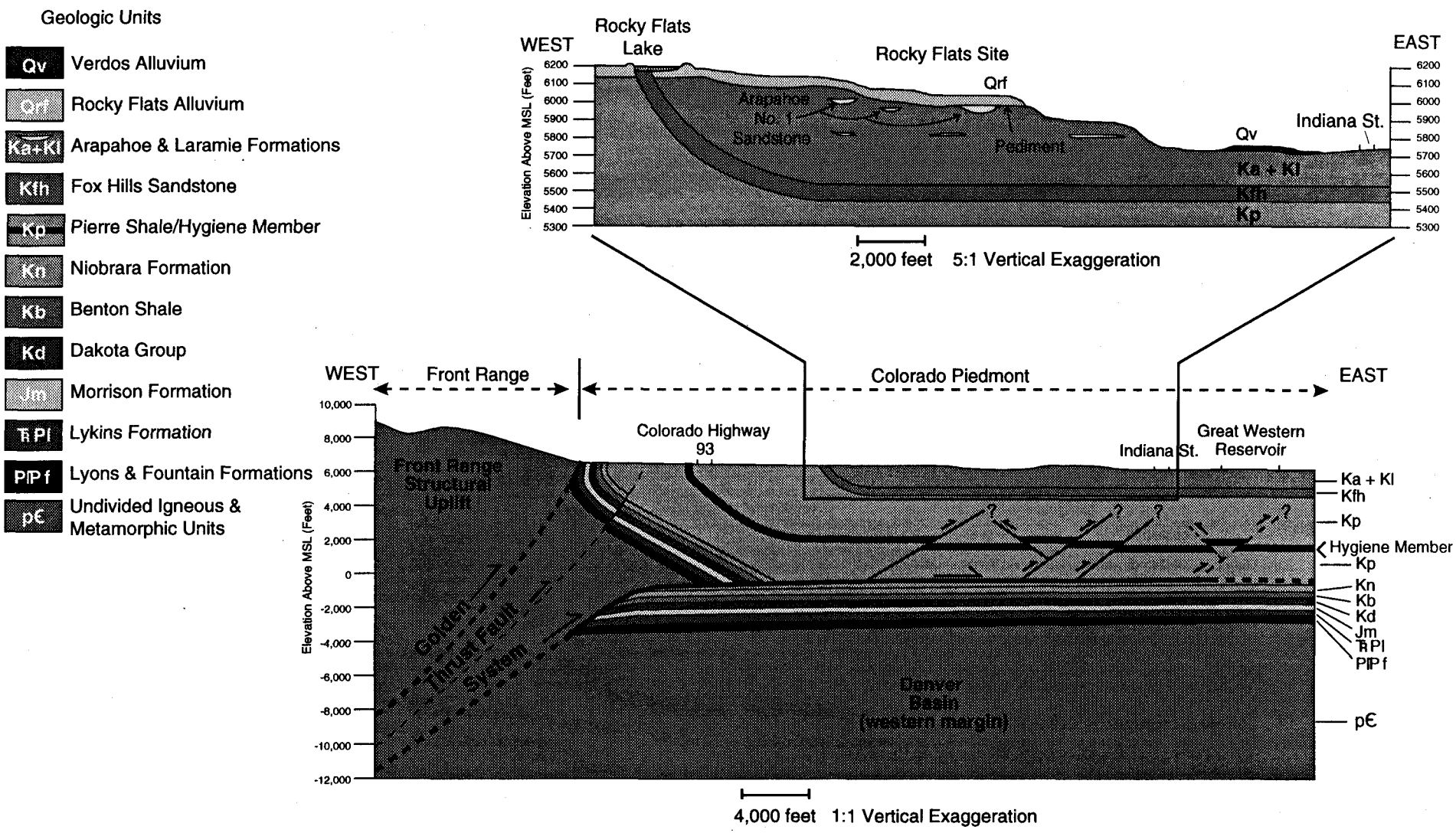
EG&G Rocky Flats, Inc.

Generalized Stratigraphic Column for the Rocky Flats Area

January 1995

Figure 3-2

M\ES\Fig 4-02 Stratigraph.mdw11-1-94



Structural interpretation from EG&G, 1993a.

EG&G Rocky Flats, Inc.

Generalized Geological Cross Section of the Front Range and the Rocky Flats Area

January 1995 | Figure 3-3

M\ES\Cross Section.ill \11-1-94

4. Hydrogeologic Setting and Description of Hydrostratigraphic Units

This section presents a brief summary of the meteorological and hydrogeologic conditions present at the Rocky Flats site. For a more comprehensive discussion of the meteorology and hydrogeology of the Rocky Flats area, the reader should refer to Volume II, Hydrogeologic Characterization Report (EG&G, 1995b).

4.1 Climate and Meteorology

The area surrounding the Rocky Flats site has a continental, semiarid climate characteristic of the Southern Rocky Mountain region. Temperatures at the site exhibit large seasonal variations and, occasionally, dramatic short-term changes. Summer high temperatures are typically in the mid-80°F range during the days, with lows below 60°F at night. During the winter months, temperatures are relatively mild, ranging from 40° to 45°F during the day and 15° to 25°F at night. Temperature extremes recorded at the plant range from 102°F to -26°F (EG&G, 1993b).

Mean annual precipitation at the Rocky Flats site, including rainfall and snowmelt, is nearly 15.5 inches. Approximately 40 percent of the annual precipitation falls during the months of April, May, and June (EG&G, 1993b). Summer thunderstorms (July and August) account for an additional 30 percent of the annual precipitation. Autumn and winter are drier seasons, accounting for 20 and 10 percent of the annual precipitation, respectively (DOE, 1980). Snowfall averages 85 inches per year, occurring generally from October through May. Heaviest snowfall occurs in spring (EG&G, 1993b). Snowfall provides approximately half of the total precipitation for the year. The average relative humidity is 46 percent (DOE, 1980). Precipitation amounts are described in greater detail in the Hydrogeologic Characterization Report (EG&G, 1995b).

The site is noted for its strong, gusty winds that are commonly associated with thunderstorms and passage of weather fronts. The highest wind speeds, however, occur as westerly windstorms known as "chinooks." These winds occur during the period from late November into April, and the height of the season is in January. Chinook wind speeds typically exceed 75 miles per hour, and gusts may exceed 100 miles per hour. However, northwesterly wind directions and wind speeds under 15 miles per hour are the predominant wind conditions at the Rocky Flats site. Moderately strong northerly or southerly winds are common in winter and summer, respectively, and easterly winds ("upslopes") may be associated with heavy snowfall or precipitation. The steep-sided canyons along the Front Range tend to channel the airflow during both upslope and downslope conditions (DOE, 1980; EG&G, 1995b).

Meteorology at the Rocky Flats site is strongly influenced by the diurnal cycle of mountain and valley breezes (EG&G, 1995b). Two dominant flow patterns exist, one during daytime conditions and one at night. During the daytime hours, as the earth heats, air tends to flow toward the higher elevations (upslope). The general airflow pattern during upslope conditions for the Denver area is typically north to south, with flow moving up the South Platte River valley and then entering canyons into the Front Range. After sunset, the air against the mountain sides is cooled and begins to flow toward the lower elevations (downslope). During downslope conditions, air flows down the canyons of the Front Range onto the plains. This flow converges with the South Platte River valley flow moving toward the north-northeast (Hodgin, 1983 and 1984; DOE, 1986). Wind roses for 1993 are included with Hydrogeologic Characterization Report (EG&G, 1995b).

4.2 Hydrogeologic Setting

An understanding of the site hydrological conditions and the mechanics of groundwater flow is important in analyzing and interpreting the groundwater geochemistry at Rocky Flats. This section provides a description of the hydrologic setting of the Rocky Flats site in terms of the groundwater hydrology. This description is based on the more detailed discussion included in the Hydrogeologic Characterization Report (EG&G, 1995b).

At the Rocky Flats site, groundwater is generally described and evaluated using two classification schemes, hydrostratigraphic units and lithostratigraphic units. For example, the Background Geochemical Characterization Report (EG&G, 1993f) described groundwaters by both hydrostratigraphic unit (i.e., flow system) and lithostratigraphic unit (i.e., geologic unit).

At least two discernible hydrostratigraphic units are present at the Rocky Flats site. These are generally referred to as the upper hydrostratigraphic unit (UHSU) and lower hydrostratigraphic unit (LHSU). The LHSU is composed mainly of unweathered bedrock of the Laramie Formation and includes unweathered portions of the Arapahoe Formation where present (EG&G, 1991). The UHSU consists of several distinct lithostratigraphic units including surficial deposits of alluvium, colluvium, valley-fill alluvium, and landslide deposits of Quaternary age; weathered portions of the Cretaceous Arapahoe/Laramie formations; and all sandstones within the Arapahoe and Laramie formations that are in connection with the overlying Quaternary deposits or the ground surface (EG&G, 1991; Plate 5-1 of EG&G, 1995a). Lithologic criteria are used to define the weathered bedrock; these criteria include color change and degree of iron-oxide staining and they are described in greater detail in the Geologic and Hydrogeologic Characterization Reports (EG&G, 1995a and 1995b).

The unweathered bedrock generally exhibits lower permeability than the overlying weathered bedrock and surficial deposits. This overall contrast in permeability is one basis for differentiating the LHSU from the UHSU. The LHSU begins with the shallowest low-permeability boundary within the bedrock (EG&G, 1995b). Higher permeability bedrock in hydraulic connection with surficial deposits or the ground surface is part of the UHSU.

The Hydrogeologic Characterization Report (EG&G, 1995b) concluded that hydrostratigraphic units were the most useful classification for discussions of groundwater flow. To remain consistent with that report, the groundwater geochemistry is also discussed in terms of the hydrostratigraphic unit hosting the groundwater.

4.2.1 Upper Hydrostratigraphic Unit

The UHSU is composed of two sub-units: the surficial deposits (unconsolidated materials), and the weathered bedrock plus the hydraulically connected sandstones. The degree of hydraulic communication between the UHSU sub-units corresponds to the permeability of the units. Because the relative amount of hydraulic communication between the UHSU sub-units is much greater than that between the UHSU and LHSU, weathered bedrock is included in the UHSU (EG&G, 1995b).

At the Rocky Flats site, unconsolidated materials are thicker on the ridge tops and thinner along the slopes and bottoms of the stream valleys. Thickness of the unconsolidated materials ranges from 0 feet to greater than 100 feet in the western portion of the site. Weathered bedrock is commonly less than 15 feet thick but may extend to 60 feet below the top of bedrock (EG&G, 1993c). Groundwater within these units usually exists under unconfined conditions, but weathered-bedrock groundwater is known to exist under confined conditions locally (EG&G, 1995b).

Precipitation, streams, and engineered water-control structures supply water to the UHSU. Recharge from precipitation and streams varies seasonally. During the spring, when recharge from precipitation is greatest, the elevation of the UHSU water table rises. Hydrographs for wells screened in the surficial deposits show a water-table peak during the month of May. During such periods, when the water table is high, the UHSU locally discharges to streams. During the winter, recharge from precipitation decreases, and the UHSU is recharged by losing reaches of the streams. Engineered structures such as ponds, ditches, and leaking pipes also locally act as sources of water to the UHSU (EG&G, 1995b).

UHSU groundwater discharges through a number of different mechanisms. These include transpiration by vegetation, evaporation in the capillary zone, discharge to surface seeps, discharge to ephemeral streams, and limited infiltration to the underlying

LHSU (EG&G, 1995b). Groundwater is typically transpired near seeps and along streams where the water table is in the rooting zone of plants. Groundwater is also discharged to the atmosphere via evaporation in the capillary zone. Evidence of this evaporation is left in the form of caliche zones in the subsurface (EG&G, 1994b and 1995b). Caliche is not pervasive but caliche zones are locally present in Rocky Flats Alluvium across the site (EG&G, 1995a and 1995b). Seeps also act as discharge points for UHSU groundwater and commonly are located on the valley slopes along the contact between surficial deposits and the underlying bedrock. Discharge to streams varies seasonally and has been quantified only along Woman Creek (Fedors, 1993). Infiltration to the LHSU is indicated by downward vertical gradients. Discharge to the LHSU is expected to be limited because of the lower hydraulic conductivities associated with LHSU claystones (EG&G, 1995b).

Seasonal variations in recharge and discharge result in variations in the potentiometric-surface elevation, saturated thickness, and unsaturated zones in the unconsolidated surficial deposits. In the spring months, the potentiometric surface is higher, unsaturated zones are smaller, and saturated thickness is greatest (EG&G, 1995b, Plates 1 and 3). During the winter months, the potentiometric surface is lower, the unsaturated zones are larger, and saturated thickness is least (EG&G, 1995b, Plates 2 and 4).

The direction of groundwater flow in the UHSU is largely controlled by the topography of the ground surface and bedrock surface. Both surfaces slope gently to the east and are incised by stream valleys. Groundwater generally flows from west to east across the Rocky Flats site following the regional topography. The incised valleys in the central area of the site have formed east-west trending ridges and east-draining valleys. Generally, groundwater in the UHSU flows to the east along the ridge tops, flows north and south along the valley sides, and flows east in the valley bottoms (EG&G, 1994c).

Locally, the direction of flow is controlled by channels in the bedrock surface and variations in the lithology of the uppermost bedrock unit. In OU2 (refer to Figure 2-2), bedrock channels and ridges locally direct groundwater movement within the surficial deposits (EG&G, 1993d). A change in the lithology of the subcropping bedrock unit creates an unsaturated zone in the unconsolidated materials in OU4 (refer to Figure 2-2). The lithology of the uppermost bedrock unit changes from claystone to sandstone, allowing water to flow out of the unconsolidated materials into the weathered bedrock sandstone (EG&G, 1994b).

Hydrographs from adjacent well pairs screened in the UHSU indicate that vertical hydraulic gradients are generally downward at Rocky Flats. The volume of groundwater and rate of groundwater flow between the sub-units of the UHSU is controlled by the local vertical gradient and hydraulic conductivities of the sub-units.

In general, groundwater movement between the surficial deposits and weathered bedrock is limited by the permeability of the subcropping bedrock (EG&G, 1995b).

The hydraulic conductivities of the unconsolidated Quaternary deposits differ by more than an order of magnitude from those of the weathered claystone and sandstone of the Arapahoe and Laramie formations. On average, the unconsolidated Quaternary deposits have the highest hydraulic conductivities compared to other lithostratigraphic units at the site (EG&G, 1995b). The geometric mean of hydraulic conductivities measured in Rocky Flats Alluvium is 2.06 x 10^{-4} cm/sec (EG&G, 1995b). Valley-fill alluvium has the highest mean hydraulic conductivity (1.15 x 10^{-4} cm/sec) (EG&G, 1995b) of the surficial deposits. The weathered claystone and sandstone/siltstone bedrock of the Arapahoe and Laramie formations have mean hydraulic conductivities of 8.82 x 10^{-7} and 2.88 to 3.89 x 10^{-5} cm/sec, respectively (EG&G, 1995b).

4.2.2 Lower Hydrostratigraphic Unit

All lithostratigraphic units in the unweathered portions of the Arapahoe and upper Laramie formations, except for subcropping sandstones, compose the LHSU. The LHSU has been described previously as consisting of only sandstone units within the unweathered portion of bedrock (EG&G, 1991). In general, saturated sandstones that lie within unweathered claystones and siltstones of the Arapahoe or Laramie formations are confined units. These sandstone units are interpreted as not being directly interconnected, and each may act as an isolated hydrostratigraphic unit. In addition, recharge to these units occurs through the confining claystone and siltstone units. Therefore, all unweathered bedrock is considered part of the LHSU (EG&G, 1993c).

Recharge to the LHSU results by leakage from the saturated UHSU. On a regional scale, the flow of groundwater in the LHSU is from west to east. However, a sitewide potentiometric-surface map for the LHSU has not been compiled because sufficient data are lacking. In addition, the degree to which individual sandstone units within the LHSU are interconnected is not known, and an accurate potentiometric-surface map cannot be constructed from existing data (EG&G, 1995b).

The rate of groundwater flow is controlled by the hydraulic conductivity of the unweathered bedrock of the Arapahoe and upper Laramie formations, and by the hydraulic gradient. The confining claystones and siltstones of these formations are much less permeable than the stratigraphic units of the UHSU. Hydraulic conductivities of unweathered claystone range from approximately 10^{-6} to 10^{-8} cm/sec with a geometric mean value of 2.48 x 10^{-7} cm/sec (EG&G, 1995b). Unweathered sandstone units are slightly more permeable with a mean hydraulic conductivity of 5.77 x 10^{-7} cm/sec (EG&G, 1995b). Relatively strong vertical hydraulic gradients exist within the LHSU. However, vertical migration of groundwater into the LHSU is

impeded by the contrast in hydraulic conductivities at the contact between the upper and lower hydrostratigraphic units.

4.2.3 Laramie/Fox Hills Aquifer

A regionally important aquifer known as the Laramie/Fox Hills aquifer (Robson, 1983) is present at greater depth below the Rocky Flats site. This deeper hydrostratigraphic unit is composed of the lower unit of the Laramie Formation and the underlying Fox Hills Sandstone. These units subcrop beneath the Rocky Flats Alluvium and are locally exposed in excavated gravel pits along the western boundary of the site. Recharge to the aquifer occurs along the Front Range. Claystones of the Laramie Formation have very low hydraulic conductivities; therefore, the U.S. Geological Survey (Hurr, 1976) has concluded that operations on the Rocky Flats site could not impact the Laramie/Fox Hills aquifer.

4.2.4 Groundwater Flow

A conceptual description of unconfined groundwater flow was developed for the Rocky Flats site as part of the Well Evaluation Report (EG&G, 1994c) and expanded on in the Hydrogeologic Characterization Report (EG&G, 1995b). Both reports describe three general zones where the characteristics of groundwater flow are distinctive. These zones trend north to south and occupy the western, central, and eastern portions of the site.

The western zone is characterized by a relatively unbroken topographic slope formed on the Rocky Flats Alluvium. In this zone, alluvial thicknesses are greatest, water-level fluctuations are minor, and the alluvium is rarely, if ever, completely unsaturated. Groundwater in the UHSU flows generally east with slight variations in flow direction occurring along the top of the bedrock surface. The predominantly claystone bedrock impedes downward vertical migration of groundwater and directs flow laterally.

The central zone has a gently eastward-sloping topographic surface that is incised by east-west-trending drainages. Topographic highs are capped by thick alluvial deposits and flanked by colluvium. Water flowing through the capping alluvium follows the bedrock surface and either emerges at seeps, drains into hillside colluvium, or migrates vertically into lower lithostratigraphic units (weathered or unweathered bedrock). The potentiometric surface of groundwater in the UHSU generally resembles the ground surface and paleotopographic (bedrock) surface. The potentiometric surface slopes gently to the east and more steeply north-northeast and south-southeast along hillslopes of the incised drainage valleys. Groundwater flows from broad areas of recharge located upgradient and on nearby topographic highs toward the erosional limit of alluvium and then directly toward creeks in incised drainages. Groundwater and surface water are in direct connection at seeps and in some alluvial deposits along these

drainages. In areas of relatively steep topography, baseflow to creeks may occur. The paleotopographic surface also plays a role in directing groundwater flow and in the development of unsaturated zones in unconsolidated surficial deposits. Channels and depressions on the top-of-bedrock surface may act as conduits or even small basins for groundwater. Surficial deposits on either side of these channels can be drained, or dewatered, by flow toward the channel.

The eastern zone is characterized by relatively flat surface topography, the absence of thick alluvial deposits (Rocky Flats Alluvium), and more widespread valley-fill deposits. The ground surface is generally covered by thin deposits of colluvium. The hydraulic gradients are relatively low, and groundwater in unconsolidated deposits may not flow directly toward the axes of stream valleys. Baseflow to creeks is probably also diminished relative to the central zone as a result of the lower hydraulic gradients.

4.2.5 Interaction Between Upper and Lower Hydrostratigraphic Units

The degree of hydraulic interaction between the UHSU and LHSU was investigated for the Hydrogeologic Characterization Report (EG&G, 1995b). Hydrographs from a series of well clusters indicate varying degrees of hydraulic connection between the two units. In general, the LHSU appears to be in limited hydraulic connection with the UHSU within approximately 50 feet of their contact. The hydraulic connection is enhanced where the LHSU contains subcropping sandstone units. The vertical saturated hydraulic conductivity of the LHSU (geometric mean = 5.83×10^{-8} cm/sec) is an order of magnitude less than the horizontal saturated hydraulic conductivity. The low vertical hydraulic conductivity indicates that the LHSU acts as a hydraulic barrier to the downward flow of groundwater (EG&G, 1995b).

The seepage velocity (vertical transport rate) into the LHSU was calculated using the average vertical hydraulic conductivity, a uniform hydraulic gradient of one, and an average effective porosity of 0.10. The estimated seepage velocity, 5.83×10^{-7} cm/sec, represents the advective transport rate of a non-reactive contaminant. However, seepage rates may also be enhanced locally by fracture flow. Open, continuous fractures have been observed in unweathered bedrock at depths as great as 60 feet below the top of bedrock (EG&G, 1995a and 1995b). The fracture surfaces are stained with iron-oxides that may have been precipitated from groundwater during downward flow. Secondary permeability introduced by interconnected fractures may increase permeability and, thereby, locally enhance the hydraulic interactions between the two hydrostratigraphic units. Secondary permeability has only been qualitatively described, however (EG&G, 1995b), and the effects of secondary permeability on the degree of interaction between the UHSU and LHSU are not known at this time.

5. Groundwater Geochemistry

Groundwater chemistry at the Rocky Flats site has been described in numerous previous reports, including the following:

- Final Well Evaluation Report (EG&G, 1994c)
- 1993 Groundwater Geochemistry Report (EG&G, 1993e)
- Site-Wide Groundwater Flow Modeling at the Rocky Flats Site (EG&G, 1993g)
- Background Geochemical Characterization Report (EG&G, 1993f)
- Final Phase III RFI/RI Report: 881 Hillside Area (Operable Unit No. 1) (DOE, 1993a)
- Draft Phase II RFI/RI Report: 903 Pad, Mound, and East Trenches (Operable Unit No. 2) (EG&G, 1993d)
- Draft Final Phase I RFI/RI Report: Solar Evaporation Ponds (Operable Unit No. 4). (EG&G, 1994b)
- Final Technical Memorandum, Revised Work Plan, Present Landfill and Inactive Hazardous Waste Storage Area (Operable Unit No. 7) (DOE, 1994a)
- 1991, 1992, and 1993 Annual RCRA Groundwater Monitoring Reports for Regulated Units at Rocky Flats Plant (EG&G, 1992b, 1993h, and 1994c)

Each of these documents provides data that describe groundwater chemistry. However, none of the existing reports describes the nature of sitewide variations in groundwater chemistry or provides a comprehensive synthesis of geochemical data for UHSU and LHSU groundwater. The Groundwater Geochemistry Report (Volume III of the Sitewide Characterization Study) evaluated more than 350,000 records of chemical data for samples collected from 1990 through the first quarter of 1994. Data quality and usability were also evaluated; results of this evaluation are presented in Appendix A. The locations of the 532 wells (some of which have since been abandoned or removed from the sampling schedule) are shown on Plate 1.

Analysis of chemical data retrieved from the Rocky Flats Environmental Database System (RFEDS) followed the general data-analysis protocols summarized in an EG&G Interoffice Correspondence (EG&G, 1994d). Data rejected (validation code = "R") by the independent, third-party validation subcontractor were excluded from the working data set. All QC data (rinsates, lab blanks, etc.) were also set aside from the

working data set for a separate evaluation (see Appendix A). Tables of sitewide summary statistics for each analyte provide a general overview of the range of chemical concentrations at the site (see Appendices B and C).

The remainder of this section presents a brief discussion of groundwater sampling as it pertains to dissolved metals, descriptive chemical diagrams (Stiff, Piper, and ion-variation diagrams), a discussion of probable flow paths for UHSU groundwater at the Rocky Flats site, and an analysis of the variations in the composition of Rocky Flats groundwaters along those flow paths. Man-made organic compounds cannot be modeled as part of water/rock interactions; consequently, these organic chemicals were not evaluated in detail for this report but are summarized in Appendix C. However, the working data set includes records for both organic and inorganic analytes, and these data are available upon request.

5.1 Evaluation of Data for Total and Dissolved Constituents in Groundwater

Collecting a sample that is representative of groundwater chemistry is the first, and most important, step toward understanding the chemical dynamics of a groundwater system. As noted by Hem (1992), "...the accuracy of the data obtained depends critically on the care used in sample collection, pretreatment, and preservation. If proper care is not taken to avoid sample contamination or loss of the minor constituents during manipulation, misleading results will be obtained."

Geochemical modeling and the analysis of water/rock interactions for a groundwater rely on data for dissolved constituents because the chemistry of a groundwater is generally defined by the dissolved constituents it contains and transports. Data for unfiltered ("total") metals and radionuclides cannot be meaningfully modeled, because such data generally describe the chemistry of suspended particulates, not the chemistry of the solution.

Dissolved constituents are operationally defined by their passage through a 0.45-micron membrane filter. In contrast, an unfiltered sample contains suspended particulates such as clay-size particles of sediment derived from the surrounding geologic units or amorphous iron-oxyhydroxide precipitates and their coprecipitates. When the unfiltered sample is acidified for preservation, the solubility of metals is greatly increased, and the particulates may partially or completely dissolve in the low pH (pH = 1.5) solution. This dissolution results in a solution that may contain relatively high concentrations of metals. In particular, concentrations of those metals that compose common rock-forming minerals — such as the family of aluminosilicate minerals — may be drastically elevated above those in the corresponding filtered sample.

Typically, the concentration of "total" metals and "total" radionuclides will be correlated with the amount of total suspended solids (TSS) measured in the unfiltered,

unacidified sample collected for analysis of water-quality parameters. This type of correlation, quantified by linear regression analysis, is exemplified by the results for well 41691 (Figures 5-1 and 5-2). Because well 41691 underwent several episodes of redevelopment and repeated sampling over a short period of time (i.e., first quarter of 1994), these data were used for correlation of total metals and total radionuclides with TSS. Use of these data was based on the premise that samples were collected in a consistent manner over a short period of time, thus providing a better opportunity to look at one isolated variable, TSS, and its correlation with total metals and radionuclides. High values (0.8 to 1.0) of the correlation coefficient indicate a strong correlation between the two parameters. In this case, the strong correlation translates to a high probability that the metals are contained in the suspended sediments rather than in the solution.

5.2 Description of Groundwater from the Upper and Lower Hydrostratigraphic Units

A variety of graphical presentations may be used to illustrate the chemistry of groundwater, from simple variation diagrams and time-series plots to Stiff (1951), Piper (1944), and Schoeller (1935) diagrams (see Hem, 1992 for more detail). These diagrams offer a means for visual, qualitative assessment of groundwater chemistry. Graphical methods employed in this report include Stiff, Piper, and ion-variation diagrams and time-series plots. The plotted concentrations of major cations and other metals were obtained from filtered samples (dissolved fraction) and the concentrations of major anions from unfiltered samples (see discussion in Section 5.1). Unlike metals, anion-forming elements (e.g., chlorine, sulfur, nitrogen, etc.) in dilute solutions are present predominantly as dissolved ions (Hem, 1992).

5.2.1 Stiff Diagrams

Stiff diagrams for 370 wells are presented in Appendix D. Each diagram was plotted from a representative sample collected from each well between 1990 and the first quarter of 1994. For each well, a representative sample was identified through visual examination and comparison of diagrams plotted from each available sample. Previous investigations have demonstrated that the major-ion contents of groundwater show no seasonal variation (EG&G, 1993f). Therefore, a single representative sample is used to describe the groundwater composition at each location. Samples with compositions of major ions that were visibly out of balance with respect to cation/anion equivalents were not included.

Stiff diagrams depict the major-ion chemistry of a water by displaying the relative proportions of selected ions in units of milliequivalents per liter (meq/L). The shape of a Stiff diagram is determined by the concentrations and relative proportions of four major cations (calcium, magnesium, potassium, and sodium) and four important anions

(bicarbonate, carbonate, sulfate, and chloride). The shape of the Stiff diagram conveys useful information on the general chemical character of the water and is particularly useful as a pattern-recognition tool. The relative size of a Stiff diagram is meaningful in that it is proportional to the concentration of total dissolved solids (TDS). The higher the TDS content of the water, the larger the area of the diagram (providing that the scale of display remains constant and the bulk of the TDS is represented by the major ions plotted).

Because an aqueous solution is electrically neutral (charge balanced), with the sum of the cations (in meq/L) equal to the sum of the anions, any deviations from neutrality indicate an incomplete or inaccurate chemical analysis. A slight inequality on the Stiff diagram (<10% charge imbalance) is typical, however, and may denote the presence of ions in the water that are not included on the Stiff diagram. Waters containing high concentrations of ions not plotted on the Stiff diagram, such as nitrate, may have visibly unbalanced Stiff diagrams.

Stiff diagrams of UHSU groundwater are generally distinctly different from those of LHSU groundwater (Figures 5-3 and 5-4). Figure 5-3 shows UHSU groundwater from five wells: B401989, screened in colluvium; B302789, valley-fill alluvium; B110889 and B200889, Rocky Flats Alluvium; and B405489, weathered bedrock. Groundwater from the various deposits of the UHSU shows similar shapes of Stiff diagrams and can be generally described as a "calcium-bicarbonate water" (the dominant type of UHSU groundwater). Stiff diagrams of UHSU groundwater from potentially contaminated areas may reflect major-ion concentrations distinct from the typical character, as discussed below in Section 5.4.

Figure 5-4 presents Stiff diagrams for LHSU groundwater from five wells: 23193, screened in an interval of sandstone, silty sandstone, and clayey sandstone; 0886, sandy siltstone; 0387, sandy siltstone and clayey siltstone; 2386, siltstone and silty claystone; and 0887, silty claystone and claystone. The LHSU groundwater ranges from calcium-bicarbonate (well 23193) to sodium-bicarbonate (0886), sodium-bicarbonate/chloride (0387), sodium-chloride/sulfate (2386), and sodium-sulfate (0887) waters. The LHSU groundwater generally has a sodium-bicarbonate to sodium-sulfate character (EG&G, 1993f). The groundwater from well 23193 is not chemically distinguishable from UHSU groundwater. This well is screened across an interval of sandstone that may be more permeable than other lithostratigraphic units comprising the LHSU. The composition of LHSU groundwater in sandstone sub-units and its similarity to UHSU groundwater may be the result of a relatively higher degree of hydraulic communication between LHSU sandstones and the UHSU. The degree of hydraulic communication between the hydrostratigraphic units is discussed in detail in the Hydrogeologic Characterization Report (EG&G, 1995b).

5.2.2 Piper Diagrams

Piper diagrams were prepared for a series of wells located along groundwater flow paths in the UHSU and for selected LHSU wells (Figures 5-5 through 5-6). For each of the well locations included, the same representative analysis is plotted on the Piper diagram as was previously used to plot the Stiff diagram.

Piper diagrams are trilinear-style diagrams and focus on essentially the same major ions as Stiff diagrams (i.e., calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulfate, and chloride). For each sample, three points are plotted on the Piper diagram; one point representing the relative abundances of the cations is plotted on the cation triangle, one representing the relative abundances of the anions is plotted on the anion triangle, and the third point representing the relative proportions of all the major ions is plotted from the triangles and projected onto the central diagram (see Figure 5-5). Piper diagrams are useful for evaluating the evolution of water chemistry or identifying waters of distinctly different chemistry. Mixing between waters of distinct compositions can also be identified.

Two Piper diagrams, presented in Figures 5-5 and 5-6, show the chemical distinctions between UHSU and LHSU groundwater. Figure 5-5 displays the compositions of UHSU and LHSU groundwater from the Rock Creek area, and Figure 5-6 shows the compositions of UHSU and LHSU groundwater from the Industrial Area. The Rock Creek area was selected because groundwater from the area is considered unaffected by production and waste-handling activities on the Rocky Flats site (EG&G, 1993f). In contrast, the major-ion chemistry of groundwater from the Industrial Area may show the effects of contaminant releases to the subsurface. As discussed in Section 5.2.1, groundwater from the Industrial Area is more chemically variable than groundwater from unaffected areas on the site.

The Piper diagram for Rock Creek shows a tightly grouped set of analyses in the anion portion of the diagram. The cation portion of the diagram shows a difference between UHSU and LHSU groundwater. The LHSU groundwater is enriched in sodium relative to the other cations and has more variable cation abundances than groundwater from the UHSU. The same distinction between LHSU and UHSU groundwater is evident on Figure 5-6. In the Industrial Area, groundwater from both units is more compositionally diverse than in the Rock Creek area, but LHSU groundwater is consistently more sodium rich than UHSU groundwater. The anion contents of groundwater from the two units are not distinguishable.

The Piper diagram for UHSU and LHSU groundwater in the Industrial Area (Figure 5-6) shows water compositions of widely varying character. The variations displayed by the data from UHSU wells may reflect natural variability or compositional changes

resulting from contamination of groundwater related to activities within the Industrial Area. Scatter among the LHSU data is probably the result of natural variations in chemistry.

5.2.3 Ion-Variation Diagrams

Ion-variation diagrams display concentrations of selected ions over time or distance, or show the correlation between two or more ions. Where data for selected constituents are displayed over a range of sampling dates, the diagram is commonly referred to as a "time-series plot." Such plots depict the temporal variation in groundwater chemistry at a given location. Concentration variations at one location over time may result from seasonal fluctuations or from external inputs to the groundwater, such as the migration of contamination from another location. Contamination to groundwater may result from the downward migration of contaminants from sources at or near the ground surface or from the downgradient migration of a contaminant plume from an upgradient source.

Concentrations of dissolved major and trace ions were plotted on time-series plots (see Appendix E) for 36 UHSU wells along the four defined flow paths (Rock Creek, Industrial Area, Woman Creek, and Southern flow paths). Non-detect values were replaced with a value of 0.5 times the reported detection limit, but are otherwise not distinguished on the plots.

Four plots are shown for each of the 36 well locations (Appendix E): one plot shows trace metals (Fe, Al, Mn, and Zn); one plot shows TDS, SiO_2, and major anions (HCO_3 as $CaCO_3$, Cl, SO_4, and NO_3); one plot shows the four major cations (Ca, Mg, Na, and K); and one plot depicts the covariation of two alkaline-earth elements (Ba and Sr) and of two redox-sensitive elements that form oxyanions (V and Se).

For the major cations, the time-series plots illustrate only minor variation in concentrations. Calcium generally has the highest concentrations, whereas potassium generally has the lowest concentrations of these four cations in the UHSU wells. The concentrations of trace metals generally show good covariation (e.g., samples with higher concentrations of iron also show higher concentrations of manganese for that given sampling event; see graph for well B400489). Some of the variability seen in the water-quality parameters may be the result of transcription or data-entry errors, because (as seen for well B400389) it is not physically possible to have a TDS concentration less than the concentration of any one ion. The alkaline-earth metals strontium and barium show some degree of covariation in their concentrations (see plot for well B302989). Selenium and vanadium are commonly below detection limits and have multiple detection limits, so the variation in concentration illustrated for these two elements is of debatable origin.

5.2.4 Results of Graphical Analyses

Both the Stiff and Piper diagrams show that groundwater samples from the different lithostratigraphic units of the UHSU are generally not distinguishable from one another on the basis of their major-ion chemistry. That is, groundwater from the Rocky Flats Alluvium, valley-fill alluvium, colluvium, and weathered bedrock is similar in composition, as a dominantly calcium-bicarbonate groundwater (see Figure 5-3). In contrast, groundwater of the LHSU ranges from a sodium-sulfate to a calcium-bicarbonate composition. Only within the Industrial Area, where groundwater composition is most likely to be affected by contamination, is the major-ion content of the UHSU groundwater as variable as that of the LHSU groundwater (Figure 5-6).

The major-ion chemistry of the UHSU and LHSU groundwater generally supports the current definition of the two hydrostratigraphic units. Hydrologic data, as discussed in Volume II of the Sitewide Characterization Study (EG&G, 1995b), provides additional evidence for limited hydraulic communication between most areas of the UHSU and LHSU.

5.3 Changes in Groundwater Chemistry Along a Flow Path

The chemistry of any groundwater is a reflection of the chemistry of the recharge water combined with the effects of water/rock interaction. As groundwater moves laterally through the rocks comprising a hydrostratigraphic unit, it acts as a reactive substance by dissolving minerals, exchanging ions, and interacting to form new minerals. As stated by Hem (1992), "solutes contained in natural water represent the net effect of a series of antecedent chemical reactions...." That is, the overall chemistry of groundwater evolves along the flow path as a direct result of water/rock interaction. Typically, this means that the concentrations of certain ions, as well as the TDS of water, will increase in a direction downgradient from the point of recharge. Additional inputs of recharge solutions of different chemical composition (i.e., mixing) or passage through contaminated materials will also impact the chemistry of a groundwater.

5.3.1 Selection of Wells Defining Probable Flow Paths in the Upper Hydrostratigraphic Unit

Wells along four probable flow paths were selected after a review of the potentiometric-surface contours for the UHSU (EG&G, 1995b and 1994e; see Figure 5-7). Selection of a flow path was made with the assumption that groundwater flow is perpendicular to the contours of the potentiometric surface. Sparse well coverage in some areas necessitated the inclusion of wells nearby, but not strictly along, such a flow path.

Flow paths were selected for the northern Buffer Zone (Rock Creek flow path), the southernmost part of the Buffer Zone (Southern flow path), along Woman Creek

(Woman Creek flow path), and through the center of the Industrial Area (Industrial Area flow path) (refer to Figure 5-7). The flow path through the Industrial Area is more problematic than the others because of the likely disruption of groundwater flow by buried structures and building footings. The impact of these features on the potentiometric surface has not yet been determined. From northernmost to southernmost, the flow paths are as follows:

Rock Creek Flow Path. The Rock Creek flow path begins near wells B111189, B110989, and B110889 near the West Spray Field (OU11). It continues north of the Present Landfill (OU7) to B200589, B200689, B200789; on to B200889; then toward B202589 or toward B201589, B201189, and B205589, near the intersection of Rock Creek and Highway 128.

Industrial Area Flow Path. The selection of wells defining a flow path through the Industrial Area relied on the detailed potentiometric-surface map from the Industrial Area IM/IRA Decision Document (DOE, 1994b). This flow path begins in the West Spray Field (OU11) at wells B411289 and B411389 and flows to B410789, P415889, and P415989, through the center of the Industrial Area past wells 4486, P115689, and 2187 south of the Solar Ponds (OU4). The path then leads down South Walnut Creek through the B-series ponds (OU6) to wells 3586, 3786, and 3886, finally reaching the boundary wells 0486 and 41691.

Woman Creek Flow Path. The Woman Creek flow path is perhaps the least well constrained; lack of data for many of the wells (i.e., dry wells) reduced the number of wells that could be used for modeling. The Woman Creek flow path begins at well B400189 northeast of Rocky Flats Lake; continues to B400289; then to 6886 south of the 881 Hillside (OU1); to 38591, 6486, and 6586; past Pond C-2 to well 6686; and on to the boundary wells 0186 and 41491.

Southern Flow Path. The Southern flow path begins in the south Buffer Zone at well B400389 just east of Rocky Flats Lake. It continues to wells B405789 and B400489, toward B302789, on to B302889 and B302989 north of the D-series ponds, and finally to boundary wells 0186 and 41491.

5.3.2 Changes in Groundwater Chemistry Along Four Flow Paths

The changes in groundwater chemistry along a flow path can be examined quantitatively by geochemical modeling; the results of such modeling are presented in Section 8 of this report. Qualitatively, however, compositional changes can be illustrated and evaluated by use of the graphical methods described in Section 5.2; discussions of these are given in the following paragraphs.

Groundwater along the Rock Creek flow path is considered to be largely unaffected by plant activities and clearly shows the effects of water/rock interaction. The concentrations of major cations (Ca, Mg, Na, and K) and TDS increase gradually in the downgradient direction (Figure 5-8). From start to finish (approximately 2.5 miles), the concentrations of many major ions increase by approximately one order of magnitude (Figure 5-8). For dissolved uranium isotopes, a similar downgradient increase is also seen (Figure 5-16). Groundwater at the head of the Rock Creek flow path (well B111189) contains uranium at much lower activities (<2 pCi/L for uranium-238) than does groundwater sampled at the end of the flow path (>80 pCi/L for uranium-238 in well B205589), yet the ratio of uranium-233,234 to uranium-238 remains essentially constant all along the flow path. The ratio varies between slightly more than one to slightly more than two.

The significance of the uranium-233,234 to uranium-238 ratio is discussed in detail in the Background Geochemical Characterization Report (EG&G, 1993f). To summarize briefly, naturally occurring uranium should have a uranium-233,234 to uranium-238 activity ratio of approximately 1.06, with a range of approximately one to three in natural waters. In contrast, the ratios of the relative activities of uranium-233,234 to uranium-238 are approximately 0.09 for depleted uranium, 5.74 for power-reactor fuel, and higher for weapons-grade uranium (EG&G, 1993f).

If the general trends in groundwater chemistry along the Rock Creek flow path are compared with those for the Industrial Area flow path (approximately 3.6 miles in length), the magnitude of the overall increases in concentrations is seen to be comparable (about one order of magnitude increase in elemental concentrations from the initial to final wells). Even though the groundwater within the central Industrial Area shows increases in the concentrations of some major ions for some wells (possible contamination), groundwater at the terminus of the Industrial Area flow path shows only equal or less of an increase than that seen over a shorter distance for background groundwater along the Rock Creek flow path (Figures 5-8, 5-10, and 5-12).

A pattern similar to that for major ions is seen for dissolved uranium isotopes in groundwater from the Industrial Area flow path (Figure 5-16); the activities of all uranium isotopes are variable, but less than the highest background values. Additionally, the isotopic ratio of uranium-233,234 to uranium-238 remains essentially constant throughout the entire flow path (see Figure 5-16), ranging from slightly less than one to about two.

Major-ion concentrations and uranium activities show a similar upgradient-to-downgradient increase in the Woman Creek and Southern flow paths (Figures 5-9, 5-11, 5-13, 5-15, and 5-17). In the groundwater of Woman Creek, the impact of plant activities is suggested in wells 38591, 6486, and 6586. However, the trend in

groundwater chemistry — comparing initial wells to final wells — again approximates that seen for groundwater along the unaffected Rock Creek flow path. As with the Industrial Area flow path, the ratios for uranium isotopes remain essentially constant in groundwater along the Woman Creek and Southern flow paths.

Comparison of the Stiff diagrams for the mean composition of groundwater at each well along each of the four flow paths shows a clear increase in TDS and constituents for the Rock Creek path and more irregular increases in TDS and other constituents for the other three flow paths (Plate 2). Ignoring for a moment the Southern flow path, the TDS concentrations of the initial wells for Rock Creek, Industrial Area, and Woman Creek are approximately equivalent at 144, 138, and 140 mg/L, respectively. The TDS concentrations in the final wells range from 455 mg/L for the Industrial Area to 1160 mg/L for the Rock Creek path. For the Southern path, mean TDS is 331 mg/L in the initial well and approximately 500 mg/L in the final well.

TDS shows the highest variability within and immediately downgradient of the Industrial Area (Figure 5-8 and Plate 2). The major-ion composition of UHSU groundwater also undergoes a change in this portion of the Industrial Area. Groundwater changes from a calcium-bicarbonate water within the Industrial Area (well P115689) to a mixed sodium-bicarbonate/sodium-sulfate water along South Walnut Creek (wells 3586 and 3786). At the end of the Industrial Area flow path (wells 0486 and 4169) the groundwater is again a calcium-bicarbonate water. Therefore, the observed major-ion variations have a limited extent and probably reflect inputs from contaminant sources in the Industrial Area or along Walnut Creek (OU6).

The Piper diagram depicting the major-ion chemistry for each well along the four flow paths (see Figure 5-18) shows that wells along the Rock Creek path exhibit the least amount of variability in the relative proportions of major ions (i.e., exhibit the tightest clustering of points of all four paths shown on the diagram). Conversely, wells along the Industrial Area path exhibit the greatest amount of variability in the relative proportions of major ions. Whereas bicarbonate is the dominant ion in groundwater along the Rock Creek and Southern flow paths, groundwater along the Woman Creek and Industrial Area paths shows local increases in the relative proportions of chloride and sulfate. Such changes to the chemistry of groundwater along the Woman Creek and Industrial Area flow paths may be indicative of groundwater affected by recharge sources of possible contamination on the plant site.

5.4 Major-Ion Variations in Groundwater from the Operable Units

Stiff diagrams of UHSU groundwater from OUs 1, 2, 4, 5, 6, 7, and 11 (refer to Figure 2-2 for OU locations) are presented for wells representing both unconsolidated surficial deposits and UHSU bedrock (see Plate 2 and Figures 5-19 through 5-25). The Stiff

diagrams for the groundwater from these areas are much more variable and generally more complex than the diagrams for UHSU groundwater in other areas of the site.

At OU4, the UHSU groundwater has high TDS concentrations, most notably in the immediate vicinity of the Solar Evaporation Ponds and the portion of North Walnut Creek located north of the Solar Evaporation Ponds. Several of the Stiff diagrams for OU4 groundwater are not balanced with respect to the abundances of cations and anions. Nitrate was added to the anion species plotted, but the diagrams remain unbalanced. Random charge imbalances may reflect analytical or reporting errors in the concentrations of cations and anions. However, the analyses of groundwater samples from a number of locations within OU4 are consistently unbalanced and may indicate the presence of negatively charged species not measured and accounted for by routine water analyses.

Leakage of process water and wastewater concentrated by evaporation from the ponds provided a source of chemically distinct water to groundwater in the OU4 area. Concentrated water is easily distinguished from the natural recharge waters by its high TDS and major-ion contents. The chemical variations observed in groundwater from OU4 are consistent with those expected from leakage from the ponds.

At OU4 groundwater in the immediate vicinity of the Solar Evaporation Ponds is most affected by sources of contamination. The major-ion content of groundwater from areas upgradient of the ponds (wells 2286 and P207489) is the same as in groundwater farther downgradient of the ponds (wells 1386 and P208089). Thus, chemically distinct sources of recharge to groundwater in OU4 appear to have only local effects on groundwater chemistry in the UHSU.

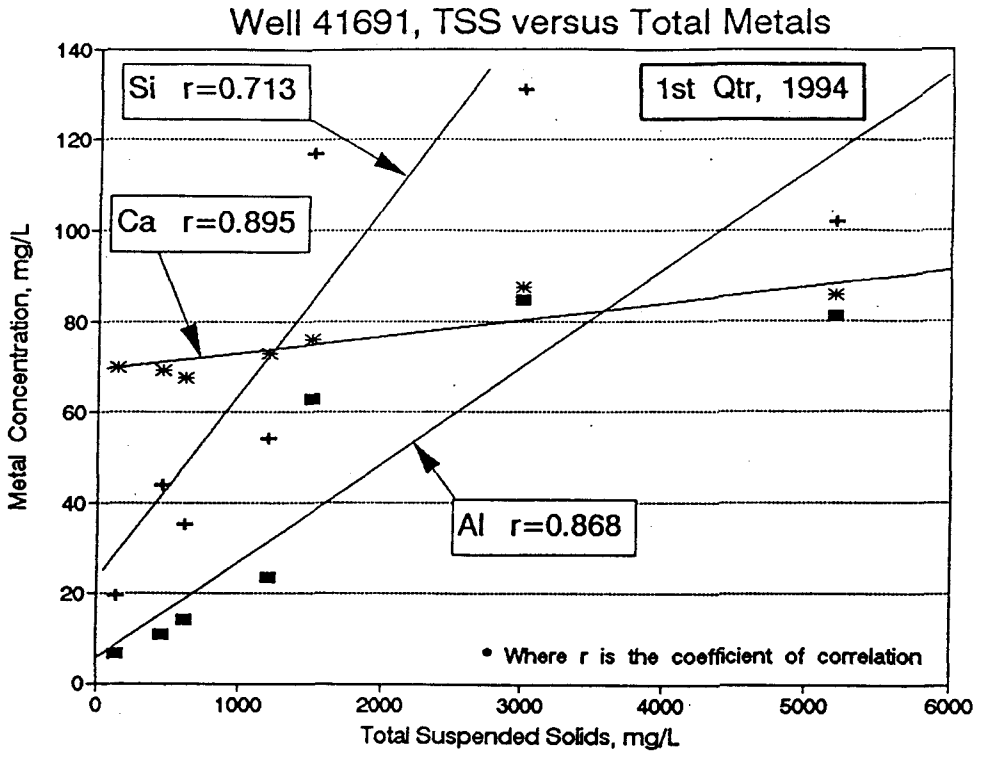
At OUs 1 and 2 (Figures 5-19 and 5-20), UHSU groundwater has significantly lower TDS concentrations and less variable major-ion contents than does UHSU groundwater from OU4. No sources of concentrated water similar to that leaked from the Solar Evaporation Ponds were present in these areas. Therefore, the major-ion chemistry of the groundwater is probably not a good indicator of contamination at either OU1 or OU2.

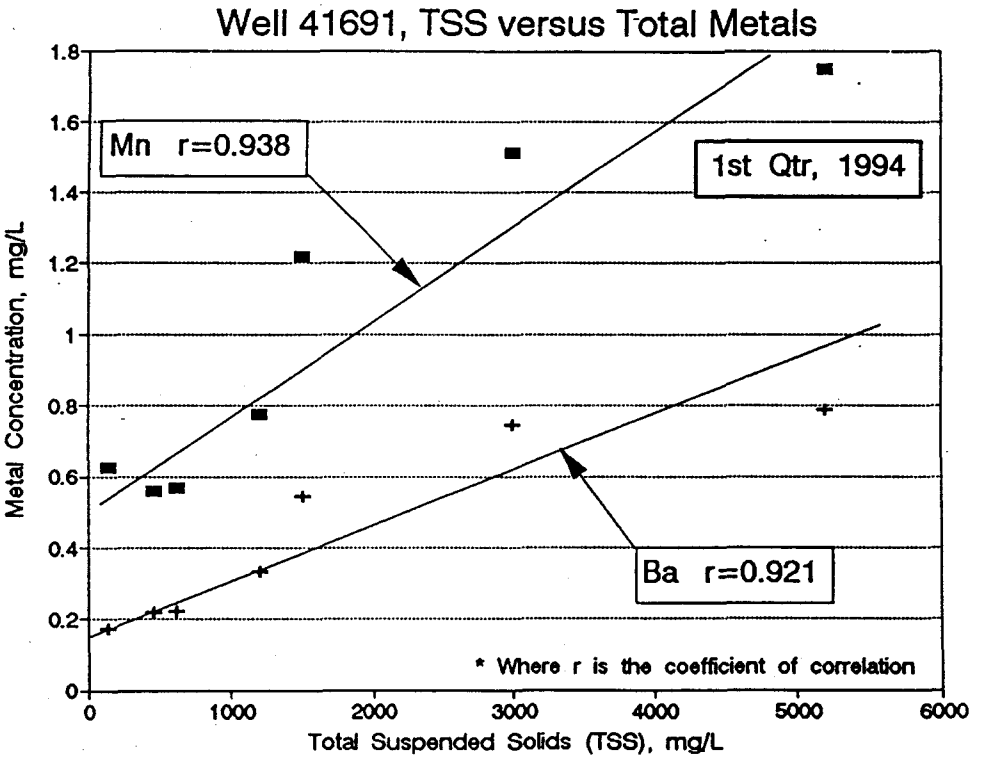
At OU7, the chemistry of groundwater as depicted on the Stiff diagrams is also variable. In addition, the major-ion chemistry of groundwater from within the landfill is distinct from groundwater outside the landfill. Within the landfill, the major-ion concentrations are higher than groundwater sampled upgradient of OU7. Groundwater collected downgradient of (east of) the East Landfill Pond in No Name Gulch is also distinct from the upgradient groundwater.

UHSU groundwater from OU11 is dilute and much less variable in composition compared to groundwater from the other OUs. In UHSU groundwater, TDS concentrations gradually increase in the direction of groundwater flow (i.e., generally from west to east). The area upgradient of OU11 is the starting point for the Rock Creek and Industrial Area flow paths. The pattern of increasing TDS in the downgradient direction was also observed along these two flow paths (Section 5.3.2). The same processes that lead to variations in the major-ion chemistry of groundwater along the Rock Creek flow path may also be responsible for the variations observed within OU11.

Piper diagrams displaying the compositions of UHSU groundwater from the OUs (1, 2, 4, 7, and 11 in Figures 5-26 and 5-27) show significantly wider variations in groundwater chemistry than do diagrams for groundwater from areas of the site thought to be unaffected by past activities at the plant (i.e., Rock Creek flow path in Figure 5-18). These variations are especially evident on the Piper diagram of OU4 and OU7 groundwater (Figure 5-27), which shows a much wider diversity of compositions than the does the diagram of groundwater from the Rock Creek flow path.

Comparison of the types of chemical variations observed in the OUs to the variations observed along sitewide flow paths reveals chemical variability on two distinct scales. The first type of variation occurs across large areas (i.e., the distance across the site). The large-scale variation typically includes increasing TDS and major-ion concentrations in the direction of groundwater flow. The second type of variation occurs within OUs or along portions of the flow paths. This smaller-scale variation reflects input from contaminant sources. The internal variations in groundwater chemistry at each of the OUs is slightly different and reflects the types of contaminant sources present.





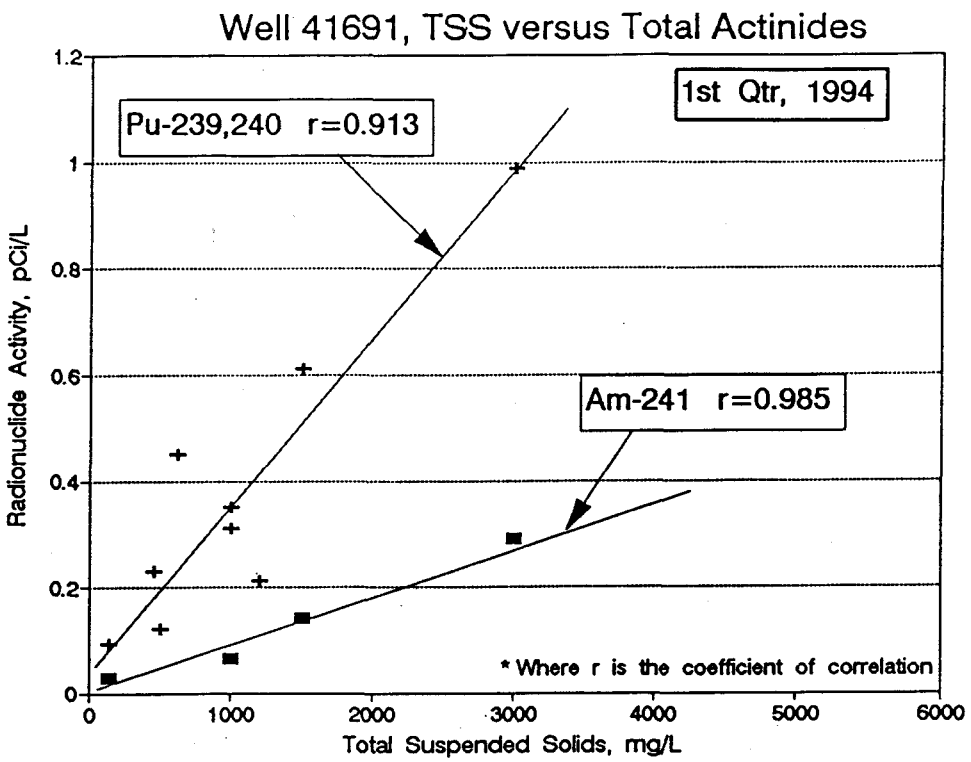
EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado

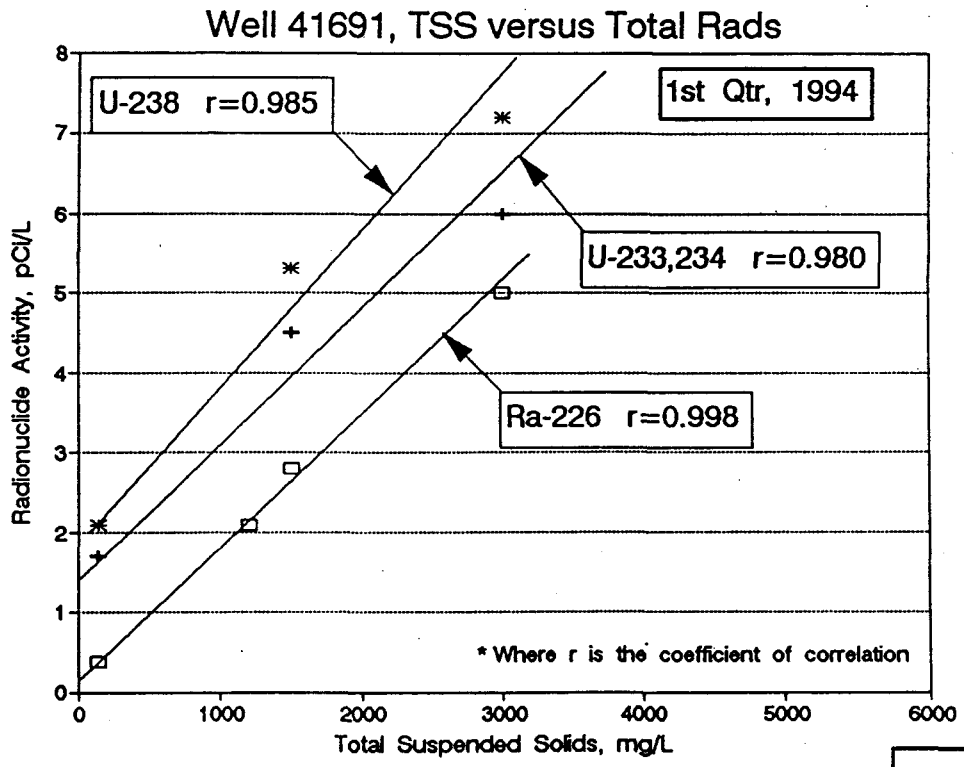
Correlation of TSS with Total Metals in Groundwater

Groundwater Geochemistry Report

Date: January 1995 | Figure 5-1

M\ES\Geochemistry title blocks.impt\11-1-94





EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado

Correlation of TSS with Total Radionuclides in Groundwater

Groundwater Geochemistry Report

Date: January 1995	Figure 5-2

M\ES\Geochemistry title blocks.impt\11-1-94

EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado

Stiff Diagrams of Selected UHSU Groundwaters

Groundwater Geochemistry Report

Date: January 1995 | Figure 5-3

Plotted Values (mg/L)

Well B401989 - Colluvium

1.26	0.51
3.92	4.40
1.00	0.81
0.00	0.33

Well B302789 - Valley - Fill Alluvium

1.41	0.68
3.99	4.60
1.22	0.42
0.00	0.33

Well B110889 - Rocky Flats Alluvium

0.58	0.25
1.52	2.00
0.54	0.21
0.00	0.03

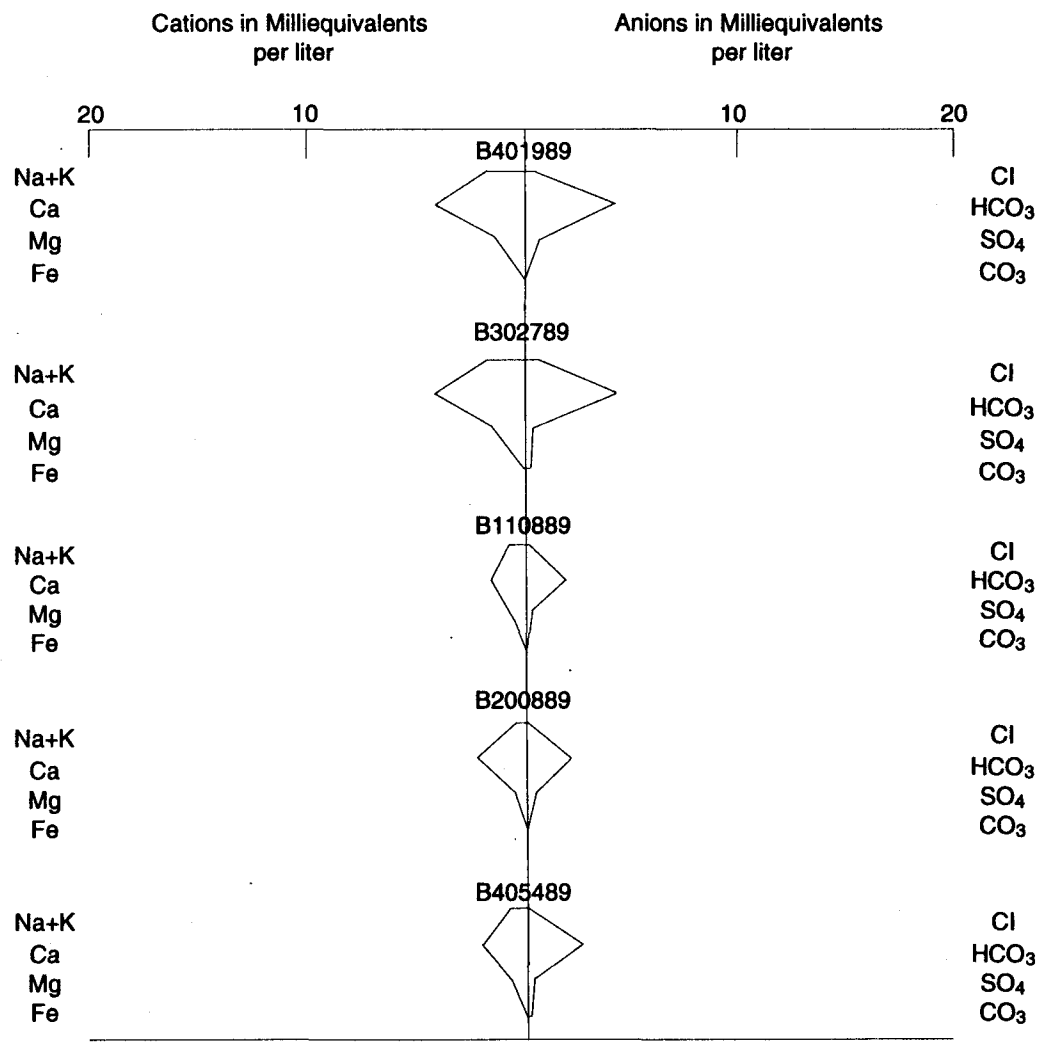
Well B200889 - Rocky Flats Alluvium

0.37	0.11
2.27	2.20
0.50	0.48
0.00	0.03

Well B405489 -Weathered Bedrock

0.75	0.08
2.01	2.60
0.63	0.46
0.00	0.20

Plotted Values Converted from mg/L to meq/L



HC-GRAM 2.1 9

M\ES\Stiff Diagrams.impt/11-1-94

EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado

Stiff Diagrams of Selected LHSU Groundwaters

Groundwater Geochemistry Report

Date: January 1995 | Figure 5-4

Plotted Values (mg/L)

Well 23193 - Sandstones

1.64	0.08
2.97	4.40
0.88	0.50
0.00	0.03

Well 0886 - Sandy Siltstone

3.28	0.48
0.65	3.80
0.41	0.77
0.00	0.43

Well 0387 - Sandy to Clayey Siltstone

5.28	2.82
1.32	4.60
0.62	0.08
0.00	0.03

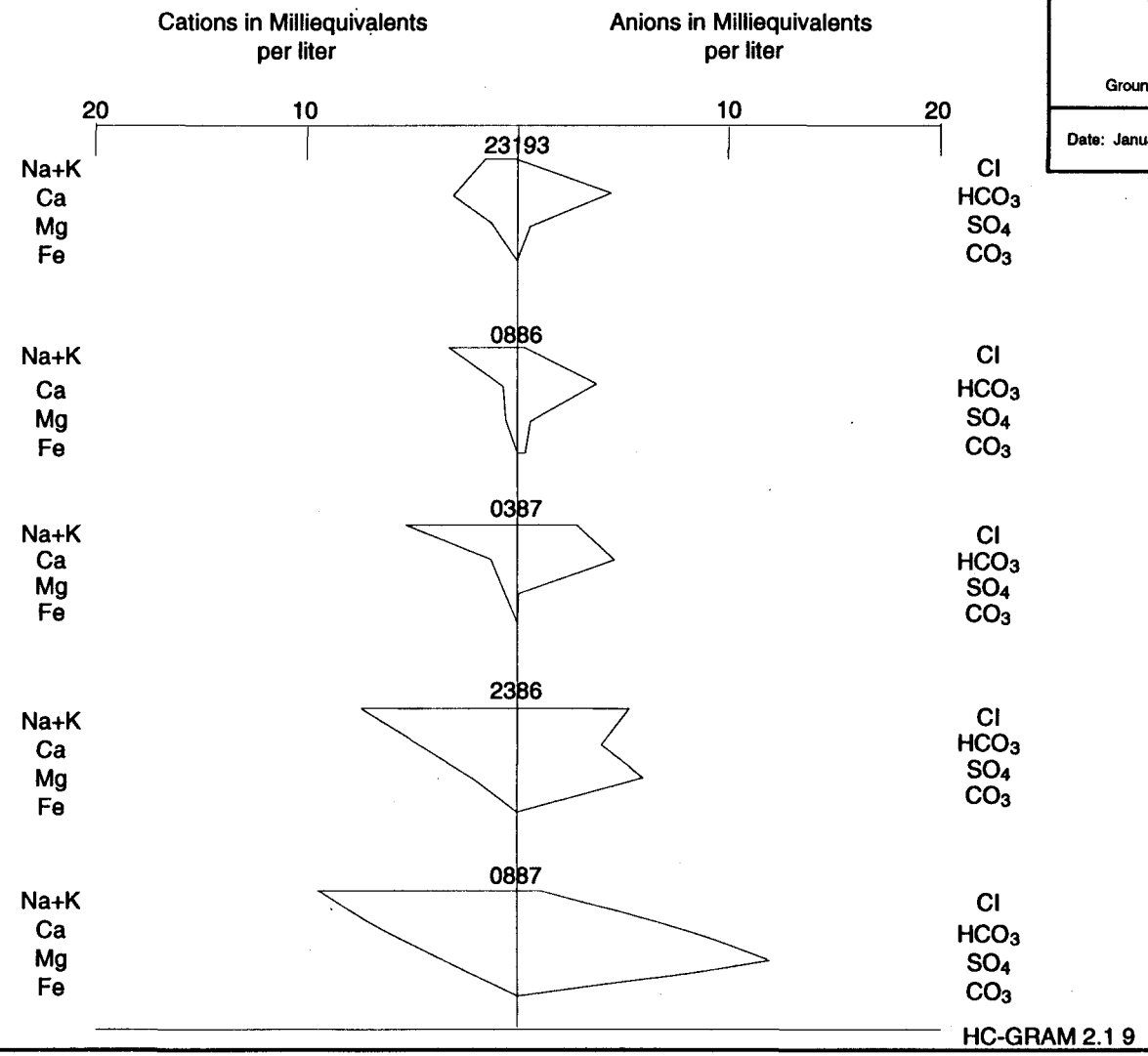
Well 2386 - Siltstone to Claystone

7.55	5.36
4.70	4.00
2.15	6.04
0.02	0.17

Well 0887 - Claystone

9.53	1.27
6.79	7.60
3.49	12.28
0.00	0.03

Plotted Values Converted from mg/L to meq/L



M\ES\Stiff Diagrams.impt/11-1-94

EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado

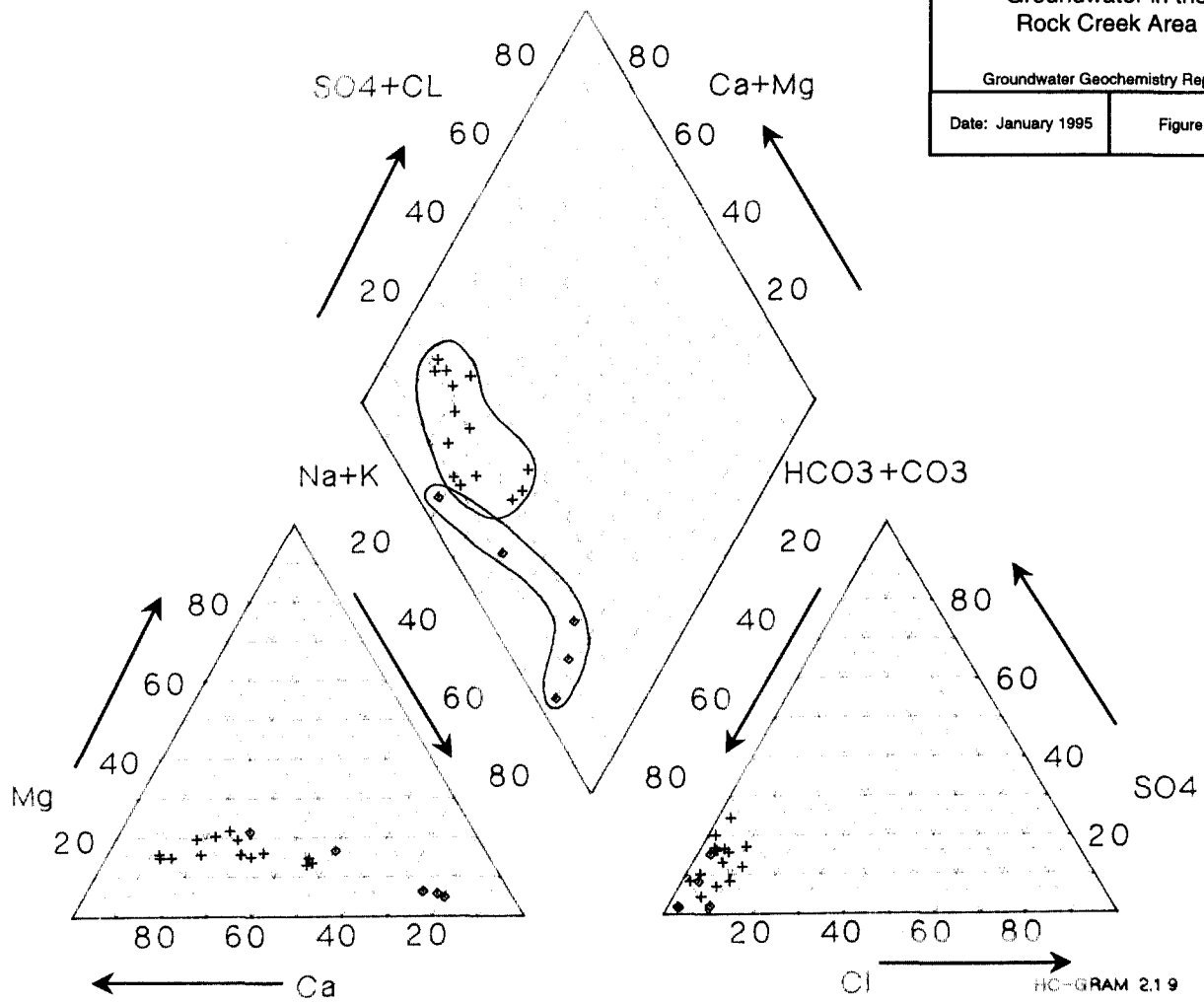
Piper Diagram for UHSU and LHSU Groundwater in the Rock Creek Area

Groundwater Geochemistry Report

Date: January 1995 | Figure 5-5

+ UHSU Wells
46192
4786
B110889
B110989
B111189
0290
B200589
B200689
B200789
B200889
B201189
B201589
B205589
B202589

◇ LHSU Wells
4686
4886
B203789
B203889
B203989



NOTE: Dissolved concentrations or activities are plotted

M\ES\Gdwater flow Paths.impt\11-1-94

EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado

Piper Diagram for UHSU and LHSU Groundwater in the Industrial Area

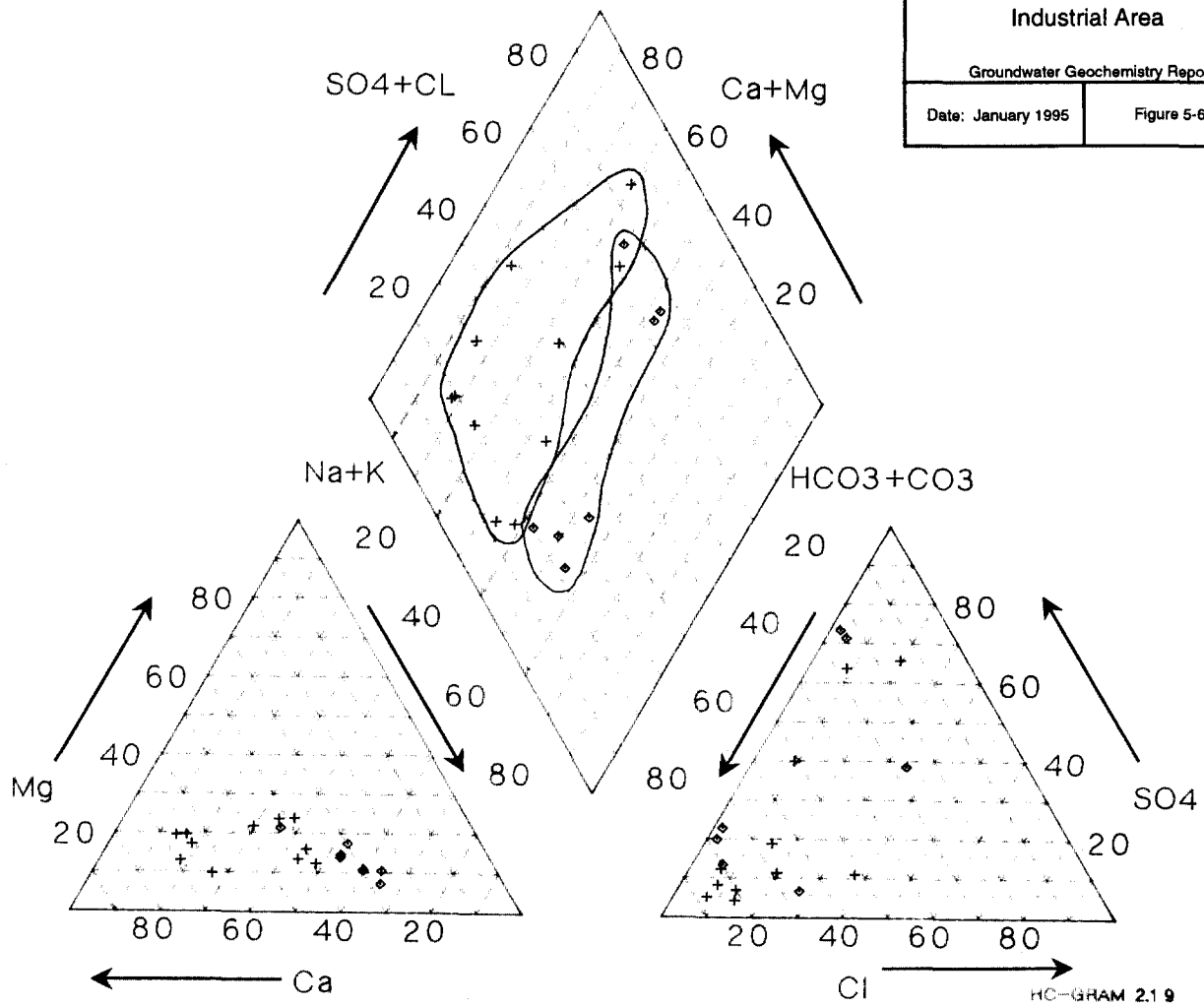
Groundwater Geochemistry Report

Date: January 1995 | Figure 5-6

+ UHSU Wells

B411289
B411389
B410789
P415889
P415989
4486
P115689
2187
3586
3786
3886

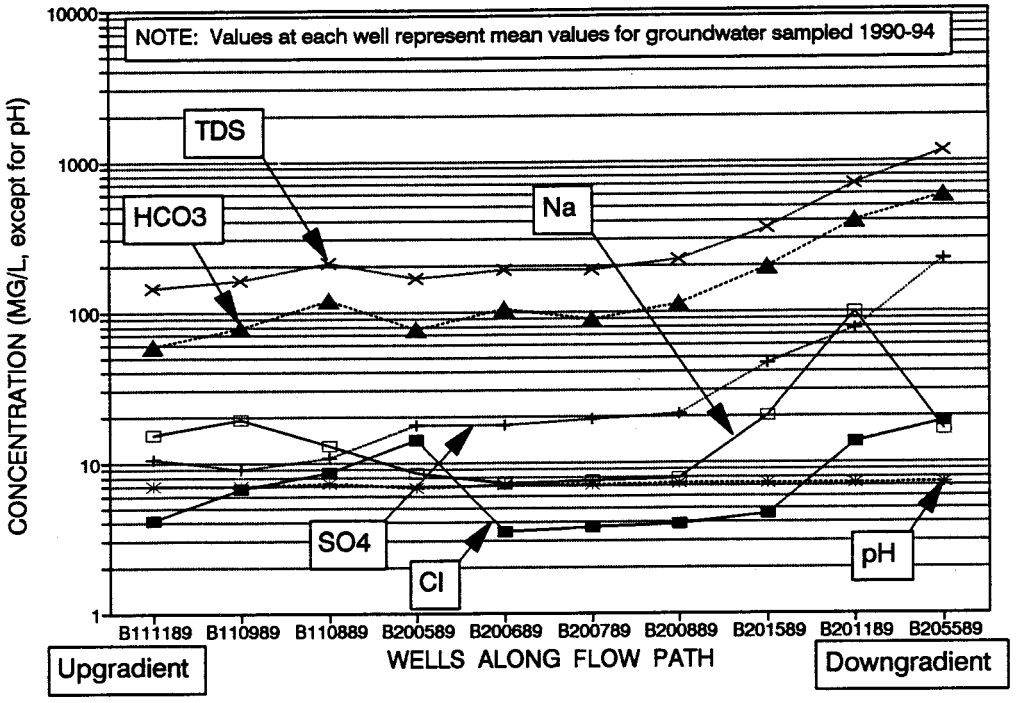
◇ LHSU Wells



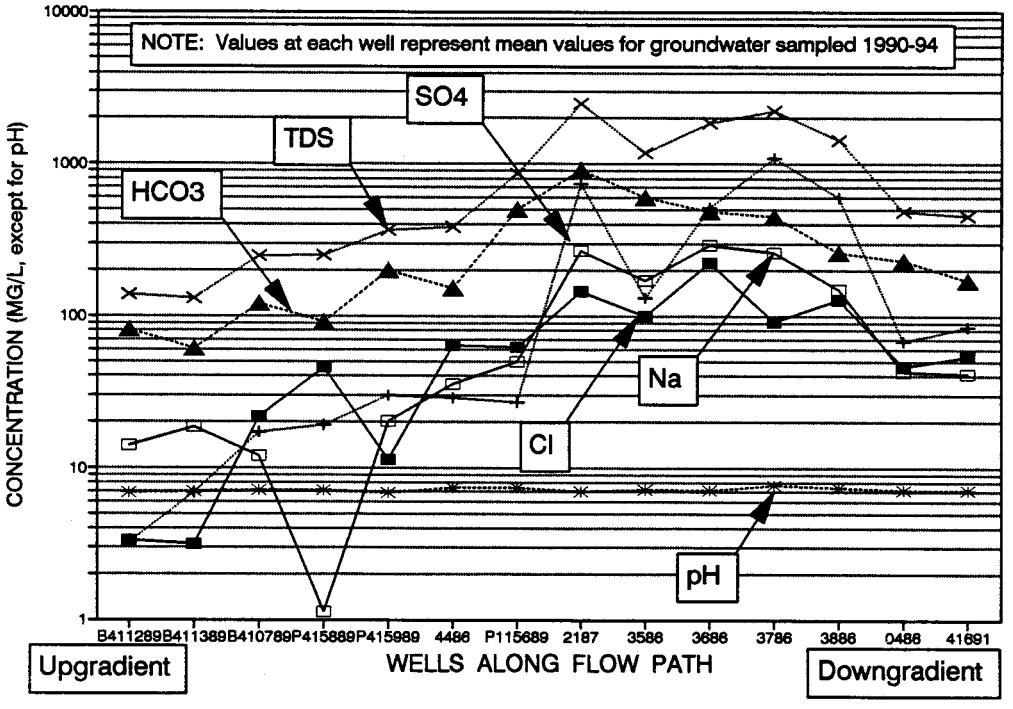
NOTE: Dissolved concentrations or activities are plotted

M:\ES\Gdwater flow Paths.impt\11-1-94

ROCK CREEK FLOW PATH



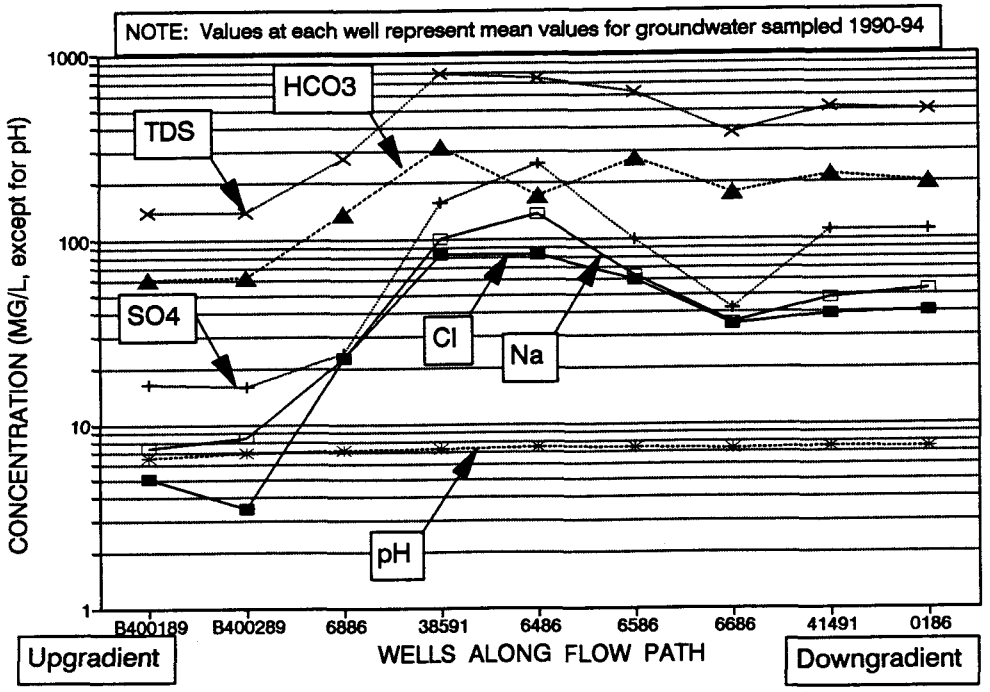
INDUSTRIAL AREA FLOW PATH



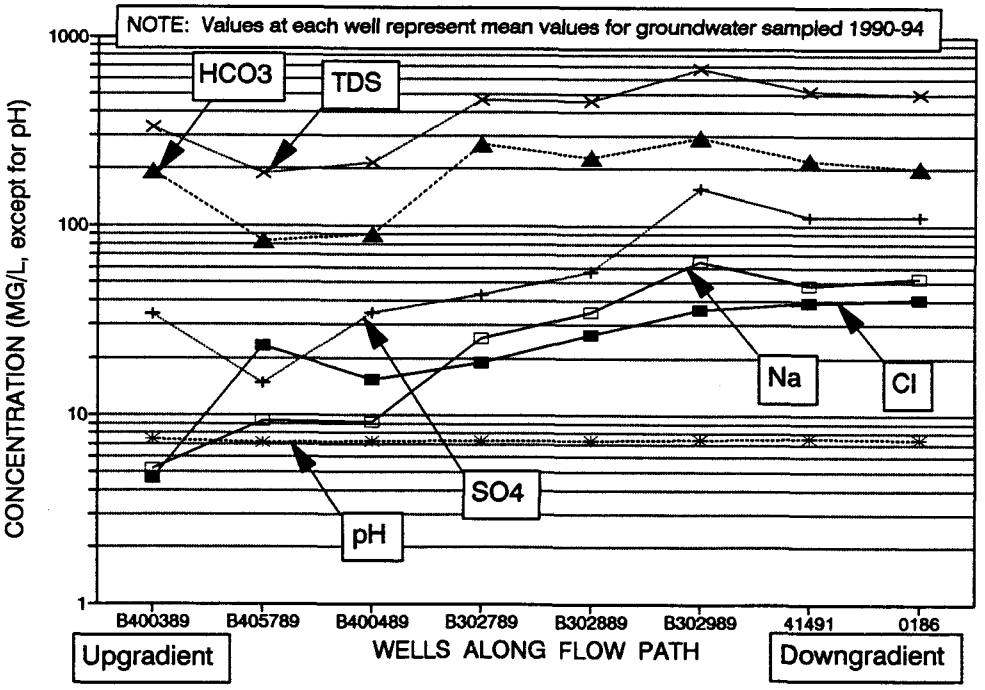
EG&G ROCKY FLATS Rocky Flats Site, Golden, Colorado	Concentrations of dissolved sodium; total bicarbonate, sulfate, and chloride; TDS, and pH	Groundwater Geochemistry Report	
		Date: January 1995	Figure 5 - 8

M\ES\Gdwr Geochemistry Figs/5-8.impt\12\9\95

WOMAN CREEK FLOW PATH



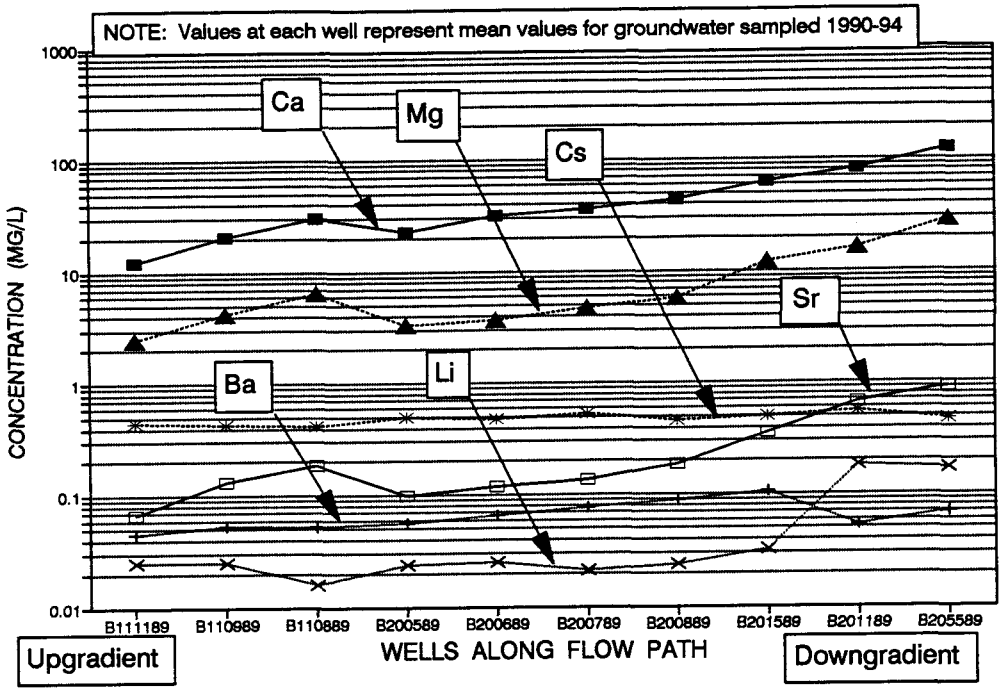
SOUTHERN FLOW PATH



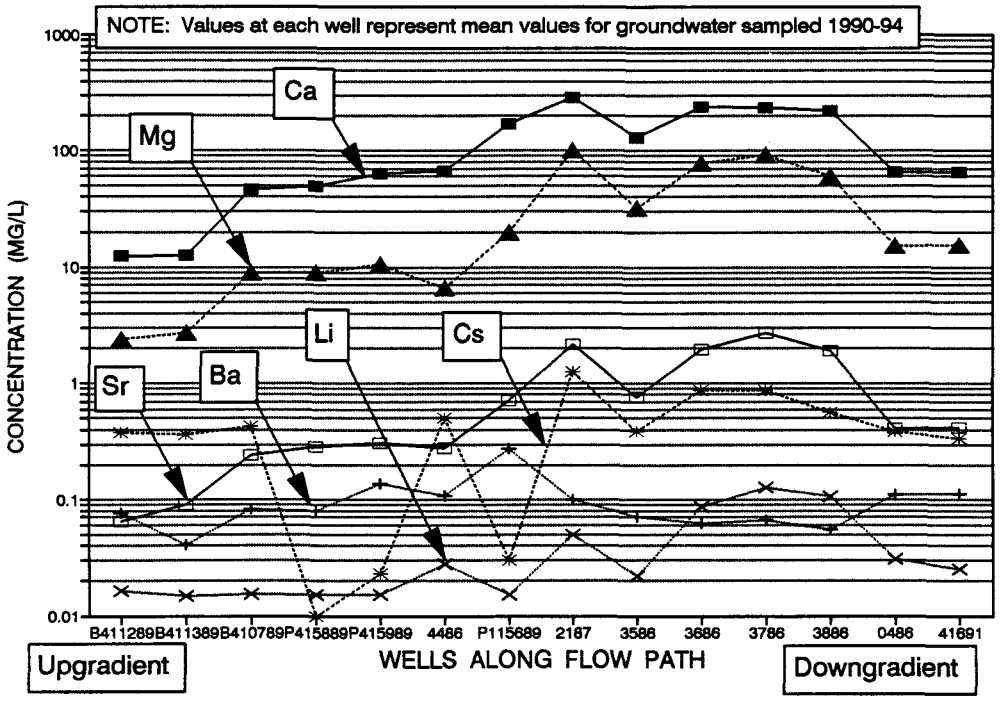
EG&G ROCKY FLATS Rocky Flats Site, Golden, Colorado	Concentrations of dissolved sodium; total bicarbonate, sulfate, and chloride; TDS, and pH	Groundwater Geochemistry Report	
		Date: January 1995	Figure 5 - 9

M\ES\Gdwr Geochemistry Figs/5-9.impt\12\9\95

ROCK CREEK FLOW PATH



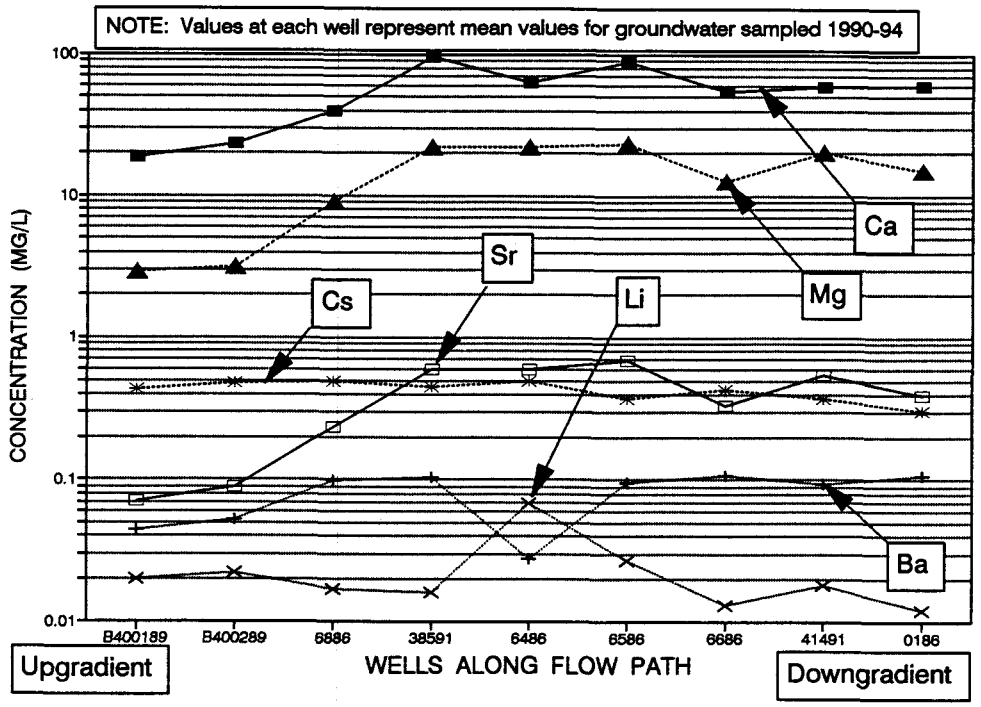
INDUSTRIAL AREA FLOW PATH



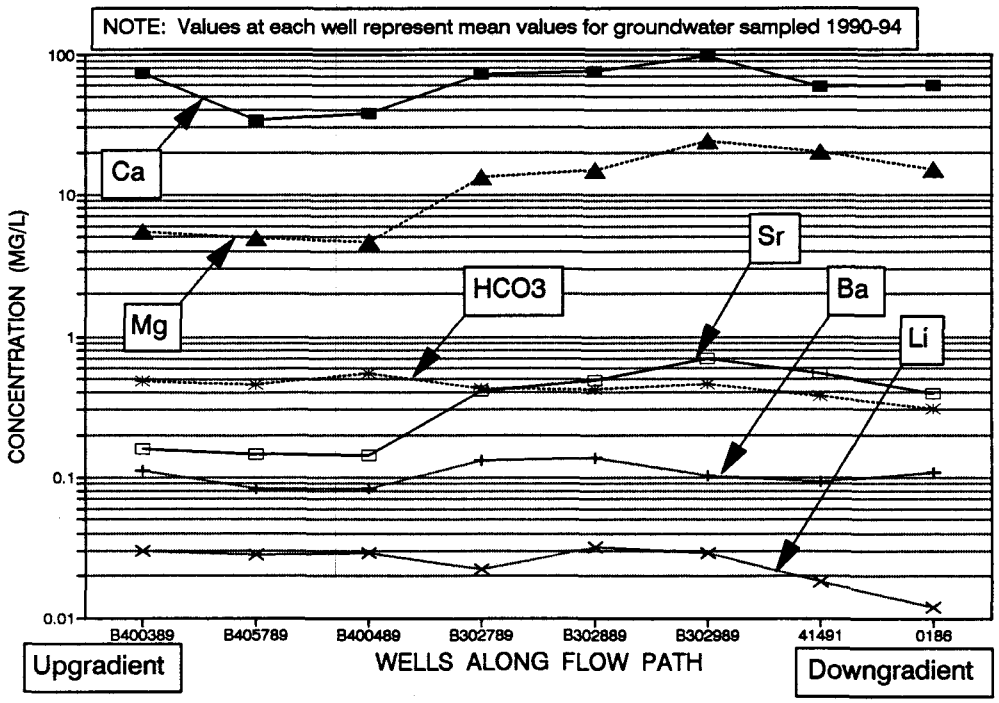
EG&G ROCKY FLATS Rocky Flats Site, Golden, Colorado	Concentrations of dissolved calcium, magnesium, cesium, barium, lithium, and strontium	Groundwater Geochemistry Report Date: January 1995 — Figure 5 - 10

M\ES\Gdwr Geochemistry Figs/5- 10.impt\12\9\95

WOMAN CREEK FLOW PATH

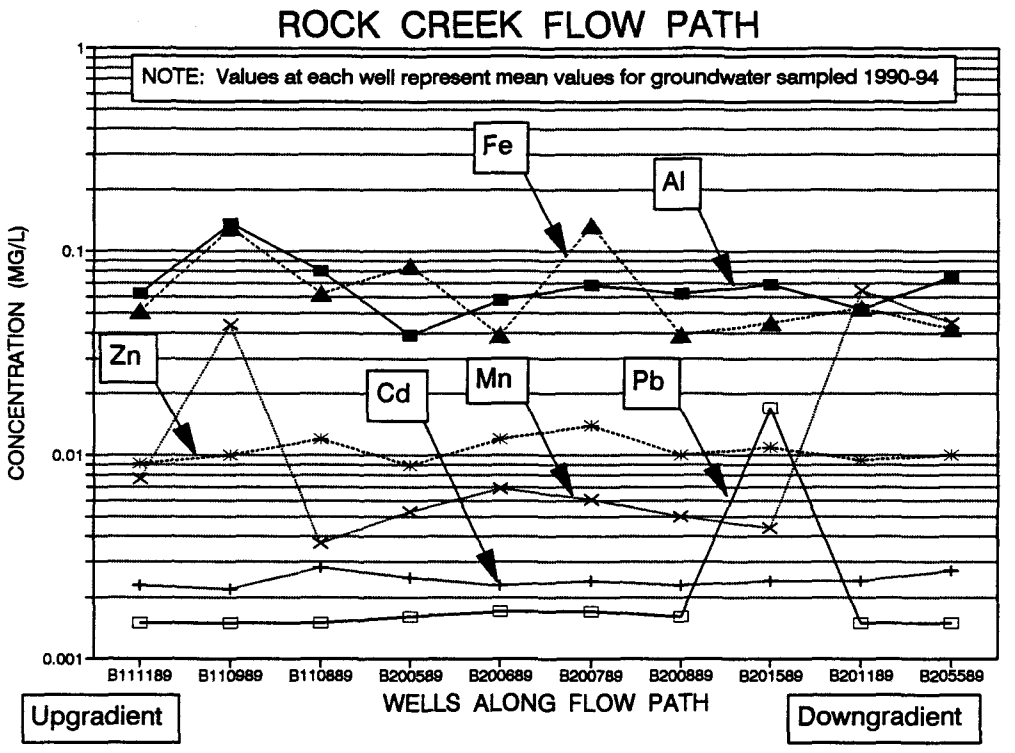


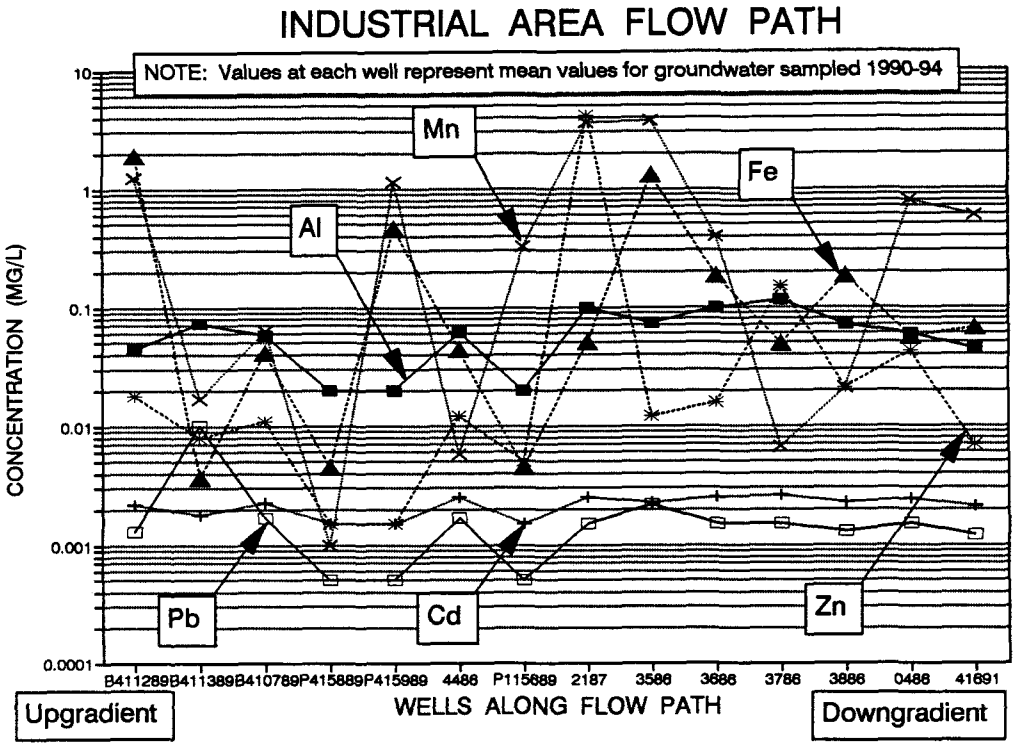
SOUTHERN FLOW PATH



EG&G ROCKY FLATS Rocky Flats Site, Golden, Colorado	Concentrations of dissolved calcium, magnesium, cesium, barium, lithium, strontium, and total bicarbonate	Groundwater Geochemistry Report	
		Date: January 1995	Figure 5 - 11

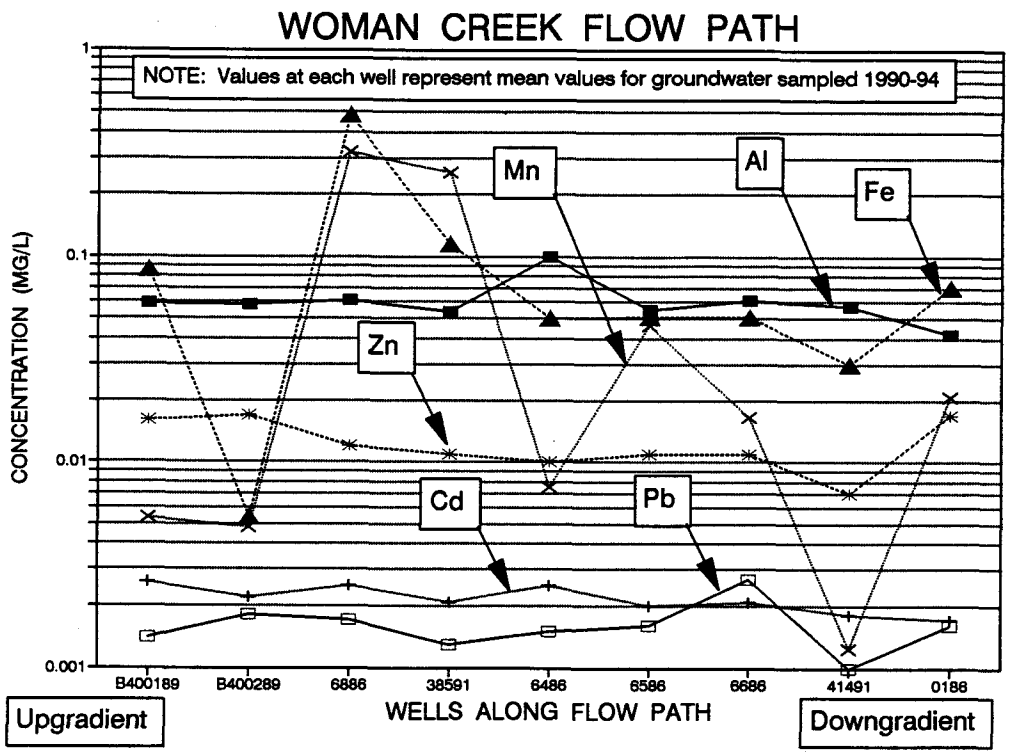
M\ES\Gdwr Geochemistry Figs/5- 11.impt\12\9\95

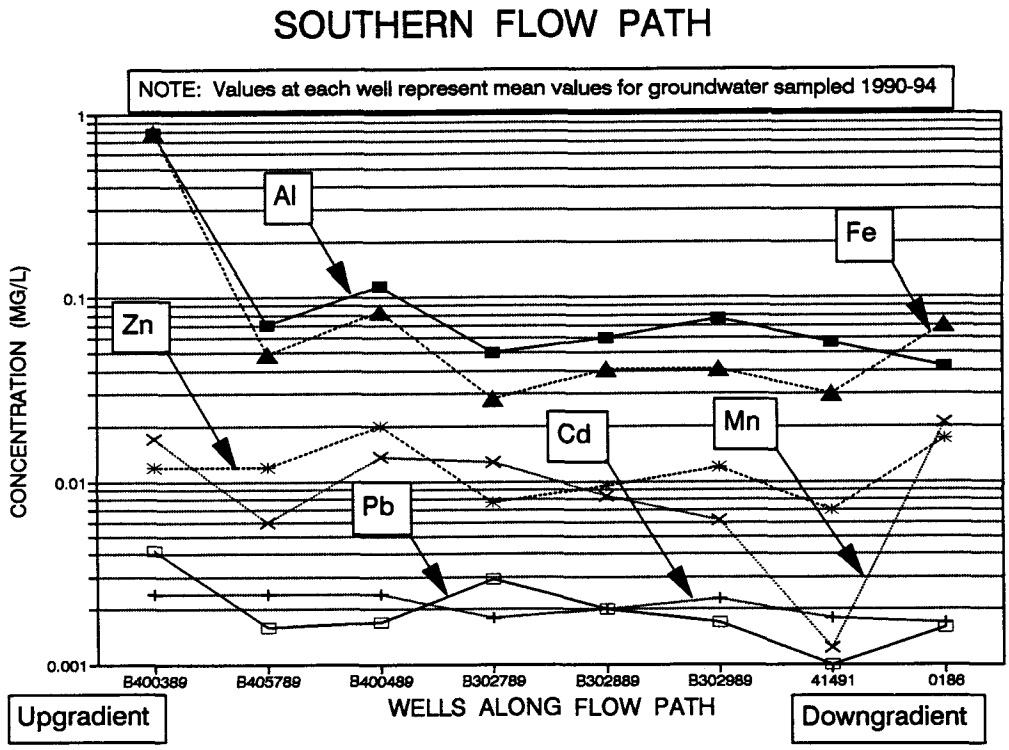




EG&G ROCKY FLATS Rocky Flats Site, Golden, Colorado	Concentrations of dissolved iron, aluminum, zinc, cadmium, manganese, and lead	Groundwater Geochemistry Report Date: January 1995 — Figure 5 - 12

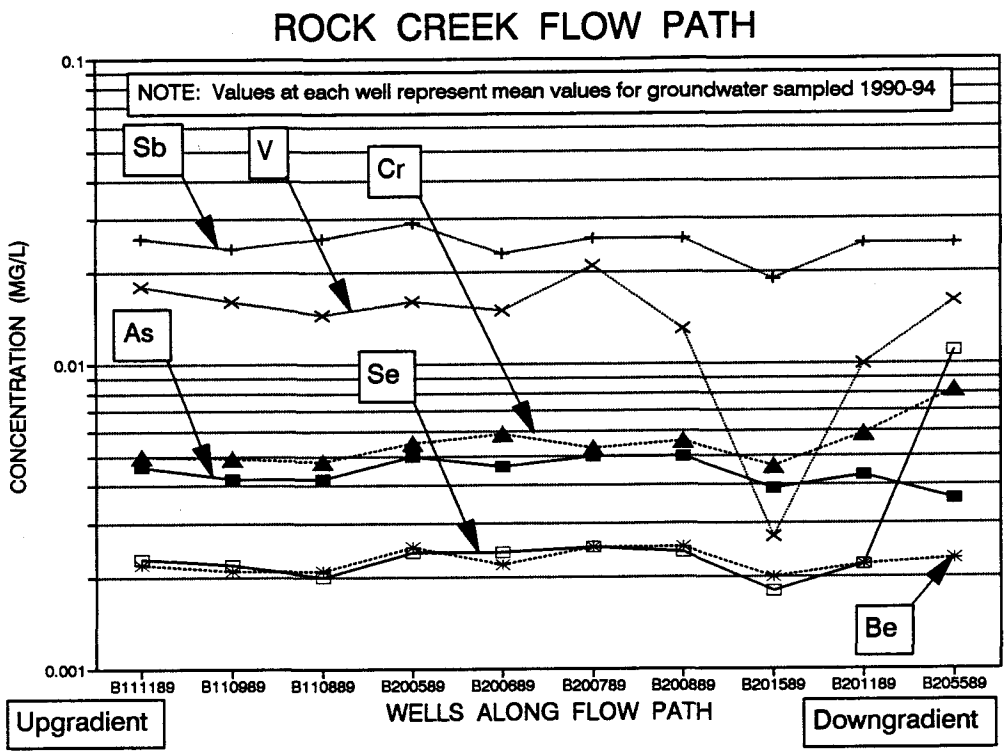
M\ES\Gdwr Geochemistry Figs/5- 12.impt\12\9\95

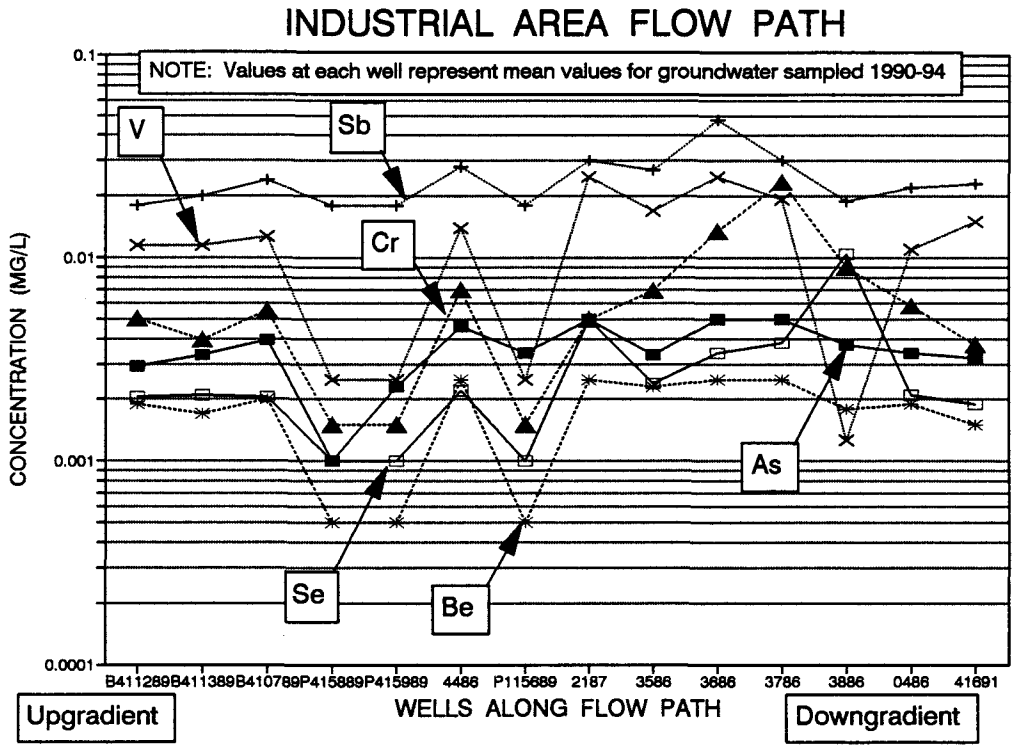




EG&G ROCKY FLATS Rocky Flats Site, Golden, Colorado	Concentrations of dissolved iron, aluminum, zinc, manganese, and lead	Groundwater Geochemistry Report	
		Date: January 1995	Figure 5 - 13

M\ES\Gdwr Geochemistry Figs/5- 13.impt\12\9\95

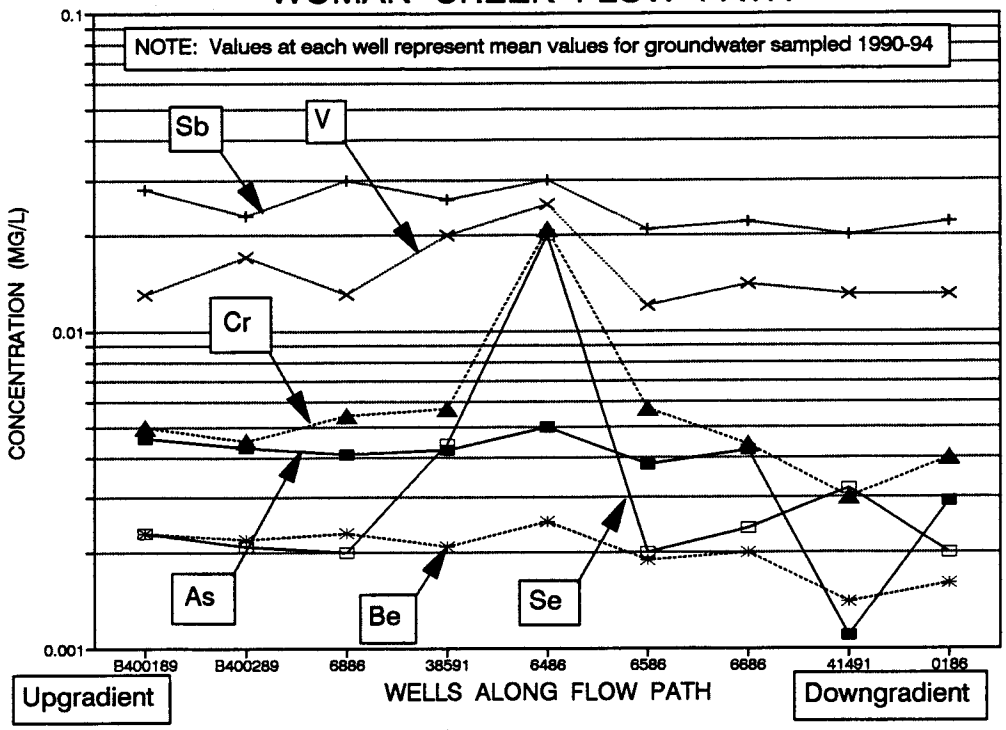




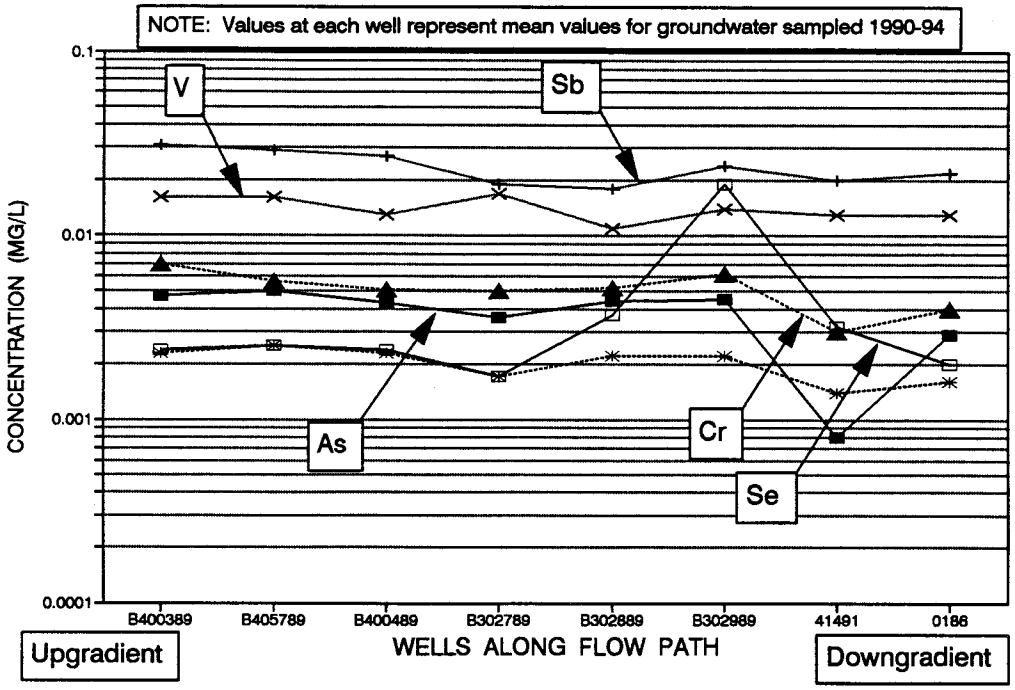
EG&G ROCKY FLATS Rocky Flats Site, Golden, Colorado	Concentrations of dissolved antimony, vanadium, chromium, arsenic, selenium, and beryllium	Groundwater Geochemistry Report Date: January 1995 — Figure 5 - 14

M\ES\Gdwr Geochemistry Figs/5- 14.impt\12\9\95

WOMAN CREEK FLOW PATH

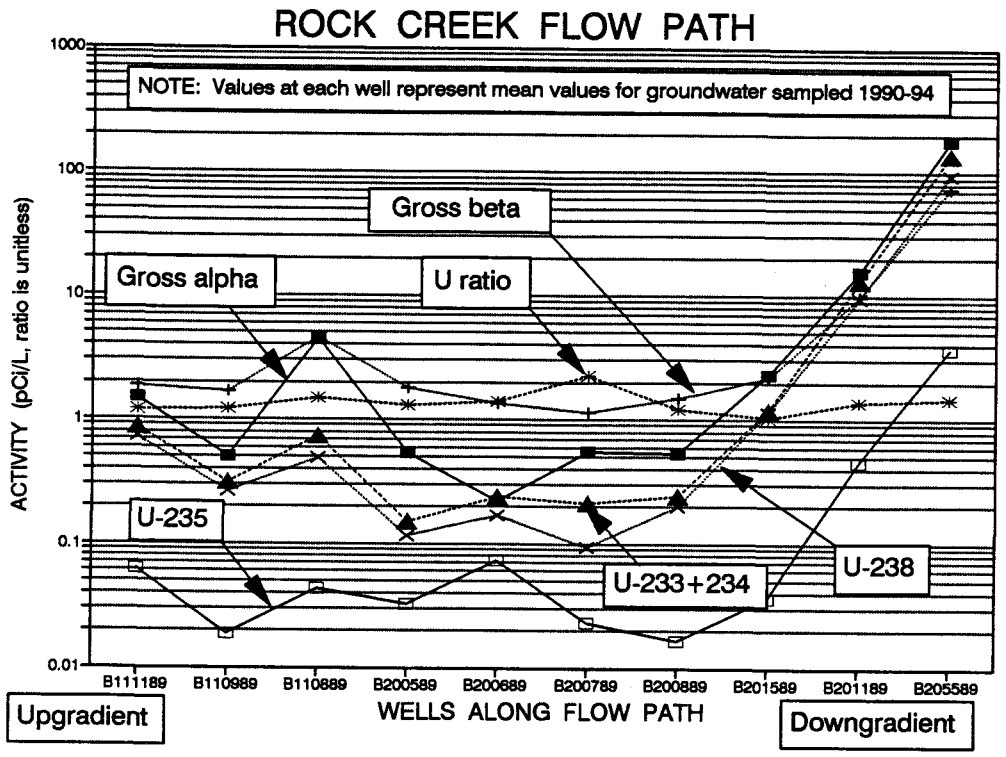


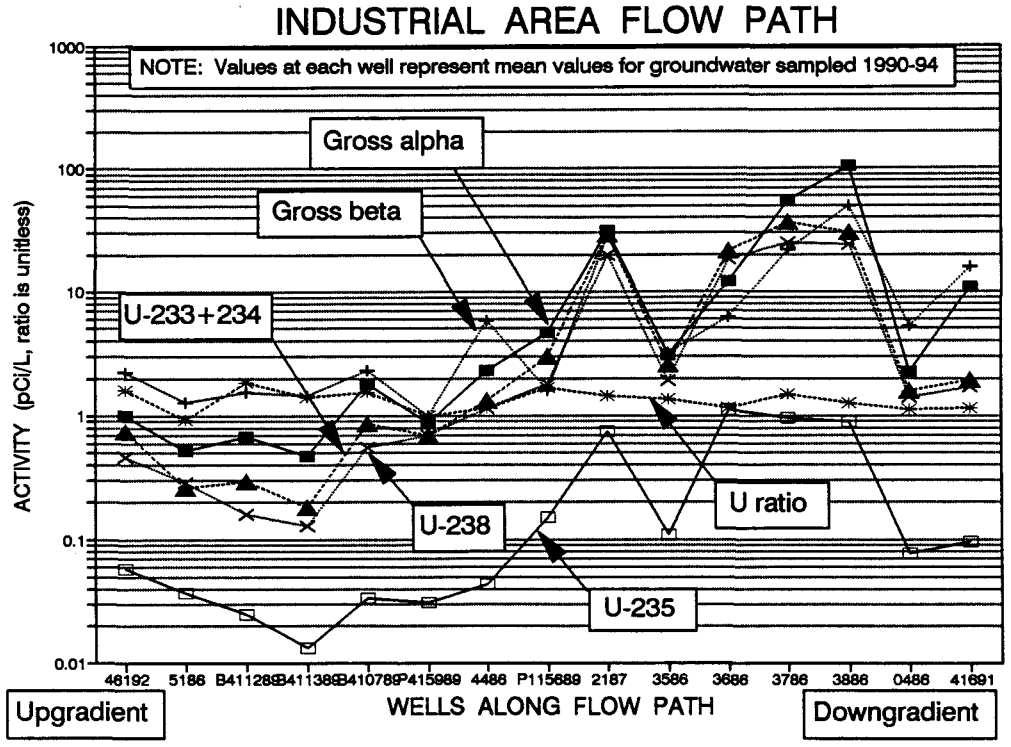
SOUTHERN FLOW PATH



EG&G ROCKY FLATS Rocky Flats Site, Golden, Colorado	Concentrations of dissolved antimony, vanadium, chromium, arsenic, selenium, and beryllium	Groundwater Geochemistry Report	
		Date: January 1995	Figure 5 - 15

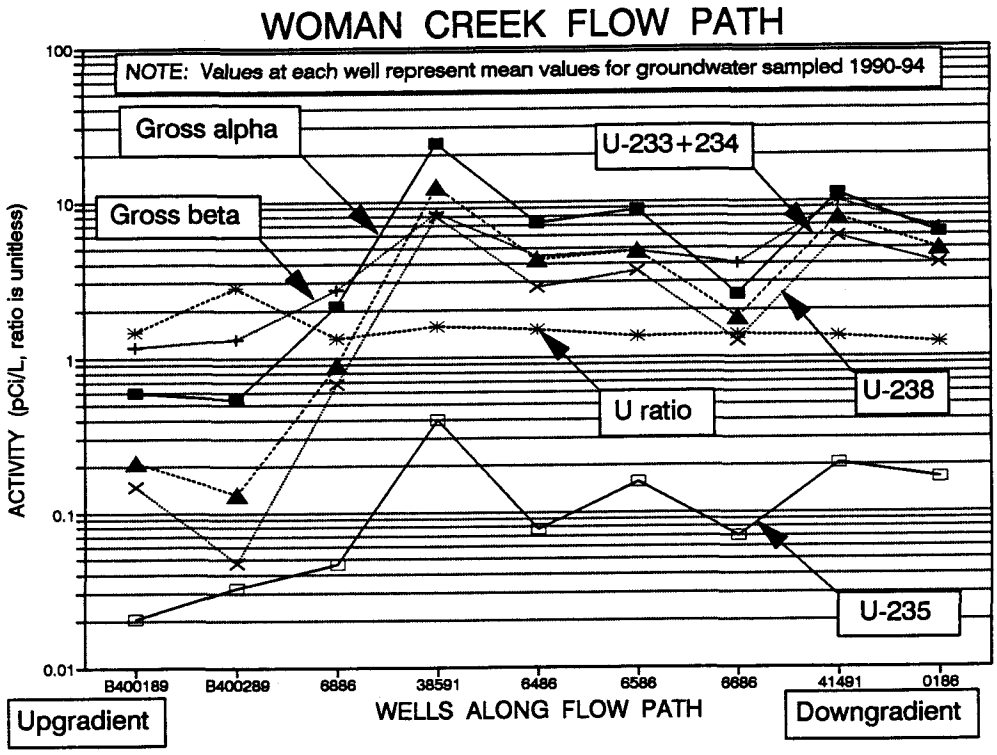
M\ES\Gdwr Geochemistry Figs/5- 15.impt\12\9\95

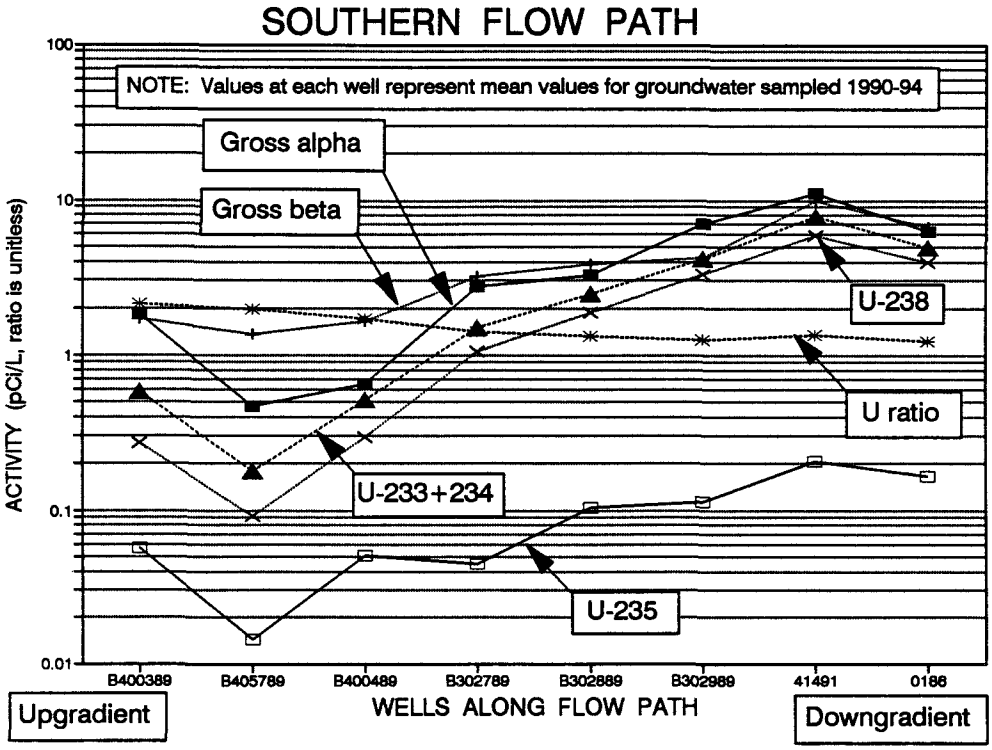




EG&G ROCKY FLATS Rocky Flats Site, Golden, Colorado	Activities of dissolved uranium isotopes, gross alpha, and gross beta, as well as the uranium-238:235 ratio	Groundwater Geochemistry Report Date: January 1995 — Figure 5 -16

M\ES\Gdwr Geochemistry Figs/5-16.impt\12\9\95





EG&G ROCKY FLATS Rocky Flats Site, Golden, Colorado	Activities of dissolved uranium isotopes, gross alpha, and gross beta, as well as the uranium-238:235 ratio	Groundwater Geochemistry Report	
		Date: January 1995	Figure 5 -17

M\ES\Gdwr Geochemistry Figs/5-17.impt\12\9\95

◇ Wells along Rock Creek Flow Path

46192	B200689
4786	B200789
B110889	B200889
B110989	B201189
B111189	B201589
0290	B205589
B200589	B202589

+ Wells along Woman Creek Flow Path

B400189	38591
B400289	6486
B401989	6586
6886	6686

□ Wells along Southern Flow Path

B400389	B302789
B400489	B302889
B405689	B302989
B405789	

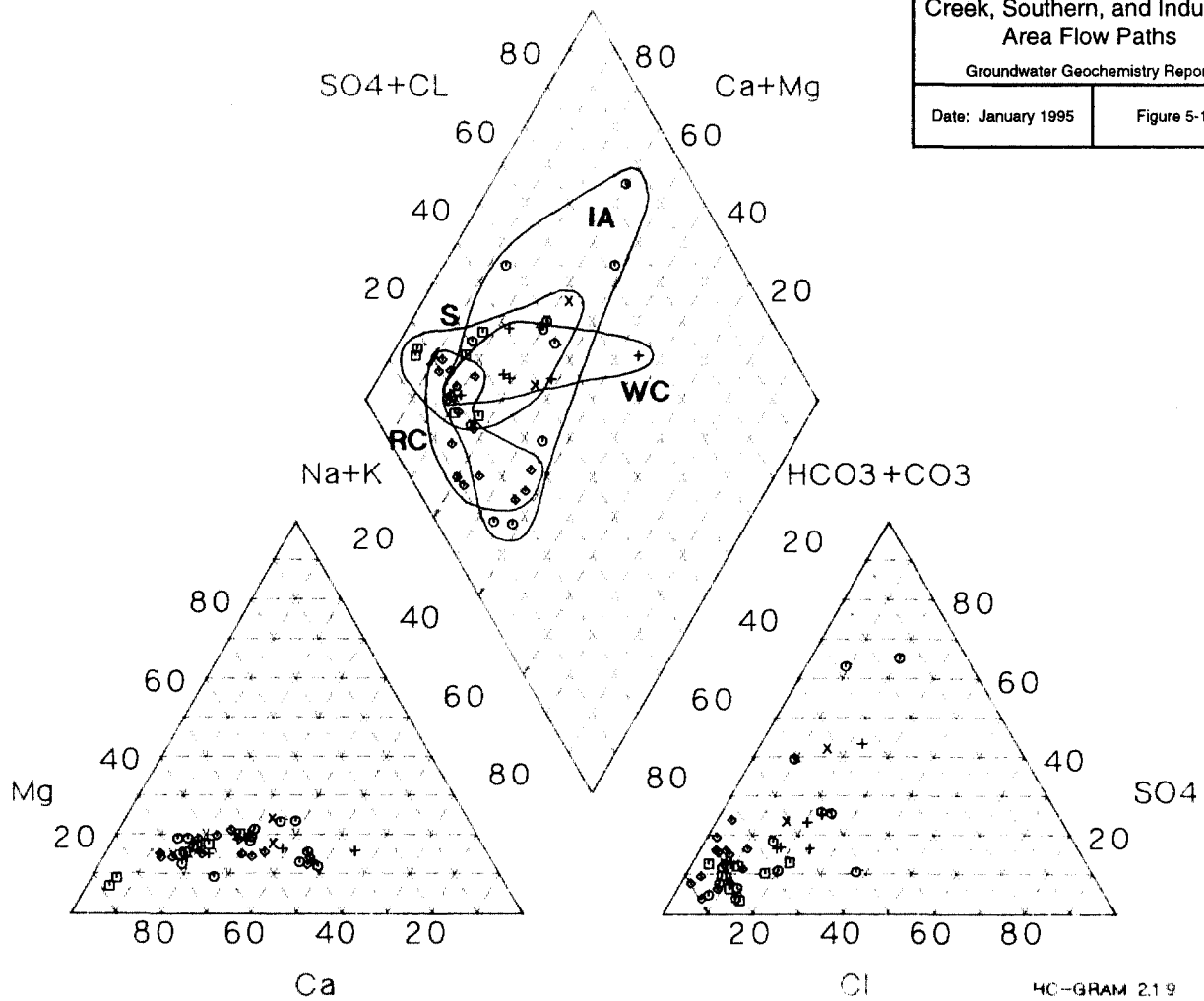
× Wells along Woman Creek/ Southern Flow Path

	0186
	41491

○ Wells along Industrial Flow Path

B411289	2187
B411389	3586
B410789	3786
P415889	3886
P415989	0486
4486	41691
P115689	

NOTE: Dissolved concentrations or activities are plotted



EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado

Piper Diagram for Groundwater within the Surficial Deposits along the Rock Creek, Woman Creek, Southern, and Industrial Area Flow Paths

Groundwater Geochemistry Report

Date: January 1995	Figure 5-18

M\ES\Gdwater flow Paths.impt\11-1-94

EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado

Piper Diagram for Groundwater in the Areas of OUs 1,2, and 11

Groundwater Geochemistry Report

Date: January 1995 | Figure 5-26

◇ OU1 Surficial Deposit Wells: 37791, 5287, 35691, 6986, 38591

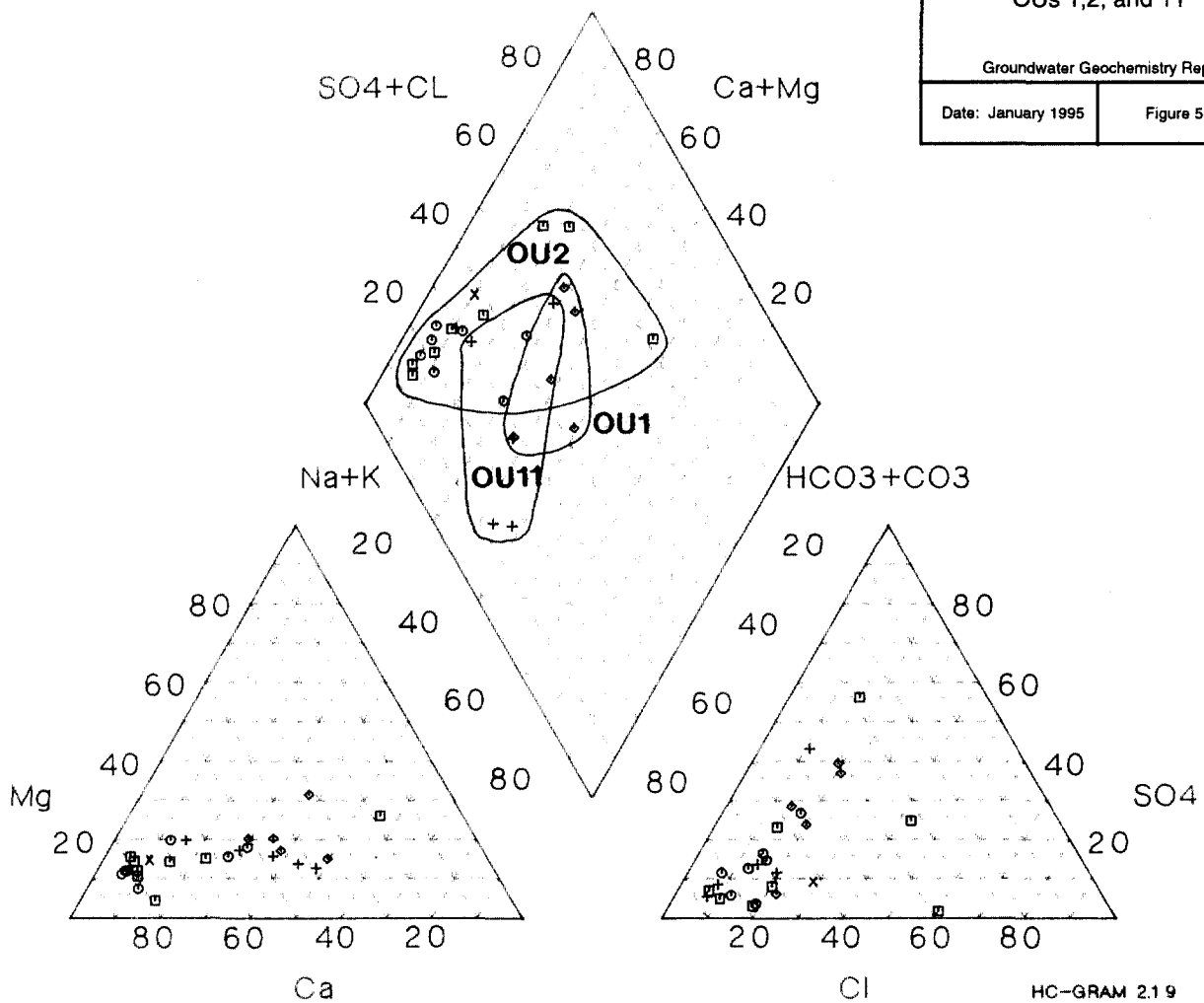
□ OU2 Surficial Deposit Wells: P317989, 1087, 08891, 00191, 4286, 05391, 06191, 3986

× OU1/OU2 Surficial Deposit Well: P320089

○ OU2 Weathered Bedrock Wells: 0987, 13191, 12991, 01991, 04291, 10991, 02591

+ OU11 Surficial Deposit Wells: 5186, B411289, B411389, 4986, B410789

NOTE: Dissolved concentrations or activities are plotted



M\ES\Gdwater flow Paths.impt\11-1-94

EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado

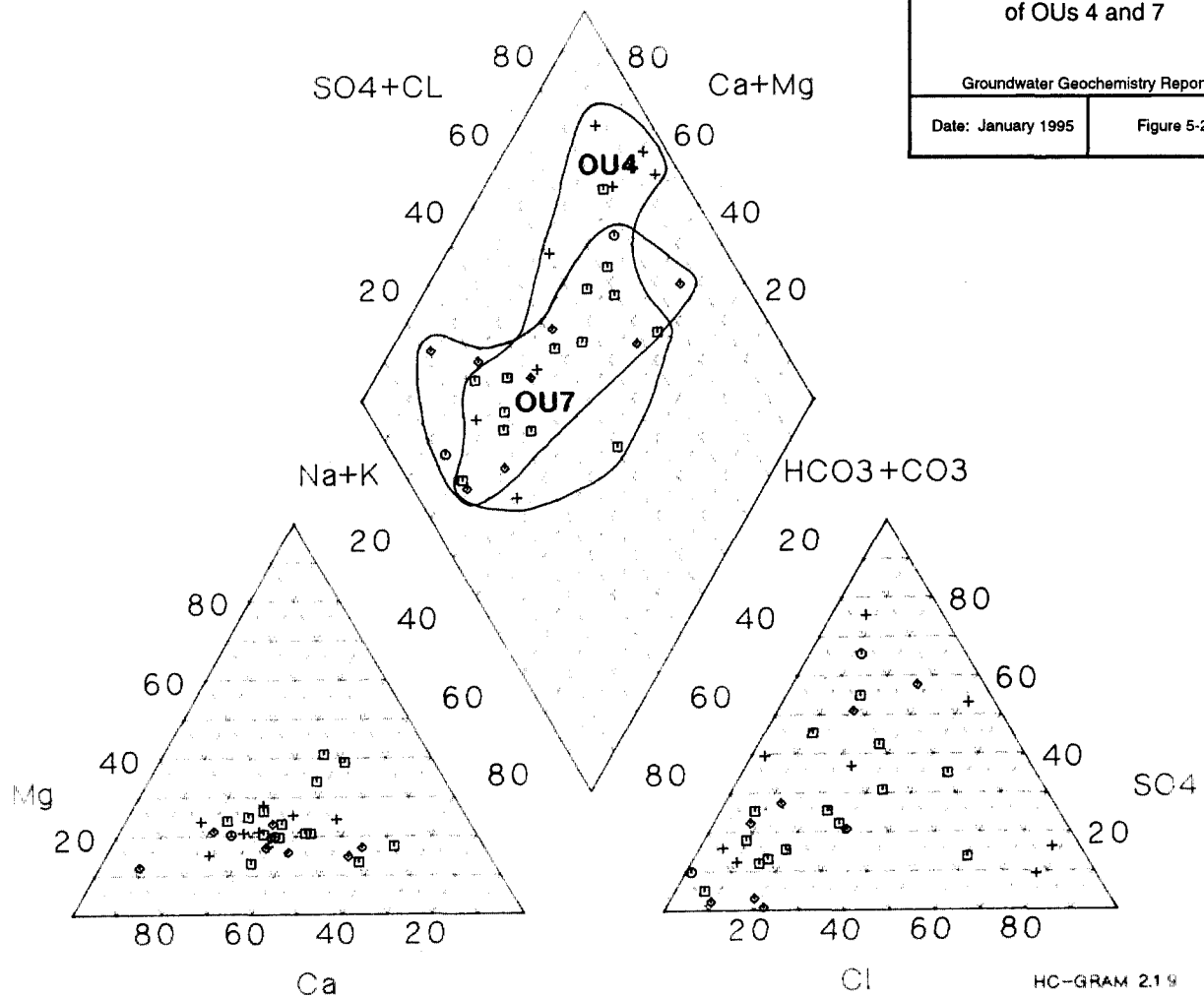
Piper Diagram for Groundwater in the Areas of OUs 4 and 7

Groundwater Geochemistry Report

Date: January 1995 | Figure 5-27

□	OU4 Surficial Deposit Wells	P207489 2286 2686 05193 P209789 05093 3686 B208089 B208789 B210489 1386 1286
+	OU4 Weathered Bedrock Wells	P207389 P209389 P209089 P208989 P209889 P208189 P210089 P208689
◇	OU7 Surficial Deposit Wells	70393 B106089 72093 72293 0786 4087 4287 0686
○	OU7 Weathered Bedrock Wells	70493 B206789

NOTE: Dissolved concentrations or activities are plotted



M\ES\Gdwater flow Paths.impt\11-1-94

6. Spatial Variations in Groundwater Chemistry

Spatial variations in groundwater geochemistry were analyzed using two different methods: (1) geostatistical analysis (ordinary kriging) and (2) hand-contouring of concentration data plotted on maps. The purpose of these analyses was to evaluate sitewide variations in groundwater chemistry and to identify spatial trends in the chemical composition of groundwater. The analyses were sitewide in scope and were not intended to provide detailed descriptions of the variations in groundwater chemistry within each of the OUs currently under investigation. Detailed RFI/RI reports are being or have been compiled to describe the nature and extent of groundwater contamination at each OU.

Use of two different methods resulted in two distinct sets of maps. The maps generated by geostatistical analysis are based solely on concentration values at each of the monitoring-well locations. For the hand-contoured maps, the position of the isoconcentration contours was inferred using the posted concentration data and taking into account the shapes of topographic and potentiometric surfaces and the direction of groundwater flow. The advantages and disadvantages of the two techniques are discussed below.

Kriging refers to the collection of generalized linear-regression techniques used for minimizing the error variance associated with an estimate based on a prior model of covariance. Ordinary kriging is the most commonly used variant of kriging and differs from simple kriging in that the local mean is re-estimated at each location. Use of geostatistical techniques, such as ordinary kriging, has the advantage of producing a "best" estimate of a parameter at a point in space. An estimate is defined as "best" based on the criteria of minimizing the error variance associated with an estimate. However, ordinary kriging will not take into account other types of information such as groundwater flow paths and topography when estimating a value. Estimates derived using ordinary kriging are only based on the locations and values of the actual data. Therefore, professional judgment needs to be exercised when evaluating an ordinary kriging (or any statistical) result to ensure that physical realities are also taken into account. Hand-contouring of data has the advantage of being able to incorporate other information, such as groundwater flow paths and flow divides; however, hand-contouring does not provide a best estimate, in the minimum-error sense, and is therefore more subjective.

Data from the existing monitoring-well network were used for the kriging analysis, even though the existing network was not designed to provide information for a kriging analysis. Therefore, the data provided by this network do not provide an optimal data

set for kriging. Limitations to the data include clustering of data in regions associated with OUs and scarcity of data in other areas. Patterns of spatial correlation inferred from data in well-characterized areas, such as the OUs, may be less applicable to areas of sparse well coverage, such as outlying areas of the Buffer Zone.

Isoconcentration maps were constructed for major ions (bicarbonate, carbonate, chloride, sulfate, calcium, magnesium, sodium, and potassium), silica, fluoride, minor and trace metals (barium, lithium, manganese, selenium, strontium, and zinc), uranium-235, pH, and TDS. The ratios of divalent to univalent cations (Ca to Na ratio and Ca+Mg to Na+K ratio) were also mapped to evaluate whether or not cation-exchange processes are affecting cation distribution in groundwater. The ratio of calcium to sodium should remain relatively constant unless Ca/Na exchange is occurring.

The concentration data used for both the geostatistical analysis and the compilation of isoconcentration-contour maps were arithmetic-mean concentrations from each well location. Arithmetic mean values were also used during groundwater geochemical modeling (see Section 8) and using mean values during kriging allows comparison of the two data sets. Using the arithmetic mean is further justified because it is a conservative estimator for distributions skewed by a few high values and because it is a non-biased estimator for non-skewed (normal) distributions. The mean values were calculated using data from 1990 through the first quarter of 1994. Individual results reported below the detection limit were replaced with values equal to one-half the reported detection limit prior to calculating the mean.

6.1 Geostatistical Analysis

The geostatistical method used, ordinary kriging, is an unbiased, linear-estimation technique that interpolates between the linear combinations of a spatially distributed, random variable. In this case, the variable used was the mean concentration of an analyte in groundwater. Ordinary kriging is linear because it estimates results from weighted linear combinations of the available data; it is unbiased because it sets the mean residual error equal to zero. In addition, ordinary kriging minimizes the error associated with a particular estimate. In ordinary kriging, a probabilistic model in which the bias and error variance can both be calculated is developed; weights are then chosen to ensure the average error of the model is zero (unbiased condition) and the error variance of the model is minimized (Isaaks and Srivastava, 1989).

6.1.1 Method

In order to calculate the weights used to provide an estimate, a model of the spatial continuity of the data must be developed. The model of spatial continuity is given by the model semivariogram, and the kriging weights are calculated using the covariance.

The model semivariogram is derived based on the experimental semivariogram, which is calculated with actual data using the following expression:

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} (x_i - y_i)^2$$

where N(h) is the number of data pairs at a given separation distance, h. The experimental semivariogram essentially represents the mean squared difference in data values for a given separation distance. Patterns in spatial continuity evident in the experimental semivariogram are modeled by a function (the model semivariogram).

Model semivariograms could only be estimated for analytes from the UHSU. In general, concentration data from the LHSU did not exhibit sufficient spatial continuity necessary to derive a semivariogram model. The degree of interconnection between sub-units within the LHSU is not known, and the chemical variation diagrams described in Section 5.2 indicate that the composition of groundwater in the LHSU is more variable than in the UHSU. In addition, there are fewer LHSU monitoring wells (less than 60 wells with usable data) than UHSU wells (more than 350 wells with usable data). The smaller number of LHSU wells makes it difficult to observe patterns of spatial continuity that may exist at different separation distances. Therefore, the inability to construct meaningful semivariograms for the LHSU may be due either to the actual lack of spatial correlation or an insufficient amount of data to describe spatial correlation on the scale that it exists.

Ordinary kriging was used to construct isoconcentration maps by the following steps: (1) evaluate the probabilistic nature of the random variables (i.e., determine the distribution of the mean concentrations), (2) determine the spatial correlation of the random variables, (3) perform a structural analysis of the spatially distributed data, (4) use ordinary kriging to calculate estimated concentrations, and (5) present the results in the form of contour maps. The first four steps were performed using the Geostatistical Software Library (GSLIB) software package (Deutsch and Journel, 1992). The SURFER™ software package was used in the last step to contour the simulated output from GSLIB. These steps are discussed in more detail below.

The probabilistic nature of the random variables (Zx) was achieved by constructing histograms of the mean concentrations to determine the probability distribution (histograms are included in Appendix F). The histograms indicated that selected ions were lognormally distributed. Kriging requires a normal distribution of the random variables; therefore, the data were normalized by a log-transformation (Cooper and Istok, 1988). Negative and zero values made log-transformations of uranium-235 measurements impossible; therefore, these measurements were normalized using a normal score transformation (Deutsch and Journel, 1992).

The spatial continuity of the data was analyzed by calculating an isotropic experimental semivariogram for each analyte (Appendix F). Isotropic experimental semivariograms were used because no patterns of anisotropy were evident in the data. The experimental semivariogram represents the average degree of dissimilarity between two points at a given distance.

Structural analysis was conducted by fitting a spherical mathematical model to the experimental semivariogram. The spatial offset from the origin observed on the semivariograms is termed the "nugget effect." This spatial discontinuity at the origin is generally caused by sampling/measurement error and/or "small" scale variability. The separation distance where the semivariogram value becomes nearly constant is defined as the range. The range is the distance at which the data are no longer spatially correlated. The sill is defined as the value at which the semivariogram reaches the range (Isaaks and Srivastava, 1989).

Structural analysis of the concentration data from the LHSU could not be performed for most analytes due to the asymmetrical distribution and lack of spatial continuity of the data. This may be attributed to the discontinuous nature of the LHSU sandstone units being monitored (EG&G, 1995a). Calcium and magnesium were the only LHSU analytes that showed a symmetrical distribution and adequate spatial correlation required for kriging. However, isoconcentration maps are not presented for these analytes because the spatial correlation present in the experimental variograms was not believed to represent data from a single population due to dissimilarities in flow paths and lithologies within the LHSU. The necessary input parameters for the structural analysis are presented in Table 6-1 and with the model semivariograms in Appendix F.

The spherical model was used in the ordinary kriging analysis. Specifically, the nugget, range, and sill of the model variogram were used as input parameters. Point estimates were used to generate the simulated values and the log-transformed values Y(x) were back-transformed using the following expressions:

$$Z(x) = \exp\left[Y(x) + \frac{s^2}{2}\right] \text{ (Cooper and Istok, 1988)}$$

where s^2 is the estimation variance.

The normal score back-transformation Z(x) of the "standard normal deviate" y_i is given by:

$$Z(x) = F^{-1}\left(G(y_i)\right)$$

where F(x) is the cumulative distribution function (cdf) of the data and $(G(y_i))$ is the standard normal cdf (Deutsch and Journel, 1992). The input parameters used in GSLIB for the ordinary kriging analysis are provided in Table 6-1.

The simulated estimates generated from the ordinary kriging analysis were contoured using the SURFER™ software package. For optimal results (i.e., prohibited reestimation of the simulated values by the SURFER™ gridding), the following gridding procedures were followed: (1) the grid size in SURFER™ was identical to the grid dimensions used in GSLIB (50 x 50), (2) the nearest number of search points was set to one, (3) the Inverse Distance Method with a weighted power function set to one was chosen, and (4) the Octant Search Method was used. The above procedure provides a SURFER™ grid file identical to the simulated output from GSLIB. The SURFER™ grid file was contoured using the SURFER™ TOPO module. This procedure is described in greater detail by Shan and Stephens (1994).

Table 6-1
Input Parameters for Two-Dimensional Ordinary Kriging

Minimum and Maximum	Debugging Options
Minimum = -100,000	Level 1
Maximum = 100,000	
Radius = 40,000	
Block Dimensions	**Database Size**
X Block Size = 1	Minimum Number = 5
Y Block Size = 1	Maximum Number = 10
Grid Dimensions[1] UHSU	**Grid Dimensions[1] LHSU**
X: 50, Y: 50	X: 50, Y:50
X-Intercept: 2076000	X-Intercept: 2078000
Y-Intercept: 741900	Y-Intercept: 2094150
X Spacing: 363	X Spacing: 323
Y Spacing: 326	Y Spacing: 244

[1]grid dimensions reported in state plane coordinates

6.1.2 Results

Figures 6-1 through 6-19 are the isoconcentration-contour maps for the UHSU, and were generated using the output from the kriging model. The kriging output consists of estimated concentration values at regularly spaced intervals (two-dimensional grid) across the analysis area. The kriged maps display major-ion concentration values at the

grid nodes. These values were generated by a geostatistical analysis of the spatial correlation among values at the measured points (as described above).

Two patterns are common to most of the maps. First, there is a general trend toward increased major-ion content in the direction of groundwater flow (from west to east). From the recharge zone in the west, ion concentrations increase in UHSU groundwater to the east. The same pattern was evident on the ion-variation diagrams and Stiff plots discussed in Section 5. Chloride, bicarbonate, and magnesium show the most regular increase in estimated concentrations. Each of these analytes has higher concentrations downgradient of the site than upgradient. Second, local sources of increased ion content are present mainly within the Industrial Area and within OUs on the site; ion contents are most variable in the Industrial Area and in parts of the Buffer Zone where waste generation and disposal have occurred (i.e., in the OUs).

A number of ions, including calcium, chloride, potassium, lithium, sodium, magnesium, sulfate, and TDS, show areas of extremely high concentrations in the vicinity of OU4. Manganese, zinc, and bicarbonate have their highest concentrations in the vicinity of OU7. The area south and east of the Industrial Area includes OU1, OU2, and OU5 and also shows high concentrations of zinc, chloride, selenium, and TDS compared to other areas of the site. Concentration variations in the vicinity of the specific OUs are discussed below in Section 6.2.2.

A number of analytes (Li, Na, Se, SO_4, TDS) are shown with elevated concentrations across a broad, northeast-trending area in the vicinity of the Walnut Creek drainages and the drainage leading from OU7. These broad areas of elevated concentration are not evident on the hand-contoured isoconcentration maps that are described in the following section and are probably an artifact of the kriging method, which does not take into account the realities of groundwater flow and transport directions. The differences between the kriged maps and hand-contoured isoconcentration maps are discussed in Section 6.3.

6.2 Isoconcentration-Contour Maps

Using kriging results as a basis for contour mapping produces a smoothing of the original data and some of the extreme values (Deutsch and Journel, 1992). Therefore, the kriged maps are less useful for detailed analysis of smaller-scale variations in areas, such as the OUs, where outlier values or extremely high concentration values may be present. For this reason, isoconcentration maps of the site were also prepared by hand-contouring the mean concentrations of analytes for UHSU monitoring wells. These maps honor all of the actual concentration data and also take into account other information about groundwater flow and contaminant transport. In areas where groundwater is well characterized, such as the OUs, the hand-contoured

isoconcentration maps reflect groundwater conditions much more accurately than the geostatistical estimates. The isoconcentration contours are most accurate in the areas where well coverage is dense (i.e., the Industrial Area and OUs); in the outlying areas of the Buffer Zone, wells are widely scattered and the contour locations more approximate.

6.2.1 Sitewide Variations in Groundwater Chemistry

The isoconcentration maps presented in Figures 6-21 through 6-41 show a general trend toward increasing major-ion concentrations from west to east across the site. These trends are best shown by the groundwater constituents with the highest average concentrations — calcium, magnesium, bicarbonate, chloride, and sulfate — and by TDS. Concentrations of these constituents increase in the direction of groundwater flow but also vary locally, with elevated concentrations in the Industrial Area and along drainages downgradient of the Industrial Area. Similar trends were evident on ion-variation diagrams and Stiff plots of groundwater along the UHSU flow paths (Section 5) and on the contour maps of kriging output (Section 6.1). The isoconcentration maps also show sodium, potassium, and several minor metals (selenium, uranium-235, and zinc) with nearly constant concentrations in UHSU groundwater from across the site, except in groundwater from OUs 1, 2, 4, 6, and 7 (refer to Figure 6-20 for well coverage and OU locations).

Two maps of the calcium-to-sodium ratio show that the relative abundances of calcium and sodium remain unchanged over much of the site. The ratio varies significantly within the Industrial Area where groundwater in the west portion of the area and in the OU2 area has the highest calcium-to-sodium ratios and groundwater in the OU1 and OU4 areas has the lowest calcium-to-sodium ratios. Variations in this ratio indicate open-system behavior that could include cation exchange, precipitation and dissolution processes, or mixing with chemically distinct water.

A number of the isoconcentration maps show relatively high concentrations of groundwater constituents in wells located along the eastern boundary of the Rocky Flats site (Figures 6-23 [Cl], 6-28 [Li], 6-29 [Mg], 6-35 [SO_4], 6-36 [Sr], and 6-37 [TDS]). There are only a few data points located along this boundary (refer to Figure 6-20 for monitoring-well locations), however, and the extent of the concentration variations cannot be determined at this time. The areas of elevated concentration shown on the maps are based on extremely limited data and should not be interpreted as contaminant "hot-spots" or plumes before additional data are available from areas between the eastern boundary and the upgradient sources of contamination. Elevated ion concentrations and radionuclide activities in the boundary wells are currently being investigated by EG&G (DOE, 1993b).

Groundwater is not as well characterized in the LHSU, and the isoconcentration-contour maps (Figures 6-43 through 6-52) provide only limited information to describe major-ion distribution in groundwater. In general, the same areas of the site show relatively high concentrations of the major ions in LHSU groundwater as were identified for UHSU groundwater, but the sitewide pattern of increasing major-ion content in the direction of groundwater flow (west to east) (EG&G, 1995b) is not evident in the LHSU groundwater. However, the existing data are not adequate to fully describe and evaluate sitewide variations in the composition of LHSU groundwater.

6.2.2 OU-Specific Variations in Groundwater Chemistry

Groundwater chemistry is also variable among specific areas of the site. These variations are evident on the hand-contoured isoconcentration maps and, within individual OUs, they are consistent with associated waste-generation and waste-disposal activities that resulted in local contamination of the groundwater. The spatial patterns displayed by the isoconcentration maps are also consistent with the more detailed descriptions of groundwater contamination provided in RFI/RI reports for each OU.

As previously discussed in Section 5.4, OU4 contains the Solar Evaporation Ponds which were used for evaporative concentration of waste liquids. Leakage of concentrated water from the Solar Evaporation Ponds in the past has contaminated the groundwater in this area (EG&G, 1994c). The effects of groundwater contamination are evident in the major-ion contents of UHSU groundwater. The isoconcentration maps for barium, calcium, potassium, lithium, magnesium sodium, selenium, strontium, uranium-235, chloride, fluoride, sulfate, and TDS show an area of high concentration, relative to surrounding areas, underlying or immediately downgradient of the Solar Evaporation Ponds. These constituents are consistent with the groundwater contaminants described in Annual RCRA Groundwater Monitoring reports for the Solar Evaporation Ponds (EG&G, 1992b, 1993h, and 1994c) and in the Draft Final Phase I RFI/RI Report for OU4 (EG&G, 1994b).

At OU2, metals and major ions have not been associated with waste-related contamination (EG&G, 1993d). None of the ions mapped, except barium, shows an increase in concentration in the OU2 area compared to adjacent areas. Within the South Walnut Creek drainage north of OU2, however, several metals and major ions are present in UHSU groundwater at concentrations higher than in surrounding areas. Lithium, magnesium, sodium, zinc, uranium-235, sulfate, and TDS concentrations increase in groundwater from the Walnut Creek drainage compared to other areas of the site.

OU7 includes the Present Landfill where a variety of wastes have been disposed. The landfill generates a relatively low pH (potentially low Eh) leachate that contains elevated concentrations of metals compared to background groundwater (DOE, 1994a). The isoconcentration maps show OU7 as an area where the concentrations of some metals (Ba, Mn, and Sr), major ions (Cl, HCO_3, K, Mg), silica, and TDS are higher than in the background areas.

At OU1, selenium was found in UHSU groundwater at elevated concentrations relative to background (DOE, 1993a). The origin of the selenium is not known; selenium-bearing wastes or minerals may serve as sources, or selenium may have been mobilized from native soils in the presence of chelating or low-pH waste products in the subsurface (DOE, 1993a). Selenium is also a reduction/oxidation(redox)-sensitive species, whose form and mobility are affected by redox (Eh) conditions. Therefore, contaminant-related changes in physical conditions may have mobilized native selenium. Selenium concentrations are also relatively high in UHSU groundwater from areas of OU5 and OU6.

6.3 Comparison and Discussion of Results

Some of the spatial distribution patterns revealed on the kriged maps are also evident on the hand-contoured isoconcentration maps. The general trend toward increasing major-ion contents in groundwater from west to east is evident on both types of maps. Other spatial distribution patterns, however, were not evident on the hand-contoured maps. The most striking example of this is in the vicinity of the Walnut Creek drainages northeast of the Industrial Area. A number of the kriged maps, including those for lithium, sodium, selenium, sulfate, and TDS, show relatively high concentrations across a broad northeast-trending area. This apparent "plume" does not appear on the hand-contoured maps where elevated concentrations are shown only within narrow bands along the drainage bottoms.

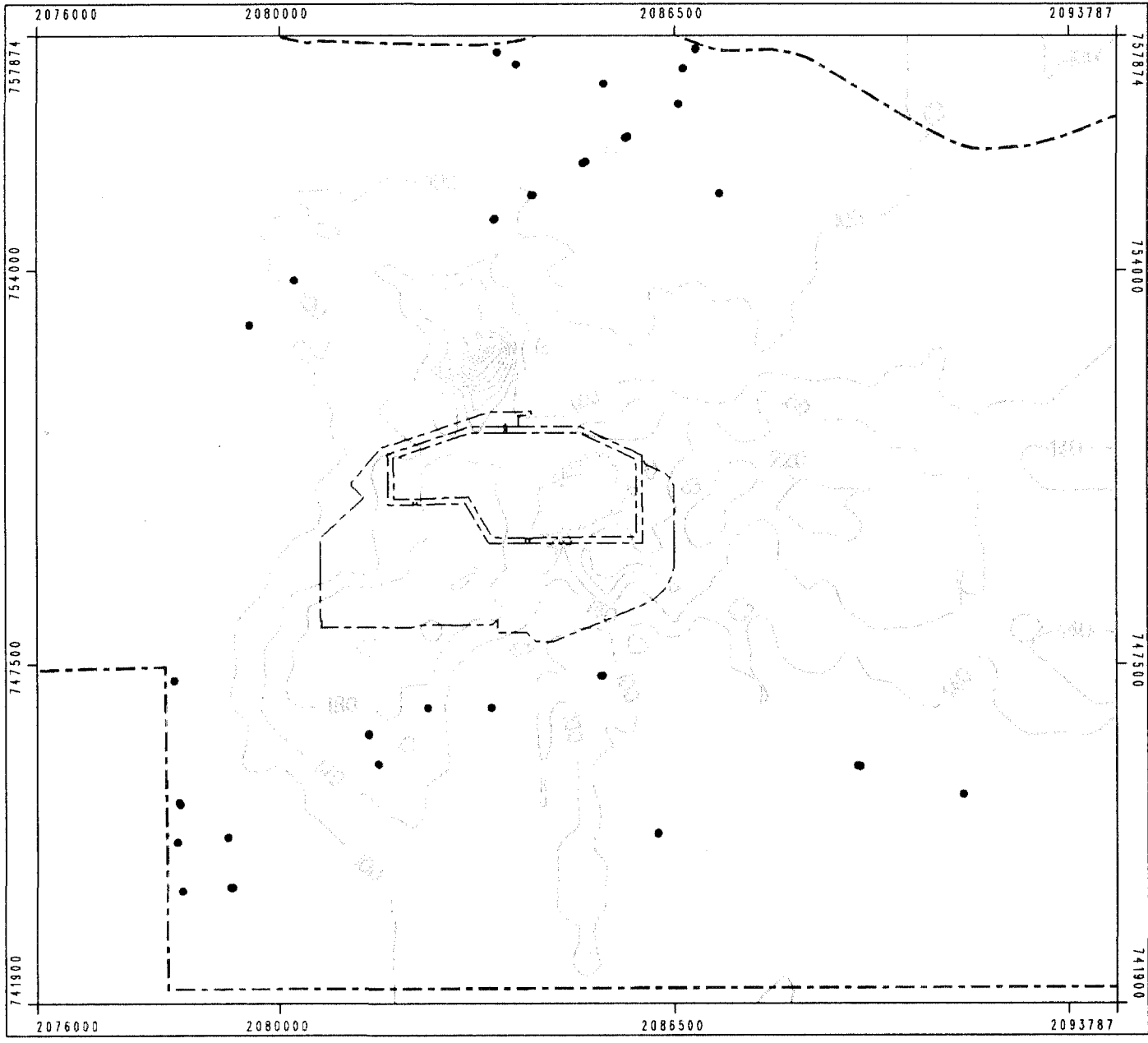
The majority of the wells in this portion of the Buffer Zone are located along drainage valleys, and there is sparse well coverage on the hillsides between drainages. In addition, potentiometric-surface maps of this area indicate that the primary direction of groundwater flow is toward the east along the drainage bottoms, and not from south to north across the topographic highs between drainages (refer to Plates 8 and 9 of Hydrogeologic Characterization Report, EG&G, 1995b). The major pathways for offsite contaminant transport are along drainage bottoms where flow is directed from west to east. An apparent plume appears on the kriged maps because the geostatistical analysis assigns estimated values to grid points based on a linear-estimation technique that does not consider the direction of groundwater flow or the presence of flow divides. Therefore, the values from wells located within drainage bottoms are used to calculate estimated values between the drainages. The contouring software identifies

and connects the points of equivalent concentration values, but these are the kriged values and not the actual concentrations in groundwater.

The strength of the kriged maps is their presentation of general trends in the spatial distribution of analytes identified by an unbiased, reproducible, geostatistical method. The primary weakness of these maps, however, is that they may be misinterpreted by the user, because the kriging method does not take into account information about groundwater flow, such as realistic flow paths, aquifer continuity, and known sources of groundwater contamination on the site. Other weaknesses include excessive smoothing of small-scale variations and accentuated areas of extreme concentration values. For these reasons, the kriging output displayed on the maps should not be used to delineate areas of actual groundwater contamination or to describe the extent of contaminated groundwater on the site.

Figures 6-2 and 6-22 provide examples of the limitations associated with using the kriged maps to delineate areas of groundwater contamination. Both figures display dissolved concentrations of calcium and indicate an area of relatively high concentration in the vicinity of OU4/Solar Evaporation Ponds. However, on the kriged map (Figure 6-2) the area of elevated concentrations is large and extends over areas of sparse well coverage (refer to Figure 6-20 for well coverage). The kriging analysis uses the spatial correlation of the data found in OU4, where wells are abundant, to estimate the concentrations of calcium in the surrounding area. The hand-contoured map (Figure 6-22) shows a smaller area of relatively high calcium concentration than the kriged map. This map was generated from concentrations at well locations. The isoconcentration contours are consistent with concentration data at each well location, and the amount of extrapolation performed was subject to professional judgment taking into account probable sources and flow direction. This example illustrates the potential problems associated with using the kriging output to delineate areas of groundwater contamination.

What the kriged maps do illustrate are the statistically significant increases in major-ion contents in UHSU groundwater from west to east across the site. Therefore, the maps provide statistical confirmation for the types of compositional variations observed qualitatively in the ion-variation diagrams discussed in Section 5 and quantitatively modeled, as discussed in Section 8.



EXPLANATION

Lines of Equal Concentrations
(hachures indicate local low)

*Contour configuration represents estimated values based on kriging analysis.

Background Wells

Industrial Area and Security Zone Boundaries

Buffer Zone Boundary

Contour Interval = 40 ug/L

Scale = 1 : 31200
1 inch = 2600 feet

1300 0 2600ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

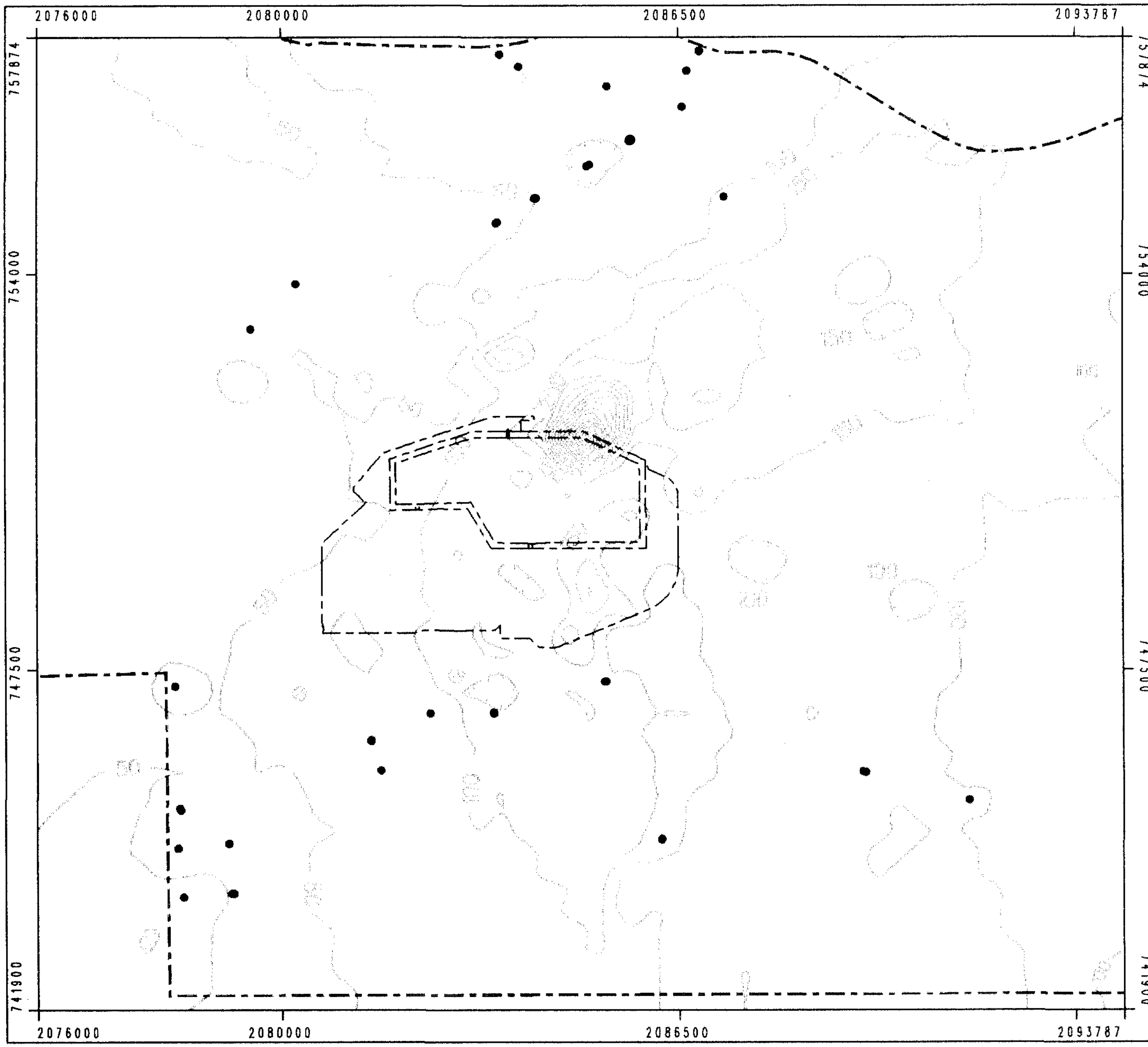
EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Kriged Isoconcentration Map of Dissolved Barium in the Upper Hydrostratigraphic Unit

Groundwater Geochemistry Report

January 1995 | Figure 6-1



EXPLANATION

Lines of Equal Concentrations (hachures indicate local low)

*Contour configuration represents estimated values based on kriging analysis.

Background Wells

Industrial Area and Security Zone Boundaries

Buffer Zone Boundary

Contour Interval = 50 mg/L

N

Scale = 1 : 31200
1 inch = 2600 feet
1300 0 2600ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Kriged Isoconcentration Map of Dissolved Calcium in the Upper Hydrostratigraphic Unit

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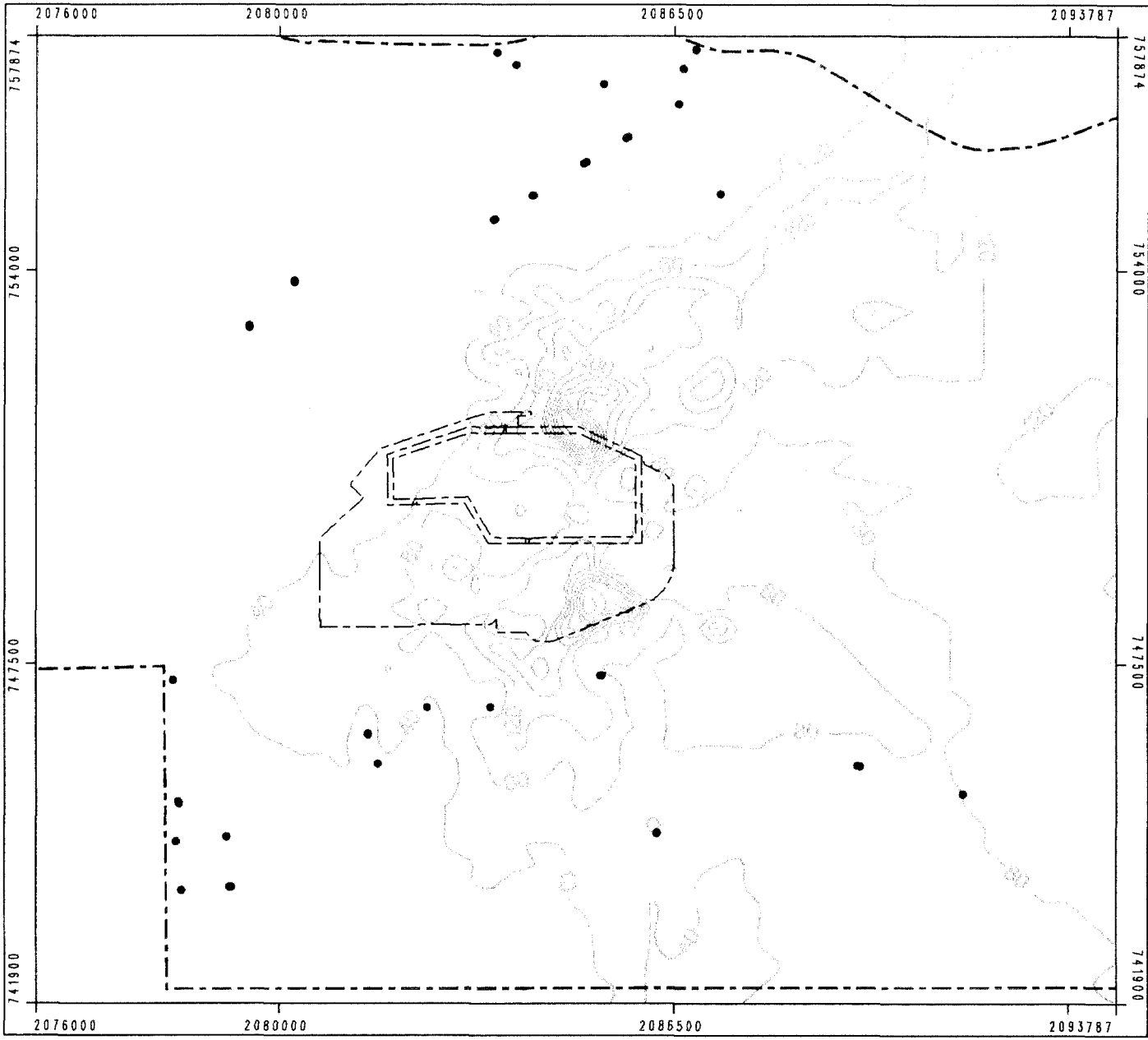
Figure 6-2



EXPLANATION

Lines of Equal Concentrations
(hachures indicate local low)

*Contour configuration represents estimated values based on kriging analysis.

Background Wells

Industrial Area and Security Zone Boundaries

Buffer Zone Boundary

Contour Interval = 40 mg/L

Scale = 1 : 31200
1 inch = 2600 feet

1300 0 2600ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Kriged Isoconcentration Map of Chloride in the Upper Hydrostratigraphic Unit

Groundwater Geochemistry Report

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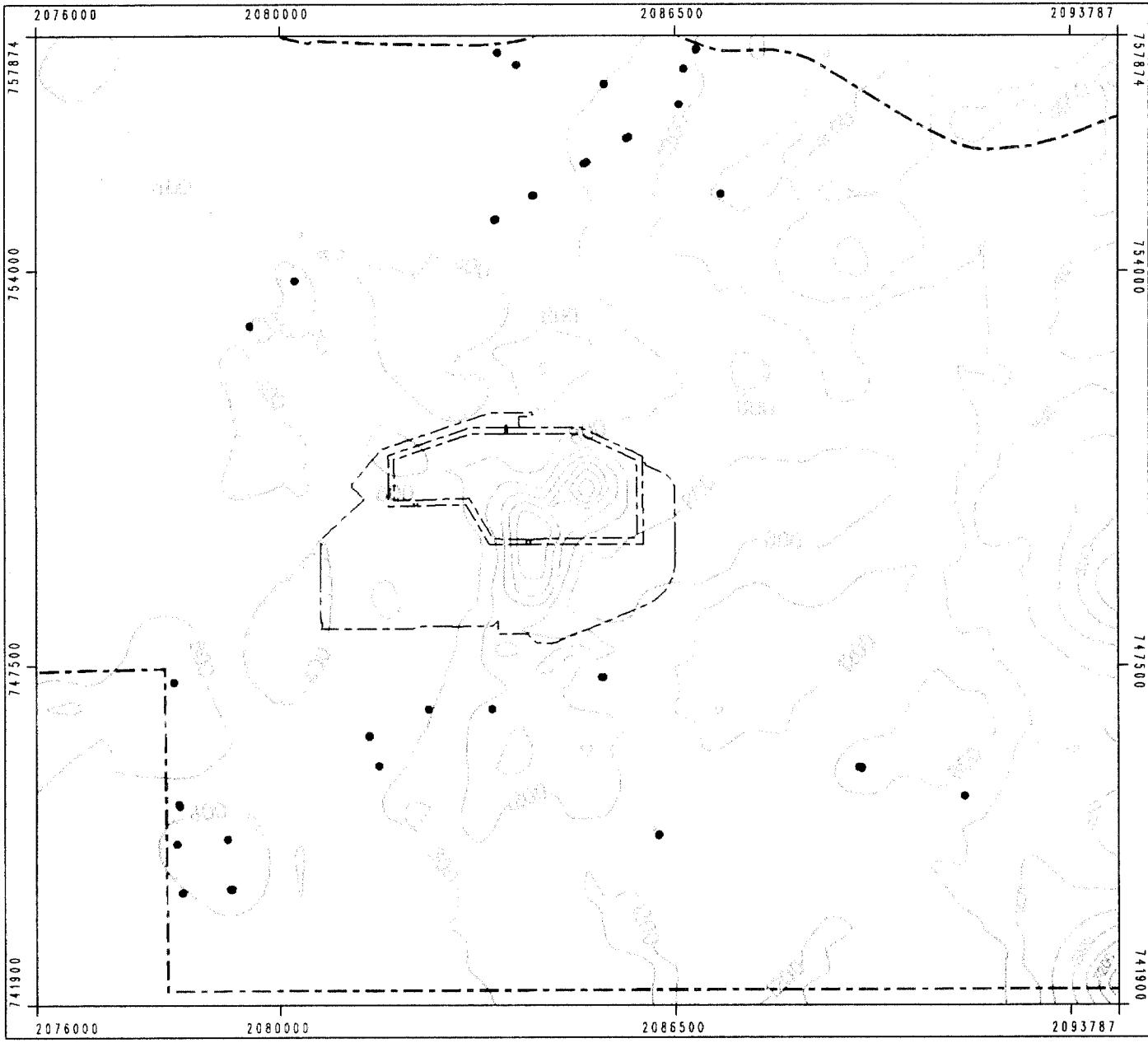

EXPLANATION

Lines of Equal Concentrations
(hachures indicate local low)

*Contour configuration represents estimated values based on kriging analysis.

Background Wells

Industrial Area and Security Zone Boundaries

Buffer Zone Boundary

Contour Interval = 400 ug/L

Scale = 1 : 31200
1 inch = 2600 feet

1300 0 2600ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Kriged Isoconcentration Map of Fluoride in the Upper Hydrostratigraphic Unit

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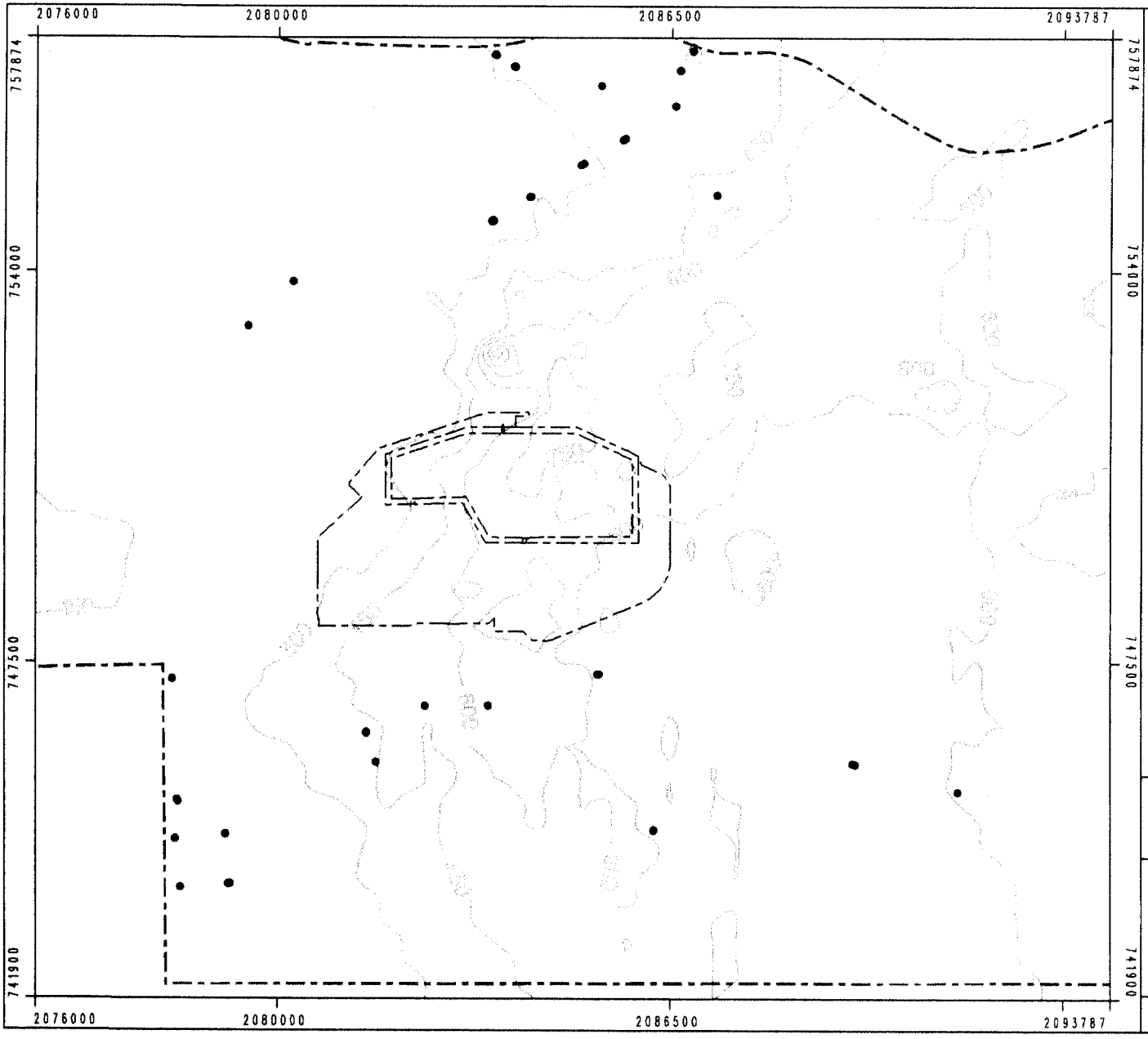

EXPLANATION

Lines of Equal Concentrations
(hachures indicate local low)

*Contour configuration represents estimated values based on kriging analysis.

Background Wells

Industrial Area and Security Zone Boundaries

Buffer Zone Boundary

Contour Interval = 150 mg/L

Scale = 1 : 31200
1 inch = 2600 feet
1300 0 2600ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Kriged Isoconcentration Map of Bicarbonate in the Upper Hydrostratigraphic Unit

Groundwater Geochemistry Report

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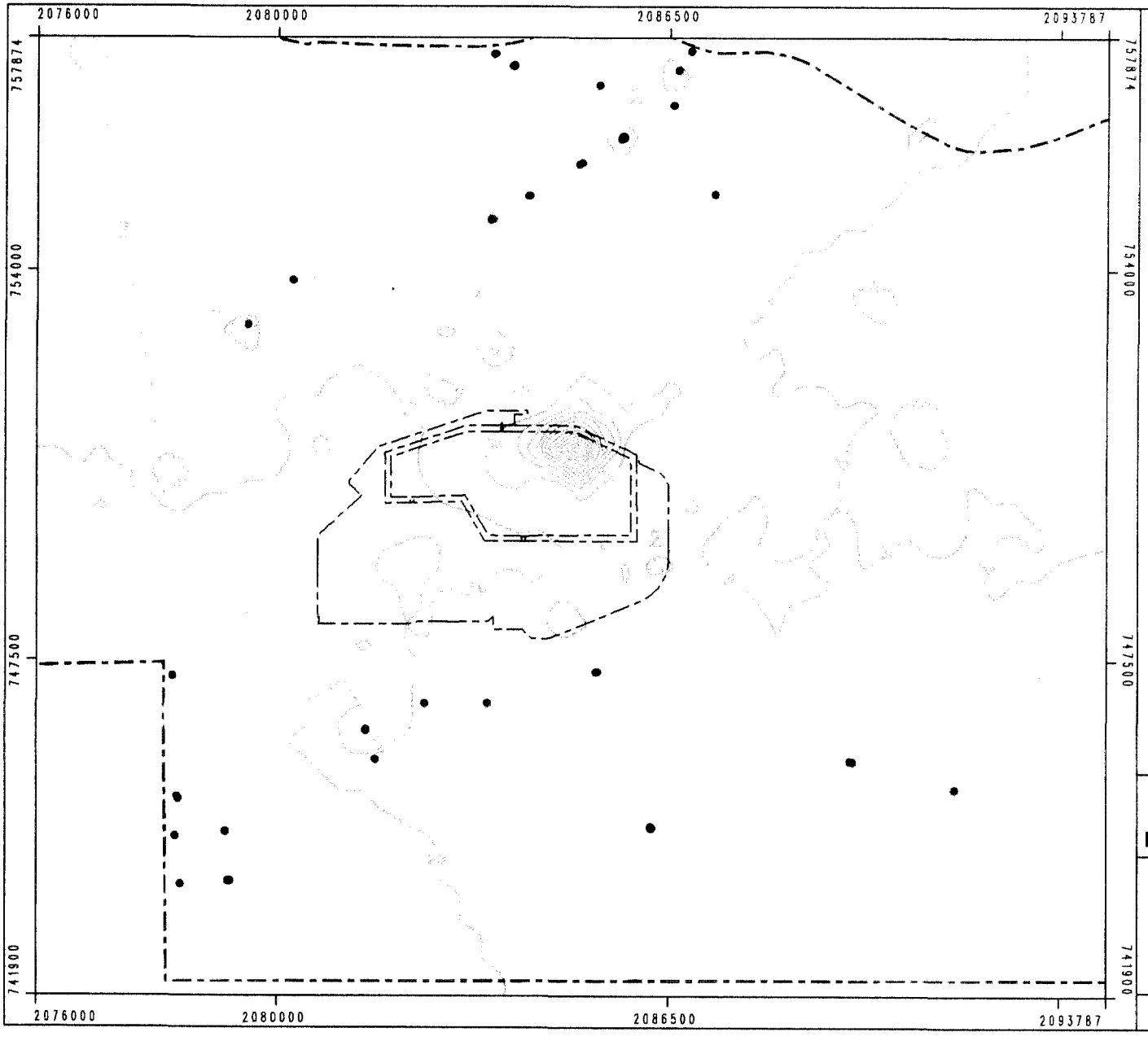

EXPLANATION

Lines of Equal Concentrations
(hachures indicate local low)

*Contour configuration represents estimated values based on kriging analysis.

Background Wells

Industrial Area and Security Zone Boundaries

Buffer Zone Boundary

Contour Interval = 2 mg/L

Scale = 1 : 31200
1 inch = 2600 feet

1300 0 2600ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Kriged Isoconcentration Map of Dissolved Potassium in the Upper Hydrostratigraphic Unit

Groundwater Geochemistry Report

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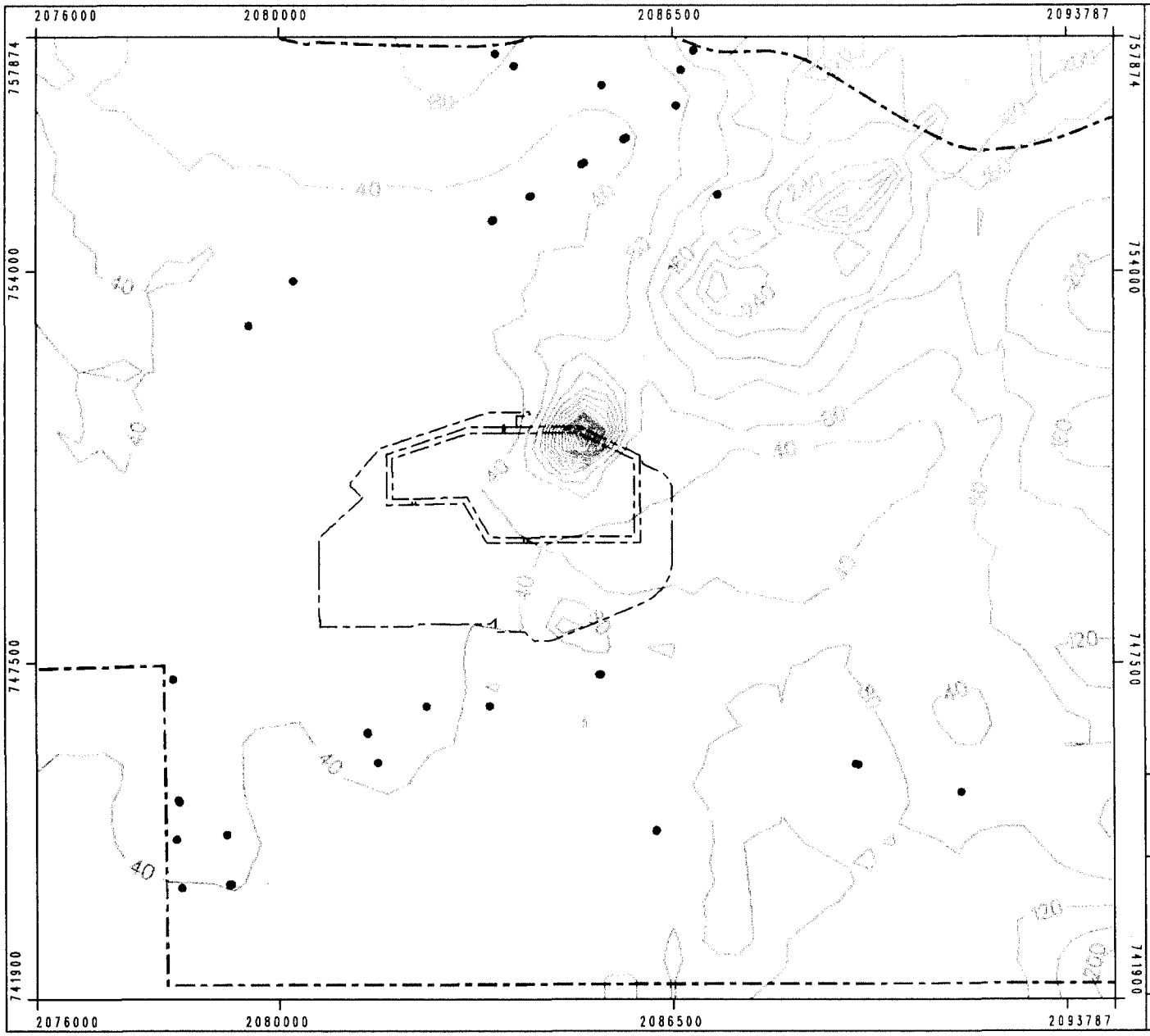

EXPLANATION

Lines of Equal Concentrations
(hachures indicate local low)

*Contour configuration represents estimated values based on kriging analysis.

Background Wells

Industrial Area and Security Zone Boundaries

Buffer Zone Boundary

Contour Interval = 40 ug/L

Scale = 1 : 31200
1 inch = 2600 feet
1300 0 2600ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Kriged Isoconcentration Map of Dissolved Lithium in the Upper Hydrostratigraphic Unit

Groundwater Geochemistry Report

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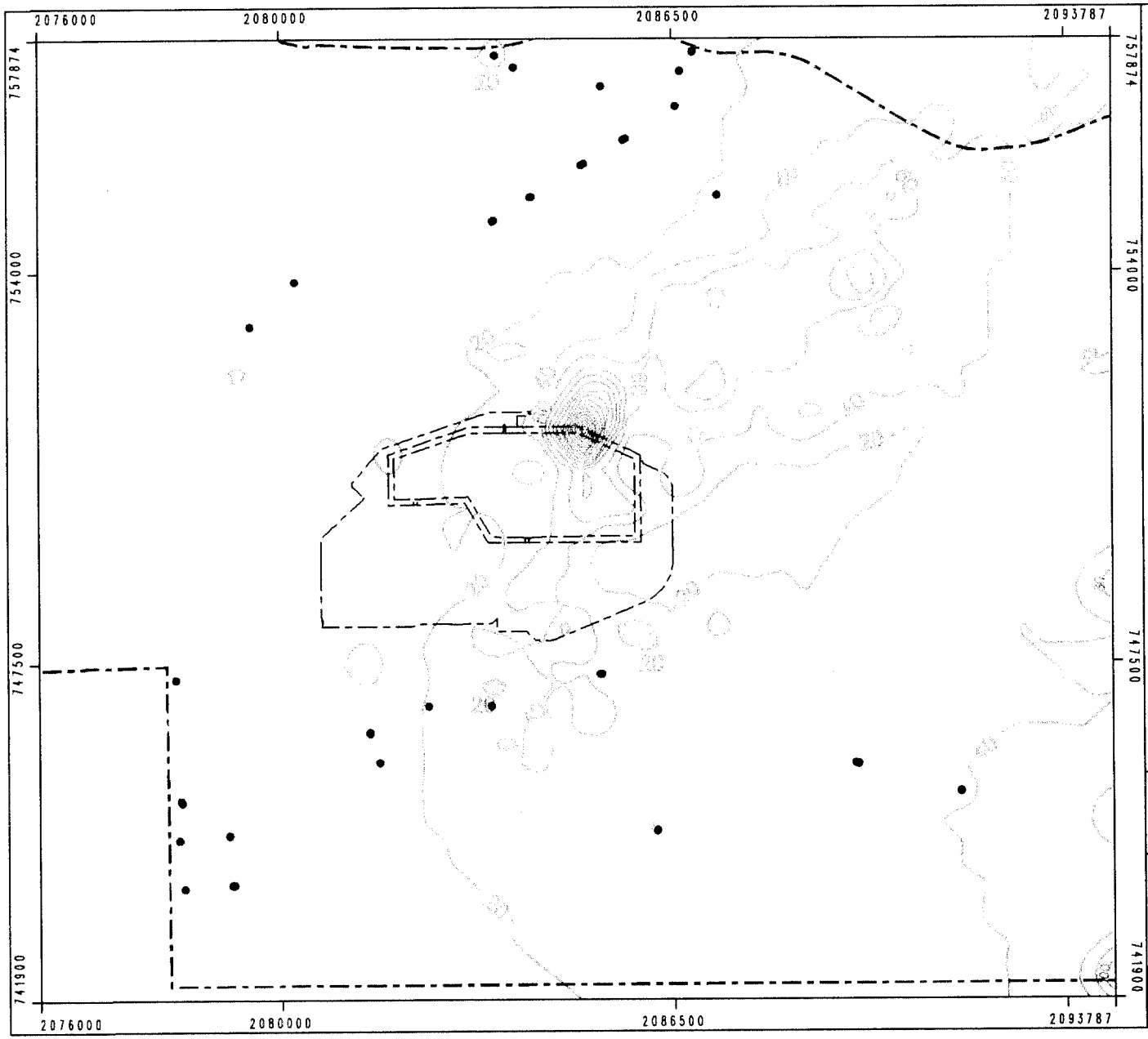

EXPLANATION

Lines of Equal Concentrations
(hachures indicate local low)

*Contour configuration represents estimated values based on kriging analysis.

Background Wells

Industrial Area and Security Zone Boundaries

Buffer Zone Boundary

Contour Interval = 20 mg/L

Scale = 1 : 31200
1 inch = 2600 feet

1300 0 2600ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Kriged Isoconcentration Map of Dissolved Magnesium in the Upper Hydrostratigraphic Unit

Groundwater Geochemistry Report

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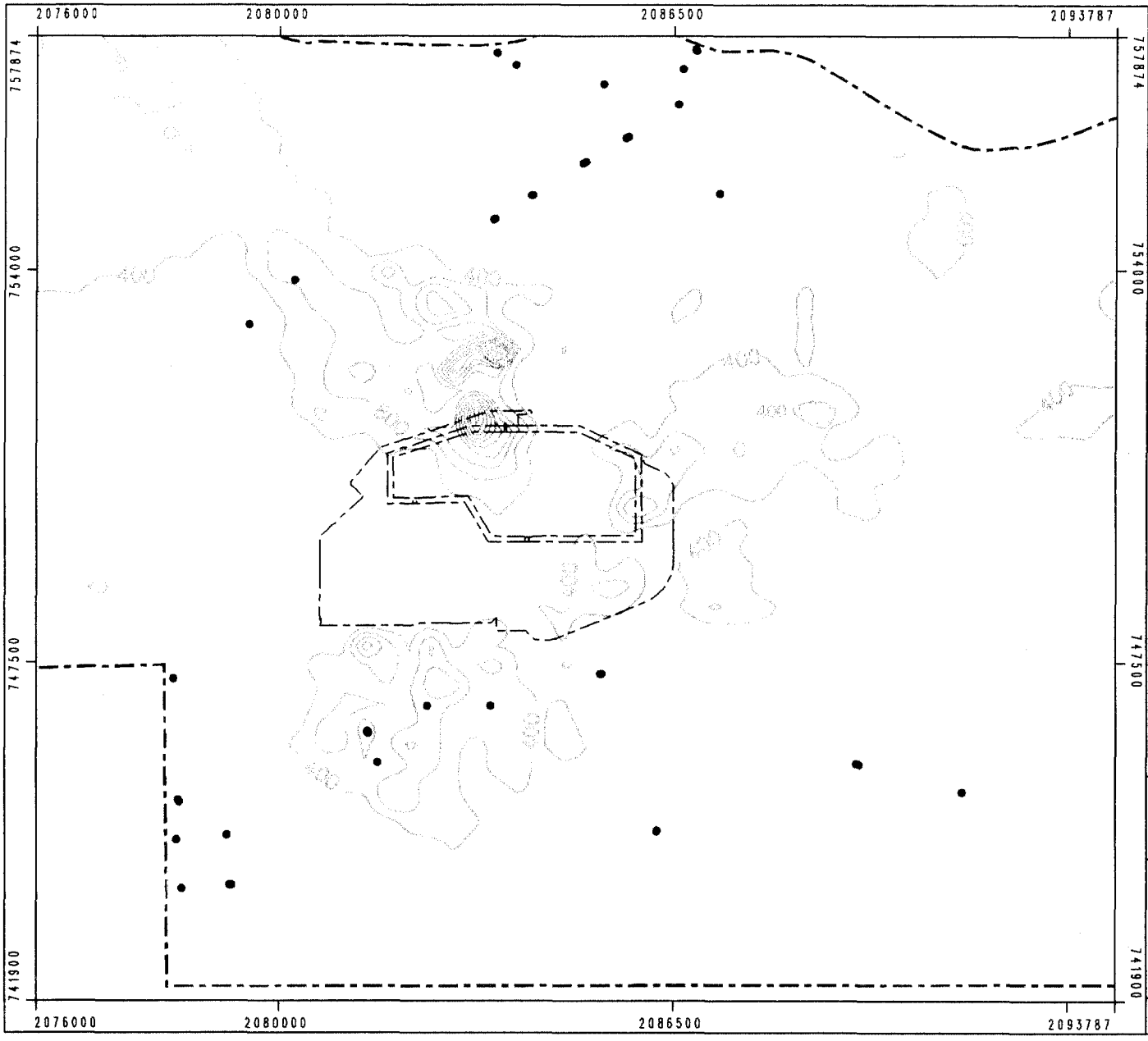

EXPLANATION

Lines of Equal Concentrations
(hachures indicate local low)

*Contour configuration represents estimated values based on kriging analysis.

Background Wells

Industrial Area and Security Zone Boundaries

Buffer Zone Boundary

Contour Interval = 400 ug/L

Scale = 1 : 31200
1 inch = 2600 feet
1300 0 2600ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Kriged Isoconcentration Map of Dissolved Manganese in the Upper Hydrostratigraphic Unit

Groundwater Geochemistry Report

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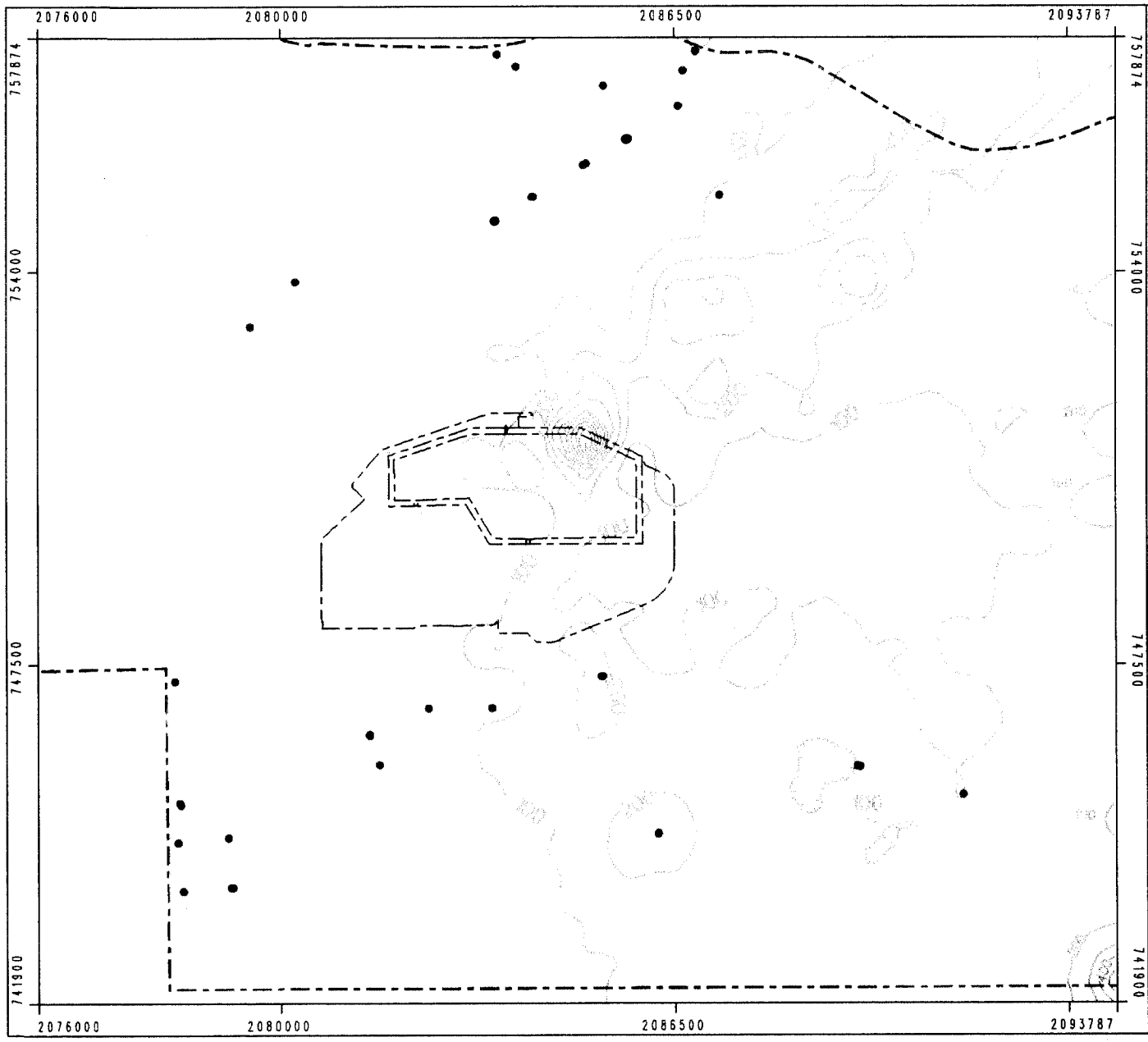

EXPLANATION

Lines of Equal Concentrations
(hachures indicate local low)

*Contour configuration represents estimated values based on kriging analysis.

Background Wells

Industrial Area and Security Zone Boundaries

Buffer Zone Boundary

Contour Interval = 100 mg/L

Scale = 1 : 31200
1 inch = 2600 feet
1300 0 2600ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Kriged Isoconcentration Map of Dissolved Sodium in the Upper Hydrostratigraphic Unit

Groundwater Geochemistry Report

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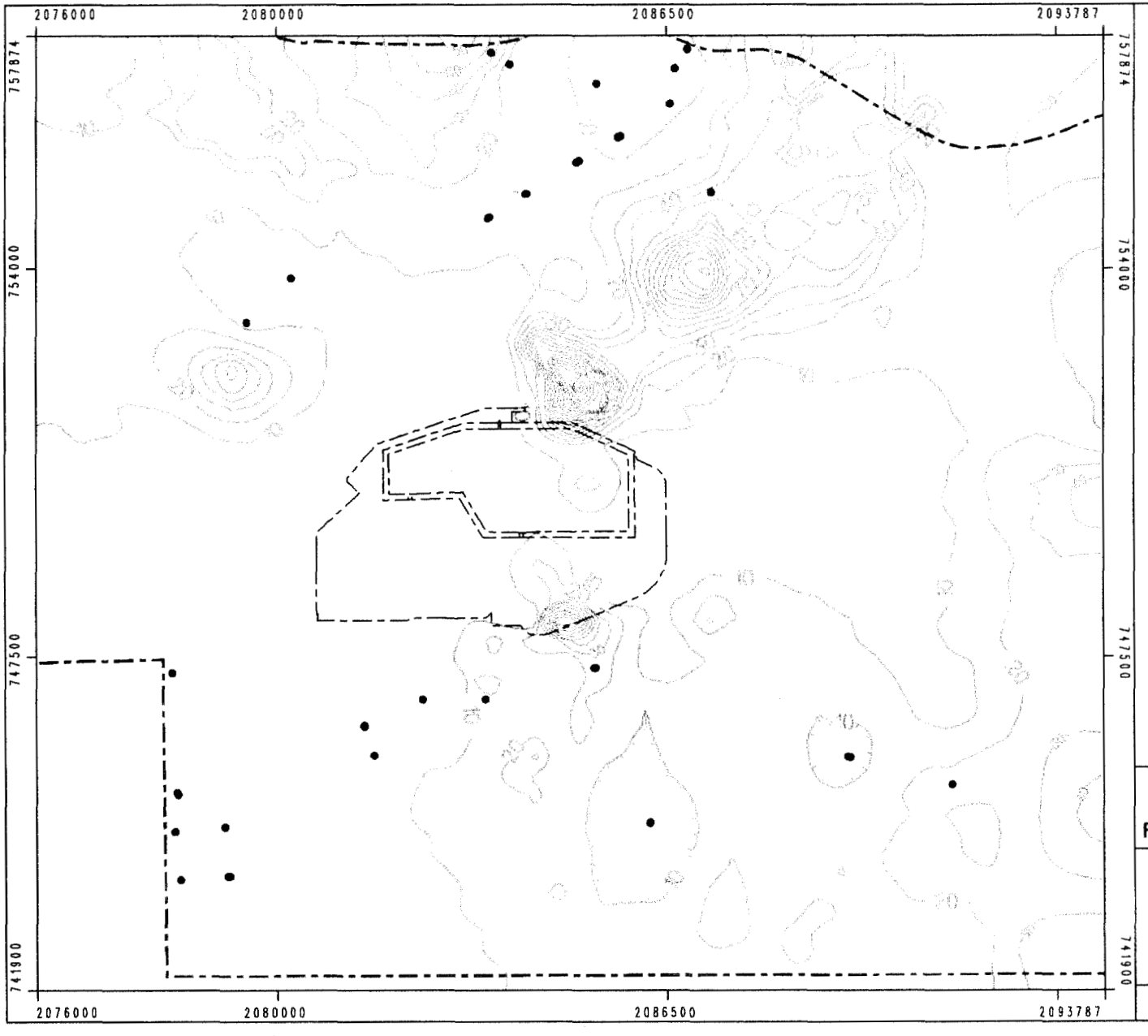


EXPLANATION

Lines of Equal Concentrations
(hachures indicate local low)

*Contour configuration represents estimated values based on kriging analysis.

Background Wells

Industrial Area and Security Zone Boundaries

Buffer Zone Boundary

Contour Interval = 10 ug/L

Scale = 1 : 31200
1 inch = 2600 feet

1300 0 2600ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

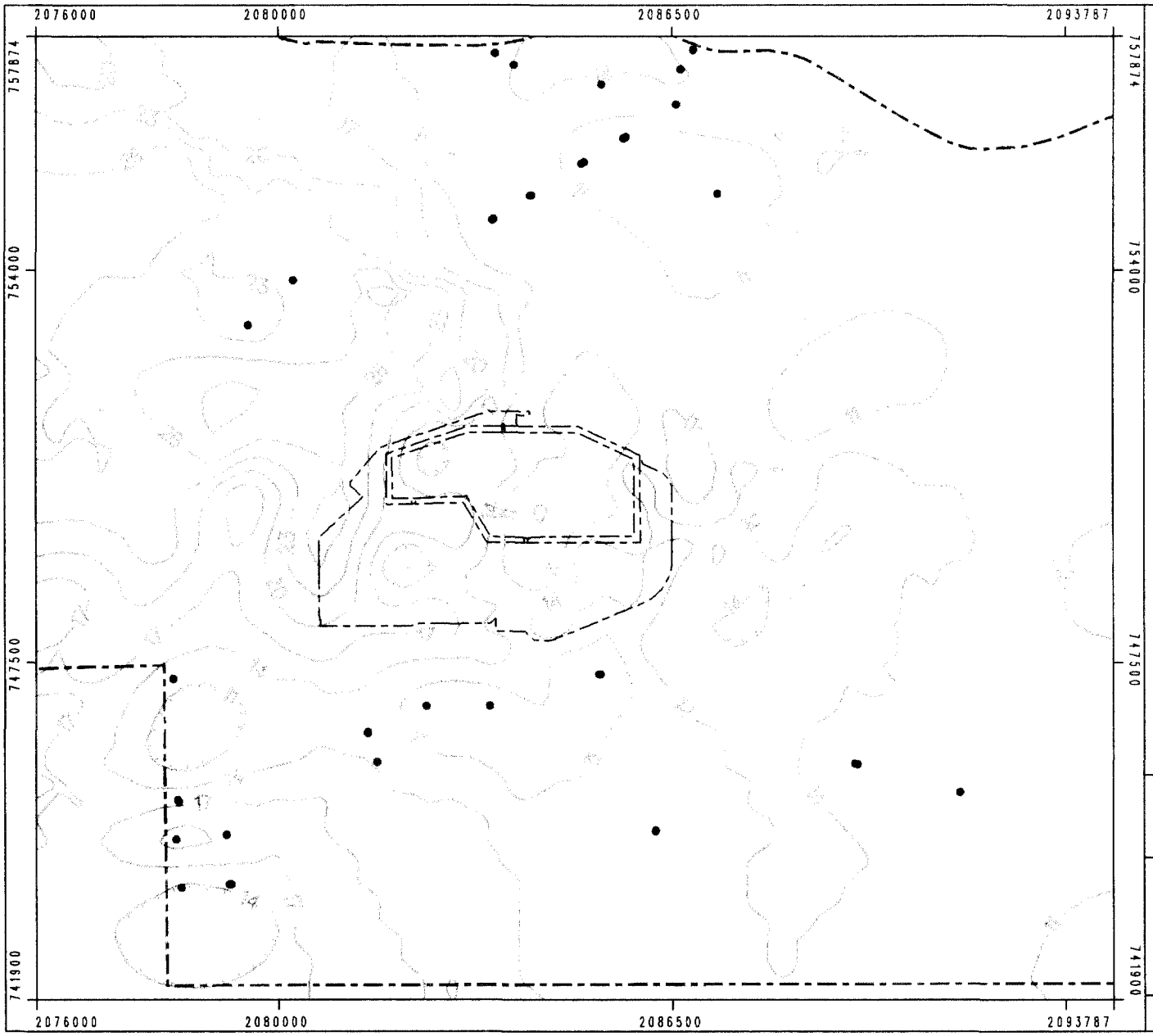
EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Kriged Isoconcentration Map of Dissolved Selenium in the Upper Hydrostratigraphic Unit

Groundwater Geochemistry Report

January 1995 | Figure 6-11



EXPLANATION

Lines of Equal Concentrations
(hachures indicate local low)

*Contour configuration represents estimated values based on kriging analysis.

Background Wells

Industrial Area and Security Zone Boundaries

Buffer Zone Boundary

Contour Interval = 3 mg/L

Scale = 1 : 31200
1 inch = 2600 feet

1300 0 2600ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Kriged Isoconcentration Map of Silica in the Upper Hydrostratigraphic Unit

Groundwater Geochemistry Report

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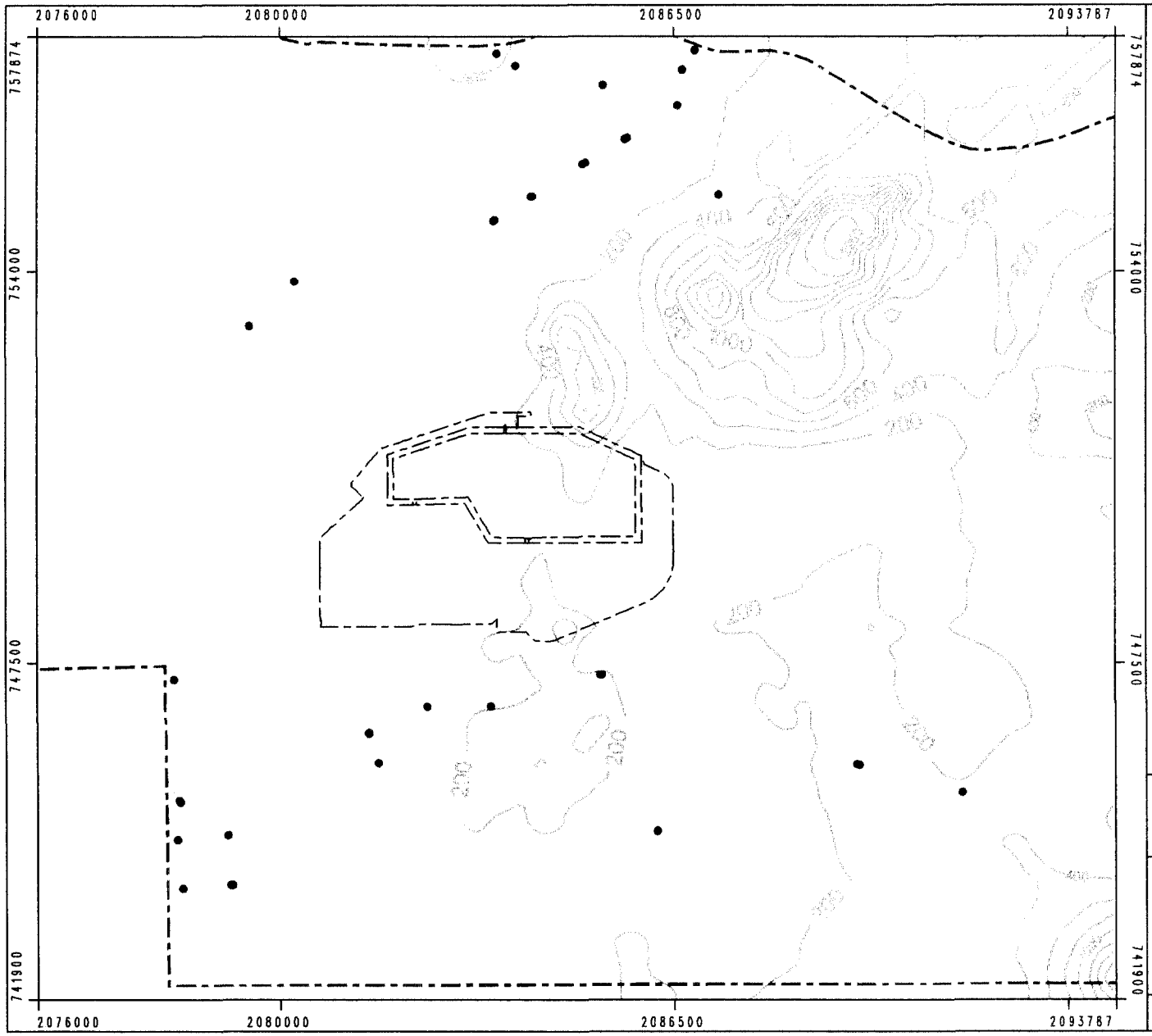

EXPLANATION

Lines of Equal Concentrations
(hachures indicate local low)

*Contour configuration represents estimated values based on kriging analysis.

Background Wells

Industrial Area and Security Zone Boundaries

Buffer Zone Boundary

Contour Interval = 200 mg/L

Scale = 1 : 31200
1 inch = 2600 feet
1300 0 2600ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Kriged Isoconcentration Map of Sulfate in the Upper Hydrostratigraphic Unit

Groundwater Geochemistry Report

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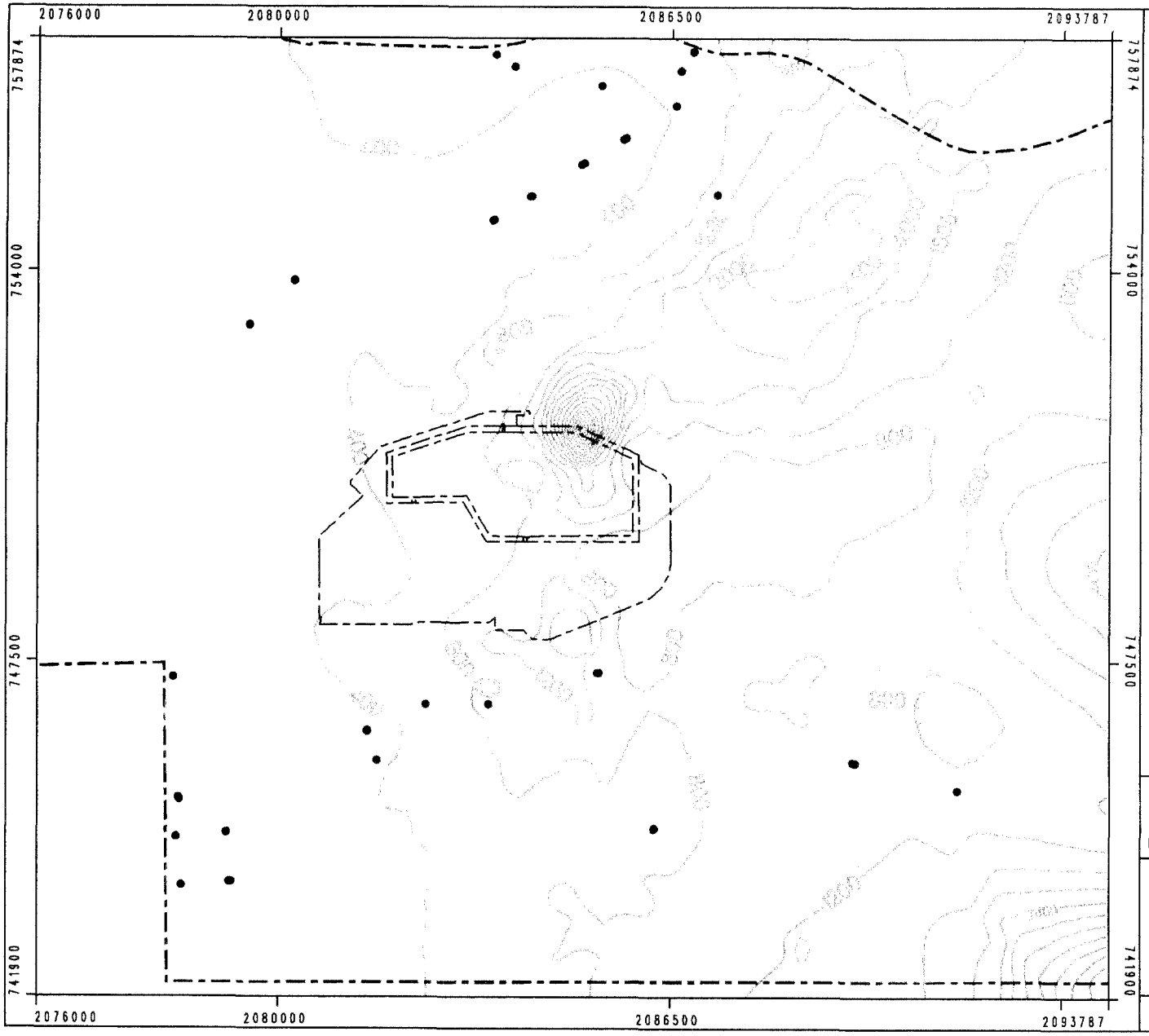


EXPLANATION

Lines of Equal Concentrations
(hachures indicate local low)

*Contour configuration represents estimated values based on kriging analysis.

Background Wells

Industrial Area and Security Zone Boundaries

Buffer Zone Boundary

Contour Interval = 400 ug/L

Scale = 1 : 31200
1 inch = 2600 feet

1300 0 2600ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

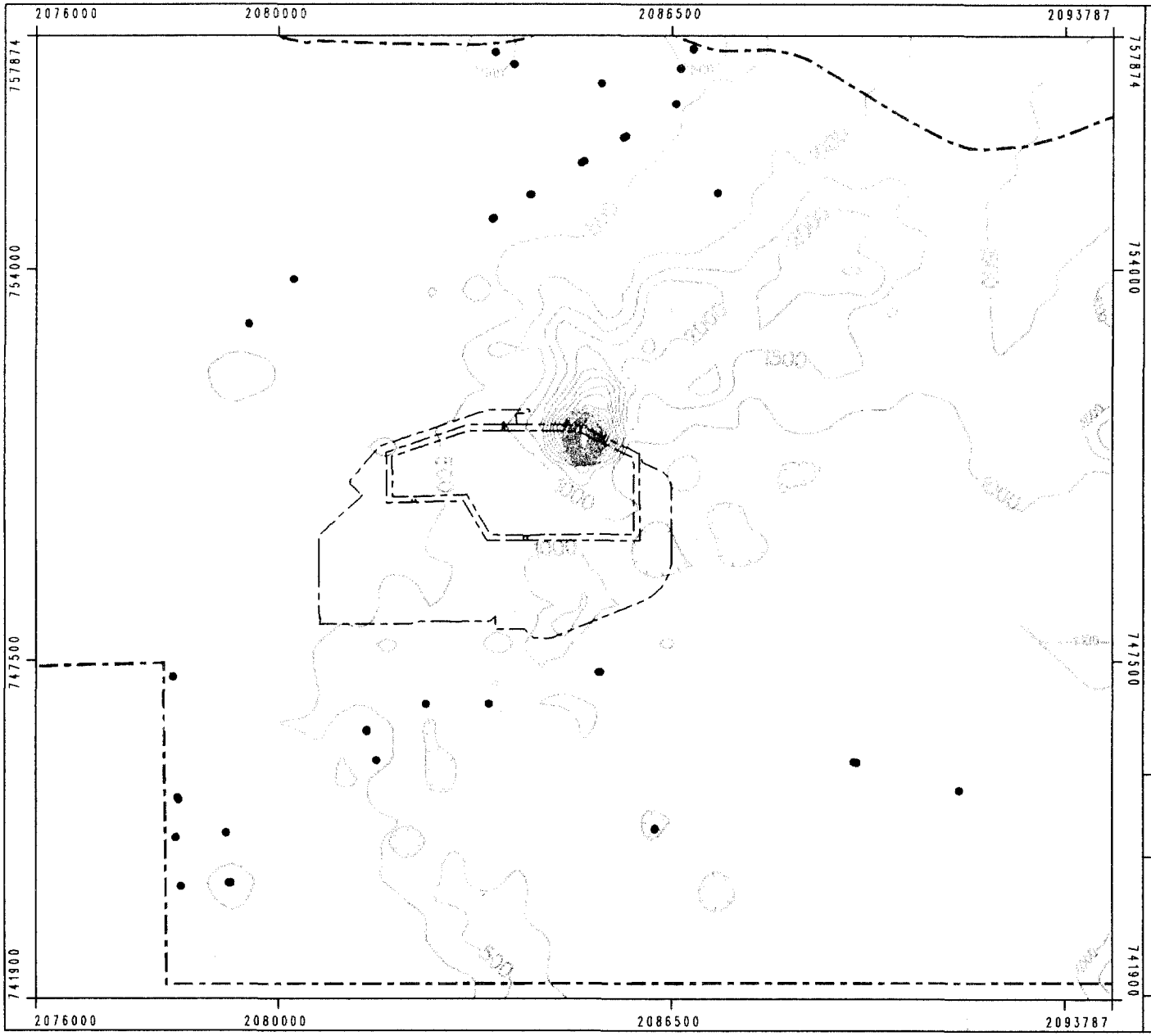
Rocky Flats Site, Golden, Colorado

Kriged Isoconcentration Map of Dissolved Strontium in the Upper Hydrostratigraphic Unit

Groundwater Geochemistry Report

January 1995

Figure 6-14



EXPLANATION

Lines of Equal Concentrations
(hachures indicate local low)

*Contour configuration represents estimated values based on kriging analysis.

Background Wells

Industrial Area and Security Zone Boundaries

Buffer Zone Boundary

Contour Interval = 500 mg/L

Scale = 1 : 31200
1 inch = 2600 feet

1300 0 2600ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

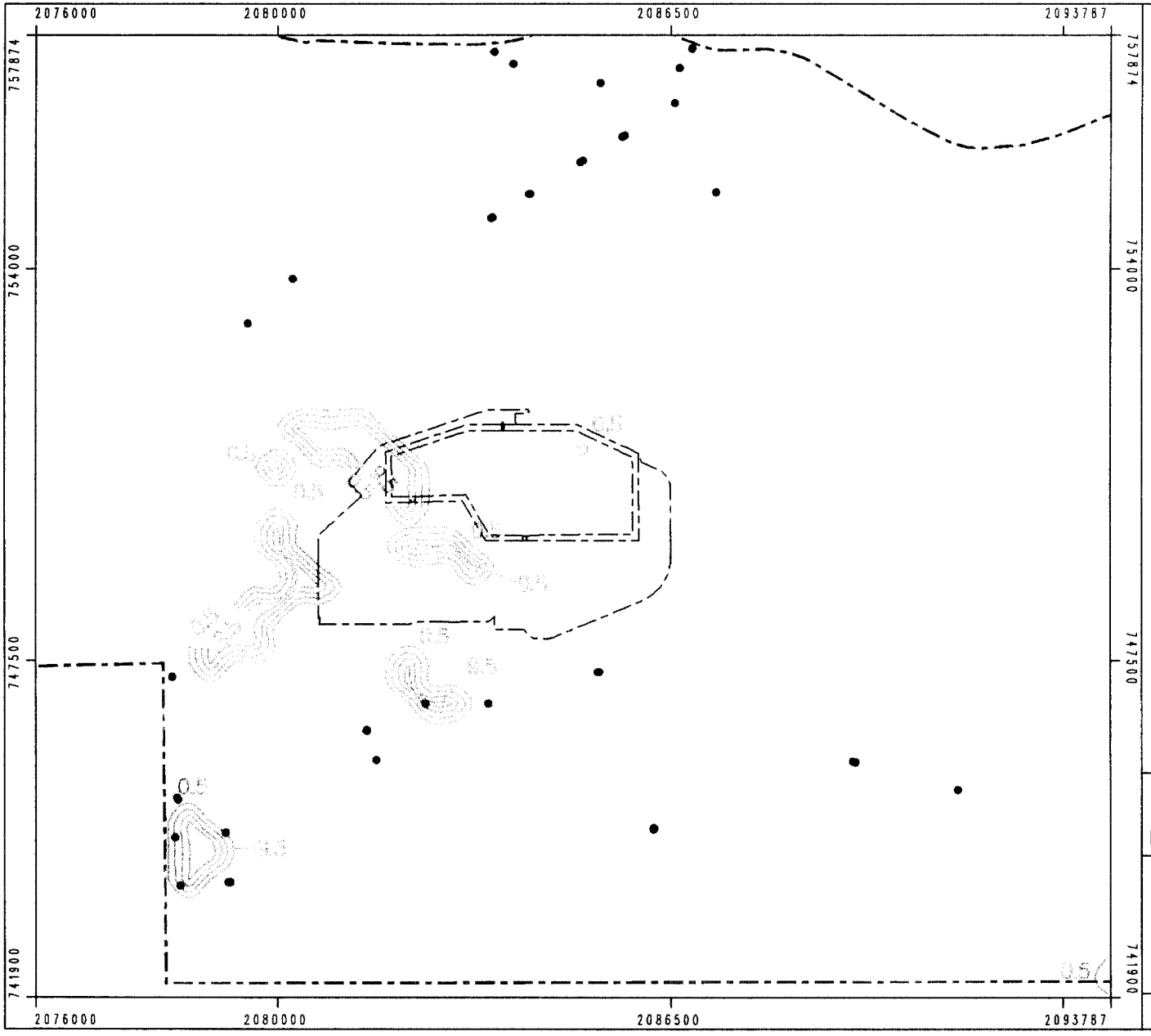
EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Kriged Isoconcentration Map of TDS in the Upper Hydrostratigraphic Unit

Groundwater Geochemistry Report

January 1995 | Figure 6-15



EXPLANATION

Lines of Equal Concentrations
(hachures indicate local low)

*Contour configuration represents estimated values based on kriging analysis.

Background Wells

Industrial Area and Security Zone Boundaries

Buffer Zone Boundary

Contour Interval = 3 pCi/L

Scale = 1 : 31200
1 inch = 2600 feet

1300 0 2600ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

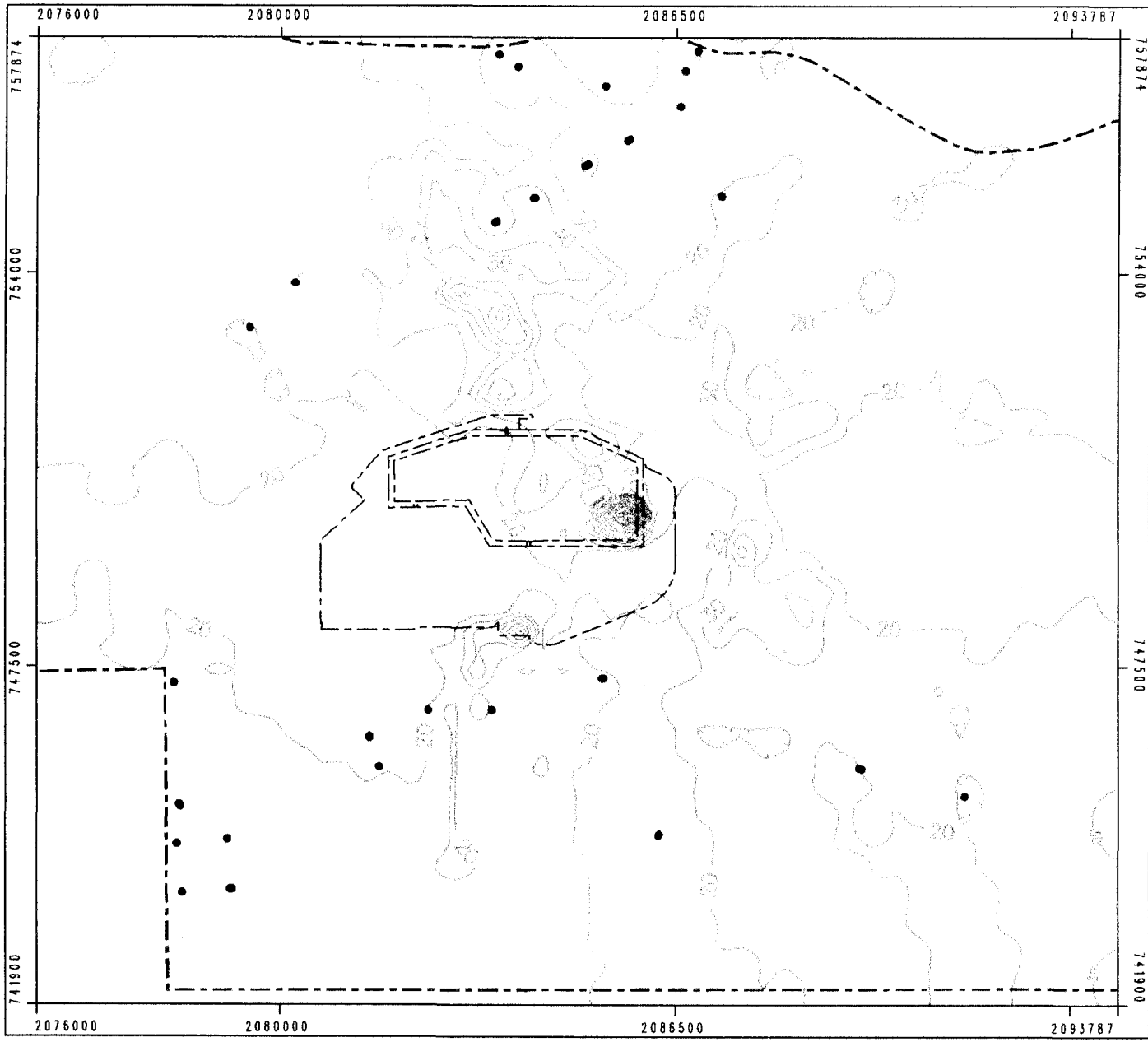
EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Kriged Isoconcentration Map of Dissolved Uranium-235 in the Upper Hydrostratigraphic Unit

Groundwater Geochemistry Report

January 1995 | Figure 6-16



EXPLANATION

Lines of Equal Concentrations
(hachures indicate local low)

*Contour configuration represents estimated values based on kriging analysis.

Background Wells

Industrial Area and Security Zone Boundaries

Buffer Zone Boundary

Contour Interval = 10 ug/L

Scale = 1 : 31200
1 inch = 2600 feet

1300 0 2600ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

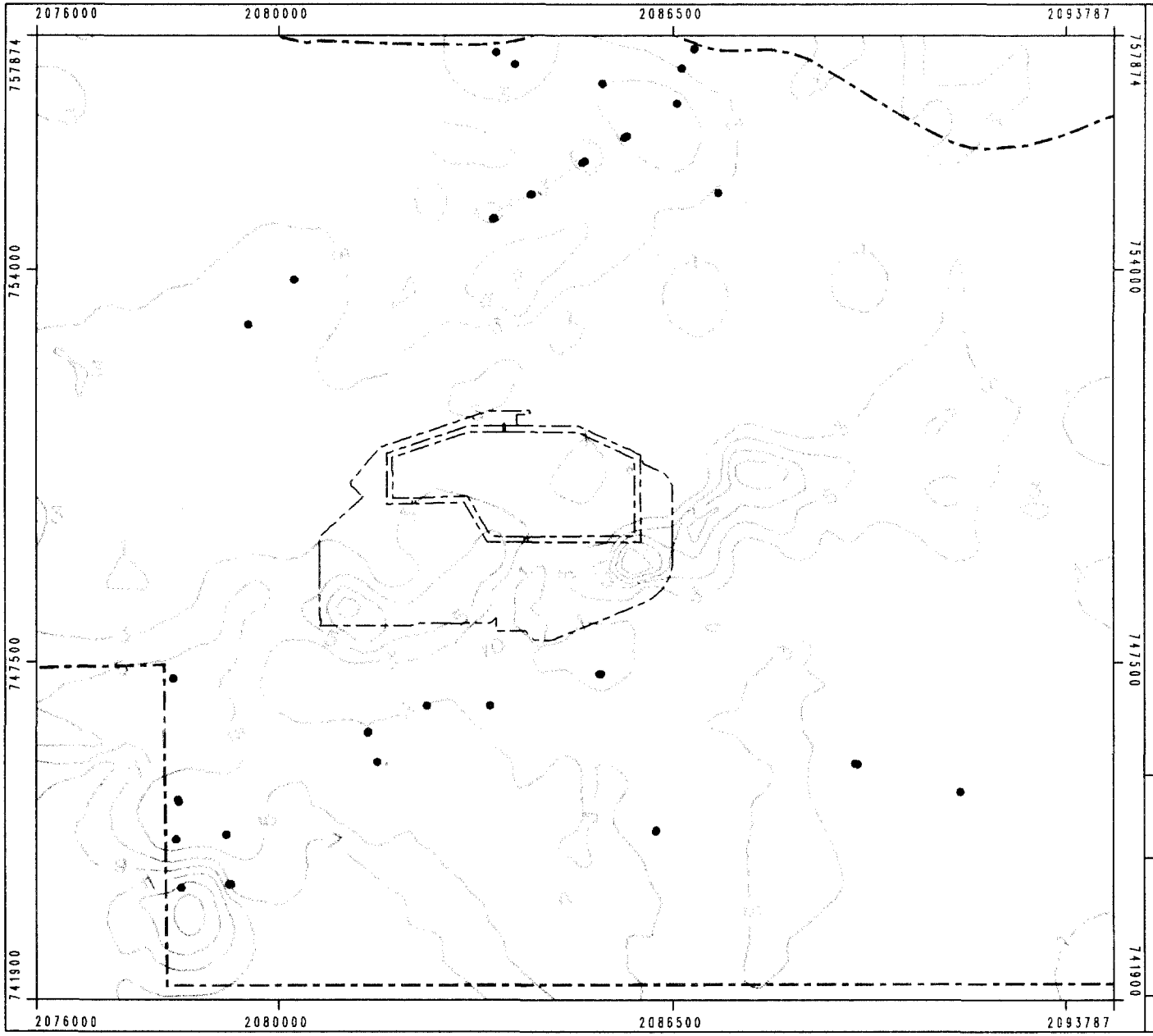
EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Kriged Isoconcentration Map of Dissolved Zinc in the Upper Hydrostratigraphic Unit

Groundwater Geochemistry Report

January 1995 | Figure 6-17



EXPLANATION

Lines of Equal Concentrations
(hachures indicate local low)

*Contour configuration represents estimated values based on kriging analysis.

Background Wells

Industrial Area and Security Zone Boundaries

Buffer Zone Boundary

Contour Interval = 2
(Ratios are based on mg/L)

Scale = 1 : 31200
1 inch = 2600 feet

1300 0 2600ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

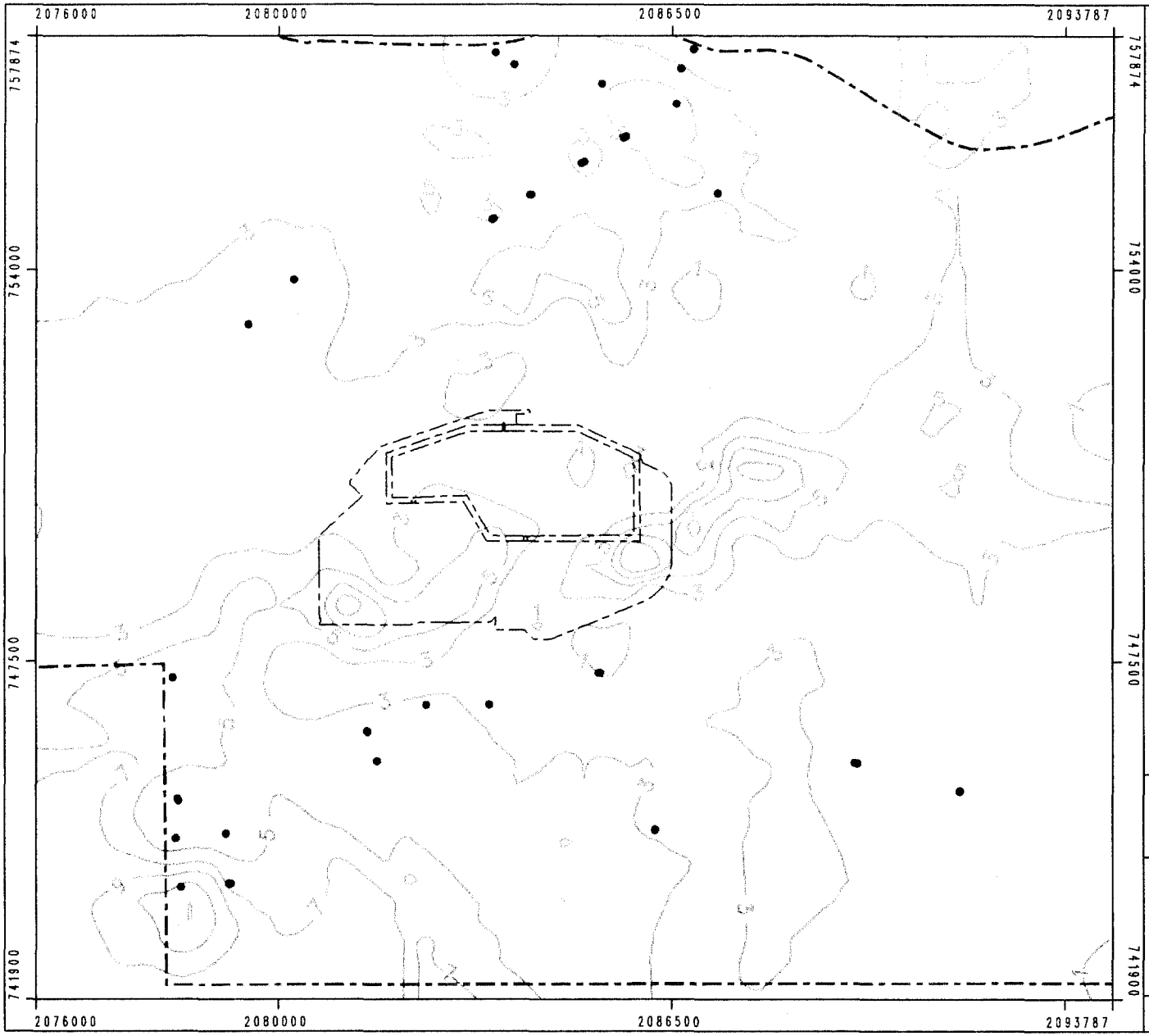
EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Kriged Isoconcentration Map of Ca/Na Ratio in the Upper Hydrostratigraphic Unit

Groundwater Geochemistry Report

January 1995 | Figure 6-18



EXPLANATION

Lines of Equal Concentrations
(hachures indicate local low)

*Contour configuration represents estimated values based on kriging analysis.

Background Wells

Industrial Area and Security Zone Boundaries

Buffer Zone Boundary

Contour Interval = 2
(Ratios are based on mg/L)

Scale = 1 : 31200
1 inch = 2600 feet

1300 0 2600ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Kriged Isoconcentration Map of Ca+Mg/Na+K Ratio in the Upper Hydrostratigraphic Unit

Groundwater Geochemistry Report

January 1995 | Figure 6-19

from Rocky Flats Lake appears to have a northward-directed component that feeds springs along the base of the surficial deposits towards Woman Creek (within OU5).

Groundwater from weathered bedrock (UHSU) in the Industrial Area has the highest tritium contents of any groundwater from the site. Groundwater samples from six monitoring wells (P207389, P209389, P209489, P209589, P209689, and P210189), located both upgradient and downgradient of the Solar Evaporation Ponds, have tritium contents between 80 and 3,703 TU (refer to Plate 4). In contrast, samples of LHSU groundwater from the same area have no detectable tritium, and groundwater samples from the overlying surficial deposits have tritium contents ranging from 35 to 90 TUs. The tritium contents of groundwater from the weathered bedrock are generally higher than expected for groundwater derived from precipitation (see discussion in Section 7.4.2). The alternate source of tritium within the Industrial Area is not known, but may be related to tritium releases that occurred at the site in 1968 and 1973 (AEC, 1973) or to tritium-enriched waters leaking from the Solar Evaporation Ponds. The high-tritium groundwater is easily traced, however, and could be used to monitor groundwater flow paths from the Solar Evaporation Ponds toward Walnut Creek and eastern portions of the Industrial Area.

7.5 Conclusions

Additional environmental-isotope data from precipitation, surface-water, and groundwater samples have helped to refine the conceptual model for groundwater flow at the Rocky Flats site. The similarity in isotopic compositions of groundwater from the various lithostratigraphic units of the UHSU supports the current definition of that hydrostratigraphic unit. White (1991) concluded that groundwater from the surficial materials and bedrock were isotopically distinct and, therefore, not mixing; the results from this study demonstrate that there is no isotopic distinction between groundwater from the diverse geologic units of the UHSU, and strongly suggest that all units within the UHSU are hydraulically connected.

Although the average isotopic compositions of groundwater in surficial deposits and weathered bedrock are not distinct, there are some areas on the site, such as east of Rocky Flats Lake, where the UHSU groundwater exhibits vertical isotopic gradients. The vertical variation in isotopic composition indicates that bodies of groundwater originating from distinct sources can remain unmixed during flow across a distance greater than one mile, through the UHSU.

Isotopic distinctions between groundwater from the UHSU and LHSU also support the current flow-system model for the Rocky Flats site. The interaction between UHSU and LHSU groundwaters is greatest within approximately 50 feet of the change in permeability that marks the weathered/unweathered contact. The apparent shift to

higher *d* values in the deep LHSU, as compared to the shallow portions of the LHSU, has not been fully explained but may be related to the age of the deeper groundwater.

There are few spatial variations in the isotopic composition of groundwater. The large-scale spatial variations observed by White (1991) were not found to be consistent through time. The main source of recharge to the UHSU is precipitation. However, groundwater in the UHSU has slightly less-negative *d* values than precipitation, and this shift may be related to evaporation from precipitation prior to or during recharge. Isotopically distinct sources of recharge can also be identified in groundwater, and White's (1991) original observation that groundwater may locally contain a component of "evaporated" water was supported by the results of this study. Groundwater on the west side of the site appears to contain a component of water derived from surface-water bodies. Groundwater from the Industrial Area contains a component of isotopically heavy water that may have originated from the Solar Evaporation Ponds or other such sources on the site.

component of LHSU groundwater, the initial isotopic compositions of the paleowaters must be known in order to calculate the fraction of the LHSU groundwater derived from this source.

Very low tritium contents in the LHSU groundwater support evidence for the presence of old groundwater in that unit. Non-detectable amounts of tritium indicate that the main component of groundwater in this unit is more than 40 years old.

7.4.2 Interaction Between Hydrostratigraphic Units

As discussed above, the contrast in tritium contents of groundwaters from the UHSU and LHSU appears related to distinct sources of recharge for the two units, but may also reflect large differences in the age of groundwater in the two units. The approximate age of groundwater in the UHSU can be estimated based on the tritium content of the groundwater and past precipitation (recharge).

Records of tritium content in precipitation from the western United States provide a rough estimate of the historic content of tritium in precipitation at Rocky Flats. Figure 7-13 shows the tritium contents of precipitation from two stations in the central and western United States. At both locations, the tritium content (weighted mean) in precipitation peaked during 1963, at 1,545 TU at St. Louis and at 1,899 TU at Albuquerque (IAEA, 1992). Recharge to groundwater since the onset of atmospheric nuclear-weapons testing in 1952, and especially during the period of peak tritium fallout, has had much higher tritium concentrations than recharge from any previous period of time. Tritium contents in precipitation prior to 1952 were not measured. The range of tritium contents in current precipitation (9 to 16 TU in 1993 and 1994), however, provides good estimates of the upper concentration range for naturally occurring tritium in pre-1952 precipitation. Using a value of 16 TU for pre-1952 tritium in precipitation, groundwater more than 40 years old would have tritium contents of less than 1.6 TU today. Groundwater derived from precipitation since 1963 should have tritium contents between approximately 10 and 300 TU depending on its age and the extent of more recent mixing with younger groundwaters. (These estimates are based on calculations of tritium decay starting from the mean annual tritium contents of precipitation collected in Albuquerque, New Mexico, from 1963 through 1987.)

At Rocky Flats, groundwater from the LHSU generally has no measurable tritium. In contrast, UHSU groundwater typically contains from 10 to 50 TU of tritium, though a tritium content as high as 3,703 TU was measured. The main component of LHSU groundwater, therefore, is older than the UHSU groundwater and apparently older than the Rocky Flats Plant (1952). The UHSU groundwater has tritium contents consistent with ages of less than 40 years, indicating that recharge to the UHSU is more recent.

The relatively sharp break in the vertical profile of tritium contents at the base of the UHSU may be the result of a zone of lower permeability. A low-permeability zone may also serve as an effective barrier to downward transport of contaminants. However, despite the sharp break in tritium contents, there is evidence for mixing between LHSU groundwater and recharge from the UHSU. Some LHSU groundwaters with no detectable tritium do contain detectable concentrations of VOCs. At well 2087 located within OU2, LHSU groundwater contains detectable tetrachloroethene and trichloroethene but no detectable tritium (EG&G, 1994d). The presence of man-made VOCs in the groundwater clearly indicates that relatively recent recharge from the near surface has occurred. Thus, tritium-depleted (i.e., old) LHSU groundwater may contain a component of relatively young UHSU groundwater. Where VOCs are present in LHSU groundwater but tritium is not detected, the VOCs provide a more sensitive indicator of contaminant infiltration and transport.

Low-tritium groundwater may also result from a process of tritium diffusion in the subsurface. Rauert *et al.* (1993) describe the loss of tritium from mobile groundwater due to diffusion into immobile pore water in clayey or silty layers. However, they concluded that this process probably has only minor effects on the tritium content of groundwater. If this process takes place at Rocky Flats, a more regular gradient in the tritium content of groundwater over depth would be expected. Tritium diffusion can also occur along a flow path in fractured media. This process of tritium loss is potentially significant (Foster, 1975; Day, 1977). At Rocky Flats, fractures are present in the shallow bedrock, but the extent to which fractures control and direct groundwater flow at the site is not known.

7.4.3 Groundwater Flow in the UHSU

The isotopic composition of groundwater can be used to trace the direction of flow if isotopically distinct groundwaters are present. At Rocky Flats, groundwater with distinctive isotopic compositions is present in a few areas. Heavy-isotope-enriched groundwater is present in the lowermost portion of the surficial deposits located downgradient of Rocky Flats Lake. Vertical gradients in the isotopic composition of groundwater provide evidence that the groundwater mixes slowly and incompletely during flow through the subsurface. Most of the mixing may occur at discharge points or in monitoring-well screens.

Similarly heavy-isotope-enriched water emanates from Antelope Spring and from several smaller springs on the south side of Woman Creek farther downgradient of Rocky Flats Lake. The spring water appears to originate from the base of the surficial deposits, and its isotopic composition suggests that it ultim2ately originates, at least in part, from a heavier source such as Rocky Flats Lake. Therefore, groundwater flow

however, the lake sits within alluvial deposits and is connected to the UHSU. Leakage from Rocky Flats Lake to the UHSU can be identified by the relatively heavy isotopic signature of the lake. The isotopic compositions of groundwater collected downgradient of the lake indicate that the water contains at least a component of relatively heavy water originating from Rocky Flats Lake. Mixing between precipitation and recharge from surface water produces the intermediate isotopic compositions measured in the groundwater.

Temporal variations in the isotopic composition of water from Rocky Flats Lake have not been described, thus a quantitative assessment of the relative contributions from the surface-water body and precipitation to groundwater recharge is not possible. Isotope data from well clusters located downgradient of Rocky Flats Lake demonstrate that the proportion of groundwater derived from surface-water bodies is highest in the deepest portion of the surficial deposits (Figure 7-11). Therefore, groundwater from wells screened at shallower levels or across extended depths may not show the same isotopic distinction from groundwater collected from the deep surficial deposits. For this reason, the apparent scatter in the spatial distribution of groundwater enriched in heavy isotopes (less-negative *d* values) may be a sampling effect related to well construction and not representative of groundwater compositions.

Slightly less-negative $\delta^{18}O$ and δD values are also observed in UHSU groundwater from the central part of the Industrial Area. In this area, groundwater from the weathered bedrock tends to have less-negative $\delta^{18}O$ values than groundwater from the overlying surficial deposits and less-negative values than groundwater from other parts of the Rocky Flats site. These groundwaters may have acquired their isotopic compositions from a component of water derived from the evaporation ponds. The isotopic compositions of the pond waters were never measured, but probably would reflect the isotopic composition of process water with heavy-isotope enrichment from evaporation (the isotopic composition of process water was never measured). At a few locations (wells P209689 and P209889, refer to Plate 1 for well locations), the heavier isotopic signature is evident only in groundwater from the weathered bedrock and not in the surficial deposits, indicating that the UHSU may no longer be receiving recharge from the isotopically heavier source. At other locations (wells P209289, P209389, and 3386, refer to Plate 1 for well locations), however, average $\delta^{18}O$ values are greater than -12 in groundwater from both the surficial deposits and weathered bedrock of the UHSU. Thus, isotopically distinct sources of recharge appear to contribute to UHSU groundwater within the Industrial Area. These sources have not been characterized.

The contributions to groundwater from streams, ditches, and retention ponds (A-, B-, and C-series ponds) on the site could not be evaluated. Not enough data are available to describe isotopic variations in these surface-water bodies. Groundwater from the UHSU below the Walnut Creek and Woman Creek drainages generally shows higher

$\delta^{18}O$ and δD values than does groundwater from adjacent areas. However, the isotopic compositions of these surface waters have not been well described, and contributions to recharge from these sources cannot be identified. Additional surface-water samples are currently (during 1995 fiscal year) being collected by EG&G to address this question.

In summary, there are at least two sources of recharge to the UHSU: (1) incident precipitation and (2) infiltration from lakes, ponds, and water impoundments. These two sources are generally isotopically distinct. Better characterization of local rainfall, snow, and snowmelt, and additional characterization of surface-water bodies on the site are required to quantitatively evaluate the relative inputs to UHSU groundwater from these two sources.

7.4.1.2 Recharge to LHSU Groundwater

In the LHSU, groundwater has $\delta^{18}O$ and δD values within the ranges defined by UHSU groundwater and local precipitation. Therefore, one may conclude that the primary source of recharge to the LHSU is leakage from the overlying UHSU. At increasing depth within the LHSU, however, both $\delta^{18}O$ and δD shift toward slightly less negative values as shown in Figures 7-8 and 7-9. The less-negative *d* values of the deeper LHSU groundwaters are distinct from the average *d* values of UHSU groundwaters.

The shift to less-negative $\delta^{18}O$ and δD values at depth could be related to water/rock interactions or the residence time of the groundwater. At low temperatures (< 80°C), oxygen exchange with rock minerals requires very long residence times (more than one million years) and generally tends to increase the ^{18}O content of the water, but without modification of the D content (Fontes, 1981). Therefore, the slight isotopic shift observed in both the ^{18}O and D contents of deep LHSU groundwaters is not consistent with the results of water/rock exchange reactions. Alternatively, increased *d* values in the deep LHSU may indicate an additional source of LHSU groundwater that is distinct in isotopic composition from UHSU groundwater (i.e., very old groundwater/ paleowater).

The age of groundwater in the LHSU has not been determined. The calculated seepage velocity (refer to Hydrogeologic Characterization Report and Section 4.2.5) can be used to estimate the vertical distance traveled by groundwater in the LHSU over a given period of time. Given a vertical seepage velocity of 5.8×10^{-7} cm/sec (EG&G, 1995b), groundwater collected from 50 feet below the top of the LHSU will be at least 100 years old (assuming vertical flow). Much older groundwater may be present at greater depth in the LHSU.

The stable-isotope contents of groundwater from the LHSU may reflect different climatic conditions at the time of recharge. A warmer or drier climate would result in higher $\delta^{18}O$ and δD values than in present precipitation. If paleowaters are a

The distribution of tritium over depth to the midpoint of the well screen is shown in Figure 7-12. UHSU groundwater from relatively shallow depths has more variable tritium contents than groundwater from deeper levels (i.e., greater than approximately 50 feet). Groundwater from the LHSU has very low tritium contents regardless of the sampling depth. Only one well screened in unweathered bedrock, well 4187 located in the vicinity of 881 Hillside (OU1), yielded groundwater with tritium contents greater than 5 TU. At the locations where low *d* values are found in LHSU groundwater, the tritium contents are also very low (generally not detectable). These results indicate that the dominant component of LHSU groundwater is much older than recent recharge and also older than groundwater in the UHSU.

7.4 Discussion

The results of the stable-isotope and tritium measurements can be used to identify sources of recharge to the hydrostratigraphic units at the Rocky Flats site, to evaluate contaminant transport from the UHSU to the LHSU, and to trace groundwater flow.

7.4.1 Sources of Recharge to Groundwater

The meteoric origin of groundwater in the UHSU is evident from hydrologic data collected at the site. Well hydrographs show peak water levels in the UHSU during the month of May (Hydrogeologic Characterization Report, EG&G, 1995b) and indicate that peak recharge occurs during the wettest season (March, April, and May). The isotopic compositions of groundwater fall within the range defined by local precipitation. However, typical ^{18}O, D, and tritium contents in UHSU groundwater are slightly higher than their contents in precipitation falling during the peak recharge period of spring and early summer. The $\delta^{18}O$ value of a composite precipitation sample collected for April 1994 was -17.5 (Table 7-1). In contrast, the $\delta^{18}O$ values of groundwater from the UHSU generally range from -13 to -15.

Similar shifts in the isotopic compositions of groundwater toward heavier values than local precipitation have been observed in arid environments (Gat, 1981). In these arid environments, the enrichment in heavy isotopes is accompanied by a decrease in the *d* values of groundwater relative to precipitation. Evaporation from both rain and snow may enrich recharge water in the heavier isotopes relative to the initial composition of precipitation.

Possible causes of such an enrichment could be evaporation of water from near-surface soil water (Dincer *et al.*, 1974), a delay in infiltration of water at the surface followed by evaporation (Gat and Tzur, 1967), evaporation of water from snowpack (Moser and Stichler, 1980), and infiltration of spray-evaporated waters. Later recharge events may then flush the heavy-isotope-enriched waters to the water table.

At Rocky Flats, the large proportion of annual precipitation that falls as snow and snowmelt may provide a significant portion of groundwater recharge. Evaporation from snowpack at the ground surface leads to heavy-isotope enrichment of the residual snow and subsequent snowmelt (Moser and Stichler, 1980; Sommerfeld *et al.*, 1991). The enriched snowmelt then serves as recharge to groundwater. To date, no isotopic measurements of snowpack samples (seasonal accumulation) or samples of snowmelt water from Rocky Flats have been performed.

Other sources of recharge may also be responsible for the shift to heavier isotopic compositions in groundwater. The other possible sources at Rocky Flats include influent streams; lakes, ponds, or water impoundments; recharge through fractures; and recharge through the unsaturated zone. Recharge contributions from surface-water bodies, such as influent streams and lakes or ponds, are distinguished by their modern tritium contents (similar to modern precipitation). In addition, contributions from lake or pond water have higher $\delta^{18}O$ and δD values and lower *d* values than local precipitation because the lake water is subject to evaporation. The effect of recharge from lakes is to raise the ^{18}O and D concentrations in groundwater above the local average for precipitation. Recharge through a porous unsaturated zone into a porous aquifer yields groundwater isotopic compositions that do not show the seasonal variations observed in the precipitation.

Recharge by precipitation through fractures or solution holes is more rapid than recharge through a low-permeability porous media. Recharge along fractures is distinguished by high (i.e., modern) tritium concentrations, which may reflect seasonal variations in the isotopic composition of local precipitation.

Even though precipitation is clearly the major source of recharge to groundwater in the UHSU, evidence for additional sources of recharge to both the UHSU and LHSU is discussed below.

7.4.1.1 Recharge to UHSU Groundwater

UHSU groundwater collected from a few wells located downgradient of Rocky Flats Lake, and from the clay pit on the west side of the site, is isotopically heavier than groundwater from most other areas of the site (refer to Plate 3). The higher ^{18}O and D contents suggest that this groundwater contains a component derived from isotopically heavy sources such as Rocky Flats Lake and the clay-pit water.

Field observations at the clay pit indicate that the lithostratigraphic units comprising the UHSU are not in direct hydraulic connection with the clay pit. Water in the clay pit is at a lower elevation than the base of the UHSU and probably acts as a source of recharge to the deep Laramie/Fox Hills Aquifer rather than to the UHSU. The source of relatively heavy water in this area remains undetermined. At Rocky Flats Lake,

groundwater from surficial deposits range from -16.5 to -10.3 and from -19.2 to -10.1 in weathered bedrock. A slightly more restricted range of $\delta^{18}O$ values is observed in the samples from the unweathered bedrock (from -15.5 to -10.5).

Figures 7-8 through 7-10 show the distribution of $\delta^{18}O$, δD, and *d* (deuterium excess) over the depth to the midpoint of the well screen. Note that the midpoint of the well screen is not necessarily representative of the depth of origin for the groundwater sampled because the depth range of effective inflow into the well is unknown. Therefore, the midpoint of the screen provides only a reference point to describe the approximate depth of groundwater sampled.

These figures show the wide spread of isotopic compositions in the surficial deposits and weathered bedrock of the UHSU, and also the similarity in the ranges of isotopic compositions for these two lithostratigraphic units. The ^{18}O and D contents of groundwater are the most variable at shallow depths (less than approximately 50 feet) in both the surficial materials and the weathered bedrock. These results indicate that the two units (surficial deposits and weathered bedrock) have isotopically indistinguishable sources of recharge and strongly suggest that they are hydraulically connected. These conclusions support the current definition of the UHSU presented in Section 4 and in the Hydrogeologic Characterization Report (EG&G, 1995b).

The ^{18}O and D contents of LHSU groundwater are also variable although a general shift toward higher ^{18}O and D contents is observed at depth in the LHSU. The histogram in Figure 7-6 also shows a slight shift toward increased ^{18}O and D contents in the LHSU compared to the surficial deposits and weathered bedrock of the UHSU.

Deuterium-excess values are also variable in groundwater. The *d* values are calculated using the slope of the global meteoric-water line as the frame of reference. Because the slope and intercept of the local meteoric-water line deviates from the global meteoric-water line, relatively lower *d* values are expected in the heavier waters. Therefore, care must be taken in the interpretation of *d* values.

Low *d* values (<5) are found in groundwater from both the UHSU and LHSU, including some groundwater from depths greater than 50 feet. UHSU groundwater from some locations within the western portion of the Buffer Zone and in the vicinity of the Solar Evaporation Ponds has low *d* values. In general, the deuterium-excess values are variable through time at these locations. However, UHSU groundwater from wells B405789 and B400489 in the western portion of the Buffer Zone south of Woman Creek, several wells in the western Buffer Zone north of Woman Creek, and a number of wells in the vicinity of the Solar Evaporation Ponds — including P208989, P209589, and P209889 — have consistently low *d* values (<0).

Groundwater from the LHSU may also have low *d* values. LHSU groundwater from wells 2386, 2586, 2786, and 3286 in the vicinity of the Solar Evaporation Ponds has *d* values generally less than 5. LHSU groundwater from the Walnut Creek drainage (wells 1486 and B217289) and in the Buffer Zone north of Walnut Creek also has low *d* values.

At a few locations, groundwater was sampled from clusters of two to three wells screened at distinct depths. The ^{18}O and D contents of groundwater at these locations vary with depth. Figure 7-11 illustrates the isotopic variations at two well clusters. The first is located in the western portion of the Buffer Zone between Rocky Flats Lake and Antelope Spring. This cluster includes three wells screened at progressively deeper levels in the surficial materials (B405689 midpoint at 12.8 feet, B400489 at 29.3 feet, and B405789 at 47.7 feet). Figure 7-11 shows that groundwater from greater depth (well B405789) has consistently higher ^{18}O contents and lower *d* values compared to shallower groundwater.

In a second well cluster, located in the northern portion of the Buffer Zone (near Rock Creek), two wells were sampled — one screened across surficial materials (B200789) and one screened across the underlying weathered bedrock (B203489). Figure 7-11 shows that groundwater in the weathered bedrock has slightly higher ^{18}O contents than groundwater from the overlying surficial materials. However, the variations observed in the *d* values are generally similar for groundwater from the two units.

At several monitoring wells, groundwater has been sampled and analyzed multiple times. At these locations, the $\delta^{18}O$ and δD values of the groundwater vary within a range of ±2‰ or less. The groundwater samples collected during one quarter, the second quarter of 1992, typically have the highest $\delta^{18}O$ values and lowest *d* values compared to groundwater samples collected during the other quarters. The average $\delta^{18}O$ and *d* (D excess) values for groundwater from each monitoring well are presented on Plate 3 and in Appendix G. Appendix G also contains time-series plots for $\delta^{18}O$ and *d* in groundwater from selected monitoring wells.

7.3.3.2 Tritium

Tritium concentrations are also highly variable in groundwater. In the UHSU, measured tritium contents range from less than the detection limit (0.8 TU) to 3,703 TU. In the LHSU, tritium contents are uniformly low. A histogram of tritium contents (Figure 7-7) shows nearly identical ranges and modes for the groundwater from surficial deposits and weathered bedrock of the UHSU and a much more limited range of values for the LHSU. In the LHSU, the majority of samples have no detectable tritium.

fallout peak is commonly observed at other locations in the northern hemisphere (IAEA, 1992).

Tritium in precipitation has been reported by the International Atomic Energy Agency (IAEA) at a number of stations in North America since the early 1960s. Monitoring stations in St. Louis, Missouri, and Albuquerque, New Mexico, provide the longest record of tritium contents in precipitation from the western and central United States. Recent tritium contents in precipitation collected from these two stations are shown in Figure 7-5 (data from R. Michel, U.S. Geological Survey). Seasonal variations in tritium content are evident. During 1993, the tritium content of precipitation collected at the Rocky Flats site was generally comparable to tritium contents at these two stations (Figure 7-5).

7.3.2 Isotopic Composition of Surface-Water Samples

7.3.2.1 Oxygen and Deuterium

A limited number of grab samples are available to describe the isotopic compositions of surface waters in the vicinity of Rocky Flats. In the 19 samples for which results are available, $\delta^{18}O$ values range from -3.7 to -17.4 and δD values range from -60.2 to -129.8 (Figure 7-4). The highest ^{18}O and D contents are found in water collected from a clay pit located immediately west of the Rocky Flats Buffer Zone. The clay pit is a closed basin with no outlet and minimal recharge (from surface runoff and incident precipitation). Therefore, water in this pit is subject to evaporation and heavy-isotope enrichment. Water from the South Boulder Diversion Canal has the lowest ^{18}O and D contents. The water in the canal originates from precipitation that fell at a higher altitude and probably at lower temperatures than precipitation at the Rocky Flats site. Therefore, its relatively light isotopic composition is expected.

The compositions of surface-water samples are plotted with precipitation data on Figure 7-4. The surface-water samples lie along a line with a lower slope than the global precipitation line.

$$\delta D = 5.2\delta^{18}O - 37.9 \qquad r = 0.99 \qquad \text{(surface-water samples)}$$

Several of the surface-water samples also have low *d* values, indicating their probable modification due to evaporation. The lowest *d* values are from the clay pit and Rocky Flats Lake, both located west of the Buffer Zone. Some of the spring samples (Antelope Spring) plot along the evaporation line and have low *d* values. These waters have also experienced some evaporation and heavy-isotope enrichment. The evaporation may have occurred at the ground surface, or the spring waters may emanate from a source of relatively heavy groundwater. Antelope Spring is directly downgradient of Rocky Flats Lake and appears to be related to a zone of high hydraulic

conductivity in the UHSU (EG&G, 1995b). Therefore, the isotopic compositions of water from Antelope Spring indicate that the spring water probably contains a component derived and transported from Rocky Flats Lake.

7.3.2.2 Tritium

The tritium contents of surface waters are also variable and range from 12.7 TU in Rocky Flats Lake to 28.9 TU in seep water discharging adjacent to the South Intercept Ditch along the Woman Creek drainage. The tritium contents of seeps and springs are consistently higher than the tritium content of local precipitation. These seeps and springs appear to receive baseflow from tritium-rich groundwater. Surface-water bodies located within and downgradient of the Industrial Area may have received additional tritium input from sources on the plant site.

Most of the surface-water locations were sampled only once and some of the samples were collected during different seasons. Therefore, direct comparison of results from different surface-water bodies is difficult.

7.3.3 Isotopic Composition of Groundwater Samples

7.3.3.1 Oxygen and Deuterium

Groundwater from the Rocky Flats site has variable isotopic compositions of oxygen and hydrogen. The results of $\delta^{18}O$ and δD measurements of groundwater samples are plotted with local precipitation, the global meteoric-water line, and data from surface-water samples in Figure 7-6.

For the purposes of discussing the isotopic variations present in groundwater, the samples have been grouped based on their origin from one of the following three lithostratigraphic units:

1. Surficial deposits including Rocky Flats Alluvium, younger alluvial deposits, colluvium, and valley-fill alluvium
2. Weathered bedrock of the UHSU
3. Unweathered bedrock of the LHSU

Histograms showing the frequency of $\delta^{18}O$ values in groundwater from these three distinct units are presented in Figure 7-7. These results show that the isotopic composition of groundwater within each of the lithostratigraphic units is variable. In addition, the modal values for groundwater from surficial deposits and from weathered bedrock (UHSU) are the same, whereas the modal values of these two units differ from that of groundwater from unweathered bedrock (LHSU). The $\delta^{18}O$ values in

7.3 Results

The quality of isotope data was evaluated through comparison of results from duplicate samples, comparison of duplicate laboratory analyses, and comparison of analyses of split samples submitted to more than one laboratory. Duplicate samples were collected and submitted along with real samples to the isotope laboratory. The results from these duplicate pairs indicate good sampling and analytical precision, with values of relative percent difference consistently less than five percent. The laboratory also supplied the results of their routine duplicate analyses of samples. These analyses, in conjunction with repeat analyses of internal standards, define the reproducibility, or precision, of their analyses. The Environmental Isotope Laboratory at the University of Waterloo reports reproducibilities of ±0.2‰ for $\delta^{18}O$ and δD and (0.8 TU for tritium analyses. The results for laboratory-duplicate analyses (run at 1-in-10 frequency) were averaged to provide a single result value per sample collected.

Comparison of results for 12 split samples submitted to both the University of Colorado and University of Waterloo shows good agreement between data from these two laboratories (refer to Appendix G). Relative percent differences from 0 to 14 percent were calculated for $\delta^{18}O$ and δD measurements of samples submitted to both laboratories. These differences, however, are significant compared to the analytical precisions reported by each of the laboratories (0.05‰ $\delta^{18}O$ at the University of Colorado and 0.2‰ $\delta^{18}O$ at the University of Waterloo). No bias was observed in the data from the University of Waterloo compared to data from the University of Colorado.

The samples collected from the first quarter of 1992 through the second quarter of 1993 were stored for periods as long as 18 months (first-quarter 1992 samples) following their collection and prior to isotopic analysis. Samples were initially stored at room temperature, but some of the samples were also stored in a trailer where temperatures may have been high during the summer. During the storage period, the samples may have partially evaporated and thus become more enriched in the heavy isotopes than their starting composition. No consistent bias in the results from the stored samples has been observed except for samples collected during the second quarter of 1992. These samples show consistently higher ^{18}O contents and lower *d* values than other samples collected from the same locations at different times. These results are discussed in greater detail in Section 7.3.3, because it has not been determined whether the isotopic characteristics of these samples are related to enrichment effects occurring during long-term storage of the samples or to actual variations in the isotopic compositions of groundwater. More rigorous sample-handling protocol has been implemented since the second quarter of 1993.

7.3.1 Isotopic Composition of Precipitation

7.3.1.1 Oxygen and Deuterium

The oxygen and hydrogen compositions of precipitation samples are plotted in Figures 7-3 and 7-4. The $\delta^{18}O$ values range from -29.2 to -7.3 and δD values range from -222 to -63. Both ^{18}O and D contents are highest during the summer months when temperatures are warm. Both isotopes also show variations among winter-storm events, demonstrating that precipitation at Rocky Flats originates from storms of different isotopic compositions.

The relationship between δD and $\delta^{18}O$ is shown in Figure 7-4. A linear-regression line calculated for all precipitation samples collected at Rocky Flats has the following equation:

$$\delta D = 7.3\delta^{18}O - 4.35 \qquad r = 0.995 \qquad \text{(rain and snow precipitation)}$$

This line differs in slope and intercept from the global meteoric-water line described by Craig (1961) and also shown on Figure 7-4. The global meteoric-water line has the following equation:

$$\delta D = 8\delta^{18}O + 10 \qquad \text{(Craig, 1961)}$$

A regression line calculated using only data from snow samples has the following equation,

$$\delta D = 7.9\delta^{18}O + 9.69 \qquad r = 0.995 \qquad \text{(snow precipitation only)}$$

which more closely matches the global meteoric-water line. The improved agreement is expected because snow is less susceptible to processes of heavy-isotope enrichment than is rain precipitation. The values falling farthest off the global line are for summer rain precipitation. Samples of summer rain have the lowest *d* values. These values indicate that the isotopic composition of the precipitation sample was probably affected by evaporation either during rainfall below the cloudbase or during collection but prior to containing and sealing the sample.

Weighted means for the $\delta^{18}O$ and δD values of precipitation have not been calculated because monthly composite samples have not been collected for one full year.

7.3.1.2 Tritium

The tritium content of precipitation at Rocky Flats shows a peak during the late spring and summer months (Figure 7-3); tritium ranged from 8.9 to 15.9 TUs. This spring

isotopic ratios of oxygen and hydrogen were measured using a multiple-collector, gas-source mass spectrometer. Oxygen ratios were determined by first equilibrating the water with carbon dioxide and then admitting the carbon dioxide to the mass spectrometer (Epstein and Mayeda, 1953; Fritz *et al.*, 1986). Hydrogen was prepared by reducing the hydrogen in water with zinc (Coleman *et al.*, 1982). Water vapor was introduced to single-sample reaction vessels containing zinc. Each vessel was then heated to approximately 450°C to release hydrogen for analysis by the mass spectrometer. The deuterium and ^{18}O isotope ratios (D/H, $^{18}O/^{16}O$) are expressed as *d* values (i.e., as the per mil deviation from the internationally accepted standard). The reference standard used is called Vienna-SMOW as defined by Craig (1961) and the International Atomic Energy Agency (Gonfiantini, 1978; IAEA, 1992).

Table 7-1
Isotopic Compositions of Precipitation Samples

Precipitation Station PC00193 (T-891 Contractor Trailer)						
Sample Number	Date	Type	$\delta^{18}O$ (SMOW)	δD (SMOW)	Tritium (TU)	D excess (*d*)
PC00001EG	4/13/93	Snow, grab	-14.62	-108	15.9	8.96
PC00002EG	8/5/93	Rain, grab	-8.99	-76.61	14.4	-4.69
PC00003EG	8/5/93	Rain , grab (2nd storm)	-7.26	-66.63		-8.55
PC00004EG	8/6/93	Rain, grab	-8.46	-63.1	15.1	4.58
PC00005EG	9/2/93	Rain, grab			13.35	
PC00006EG	9/14/93	Snow, grab	-19.05	-139.2	11.1	13.2
PC00007EG	11/15/93	Snow, grab	-23.28	-176.3	11.1	9.94
PC00008EG	11/12/93	Snow, grab	-21.33	-159		11.64
PC00009EG	12/23/93	Snow, grab	-27.07	-210.2	10.3	6.36
PC00010EG	1/28/94	Snow, grab	-16.9	-118.5	11.1	16.7
PC00011EG	1/31/94	Snow, grab	-29.47	-219.5		16.26
PC00012EG	2/14/94	Snow, grab	-25.68	-191.6	8.9	13.84
PC00013EG	2/23/94	Snow, grab	-19.76	-139.6	10	18.48
PC00014EG	3/1/94	Snow, grab	-29.18	-222		11.44
PC00015EG	3/8/94	Rain and snow, grab	-15.1	-115.9	11.8	4.9
PC00016EG	3/28/94	Snow (3/26 - 3/27 snowfall), grab	-21.52	-162.6	13.9	9.56
PC00017EG	4/1/94	Snow (3/29 snowfall), grab			14.6	
PC00018EG	5/4/94	Snow and rain, April composite	-17.5	-129.5	12.85	10.5
PC00019EG	May	Rain, composite				

SMOW = Standard Mean Ocean Water; refer to Section 7.1 for definition of δ values.

Table 7-2
Isotopic Compositions of Surface-Water Samples

Surface-Water Samples						
Location	Date	Description	$\delta^{18}O$ (SMOW)	δD (SMOW)	Tritium (TU)	D excess (d)
SW112	7/23/93	South Boulder Diversion Canal	-17.42	-129.8	15.8	9.56
	8/5/93	South Boulder Diversion Canal	-17.42	-128.6		10.76
SW131	7/23/93	Antelope Spring	-12.17	-100.0	21.3	-2.64
SW080	7/23/93	Orchard Spring	-12.59	-98.53	24.2	2.19
SW068	12/14/93	South Intercept Ditch (SID)	-16.8	-128.7	21.7	5.7
SW00193	7/26/93	Clay pit west of OU11	-3.69	-60.19	13.9	-30.67
SW00293	7/23/93	Spring west of Apple Orchard	-12.21	-101.6	23.2	-3.92
SW00393	8/5/93	Spring at ranch pond in Rock Creek	-14.35	-113.3	16.9	1.5
SW00493	8/19/93	Spring in Rock Creek drainage	-14.6	-108.6	25.85	8.2
SW00593	12/14/93	Seep below SID	-14.5	-111.9	28.9	4.1
SW00693	12/14/93	Woman Creek. near SID seep	-13.8	-111.6	22	-1.2
SW00793	12/14/93	Antelope Spring North	-11.84	-98.6		-3.88
SW00793	12/14/93	Antelope Spring North	-11.99	-100.9	22.1	-4.98
SW00893	1/28/94	Coal Creek at bridge to Plainview	-15.31	-114.1	15.1	8.38
SW00893	2/28/94	Coal Creek at bridge to Plainview	-15.36	-117.6	15.5	5.28
SW00893	3/31/94	Coal Creek at bridge to Plainview	-16.26	-124.3	15.4	5.78
SW00893	5/3/94	Coal Creek at bridge to Plainview	-16.63	-124.6	14.3	8.44
SW00993	2/28/94	Rocky Flats Lake	-9.35	-84.19	12.7	-9.39
SW01093	5/3/94	Standley Lake	-14.84	-116.7	16.8	2.02
SW01194	5/3/94	Great Western Reservoir	-14.37	-114.95	16.5	0.01

SMOW = Standard Mean Ocean Water; refer to Section 7.1 for definition of δ values.

The deuterium excess, d, is calculated on the basis of the relationship between deuterium and ^{18}O content in fresh water on a global scale, as defined by Dansgaard (1964):

$$d = \delta D - 8\delta^{18}O$$

Water samples analyzed for tritium by liquid-scintillation counting were electrolytically enriched to yield precisions better than (2 TU (Packard, 1986; Taylor, 1977). The results are reported as TUs. One TU is defined as one atom of ^{3}H per 10^{18} atoms of hydrogen (^{1}H), which is equivalent to 0.118 Bq or 3.193 pCi/L of water.

7.1.3 Purpose of this Study

The environmental-isotope study was undertaken to compare the isotopic compositions of groundwater to the isotopic compositions of potential recharge waters, and to relate the isotopic variations in groundwater to the processes that are expected to affect groundwater chemistry. Therefore, the objectives of the sampling and analysis were to describe the compositions of potential sources of groundwater recharge (precipitation and surface waters) and to obtain representative values of the environmental-isotope composition of groundwater in each of the hydrostratigraphic units at the Rocky Flats site.

7.2 Sampling and Analysis Methods

7.2.1 Sampling

From the first quarter of 1991 through the first quarter of 1994, groundwater samples were collected for measurement of δD, $\delta^{18}O$, and, in some cases, tritium. Precipitation and surface-water samples were collected for measurement of δD and $\delta^{18}O$, with some samples also analyzed for tritium, during 1993 and 1994.

7.2.1.1 Precipitation and Surface Water

EG&G began collecting precipitation samples for isotopic analysis in April 1993. Grab samples were obtained from a central location on the Rocky Flats site. Rain was collected as it drained from the roof of trailer T891E at the end of a precipitation event. Snow samples were obtained using a 2.5-gallon bucket as a collector or directly from the ground surface by collecting snow from depths representing the entire snowfall event. Snow samples were collected immediately following the snowfall event. Nineteen precipitation samples were collected between April 1993 and May 1994. These included grab samples of rainfall and snow, and two composite samples collected for the months of April 1994 and May 1994 (Table 7-1).

Surface-water samples were also collected in 1993 and 1994. Twenty-one grab samples were collected from 15 locations on and off the Rocky Flats site (refer to Table 7-2 and Figure 7-1). The locations sampled on the site included several springs, a water-filled clay pit, and Woman Creek. East of the site, Standley Lake and Great Western Reservoir were sampled. West of the site, Coal Creek, the South Boulder Creek Diversion Canal, and Rocky Flats Lake were sampled. Grab samples were collected with sample bottles according to Standard Operating Procedure (SOP) SW.03 (EG&G, 1992c).

The temperature, pH, and conductivity of each surface-water sample were measured in the field at the time of sampling. Each sample was then submitted for measurement of

oxygen and hydrogen isotopes, including tritium. The results of isotopic analyses are presented in Tables 7-1 and 7-2.

7.2.1.2 Groundwater

The groundwater investigation was designed primarily as a sitewide reconnaissance-level effort to identify areas with sufficient variation to trace groundwater flow paths. The number of monitoring wells selected for isotopic analysis reflects (1) the number and complexity of potential source areas at Rocky Flats (ponds, spray fields, leakage from pipelines, etc.); (2) the need to characterize background conditions; and (3) the need to verify, on a larger scale, the vertical isotopic stratification observed in bedrock during the pilot study.

Groundwater samples were collected from 253 monitoring wells and 13 well points. The samples were collected during routine groundwater sampling activities and in accordance with EG&G SOPs for groundwater sampling (EG&G, 1992c). Figure 7-2 shows the locations of the monitoring wells sampled for isotopic analyses. The wells and well points sampled are screened at depths ranging from a few feet to more than 100 feet below the ground surface, and from multiple depths within each hydrostratigraphic unit (UHSU and LHSU). Many of the wells sampled have well screens that extend over wide intervals; these screens are typically 5 to 20 feet long, and as long as 93 feet.

In addition, the well screens and surrounding filter pack may extend across more than one lithostratigraphic unit. Thus, groundwater from multiple depths and from more than one lithostratigraphic unit can enter the wells. For these reasons, many of the samples taken may represent mixtures of water from various depths in the hydrostratigraphic unit.

During 1991, 1992, and the first quarter of 1993, 173 groundwater samples were submitted for analysis of δD and $\delta^{18}O$. Starting in the second quarter of 1993, analyses for tritium were also performed on selected samples. Two-hundred eighty-eight groundwater samples have been collected and analyzed since the second quarter of 1993. The results of isotopic measurements for groundwater samples are provided in Appendix G.

During the collection of groundwater samples, temperature, pH, and conductivity were measured in the field.

7.2.2 Analytical Methods

Isotopic analyses of precipitation, surface-water, and groundwater samples were performed by the Environmental Isotope Laboratory at the University of Waterloo. The

Water with less deuterium than SMOW has a negative δD, and water with more deuterium than SMOW has a positive δD; the same is true for $\delta^{18}O$.

7.1.1 Environmental-Isotope Ratios in Natural Waters

The isotopic composition of water vapor is controlled by several interrelated factors; the composition of precipitation depends on the temperature at which the oceanic water is evaporated into the air and, even more important, the temperature of condensation at which clouds and rain or snow are formed. This temperature dependence is responsible for the large variations in the isotopic composition of precipitation and, to a lesser extent, groundwater.

Fractional condensation results in gradual depletion of heavy isotopes in the residual moisture in air masses and subsequent precipitation from those air masses. Heavy isotopes are also depleted from a cloud as it rises up mountains (the "altitude effect"), and consequently the residual precipitation gets isotopically lighter. The isotopic composition of precipitation is also affected by the amount of precipitation; the heavier the rain event or the greater the amount of precipitation, the lighter the isotopic compositions. The explanation for this effect is related to the "temperature effect" (lower temperatures cause increased rainfall) and decreased fractionation during rainfall (raindrops undergo less evaporation than water vapor).

The global meteoric-water line defined by Craig (1961) describes the combined δD and $\delta^{18}O$ dependences on temperature. The meteoric-water line is a convenient reference line for understanding and tracing local groundwater origins and movements. Hence, in each hydrochemical investigation, the local meteoric-water line has to be established from samples of individual rain events or monthly means of precipitation. Prior to establishment of the local meteoric-water line, the global meteoric-water line can serve as an adequate frame of reference for the discussion of isotopic variations. In addition, the composition of precipitation is reflected, directly or modified, in the composition of groundwater from the same area.

The isotopic composition of most groundwater closely reflects the annual weighted-average composition of precipitation in the recharge area. Minor shifts may result from seasonally selective recharge. For example, isotopically heavy summer rains may be consumed by vegetation, and only isotopically lighter fall-to-spring rains recharge groundwater reservoirs. Under more arid conditions, evaporation of precipitation as it falls to the ground can result in an enrichment of the heavy-isotope species in the rain that reaches the ground surface.

Other physical and chemical processes also produce shifts in the stable-isotope composition of water. Exchange with oxygen-bearing minerals causes a shift in oxygen isotopic ratios in geothermal systems with temperatures generally higher than

80°C. In strongly reducing environments, H_2S may become an important component of geochemical systems. Exchange of hydrogen between H_2S and H_2O results in large shifts in the hydrogen-isotope composition of water. Normal groundwater is not affected by these processes.

7.1.2 Results of Previous Investigations

In a pilot study conducted for EG&G by the University of Colorado (White, 1991), the environmental-isotope contents of groundwater samples collected during the first and second quarters of 1991 were determined. A total of 221 measurements were performed on samples from 124 wells. The results of these measurements indicated that groundwater on the site is isotopically variable and that the isotopic compositions of groundwater bodies may be used to trace groundwater flow and evaluate rates of groundwater transport. The results of the pilot study are included in Appendix G.

Comparison of the results from first- and second-quarter samples revealed a slight shift (one per mil) in the modal $\delta^{18}O$ value of groundwater to a higher value during the second quarter. White (1991) described a general trend toward decreasing $\delta^{18}O$ values in groundwater from west to east across the site, and also concluded that some groundwater in the vicinity of OU4 contained a component of "evaporated" water. The differences in the isotopic compositions of groundwater from surficial materials and bedrock in the vicinity of Woman Creek also led White (1991) to conclude that no mixing was occurring between groundwater in these two units (surficial deposits and bedrock). The tritium contents of groundwater were also found to be variable. Tritium contents in groundwater from the Walnut Creek area were high (> 30 TU) and may have originated from sources of tritium contamination on the site. Although historic releases of tritium from the Rocky Flats Plant have been documented (AEC, 1973), the sources of tritium contamination were not discussed in the pilot study.

Although the results of the pilot study revealed isotopic variability in groundwater from the Rocky Flats site, the data were not sufficient to identify and describe the chemical and physical processes that lead to the observed isotopic variations. White (1991) recommended additional analyses of stable isotopes in groundwater and other waters from the site to aid in interpretation of the pilot study results. The pilot study recommended that groundwater be collected from a large number of wells from across the site and analyzed for oxygen and hydrogen isotopes. Collection and analysis of precipitation and atmospheric moisture from the site, and routine sampling and analysis of surface water and sources of potable water used on the Rocky Flats site were also recommended. Data collected using evaporation pans to describe the evaporation rates and the isotopic signatures of water experiencing evaporation were also considered useful to further interpretation of the environmental-isotope results.

7. Environmental Isotopes in Groundwater at the Rocky Flats Site

An environmental-isotope study of groundwater at the Rocky Flats site was conducted to better describe recharge sources, groundwater flow, and interactions between hydrostratigraphic units. Stable isotopes can be used as tracers in the subsurface — in combination with hydrogeological and hydrochemical investigations — to provide information on the origin, age, and movement of groundwater, which cannot be obtained by more conventional methods.

Ideal tracers for water movements are those that are incorporated into the water molecule (i.e., the isotopes of oxygen and hydrogen). The isotopes of an element exhibit the same chemical properties, but their behavior may vary slightly in some physical, chemical, or biochemical processes due to their different weights. The variation of ^{18}O and deuterium (^{2}H or D) contents in natural waters generally results from the temperature-dependent isotope fractionation during evaporation of water, condensation of water vapor, or by water/rock interaction. Thus, ^{18}O and D analyses generally allow recognition of groundwater of different local and temporal origin. Therefore, where stable-isotope analyses of groundwater samples are carried out parallel to hydrochemical analyses, one can obtain a more complete understanding of the hydrogeological characteristics of an aquifer and the history of different groundwater masses.

Tritium (^{3}H), the radioactive isotope of hydrogen, can also be used as a tracer in hydrologic processes. Though some tritium is naturally occurring, historically the main source of tritium in precipitation has been atmospheric fallout originating from above-ground detonation of thermonuclear bombs. Following nuclear tests, atmospheric tritium concentrations increased sharply, reaching a peak between 1963 and 1964. During these peak years, average annual fallout values exceeded several thousand tritium units (TUs — one atom of ^{3}H per 10^{18} atoms of ^{1}H). Today, fallout contributes much less tritium to precipitation, and the average contents in precipitation are much lower (IAEA, 1992). Pre-1952 levels of natural tritium in precipitation are not well known, but have been estimated from 10 to 15 TUs for North America. The half-life decay rate of tritium is 12.43 years. Therefore, groundwater recharged prior to 1952 should have a present tritium content of less than 1.3 TUs (based on the assumed natural content and adjusted for radioactive decay).

It is generally assumed that concentrations of tritium are not significantly affected by reactions with geologic materials. Thus, if a sample of groundwater from a given area contains several tens of TUs or larger, it can be assumed that all or part of this water entered the groundwater system since 1952. The presence of elevated tritium also

indicates that anthropogenic pollution could also penetrate into those parts of the aquifer under similar hydraulic conditions within comparable times if the contaminant is not substantially retarded or decomposed by other chemical processes.

A pilot study conducted at Rocky Flats in 1991 (White, 1991) demonstrated that groundwater from the site has a wide range of oxygen and hydrogen isotopic compositions. The study recommended that additional groundwater samples be collected and analyzed and that baseline data describing precipitation and surface-water compositions also be compiled.

Based on the results of the pilot study, additional environmental-isotope analyses of precipitation, surface waters, and groundwater from the Rocky Flats site and immediate vicinity have been conducted. The objectives of the environmental-isotope investigation are to better identify groundwater recharge areas, describe groundwater flow directions and flow rates, and determine the extent of mixing between the upper and lower hydrostratigraphic units. The following section explains the technical basis for the use of stable isotopes as groundwater tracers, describes the data-collection activities and analytical methods used to provide environmental-isotope data, summarizes the results of isotopic analyses, and discusses the implications of these results for hydrogeologic and hydrochemical models of the Rocky Flats site.

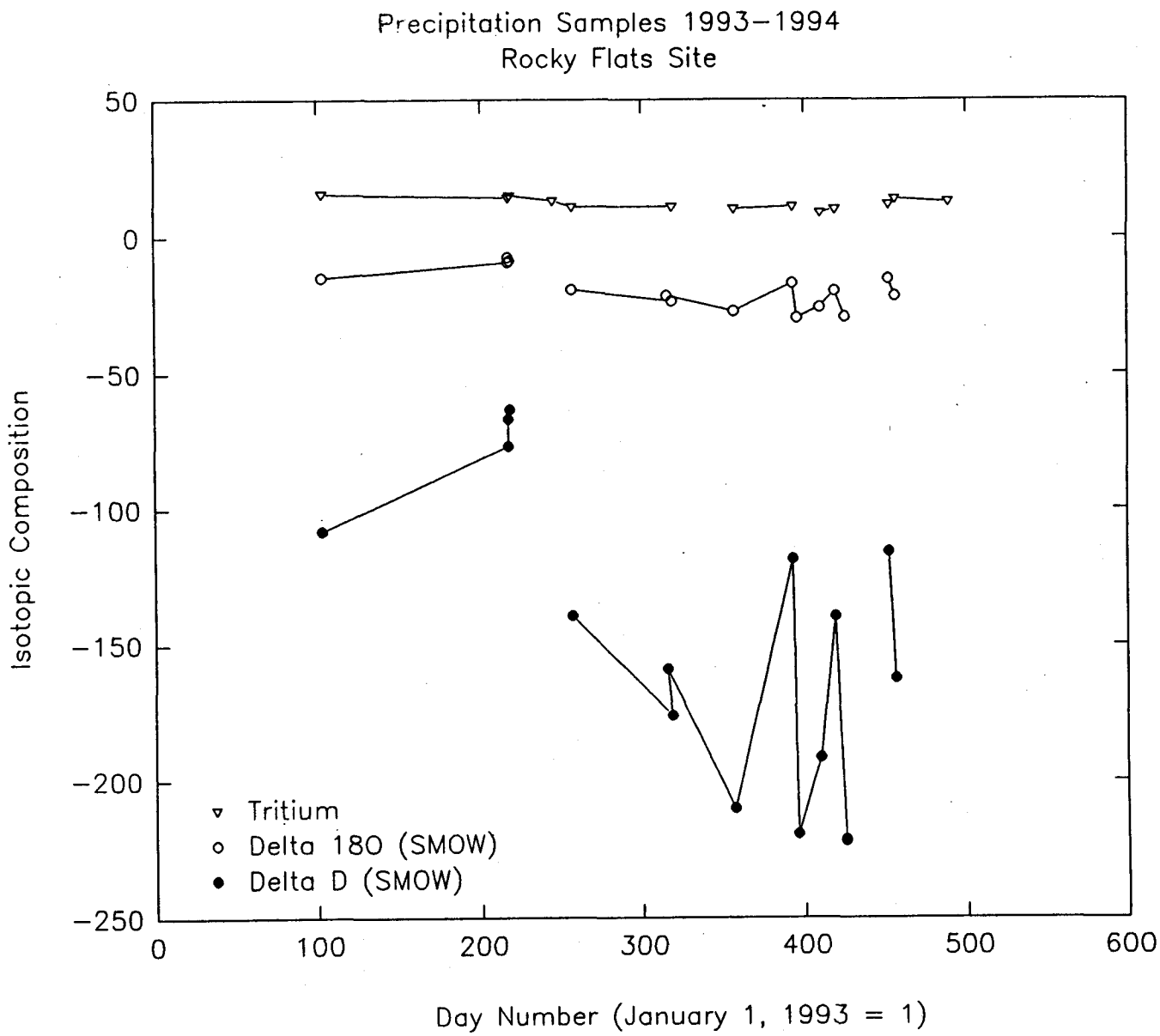
7.1 Technical Approach

The stable isotopes of oxygen (^{16}O, ^{17}O, and ^{18}O) and hydrogen (^{1}H and ^{2}H or D) are an integral part of any water mass. Although the overall terrestrial abundance remains essentially unchanged, stable-isotope ratios ($^{18}O/^{16}O$ and $^{2}H/^{1}H$ or D/H) in waters vary in response to temperature-dependent fractionation within the water cycle. During evaporation, the lighter isotope is preferentially evaporated, enriching the remaining liquid in the heavy isotope; the resulting water vapor is, therefore, relatively enriched in the light isotope. This fractionation effect is enhanced at low temperatures and reduced at high temperatures. In this way, ^{2}H and ^{18}O contents of precipitation show characteristic differences in time and space.

The relative isotopic abundances of oxygen and hydrogen are usually expressed in reference to their standard abundances in ocean water. For this purpose, an internationally agreed sample of ocean water, called Standard Mean Ocean Water (SMOW), has been selected. The isotopic composition of water is expressed as parts per thousand (‰, per mil) difference from SMOW, the standard. These differences are written as δD for the deuterium and $\delta^{18}O$ for ^{18}O:

$$\delta D \text{‰} = \{(D/H_{(sample)} - D/H_{(SMOW)})/D/H_{(SMOW)}\} * 10^3$$

$$\delta^{18}O \text{‰} = \{(^{18}O/^{16}O_{(sample)} - {}^{18}O/^{16}O_{(SMOW)})/^{18}O/^{16}O_{(SMOW)}\} * 10^3$$



SMOW = Standard Mean Ocean Water

EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado

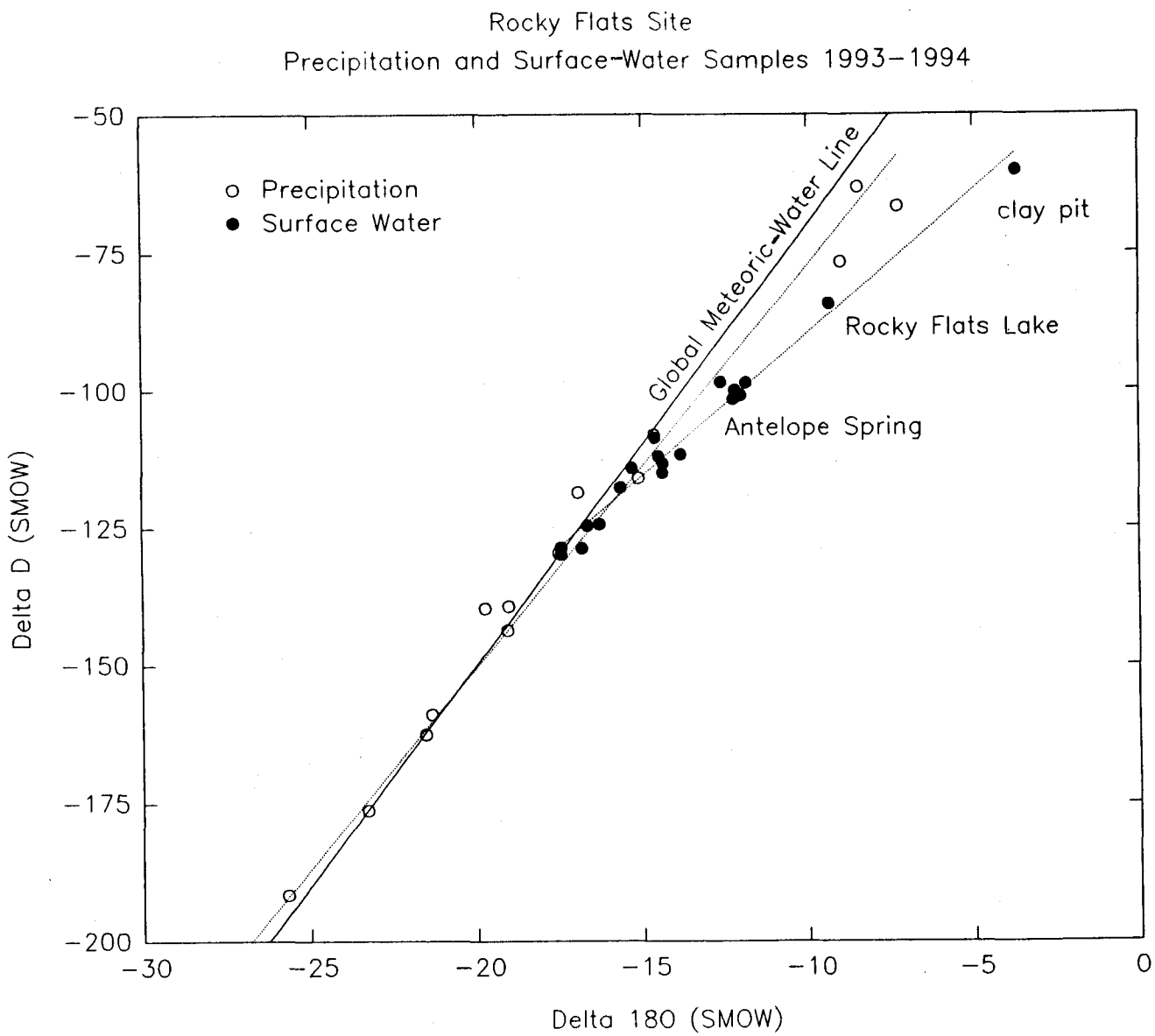
Precipitation Samples
from Rocky Flats Site
1993-1994

Groundwater Geochemistry Report

Date: January 1995

Figure 7-3

M\ES\Geochemistry title blocks2.impt\9/19/94



SMOW = Standard Mean Ocean Water

EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado

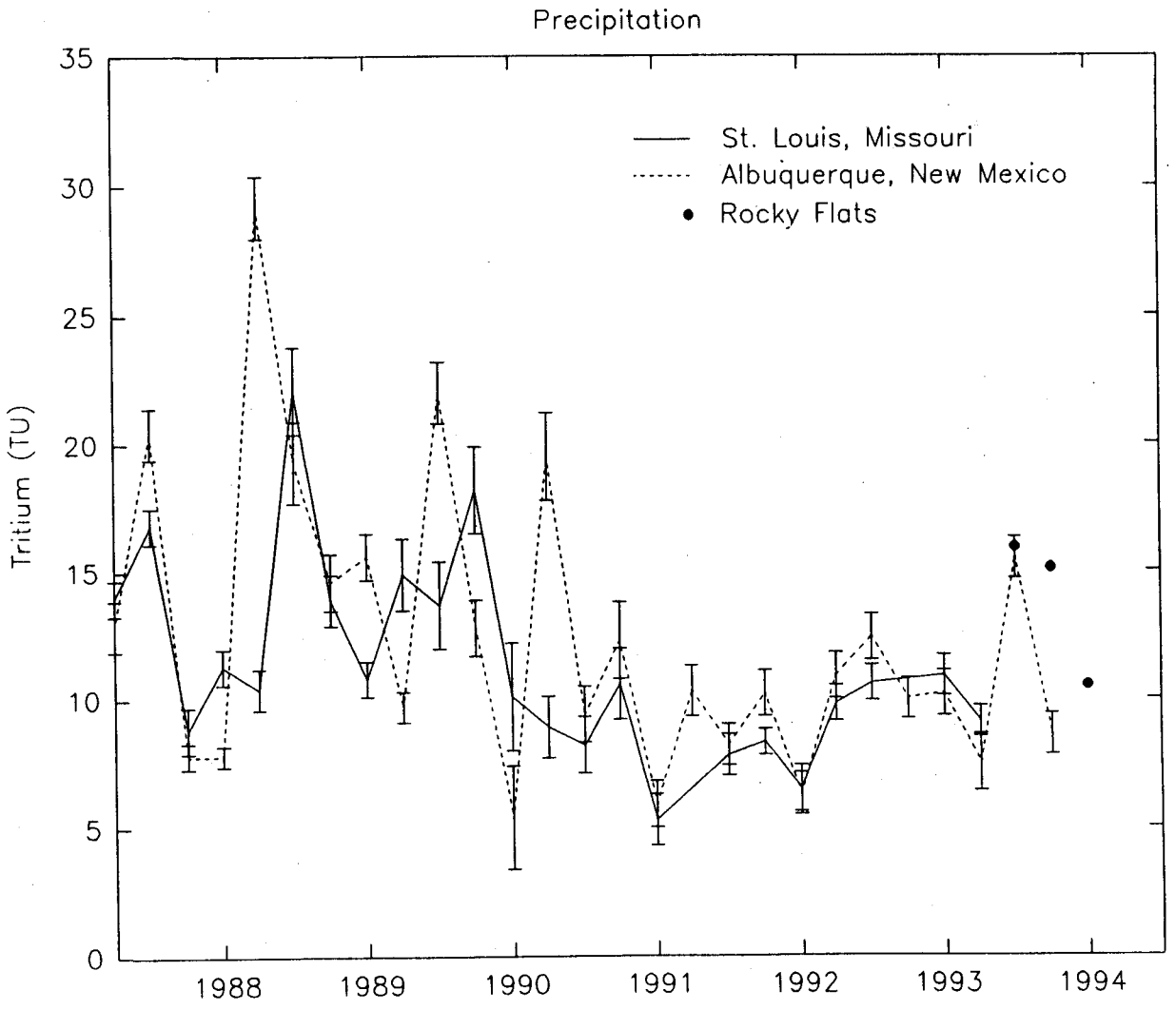
Isotopic Compositions of Precipitation and Surface Water

Groundwater Geochemistry Report

Date: January 1995

Figure 7-4

M\ES\Geochemistry title blocks.2.impt\9/19/94



EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado

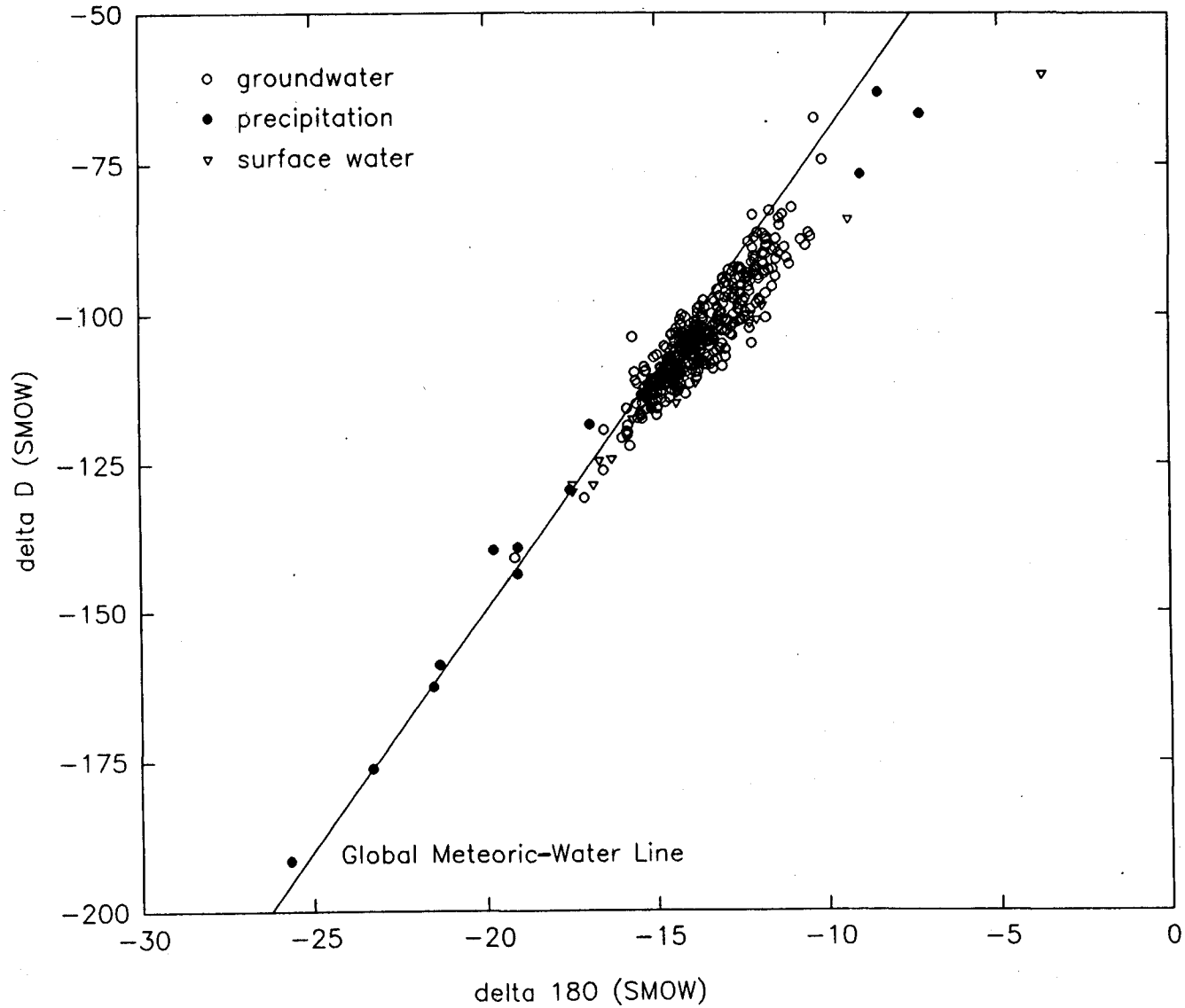
Isotopic Compositions of Precipitation

Groundwater Geochemistry Report

Date: January 1995

Figure 7-5

M\ES\Geochemistry title blocks.2.impt\9/19/94



SMOW = Standard Mean Ocean Water

EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado

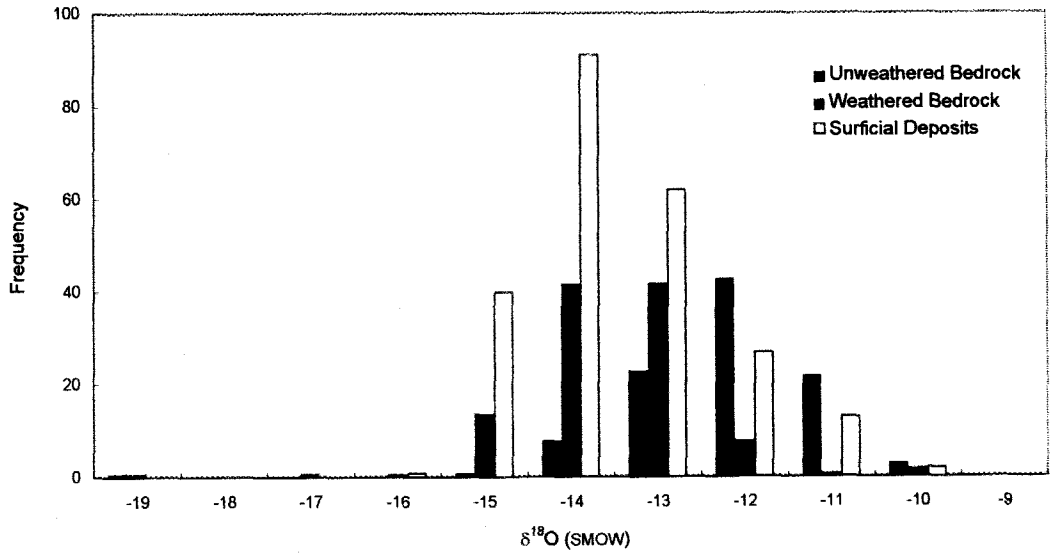
Isotopic Compositions of Groundwater Samples

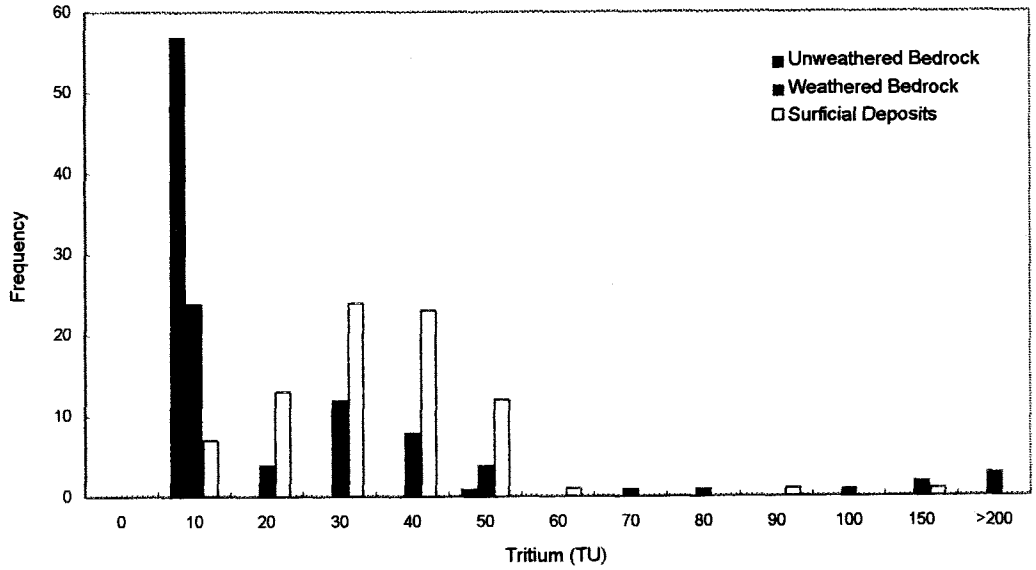
Groundwater Geochemistry Report

Date: January 1995

Figure 7-6

M\ES\Geochemistry title blocks.2.impt\9/19/94





SMOW = Standard Mean Ocean Water

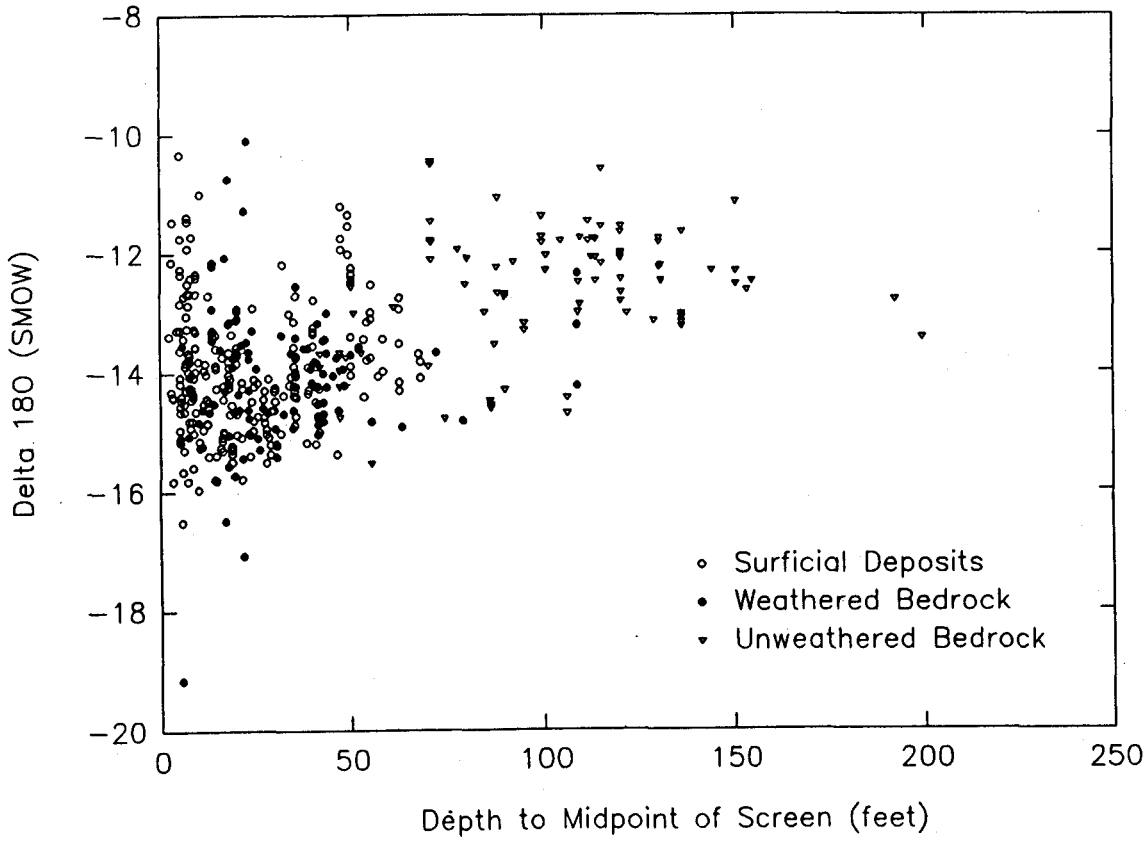
EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado

$\delta^{18}O$ and Tritium Contents in Groundwater Samples

Groundwater Geochemistry Report

Date: January 1995 | Figure 7-7

M\ES\Geo title vert blocks.2.impt\9/19/94



SMOW = Standard Mean Ocean Water

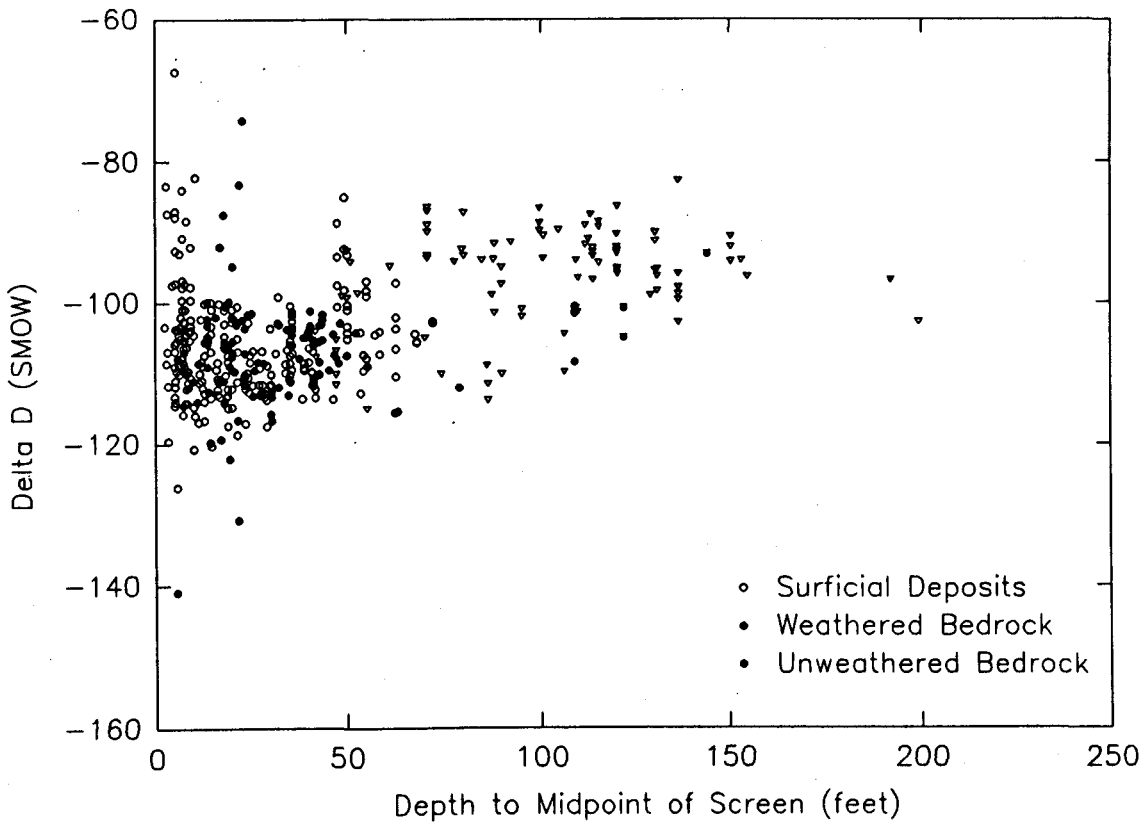
EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado

$\delta^{18}O$ in Groundwater: Variations with Depth to Mid-Point of Screen

Groundwater Geochemistry Report

Date: January 1995 | Figure 7-8

M\ES\Geochemistry title blocks.2.impt\9/19/94



SMOW = Standard Mean Ocean Water

EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado

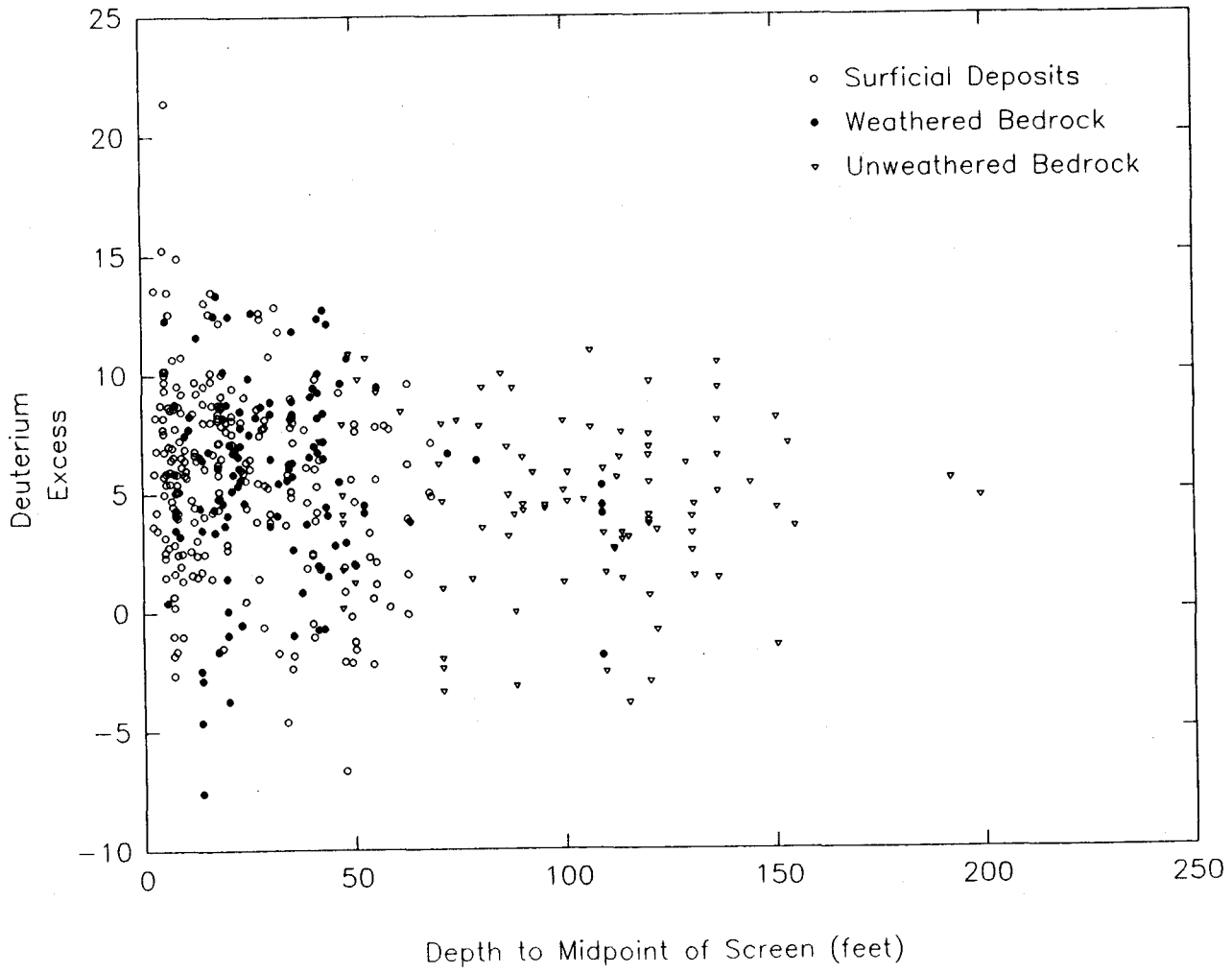
δ D in Groundwater:
Variations with Depth to
Mid-Point of Screen

Groundwater Geochemistry Report

Date: January 1995

Figure 7-9

M:\ES\Geochemistry title blocks.2.impt\9/19/94



EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado

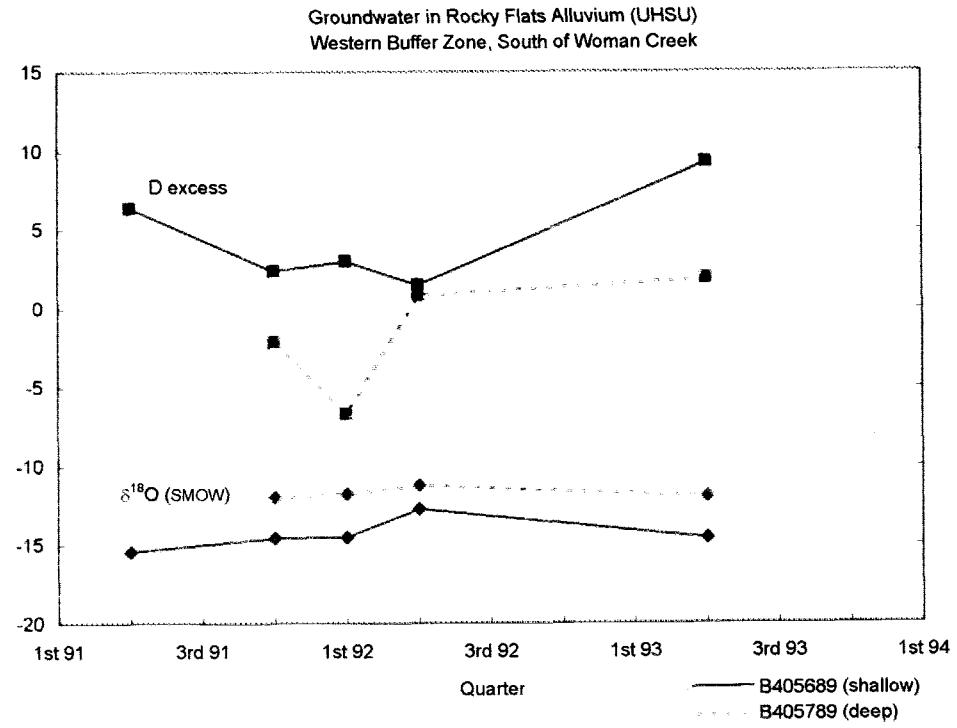
D Excess in Groundwater: Variations with Depth to Mid-Point of Screen

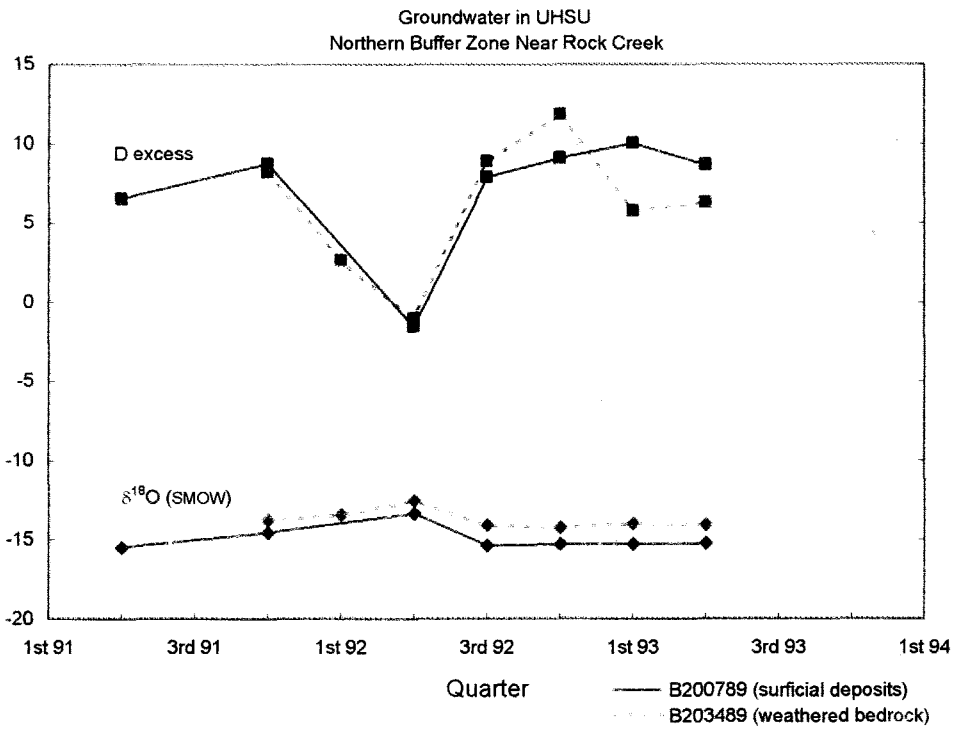
Groundwater Geochemistry Report

Date: January 1995

Figure 7-10

M\ES\Geochemistry title blocks2.impt\9/19/94





SMOW = Standard Mean Ocean Water

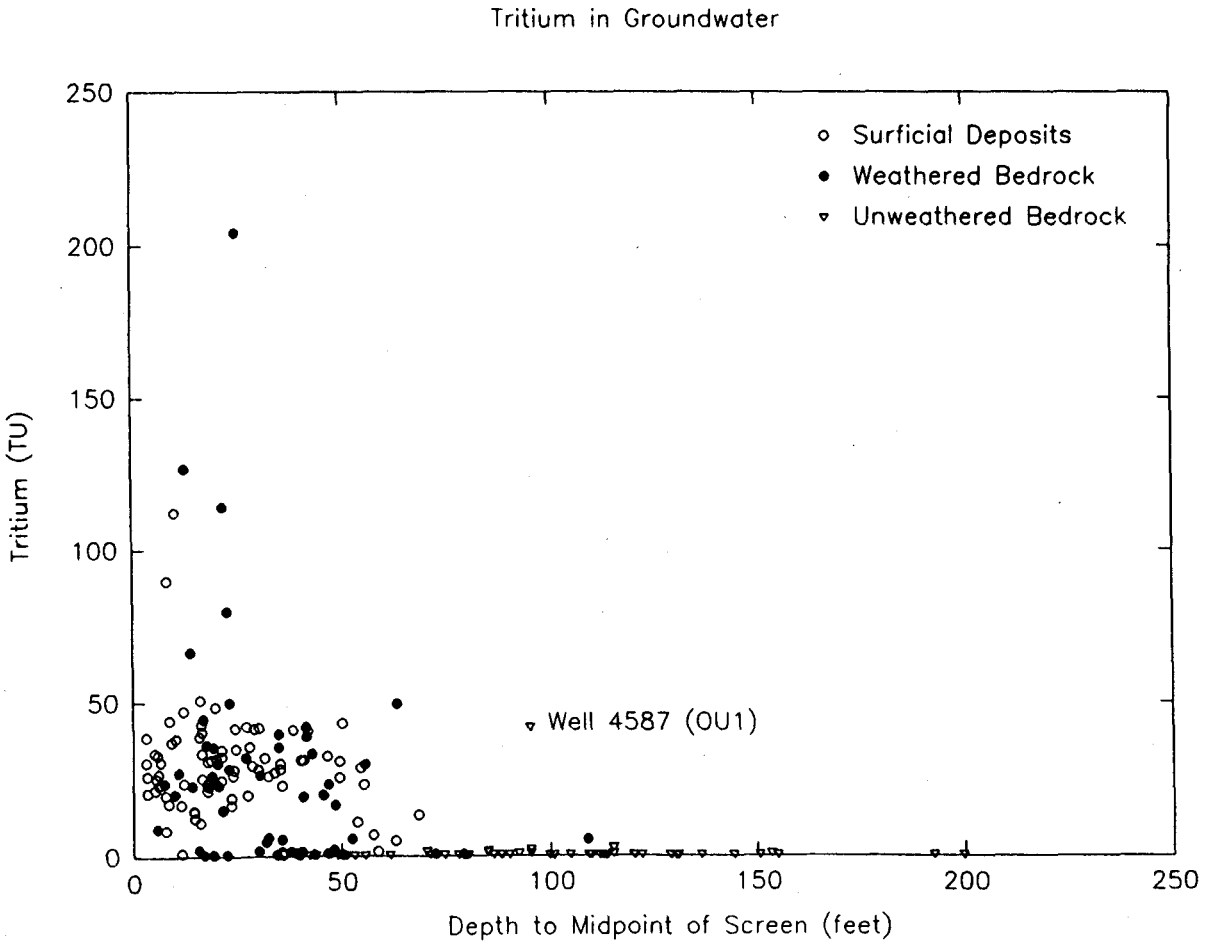
EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado

Vertical Isotopic Gradients in UHSU Groundwater

Groundwater Geochemistry Report

Date: January 1995 | Figure 7-11

M\ES\Geo title vert blocks.2.impt\9/19/94



EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado

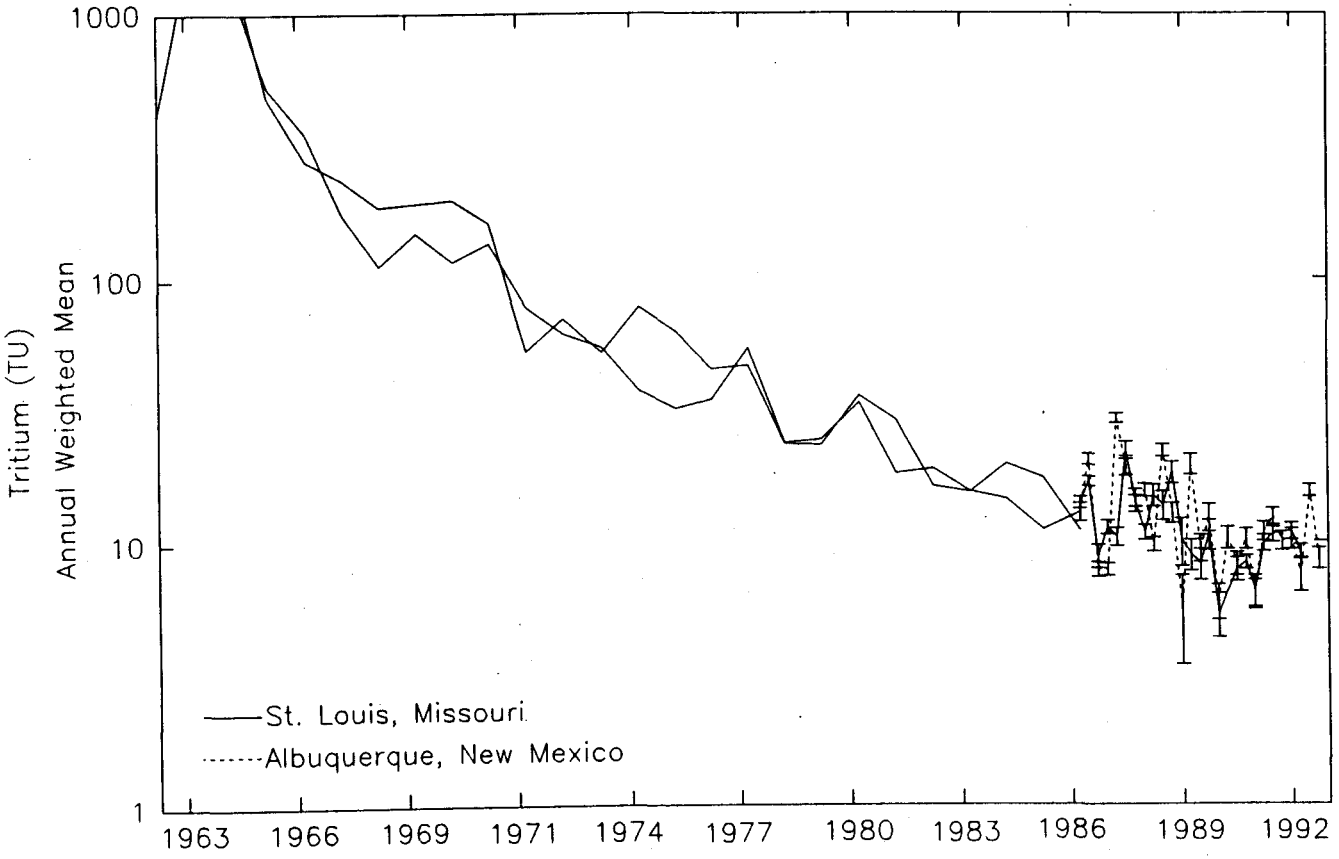
Tritium in Groundwater: Variations with Depth to Mid-Point of Screen

Groundwater Geochemistry Report

Date: January 1995

Figure 7-12

M\ES\Geochemistry title blocks.2.impt\9/19/94



Tritium content of precipitation at St. Louis, Missouri and Albuquerque, New Mexico.
Annual weighted means plotted 1962–1987
Quarterly means with 1–sigma error bars plotted 1987–1993

EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado

Tritium Contents of Precipitation from the Western and Central United States

Groundwater Geochemistry Report

Date: January 1995

Figure 7-13

M\ES\Geochemistry title blocks.2.impt\9/19/94

8. Geochemical Modeling of Groundwater

The geochemical models employed in this study use data for dissolved constituents (i.e., filtered metals, filtered radionuclides, and water-quality parameters). Data for unfiltered ("total") metals and radionuclides cannot be meaningfully modeled, because such data generally describe the chemistry of suspended particulates, not the chemistry of the water.

Geochemical models rely on the assumption that equilibrium conditions are achieved between the aqueous and solid phases. However, the attainment of equilibrium in a groundwater environment is, at best, problematic. There is also evidence to suggest that aquifers dominated by silicate minerals are characterized by slow dissolution kinetics (Kenoyer and Bowser, 1992a and 1992b). Silicate minerals (such as quartz, feldspars, and clays) dominate the mineralogy of the hydrostratigraphic units at Rocky Flats, suggesting that true water/rock equilibrium may not be achieved at the site. However, until the kinetics for a multitude of environments and solution compositions are better understood, the use of thermodynamic data and the assumption of equilibrium conditions will continue to provide the best approximation for the complex interactions between the aqueous and solid phases in a groundwater system.

Assuming the attainment of equilibrium or near-equilibrium conditions, the simplest case of modeling water/rock interactions is that of dissolution/precipitation. Among dissolution reactions, the weathering (both congruent and incongruent) of aluminosilicates is probably most important. Other processes that can influence the composition of groundwater include the mixing of waters having different compositions, sorption/desorption (including cation-exchange reactions), acid/base reactions, oxidation/reduction reactions, complexation of ions, and dissolution/ exsolution of gases, as well as biological factors (Runnells, 1993). Bearing in mind the inherent limitations of using thermodynamic equilibria to model a natural aqueous system, results from such modeling can be used to predict changes in groundwater chemistry and to provide probable answers to other geochemical questions.

8.1 Modeling Along a Flow Path

The evolution of groundwater chemistry along a flow path can be predicted, given a set of interacting mineral phases and an initial solution composition (the "forward problem," Plummer, 1984), or, using the analytical results for initial and final chemistries, a series of minerals and reactions along the flow path can be hypothesized and tested (the "inverse problem," Plummer, 1984). The inverse method can be employed only where sufficient geochemical data are available.

As described above, the inverse problem utilizes available geochemical data for the initial and final water compositions and attempts to find a set of net-transfer reactions that describe the change in water composition along the flow path (Plummer, 1984). The results of this modeling may provide a number of plausible solutions, which must then be scrutinized by the modeler for satisfying thermodynamic and mass-balance constraints. For the Rocky Flats site, the inverse approach was used for modeling because of the large amount of available chemical data for groundwater across the site.

The geochemical modeling performed for this study represents the "first approximation" for the chemical evolution of groundwater as it traverses the site. Geochemical modeling was only performed for groundwater of the UHSU, using wells screened in both surficial deposits and weathered bedrock. Well coverage for the LHSU was too sparse to permit flow-path modeling.

8.1.1 Types of Geochemical Models

Three basic types of calculations are used to describe the geochemistry of a groundwater system. Speciation calculations provide the basis for a measure of the tendency of a particular mineral to dissolve or precipitate under a given set of conditions. This tendency is quantified as the "saturation index" (SI value), which is the log of the ratio of the ion-activity product (IAP) to the equilibrium solubility product (Ksp). Examination of these calculated SI values can then be used to eliminate from consideration any hypothesized reactions that are thermodynamically invalid. Undersaturation is indicated by a negative SI value, although analytical uncertainty generally broadens the "at equilibrium" value to ±0.5 SI units (Siders, 1992). For the purposes of this study, species SI values in the range of -0.5 to +0.5 were considered to be at equilibrium, species with SI values less than -0.5 were generally considered to be undersaturated, and species for which the SI values were greater than 0.5 were considered to be oversaturated. The WATEQF model (Plummer *et al.*, 1976) was used in this study.

Speciation programs also compute the distribution of dissolved species, as well as the speciated and non-speciated charge balance. The charge balance offers an important check on the validity of the analytical results. Because aqueous solutions are electrically neutral, the charge balance should be relatively close (within ±10 percent) to zero; large deviations from zero may indicate unacceptable analyses that should not be used in modeling. Large imbalances in charge may be the result of analytical errors or incomplete analyses (i.e., not all significant cations or anions were analyzed).

Mass-balance calculations constrain the chemistry of groundwater along the flow path, based on the conservation of mass (NETPATH, Plummer *et al.*, 1992). To perform this type of calculation, a knowledge of the mineralogy of the water-bearing unit, as well as

the initial and final water chemistries, is required. Because the possible reactions called on to achieve mass balance are not constrained by thermodynamic data, their feasibility must be checked prior to accepting the model.

Mass-transfer calculations employ thermodynamic data to predict solution composition and transfers between the aqueous, solid, and gaseous phases in a system. MINTEQA2 is the mass-transfer program developed and used by the EPA. MINTEQA2 utilizes the same thermodynamic database as WATEQF (Truesdell and Jones, 1974). It also includes algorithms for ion-exchange and sorption reactions, and permits the user to select one of seven sorption models and to fix solids to precipitate (if oversaturated). Mass-transfer modeling was not performed for this report.

8.2 Selection of Parameters for Modeling

For modeling the inverse problem, the composition of the initial and final solutions, as well as mineralogy of the lithologic units, must be known. Physical parameters, such as the temperature, pH, and Eh of groundwater, are also required as input parameters.

8.2.1 Mineralogical Analyses

To constrain the models as much as possible, and to promote the development of realistic models, the mineralogy of the geologic units comprising the UHSU was examined by standard petrography (thin-section analysis), XRF, XRD, SEM, and microprobe. The results of these analyses were used to select input parameters for modeling. The analytical results for analysis of geologic materials are reported in Volume I of this study, the Geologic Characterization Report (EG&G, 1995a), but are summarized below for the convenience of the reader.

Based on standard petrography, the mineralogy of the UHSU consists of quartz, clays (clay minerals, including authigenic kaolinite, and clay-sized particles), lithic fragments (chert, quartzite, gneiss), microcline/orthoclase, opaque minerals (oxides, hydroxides, oxyhydroxides, pyrite, and carbonaceous fragments), muscovite/biotite, siderite, and trace amounts of zircon, apatite, chlorite, calcite (including some carbonate cement), hornblende, and rutile (as inclusions in quartz). The carbonate cement, which includes some siderite, appears relatively recent and is present mostly at depth.

The results from quantitative mineral analysis by XRD confirm that the main constituent is quartz, which constitutes 45 to 67 percent of the bulk mineralogy in the six samples analyzed. Potassium feldspars (microcline and orthoclase) are dominant over plagioclase, and the two most abundant clay minerals are kaolinite and mixed-layer illite/smectite. Additional minerals identified by XRD include dolomite, clinopyroxene, siderite, apatite, undifferentiated clays, discrete illite, gibbsite, and chlorite.

8.2.2 Reduction-Oxidation (Redox) Potential

As stated by Hem (1992), redox potential (known as Eh or pe, where Eh=0.059*pe) "...is a numerical index of the intensity of oxidizing or reducing conditions within a system, with the hydrogen-electrode potential serving as a reference point of zero volts."

A number of factors determine the value of Eh within a given system. According to Drever (1988), the four most important variables in determining the redox state of groundwater are (1) the oxygen content of recharge water, (2) the distribution and reactivity of organic matter and other potential reductants in the aquifer, (3) the distribution of potential redox buffers in the aquifer, and (4) the circulation rate of the groundwater. One implication of the presence of organic matter or other potential reductants is that, for a site with organic contaminants in groundwater, the possible alteration to a lower redox state in groundwater may affect the speciation, and hence mobility, of redox-sensitive species (Fe, Mn, As, Se, U, Sb, Cr, V, etc.). However, speciation is also influenced by pH and solution composition and cannot be determined from Eh alone.

Eh must be measured in the field at the time of sampling; Eh measured in the lab has little relevance to actual groundwater conditions (Lindberg and Runnells, 1984). Use of a closed, flow-through cell for measurement of Eh avoids alteration of Eh by contact with atmospheric oxygen and therefore gives a better measure of in-ground redox conditions than do methods that expose the sample to the atmosphere.

Numerous redox couples — NO_2^-/NO_3^-, Fe^{+2}/Fe^{+3}, Mn^{+4}/Mn^{+2}, As^{+3}/As^{+5}, etc. — affect the measured Eh of a solution. Measurement of the relative abundance of such redox pairs provides an estimate of the redox conditions; however, because of the inherent disequilibrium (i.e., the various redox couples are not in equilibrium with each other), a single value of Eh to define the redox state of a solution is necessarily inaccurate. As noted by Hem (1992), "The measurement of electrode potentials in natural aqueous systems that correspond to theoretical Eh values encounters many difficulties." However, Hem (1992) also acknowledges that "Measured redox potentials have been shown to be useful in studies of systems that can be well characterized...." Drever (1988) suggests that it may be best to simply consider oxygenated systems (i.e., those systems defined by $O_2 > H_20$) as having a "high" Eh and those without free oxygen (i.e., those systems defined by $SO_4^{-2} > H_2S$) as having a "low" Eh.

Redox potential has not, historically, been measured during the sampling of groundwater at the Rocky Flats site. However, some data from a recent equipment-testing program are available (EG&G, September 7, 1994, preliminary draft of the 1994 Well Evaluation Report); these data were obtained using a flow-through cell and

indicate an Eh range of 0.09 to 0.32 volts for groundwater at the site. Alternatively, in the absence of measured values for Eh — if the chemistry and general condition of the groundwater are known — a general estimate of Eh may be made (see Garrels and Christ, 1965, page 381). For a shallow, unconfined aquifer, some amount of free oxygen may reasonably be assumed, and, as noted in the preceding paragraph, in the presence of measurable oxygen, the Eh of the groundwater will remain high (i.e., an "oxidizing" environment). For unconfined groundwater of the UHSU at the Rocky Flats site, field measurements of dissolved oxygen in groundwater indicate the presence of at least a few mg/L of dissolved oxygen.

Although field measurements of dissolved oxygen indicate an oxygenated groundwater at the site, minerals suggestive of low Eh — such as siderite and pyrite, as well as carbonaceous materials — have been identified in core samples from the weathered claystone bedrock of the UHSU. This disparity suggests that variable redox conditions may exist throughout the hydrostratigraphic unit and that modeling can offer only a general approximation of the speciation and relative stability of redox-sensitive species. Consequently, a mildly oxidizing Eh (0.2 volts at pH values near 7) was selected for the speciation calculations using WATEQF. As noted above, this value of 0.2 volts is supported by the limited data recently acquired for Eh during the testing of various pieces of equipment for field sampling and analysis (EG&G, 1994e, Preliminary Draft of 1994 Well Evaluation Report) and is consistent with general range of redox values for natural waters (see Figure 8-1).

In summary then, the assumption of equilibrium redox conditions — as used by geochemical computer models for speciation and other calculations — is an erroneous but necessary assumption. The state of any redox-sensitive species as determined by the models should, therefore, be viewed with these limitations in mind.

8.2.3 Selection of Wells Defining a Probable Flow Path

Analytical data for wells along the flow paths described in Section 5.3 were used in the geochemical modeling. Flow paths included the northern Buffer Zone (Rock Creek flow path), the center of the Industrial Area (Industrial Area flow path), the area just south of Woman Creek (Woman Creek flow path), and the southernmost part of the south Buffer Zone (Southern flow path) (refer to Figure 5-7).

8.3 WATEQF Modeling

The mean chemistry of each of the wells along a flow path was input to WATEQF, and the speciation and the SI output reviewed. Field data were used for pH, temperature, and dissolved oxygen (DO). As noted earlier, Eh, which is not measured during sampling at the Rocky Flats site, was estimated as 0.2 volts. The estimated Eh value was used to calculate redox species in WATEQF. The Davies equation was used to

determine the ion-activity coefficients, and alkalinity was entered as HCO_3 (as mg/L $CaCO_3$). A listing of analytes whose concentrations were entered into the model is given as Table 8-1.

Table 8-1
Parameters Used in Geochemical Modeling

Major Ions
Bicarbonate (as mg/L $CaCO_3$)
Calcium
Chloride
Magnesium
Potassium
Sodium
Sulfate
Other Parameters
Aluminum
Arsenic
Barium
Cesium
Chromium
Fluoride
Iron
Lead
Lithium
Manganese
Phosphate
Selenium
Silica
Silver
Strontium
Uranium
Vanadium
Zinc

For uranium, the reported values for filtered radionuclide samples were used after a conversion from pCi/L to mg/L was calculated for all isotopes (233+234, 235, and 238) reported in the database. The conversion factors were calculated using half-lives reported in Friedlander *et al.* (1964). The calculated conversion factors for uranium are:

$U^{233/234}$ = 0.00297 mg/pCi, where XpCi/L*0.00297 mg/pCi = Ymg/L
U^{235} = 4.63 x 10-4 mg/pCi
U^{238} = 1.604 x 10-7 mg/pCi

8.3.1 Results of WATEQF Modeling

Mean values for the chemical composition of groundwater collected from each well along the four flow paths were used as input for WATEQF, and a WATEQF analysis was performed for each well. In general, the results of WATEQF modeling are consistent with the mineralogy observed in the cores. Saturation indices for selected mineral phases are presented in Table 8-2 for wells from all four flow paths; discussion of each flow path is presented below.

8.3.1.1 Rock Creek Flow Path

For the Rock Creek flow path, samples from wells B111189, B110989, and B110889 were selected as probable representatives of the "initial water." For the initial wells, and on through well B200789, the results of the WATEQF runs indicate a slight undersaturation (SI = -2.0 to -0.8) with respect to calcite; the groundwater reaches equilibrium with calcite in wells B201189, B201589, B205589, and B202589 (SI = -0.3 to +0.4). Throughout the flow path, the groundwater remains in equilibrium, or oversaturated, with respect to illite, smectite, kaolinite, native silver, fluorapatite, microcline, various iron- and aluminum-oxyhydroxides, and witherite. For several phases, the groundwater chemistry ranges from generally undersaturated to oversaturated; these include strontianite (SI = -1.1 to 1.1), barite (SI = -0.7 to 0.5), and biotite (SI = -4.4 to 0.7). The groundwater is generally undersaturated with respect to siderite (SI = -2.2 to -1.2), native selenium (SI = -3.0 to -0.3), fluorite (SI = -3.2 to -0.5), rhodochrosite (SI = -3.3 to -1.1), gypsum (SI = -3.6 to -1.0), sepiolite (SI = -9.2 to -5.0), and pyrolusite (SI = -14.8 to -13.0) (Figure 8-2).

A summary of the average condition of groundwater analyses from each of the wells along the Rock Creek flow path is given below (Table 8-3). Temperature and pH were measured in the field at the time of sampling; an Eh = 0.2 volts was assumed in the model. Temperatures are in degrees Celsius, and ionic strength is shown as molarity (M) (moles per liter of solution) of the solution.

Table 8-2A
WATEQF Results for Rock Creek Flow Path

Mineral	Formula	Well B111189 SI Values	Well B110989 SI Values	Well B110889 SI Values	Well B200589 SI Values
$Al(OH)_3$ amorphous	$Al(OH)_3$	-0.8	-0.5	-0.8	-0.9
Albite	$NaAlSi_3O_8$	-0.9	-0.6	-1.0	-1.8
Barite	$BaSO_4$	*	-0.7	-0.7	-0.4
Biotite	$K(Mg_2Fe)(AlSi_3)O_{10}(OH)_2$	-2.2	-1.6	-0.3	-4.4
Birnessite	MnO_2, delta	-16.1	-15.7	-15.6	-17.4
Boehmite	AlO(OH)	0.9	1.3	1.0	0.8
Calcite	$CaCO_3$	-1.5	-1.4	-0.8	-1.6
Celestite	$SrSO_4$	-4.3	-4.1	-4.0	-4.0
Chalcedony	SiO_2	0.2	0.2	0.1	0.1
Chlorite-A	$Mg_5Al_2Si_3O_{10}(OH)_8$	-9.6	-8.6	-5.7	-12.5
Chlorite-B	$Mg_5FeAlSi_3O_{10}(OH)_8$	-7.0	-6.2	-2.5	-10.4
Chlorite-C	$Mg_5Fe_{.6}Al_{1.4}Si_3O_{10}(OH)_8$	-9.4	-8.6	-5.2	-12.6
Diaspore	AlO(OH)	1.7	2.1	1.8	1.6
Dolomite	$MgCa(CO_3)_2$	-3.6	-3.3	-2.0	-3.8
$Fe(OH)_3$ amorphous	$Fe(OH)_3$	1.2	1.4	1.9	0.5
Fluorite	CaF_2	-2.4	-2.5		
Fluorapatite	$Ca_5(PO_4)_3F$	2.0	1.2	3.6	1.3
Gibbsite	$Al(OH)_3$	0.4	0.8	0.4	0.3
Goethite	FeO(OH)	4.0	4.2	4.6	3.3
Gypsum	$CaSO_4$-2(H_2O)	-2.9	-2.8	-2.6	-2.5
Hematite	Fe_2O_3	13.5	13.9	14.8	12.2
Hydroxapatite	$Ca_5(PO_4)_3(OH)$	-8.2	-9.0	-6.6	-9.1
Illite-A	$K_{.6}Mg_{.25}Al_{2.3}Si_{3.5}O_{12}H_2$	3.7	4.4	3.7	2.7
Illite-B	K,Fe,H,Mg Al-silicate	6.9	7.8	6.9	5.8
Kaolinite	$Al_2Si_2O_5(OH)_4$	5.2	5.9	5.1	4.8
Magnesite	$MgCO_3$	-2.4	-2.2	-1.6	-2.6
Manganite	MnO(OH)	-8.3	-7.8	-8.1	-9.4
Microcline	$KAlSi_3O_8$	2.2	2.4	2.0	1.3
$MnHPO_4$	$MnHPO_4$	-0.9	-0.7	-1.6	-1.4
Muscovite	$KAl_3Si_3O_{10}(OH)_2$	3.9	4.9	5.0	2.8
Pyrolusite	MnO_2	-14.8	-14.3	-14.3	-16.2
Quartz	SiO_2	0.7	0.7	0.7	0.7
Rhodochrosite	$MnCO_3$	-2.8	-2.1	-2.8	-3.3
Selenium, native	Se	-1.8	-1.4	-2.9	-0.3
Sepiolite-A	$Mg_2Si_3O_{7.5}(OH)$-3(H_2O)	-7.1	-7.1	-5.7	-8.3
Sepiolite-B	$Mg_2Si_3O_{7.5}(OH)$-3(H_2O)	-10.8	-10.8	-9.4	-12.1
Siderite	$FeCO_3$	-2.1	-1.7	-1.6	-2.2
Silica Gel	SiO_2	-0.3	-0.3	-0.4	-0.4
Smectite-A	Mg,Na,K,H,Fe Al-silicate	6.9	7.3	7.0	5.9
Smectite-B	Mg,Na,K,H,Fe Al-silicate	5.7	6.1	6.1	4.6
Smectite-Ca	$Ca_{.17}Al_{2.3}Si_{3.67}O_{12}H_2$	5.2	5.9	5.1	4.6
Smectite-V	K,V,Mg,Fe Al-silicate	-0.1	0.4	-0.5	-0.9
Smithsonite	$ZnCO_3$	-3.5	-3.5	-3.1	-3.8
Strontianite	$SrCO_3$	-1.1	-0.8	-0.2	-1.2
Witherite	$BaCO_3$	0.6	0.6	1.1	0.4

Temperature set at mean value for well, pH set at mean value for well, Eh set at 0.2 volts for all wells.

Table 8-2A (continued)
WATEQF Results for Rock Creek Flow Path

Mineral	Formula	Well B200689 SI Values	Well B200789 SI Values	Well B200889 SI Values	Well B201589 SI Values
$Al(OH)_3$ amorphous	$Al(OH)_3$	-0.8	-0.8	-0.8	-0.9
Albite	$NaAlSi_3O_8$	-1.5	-1.4	-1.5	-1.2
Barite	$BaSO_4$	-0.3	-0.3	-0.2	0.1
Biotite	$K(Mg_2Fe)(AlSi_3)O_{10}(OH)_2$	-2.2	-1.2	-1.1	-0.7
Birnessite	MnO_2, delta	-16.1	-16.0	-15.7	-15.6
Boehmite	AlO(OH)	0.9	1.0	0.9	0.9
Calcite	$CaCO_3$	-1.0	-1.0	-0.7	-0.3
Celestite	$SrSO_4$	-3.9	-3.8	-3.7	-3.1
Chalcedony	SiO_2	0.1	0.1	0.1	0.0
Chlorite-A	$Mg_5Al_2Si_3O_{10}(OH)_8$	-9.0	-8.0	-7.0	-5.2
Chlorite-B	$Mg_5FeAlSi_3O_{10}(OH)_8$	-6.3	-4.7	-3.8	-2.1
Chlorite-C	$Mg_5Fe_{.6}Al_{1.4}Si_3O_{10}(OH)_8$	-8.7	-7.4	-6.4	-4.7
Diaspore	AlO(OH)	1.7	1.7	1.6	1.7
Dolomite	$MgCa(CO_3)_2$	-2.8	-2.7	-2.1	-1.2
$Fe(OH)_3$ amorphous	$Fe(OH)_3$	1.1	1.8	1.5	1.6
Fluorite	CaF_2	-2.3	-2.2	-1.9	-1.1
Fluorapatite	$Ca_5(PO_4)_3F$	3.9	4.2	3.7	6.3
Gibbsite	$Al(OH)_3$	0.4	0.4	0.4	0.4
Goethite	FeO(OH)	3.9	4.6	4.3	4.4
Gypsum	$CaSO_4$-2(H_2O)	-2.3	-2.2	-2.2	-1.8
Hematite	Fe_2O_3	13.3	14.7	18.4	14.4
Hydroxapatite	$Ca_5(PO_4)_3(OH)$	-6.1	-5.8	-6.3	-4.0
Illite-A	$K_{.6}Mg_{.25}Al_{2.3}Si_{3.5}O_{12}H_2$	3.4	3.5	3.4	3.1
Illite-B	K,Fe,H,Mg Al-silicate	6.5	6.7	6.4	6.1
Kaolinite	$Al_2Si_2O_5(OH)_4$	5.0	5.1	4.9	4.8
Magnesite	$MgCO_3$	-2.1	-2.0	-1.7	-1.2
Manganite	MnO(OH)	-8.4	-8.3	-8.1	-8.1
Microcline	$KAlSi_3O_8$	1.9	1.9	1.8	1.4
$MnHPO_4$	$MnHPO_4$	-0.9	-1.0	-1.5	-1.1
Muscovite	$KAl_3Si_3O_{10}(OH)_2$	3.6	3.7	3.5	3.1
Pyrolusite	MnO_2	-14.8	-14.7	-14.5	-14.3
Quartz	SiO_2	0.6	0.6	0.6	0.5
Rhodochrosite	$MnCO_3$	-2.7	-2.8	-2.7	-2.6
Selenium, native	Se	-1.8	-2.0	-2.4	-2.9
Sepiolite-A	$Mg_2Si_3O_{7.5}(OH)$-3(H_2O)	-7.0	-6.7	-6.2	-5.6
Sepiolite-B	$Mg_2Si_3O_{7.5}(OH)$-3(H_2O)	-10.8	-10.4	-10.1	-9.4
Siderite	$FeCO_3$	-2.1	-1.6	-1.9	-1.6
Silica Gel	SiO_2	-1.4	-0.4	-0.4	-0.5
Smectite-A	Mg,Na,K,H,Fe Al-silicate	6.5	6.7	6.5	6.5
Smectite-B	Mg,Na,K,H,Fe Al-silicate	5.3	5.7	5.4	5.5
Smectite-Ca	$Ca_{.17}Al_{2.3}Si_{3.67}O_{12}H_2$	4.9	5.0	4.8	4.6
Smectite-V	K,V,Mg,Fe Al-silicate	-0.6	-0.3	-0.9	-1.8
Smithsonite	$ZnCO_3$	-3.3	-3.2	-3.2	-3.0
Strontianite	$SrCO_3$	-0.7	-0.6	-0.3	0.2
Witherite	$BaCO_3$	1.0	1.0	1.2	1.5

Temperature set at mean value for well, pH set at mean value for well, Eh set at 0.2 volts for all wells.

Table 8-2A (continued)
WATEQF Results for Rock Creek Flow Path

Mineral	Formula	Well B201189 SI Values	Well B205589 SI Values	Well B202589 SI Values
$Al(OH)_3$ amorphous	$Al(OH)_3$	-1.0	-0.9	-0.6
Albite	$NaAlSi_3O_8$	-0.8	-0.5	-0.6
Barite	$BaSO_4$	0.0	0.5	0.1
Biotite	$K(Mg_2Fe)(AlSi_3)O_{10}(OH)_2$	-0.1	0.6	0.7
Birnessite	MnO_2, delta	-14.5	-14.3	-14.3
Boehmite	AlO(OH)	0.8	0.9	1.1
Calcite	$CaCO_3$	0.1	0.4	-0.5
Celestite	$SrSO_4$	-2.7	-2.2	-3.2
Chalcedony	SiO_2	-0.1	-0.1	0.1
Chlorite-A	$Mg_5Al_2Si_3O_{10}(OH)_8$	-5.1	-3.2	-4.8
Chlorite-B	$Mg_5FeAlSi_3O_{10}(OH)_8$	-4.4	0.3	-1.3
Chlorite-C	$Mg_5Fe_{.6}Al_{1.4}Si_3O_{10}(OH)_8$	-4.5	-2.5	-4.1
Diaspore	AlO(OH)	1.6	1.6	1.9
Dolomite	$MgCa(CO_3)_2$	-0.4	0.4	-1.4
$Fe(OH)_3$ amorphous	$Fe(OH)_3$	1.7	1.8	2.1
Fluorite	CaF_2	-1.2	-0.5	-2.0
Fluorapatite	$Ca_5(PO_4)_3F$	4.3	6.9	4.7
Gibbsite	$Al(OH)_3$	0.2	0.3	0.6
Goethite	FeO(OH)	4.5	4.6	4.9
Gypsum	$CaSO_4$-2(H_2O)	-1.5	-1.0	-1.9
Hematite	Fe_2O_3	14.6	14.8	15.3
Hydroxapatite	$Ca_5(PO_4)_3(OH)$	-5.9	-3.5	-10.8
Illite-A	$K_{.6}Mg_{.25}Al_{2.3}Si_{3.5}O_{12}H_2$	2.9	3.2	4.2
Illite-B	K,Fe,H,Mg Al-silicate	6.1	6.2	7.4
Kaolinite	$Al_2Si_2O_5(OH)_4$	4.4	4.5	5.3
Magnesite	$MgCO_3$	-0.8	-0.4	-1.3
Manganite	MnO(OH)	-6.9	-9.0	-6.8
Microcline	$KAlSi_3O_8$	1.7	1.7	2.4
$MnHPO_4$	$MnHPO_4$	-0.8	-0.6	-0.1
Muscovite	$KAl_3Si_3O_{10}(OH)_2$	3.1	3.3	4.5
Pyrolusite	MnO_2	-13.2	-13.1	-13.0
Quartz	SiO_2	0.5	0.5	0.6
Rhodochrosite	$MnCO_3$	-1.2	-1.1	-1.3
Selenium, native	Se	-3.0	-2.7	-2.8
Sepiolite-A	$Mg_2Si_3O_{7.5}(OH)$-3(H_2O)	-5.6	-5.0	-5.5
Sepiolite-B	$Mg_2Si_3O_{7.5}(OH)$-3(H_2O)	-9.3	-8.7	-9.3
Siderite	$FeCO_3$	-1.3	-6.4	-1.2
Silica Gel	SiO_2	-0.6	-0.6	-0.4
Smectite-A	Mg,Na,K,H,Fe Al-silicate	6.1	6.3	7.2
Smectite-B	Mg,Na,K,H,Fe Al-silicate	5.2	5.5	6.3
Smectite-Ca	$Ca_{.17}Al_{2.3}Si_{3.67}O12H_2$	4.0	4.3	5.3
Smectite-V	K,V,Mg,Fe Al-silicate	-1.1	-1.0	0.1
Smithsonite	$ZnCO_3$	-2.9	-2.8	-2.8
Strontianite	$SrCO_3$	0.8	1.1	0.1
Witherite	$BaCO_3$	1.5	1.9	1.4

Temperature set at mean value for well, pH set at mean value for well, Eh set at 0.2 volts for all wells.

Table 8-2B
WATEQF Results for Industrial Area Flow Path

Mineral	Formula	Well B411289 SI Values	Well B411389 SI Values	Well 410789 SI Values	Well P415889 SI Values
$Al(OH)_3$ amorphous	$Al(OH)_3$	-0.9	-0.7	-0.9	-1.3
Albite	$NaAlSi_3O_8$	-1.5	-0.7	-1.4	-1.2
Barite	$BaSO_4$	-1.0	-0.9	-0.3	-0.3
Biotite	$K(Mg_2Fe)(AlSi_3)O_{10}(OH)_2$	-2.9	-3.5	-1.4	-3.2
Birnessite	MnO_2, delta	-14.8	-15.9	-14.9	-17.1
Boehmite	AlO(OH)	0.9	1.0	0.9	0.5
Calcite	$CaCO_3$	-1.7	-1.6	-0.7	-0.9
Celestite	$SrSO_4$	-4.9	-4.4	-3.7	-3.6
Chalcedony	SiO_2	0.1	0.2	0.1	0.3
Chlorite-A	$Mg_5Al_2Si_3O_{10}(OH)_8$	-12.4	-9.6	-6.6	-7.8
Chlorite-B	$Mg_5FeAlSi_3O_{10}(OH)_8$	-8.7	-8.4	-3.9	-5.8
Chlorite-C	$Mg_5Fe_{.6}Al_{1.4}Si_3O_{10}(OH)_8$	-11.6	-10.3	-6.4	-8.0
Diaspore	AlO(OH)	1.6	1.8	1.7	1.3
Dolomite	$MgCa(CO_3)_2$	-4.0	-3.8	-2.0	-2.4
$Fe(OH)_3$ amorphous	$Fe(OH)_3$	2.1	-0.1	1.3	0.0
Fluorite	CaF_2	-2.5	-2.3	-1.8	-2.3
Fluorapatite	$Ca_5(PO_4)_3F$	-0.8	2.4	3.1	2.1
Gibbsite	$Al(OH)_3$	0.3	0.5	0.3	-0.1
Goethite	FeO(OH)	4.9	2.5	4.1	2.9
Gypsum	$CaSO_4$-2(H_2O)	-3.4	-3.1	-2.2	-2.2
Hematite	Fe_2O_3	15.3	10.9	13.8	11.3
Hydroxapatite	$Ca_5(PO_4)_3(OH)$	-11.1	-7.8	-7.0	-7.9
Illite-A	$K_{.6}Mg_{.25}Al_{2.3}Si_{3.5}O_{12}H_2$	2.7	3.9	3.2	2.6
Illite-B	K,Fe,H,Mg Al-silicate	6.0	7.0	6.3	5.4
Kaolinite	$Al_2Si_2O_5(OH)_4$	4.8	5.4	4.8	4.4
Magnesite	$MgCO_3$	-2.6	-2.5	-1.6	-1.8
Manganite	MnO(OH)	-6.8	-8.1	-7.2	-9.3
Microcline	$KAlSi_3O_8$	1.3	2.3	1.6	1.4
$MnHPO_4$	$MnHPO_4$	0.6	-0.4	-0.7	-2.6
Muscovite	$KAl_3Si_3O_{10}(OH)_2$	2.9	4.2	3.2	2.1
Pyrolusite	MnO_2	-13.5	-14.6	-13.6	-15.7
Quartz	SiO_2	0.6	0.8	0.6	0.8
Rhodochrosite	$MnCO_3$	-0.8	-2.6	-1.7	-3.7
Selenium, native	Se	-0.7	-1.6	-2.3	-2.1
Sepiolite-A	$Mg_2Si_3O_{7.5}(OH)$-3(H_2O)	-8.3	-7.1	-6.1	-5.8
Sepiolite-B	$Mg_2Si_3O_{7.5}(OH)$-3(H_2O)	-12.1	-10.8	-9.8	-9.5
Siderite	$FeCO_3$	-0.7	-3.4	-1.9	-3.1
Silica Gel	SiO_2	-0.4	-0.3	-0.4	-0.2
Smectite-A	Mg,Na,K,H,Fe Al-silicate	6.3	6.8	6.5	6.4
Smectite-B	Mg,Na,K,H,Fe Al-silicate	5.2	5.4	5.5	5.2
Smectite-Ca	$Ca_{.17}Al_{2.3}Si_{3.67}O_{12}H_2$	4.5	5.5	4.6	4.5
Smectite-V	K,V,Mg,Fe Al-silicate	-0.8	-0.4	-0.8	-1.9
Smithsonite	$ZnCO_3$	-3.4	-3.7	-3.2	-4.3
Strontianite	$SrCO_3$	-1.2	-1.1	-0.3	-0.4
Witherite	$BaCO_3$	0.7	0.5	1.1	0.9

Temperature set at mean value for well, pH set at mean value for well, Eh set at 0.2 volts for all wells.

Table 8-2B (continued)
WATEQF Results for Industrial Area Flow Path

Mineral	Formula	Well P415989 SI Values	Well 4486 SI Values	Well P115689 SI Values	Well 2187 SI Values
$Al(OH)_3$ amorphous	$Al(OH)_3$	-1.3	-1.1	-1.5	-0.6
Albite	$NaAlSi_3O_8$	-1.1	-0.7	-0.8	-0.5
Barite	$BaSO_4$	0.1	-0.1	0.2	0.9
Biotite	$K(Mg_2Fe)(AlSi_3)O_{10}(OH)_2$	-1.5	0.8	-0.2	-1.1
Birnessite	MnO_2, delta	-14.6	-14.9	-13.2	-14.2
Boehmite	AlO(OH)	0.5	0.7	0.3	1.2
Calcite	$CaCO_3$	-0.6	-0.2	0.6	0.4
Celestite	$SrSO_4$	-3.4	-3.4	-3.3	-1.6
Chalcedony	SiO_2	0.3	0.1	0.2	-0.1
Chlorite-A	$Mg_5Al_2Si_3O_{10}(OH)_8$	-8.8	-4.5	-3.6	-4.7
Chlorite-B	$Mg_5FeAlSi_3O_{10}(OH)_8$	-5.4	1.4	-0.2	-2.7
Chlorite-C	$Mg_5Fe_{.6}Al_{1.4}Si_3O_{10}(OH)_8$	-8.3	-4.3	-2.9	-4.8
Diaspore	AlO(OH)	1.3	1.7	1.0	1.9
Dolomite	$MgCa(CO_3)_2$	-1.9	-1.2	0.5	0.6
$Fe(OH)_3$ amorphous	$Fe(OH)_3$	1.7	2.2	1.1	0.4
Fluorite	CaF_2	-1.8	-1.7	-1.3	-0.8
Fluorapatite	$Ca_5(PO_4)_3F$	2.5	7.1	5.8	6.0
Gibbsite	$Al(OH)_3$	-0.1	0.1	-0.2	0.6
Goethite	FeO(OH)	4.5	5.0	3.9	3.4
Gypsum	$CaSO_4$-2(H_2O)	-1.9	-1.9	-1.7	-0.4
Hematite	Fe_2O_3	14.4	15.5	13.3	12.3
Hydroxapatite	$Ca_5(PO_4)_3(OH)$	-7.8	-2.6	-4.2	-4.7
Illite-A	$K_{.6}Mg_{.25}Al_{2.3}Si_{3.5}O_{12}H_2$	2.9	3.4	2.6	3.5
Illite-B	K,Fe,H,Mg Al-silicate	6.0	7.2	5.2	6.4
Kaolinite	$Al_2Si_2O_5(OH)_4$	4.5	4.4	3.9	5.1
Magnesite	$MgCO_3$	-3.4	-1.3	-0.5	-0.2
Manganite	MnO(OH)	-6.7	-7.4	-5.8	-6.4
Microcline	$KAlSi_3O_8$	1.7	2.4	1.7	1.6
$MnHPO_4$	$MnHPO_4$	0.4	-0.9	-0.3	1.0
Muscovite	$KAl_3Si_3O_{10}(OH)_2$	2.5	3.6	2.2	3.8
Pyrolusite	MnO_2	-13.3	-13.3	-11.9	-13.0
Quartz	SiO_2	0.8	0.6	0.7	0.4
Rhodochrosite	$MnCO_3$	-0.5	-2.4	-0.3	0.4
Selenium, native	Se	-1.5	-4.0	-4.0	-0.9
Sepiolite-A	$Mg_2Si_3O_{7.5}(OH)$-3(H_2O)	-6.2	-5.0	-4.2	-5.9
Sepiolite-B	$Mg_2Si_3O_{7.5}(OH)$-3(H_2O)	-9.9	-8.4	-8.0	-12.6
Siderite	$FeCO_3$	-0.9	-1.6	-2.2	-1.5
Silica Gel	SiO_2	-0.2	-0.4	-0.4	-0.6
Smectite-A	Mg,Na,K,H,Fe Al-silicate	6.7	7.1	6.1	6.0
Smectite-B	Mg,Na,K,H,Fe Al-silicate	5.7	6.2	5.2	5.0
Smectite-Ca	$Ca_{.17}Al_{2.33}Si_{3.67}O_{12}H_2$	4.5	4.4	3.8	4.7
Smectite-V	K,V,Mg,Fe Al-silicate	-0.9	0.0	-2.2	-0.5
Smithsonite	$ZnCO_3$	-4.2	-2.9	-3.1	-0.5
Strontianite	$SrCO_3$	-0.2	0.1	1.0	1.2
Witherite	$BaCO_3$	1.3	1.5	2.5	1.7

Temperature set at mean value for well, pH set at mean value for well, Eh set at 0.2 volts for all wells.

Table 8-2B (continued)
WATEQF Results for Industrial Area Flow Path

Mineral	Formula	Well 3586 SI Values	Well 3686 SI Values	Well 3786 SI Values	Well 3886 SI Values
$Al(OH)_3$ amorphous	$Al(OH)_3$	-0.7	-0.7	-0.8	-1.0
Albite	$NaAlSi_3O_8$	-0.4	-1.1	0.1	-0.9
Barite	$BaSO_4$	0.3	0.6	1.0	0.7
Biotite	$K(Mg_2Fe)(AlSi_3)O_{10}(OH)_2$	0.6	-0.6	2.9	2.0
Birnessite	MnO_2, delta	-13.4	-14.5	-14.3	-14.4
Boehmite	AlO(OH)	1.0	1.1	0.9	0.8
Calcite	$CaCO_3$	0.2	0.4	0.6	0.3
Celestite	$SrSO_4$	-2.6	-1.7	-1.3	-1.6
Chalcedony	SiO_2	0.0	-0.4	0.0	-0.2
Chlorite-A	$Mg_5Al_2Si_3O_{10}(OH)_8$	-5.0	-4.3	1.1	-1.6
Chlorite-B	$Mg_5FeAlSi_3O_{10}(OH)_8$	-0.6	-1.4	5.0	2.5
Chlorite-C	$Mg_5Fe_{.6}Al_{1.4}Si_3O_{10}(OH)_8$	-3.7	-4.0	2.1	-0.5
Diaspore	AlO(OH)	1.7	1.9	1.7	1.6
Dolomite	$MgCa(CO_3)_2$	0.0	0.4	1.0	0.2
$Fe(OH)_3$ amorphous	$Fe(OH)_3$	-2.6	1.6	2.3	2.6
Fluorite	CaF_2	-1.1	-0.7	-0.7	-1.1
Fluorapatite	$Ca_5(PO_4)_3F$	8.0	4.1	9.3	7.0
Gibbsite	$Al(OH)_3$	0.5	0.5	0.4	0.3
Goethite	FeO(OH)	5.4	4.4	5.1	5.4
Gypsum	$CaSO_4$-2(H_2O)	-1.2	-0.5	-0.3	-0.5
Hematite	Fe_2O_3	16.3	14.4	15.8	16.3
Hydroxapatite	$Ca_5(PO_4)_3(OH)$	-5.1	-6.4	-0.8	-3.0
Illite-A	$K_{.6}Mg_{.25}Al_{2.3}Si_{3.5}O_{12}H_2$	-2.9	2.5	3.8	2.9
Illite-B	K,Fe,H,Mg Al-silicate	6.3	5.7	6.7	6.0
Kaolinite	$Al_2Si_2O_5(OH)_4$	5.0	4.4	4.7	4.2
Magnesite	$MgCO_3$	-0.5	-0.3	0.1	-0.4
Manganite	MnO(OH)	-5.7	-6.8	-7.1	-7.0
Microcline	$KAlSi_3O_8$	1.6	0.7	2.1	1.6
$MnHPO_4$	$MnHPO_4$	2.0	-0.6	-1.0	-1.1
Muscovite	$KAl_3Si_3O_{10}(OH)_2$	3.5	2.8	3.8	3.1
Pyrolusite	MnO_2	-12.2	-13.1	-13.1	-13.1
Quartz	SiO_2	0.5	0.2	0.5	0.3
Rhodochrosite	$MnCO_3$	0.5	-0.5	-2.0	-1.8
Selenium, native	Se	-1.9	-2.0	-4.3	-3.1
Sepiolite-A	$Mg_2Si_3O_{7.5}(OH)$-3(H_2O)	-5.7	-6.1	-3.2	-4.5
Sepiolite-B	$Mg_2Si_3O_{7.5}(OH)$-3(H_2O)	-9.6	-9.8	-7.0	-8.2
Siderite	$FeCO_3$	0.0	-0.9	-1.3	-1.0
Silica Gel	SiO_2	-0.5	-0.9	-0.5	-0.7
Smectite-A	Mg,Na,K,H,Fe Al-silicate	6.6	5.4	7.0	6.1
Smectite-B	Mg,Na,K,H,Fe Al-silicate	5.8	4.6	6.3	5.4
Smectite-Ca	$Ca_{.17}Al_{2.33}Si_{3.67}O_{12}H_2$	4.8	3.7	4.7	3.7
Smectite-V	K,V,Mg,Fe Al-silicate	-0.7	-1.3	-0.7	-1.9
Smithsonite	$ZnCO_3$	-2.9	-2.8	-1.7	-2.7
Strontianite	$SrCO_3$	0.8	1.1	1.6	1.1
Witherite	$BaCO_3$	1.6	1.4	1.8	1.4

Temperature set at mean value for well, pH set at mean value for well, Eh set at 0.2 volts for all wells.

Table 8-2B (continued)
WATEQF Results for Industrial Area Flow Path

Mineral	Formula	Well 0486 SI Values	Well 41691 SI Values
$Al(OH)_3$ amorphous	$Al(OH)_3$	-0.9	-0.9
Albite	$NaAlSi_3O_8$	-1.3	-1.2
Barite	$BaSO_4$	0.3	0.4
Biotite	$K(Mg_2Fe)(AlSi_3)O_{10}(OH)_2$	-0.7	-0.6
Birnessite	MnO_2, delta	-13.9	-14.0
Boehmite	AlO(OH)	0.9	0.8
Calcite	$CaCO_3$	-0.4	-0.5
Celestite	$SrSO_4$	-2.9	-2.8
Chalcedony	SiO_2	-0.1	0.0
Chlorite-A	$Mg_5Al_2Si_3O_{10}(OH)_8$	-8.2	-6.6
Chlorite-B	$Mg_5FeAlSi_3O_{10}(OH)_8$	-3.4	-3.4
Chlorite-C	$Mg_5Fe_{.6}Al_{1.4}Si_3O_{10}(OH)_8$	-6.0	-6.0
Diaspore	AlO(OH)	1.7	1.5
Dolomite	$MgCa(CO_3)_2$	-1.2	-1.5
$Fe(OH)_3$ amorphous	$Fe(OH)_3$	1.4	1.4
Fluorite	CaF_2	-1.6	-1.6
Fluorapatite	$Ca_5(PO_4)_3F$	7.1	4.1
Gibbsite	$Al(OH)_3$	0.3	0.3
Goethite	FeO(OH)	4.2	4.2
Gypsum	$CaSO_4$-2(H_2O)	-1.6	-1.5
Hematite	Fe_2O_3	13.9	13.9
Hydroxapatite	$Ca_5(PO_4)_3(OH)$	-3.1	-6.2
Illite-A	$K_{.6}Mg_{.25}Al_{2.3}Si_{3.5}O_{12}H_2$	3.1	3.2
Illite-B	K,Fe,H,Mg Al-silicate	6.4	6.2
Kaolinite	$Al_2Si_2O_5(OH)_4$	4.5	4.5
Magnesite	$MgCO_3$	-1.1	-1.3
Manganite	MnO(OH)	-6.2	-6.4
Microcline	$KAlSi_3O_8$	1.9	2.0
$MnHPO_4$	$MnHPO_4$	1.6	0.5
Muscovite	$KAl_3Si_3O_{10}(OH)_2$	3.5	3.5
Pyrolusite	MnO_2	-12.6	-12.9
Quartz	SiO_2	0.5	0.5
Rhodochrosite	$MnCO_3$	-0.4	-0.6
Selenium, native	Se	-2.2	-2.1
Sepiolite-A	$Mg_2Si_3O_{7.5}(OH)$-3(H_2O)	-6.2	-6.2
Sepiolite-B	$Mg_2Si_3O_{7.5}(OH)$-3(H_2O)		-10.0
Siderite	$FeCO_3$	-1.6	-1.7
Silica Gel	SiO_2	-0.6	-0.5
Smectite-A	Mg,Na,K,H,Fe Al-silicate	6.0	5.9
Smectite-B	Mg,Na,K,H,Fe Al-silicate	5.0	5.0
Smectite-Ca	$Ca_{.17}Al_{2.33}Si_{3.67}O_{12}H_2$	4.2	4.2
Smectite-V	K,V,Mg,Fe Al-silicate	-0.7	-0.6
Smithsonite	$ZnCO_3$	-2.5	-3.4
Strontianite	$SrCO_3$	0.2	0.1
Witherite	$BaCO_3$	1.5	1.4

Temperature set at mean value for well, pH set at mean value for well, Eh set at 0.2 volts for all wells.

Table 8-2C
WATEQF Results for Woman Creek Flow Path

Mineral	Formula	Well B400189 SI Values	Well B400289 SI Values	Well 6886 SI Values	Well 38591 SI Values
$Al(OH)_3$ amorphous	$Al(OH)_3$	-0.8	-0.8	-0.7	-1.0
Albite	$NaAlSi_3O_8$	-1.4	-1.2	-1.3	-1.1
Barite	$BaSO_4$	-0.5	-0.5	-0.1	0.6
Biotite	$K(Mg_2Fe)(AlSi_3)O_{10}(OH)_2$	-4.3	-4.1	0.0	0.3
Birnessite	MnO_2, delta	-17.9	-16.9	-13.9	-13.7
Boehmite	AlO(OH)	1.0	1.0	1.0	0.8
Calcite	$CaCO_3$	-1.8	-1.5	-0.7	0.1
Celestite	$SrSO_4$	-4.1	-4.0	-3.5	-2.5
Chalcedony	SiO_2	0.3	0.2	-0.1	-0.1
Chlorite-A	$Mg_5Al_2Si_3O_{10}(OH)_8$	-13.0	-10.4	-6.4	-4.3
Chlorite-B	$Mg_5FeAlSi_3O_{10}(OH)_8$	-11.6	-8.2	-2.2	-0.5
Chlorite-C	$Mg_5Fe_{.6}Al_{1.4}Si_3O_{10}(OH)_8$	-13.6	-10.5	-5.2	-3.5
Diaspore	AlO(OH)	1.8	1.7	2.1	1.5
Dolomite	$MgCa(CO_3)_2$	-4.3	-3.7	-1.9	-0.4
$Fe(OH)_3$ amorphous	$Fe(OH)_3$	0.2	0.8	2.5	2.2
Fluorite	CaF_2	-2.7	-4.1	-2.0	-1.2
Fluorapatite	$Ca_5(PO_4)_3F$	1.1	1.3	3.3	4.6
Gibbsite	$Al(OH)_3$	0.4	0.4	0.5	0.2
Goethite	FeO(OH)	3.0	4.7	5.3	5.0
Gypsum	$CaSO_4$-2(H_2O)	-2.5	-2.5	-2.2	-1.2
Hematite	Fe_2O_3	11.5	12.7	16.2	-15.5
Hydroxapatite	$Ca_5(PO_4)_3(OH)$	-9.3	-8.1	-6.8	-5.6
Illite-A	$K_{.6}Mg_{.25}Al_{2.3}Si_{3.5}O_{12}H_2$	3.6	3.6	3.3	2.6
Illite-B	K,Fe,H,Mg Al-silicate	3.0	6.7	6.4	5.7
Kaolinite	$Al_2Si_2O_5(OH)_4$	5.4	5.3	4.9	4.1
Magnesite	$MgCO_3$	-2.8	-2.5	-1.5	-0.7
Manganite	MnO(OH)	-9.7	-9.0	-6.4	-6.2
Microcline	$KAlSi_3O_8$	2.2	1.9	1.6	1.3
$MnHPO_4$	$MnHPO_4$	-1.2	-1.3	0.2	-0.2
Muscovite	$KAl_3Si_3O_{10}(OH)_2$	4.0	3.7	3.6	2.7
Pyrolusite	MnO_2	-16.5	-15.6	-12.7	-12.4
Quartz	SiO_2	0.8	0.8	0.5	0.4
Rhodochrosite	$MnCO_3$	-3.5	-3.3	-0.9	-0.6
Selenium, native	Se	0.2	-1.1	-2.4	-2.9
Sepiolite-A	$Mg_2Si_3O_{7.5}(OH)$-3(H_2O)	-8.3	-7.4	-6.3	-5.5
Sepiolite-B	$Mg_2Si_3O_{7.5}(OH)$-3(H_2O)	-12.0	-11.1	-10.2	-9.2
Siderite	$FeCO_3$	-2.3	-2.3	-0.8	-1.1
Silica Gel	SiO_2	-0.2	-0.3	-0.6	-0.7
Smectite-A	Mg,Na,K,H,Fe Al-silicate	6.7	6.8	6.4	5.9
Smectite-B	Mg,Na,K,H,Fe Al-silicate	5.2	5.5	5.6	5.1
Smectite-Ca	$Ca_{.17}Al_{2.3}Si_{3.67}O_{12}H_2$	5.4	5.3	4.6	3.7
Smectite-V	K,V,Mg,Fe Al-silicate	0.2	-0.3	-0.8	-1.2
Smithsonite	$ZnCO_3$	-3.7	-3.4	-3.1	-2.9
Strontianite	$SrCO_3$	-1.5	-1.2	-0.1	0.6
Witherite	$BaCO_3$	0.1	0.5	1.4	1.7

Temperature set at mean value for well, pH set at mean value for well, Eh set at 0.2 volts for all wells.

Table 8-2C (continued)
WATEQF Results for Woman Creek Flow Path

Mineral	Formula	Well 6486 SI Values	Well 6586 SI Values	Well 6686 SI Values	Well 0186 SI Values
$Al(OH)_3$ amorphous	$Al(OH)_3$	-1.1	-1.0	-0.9	-1.2
Albite	$NaAlSi_3O_8$	-0.5	-0.8	-1.1	-1.2
Barite	$BaSO_4$	0.2	0.4	0.1	0.5
Biotite	$K(Mg_2Fe)(AlSi_3)O_{10}(OH)_2$	1.2	0.6	0.2	0.6
Birnessite	MnO_2, delta	-14.7	-14.2	-14.7	-14.3
Boehmite	AlO(OH)	0.7	0.8	0.8	0.6
Calcite	$CaCO_3$	-0.3	1.0	-0.3	-0.2
Celestite	$SrSO_4$	-2.3	-2.6	-3.2	-2.7
Chalcedony	SiO_2	0.0	0.0	-0.1	-0.1
Chlorite-A	$Mg_5Al_2Si_3O_{10}(OH)_8$	-3.1	-3.4	-4.7	-4.1
Chlorite-B	$Mg_5FeAlSi_3O_{10}(OH)_8$	0.9	0.4	-1.2	-0.1
Chlorite-C	$Mg_5Fe_{.6}Al_{1.4}Si_3O_{10}(OH)_8$	-2.1	-2.3	-4.0	-3.1
Diaspore	AlO(OH)	1.4	1.5	1.6	1.4
Dolomite	$MgCa(CO_3)_2$	-0.9	-0.4	-1.1	-0.8
$Fe(OH)_3$ amorphous	$Fe(OH)_3$	2.1	2.0	1.9	2.3
Fluorite	CaF_2	-0.6	-0.9	-2.0	-1.7
Fluorapatite	$Ca_5(PO_4)_3F$	7.4	5.9	5.8	5.5
Gibbsite	$Al(OH)_3$	0.1	0.2	0.3	0.0
Goethite	FeO(OH)	4.9	4.8	4.7	5.1
Gypsum	$CaSO_4$-2(H_2O)	-1.1	-1.4	-1.8	-1.4
Hematite	Fe_2O_3	15.4	15.1	15.0	15.7
Hydroxapatite	$Ca_5(PO_4)_3(OH)$	-3.0	-4.4	-4.1	-4.4
Illite-A	$K_{.6}Mg_{.25}Al_{2.3}Si_{3.5}O_{12}H_2$	3.1	3.0	3.1	2.5
Illite-B	K,Fe,H,Mg Al-silicate	6.0	5.9	6.2	5.7
Kaolinite	$Al_2Si_2O_5(OH)_4$	4.3	4.4	4.5	3.9
Magnesite	$MgCO_3$	-0.9	0.7	-1.1	-0.9
Manganite	MnO(OH)	-7.4	-6.8	-7.2	-6.9
Microcline	$KAlSi_3O_8$	1.9	1.6	1.8	1.4
$MnHPO_4$	$MnHPO_4$	-0.7	-0.6	-0.6	-0.8
Muscovite	$KAl_3Si_3O_{10}(OH)_2$	3.1	3.0	3.3	2.5
Pyrolusite	MnO_2	-13.5	-13.0	-13.5	-13.0
Quartz	SiO_2	0.5	0.5	0.5	0.4
Rhodochrosite	$MnCO_3$	-2.3	-1.3	-2.0	-1.7
Selenium, native	Se	-2.8	-3.4	-3.1	-3.8
Sepiolite-A	$Mg_2Si_3O_{7.5}(OH)$-3(H_2O)	-4.7	-4.9	-5.5	-5.1
Sepiolite-B	$Mg_2Si_3O_{7.5}(OH)$-3(H_2O)	-8.5	-8.7	-9.3	-8.8
Siderite	$FeCO_3$	-1.6	-1.4	-1.6	-1.3
Silica Gel	SiO_2	-0.5	-0.5	-0.6	-0.6
Smectite-A	Mg,Na,K,H,Fe Al-silicate	6.3	6.3	6.2	6.0
Smectite-B	Mg,Na,K,H,Fe Al-silicate	5.5	5.5	5.4	5.2
Smectite-Ca	$Ca_{.17}Al_{2.3}Si_{3.67}O_{12}H_2$	4.0	4.2	4.2	3.5
Smectite-V	K,V,Mg,Fe Al-silicate	-0.8	-1.3	-0.9	-2.1
Smithsonite	$ZnCO_3$	-3.0	-3.1	-3.0	-2.7
Strontianite	$SrCO_3$	0.5	0.7	0.2	0.4
Witherite	$BaCO_3$	1.0	1.7	1.6	1.4

Temperature set at mean value for well, pH set at mean value for well, Eh set at 0.2 volts for all wells.

Table 8-2C (continued)
WATEQF Results for Woman Creek Flow Path

Mineral	Formula	Well 41419 SI Values
$Al(OH)_3$ amorphous	$Al(OH)_3$	-1.0
Albite	$NaAlSi_3O_8$	-0.7
Barite	$BaSO_4$	0.5
Biotite	$K(Mg_2Fe)(AlSi_3)O_{10}(OH)_2$	1.4
Birnessite	MnO_2, delta	-15.3
Boehmite	AlO(OH)	0.8
Calcite	$CaCO_3$	-0.1
Celestite	$SrSO_4$	-2.6
Chalcedony	SiO_2	0.0
Chlorite-A	$Mg_5Al_2Si_3O_{10}(OH)_8$	-2.4
Chlorite-B	$Mg_5FeAlSi_3O_{10}(OH)_8$	1.7
Chlorite-C	$Mg_5Fe_{.6}Al_{1.4}Si_3O_{10}(OH)_8$	-1.3
Diaspore	AlO(OH)	1.4
Dolomite	$MgCa(CO_3)_2$	-0.5
$Fe(OH)_3$ amorphous	$Fe(OH)_3$	2.0
Fluorite	CaF_2	-1.2
Fluorapatite	$Ca_5(PO_4)_3F$	5.6
Gibbsite	$Al(OH)_3$	0.2
Goethite	FeO(OH)	4.8
Gypsum	$CaSO_4$-2(H_2O)	-1.4
Hematite	Fe_2O_3	15.4
Hydroxapatite	$Ca_5(PO_4)_3(OH)$	-4.5
Illite-A	$K_{.6}Mg_{.25}Al_{2.3}Si_{3.5}O_{12}H_2$	3.4
Illite-B	K,Fe,H,Mg Al-silicate	6.1
Kaolinite	$Al_2Si_2O_5(OH)_4$	4.5
Magnesite	$MgCO_3$	-0.7
Manganite	MnO(OH)	-8.0
Microcline	$KAlSi_3O_8$	2.0
$MnHPO_4$	$MnHPO_4$	-2.1
Muscovite	$KAl_3Si_3O_{10}(OH)_2$	3.4
Pyrolusite	MnO_2	-14.1
Quartz	SiO_2	0.6
Rhodochrosite	$MnCO_3$	-2.9
Selenium, native	Se	-3.7
Sepiolite-A	$Mg_2Si_3O_{7.5}(OH)$-3(H_2O)	-4.4
Sepiolite-B	$Mg_2Si_3O_{7.5}(OH)$-3(H_2O)	-8.3
Siderite	$FeCO_3$	-1.7
Silica Gel	SiO_2	-0.5
Smectite-A	Mg,Na,K,H,Fe Al-silicate	6.5
Smectite-B	Mg,Na,K,H,Fe Al-silicate	5.7
Smectite-Ca	$Ca_{.17}Al_{2.3}Si_{3.67}O_{12}H_2$	4.3
Smectite-V	K,V,Mg,Fe Al-silicate	-1.1
Smithsonite	$ZnCO_3$	-3.1
Strontianite	$SrCO_3$	0.7
Witherite	$BaCO_3$	1.8

Temperature set at mean value for well, pH set at mean value for well, Eh set at 0.2 volts for all wells.

Table 8-2D
WATEQF Results for Southern Flow Path

Mineral	Formula	Well B400389 SI Values	Well B400489 SI Values	Well B405789 SI Values	Well B302789 SI Values
$Al(OH)_3$ amorphous	$Al(OH)_3$	0.1	-0.7	-0.8	-1.0
Albite	$NaAlSi_3O_8$	-0.9	-1.1	-1.2	-1.2
Barite	$BaSO_4$	0.1	0.0	0.3	0.2
Biotite	$K(Mg_2Fe)(AlSi_3)O_{10}(OH)_2$	2.2	-0.4	-1.1	0.0
Birnessite	MnO_2, delta	-14.2	-15.1	-15.7	-14.8
Boehmite	AlO(OH)	1.9	1.1	1.0	0.8
Calcite	$CaCO_3$	0.0	-0.8	-1.0	0.0
Celestite	$SrSO_4$	-3.6	-3.6	-3.9	-3.1
Chalcedony	SiO_2	-0.1	0.1	0.1	0.0
Chlorite-A	$Mg_5Al_2Si_3O_{10}(OH)_8$	-3.2	-6.5	-7.2	-4.7
Chlorite-B	$Mg_5FeAlSi_3O_{10}(OH)_8$	0.8	-3.4	-4.3	-1.0
Chlorite-C	$Mg_5Fe_{.6}Al_{1.4}Si_3O_{10}(OH)_8$	-2.2	-6.1	-6.8	-3.8
Diaspore	AlO(OH)	2.6	1.9	1.7	1.4
Dolomite	$MgCa(CO_3)_2$	-1.0	-2.4	-2.6	-0.7
$Fe(OH)_3$ amorphous	$Fe(OH)_3$	3.5	2.0	1.5	1.6
Fluorite	CaF_2	-1.8	-0.5	-2.5	-1.6
Fluorapatite	$Ca_5(PO_4)_3F$	7.6	4.8	2.7	7.2
Gibbsite	$Al(OH)_3$	1.3	0.5	0.4	0.2
Goethite	FeO(OH)	6.3	4.7	4.3	4.5
Gypsum	$CaSO_4$-2(H_2O)	-1.8	-2.0	-2.4	-1.7
Hematite	Fe_2O_3	18.1	15.0	14.1	-14.4
Hydroxapatite	$Ca_5(PO_4)_3(OH)$	-2.1	-5.9	-7.2	-2.8
Illite-A	$K_{.6}Mg_{.25}Al_{2.3}Si_{3.5}O_{12}H_2$	5.3	3.9	3.7	3.1
Illite-B	K,Fe,H,Mg Al-silicate	8.9	7.3	6.8	5.9
Kaolinite	$Al_2Si_2O_5(OH)_4$	6.5	5.3	5.1	4.5
Magnesite	$MgCO_3$	-1.3	-1.9	-1.9	-0.9
Manganite	MnO(OH)	-6.9	-7.6	-8.1	-7.4
Microcline	$KAlSi_3O_8$	2.7	2.2	2.1	1.7
$MnHPO_4$	$MnHPO_4$	-0.3	-0.9	-1.5	-0.5
Muscovite	$KAl_3Si_3O_{10}(OH)_2$	6.2	4.2	3.9	3.1
Pyrolusite	MnO_2	-12.9	-13.8	-14.5	-13.6
Quartz	SiO_2	0.5	0.6	0.7	0.5
Rhodochrosite	$MnCO_3$	-1.8	-2.3	-2.8	-1.9
Selenium, native	Se	-3.9	-2.8	-2.3	-3.2
Sepiolite-A	$Mg_2Si_3O_{7.5}(OH)$-3(H_2O)	-5.8	-6.1	-6.3	-5.4
Sepiolite-B	$Mg_2Si_3O_{7.5}(OH)$-3(H_2O)	-9.5	-9.8	-10.0	-9.2
Siderite	$FeCO_3$	-0.2	-1.7	-2.0	-1.7
Silica Gel	SiO_2	-0.6	-0.4	-0.4	-0.5
Smectite-A	Mg,Na,K,H,Fe Al-silicate	8.1	7.2	6.9	6.1
Smectite-B	Mg,Na,K,H,Fe Al-silicate	7.3	6.2	5.8	5.3
Smectite-Ca	$Ca_{.17}Al_{2.3}Si_{3.67}O_{12}H_2$	6.5	5.3	5.1	4.2
Smectite-V	K,V,Mg,Fe Al-silicate	0.5	-0.2	-0.4	-1.1
Smithsonite	$ZnCO_3$	-2.8	-3.0	-3.3	-3.0
Strontianite	$SrCO_3$	0.1	-0.5	-0.6	0.5
Witherite	$BaCO_3$	1.8	1.1	1.0	1.9

Temperature set at mean value for well, pH set at mean value for well, Eh set at 0.2 volts for all wells.

Table 8-2D (continued)
WATEQF Results for Southern Flow Path

Mineral	Formula	Well B302889 SI Values	Well B302989 SI Values	Well 0186 SI Values	Well 41419 SI Values
$Al(OH)_3$ amorphous	$Al(OH)_3$	-1.0	-0.9	-1.2	-1.0
Albite	$NaAlSi_3O_8$	-1.2	-0.8	-1.2	-0.7
Barite	$BaSO_4$	0.3	0.6	0.5	0.5
Biotite	$K(Mg_2Fe)(AlSi_3)O_{10}(OH)_2$	0.0	0.9	0.6	1.4
Birnessite	MnO_2, delta	-15.0	-14.9	-14.3	-15.3
Boehmite	$AlO(OH)$	0.8	0.9	0.6	0.8
Calcite	$CaCO_3$	-0.1	0.1	-0.2	-0.1
Celestite	$SrSO_4$	-2.9	-2.4	-2.7	-2.6
Chalcedony	SiO_2	-0.1	-0.1	-0.1	0.0
Chlorite-A	$Mg_5Al_2Si_3O_{10}(OH)_8$	-4.4	-2.8	-4.1	-2.4
Chlorite-B	$Mg_5FeAlSi_3O_{10}(OH)_8$	-0.8	0.9	-0.1	1.7
Chlorite-C	$Mg_5Fe_{.6}Al_{1.4}Si_3O_{10}(OH)_8$	-3.6	-2.0	-3.1	-1.3
Diaspore	$AlO(OH)$	1.5	1.6	1.4	1.4
Dolomite	$MgCa(CO_3)_2$	-0.7	-0.2	-0.8	-0.5
$Fe(OH)_3$ amorphous	$Fe(OH)_3$	1.9	1.9	2.3	2.0
Fluorite	CaF_2	-1.3	-1.4	-1.7	-1.2
Fluorapatite	$Ca_5(PO_4)_3F$	4.5	7.8	5.5	5.6
Gibbsite	$Al(OH)_3$	0.3	0.4	0.0	0.2
Goethite	$FeO(OH)$	4.7	4.7	5.1	4.8
Gypsum	$CaSO_4$-2(H_2O)	-1.6	-1.2	-1.4	-1.4
Hematite	Fe_2O_3	14.9	15.0	15.7	15.4
Hydroxapatite	$Ca_5(PO_4)_3(OH)$	-5.6	-2.2	-4.4	-4.5
Illite-A	$K_{.6}Mg_{.25}Al_{2.3}Si_{3.5}O_{12}H_2$	2.9	3.3	2.5	3.4
Illite-B	K,Fe,H,Mg Al-silicate	5.9	6.2	5.7	6.1
Kaolinite	$Al_2Si_2O_5(OH)_4$	4.4	4.6	3.9	4.5
Magnesite	$MgCO_3$	-0.9	-0.6	-0.9	-0.7
Manganite	$MnO(OH)$	-7.5	-7.6	-6.9	-8.0
Microcline	$KAlSi_3O_8$	1.5	1.8	1.4	2.0
$MnHPO_4$	$MnHPO_4$	-1.7	-0.9	-0.8	-2.1
Muscovite	$KAl_3Si_3O_{10}(OH)_2$	2.9	3.4	2.5	3.4
Pyrolusite	MnO_2	-13.7	-13.7	-13.0	-14.1
Quartz	SiO_2	0.4	0.5	0.4	0.6
Rhodochrosite	$MnCO_3$	-2.1	-2.2	-1.7	-2.9
Selenium, native	Se	-3.1	-2.6	-3.8	-3.7
Sepiolite-A	$Mg_2Si_3O_{7.5}(OH)$-3(H_2O)	-5.4	-4.8	-5.1	-4.4
Sepiolite-B	$Mg_2Si_3O_{7.5}(OH)$-3(H_2O)	-9.2	-8.7	-8.8	-8.3
Siderite	$FeCO_3$	-1.6	-1.5	-1.3	-1.7
Silica Gel	SiO_2	-0.6	-0.6	-0.6	-0.5
Smectite-A	Mg,Na,K,H,Fe Al-silicate	6.1	6.3	6.0	6.5
Smectite-B	Mg,Na,K,H,Fe Al-silicate	5.2	5.6	5.2	5.7
Smectite-Ca	$Ca_{.17}Al_{2.3}Si_{3.67}O_{12}H_2$	4.0	4.4	3.5	4.3
Smectite-V	K,V,Mg,Fe Al-silicate	-1.4	-1.1	-2.1	-1.1
Smithsonite	$ZnCO_3$	-3.2	-2.8	-2.7	-3.1
Strontianite	$SrCO_3$	0.5	0.8	0.4	0.7
Witherite	$BaCO_3$	1.8	1.8	1.4	1.8

Temperature set at mean value for well, pH set at mean value for well, Eh set at 0.2 volts for all wells.

Table 8-3
Groundwater Analyses for Rock Creek Flow Path

Well	Charge Balance	Ionic Strength (Molarity)	Mean pH (pH units)	Mean Temp. (°C)
B111189	-2.10%	2.057×10^{-3}	7.06	12.7
B110989	+14.7%	2.741×10^{-3}	6.98	12.7
B110889	+3.98%	3.652×10^{-3}	7.26	12.7
B200589	-6.22%	2.794×10^{-3}	6.77	12.2
B200689	+1.14%	3.295×10^{-3}	7.09	11.9
B200789	+13.4%	3.563×10^{-3}	7.13	12.1
B200889	+11.1%	4.192×10^{-3}	7.23	11.5
B201589	+7.10%	6.845×10^{-3}	7.26	12.4
B201189	+7.51%	1.205×10^{-2}	7.28	12.6
B205589	+2.95%	1.977×10^{-2}	7.38	12.0

8.3.1.2 Industrial Area Flow Path

Groundwater along this flow path is generally in equilibrium with calcite; however, values for the initial wells in the West Spray Field, B411289 and B411389, show a slight undersaturation with respect to calcite (SI = -1.70 and -1.64, respectively). Barite and strontianite show a pattern similar to that for calcite; the initial wells show a slight undersaturation with respect to these two minerals. The remainder of the wells contain groundwater that is essentially at equilibrium with respect to barite and strontianite. Groundwater along the flow path is also at equilibrium, or oversaturated, with respect to quartz, illite, smectite, kaolinite, native silver, muscovite, witherite, fluorapatite, microcline, gibbsite, magnetite, and hematite. The groundwater is generally undersaturated with respect to siderite (SI = -3.4 to 0.0), sepiolite (SI = -8.3 to -3.2), fluorite (SI = -3.1 to -0.6), gypsum (SI = -3.4 to -0.3), native selenium (SI = -4.3 to -0.7), and pyrolusite (SI = -15.7 to -11.9) (Figure 8-3).

A summary of the average condition of groundwater analyses from each of the wells along the Industrial Area flow path is given below. Temperature and pH were measured in the field at the time of sampling; an Eh of 0.2 volts was assumed in the model. Temperatures are given in degrees Celsius, and ionic strength is shown as molarity of the solution.

Table 8-4
Groundwater Analyses for Industrial Area Flow Path

Well	Charge Balance	Ionic Strength (Molarity)	Mean pH (pH units)	Mean Temp. (°C)
B411289	+1.54%	2.022×10^{-3}	6.84	12.3
B411389	+15.0%	1.969×10^{-3}	7.01	12.6
B410789	+9.73%	4.931×10^{-3}	7.14	13.0
P415889	+7.00%	5.125×10^{-3}	7.05	12.8
P415989	+8.31%	6.746×10^{-3}	6.90	13.3
4486	+5.39%	7.281×10^{-3}	7.38	16.3
P115689	+7.98%	1.615×10^{-2}	7.45	11.5
2187	+0.33%	4.443×10^{-2}	6.98	11.3
3586	+4.83%	2.076×10^{-2}	7.15	10.6
3686	+8.75%	3.742×10^{-2}	7.11	12.8
3786	-3.76%	4.196×10^{-2}	7.60	11.9
3886	+6.25%	2.946×10^{-2}	7.44	12.4
0486	-0.01%	8.986×10^{-3}	7.14	12.5
41691	+3.20%	8.898×10^{-3}	7.14	11.2

8.3.1.3 Woman Creek Flow Path

The initial wells (B400189, B400289) along the Woman Creek flow path show a slight undersaturation with respect to calcite (SI = -1.84 and -1.48, respectively); groundwater in the remainder of the wells is near equilibrium with calcite (SI = -0.67 to 0.07). Groundwater along the Woman Creek flow path is at equilibrium, or oversaturated, with respect to chalcedony, quartz, illite, smectite, kaolinite, native silver, witherite, fluorapatite, microcline, gibbsite, magnetite, and hematite. The groundwater along the flow path is consistently undersaturated with respect to rhodochrosite (SI = -3.5 to -0.6), siderite (SI = -2.4 to -0.8), sepiolite (SI = -2.0 to -.4), gypsum (SI = -2.5 to -1.2), and pyrolusite (SI< -12.0) (Figure 8-4).

A summary of the average condition of groundwater analyses from each of the wells along the Woman Creek flow path is given below. Temperature and pH were measured in the field at the time of sampling; an Eh of 0.2 volts was assumed in the model. Temperatures are given in degrees Celsius, and ionic strength given as molarity of the solution.

Table 8-5
Groundwater Analyses for Woman Creek Flow Path

Well	Charge Balance	Ionic Strength (Molarity)	Mean pH (pH units)	Mean Temp. (°C)
B400189	+1.62%	2.253×10^{-3}	6.64	13.4
B400289	+11.1%	2.477×10^{-3}	6.92	12.4
6886	+5.46%	5.101×10^{-3}	7.22	11.3
38591	+1.28%	1.462×10^{-2}	7.33	12.4
6486	+1.87%	1.443×10^{-2}	7.46	11.7
6586	+5.19%	1.208×10^{-2}	7.39	11.5
6686	+6.16%	7.129×10^{-3}	7.34	12.2
0186	-1.50%	9.294×10^{-3}	7.42	13.2
41491	-2.90%	9.686×10^{-3}	7.52	10.6

8.3.1.4 Southern Flow Path

Groundwater along this flow path is generally in equilibrium with calcite; however, values for wells B400489 and B405789 (at the start of the flow path) show a slight undersaturation with respect to calcite (SI = -0.8 and -1.0, respectively). Groundwater along the flow path is also at equilibrium, or oversaturated, with respect to chalcedony, quartz, illite, smectite, kaolinite, native silver, muscovite, witherite, fluorapatite, microcline, gibbsite, magnetite, hematite, barite, and strontianite. The groundwater is generally undersaturated with respect to siderite (SI = -2.1 to -0.2), sepiolite (SI = -8.0 to -4.4), fluorite (SI = -2.5 to -0.5), gypsum (SI = -3.1 to -1.2), rhodochrosite (SI = -2.9 to -1.7), native selenium (SI = -3.9 to -2.4), and pyrolusite (SI = -14.5 to -12.9) (Figure 8-5).

A summary of the average condition of groundwater analyses from each of the wells along the Southern flow path is given below. Temperature and pH were measured in the field at the time of sampling; an Eh of 0.2 volts was assumed in the model. Temperatures are given in degrees Celsius, and ionic strength given as molarity of the solution.

Table 8-6
Groundwater Analyses for Southern Flow Path

Well	Charge Balance	Ionic Strength (Molarity)	Mean pH (pH units)	Mean Temp. (°C)
B400389	+4.33%	6.336×10^{-3}	7.47	12.5
B400489	-0.19%	4.098×10^{-3}	7.24	13.3
B405789	+4.32%	3.574×10^{-3}	7.18	12.5
B302789	-0.23%	8.317×10^{-3}	7.37	11.0
B302889	+7.11%	8.819×10^{-3}	7.37	12.0
B302989	+3.58%	1.313×10^{-2}	7.43	11.3
0186	-1.50%	9.294×10^{-3}	7.42	13.2
41491	-2.90%	9.686×10^{-3}	7.52	10.6

8.3.2 Discussion of WATEQF Results

In accordance with the mineralogical analyses, illite/smectite and kaolinite clays are predicted to form and be stable in the current geochemical environment of UHSU groundwater. However, as noted in Section 3, kaolinite was the only clay conclusively identified as forming authigenically (see Geologic Characterization Report, EG&G, 1995a). Other mineral phases seen in the core samples — including quartz, microcline, and iron oxides — are also predicted as stable phases by the WATEQF modeling. Another mineral phase, sepiolite, was initially suggested by the results of XRD analyses, but discounted upon review of the diffractograms; modeling supports the latter (that is, all groundwaters were shown to be significantly undersaturated with respect to sepiolite).

There is some disagreement between mineralogical analysis and modeling for siderite and pyrite; these phases were observed in samples of core but generally are predicted to be unstable by the modeling. However, many phases exist outside of their stability fields (e.g., diamond at the Earth's surface), but the chemical reactions transforming the mineral phase may proceed so slowly that no change is perceived on the human time-scale. The pyrite and siderite observed in core samples from Rocky Flats may reflect localized areas of reducing conditions, or represent reducing conditions at their time of crystallization and do not necessarily indicate reducing conditions at present.

Goethite and other oxyhydroxides and oxides for which the groundwater is oversaturated are likely candidates to influence the concentration of iron in

groundwater. Concentrations of other elements associated with such oxyhydroxides and oxides, either by coprecipitation or adsorption, may also be strongly influenced by such phases. The results of WATEQF modeling, which indicate oversaturation of hematite, goethite, and amorphous $Fe(OH)_3$ in every well (see Table 8-2, SI values), are consistent with SEM photos showing iron-hydroxide floccules (EG&G, 1995a). The saturation state of all groundwater samples with respect to calcite and gypsum is shown in Figure 8-6.

For metals that form carbonate minerals, such phases may control the solubility of the metal. Carbonate phases include calcite ($CaCO_3$), witherite ($BaCO_3$), rhodochrosite ($MnCO_3$), strontianite ($SrCO_3$), and siderite ($FeCO_3$). Uranium also forms various carbonate complexes, and, as noted by Hem (1992), "Uranyl complexes with carbonate and sulfate may influence the behavior of dissolved uranium." Under oxidizing conditions with neutral or higher pH, the solubility of uranium increases over that of more reduced (i.e., U^{+4}) forms (Hem, 1992). Radium will also form carbonate and sulfate species (Hem, 1992).

The results of modeling suggest that carbonate species are important for at least barium and strontium, and possibly manganese. The groundwater ranges from moderately undersaturated to moderately oversaturated with respect to these "pure" carbonate phases (see Table 8-2, SI values). However, metals dissolved in groundwater may be controlled by the solubility of impure (substituted) calcium carbonate or other "impure" phases. Generally speaking, thermodynamic values are calculated for pure phases rather than impure ones. Because a variety of metal cations can substitute in the crystal lattice for calcium in calcium carbonate, these cannot be specifically modeled unless thermodynamic data exist for such an impure phase.

Sulfate minerals may also influence the concentrations of dissolved calcium, strontium, and barium in groundwater. Gypsum ($CaSO_4$), celestite ($SrSO_4$), and barite ($BaSO_4$) are phases seen to exhibit reversible behavior (Jones, 1992). The groundwater is at approximate equilibrium (SI = -1.0 to + 1.0) with respect to barite in virtually every well along the four flow paths. This indicates the likelihood that the concentration of dissolved barium in UHSU groundwater is controlled by barite solubility.

Dissolved manganese displays a wide range of concentration, and the calculated SI values indicate that the UHSU groundwater is undersaturated with respect to several mineral phases likely to control the equilibrium solubility of manganese. The groundwater is undersaturated with respect to the manganese oxyhydroxide, manganite [MnO(OH)]; the manganese carbonate, rhodochrosite ($MnCO_3$); and the manganese oxides, birnessite (MnO_2) and pyrolusite (MnO_2). Pyrolusite, which forms the well-known "desert varnish" — the black veneer seen on exposed rocks across the desert southwest — is well below equilibrium solubility in the flow-path wells

evaluated for this report. Any manganese oxide contained within the UHSU, along fractures and elsewhere, is predicted to dissolve into the groundwater until the equilibrium concentration of manganese is attained or different redox conditions are encountered. (As noted earlier, manganese is one of the redox-sensitive species, whose form and mobility are affected by redox conditions.)

8.3.3 Conclusions from WATEQF Modeling

As noted in Section 8, WATEQF uses thermodynamic data to calculate equilibrium status of a solution, without regard to kinetic factors. Some reactions may not be easily reversible due to kinetic barriers. Minerals that have been observed to exhibit reversible behavior include carbonates (calcite, dolomite, siderite, rhodocrosite), sulfates (gypsum, celestite, barite), phosphates (hydroxyapatite, vivianite), oxyhydroxides (amorphous $Fe(OH)_3$, goethite, hematite, gibbsite, birnessite, manganite), silicates (silica gel, silica glass, chalcedony, quartz, kaolinite, sepiolite), sulfides (FeS amorphous, mackinawite), and fluorite (Table 8-7).

One salient point that comes from the WATEQF modeling is that the concentrations of various dissolved metals are generally not greatly in excess of those expected on the basis of thermodynamic calculations of solubility controlled by naturally occurring mineral phases; barium, manganese, selenium, and strontium are notable examples of such metals. (See example in Appendix H for WATEQF output for Industrial Area well 2187.) The calculated mean TDS for well 2187 is nearly 2,500 mg/L, with a calculated ionic strength (IS) of 4.44×10^{-2} M. For barium in well 2187, $SI_{witherite} = 1.7$, $SI_{barite} = 0.9$; for manganese, $SI_{MnHPO4} = 1.0$, $SI_{rhodochrosite} = 0.4$, $SI_{pyrolusite} = -13.0$; for selenium, $SI_{native\ selenium} = -0.9$; and for strontium, $SI_{strontianite} = 1.2$, $SI_{celestite} = -1.6$.

In summary, naturally occurring mineral phases may well control the amount of some dissolved metals in groundwater at the Rocky Flats site. Metals that readily substitute for calcium in the crystal lattice of calcium carbonate may have concentrations regulated by the equilibrium solubility of that mineral. This potential exists for the alkaline earth metals (magnesium, strontium, barium, etc.), as well as for some transition metals (manganese and iron), and possibly for zinc, lead, and uranium as well. Sulfate species, such as barite ($BaSO_4$), may also play a major role in regulating the concentrations of certain metals in solution. Additionally, Hem (1992) noted that "Redox equilibria appear to control behavior of iron in groundwater and also may be extended to other oxidizable or reducible elements that can be coupled to the iron system." Thus, the behavior of some species — especially trace metals — may be coupled to that of iron. The precipitation, coprecipitation, or adsorption of these metals along with iron oxides and oxyhydroxides could be the factor controlling the amount of these metals in solution.

One phase that is predicted to be oversaturated in all the models is naumannite (Ag_2Se). Whether or not such a phase actually exists at Rocky Flats is debatable; the solubility of this phase may be so low that detection-limit concentrations are sufficient to trigger its appearance as an oversaturated phase in the model output. The same argument may also hold true for native silver, which is also predicted as oversaturated in all the models.

Table 8-7
WATEQF List of Minerals with Reversible[1] Precipitation/Dissolution

Mineral	Chemical Formula
Carbonates	
calcite	$CaCO$
dolmite	$CaMg\ (CO_3)_2$
siderite	$FeCO_3$
rhodocrosite	$MnCO_3$
Sulfates	
gypsum	$CaSO_4.2H_20$
celestite	$SrSO_4$
barite	$BaSO_4$
Phosphates	
hydroxyapatite	$Ca_5(PO_4)OH$
vivianite	$Fe_3(PO_4)_2.8H_2O$
Fluoride	
fluorite	CaF_2
Oxyhydroxides	
$Fe(OH)_3$ amorphous	$Fe(OH)_3$
goethite	$FeO(OH)$
gibbsite	$Al(OH)_3$
birnessite	MnO_2
manganite	$MnO(OH)$
Silicates	
silica gel	$SiO_2.2H_2O$
silica glass	$SiO_2.H_2O$
chalcedony	SiO_2
quartz	SiO_2
kaolinite	$Al_2Si_2O_5(OH)$
sepiolite ppt.	$Mg_2Si_3O_{7.5}(OH).3H_20$
sepiolite	$Mg_2Si_3O_{7.5}(OH).3H_20$
Sulfides	
FeS amorphous	FeS
mackinawite	FeS

[1] from Jones (1992)

8.4 NETPATH Modeling

The NETPATH program requires the user to choose "initial" and "final" wells, which define the flow path and the initial and final groundwater chemistries. The mass-balance modeling is then used to describe the chemical evolution of the groundwater along this user-defined flow path, in terms of mineral dissolution and precipitation, as well as ion-exchange reactions. The user also determines which elements and minerals should be considered in the modeling. The best definition of groundwater evolution along the user-determined flow path requires the use of site-specific mineralogy in the model. To this end, mineralogic and petrographic data from the Geologic Characterization Report (EG&G, 1995a) were used for the input of site-specific mineral chemistry for the mass-balance modeling of groundwater at Rocky Flats.

Ideally, NETPATH modeling is applied to truly evolutionary waters along a well-defined, confined groundwater system. The UHSU at the Rocky Flats site is a largely unconfined groundwater system, and groundwater along the four flow paths is subject to mixing via recharge solutions at any point along the defined paths. Recognizing this inherent limitation, the models produced here offer a first approximation of how the chemistry of groundwater may evolve along a flow path at Rocky Flats. As more hydrologic and geologic data become available, the flow paths and the specific water/rock interactions used in the geochemical modeling can be more narrowly defined to produce more realistic models.

Compositional data for groundwater are entered as mg/L, which the NETPATH program recalculates to millimoles per kilogram (mmol/kg). For dilute solutions, such as the groundwater at Rocky Flats, one liter of water is essentially equal to one kilogram (i.e., mg/kg = mg/L). Selected mineral phases may be "fixed" as mandatory for all models (i.e., the program must include the designated fixed phases in every model), and phases can also be marked for precipitation, dissolution, or either. After the user accepts all the input specifications and initiates the program, NETPATH tests all possible models, then provides a listing of all models found to generate the final water composition from the initial water composition. The user must then examine all models found and determine which are most realistic, given the results of thermodynamic calculations and all other known factors.

Using the mineralogical and compositional data obtained by petrographic and geochemical analyses, a set of phases was selected as representative of the UHSU substrate. Table 8-8 lists the user-specified constraints and phases defined for the model.

Table 8-8
User-Specified Constraints and Phases

Constraints		Phases	
carbon	calcium	biotite	illite
aluminum	magnesium	kaolinite	smectites[1]
sodium	potassium	quartz	microcline
fluoride	SiO_2	calcite	siderite
barium	strontium	dolomite	chlorite
iron	manganese	CO_2 gas	fluorapatite
		gibbsite	goethite
		K-mica	MnO_2
		pyrite	albite
		strontianite	witherite
		FeOOH	Ca-Na ion exchange
		K-Na ion exchange	Mg-Na ion exchange

[1]Ca-montmorillonite, K-montmorillonite, Na-montmorillonite

Quartz, microcline, illite, and kaolinite were fixed as mandatory for inclusion in all models; kaolinite, montmorillonites, and quartz were set for "precipitation only," and several of the above phases (pyrite, biotite, microcline, albite, siderite, dolomite, exchange complexes) were set for "dissolution only."

Under dilute groundwater conditions, divalent cations will generally replace monovalent cations from the sorption sites. In accordance with this, exchange complexes were fixed so that calcium and magnesium cations would replace sodium ions from the matrix materials. Marine or near-marine shales and sandstones, such as the Arapahoe/Laramie Formation at Rocky Flats, "...would be expected to have sodium ions adsorbed on most exchange sites" (Hem, 1992). The calcium-bicarbonate chemistry of present-day UHSU groundwater may therefore result in displacement of remaining sodium ions from the sorption sites and replacement with calcium (and magnesium) ions. Statistically however, as noted in Section 6 (Figures 6-39 and 6-40), there is no evidence of an east-to-west trend in the Ca/Na or Ca+Mg/Na+K ratios across the site. Thus, further refinements of the model should take this into account.

Data from microprobe analyses were used to calculate mole percents for some specific phases, including biotite, FeOOH, siderite, microcline, and albite (Table 8-9); these site-specific compositions were then used in the NETPATH modeling, along with

stoichiometric compositions for other phases included in the model. The system was designated as open to CO_2. In general, the following limitations were used in the mass-balance modeling:

- Microcline, illite, kaolinite, and SiO_2 were fixed for mandatory inclusion in all models
- Kaolinite, montmorillonites (smectites), and SiO_2 were set for precipitation only
- Biotite, siderite, pyrite, albite, microcline, MnO_2, and dolomite were set for dissolution only
- Exchange reactions were all set for incorporation of divalent cations and potassium onto the solid phase and release of sodium cations to solution

Table 8-9
User-Specified Phase Compositions

Biotite	2.145 SiO_2, 1.0 Al, 0.663 Fe, 0.58 K, 0.517 Mg, 0.032 Ca, 0.037 Mn
FeOOH	1.0 Fe, 0.08 Ca, 0.034 SiO_2, 0.017 Mg, 0.016 Mn
Siderite	1.0 CO_2, 0.771 Fe, 0.17 Ca, 0.15 Mg, 0.007 Mn, 0.004 SiO_2
Microcline	3.0 SiO_2, 1.0 Al, 0.675 K, 0.052 Na, 0.012 Ca, 0.009 Mg, 0.005 Mn, 0.002 Fe
Plagioclase (albite)	3.397 SiO_2, 1.0 Al, 0.416 Na, 0.192 K, 0.017 Ca, 0.01 Fe
Montmorillonite	2.4 SiO_2, 1.0 Al, 0.2 Mg, 0.1 Ca, 0.1 Na

8.4.1 Results of NETPATH Modeling

Mass-balance modeling was conducted for each of the four flow paths (Rock Creek, Industrial Area, Woman Creek, and Southern). The results for each of the flow paths will be discussed in turn, followed by a discussion of conclusions derived from the NETPATH modeling, and an overview of probable water/rock interactions at the Rocky Flats site.

Those models requiring more than 10 millimoles of dissolution or precipitation were excluded from consideration as viable models. For example, 10 mmol of SiO_2 equates to about 600 mg/L, clearly unrealistic for groundwater at the Rocky Flats site, where SiO_2 concentrations are generally 10 to 20 mg/L. However, 10 mmol calcium equates to approximately 400 mg/L calcium, which is within the concentration range of dissolved calcium in site groundwater. Species-specific concentration limits could be established for future modeling efforts.

8.4.1.1 *Rock Creek Flow Path*

The Rock Creek path is perhaps the most well-defined of the four flow paths and represents groundwater evolution unimpacted by industrial activities at the former plant site. Well B111189 was defined as the initial well of the flow path, and well B202589 was defined as the final well for NETPATH modeling. Using the mean values for chemistry of these two wells, and the specifications given above, more than two-million possible models were tested by NETPATH; of these, 82 models were found to fit the user-specified constraints. Initial review of these 82 models resulted in the elimination of those models requiring relatively large (10 mmol or greater) amounts of dissolution or precipitation. This culling left 59 models for a more in-depth review.

All remaining models included microcline, illite, kaolinite, SiO_2, strontianite, witherite, fluorapatite, CO_2 gas, and at least one iron-containing phase (i.e., FeOOH, goethite, biotite, pyrite, or siderite). These remaining 59 models were individually evaluated for "geochemical reasonableness." This "reasonableness" takes into account the known mineralogy and groundwater chemistry at the Rocky Flats site. For example, dolomite was identified as a minor constituent in the geologic units examined for the Geologic Characterization Report (EG&G, 1995a), so it is probably unrealistic to invoke large amounts of dolomite dissolution to describe the changes in groundwater chemistry. On the other hand, dissolution of microcline and precipitation of clays would be a more realistic model, given the known mineralogy. SEM analysis showed evidence of dissolution of feldspar grains and the precipitation of authigenic kaolinite. Illite/smectite clays are predicted to precipitate, based on their calculated saturation indices, but evidence of authigenic illite/smectite was not seen in the six samples analyzed by SEM.

Several of the models for the Rock Creek path offer rather small amounts (0.001 to 2.00 mmol/L) of dissolution and precipitation to describe the changes in groundwater chemistry along the flow path. These models are compatible with the known bedrock mineralogy and with the known groundwater geochemistry. In general, the models call for the precipitation of kaolinite, SiO_2, and FeOOH or goethite (iron phases seen in SEM micrographs taken for Geologic Characterization Report, EG&G, 1995a), along with the dissolution of microcline, calcite, chlorite, fluorapatite, pyrite, strontianite, and witherite; illite may dissolve or precipitate.

8.4.1.2 *Industrial Area Flow Path*

For the Industrial Area flow path, well B411289 was selected as the initial well and wells 41691 and 0486 were chosen as final wells. Because two final wells were used, two separate modeling runs were made; the output from each is discussed below.

Using well 41691 as the final well, more than two-million models were tested; of these, 24 models satisfied the user-specified limitations. Only four of these 24 models called for excessive amounts (i.e., more than 10 mmol/L) of dissolution or precipitation.

Using well 0486 as the final well, more than two-million models were tested; of these, 23 models satisfied the user-specified limitations. Only 4 of these 24 models called for excessive amounts (i.e., more than 10 mmol/L) of dissolution or precipitation.

The models produced using either of the two final wells are generally similar, with the exception of biotite (dissolution) and chlorite (dissolution or precipitation) appearing only in some models for final well 0486. The most realistic models are characterized by relatively small amounts (0 to 3 mmol/L) of dissolution and precipitation of approximately one-dozen mineral phases. The precipitation of SiO_2 and kaolinite and the dissolution of microcline, strontianite, witherite, fluorapatite, and pyrite are common to all the models; illite may precipitate or dissolve in small amounts. For final wells 0486 and 41691, other phases that appear in the models include (1) (dissolution only) albite, siderite, dolomite, ion-exchange reactions for K/Na, Mg/Na, and Ca/Na; (2) (precipitation only) FeOOH; and (3) (either precipitation or dissolution) goethite, MnOOH, and MnO_2.

8.4.1.3 Woman Creek Flow Path

Well B400189 was defined as the initial well for the Woman Creek flow path. Two wells, 0186 and 41491, were selected as possible final wells. Models using each of these final wells were run separately.

More than two-million models were tested, and (using well 41491 as the final well) 91 models fit the user-specified limitations. Only 2 of the 91 models required more than 10 mmoles of dissolution or precipitation; these were excluded from consideration as viable models. Several models looked exceptionally realistic; model 19 called for the precipitation of illite (.0133 mmol/L), kaolinite (0.30563 mmol/L), SiO_2 (-0.49897 mmol/L), and goethite (0.498 mmol/L), as well as the dissolution of calcite (0.811 mmol/L), chlorite (0.32097 mmol/L), fluorapatite (0.038 mmol/L) pyrite (0.497 mmol/L), strontianite (0.005 mmol/L), witherite (0.001 mmol/L) and the exchange of magnesium for sodium (i.e., sodium released into solution). This model agrees not only with the results of WATEQF modeling but also with the known mineralogy as analyzed in core samples (see EG&G, 1995a).

Using well 0186 as the final well, more than two-million models were tested; 97 models fit the user-specified limitations. Only 2 of these 97 models required more than 10 mmoles of dissolution or precipitation and were excluded from consideration as viable models. Model 35 offered a credible scenario, with the precipitation of illite (0.00167 mmol/L), kaolinite (0.9937 mmol/L), SiO_2 (0.33128 mmol/L), and goethite (0.499 mmol/L), in addition to the dissolution of calcite (1.952 mmol/L), chlorite (0.10128

mmol/L), fluorapatite (0.014 mmol/L), pyrite (0.498 mmol/L), strontianite (0.003 mmol/L), witherite (0.001 mmol/L) and the exchange of calcium for sodium (i.e., calcium replaces sodium on the solid surfaces).

8.4.1.4 Southern Flow Path

Well B400389 was taken as the initial well, and, like the Woman Creek path, two wells were selected as final wells (41491 and 0186). Models using each of these final wells were run separately.

For the path using well 41491, more than two-million models were tested; 51 of these were found to fit the user-specified limitations. None of the 51 models required more than 10 mmoles of dissolution or precipitation. Several realistic models requiring small amounts (0.0 to 2.6 mmol/L) of dissolution and precipitation were found by NETPATH. Common to five such models is the precipitation of kaolinite, SiO_2, and an iron-bearing phase (FeOOH or goethite); the dissolution of microcline, chlorite, fluorapatite, pyrite, strontianite, witherite; and some ion-exchange reactions (Ca/Na, Mg/Na, or K/Na). Illite appears in these five models, either precipitating or dissolving in small amounts (0.12 mmol/L or less); calcite is present in three of the five models, showing precipitation in one model and dissolution in the other two.

For the path using well 0186, more than two-million models were tested; 126 of these were found to fit the user-specified limitations. Two of the 126 models required more than 10 mmoles of dissolution or precipitation and were eliminated from consideration as viable models. Alternative probable models (0.0 to 2.4 mmol/L) include those that indicate the precipitation of kaolinite, SiO_2, and FeOOH or goethite and the dissolution of microcline, illite, biotite, calcite, chlorite, fluorapatite, pyrite, strontianite, and witherite; exchange reactions include calcium, magnesium, and potassium replacing sodium on the solid surfaces.

8.4.2 Discussion of NETPATH Results

Evaluation of NETPATH models indicates the feasibility of producing final water compositions from initial water chemistry by water/rock interactions using realistic mineralogy and reasonable amounts of dissolution, precipitation, and ion-exchange. Specifically, the dissolution and precipitation of reasonable amounts of mineral phases as the groundwater migrates downgradient can explain the changes in the chemical composition of the groundwater. Mixing of other solutions is not required to produce the chemistry reported for groundwater samples collected from the eastern boundary of the site.

Evaluation of groundwater data from wells along the eastern, downgradient boundary of the Rocky Flats site indicates only a few metals, water-quality parameters, and

radionuclides above background levels. Review of the chemistry of background wells shows that upgradient background concentrations (for some analytes) exceed some water standards, without even considering the added effect of geochemical evolution as groundwater migrates along a flow path. The dissolution of naturally occurring minerals by groundwater as it traverses the site may add additional inorganic constituents to the water. Such a scenario of increasing concentrations due to groundwater evolution (i.e., water/rock interaction) along a flow path is consistent with the results of modeling performed for this report.

8.4.3 Conclusions from NETPATH Modeling

As noted earlier in Section 8.4, NETPATH modeling is best applied to evolutionary, confined groundwater systems. Because much of the UHSU is an unconfined groundwater system, the results discussed here can only be considered a first approximation of groundwater evolution at the Rocky Flats site. As additional geologic and hydrologic data are collected, these data can be used to refine the geochemical models.

In summary, the results from NETPATH modeling show that groundwater at the Rocky Flats site undergoes chemical evolution as it traverses the site. The mixing of additional solutions (i.e., inorganic contaminants) is not required to produce a credible model that explains the overall changes in groundwater chemistry from west to east across the site, although localized mixing with other solutions is suggested in parts of the main plant area (see Figures 5-8 to 5-17).

8.5 Conclusions and Implications from Geochemical Modeling

Groundwater chemistry at the terminus of all four flow paths can be realistically modeled without the necessity of mixing with another solution (such as a contaminant-bearing solution). However, the model results can neither prove nor disprove the existence of groundwater contamination and contaminant transport. As can be seen in the chemical variation diagrams (Figures 6-20 to 6-40), there are some locations where input from the OUs does appear to have affected groundwater in the immediate vicinity. Whether this localized influx has the potential for downgradient migration, or whether it will be attenuated within a short distance of the OUs, is a critical concern. A better understanding of the hydrogeology of the site, and the refinement of hydrologic and geochemical models will assist in addressing this concern.

Unlike the Rocky Mountain Arsenal, where offsite migration of contaminants in groundwater has been definitively demonstrated (EPA, 1986 and 1993; ESE, 1988; also refer to Appendix I), evidence to date suggests that groundwater transport of contaminants derived from the Rocky Flats site to offsite locations is minimal to none. Analysis of boundary-well data is currently being performed as part of the OU2 remedial

investigation (DOE, 1993b), and the reader is referred to this document for a more detailed evaluation of these data.

Other factors, unrelated to contaminant transport via groundwater, may have also affected the chemistry of samples collected from some Rocky Flats wells. For example, groundwater data for unfiltered samples collected from boundary well 41691 strongly suggest that plutonium- and americium-contaminated surficial soils may accidentally have been carried into the well-bore during drilling and installation of this well. The activities of plutonium and americium in unfiltered samples from this well have ranged from 0.26 to 2.20 pCi/L and exhibit a strong correlation with TSS (see Figure 5-2). However, activities of dissolved plutonium and americium in this well are (and have been) less than the site-specific standard of 0.05 pCi/L (CDPHE WQCC, 1994). The strong correlation of total metals and radionuclides with TSS in well 41691 (see Figures 5-1 and 5-2) is consistent with the hypothesis that these radionuclides represent cross-contamination by plutonium-contaminated soils, which are known to occur in the Buffer Zone east of the main plant site (Litaor, 1993). The aseptic installation of additional wells in the Walnut Creek drainage should provide evidence as to the mechanism by which plutonium and americium came to reside in the sediments of monitoring well 41691.

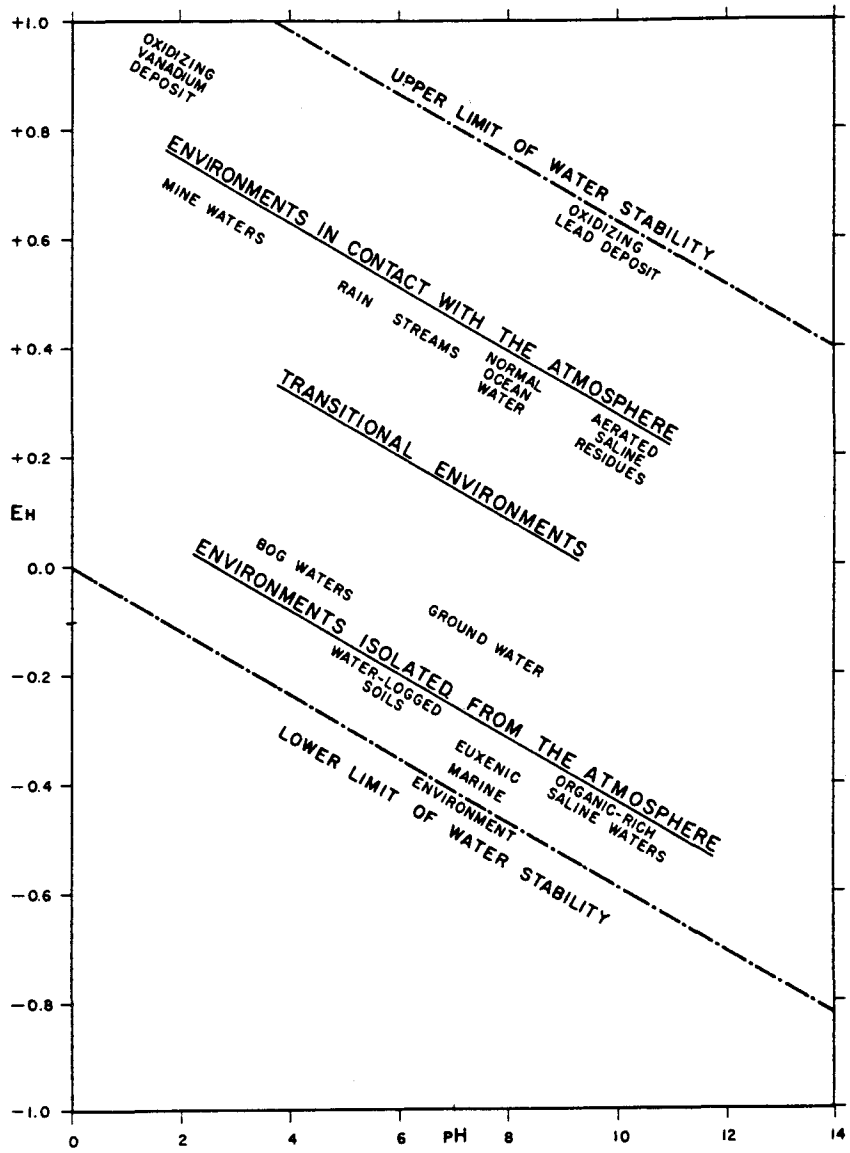
Contaminant-transport models use the concentrations of dissolved (i.e., filtered) metals; data from unfiltered metals samples of groundwater are not used in transport modeling. Particularly for a clay-rich matrix, such as the geologic materials at the Rocky Flats site, pore sizes would not permit the migration of particulates via groundwater. In addition, flow velocities would be too low to suspend the particulates for transport. Thus, the focus of contaminant-transport and geochemical models is on the dissolved fraction, the constituents in solution. Geochemical modeling of groundwater must use the concentrations of dissolved constituents in order to produce meaningful results.

What the geochemical modeling of Rocky Flats groundwater does show is the natural evolution in groundwater chemistry along the flow path. The significance of the geochemical evolution of groundwater as it traverses through geologic materials relates to the definition of background. Many environmental studies use as a baseline the concentration of chemicals in a pre-determined background area. The concept here is that if a site contains concentrations of chemicals that exceed those in the background, then contamination of the site is suspected or declared. The possible flaw in this reasoning comes about if the background area is upgradient of the site and the chemical composition of groundwater evolves due to natural water/rock interactions as it traverses the site. In this case, the background area would contain less-evolved groundwater, with correspondingly lower concentrations of inorganic constituents than downgradient groundwater at the site. Compounding this potential problem is that the density of sampling is generally much higher at the site than in the background area. The question

then becomes, "Is it possible to obtain a fair estimate of background groundwater that is independent of an upgradient bias?"

Thus, background studies are potentially biased by the lower concentrations of many constituents in the upgradient (background) samples. Although the background study conducted at the Rocky Flats site (Background Geochemical Characterization Report, EG&G, 1993f) attempted to minimize the degree of upgradient bias by including as some of the background wells those that were sidegradient to the main plant area (rather than all upgradient wells), statistical comparisons of background-to-site chemistry still do not take into account the geochemical evolution of groundwater along a flow path. Persons evaluating the results of such statistical tests should consider groundwater evolution as another variable, and apply their professional assessment of statistical results in light of an inherently heterogeneous and complex natural system.

The modeling results and concepts discussed here can be used to provide additional information that should be included in weight-of-evidence discussions of possible groundwater contamination by metals and other inorganic analytes. For example, if a groundwater is undersaturated with respect to a particular mineral phase, and that mineral phase is suspected to control the solubility of an inorganic chemical (i.e., a metal such as barium or manganese), then such modeling results — along with geochemical evolution of groundwater along a flow path — could be a critical factor in the evaluation and assessment of potential contaminants.



EG&G ROCKY FLATS Rocky Flats Site, Golden, Colorado	Eh-pH Conditions of Natural Environments from Garrels & Christ, 1965	Groundwater Geochemistry Report Date: January 1995 — Figure 8-1

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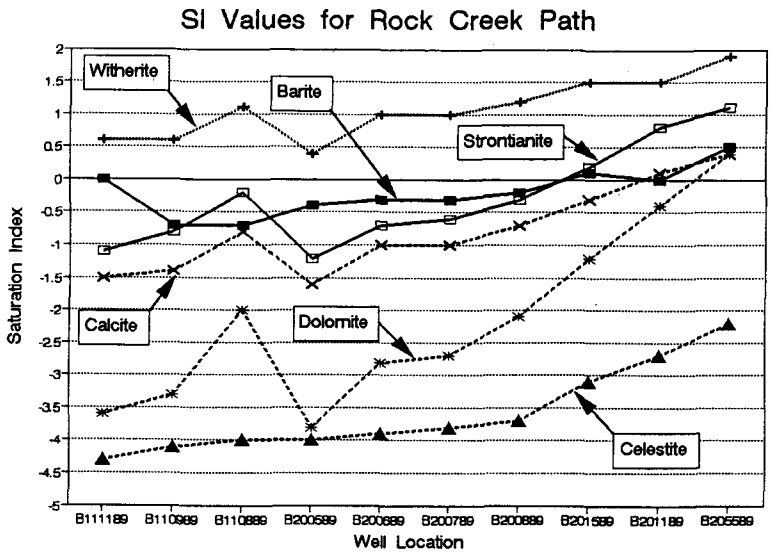

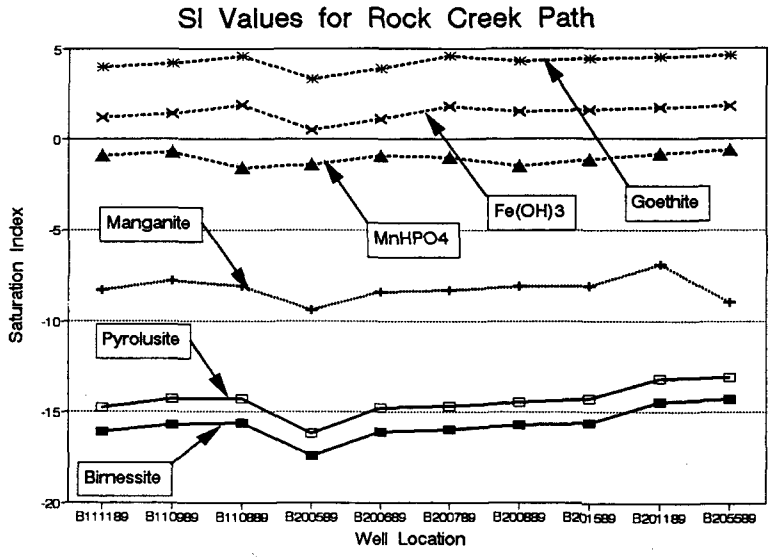

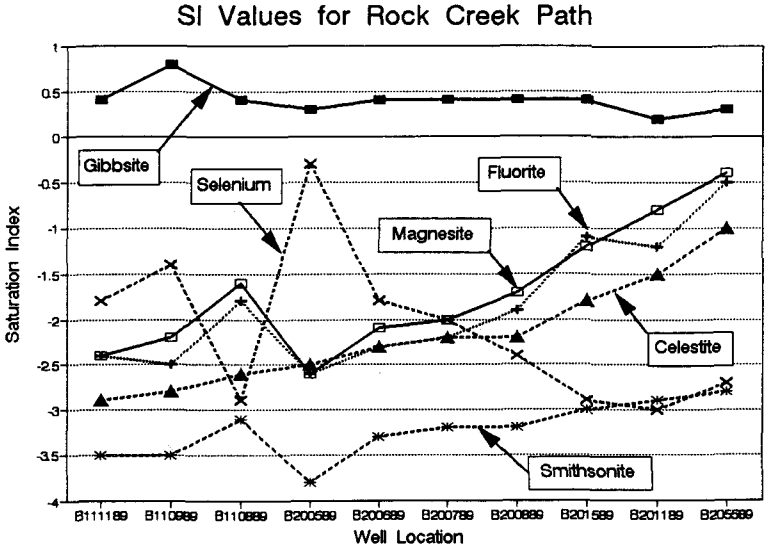

EG&G ROCKY FLATS Rocky Flats Site, Golden, Colorado	Saturation Indices for Mineral Phases in Groundwater from Rock Creek Flow Path	Groundwater Geochemistry Report	
		Date: January 1995	Figure 8-2

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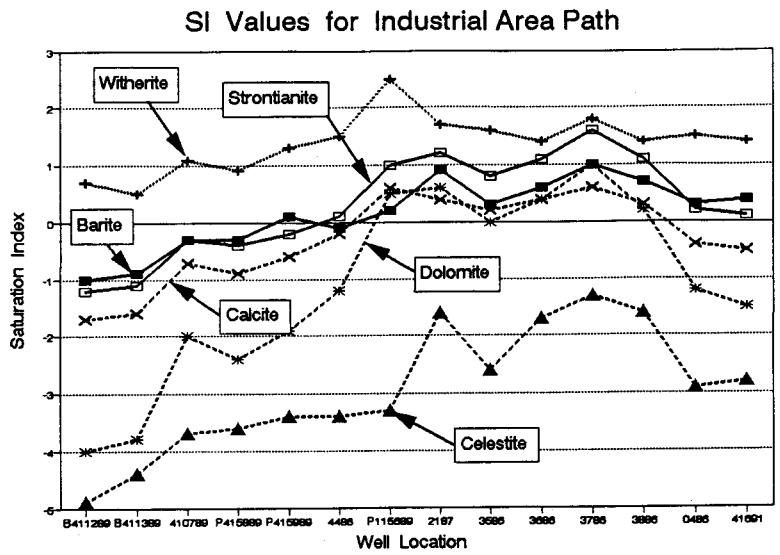

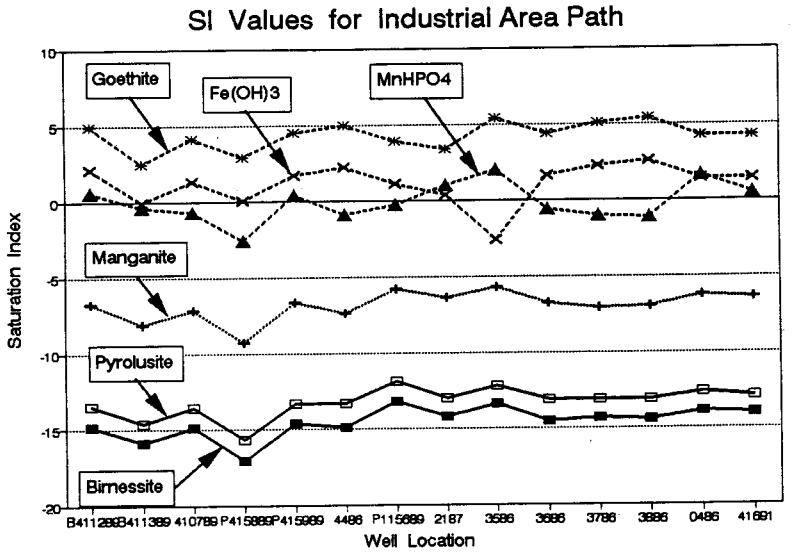

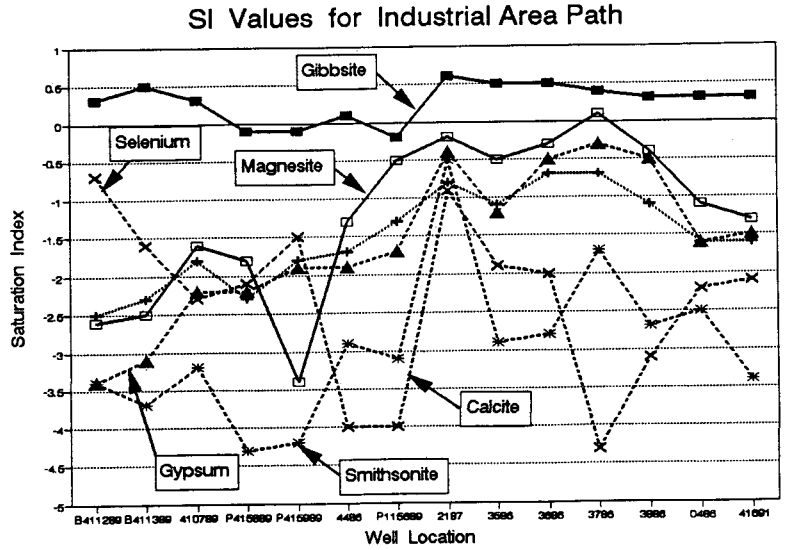

EG&G ROCKY FLATS Rocky Flats Site, Golden, Colorado	Saturation Indices for Mineral Phases in Groundwater from Industrial Area Flow Path	Groundwater Geochemistry Report	
		Date: January 1995	Figure 8-3

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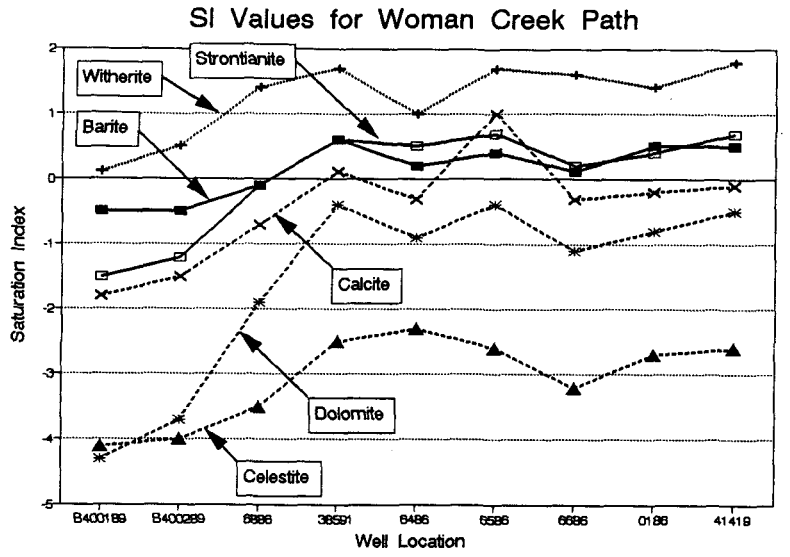

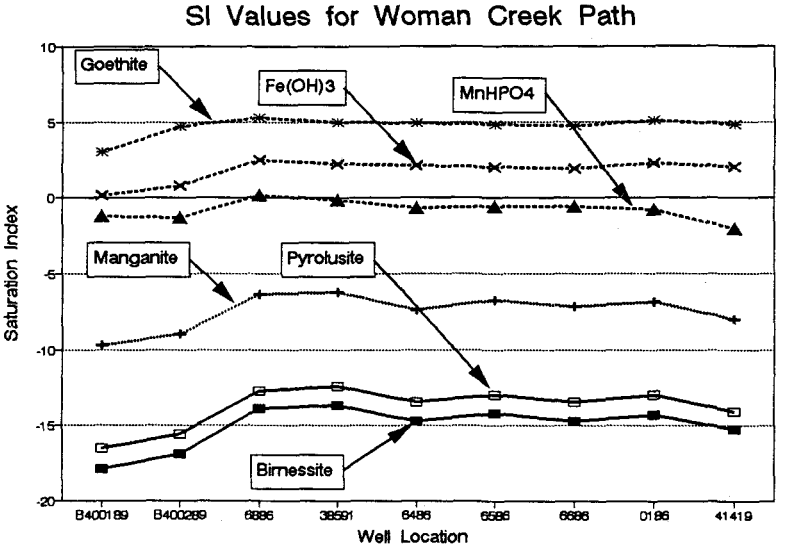

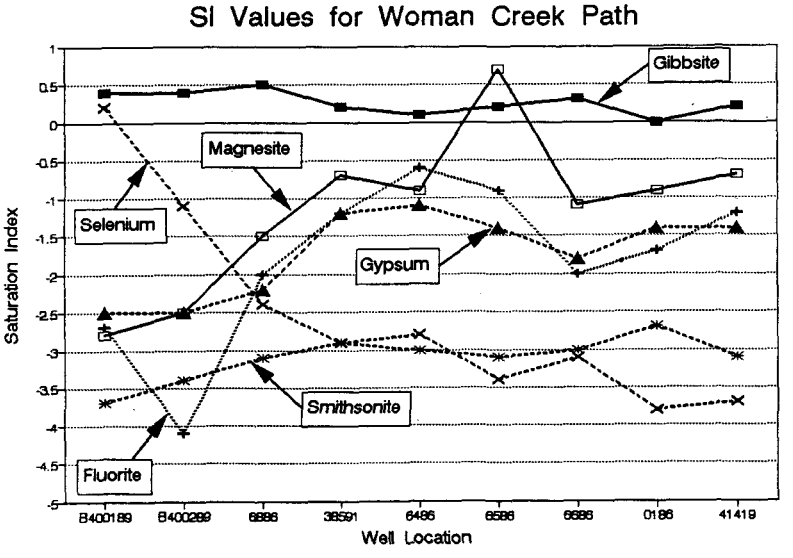

EG&G ROCKY FLATS Rocky Flats Site, Golden, Colorado	Saturation Indices for Mineral Phases in Groundwater from Woman Creek Flow Path	Groundwater Geochemistry Report	
		Date: January 1995	Figure 8-4

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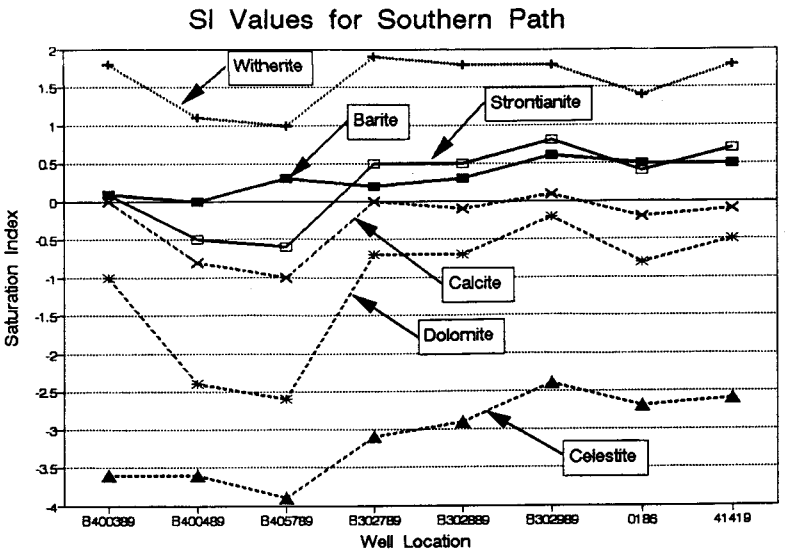

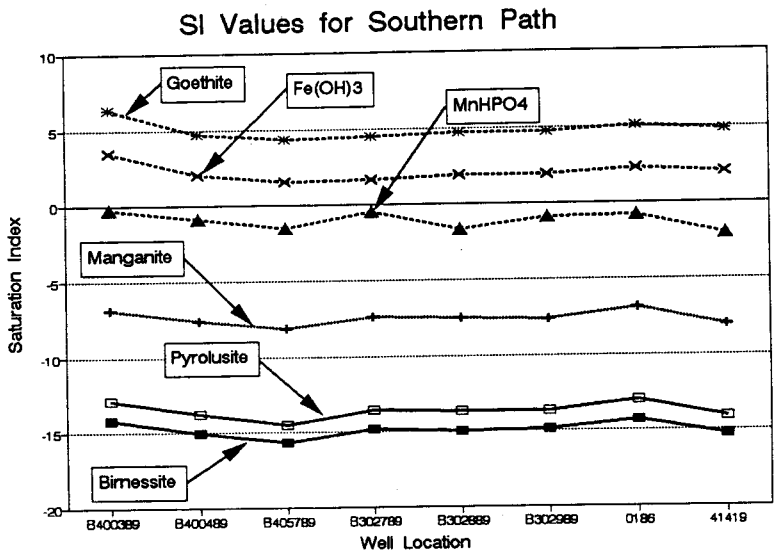

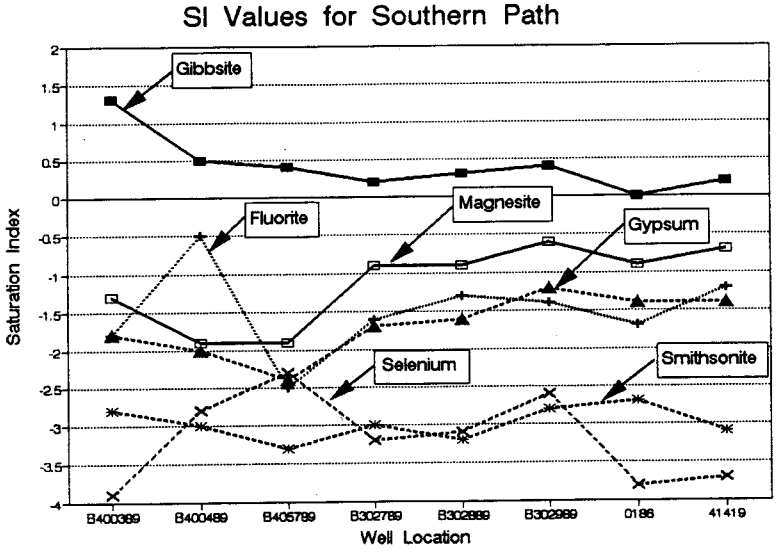

EG&G ROCKY FLATS Rocky Flats Site, Golden, Colorado	Saturation Indices for Mineral Phases in Groundwater from Southern Flow Path	Groundwater Geochemistry Report	
		Date: January 1995	Figure 8-5

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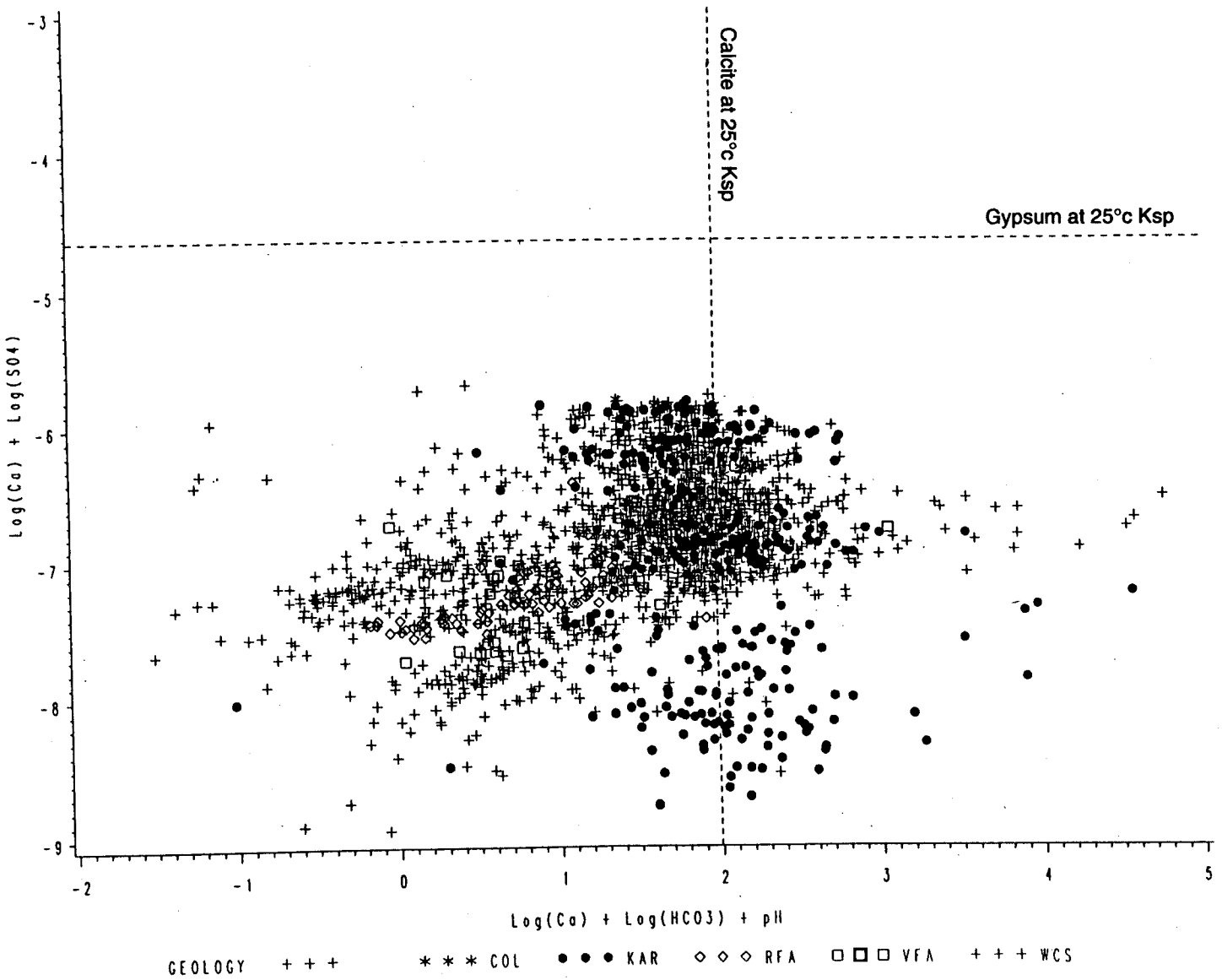

Geology = Unweathered Bedrock
COL = Colluvium
KAR = Arapahoe Formation (UHSU)
RFA = Rocky Flats Alluvium
VFA = Valley-Fill Alluvium
WCS = Weathered Claystone

Saturation indices for gypsum and calcite calculated for T = 25°c and P = 1 atmosphere

EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado

Gypsum and Calcite Saturation Indices in Groundwater

Groundwater Geochemistry Report

Date: January 1995

Figure 8-6

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9. Summary and Recommendations

The evaluation of groundwater chemistry has provided additional evidence to support and strengthen the current interpretation of hydrologic flow systems at the Rocky Flats site and has helped to define the types of chemical variations that are present in groundwater from the site.

9.1 Definition of Hydrostratigraphic Units

The Hydrogeologic Characterization Report (Volume II of the Sitewide Geoscience Characterization Report, EG&G, 1995b) presented the following definition of the two uppermost hydrostratigraphic units at the Rocky Flats site. The UHSU is composed of alluvial, colluvial, valley-fill, and artificial-fill deposits, weathered portions of the bedrock, and unweathered, subcropping sandstones in the bedrock. The hydraulic connection among these sub-units is suggested by the similarity of potentiometric heads in the various sub-units and covariation in hydraulic head through time at numerous well clusters. The LHSU is a separate unit composed of unweathered bedrock. The hydraulic separation of the UHSU and LHSU is supported by the contrasting permeabilities of the units, and well-hydrographs that indicate different responses in the two units to seasonal recharge events. These definitions were fully supported by the geochemical data evaluated for this report.

As noted in Section 5 of this report, the major-ion chemistry of the UHSU and LHSU groundwater generally supports the current definition of the two hydrostratigraphic units. The major-ion composition of groundwater is much less variable in the UHSU than in the LHSU. Groundwater in the UHSU is generally distinct in composition from groundwater in the LHSU, although groundwater in the two hydrostratigraphic units can be similar. These observations are consistent with hydrologic evidence for two distinct hydrostratigraphic units that experience only limited hydraulic communication with each other.

The environmental-isotope compositions of groundwater reveal that the dominant component of the LHSU groundwater is much older than recent recharge and also older than groundwater in the UHSU, further confirming the current hydrostratigraphic-unit concept. The isotopic data indicate that the main component of LHSU groundwater is apparently older than the Rocky Flats Plant (1952). In short, the isotopic distinctions between groundwater from the UHSU and LHSU support the current flow-system model for groundwater at the Rocky Flats site.

Results of the environmental-isotope study also indicate that the two sub-units of the UHSU (surficial deposits and weathered bedrock) have isotopically indistinguishable

sources of recharge. The similarity in isotopic compositions of groundwater from the various lithostratigraphic units of the UHSU supports the current definition of that hydrostratigraphic unit and strongly suggests that all units within the UHSU are hydraulically connected. These conclusions support the current definition of the UHSU presented in Section 4 and in the Hydrogeologic Characterization Report (EG&G, 1995b).

9.2 Evolution of Groundwater Chemistry in the UHSU

The sitewide evolution in groundwater chemistry, illustrated in the flow-path variation diagrams in Section 5 of this report, is supported by objective statistical analysis. The isoconcentration maps produced from kriging analysis illustrate statistically significant increases in the major-ion content of UHSU groundwater from west to east across the site. These maps provide statistical evidence for the types of compositional variations observed qualitatively in the ion-variation diagrams discussed in Section 5 and the hand-contoured isoconcentration maps described in Section 6.

Groundwater chemistry at the terminus of all four flow paths can be realistically modeled without the necessity of mixing with another solution (such as a contaminant-bearing solution). However, as shown in the chemical variation diagrams (Figures 5-8 to 5-17), there are some locations within the former Rocky Flats Plant where input from the OUs does appear to have affected UHSU groundwater in the immediate vicinity. Whether this localized influx has the potential for downgradient migration, or whether it will be attenuated within a short distance of the OUs, is a critical concern. A better understanding of the geology and hydrogeology of the site and the refinement of hydrologic and geochemical models will assist in addressing this concern.

The evidence to-date suggests that groundwater transport of contaminants derived from the Rocky Flats site to offsite locations is minimal to none. In addition, as discussed in Section 8, the sitewide evolution in groundwater chemistry can create an "upgradient bias" when the chemistry of upgradient background wells is compared to that of any downgradient well. The implications of this bias should be addressed in any comparison of upgradient and downgradient groundwater chemistry.

The evaluation and modeling of chemical data, as performed for this report, also emphasize the importance of determining whether the concentrations of various dissolved metals are consistent with those expected on the basis of thermodynamic calculations of solubility controlled by naturally occurring mineral phases. Alternatively, the behavior of some species may be coupled to that of iron. The precipitation, coprecipitation, or adsorption of other metals (especially trace metals) along with iron oxides and oxyhydroxides could be the factor controlling the amount of these metals in solution.

The modeling results and concepts discussed here can be used to provide additional information that should be included in weight-of-evidence discussions of possible groundwater contamination by metals and other inorganic analytes. Persons evaluating the results of statistical comparisons between background and site data should consider the geochemical evolution of groundwater as another variable and apply their professional assessment of statistical results in light of an inherently heterogenous and complex natural system.

9.3 Recommendations

Based on the results of this study, the following tasks are recommended to improve the description of groundwater chemistry at the Rocky Flats site:

- Investigate historic records for descriptions of the chemistry of historic process water. Determine the effects that releases of process water would have on the chemistry of UHSU and LHSU groundwater.

- Obtain Eh and dissolved oxygen (DO) data in the field at the time of groundwater sampling. Use a flow-through cell to prevent contamination with atmospheric oxygen. Eh measurements are particularly important to obtain in areas where organics are detected. Information on redox couples (sulfate/sulfide, ferric/ferrous iron, etc.) would also be useful to describe redox conditions.

- Characterize groundwater chemistry in the area between the eastern boundary of the site and OUs 1, 2, 5, and 6 to better define both natural, evolutionary changes in groundwater chemistry and changes due to input from contaminant sources in this area.

- Resolve the charge-imbalance problem for groundwater from the Solar Evaporation Ponds by determining the presence and abundance of other anions in groundwater.

- Although inherently difficult, attempts should be made to collect representative mineralogical data for the surficial deposits at Rocky Flats, as was done for bedrock (Geologic Characterization Report, EG&G, 1995a).

- Examine in more detail the chemistry of groundwater in OU4 (Solar Evaporation Ponds), OU5 (Woman Creek), and OU6 (Walnut Creek) as it relates to the observed variations in chemistry along the Industrial Area and Woman Creek flow paths.

- Perform reaction-path modeling to describe chemical changes from well to well to compliment the mass-balance modeling of the overall change (from initial to final well) in chemistry along a flow path performed for this report.

- Perform additional groundwater sampling and analyses of groundwater from the LHSU. The existing monitoring-well network is not sufficient to characterize changes in groundwater chemistry as water flows across the site.

- Perform sitewide evaluation of surface-water chemistry and integrate with this study to identify the regions of the site where groundwater/surface-water interactions take place and the effects of such interactions on groundwater and surface-water chemistry.

The following tasks are recommended to improve the reliability of interpretations of isotopic data from groundwater and to support hydrogeologic investigations of groundwater flow:

- Improve the description of local precipitation by continuing to collect and analyze precipitation samples for stable isotopes and tritium. Describe the local meteoric-water line for Rocky Flats.

- Evaluate the shift in the isotopic composition of recharge water relative to that of local precipitation. Collect seasonal evapotranspiration data from the site, and collect and analyze samples of accumulated snowpack and snowmelt.

- Collect additional surface-water samples from streams and ponds in the Walnut Creek and Woman Creek drainages. The isotopic compositions of these waters may be useful in describing mixing between groundwater and surface water and other groundwater/surface-water interactions (i.e., identifying losing and gaining reaches of these streams, evaluating the effectiveness of pond dams in preventing downgradient releases of contaminants).

- Determine the environmental-isotope compositions of water currently discharged from facilities on the site (potable water and wastewater) and estimate the isotopic composition of process water historically generated on the site

- Use high-tritium groundwater in the Industrial Area to monitor the direction and rate of groundwater flow within weathered bedrock of the UHSU.

- Use the available hydrologic and isotopic data to refine flow paths within RFETS hydrostratigraphic units.

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PLATE 4

A. Data Types and Data Quality

Chemical data collected as part of field quality-control (QC) sampling were reviewed to evaluate the quality and general usability of groundwater data collected for the groundwater monitoring programs at the Rocky Flats Environmental Technology Site (Rocky Flats site). Chemical data for groundwater samples collected from 1990 to 1994 were obtained from the Rocky Flats Environmental Database System (RFEDS). These data comprise the analytical results for dissolved and total metals, dissolved and total radionuclides, water-quality parameters (e.g., anions and cyanide), semivolatile acid/base/neutral (ABN) compounds, volatile organic compounds (VOCs), organochlorine pesticides and polychlorinated biphenyls (PCBs), and field measurements (e.g., dissolved oxygen, water temperature, specific conductivity, and pH).

The review of the data included an assessment of the results reported for field-blank, trip-blank, and equipment-rinsate samples. These data may be used to determine whether contaminants detected in selected samples are representative of in-ground conditions or are present as a result of contamination that occurred during sample collection or processing.

In addition, the relative percent difference (RPD) between results for original samples and field duplicates was calculated (for metals, radionuclides, water-quality parameters, and pesticides/PCBs) and reviewed. The data for field duplicates provide an estimate of sampling variability or precision and can be used to assess the reproducibility of the monitoring data.

A.1. Assessing Data Quality

The initial review of QC data indicated several irregularities within the RFEDS database. Generally, these are (1) missing data for duplicate sample analyses, (2) different data qualifiers used for identical sample results entered for the same sample, (3) apparent anomalous results that may represent transcription errors (e.g., outlier values exceeding other results by several orders of magnitude), (4) two different results reported for the same analyte in the same sample, and (5) null entries (i.e., result field is blank).

These irregularities in the data, and the subsequent actions taken to facilitate this review, are summarized below:

- **No matching duplicate data found:** For every datum identified as a duplicate, there should exist within RFEDS a corresponding value for an original sample. In

approximately 10 percent of all cases, a corresponding original value could not be found. Most of these cases arose for duplicates that were not sampled on the same day as the original sample. Because field duplicates are intended to measure field and sampling variability rather than temporal variability, these mismatched results were not used for this review.

- **Qualifiers differ for two records for the same sample:** In several instances, two records for the same sample were reported in the database, each with a different qualifier assigned to the same reported value. In cases where one result had a laboratory-assigned data qualifier and the other entry had only a validation code (i.e., data verified by a third-party subcontractor), the original laboratory-qualified record was deleted, and the laboratory qualifier was added to the validated record.

- **Apparent outlier values reported:** Results that appeared to be anomalous (i.e., extreme outliers) were not used for the purposes of this review; these include results that deviated an order of magnitude or more from the average result at the same sampling site for the analyte in question.

- **Two records for same sample reported with different result values:** Where two records were reported for the same sample (same station and date), it was not possible to determine whether the two records were associated with laboratory or field duplicates, sample dilutions, or sample reanalyses. For this review, the lowest value was ignored and only the greater value was used. The only exception to this amendment was for data reported for trip blanks for VOCs; all of these records were retained for review, because multiple trip blanks are associated with sample collection.

- **Null entry reported:** In rare cases, a null entry (i.e., 0.00) was reported for an analyte and the entry was not used for interpretative purposes. The source of the null records within the database is unknown.

After the initial review of data, identification of irregularities, and completion of corrective actions listed above, all remaining results were subjected to a statistical analysis.

Approximately 98 percent of all the original field QC data was usable for this analysis; the remaining two percent of all data consisted of rejected data. The statistical analysis of the data included the identification of minimum, maximum, and average concentrations for all analytes. The precision of the data was evaluated by assessing the RPDs of duplicate sample analyses (for detected analytes only) as follows:

$$RPD = \frac{C_1 - C_2}{(C_1 + C_2)/2} x100$$

where:

RPD	=	relative percent difference
C_1	=	original sample analyte concentration
C_2	=	duplicate sample analyte concentration

A.2. Review of Field Quality-Control Samples

A.2.1 Metals

The specific metal analytes for which field-duplicate and field-blank data were present are provided in Attachment 1. The detected metals were typically reported at concentrations greater than the instrument detection limit (IDL), but less than the U.S. Environmental Protection Agency (EPA) contract-required detection limit (CRDL). Such results are qualified (for inorganic analytes) with a laboratory qualifier "B." For this review, metals were considered detected in accordance with the laboratory qualifiers and validation codes listed and defined in Attachment 2. A summary of the metals results for all field-blank and equipment-rinsate samples in the amended database is provided in Tables A-1 through A-4. An archived data file containing a list of all blank samples that contained detected metals is provided in Attachment 3.

The RPDs for all duplicate sample analyses identified in the database were calculated. Summary statistics of RPDs for the duplicate sample analyses for dissolved and total metals are provided in Tables A-5 and A-6, respectively. Matches between original and duplicate values were based on location, sample date, analytical group, and analyte.

The primary irregularity identified during the assessment of metals data is that results reported at concentrations greater than the IDL, but less than the CRDL, were not consistently assigned a "B" result qualifier. In accordance with procedures established by EPA's Contract Laboratory Program (CLP), the "B" result qualifier should be assigned (by the laboratory) where a target analyte is detected at a concentration greater than the IDL but less than the CRDL.

A.2.1.1 Dissolved Metals

Precision (Relative Percent Difference)

Duplicate samples collected in the field provide a measure of the reproducibility (i.e., precision) of sample collection and analysis. For dissolved metals, the RPDs were greater than 20 percent for just over half of the analytes (15 of 29 total). The poor precision for these analytes is a result of the low concentrations (concentrations near the IDL) of many of the metals. For major metals (calcium, sodium, etc.), that have

concentrations well above the detection limit, the precision is much better; RPDs are as low as 2 percent for such metals.

RPDs ranged from a low of 2 percent for strontium to a high of 57 percent for iron. The RPDs for all analytes in the suite of dissolved metals (by year and overall totals) are summarized in Table A-5.

Field Blanks

For field blanks, 829 records were reported for the suite of dissolved metals. Of these records, 202 (24.4 percent) were reported as detected (primarily between the IDL and CRDL), 626 (75.5 percent) were reported as undetected at the IDL, and 1 (0.1 percent) was rejected. Of the data reviewed, results for field blanks were reported for the period from 1990 to first quarter 1994. The highest detection frequencies were for aluminum, barium, calcium, iron, magnesium, manganese, silver, sodium, strontium, and zinc. Table A-1 presents the field-blank results for dissolved metals.

Trip Blanks

No records for trip blanks were reported for the suite of dissolved metals during the 1990 to 1994 period. Results available from RFEDS for trip blanks are only for 1986 to 1989; these early data were not evaluated for this report.

Equipment-Rinsate Blanks

A total of 5,551 records was reported for the suite of dissolved metals in equipment-rinsate samples. Of these results, 865 (15.6 percent) were reported as detected (primarily between the IDL and CRDL), 4,638 (83.6 percent) were reported as undetected at the IDL, and 48 (approximately 0.9 percent) were rejected. The rejected data are associated with equipment-rinsate analyses performed in 1990, 1991, 1992, and 1993. The highest detection frequencies were for aluminum, barium, calcium, iron, magnesium, manganese, sodium, strontium, and zinc. Table A-3 presents the equipment-rinsate results for dissolved metals.

A.2.1.2 Total Metals

Precision (Relative Percent Difference)

For total metals, the RPDs were greater than 20 percent for just over one-third of the analytes (20 of 29 total). The poor precision for these analytes is a result of the low concentrations (concentrations near the instrumental detection limit) of many of the metals.

RPDs ranged from a low of 3.2 percent for thallium to a high of 52 percent for cadmium. The RPDs for all analytes in the suite of total metals (by year and overall totals) are summarized in Table A-6.

Field Blanks

A total of 314 records was reported for the suite of total metals in field blanks. Of these results, 64 (20.4 percent) were reported as detected (primarily between the IDL and CRDL), 248 (79 percent) were reported as undetected at the IDL, and 2 (0.6 percent) were rejected. The rejected data are associated with field-blank measurements performed in 1990. Results for field blanks were reported only for 1990 and 1993. The highest detection frequencies were for aluminum, barium, calcium, iron, magnesium, manganese, sodium, strontium, and zinc. Table A-2 presents field-blank results for total metals.

Trip Blanks

No records for trip blanks were reported in the database for the suite of dissolved metals.

Equipment-Rinsate Blanks

A total of 2,894 records was reported for total metals in equipment-rinsate samples. Of these results, 493 (17 percent) were reported as detected (primarily between the IDL and CRDL), 2,362 (81.6 percent) were reported as undetected at the IDL, and 39 (1.3 percent) were rejected. The rejected data are associated with analysis of equipment-rinsate samples from 1991 and 1992. The highest detection frequencies were for aluminum, barium, calcium, iron, magnesium, manganese, silicon, sodium, strontium, and zinc. Table A-4 presents equipment-rinsate results for total metals.

A.2.2 Radionuclides

Analyses were performed for 21 radionuclide parameters, which are listed in Attachment 1. For this review, all radionuclides were considered detected unless explicitly rejected in accordance with the laboratory qualifiers and validation codes listed and defined in Attachment 2. A summary of the radionuclide results for all field-blank and equipment-rinsate samples contained in the amended database is provided in Tables A-7 through A-10.

As a result of the presence of zero and negative values for radionuclides, the RPDs may show negative values. Summary statistics of RPDs for dissolved and total radionuclides are presented in Tables A-11 and A-12, respectively. Overall, the RPDs calculated for duplicate radionuclide analyses indicate poor reproducibility of results.

Matches between original and duplicate values were based on location, sample date, analytical group, and analyte.

Another estimator of the "quality" of radionuclide results is given in the data as the "ERROR" variable. This variable is the value of the 95-percent upper confidence limit (UCL) for the corresponding analytical result.

A.2.2.1 *Dissolved Radionuclides*

Precision (Relative Percent Difference)

Using all results for dissolved radionuclides, the average RPDs ranged from a low of 12.4 percent for uranium 233, 234 to a high of 197.3 percent for americium-241 (Table A-11). Duplicates were available for most analytes and for most years between 1990 and 1994.

Field Blanks

A total of 140 records was reported for field-blank samples for dissolved radionuclides. Of these results, 124 (88.6 percent) were reported as accepted and 16 (11.4 percent) were rejected. Results for field blanks were reported only for 1990 and 1993. Table A-7 presents field-blank results for dissolved radionuclides.

Trip Blanks

No records for trip blanks were reported in the database for the suite of dissolved radionuclides for the 1990 to 1994 period. Results available in RFEDS for trip blanks are reported only for 1987 to 1989; data from this earlier time period were not evaluated for this report.

Equipment-Rinsate Blanks

A total of 1,317 records was reported for the suite of dissolved radionuclides in equipment-rinsate samples. Of these results, 1,245 (94.5 percent) were reported as accepted and 72 (5.5 percent) were rejected. Results for equipment-rinsate blanks were reported for the entire 1990 to 1994 period. Table A-9 presents equipment-rinsate results for dissolved radionuclides.

A.2.2.2 *Total Radionuclides*

Precision (Relative Percent Difference)

Using all results for total radionuclides, the average RPDs ranged from a low of 16 percent for radium-226 to a high of 9,360.2 percent for cesium-137 (Table A-12).

Duplicates were available for most analytes and for most years between 1990 and 1994.

Field Blanks

A total of 335 analytical results was reported for the suite of total radionuclides in field-blank samples. Of these results, 297 (88.6 percent) were reported as accepted and 38 (11.3 percent) were rejected. Results for field blanks were reported only for 1990 and 1993. Table A-8 presents field-blank results for total radionuclides.

Trip Blanks

No records for trip blanks were reported in the database for the suite of total radionuclides for the 1990 to 1994 period. Results for trip blanks were reported only for 1987 to 1989; data from this earlier time period were not evaluated for this report.

Equipment-Rinsate Blanks

A total of 821 records was reported for the suite of total radionuclides in equipment-rinsate samples. Of these results, 758 (92.3 percent) were reported as accepted and 63 (7.7 percent) were rejected. Results for equipment-rinsate blanks were reported for 1990, 1991, 1992, and 1993. Table A-10 presents equipment-rinsate results for total radionuclides.

A.2.3 Water-Quality Parameters

In general, target analytes (listed in Attachment 1) associated with water-quality parameters (e.g., anions and cyanide) were undetected at concentrations above the method detection limit (MDL). A summary of the water-quality parameter results for all field blanks and equipment-rinsate samples in the amended database is provided in Tables A-13 and A-14, respectively. All blank samples that contained detectable concentrations of target analytes are summarized in data files included as Attachment 3. Table A-15 presents the RPDs for water-quality parameters.

A.2.3.1 Precision (Relative Percent Difference)

There are no clearly established acceptance criteria for the precision of water-quality parameters. RPDs for alkalinity, bicarbonate, carbonate, cyanide, chemical oxygen demand, chloride, fluoride, nitrate, silica, sulfate, total dissolved solids (TDS), total organic carbon (TOC), total suspended solids (TSS), and pH were therefore considered acceptable using a general criterion of 20 percent.

For water-quality parameters, the RPDs were greater than 20 percent for one-third of the analytes (6 of 18 total). The poor precision for these analytes is a result of the low

concentrations (concentrations near the instrumental detection limit) of many of the analytes.

RPDs ranged from a low of 1.2 percent for pH to a high of 96.6 percent for carbonate. The RPDs for all analytes in the suite of water-quality parameters (by year and overall totals) are summarized in Table A-15.

A.2.3.2 Field Blanks

A total of 320 records was reported for water-quality parameters in field-blank samples. Of these records, 49 (15.3 percent) were reported as detected, 271 (84.7 percent) were reported as undetected, and 0 (0 percent) were rejected. Results for field blanks were reported only for 1990 and 1993. Table A-13 presents field-blank results for water-quality parameters.

A.2.3.3 Trip Blanks

No records for trip blanks were reported in the database for the suite of water-quality parameters for the 1990 to 1994 period. Results for trip blanks were reported only for 1987 to 1989; data from this earlier time period were not evaluated for this report.

A.2.3.4 Equipment-Rinsate Blanks

A total of 2,258 records was reported for water-quality parameters in equipment-rinsate samples. Of these results, 335 (14.8 percent) were reported as detected, 1,907 (84.5 percent) were reported as undetected, and 16 (0.7 percent) were rejected. Results for equipment-rinsate blanks were reported throughout 1990 to 1994. Table A-14 presents equipment-rinsate results for water-quality parameters.

A.2.4 Organic Compounds

The RFEDS data analyzed for this report contain results for 65 semivolatile ABN compounds, 69 VOCs, 23 organochlorine pesticides, and 7 PCBs. For this review, results were considered detected in accordance with the laboratory qualifiers and validation codes listed in Attachment 2. The results of the data review are summarized below.

A.2.4.1 Semivolatile Acid/Base/Neutral Compounds

Precision (Relative Percent Difference)

The RPDs for all duplicate sample results and precision could not be adequately assessed because of the limited data set for detected analytes.

Field Blanks

No field-blank records were reported for ABNs for the 1990 to 1994 time period. Results for field blanks are reported in RFEDS only for 1986; these historic data were not evaluated for this report.

Trip Blanks

No trip-blank records were reported for ABNs for the 1990 to 1994 time period. Results for trip blanks are reported in RFEDS only for 1986; these historic data were not evaluated for this report.

Equipment-Rinsate Blanks

A total of 690 records was reported for ABNs in rinsate samples collected from 1990 to 1994. Of these results, 7 (1 percent) were reported as detected, 672 (97.4 percent) were reported as undetected, and 11 (1.6 percent) were rejected. Results for equipment-rinsate samples were reported only for 1992 and 1993. Table A-16 presents equipment-rinsate results for semivolatiles.

A.2.4.2 Volatile Organic Compounds

Several VOCs were detected in each type of blank sample. Typically, these detected analytes are associated with common laboratory contaminants (e.g., methylene chloride, acetone, 2-butanone, and toluene). Several of the other VOCs detected may be indicative of breakdown associated with the VOC absorbent trap. Caution should be used in determining whether a VOC detected in both a blank sample and any associated natural sample is actually present at the sampling location. Specific assessment of this problem could not be performed during this review because detailed information (e.g., original laboratory data and field logs) was not available. A summary of the results for detected analytes in the associated blanks (e.g., field, trip, and equipment-rinsates) is provided in Tables A-17, A-18, and A-19, respectively.

Precision (Relative Percent Difference)

The RPDs for all duplicate sample results and precision could not be adequately assessed because of the limited data set for detected analytes. In addition, there are no specific criteria established by EPA for determining acceptable RPDs for field duplicates.

Field Blanks

A total of 1,879 records was reported for the target VOCs in field-blank samples. Of these results, 72 (3.8 percent) were reported as detected, 1,786 (95.1 percent) were

reported as undetected, and 21 (1.1 percent) were rejected. Results for field blanks were reported for 1990, 1991, 1993, and 1994. Table A-17 presents field-blank results for VOCs.

Trip Blanks

A total of 7,670 records was reported for the target VOCs in trip-blank samples. Of these results, 296 (3.9 percent) were reported as detected, 7,355 (95.9 percent) were reported as undetected, and 19 (0.2 percent) were rejected. Results for trip blanks were reported for 1990, 1991, and 1993. Table A-18 presents trip-blank results for VOCs.

Equipment-Rinsate Blanks

A total of 7,903 records was reported for the target VOCs. Of these results, 178 (2.2 percent) were reported as detected, 7,507 (95 percent) were reported as undetected, and 218 (2.8 percent) were rejected. Results for equipment-rinsate samples were reported for 1990 to 1994. Table A-19 presents equipment-rinsate results for VOCs.

A.2.4.3 Organochlorine Pesticides and Polychlorinated Biphenyls

There were no records for field or trip blanks reported in the database for pesticides and PCBs for the 1990 to 1994 period. Neither target organochlorine pesticides nor PCB compounds were detected in the equipment-rinsate samples.

Precision (Relative Percent Difference)

The RPDs for all duplicate sample analyses and the assessment of precision cannot be assessed because no target analytes were detected (see Table A-20).

Field Blanks

No records for field blanks were reported in the database for the suite of pesticides and PCBs for the 1990 to 1994 period.

Trip Blanks

No records for trip blanks were reported in the database for the suite of pesticides and PCBs for the 1990 to 1994 period.

Equipment-Rinsate Blanks

A total of 216 analytical results was reported for the target organochlorine pesticides and PCBs. All 216 results were reported as undetected; no data were rejected. Results

for equipment-rinsate blanks were reported only for 1992 and 1993. Table A-21 presents equipment-rinsate results for pesticides and PCBs.

A.2.5 Field Measurements

Field-measurement data could not be quantitatively assessed; both numeric and non-numeric values were present for most variables (pH, dissolved oxygen, specific conductance, temperature, total alkalinity, and depth to water table). The following table summarizes salient points for the entire data file of field measurements from 1990 to 1994:

Variable	Total Records	Numeric	Non-numeric	Missing
pH	7,424	5,208	63	2,153
DO	7,424	3,211	832	3,381
TEMP	7,424	5,210	63	2,151
SCOND	7,424	4,590	85	2,749
TOT_ALK	7,424	3,863	155	3,406
WAT_DEP	7,424	4,489	165	2,770

Where:
DO = dissolved oxygen
TEMP = temperature
SCOND = specific conductance
TOT_ALK = total alkalinity
WAT_DEP = depth to water table from top of casing

A.3. Conclusions and Recommendations for Data Usability

During the review of QC data, several specific deficiencies were identified, some of which may result in specific limitations of data usability. The deficiencies or limitations identified with the QC data set are as follows:

- Results for accuracy (i.e., matrix spike recoveries) were not available for review and are not available from RFEDS. Without an assessment of accuracy measurements, the possible bias that may be associated with specific data cannot be evaluated.

- The frequency of metals detected in trip and field blanks is relatively high, and the most frequently detected analytes include aluminum, calcium, iron, magnesium, silicon, sodium, and zinc. Commercial-grade distilled water is used to prepare

these blanks and is one likely source for the frequently detected metals. For this reason, analyses of these frequently detected metals in field blanks may not be useful in identifying field or laboratory contamination of real samples. However, the concentrations of most metals detected are lower than the EPA CRDL.

- The RPDs for all duplicate analyses performed for metals, excluding silicon and the infrequently measured thallium and phosphorus, exceeded the 20 percent RPD criterion for acceptable performance for nearly one-half of all metals. Elevated RPDs are not unusual when analyte concentrations are at or near the detection limit (especially for metals). For radionuclide analyses, RPDs were highly variable and typically high. For radionuclides, elevated RPDs are associated with low radionuclide activities that are not within the range required to obtain reproducible results. As a result of the low activities of radionuclides in natural waters at Rocky Flats, and the poor laboratory precision associated with measuring these activities, analysis of duplicate samples for radionuclides does not provide a reliable measure of sampling precision.

- Analyses of VOCs in trip-blank or field-blank samples indicate that acetone, carbon disulfide, dichloromethane, methylene chloride, toluene, and 2-butanone were typically present in the blanks. These compounds may originate from the commercial-grade distilled water used to prepare the blanks, and they have also been identified as common laboratory contaminants (EPA, 1988a). In accordance with procedures specified by EPA functional guidelines (EPA, 1988a, 1988b, 1990a), results for analytes detected in blanks may require restating results from associated real samples as undetected. This assessment should be performed during data validation. Until the results of such an assessment are available, the presence of acetone, carbon disulfide, dichloromethane, methylene chloride, toluene, and 2-butanone in a field sample should be considered as potentially resulting from laboratory contamination. Results for this group of compounds should be qualified in RFEDS and further evaluated. At present, these results are considered usable as screening-level data.

- Temporal trends in detection frequency of blanks and RPD values are not readily apparent. The types of QC samples collected appear to have changed over time. In most cases, only four years of data were available to make comparisons, and the sample sizes in some of these years were small. There is a tendency, however, toward decreased detection of heavy metals and VOCs in equipment-rinsate blanks (Tables A-3 and A-19, respectively) for the period 1990 to 1992.

The data records reviewed for this analysis were obtained from RFEDS in March 1994. The validated data are Level IV data and are considered usable for site characterization, human health and environmental risk assessments, evaluation of remedial alternatives, engineering design or remedial actions, and determination of the potentially responsible party (EPA, 1987).

Data that have not yet undergone the data-validation process (i.e., unvalidated data) may not be as usable as the validated Level IV data. According to EPA's Guidance for Data Usability in Risk Assessment (EPA, 1990b), unvalidated data may be used in risk assessments only qualitatively to identify analytes during preparation of a sampling and analysis plan. The data used for a baseline risk assessment must also meet criteria for analytical precision, accuracy, representativeness, completeness, and comparability. These data-quality parameters were not addressed as part of this study but should be evaluated to establish data usability for risk assessments. The data required to evaluate laboratory precision and accuracy (percent spike recovery and results for standards) are not currently available to data users from RFEDS.

A.4. References

EPA, 1987, Data Quality Objectives For Remedial Response Activities. Volume 1 - Development Process: EPA 540/G-87/003A, U.S. Environmental Protection Agency, Office of Emergency and Remedial Response and Office of Waste Programs Enforcement, Washington, D.C.

EPA, 1988a, Laboratory Data Validation Functional Guidelines For Evaluating Inorganics Analyses: U.S. Environmental Protection Agency, Washington, D.C.

EPA, 1988b, Laboratory Data Validation Functional Guidelines For Evaluating Inorganics Analyses: U.S. Environmental Protection Agency, Washington, D.C.

EPA, 1990a, National Functional Guidelines For Organic Data Review: December 1990 (revised 1991), U.S. Environmental Protection Agency, Washington, D.C.

EPA, 1990b, Guidance for Data Usability In Risk Assessment. Interim Final: EPA/540/G-90/008, U.S. Environmental Protection Agency, Office of Emergency Response and Remedial Response, Washington, D.C.

Table A-1
Field-Blank Results for Dissolved Metals

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(µg/l) Minimum	Maximum	Average
ALUMINUM	1990	29	0	18	11	37.93	16.60	231.00	56.49
	1993	1	0	1	0	0.00	.	.	.
ANTIMONY	1990	29	0	25	4	13.79	16.10	23.90	18.37
	1993	1	0	1	0	0.00	.	.	.
ARSENIC	1990	29	0	28	1	3.45	1.00	1.00	1.00
	1993	1	0	1	0	0.00	.	.	.
BARIUM	1990	29	0	14	15	51.72	1.10	12.40	4.47
	1993	1	0	1	0	0.00	.	.	.
BERYLLIUM	1990	29	0	28	1	3.45	4.80	4.80	4.80
	1993	1	0	1	0	0.00	.	.	.
CADMIUM	1990	29	0	28	1	3.45	2.40	2.40	2.40
	1993	1	0	1	0	0.00	.	.	.
CALCIUM	1990	29	0	10	19	65.52	43.50	139000	7441.22
	1993	1	0	0	1	100.00	85.30	85.30	85.30
CESIUM	1990	27	0	23	4	14.81	100.00	200.00	175.00
	1993	1	1	0	0	.	.	.	.
CHROMIUM	1990	29	0	26	3	10.34	6.70	7.80	7.23
	1993	1	0	1	0	0.00	.	.	.
COBALT	1990	29	0	28	1	3.45	5.00	5.00	5.00
	1993	1	0	1	0	0.00	.	.	.
COPPER	1990	29	0	24	5	17.24	5.20	16.50	8.90
	1993	1	0	1	0	0.00	.	.	.
IRON	1990	29	0	17	12	41.38	8.60	200.00	46.59
	1993	1	0	1	0	0.00	.	.	.
LEAD	1990	29	0	27	2	6.90	1.30	3.40	2.35
	1993	1	0	1	0	0.00	.	.	.
LITHIUM	1990	27	0	25	2	7.41	4.55	5.70	5.12
	1993	1	0	1	0	0.00	.	.	.
MAGNESIUM	1990	29	0	15	14	48.28	16.40	119.00	53.28
	1993	1	0	0	1	100.00	18.60	18.60	18.60
MANGANESE	1990	29	0	14	15	51.72	1.10	8.30	3.97
	1993	1	0	1	0	0.00	.	.	.
MERCURY	1990	28	0	27	1	3.57	0.30	0.30	0.30
	1993	1	0	1	0	0.00	.	.	.
MOLYBDENUM	1990	27	0	19	8	29.63	2.90	28.70	10.21
	1993	1	0	1	0	0.00	.	.	.
NICKEL	1990	29	0	25	4	13.79	4.60	9.10	6.60
	1993	1	0	1	0	0.00	.	.	.
POTASSIUM	1990	29	0	21	8	27.59	40.50	1950.00	877.56
	1993	1	0	1	0	0.00	.	.	.
SELENIUM	1990	29	0	28	1	3.45	0.80	0.80	0.80
	1993	1	0	1	0	0.00	.	.	.

Table A-1 (continued)
Field-Blank Results for Dissolved Metals

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(µg/l) Minimum	Maximum	Average
SILVER	1990	29	0	18	11	37.93	2.30	9.90	4.65
	1993	1	0	1	0	0.00	.	.	.
SODIUM	1990	29	0	14	15	51.72	84.20	276.00	138.84
	1993	1	0	1	0	0.00	.	.	.
STRONTIUM	1990	27	0	14	13	48.15	1.30	2.90	2.00
	1993	1	0	1	0	0.00	.	.	.
THALLIUM	1990	29	0	29	0	0.00	.	.	.
	1993	1	0	1	0	0.00	.	.	.
TIN	1990	27	0	21	6	22.22	11.30	47.30	21.78
	1993	1	0	1	0	0.00	.	.	.
VANADIUM	1990	29	0	21	8	27.59	2.30	19.80	8.23
	1993	1	0	1	0	0.00	.	.	.
ZINC	1990	29	0	14	15	51.72	3.50	34.60	12.09
	1993	1	0	1	0	0.00	.	.	.
Totals	1990	801	0	601	200	25.00			
	1991	0	0	0	0	.			
	1992	0	0	0	0	.			
	1993	28	1	25	2	7.14			
	1994	0	0	0	0	.			
	Overall	829	1	626	202	24.37			

Table A-2
Field-Blank Results for Total Metals

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(µg/l) Minimum	Maximum	Average
ALUMINUM	1990	6	0	3	3	50.00	15.20	109.00	50.07
	1993	5	0	5	0	0.00	.	.	.
ANTIMONY	1990	6	0	5	1	16.67	8.90	8.90	8.90
	1993	5	0	5	0	0.00	.	.	.
ARSENIC	1990	6	0	5	1	16.67	1.00	1.00	1.00
	1993	5	0	5	0	0.00	.	.	.
BARIUM	1990	6	0	1	5	83.33	1.80	14.40	5.64
	1993	5	0	5	0	0.00	.	.	.
BERYLLIUM	1990	6	0	6	0	0.00	.	.	.
	1993	5	0	5	0	0.00	.	.	.
CADMIUM	1990	6	0	6	0	0.00	.	.	.
	1993	5	0	5	0	0.00	.	.	.
CALCIUM	1990	6	0	0	6	100.00	79.80	241.00	165.47
	1993	5	0	4	1	20.00	10100.0	10100.0	10100.0
CESIUM	1990	6	0	5	1	16.67	200.00	200.00	200.00
	1993	5	0	5	0	0.00	.	.	.
CHROMIUM	1990	6	0	6	0	0.00	.	.	.
	1993	5	0	5	0	0.00	.	.	.
COBALT	1990	6	0	6	0	0.00	.	.	.
	1993	5	0	5	0	0.00	.	.	.
COPPER	1990	6	0	4	2	33.33	2.30	13.10	7.70
	1993	5	0	5	0	0.00	.	.	.
IRON	1990	6	0	3	3	50.00	36.40	97.70	64.17
	1993	5	0	5	0	0.00	.	.	.
LEAD	1990	6	0	5	1	16.67	1.00	1.00	1.00
	1993	5	0	4	1	20.00	1.20	1.20	1.20
LITHIUM	1990	6	0	5	1	16.67	5.50	5.50	5.50
	1993	5	0	5	0	0.00	.	.	.
MAGNESIUM	1990	6	0	3	3	50.00	17.10	110.00	52.80
	1993	5	0	4	1	20.00	1720.00	1720.00	1720.00
MANGANESE	1990	6	0	2	4	66.67	1.30	4.50	3.25
	1993	5	0	5	0	0.00	.	.	.
MERCURY	1990	6	1	5	0	0.00	.	.	.
	1993	5	0	5	0	0.00	.	.	.
MOLYBDENUM	1990	6	0	4	2	33.33	2.20	2.20	2.20
	1993	5	0	5	0	0.00	.	.	.
NICKEL	1990	6	0	6	0	0.00	.	.	.
	1993	5	0	5	0	0.00	.	.	.
POTASSIUM	1990	6	0	4	2	33.33	44.30	888.00	466.15
	1993	5	0	4	1	20.00	7240.00	7240.00	7240.00
SELENIUM	1990	6	0	6	0	0.00	.	.	.
	1993	5	0	4	1	20.00	2.60	2.60	2.60

Table A-2 (continued)
Field-Blank Results for Total Metals

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(µg/l) Minimum	Maximum	Average
SILICON	1990	1	1	0	0	.	.	.	.
	1993	5	0	3	2	40.00	108.00	121.00	114.50
SILVER	1990	6	0	5	1	16.67	6.30	6.30	6.30
	1993	5	0	5	0	0.00	.	.	.
SODIUM	1990	6	0	0	6	100.00	35.00	288.00	131.12
	1993	5	0	4	1	20.00	77.40	77.40	77.40
STRONTIUM	1990	6	0	2	4	66.67	1.60	1.80	1.72
	1993	5	0	4	1	20.00	6.70	6.70	6.70
THALLIUM	1990	6	0	6	0	0.00	.	.	.
	1993	5	0	5	0	0.00	.	.	.
TIN	1990	6	0	4	2	33.33	9.70	12.10	10.90
	1993	5	0	5	0	0.00	.	.	.
VANADIUM	1990	6	0	5	1	16.67	5.90	5.90	5.90
	1993	5	0	5	0	0.00	.	.	.
ZINC	1990	6	0	0	6	100.00	3.30	24.30	10.40
	1993	5	0	5	0	0.00	.	.	.
Totals	1990	169	2	112	55	32.54			
	1991	0	0	0	0	.			
	1992	0	0	0	0	.			
	1993	145	0	136	9	6.21			
	1994	0	0	0	0	.			
	Overall	314	2	248	64	20.38			

Table A-3
Equipment-Rinsate Results for Dissolved Metals

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(µg/l) Minimum	Maximum	Average
ALUMINUM	1990	26	0	13	13	50.00	10.60	234.00	63.65
	1991	43	0	36	7	16.28	9.60	51.20	27.23
	1992	62	3	45	14	23.73	6.40	40.00	18.99
	1993	66	2	60	4	6.25	15.20	62.70	28.52
	1994	2	0	2	0	0.00	.	.	.
ANTIMONY	1990	26	0	22	4	15.38	11.10	14.20	12.88
	1991	43	2	35	6	14.63	8.10	42.70	21.75
	1992	62	1	57	4	6.56	11.50	19.40	15.33
	1993	66	0	65	1	1.52	27.00	27.00	27.00
	1994	2	0	2	0	0.00	.	.	.
ARSENIC	1990	26	0	26	0	0.00	.	.	.
	1991	43	0	43	0	0.00	.	.	.
	1992	62	1	61	0	0.00	.	.	.
	1993	66	0	64	2	3.03	1.10	15.30	8.20
	1994	2	0	2	0	0.00	.	.	.
BARIUM	1990	26	0	9	17	65.38	1.20	52.60	7.11
	1991	43	0	27	16	37.21	1.10	8.20	3.23
	1992	62	0	60	2	3.23	2.60	3.00	2.80
	1993	66	0	63	3	4.55	1.30	1.50	1.43
	1994	2	0	2	0	0.00	.	.	.
BERYLLIUM	1990	26	0	26	0	0.00	.	.	.
	1991	43	0	43	0	0.00	.	.	.
	1992	62	0	62	0	0.00	.	.	.
	1993	66	0	65	1	1.52	1.50	1.50	1.50
	1994	2	0	2	0	0.00	.	.	.
CADMIUM	1990	26	0	25	1	3.85	7.00	7.00	7.00
	1991	43	0	41	2	4.65	1.00	2.60	1.80
	1992	62	0	62	0	0.00	.	.	.
	1993	66	0	65	1	1.52	3.10	3.10	3.10
	1994	2	0	2	0	0.00	.	.	.
CALCIUM	1990	26	0	3	23	88.46	41.00	174000	8468.98
	1991	43	0	10	33	76.74	55.40	1880.00	246.75
	1992	62	0	32	30	48.39	29.60	798.00	171.22
	1993	66	1	39	26	40.00	39.30	201.00	96.93
	1994	2	0	0	2	100.00	56.80	66.10	61.45
CESIUM	1990	26	0	20	6	23.08	100.00	300.00	183.33
	1991	43	0	42	1	2.33	120.00	120.00	120.00
	1992	61	7	54	0	0.00	.	.	.
	1993	66	12	51	3	5.56	15.00	40.00	26.33
	1994	2	0	1	1	50.00	16.00	16.00	16.00
CHROMIUM	1990	26	0	25	1	3.85	10.30	10.30	10.30
	1991	43	0	40	3	6.98	5.10	12.00	9.27
	1992	61	0	60	1	1.64	2.60	2.60	2.60
	1993	66	0	66	0	0.00	.	.	.
	1994	2	0	2	0	0.00	.	.	.
COBALT	1990	26	0	26	0	0.00	.	.	.
	1991	43	0	41	2	4.65	3.00	3.80	3.40
	1992	61	1	60	0	0.00	.	.	.
	1993	66	0	66	0	0.00	.	.	.
	1994	2	0	2	0	0.00	.	.	.
COPPER	1990	26	0	20	6	23.08	2.00	15.60	5.20
	1991	43	0	38	5	11.63	2.10	5.80	3.96
	1992	61	0	53	8	13.11	2.00	12.80	4.45
	1993	66	1	62	3	4.62	2.30	5.60	3.63
	1994	2	0	2	0	0.00	.	.	.

Table A-3 (continued)
Equipment-Rinsate Results for Dissolved Metals

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(µg/l) Minimum	Maximum	Average
IRON	1990	26	0	11	15	57.69	3.20	282.00	54.77
	1991	43	0	29	14	32.56	2.80	184.00	54.51
	1992	61	1	42	18	30.00	4.60	100.00	29.99
	1993	66	0	62	4	6.06	26.80	178.00	97.53
	1994	2	0	1	1	50.00	8.80	8.80	8.80
LEAD	1990	26	0	21	5	19.23	0.70	45.30	10.24
	1991	43	0	42	1	2.33	1.20	1.20	1.20
	1992	61	0	57	4	6.56	1.40	2.30	1.97
	1993	66	0	65	1	1.52	1.60	1.60	1.60
	1994	2	0	2	0	0.00	.	.	.
LITHIUM	1990	26	0	23	3	11.54	6.10	7.10	6.70
	1991	43	1	38	4	9.52	1.00	3.90	2.27
	1992	61	0	53	8	13.11	1.00	13.20	3.12
	1993	66	0	66	0	0.00	.	.	.
	1994	2	0	2	0	0.00	.	.	.
MAGNESIUM	1990	26	0	14	12	46.15	15.60	3850.00	389.08
	1991	43	2	25	16	39.02	12.60	67.60	26.53
	1992	61	2	43	16	27.12	9.30	74.20	25.81
	1993	66	0	58	8	12.12	15.00	26.50	19.01
	1994	2	0	2	0	0.00	.	.	.
MANGANESE	1990	26	0	4	22	84.62	1.60	34.60	5.13
	1991	43	0	3	40	93.02	1.20	18.90	3.93
	1992	61	0	37	24	39.34	1.30	13.50	3.70
	1993	66	1	44	21	32.31	1.00	6.20	2.61
	1994	2	0	0	2	100.00	2.00	3.60	2.80
MERCURY	1990	26	1	25	0	0.00	.	.	.
	1991	43	0	39	4	9.30	0.21	0.28	0.25
	1992	61	0	57	4	6.56	0.21	0.64	0.34
	1993	66	0	66	0	0.00	.	.	.
	1994	2	0	2	0	0.00	.	.	.
MOLYBDENUM	1990	26	0	21	5	19.23	2.20	9.70	4.48
	1991	43	0	34	9	20.93	3.10	10.00	6.79
	1992	61	0	61	0	0.00	.	.	.
	1993	66	0	66	0	0.00	.	.	.
	1994	2	0	2	0	0.00	.	.	.
NICKEL	1990	26	0	24	2	7.69	4.30	17.30	10.80
	1991	43	0	40	3	6.98	5.00	18.90	10.43
	1992	61	1	57	3	5.00	2.10	13.40	6.10
	1993	66	0	65	1	1.52	7.60	7.60	7.60
	1994	2	0	2	0	0.00	.	.	.
POTASSIUM	1990	26	0	15	11	42.31	36.20	2890.00	1059.55
	1991	43	0	35	8	18.60	74.50	154.00	105.99
	1992	61	0	55	6	9.84	51.40	203.00	96.55
	1993	66	0	63	3	4.55	390.00	1020.00	707.33
	1994	2	0	2	0	0.00	.	.	.
SELENIUM	1990	26	0	25	1	3.85	2.00	2.00	2.00
	1991	43	0	42	1	2.33	1.00	1.00	1.00
	1992	61	0	60	1	1.64	1.60	1.60	1.60
	1993	66	0	66	0	0.00	.	.	.
	1994	2	0	2	0	0.00	.	.	.
SILVER	1990	26	0	17	9	34.62	2.30	8.50	4.22
	1991	43	1	36	6	14.29	2.30	4.00	3.05
	1992	61	1	60	0	0.00	.	.	.
	1993	66	2	63	1	1.56	5.20	5.20	5.20
	1994	2	0	2	0	0.00	.	.	.

Table A-3 (continued)
Equipment-Rinsate Results for Dissolved Metals

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(µg/l) Minimum	Maximum	Average
SODIUM	1990	26	0	4	22	84.62	51.40	113000	5889.13
	1991	43	0	21	22	51.16	33.70	1750.00	307.53
	1992	61	0	29	32	52.46	67.60	5740.00	357.70
	1993	66	0	34	32	48.48	47.80	1580.00	182.70
	1994	2	0	0	2	100.00	61.50	122.00	91.75
STRONTIUM	1990	26	0	10	16	61.54	1.10	89.80	7.22
	1991	43	0	11	32	74.42	1.40	7.30	2.82
	1992	61	0	51	10	16.39	1.00	3.40	2.04
	1993	66	0	63	3	4.55	1.40	2.00	1.80
	1994	2	0	1	1	50.00	1.10	1.10	1.10
THALLIUM	1990	26	0	25	1	3.85	3.00	3.00	3.00
	1991	43	0	41	2	4.65	1.00	1.00	1.00
	1992	61	0	60	1	1.64	1.10	1.10	1.10
	1993	66	0	66	0	0.00	.	.	.
	1994	2	0	2	0	0.00	.	.	.
TIN	1990	26	0	20	6	23.08	12.40	43.40	23.83
	1991	43	0	41	2	4.65	11.20	15.10	13.15
	1992	61	1	57	3	5.00	23.70	39.60	30.73
	1993	66	0	66	0	0.00	.	.	.
	1994	2	0	2	0	0.00	.	.	.
VANADIUM	1990	26	0	20	6	23.08	2.10	30.20	10.17
	1991	43	0	39	4	9.30	2.00	4.10	3.00
	1992	61	2	55	4	6.78	1.30	4.00	2.50
	1993	66	0	66	0	0.00	.	.	.
	1994	2	0	2	0	0.00	.	.	.
ZINC	1990	26	0	8	18	69.23	3.50	17.90	9.11
	1991	43	0	21	22	51.16	5.40	58.20	12.01
	1992	61	0	39	22	36.07	4.20	28.90	10.95
	1993	66	1	34	31	47.69	3.10	318.00	25.95
	1994	2	0	0	2	100.00	5.50	11.00	8.25
Totals	1990	728	1	502	225	30.91			
	1991	1204	6	933	265	22.01			
	1992	1715	21	1479	215	12.54			
	1993	1848	20	1679	149	8.06			
	1994	56	0	45	11	19.64			
	Overall	5551	48	4638	865	15.58			

Table A-4
Equipment-Rinsate Results for Total Metals

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(µg/l) Minimum	Maximum	Average
ALUMINUM	1991	25	0	22	3	12.00	9.10	31.90	19.03
	1992	62	3	39	20	33.90	6.80	8510.00	445.69
	1993	15	0	10	5	33.33	29.90	73.20	45.78
ANTIMONY	1991	25	0	23	2	8.00	9.30	14.90	12.10
	1992	62	4	56	2	3.45	8.70	12.60	10.65
	1993	15	0	15	0	0.00	.	.	.
ARSENIC	1991	25	0	25	0	0.00	.	.	.
	1992	62	3	58	1	1.69	1.00	1.00	1.00
	1993	15	0	15	0	0.00	.	.	.
BARIUM	1991	25	0	15	10	40.00	2.30	9.10	4.28
	1992	62	0	49	13	20.97	1.10	63.90	7.58
	1993	15	0	15	0	0.00	.	.	.
BERYLLIUM	1991	25	0	25	0	0.00	.	.	.
	1992	62	2	60	0	0.00	.	.	.
	1993	15	0	15	0	0.00	.	.	.
CADMIUM	1991	25	0	20	5	20.00	1.20	5.10	2.20
	1992	62	1	58	3	4.92	1.50	3.40	2.60
	1993	15	0	15	0	0.00	.	.	.
CALCIUM	1991	25	0	4	21	84.00	96.50	425.00	216.98
	1992	62	0	27	35	56.45	20.60	11900.0	506.49
	1993	15	0	7	8	53.33	42.80	1960.00	518.29
CESIUM	1991	25	0	22	3	12.00	60.00	80.00	66.67
	1992	62	5	57	0	0.00	.	.	.
	1993	15	1	14	0	0.00	.	.	.
CHROMIUM	1991	25	1	20	4	16.67	6.10	6.40	6.25
	1992	61	1	59	1	1.67	20.40	20.40	20.40
	1993	15	0	15	0	0.00	.	.	.
COBALT	1991	25	0	22	3	12.00	2.00	3.50	2.83
	1992	61	0	61	0	0.00	.	.	.
	1993	15	0	15	0	0.00	.	.	.
COPPER	1991	25	0	23	2	8.00	3.70	4.60	4.15
	1992	61	0	50	11	18.03	1.00	8.00	3.59
	1993	15	0	10	5	33.33	2.90	12.50	7.00
IRON	1991	25	1	15	9	37.50	4.90	117.00	51.21
	1992	61	0	39	22	36.07	4.80	8590.00	446.39
	1993	15	1	6	8	57.14	4.40	108.00	29.37
LEAD	1991	25	1	24	0	0.00	.	.	.
	1992	61	0	57	4	6.56	1.50	2.90	2.20
	1993	15	1	13	1	7.14	3.10	3.10	3.10
LITHIUM	1991	25	1	23	1	4.17	1.50	1.50	1.50
	1992	61	1	50	10	16.67	1.00	10.70	2.60
	1993	15	0	15	0	0.00	.	.	.
MAGNESIUM	1991	25	1	19	5	20.83	15.00	22.30	17.82
	1992	61	1	45	15	25.00	9.10	4190.00	299.03
	1993	15	0	14	1	6.67	34.60	34.60	34.60
MANGANESE	1991	25	0	5	20	80.00	1.10	7.70	3.30
	1992	61	0	34	27	44.26	2.30	78.00	6.76
	1993	15	0	5	10	66.67	1.90	3.80	2.75

Table A-4 (continued)
Equipment-Rinsate Results for Total Metals

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(µg/l) Minimum	Maximum	Average
MERCURY	1991	25	0	25	0	0.00	.	.	.
	1992	61	0	59	2	3.28	0.21	0.22	0.22
	1993	15	0	15	0	0.00	.	.	.
MOLYBDENUM	1991	25	0	25	0	0.00	.	.	.
	1992	61	0	60	1	1.64	2.60	2.60	2.60
	1993	15	0	15	0	0.00	.	.	.
NICKEL	1991	25	0	24	1	4.00	4.20	4.20	4.20
	1992	61	2	57	2	3.39	14.00	14.60	14.30
	1993	15	0	15	0	0.00	.	.	.
POTASSIUM	1991	25	0	22	3	12.00	68.40	83.60	77.20
	1992	61	0	53	8	13.11	61.80	1700.00	537.77
	1993	15	0	15	0	0.00	.	.	.
SELENIUM	1991	25	0	25	0	0.00	.	.	.
	1992	61	1	60	0	0.00	.	.	.
	1993	15	0	15	0	0.00	.	.	.
SILICON	1991	2	0	1	1	50.00	170.00	170.00	170.00
	1992	44	2	14	28	66.67	27.90	300.00	128.06
	1993	15	0	11	4	26.67	91.90	205.00	131.97
SILVER	1991	25	1	22	2	8.33	2.30	2.90	2.60
	1992	61	0	59	2	3.28	2.10	12.30	7.20
	1993	15	0	15	0	0.00	.	.	.
SODIUM	1991	25	0	11	14	56.00	55.70	1150.00	261.06
	1992	61	0	27	34	55.74	71.90	13700.0	984.25
	1993	15	0	5	10	66.67	78.20	2730.00	694.52
STRONTIUM	1991	25	0	4	21	84.00	1.80	4.50	2.68
	1992	60	0	48	12	20.00	1.00	75.90	8.17
	1993	15	0	12	3	20.00	1.20	4.90	3.33
THALLIUM	1991	25	0	24	1	4.00	1.00	1.00	1.00
	1992	61	0	61	0	0.00	.	.	.
	1993	15	0	15	0	0.00	.	.	.
TIN	1991	25	0	24	1	4.00	11.60	11.60	11.60
	1992	61	1	57	3	5.00	11.10	29.80	18.50
	1993	15	0	15	0	0.00	.	.	.
VANADIUM	1991	24	0	21	3	12.50	2.40	2.80	2.57
	1992	61	1	52	8	13.33	1.50	13.70	3.45
	1993	15	1	14	0	0.00	.	.	.
ZINC	1991	24	0	16	8	33.33	2.50	17.20	8.76
	1992	61	1	39	21	35.00	4.80	60.20	15.23
	1993	15	0	5	10	66.67	6.30	662.00	83.11
Totals	1990	0	0	0	0	.			
	1991	700	6	551	143	20.43			
	1992	1759	29	1445	285	16.20			
	1993	435	4	366	65	14.94			
	1994	0	0	0	0	.			
	Overall	2894	39	2362	493	17.03			

Table A-5
Relative Percent Differences for Dissolved Metals

Analyte	Year	Number of Samples	Number Rejected	Nondetect Mismatch	Both are Nondets	Both are Detects	Average	Std Dev.	Minimum	Maximum
ALUMINUM	1990	36	2	4	10	20	40.72	42.49	0.00	155.69
	1991	21	1	6	1	13	43.07	44.17	1.65	161.86
	1992	11	0	2	9	0	.	.	.	.
	1993	55	0	9	44	2	17.44	13.95	7.58	27.30
	1994	2	0	0	1	1	7.57	.	7.57	7.57
	* Overall	125	3	21	65	36	39.35	41.44	0.00	161.86
ANTIMONY	1990	36	0	4	21	11	22.38	23.44	0.00	64.69
	1991	21	1	9	4	7	15.63	17.56	1.69	52.60
	1992	11	0	0	11	0	.	.	.	.
	1993	55	0	4	51	0	.	.	.	.
	1994	2	0	0	2	0	.	.	.	.
	Overall	125	1	17	89	18	19.76	21.06	0.00	64.69
ARSENIC	1990	36	0	3	30	3	29.63	33.95	0.00	66.67
	1991	20	0	0	18	2	36.11	19.64	22.22	50.00
	1992	6	0	0	6	0	.	.	.	.
	1993	54	2	1	49	2	18.60	10.59	11.11	26.09
	1994	2	0	0	2	0	.	.	.	.
	* Overall	118	2	4	105	7	28.33	22.80	0.00	66.67
BARIUM	1990	36	0	0	6	30	6.76	15.69	0.00	87.06
	1991	21	0	0	0	21	5.72	5.23	0.06	19.76
	1992	11	0	0	10	1	2.96	.	2.96	2.96
	1993	55	0	0	0	55	1.90	1.69	0.00	7.74
	1994	2	0	0	0	2	2.60	0.43	2.30	2.90
	Overall	125	0	0	16	109	4.00	8.81	0.00	87.06
BERYLLIUM	1990	36	1	1	33	1	47.62	.	47.62	47.62
	1991	21	0	0	20	1	7.41	.	7.41	7.41
	1992	11	0	0	11	0	.	.	.	.
	1993	55	0	0	55	0	.	.	.	.
	1994	2	0	0	2	0	.	.	.	.
	* Overall	125	1	1	121	2	27.51	28.43	7.41	47.62
CADMIUM	1990	36	0	6	29	1	0.00	.	0.00	0.00
	1991	21	0	1	18	2	37.75	38.91	10.23	65.26
	1992	11	0	0	11	0	.	.	.	.
	1993	55	0	1	54	0	.	.	.	.
	1994	2	0	0	2	0	.	.	.	.
	* Overall	125	0	8	114	3	25.17	35.10	0.00	65.26
CALCIUM	1990	36	0	0	0	36	7.08	26.78	0.00	162.82
	1991	21	0	0	0	21	2.97	3.85	0.00	14.84
	1992	11	0	0	0	11	4.52	9.92	0.00	33.95
	1993	55	0	0	0	55	1.36	1.47	0.00	7.86
	1994	2	0	0	0	2	1.87	1.35	0.91	2.82
	Overall	125	0	0	0	125	3.57	14.82	0.00	162.82
CESIUM	1990	34	1	2	28	3	22.22	38.49	0.00	66.67
	1991	21	0	4	17	0	.	.	.	.
	1992	12	0	0	12	0	.	.	.	.
	1993	55	11	1	41	2	17.14	4.04	14.29	20.00
	1994	2	0	0	1	1	8.70	.	8.70	8.70
	Overall	124	12	7	99	6	18.27	24.98	0.00	66.67
CHROMIUM	1990	36	0	4	25	7	37.78	34.84	1.55	102.93
	1991	21	0	2	14	5	10.00	8.61	0.35	20.56
	1992	11	0	0	11	0	.	.	.	.
	1993	55	0	2	53	0	.	.	.	.
	1994	2	0	0	2	0	.	.	.	.
	* Overall	125	0	8	105	12	26.21	29.89	0.35	102.93

Table A-5 (continued)
Relative Percent Differences for Dissolved Metals

Analyte	Year	Number of Samples	Number Rejected	Nondetect Mismatch	Both are Nondets	Both are Detects	Average	Std Dev.	Minimum	Maximum
COBALT	1990	36	0	4	29	3	22.73	19.36	11.35	45.08
	1991	21	0	1	16	4	6.69	2.97	2.25	8.34
	1992	11	0	0	11	0	.	.	.	.
	1993	55	0	3	51	1	35.71	.	35.71	35.71
	1994	2	0	0	2	0	.	.	.	.
	Overall	125	0	8	109	8	16.33	15.34	2.25	45.08
COPPER	1990	36	1	4	21	10	39.10	28.68	8.33	83.54
	1991	21	0	2	17	2	15.68	5.92	11.49	19.86
	1992	11	0	1	10	0	.	.	.	.
	1993	55	0	10	44	1	12.50	.	12.50	12.50
	1994	2	0	0	2	0	.	.	.	.
	* Overall	125	1	17	94	13	33.45	27.13	8.33	83.54
IRON	1990	36	0	2	13	21	53.96	53.28	0.78	176.56
	1991	21	0	7	1	13	58.93	68.44	2.35	190.83
	1992	11	0	0	11	0	.	.	.	.
	1993	55	1	5	39	10	62.02	51.93	10.31	149.77
	1994	2	0	1	0	1	44.23	.	44.23	44.23
	* Overall	125	1	15	64	45	56.97	55.99	0.78	190.83
LEAD	1990	36	0	5	24	7	79.20	80.09	0.00	197.12
	1991	20	0	2	16	2	6.98	3.59	4.44	9.52
	1992	7	0	0	7	0	.	.	.	.
	1993	52	0	0	49	3	20.93	21.05	5.41	44.90
	1994	2	0	0	2	0	.	.	.	.
	* Overall	117	0	7	98	12	52.60	68.43	0.00	197.12
LITHIUM	1990	34	0	2	14	18	16.12	29.92	0.00	129.41
	1991	21	1	1	3	16	16.81	22.51	0.68	84.18
	1992	12	0	1	9	2	6.85	9.69	0.00	13.70
	1993	55	0	0	23	32	9.06	6.91	0.00	25.74
	1994	2	0	0	1	1	6.56	.	6.56	6.56
	Overall	124	1	4	50	69	12.60	19.33	0.00	129.41
MAGNESIUM	1990	36	0	0	1	35	2.51	2.18	0.00	8.98
	1991	21	0	0	0	21	2.73	3.24	0.03	12.64
	1992	11	0	0	3	8	15.27	40.12	0.00	114.56
	1993	55	0	0	0	55	1.42	1.62	0.00	7.64
	1994	2	0	0	0	2	1.85	0.36	1.59	2.10
	Overall	125	0	0	4	121	2.89	10.46	0.00	114.56
MANGANESE	1990	36	0	2	4	30	23.39	33.60	0.00	138.46
	1991	21	0	0	6	15	18.39	19.44	0.67	59.16
	1992	11	0	1	9	1	79.83	.	79.83	79.83
	1993	55	0	7	23	25	13.34	17.62	0.00	65.99
	1994	2	0	1	0	1	3.69	.	3.69	3.69
	Overall	125	0	11	42	72	19.37	26.75	0.00	138.46
MERCURY	1990	35	2	0	32	1	33.33	.	33.33	33.33
	1991	20	0	1	19	0	.	.	.	.
	1992	7	0	0	7	0	.	.	.	.
	1993	55	0	0	55	0	.	.	.	.
	1994	2	0	0	2	0	.	.	.	.
	* Overall	119	2	1	115	1	33.33	.	33.33	33.33
MOLYBDENUM	1990	34	0	3	21	10	30.04	19.39	0.00	74.16
	1991	21	1	5	11	4	47.69	47.87	7.89	117.28
	1992	11	0	0	11	0	.	.	.	.
	1993	55	0	2	53	0	.	.	.	.
	1994	2	0	1	1	0	.	.	.	.
	* Overall	123	1	11	97	14	35.08	29.28	0.00	117.28

Table A-5 (continued)
Relative Percent Differences for Dissolved Metals

Analyte	Year	Number of Samples	Number Rejected	Nondetect Mismatch	Both are Nondets	Both are Detects	Average	Std Dev.	Minimum	Maximum
NICKEL	1990	36	1	6	22	7	42.35	55.22	6.90	163.93
	1991	21	0	5	12	4	14.74	9.51	3.03	25.93
	1992	11	0	0	11	0	.	.	.	.
	1993	55	0	7	48	0	.	.	.	.
	1994	2	0	0	2	0	.	.	.	.
	* Overall	125	1	18	95	11	32.31	45.29	3.03	163.93
POTASSIUM	1990	36	2	0	8	26	14.18	24.73	0.00	109.13
	1991	21	0	1	1	19	9.88	15.58	0.00	67.05
	1992	11	0	1	10	0	.	.	.	.
	1993	55	1	11	16	27	17.51	14.29	1.12	58.28
	1994	2	0	0	0	2	17.58	12.94	8.43	26.72
	Overall	125	3	13	35	74	14.38	18.80	0.00	109.13
SELENIUM	1990	36	0	3	27	6	9.40	10.49	0.00	27.91
	1991	20	0	5	11	4	25.86	27.27	9.49	66.67
	1992	7	0	0	7	0	.	.	.	.
	1993	52	0	2	46	4	11.53	8.46	5.71	24.00
	1994	2	0	0	2	0	.	.	.	.
	Overall	117	0	10	93	14	14.71	16.88	0.00	66.67
SILICON	1990	15	0	0	0	15	4.74	4.50	0.00	14.44
	1991	4	0	0	0	4	20.97	31.29	0.79	67.59
	1992	9	0	0	0	9	1.90	2.16	0.00	6.96
	1993	55	0	0	0	55	1.72	1.71	0.00	6.90
	1994	2	0	0	0	2	0.53	0.46	0.21	0.86
	Overall	85	0	0	0	85	3.15	7.61	0.00	67.59
SILVER	1990	36	0	7	21	8	28.29	18.04	0.00	52.83
	1991	21	1	3	14	3	23.97	20.35	0.69	38.38
	1992	11	0	0	11	0	.	.	.	.
	1993	55	1	1	53	0	.	.	.	.
	1994	2	0	0	2	0	.	.	.	.
	* Overall	125	2	11	101	11	27.11	17.74	0.00	52.83
SODIUM	1990	36	0	0	0	36	8.23	26.76	0.00	162.86
	1991	21	0	0	0	21	2.26	2.83	0.03	12.02
	1992	11	0	0	0	11	3.39	6.85	0.00	23.63
	1993	55	0	0	0	55	2.15	3.26	0.00	16.26
	1994	2	0	0	0	2	3.15	0.18	3.03	3.28
	Overall	125	0	0	0	125	4.05	14.80	0.00	162.86
STRONTIUM	1990	34	0	0	3	31	2.43	2.25	0.00	8.74
	1991	21	0	0	0	21	2.69	3.05	0.02	13.45
	1992	12	0	1	5	6	1.17	0.91	0.00	2.26
	1993	55	0	0	0	55	1.52	1.57	0.00	7.34
	1994	2	0	0	0	2	1.97	0.83	1.38	2.55
	Overall	124	0	1	8	115	1.97	2.11	0.00	13.45
THALLIUM	1990	36	0	2	34	0	.	.	.	.
	1991	20	0	0	19	1	0.00	.	0.00	0.00
	1992	7	0	0	7	0	.	.	.	.
	1993	52	0	0	52	0	.	.	.	.
	1994	2	0	0	2	0	.	.	.	.
	Overall	117	0	2	114	1	0.00	.	0.00	0.00
TIN	1990	34	0	2	18	14	30.74	48.48	0.00	192.34
	1991	21	0	7	6	8	13.98	14.43	0.00	43.42
	1992	10	0	1	8	1	7.89	.	7.89	7.89
	1993	55	0	8	43	4	31.83	21.68	5.87	56.17
	1994	2	0	0	2	0	.	.	.	.
	* Overall	122	0	18	77	27	25.09	36.86	0.00	192.34

Table A-5 (continued)
Relative Percent Differences for Dissolved Metals

Analyte	Year	Number of Samples	Number Rejected	Nondetect Mismatch	Both are Nondets	Both are Detects	Average	Std Dev.	Minimum	Maximum
VANADIUM	1990	36	0	2	15	19	26.66	25.66	2.08	85.71
	1991	21	0	3	10	8	27.77	25.41	3.12	81.90
	1992	11	0	0	11	0	.	.	.	.
	1993	55	0	5	47	3	9.95	9.39	3.28	20.69
	1994	2	0	0	2	0	.	.	.	.
	* Overall	125	0	10	85	30	25.29	24.45	2.08	85.71
ZINC	1990	36	0	7	5	24	27.91	25.30	0.00	74.92
	1991	21	0	5	1	15	40.30	33.86	0.73	97.57
	1992	11	0	1	9	1	50.21	.	50.21	50.21
	1993	55	1	8	34	12	57.12	59.98	1.98	195.80
	1994	2	0	0	2	0	.	.	.	.
	* Overall	125	1	21	51	52	38.65	38.95	0.00	195.80

Table A-6
Relative Percent Differences for Total Metals

Analyte	Year	Number of Samples	Number Rejected	Nondetect Mismatch	Both are Nondets	Both are Detects	Average	Std Dev.	Minimum	Maximum
ALUMINUM	1991	23	0	1	0	22	51.14	46.12	0.00	198.35
	1992	51	0	0	1	50	47.80	43.11	1.29	182.45
	1993	17	0	1	4	12	34.31	22.49	3.74	70.39
	* Overall	91	0	2	5	84	46.75	41.60	0.00	198.35
ANTIMONY	1991	23	1	4	9	9	30.32	30.43	2.06	98.45
	1992	51	6	8	34	3	51.85	17.73	39.36	72.15
	1993	17	0	1	15	1	12.07	.	12.07	12.07
	* Overall	91	7	13	58	13	33.89	28.28	2.06	98.45
ARSENIC	1991	23	0	4	13	6	22.40	34.67	0.00	85.71
	1992	55	0	9	24	22	20.87	16.97	0.00	75.00
	1993	18	0	2	6	10	17.27	16.32	0.00	56.00
	* Overall	96	0	15	43	38	20.16	19.85	0.00	85.71
BARIUM	1991	23	0	0	0	23	23.77	41.62	0.00	186.07
	1992	51	0	0	1	50	21.25	27.70	0.00	134.26
	1993	17	0	0	0	17	7.91	11.14	0.16	38.67
	Overall	91	0	0	1	90	19.37	30.09	0.00	186.07
BERYLLIUM	1991	23	0	5	15	3	32.44	55.62	0.00	96.66
	1992	51	2	7	34	8	28.82	34.93	5.71	109.09
	1993	17	0	2	13	2	15.76	3.43	13.33	18.18
	* Overall	91	2	14	62	13	27.65	35.47	0.00	109.09
CADMIUM	1991	23	0	5	13	5	42.16	53.86	0.00	133.08
	1992	51	2	5	41	3	68.29	65.39	25.00	143.52
	1993	17	0	1	16	0	.	.	.	.
	* Overall	91	2	11	70	8	51.96	55.34	0.00	143.52
CALCIUM	1991	23	0	0	0	23	13.87	41.15	0.00	197.82
	1992	51	0	0	0	51	6.71	14.61	0.26	93.72
	1993	17	0	0	0	17	3.39	3.74	0.00	12.65
	Overall	91	0	0	0	91	7.90	23.42	0.00	197.82
CESIUM	1991	23	0	1	20	2	15.76	3.43	13.33	18.18
	1992	50	9	2	39	0	.	.	.	.
	1993	17	2	0	15	0	.	.	.	.
	Overall	90	11	3	74	2	15.76	3.43	13.33	18.18
CHROMIUM	1991	23	0	3	2	18	26.99	31.09	0.00	120.16
	1992	50	0	8	11	31	47.60	40.61	1.10	149.83
	1993	17	0	4	6	7	35.40	24.85	0.97	67.01
	• Overall	90	0	15	19	56	39.45	36.83	0.00	149.83
COBALT	1991	23	0	6	9	8	40.32	47.92	0.70	135.63
	1992	50	0	8	22	20	40.62	40.13	4.36	155.47
	1993	17	0	2	11	4	23.40	26.81	4.94	63.11
	• Overall	90	0	16	42	32	38.39	40.10	0.70	155.47
COPPER	1991	23	0	5	6	12	40.68	35.49	6.61	122.65
	1992	50	0	8	14	28	42.93	39.25	1.96	150.88
	1993	17	0	1	4	12	37.00	35.26	1.02	125.11
	* Overall	90	0	14	24	52	41.04	36.90	1.02	150.88
IRON	1991	23	0	1	1	21	42.58	45.14	0.00	175.10
	1992	50	0	1	0	49	45.62	46.65	0.31	183.85
	1993	17	0	1	3	13	24.65	24.65	0.40	77.44
	* Overall	90	0	3	4	83	41.57	43.76	0.00	183.85
LEAD	1991	23	0	3	5	15	38.21	36.62	0.00	122.29
	1992	53	1	5	4	43	38.58	39.65	0.00	153.68
	1993	20	0	2	5	13	23.39	18.20	4.38	65.43
	* Overall	96	1	10	14	71	35.72	36.10	0.00	153.68

Table A-6 (continued)
Relative Percent Differences for Total Metals

Analyte	Year	Number of Samples	Number Rejected	Nondetect Mismatch	Both are Nondets	Both are Detects	Average	Std Dev.	Minimum	Maximum
LITHIUM	1991	23	0	2	1	20	15.93	22.89	0.00	91.18
	1992	49	0	3	7	39	25.27	29.59	0.00	130.89
	1993	17	0	1	3	13	8.37	10.28	0.27	31.75
	Overall	89	0	6	11	72	19.63	25.91	0.00	130.89
MAGNESIUM	1991	23	0	1	0	22	10.73	17.13	0.00	72.87
	1992	50	0	0	0	50	12.72	19.59	0.00	92.26
	1993	17	0	0	0	17	16.52	42.85	0.00	178.71
	Overall	90	0	1	0	89	12.95	24.93	0.00	178.71
MANGANESE	1991	23	0	1	0	22	40.14	49.44	0.00	166.78
	1992	50	0	0	1	49	38.26	41.45	0.00	164.29
	1993	17	0	1	1	15	28.04	46.59	0.00	179.84
	* Overall	90	0	2	2	86	36.96	44.15	0.00	179.84
MERCURY	1991	23	0	1	21	1	14.49	.	14.49	14.49
	1992	54	0	3	50	1	0.00	.	0.00	0.00
	1993	17	0	1	15	1	49.18	.	49.18	49.18
	* Overall	94	0	5	86	3	21.22	25.27	0.00	49.18
MOLYBDENUM	1991	23	0	8	7	8	28.62	31.83	0.55	100.27
	1992	50	1	4	41	4	26.08	13.69	7.14	38.71
	1993	17	0	0	16	1	44.86	.	44.86	44.86
	* Overall	90	1	12	64	13	29.09	25.72	0.55	100.27
NICKEL	1991	23	0	4	7	12	29.85	34.99	0.00	112.83
	1992	50	1	8	9	32	46.47	42.03	0.67	155.97
	1993	17	1	3	7	6	25.89	15.98	1.98	48.53
	* Overall	90	2	15	23	50	40.01	38.67	0.00	155.97
POTASSIUM	1991	23	0	1	0	22	20.17	26.27	0.00	95.48
	1992	50	0	1	5	44	28.57	32.00	0.95	139.82
	1993	17	0	1	3	13	18.41	12.22	0.75	39.73
	* Overall	90	0	3	8	79	24.56	28.18	0.00	139.82
SELENIUM	1991	23	0	1	19	3	6.22	10.77	0.00	18.65
	1992	54	1	6	42	5	25.13	22.78	9.52	63.41
	1993	20	1	1	14	4	20.74	13.69	9.69	38.10
	Overall	97	2	8	75	12	18.94	17.99	0.00	63.41
SILICON	1991	1	0	0	0	1	0.55	.	0.55	0.55
	1992	34	0	0	0	34	23.67	25.48	0.58	123.22
	1993	17	0	0	0	17	20.25	22.62	0.15	73.29
	* Overall	52	0	0	0	52	22.11	24.34	0.15	123.22
SILVER	1991	23	0	8	12	3	13.70	19.99	0.83	36.73
	1992	50	0	5	44	1	79.17	.	79.17	79.17
	1993	17	0	1	16	0	.	.	.	.
	* Overall	90	0	14	72	4	30.07	36.58	0.83	79.17
SODIUM	1991	23	0	0	0	23	13.19	41.17	0.00	198.93
	1992	50	0	0	0	50	6.50	24.63	0.00	170.85
	1993	17	0	0	0	17	3.22	2.69	0.78	10.54
	Overall	90	0	0	0	90	7.59	27.69	0.00	198.93
STRONTIUM	1991	23	0	0	0	23	15.19	41.14	0.00	195.63
	1992	49	0	0	1	48	8.96	15.26	0.00	79.34
	1993	17	0	0	0	17	4.44	4.49	0.00	15.22
	Overall	89	0	0	1	88	9.71	23.90	0.00	195.63
THALLIUM	1991	23	0	3	19	1	0.00	.	0.00	0.00
	1992	54	0	2	51	1	6.45	.	6.45	6.45
	1993	20	0	0	20	0	.	.	.	.
	Overall	97	0	5	90	2	3.23	4.56	0.00	6.45

Table A-6 (continued)
Relative Percent Differences for Total Metals

Analyte	Year	Number of Samples	Number Rejected	Nondetect Mismatch	Both are Nondets	Both are Detects	Average	Std Dev.	Minimum	Maximum
TIN	1991	23	0	6	12	5	53.29	33.74	10.46	97.67
	1992	51	3	5	43	0	.	.	.	.
	1993	17	1	1	14	1	0.93	.	0.93	0.93
	* Overall	91	4	12	69	6	44.56	36.98	0.93	97.67
VANADIUM	1991	23	0	2	0	21	34.64	40.70	0.00	152.38
	1992	50	0	1	7	42	44.47	42.84	1.81	173.84
	1993	17	0	1	8	8	37.46	33.05	1.02	84.21
	* Overall	90	0	4	15	71	40.78	40.96	0.00	173.84
ZINC	1991	23	0	3	2	18	41.17	39.28	3.07	127.57
	1992	50	0	5	5	40	40.88	38.95	0.12	163.29
	1993	17	0	0	3	14	30.87	41.77	0.34	157.84
	* Overall	90	0	8	10	72	39.01	39.22	0.12	163.29

Table A-7
Field-Blank Results for Dissolved Radionuclides

Analyte	Year	Number Sampled	Number Rejected	Number Accepted	----Concentrations(pCi/l)---- Minimum	Maximum	Average
AMERICIUM-241	1990	1	1	0	.	.	.
CESIUM-137	1990	1	1	0	.	.	.
GROSS ALPHA	1990	22	1	21	-0.1530	86.4000	4.1755
GROSS BETA	1990	22	1	21	-0.2800	61.7300	3.3883
RADIUM-226	1990	1	0	1	1.7760	1.7760	1.7760
STRONTIUM-89	1990	2	2	0	.	.	.
STRONTIUM-89,90	1990	20	2	18	0.0854	0.5490	0.3189
STRONTIUM-90	1990	2	2	0	.	.	.
URANIUM-233,-234	1990	22	2	20	-0.0405	92.5200	5.8451
	1993	1	0	1	0.0705	0.0705	0.0705
URANIUM-235	1990	22	2	20	-0.0115	3.3980	0.2399
	1993	1	0	1	0.1708	0.1708	0.1708
URANIUM-238	1990	22	2	20	-0.0188	59.9400	4.0311
	1993	1	0	1	0.0390	0.0390	0.0390
Totals	1990	137	16	121			
	1991	0	0	0			
	1992	0	0	0			
	1993	3	0	3			
	1994	0	0	0			
	Overall	140	16	124			

Table A-8
Field-Blank Results for Total Radionuclides

Analyte	Year	Number Sampled	Number Rejected	Number Accepted	----Concentrations(pCi/l)---- Minimum	Maximum	Average
AMERICIUM-241	1990	41	3	38	-0.0002	0.0110	0.0043
	1993	5	2	3	-0.0030	0.0067	0.0018
CESIUM-137	1990	37	3	34	-0.4500	0.8800	0.1704
GROSS ALPHA	1990	21	4	17	-0.4000	1.2000	0.1400
	1993	4	1	3	-0.2800	0.8873	0.2691
GROSS BETA	1990	21	5	16	-0.7000	1.9000	0.2728
	1993	4	0	4	-0.3100	5.6000	2.6464
PLUTONIUM-238	1990	12	0	12	-0.0005	0.0079	0.0019
PLUTONIUM-239/240	1990	43	5	38	-0.0040	0.0296	0.0039
	1993	5	0	5	-0.0007	0.0030	0.0015
STRONTIUM-89,90	1990	9	2	7	0.0400	1.9400	0.4086
	1993	4	0	4	-0.0300	0.5980	0.3070
STRONTIUM-90	1990	13	0	13	-0.1200	0.6800	0.1414
TOTAL RADIOCESIUM	1990	2	0	2	0.0000	0.1000	0.0500
	1993	3	0	3	-0.1400	0.8300	0.3767
TRITIUM	1990	32	4	28	-129.0000	4759.0000	283.4810
	1993	4	0	4	-28.0000	792.2000	207.3000
URANIUM-233,-234	1990	21	3	18	-0.0200	1.4300	0.3309
	1993	4	0	4	-0.0390	0.3471	0.1348
URANIUM-235	1990	21	3	18	-0.0600	0.8740	0.1517
	1993	4	0	4	-0.0096	0.0000	-0.0024
URANIUM-238	1990	21	3	18	0.0000	1.2200	0.2468
	1993	4	0	4	0.0110	0.0720	0.0372
Totals	1990	294	35	259			
	1991	0	0	0			
	1992	0	0	0			
	1993	41	3	38			
	1994	0	0	0			
	Overall	335	38	297			

Table A-9
Equipment-Rinsate Results for Dissolved Radionuclides

Analyte	Year	Number Sampled	Number Rejected	Number Accepted	----Concentrations(pCi/l)---- Minimum	Maximum	Average
AMERICIUM-241	1993	3	0	3	0.0011	0.0040	0.0030
CESIUM-134	1993	7	2	5	0.0000	1.6800	0.7300
CESIUM-137	1990	2	2	0	.	.	.
	1991	2	0	2	-0.0550	0.2510	0.0980
	1992	3	0	3	-0.2700	0.6100	0.2167
	1993	16	0	16	-0.4260	0.7500	0.0807
GROSS ALPHA	1990	23	2	21	-0.1130	40.6600	2.0544
	1991	44	4	40	-0.1320	0.2288	0.0397
	1992	67	4	63	-0.3900	1.2000	0.0906
	1993	59	0	59	-0.3500	0.9300	0.0943
	1994	1	0	1	0.0000	0.0000	0.0000
GROSS BETA	1990	23	2	21	-0.1900	35.7800	2.1549
	1991	44	3	41	-0.4180	1.5110	0.4429
	1992	67	1	66	-2.2000	1.6000	0.2012
	1993	59	0	59	-1.0000	2.4700	0.1831
	1994	1	0	1	-0.5200	-0.5200	-0.5200
PLUTONIUM-239/240	1993	4	0	4	-0.0060	0.0008	-0.0015
RADIUM-226	1990	1	0	1	4.3380	4.3380	4.3380
	1992	11	0	11	-0.0200	0.2400	0.1081
	1993	11	0	11	-0.0600	0.2700	0.0687
RADIUM-228	1990	1	0	1	6.6670	6.6670	6.6670
	1992	11	2	9	-1.0000	3.3000	0.7956
	1993	11	0	11	-0.2100	8.3000	1.0655
STRONTIUM-89	1990	2	2	0	.	.	.
STRONTIUM-89,90	1990	21	2	19	0.1220	2.8490	0.4531
	1991	41	1	40	-0.1900	0.7603	0.2548
	1992	66	1	65	-0.1800	1.0200	0.2375
	1993	59	0	59	-0.5900	0.9400	0.1913
	1994	1	0	1	-0.0500	-0.0500	-0.0500
STRONTIUM-90	1990	2	2	0	.	.	.
TOTAL RADIOCESIUM	1992	19	0	19	-0.0970	1.3000	0.3370
	1993	46	0	46	-0.4700	2.4000	0.4732
	1994	1	0	1	0.1600	0.1600	0.1600
URANIUM-233,-234	1990	23	3	20	-0.0116	36.1600	1.8529
	1991	44	1	43	-0.0374	0.3830	0.0732
	1992	67	10	57	-0.0460	0.8600	0.1355
	1993	61	0	61	-0.0060	1.7000	0.3187
	1994	1	0	1	0.2600	0.2600	0.2600
URANIUM-235	1990	23	3	20	-0.0207	1.5160	0.0853
	1991	44	1	43	-0.0347	0.1281	0.0126
	1992	67	10	57	-0.0217	0.3400	0.0325
	1993	61	0	61	-0.0177	0.5975	0.0535
	1994	1	0	1	-0.0130	-0.0130	-0.0130
URANIUM-238	1990	23	3	20	-0.0101	27.9800	1.4443
	1991	44	1	43	-0.0954	0.4251	0.0539
	1992	67	10	57	-0.0460	0.7300	0.0991
	1993	61	0	61	-0.0190	1.4000	0.2740
	1994	1	0	1	0.3900	0.3900	0.3900

Table A-10
Equipment-Rinsate Results for Total Radionuclides

Analyte	Year	Number Sampled	Number Rejected	Number Accepted	----Concentrations(pCi/l)---- Minimum	Maximum	Average
AMERICIUM-241	1990	31	2	29	-0.0030	0.0276	0.0052
	1991	44	8	36	-0.0408	0.0447	0.0033
	1992	65	4	61	-0.0020	0.0140	0.0032
	1993	62	2	60	-0.0010	0.0204	0.0037
CESIUM-134	1993	1	0	1	-0.0208	-0.0208	-0.0208
CESIUM-137	1990	29	2	27	-0.4200	358.9000	13.3195
	1991	42	7	35	-1.3500	0.9213	0.0069
	1992	43	3	40	-0.5280	0.7547	0.0493
	1993	1	0	1	0.3472	0.3472	0.3472
GROSS ALPHA	1990	10	5	5	-0.1000	0.6000	0.2074
	1993	4	0	4	-0.5700	0.2000	-0.0863
GROSS BETA	1990	10	5	5	-0.4260	-0.2000	-0.2748
	1993	4	0	4	-2.7000	0.1098	-0.9476
PLUTONIUM-238	1990	12	0	12	-0.0005	0.0132	0.0025
	1991	1	0	1	0.0000	0.0000	0.0000
	1993	9	0	9	-0.0038	0.0020	0.0001
PLUTONIUM-239/240	1990	30	3	27	-0.0020	0.0322	0.0029
	1991	44	1	43	-0.0007	0.0664	0.0031
	1992	67	8	59	-0.0082	0.0944	0.0030
	1993	62	2	60	-0.0130	0.0502	0.0030
STRONTIUM-89,90	1990	5	2	3	-0.0200	0.1100	0.0400
	1991	2	0	2	0.1900	0.2100	0.2000
	1992	1	0	1	0.0900	0.0900	0.0900
	1993	4	0	4	-1.0000	0.5221	-0.1370
STRONTIUM-90	1990	5	0	5	-0.1578	0.1090	-0.0100
TOTAL RADIOCESIUM	1992	1	0	1	1.3000	1.3000	1.3000
TRITIUM	1990	28	5	23	-212.0000	7418.0000	394.5604
	1991	44	1	43	-198.0000	217.2000	25.0261
	1992	65	2	63	-238.0000	380.0000	14.7701
	1993	62	1	61	-290.0000	420.0000	10.5764
URANIUM-233,-234	1990	8	0	8	0.0000	0.4000	0.1894
	1993	3	0	3	0.0390	0.1391	0.0784
URANIUM-235	1990	8	0	8	-0.0100	0.2360	0.0685
	1993	3	0	3	-0.0171	0.0230	0.0020
URANIUM-238	1990	8	0	8	0.0000	0.2110	0.1054
	1993	3	0	3	0.0130	0.0235	0.0185
Totals	1990	184	24	160			
	1991	177	17	160			
	1992	242	17	225			
	1993	218	5	213			
	1994	0	0	0			
	Overall	821	63	758			

Table A-11
Relative Percent Differences for Dissolved Radionuclides

Analyte	Year	Number of Samples	Number Rejected	Nondetect Mismatch	Both are Nondets	Both are Detects	Average	Std Dev.	Minimum	Maximum
AMERICIUM-241	1990	7	1	3	2	1	40.00	.	40.00	40.00
	1992	2	0	1	0	1	10.44	.	10.44	10.44
	1993	3	0	0	3	0	.	.	.	.
	* Overall	12	1	4	5	2	25.22	20.90	10.44	40.00
CESIUM-134	1993	8	2	1	5	0	.	.	.	.
	Overall	8	2	1	5	0	.	.	.	.
CESIUM-137	1990	10	2	1	7	0	.	.	.	.
	1991	2	1	0	1	0	.	.	.	.
	1992	2	0	1	1	0	.	.	.	.
	1993	15	0	2	12	1	69.50	.	69.50	69.50
	* Overall	29	3	4	21	1	69.50	.	69.50	69.50
GROSS ALPHA	1990	28	2	9	3	14	50.76	45.55	0.00	131.49
	1991	44	4	13	8	19	31.22	23.96	4.37	97.73
	1992	68	4	19	21	24	39.33	30.34	0.52	108.22
	1993	60	0	16	21	23	27.65	20.42	2.53	73.42
	1994	1	0	1	0	0	.	.	.	.
	* Overall	201	10	58	53	80	36.05	30.40	0.00	131.49
GROSS BETA	1990	28	1	2	1	24	40.15	27.80	0.00	97.95
	1991	44	4	11	0	29	41.65	42.05	0.00	170.78
	1992	68	1	21	6	40	28.83	23.63	0.67	86.83
	1993	60	0	19	16	25	32.36	29.99	0.00	116.36
	1994	1	0	0	0	1	35.29	.	35.29	35.29
	* Overall	201	6	53	23	119	35.03	31.12	0.00	170.78
PLUTONIUM-239/240	1990	5	0	3	2	0	.	.	.	.
	1992	2	0	1	1	0	.	.	.	.
	1993	4	0	2	2	0	.	.	.	.
	Overall	11	0	6	5	0	.	.	.	.
RADIUM-226	1990	1	0	0	0	1	41.67	.	41.67	41.67
	1991	4	0	1	0	3	10.02	10.64	0.69	21.61
	1992	13	0	1	3	9	40.05	35.71	0.00	84.44
	1993	14	0	4	0	10	44.36	37.54	5.71	117.46
	* Overall	32	0	6	3	23	38.08	34.32	0.00	117.46
RADIUM-228	1992	12	2	5	2	3	44.88	48.18	4.44	98.18
	1993	10	0	0	6	4	22.20	30.63	4.08	68.04
	* Overall	22	2	5	8	7	31.92	37.28	4.08	98.18
STRONTIUM-89	1990	1	1	0	0	0	.	.	.	.
	Overall	1	1	0	0	0	.	.	.	.
STRONTIUM-89,90	1990	23	1	5	7	10	20.78	16.25	6.06	48.11
	1991	41	1	18	8	14	26.96	25.93	1.32	83.39
	1992	68	5	27	20	16	24.18	16.07	5.37	52.91
	1993	58	0	13	35	10	39.41	41.13	8.70	139.29
	1994	1	0	0	1	0	.	.	.	.
	* Overall	191	7	63	71	50	27.33	25.66	1.32	139.29
STRONTIUM-90	1990	7	1	2	3	1	7.87	.	7.87	7.87
	Overall	7	1	2	3	1	7.87	.	7.87	7.87
TOTAL RADIOCESIUM	1992	23	1	12	8	2	22.08	6.48	17.50	26.67
	1993	44	0	13	12	19	25.84	16.59	0.00	67.92
	1994	1	0	0	1	0	.	.	.	.
	* Overall	68	1	25	21	21	25.48	15.84	0.00	67.92
URANIUM-233,-234	1990	28	2	2	9	15	23.77	21.30	0.00	73.85
	1991	44	4	5	10	25	19.27	14.80	0.17	53.25
	1992	68	14	8	10	36	21.58	17.70	0.00	66.67
	1993	61	2	7	6	46	27.91	26.22	0.00	146.15
	1994	1	0	0	0	1	54.90	.	54.90	54.90
	* Overall	202	22	22	35	123	24.02	21.41	0.00	146.15

Table A-11 (continued)
Relative Percent Differences for Dissolved Radionuclides

Analyte	Year	Number of Samples	Number Rejected	Nondetect Mismatch	Both are Nondets	Both are Detects	Average	Std Dev.	Minimum	Maximum
URANIUM-235	1990	28	2	3	21	2	64.88	49.66	29.77	100.00
	1991	44	4	4	34	2	18.57	2.11	17.08	20.07
	1992	68	14	2	49	3	41.60	13.12	27.30	53.06
	1993	60	2	21	34	3	9.56	5.69	5.88	16.11
	1994	1	0	0	1	0	.	.	.	.
	* Overall	201	22	30	139	10	32.04	28.27	5.88	100.00
URANIUM-238	1990	27	2	6	8	11	20.30	22.70	0.00	57.91
	1991	44	4	5	12	23	26.50	18.03	1.68	83.00
	1992	68	14	11	15	28	26.08	20.54	4.69	93.98
	1993	61	2	9	11	39	28.60	24.97	0.00	106.05
	1994	1	0	0	0	1	43.75	.	43.75	43.75
	* Overall	201	22	31	46	102	26.69	21.87	0.00	106.05

Table A-12
Relative Percent Differences for Total Radionuclides

Analyte	Year	Number of Samples	Number Rejected	Nondetect Mismatch	Both are Nondets	Both are Detects	Average	Std Dev.	Minimum	Maximum
AMERICIUM-241	1990	32	2	12	13	5	24.06	30.21	0.00	75.60
	1991	44	4	12	22	6	27.54	13.34	14.32	48.96
	1992	68	10	21	29	8	45.58	32.05	15.85	100.00
	1993	64	6	24	23	11	40.80	25.83	7.25	97.23
	* Overall	208	22	69	87	30	36.63	26.60	0.00	100.00
CESIUM-134	1993	1	0	1	0	0	.	.	.	.
	Overall	1	0	1	0	0	.	.	.	.
CESIUM-137	1990	33	3	3	24	3	29.73	23.49	2.94	46.81
	1991	42	6	8	27	1	7.68	.	7.68	7.68
	1992	43	3	6	34	0	.	.	.	.
	1993	1	0	0	1	0	.	.	.	.
	* Overall	119	12	17	86	4	24.22	22.12	2.94	46.81
GROSS ALPHA	1990	17	5	3	0	9	67.02	68.73	0.00	187.20
	1993	7	2	1	1	3	55.84	28.75	28.14	85.54
	* Overall	24	7	4	1	12	64.22	60.09	0.00	187.20
GROSS BETA	1990	17	5	2	2	8	52.60	48.61	0.17	125.08
	1993	7	1	0	2	4	35.51	36.36	5.89	86.46
	* Overall	24	6	2	4	12	46.91	43.99	0.17	125.08
PLUTONIUM-238	1990	10	0	2	6	2	44.11	48.78	9.62	78.61
	1991	1	0	0	1	0	.	.	.	.
	1993	9	0	3	5	1	138.39	.	138.39	138.39
	* Overall	20	0	5	12	3	75.54	64.44	9.62	138.39
PLUTONIUM-239/240	1990	38	5	3	19	11	57.57	37.37	4.14	126.98
	1991	43	0	9	30	4	32.28	31.68	7.99	78.05
	1992	69	11	7	39	12	45.60	24.39	0.00	81.74
	1993	62	2	10	28	22	50.29	47.94	0.00	200.00
	* Overall	212	18	29	116	49	49.31	39.24	0.00	200.00
RADIUM-226	1990	2	0	0	0	2	24.33	1.86	23.01	25.64
	1993	2	0	0	0	2	7.57	1.59	6.45	8.70
	Overall	4	0	0	0	4	15.95	9.77	6.45	25.64
STRONTIUM-89,90	1990	6	2	2	0	2	21.83	9.53	15.09	28.57
	1991	2	0	0	0	2	52.64	23.94	35.71	69.57
	1993	7	0	2	3	2	70.14	20.97	55.32	84.97
	* Overall	15	2	4	3	6	48.21	26.44	15.09	84.97
STRONTIUM-90	1990	8	0	2	5	1	140.14	.	140.14	140.14
	* Overall	8	0	2	5	1	140.14	.	140.14	140.14
TOTAL RADIOCESIUM	1990	2	0	1	1	0	.	.	.	.
	1993	3	0	1	1	1	5.99	.	5.99	5.99
	Overall	5	0	2	2	1	5.99	.	5.99	5.99
TRITIUM	1990	33	5	4	11	13	23.38	15.32	0.75	42.42
	1991	44	1	7	26	10	15.01	17.18	0.00	54.56
	1992	67	2	14	39	12	29.33	51.00	0.17	147.03
	1993	65	1	13	46	5	33.07	13.22	12.05	46.67
	* Overall	209	9	38	122	40	24.28	30.53	0.00	147.03
URANIUM-233,-234	1990	15	2	3	0	10	27.73	31.22	1.87	99.16
	1993	6	0	0	0	6	13.82	6.83	4.55	25.00
	* Overall	21	2	3	0	16	22.51	25.47	1.87	99.16
URANIUM-235	1990	15	2	3	7	3	18.75	27.12	1.34	50.00
	1993	6	0	0	4	2	24.01	18.42	10.99	37.04
	* Overall	21	2	3	11	5	20.86	21.47	1.34	50.00
URANIUM-238	1990	16	2	2	2	10	23.10	16.30	1.86	54.88
	1993	6	0	0	0	6	19.95	25.55	3.92	71.01
	* Overall	22	2	2	2	16	21.92	19.48	1.86	71.01

Table A-13
Field-Blank Results for Water-Quality Parameters

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(mg/l) Minimum	Maximum	Average
BICARBONATE AS CACO3	1990	24	0	4	20	83.33	2.00	10.00	2.95
	1993	5	0	4	1	20.00	3.00	3.00	3.00
CARBONATE	1990	24	0	24	0	0.00	.	.	.
	1993	5	0	5	0	0.00	.	.	.
CHLORIDE	1990	24	0	9	15	62.50	0.30	1.60	0.76
	1993	5	0	4	1	20.00	20.60	20.60	20.60
CYANIDE	1990	27	0	25	2	7.41	0.00	0.00	0.00
FLUORIDE	1990	24	0	24	0	0.00	.	.	.
	1993	5	0	5	0	0.00	.	.	.
NITRATE	1990	3	0	3	0	0.00	.	.	.
NITRATE/NITRITE	1990	21	0	19	2	9.52	0.03	0.03	0.03
	1993	5	0	3	2	40.00	0.08	0.13	0.10
NITRITE	1990	14	0	14	0	0.00	.	.	.
ORTHOPHOSPHATE	1990	23	0	22	1	4.35	0.28	0.28	0.28
SILICA	1990	24	0	22	2	8.33	0.50	4.00	2.25
	1993	1	0	1	0	0.00	.	.	.
SULFATE	1990	24	0	24	0	0.00	.	.	.
	1993	5	0	5	0	0.00	.	.	.
TOTAL DISSOLVED SOLIDS	1990	24	0	23	1	4.17	16.00	16.00	16.00
	1993	5	0	3	2	40.00	11.00	55.00	33.00
TOTAL SUSPENDED SOLIDS	1990	23	0	23	0	0.00	.	.	.
	1993	5	0	5	0	0.00	.	.	.
Totals	1990	279	0	236	43	15.41			
	1991	0	0	0	0	.			
	1992	0	0	0	0	.			
	1993	41	0	35	6	14.63			
	1994	0	0	0	0	.			
	Overall	320	0	271	49	15.31			

Table A-14
Equipment-Rinsate Results for Water-Quality Parameters

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(mg/l) Minimum	Maximum	Average
ALKALINITY AS CACO3	1991	1	0	0	1	100.00	0.00	0.00	0.00
	1992	2	0	2	0	0.00	.	.	.
AMMONIA	1992	13	0	10	3	23.08	0.13	0.36	0.22
	1993	13	0	7	6	46.15	0.16	0.20	0.19
	1994	1	0	1	0	0.00	.	.	.
BICARBONATE AS CACO3	1990	25	0	4	21	84.00	2.00	19.00	3.67
	1991	43	0	4	39	90.70	2.00	195.00	11.26
	1992	66	0	31	35	53.03	2.00	33.00	5.60
	1993	60	0	22	38	63.33	2.00	15.00	3.74
	1994	1	0	0	1	100.00	2.00	2.00	2.00
CARBONATE	1990	25	0	25	0	0.00	.	.	.
	1991	43	0	43	0	0.00	.	.	.
	1992	65	0	65	0	0.00	.	.	.
	1993	60	0	59	1	1.67	4.00	4.00	4.00
	1994	1	0	1	0	0.00	.	.	.
CHEMICAL OXYGEN DEMAND	1992	13	0	7	6	46.15	5.00	25.00	10.77
	1993	13	0	12	1	7.69	13.00	13.00	13.00
	1994	1	0	1	0	0.00	.	.	.
CHLORIDE	1990	25	0	8	17	68.00	0.20	4.20	0.92
	1991	44	1	35	8	18.60	0.30	48.00	6.41
	1992	67	1	65	1	1.52	11.20	11.20	11.20
	1993	61	0	56	5	8.20	0.01	0.03	0.02
	1994	1	0	1	0	0.00	.	.	.
CYANIDE	1990	25	0	23	2	8.00	0.00	0.00	0.00
	1991	44	0	44	0	0.00	.	.	.
	1992	67	5	57	5	8.06	0.00	0.02	0.01
	1993	58	0	58	0	0.00	.	.	.
	1994	1	0	1	0	0.00	.	.	.
FLUORIDE	1990	25	0	25	0	0.00	.	.	.
	1991	44	0	43	1	2.27	0.20	0.20	0.20
	1992	66	0	65	1	1.52	0.20	0.20	0.20
	1993	61	0	57	4	6.56	0.02	0.30	0.09
	1994	1	0	1	0	0.00	.	.	.
NITRATE	1990	3	0	3	0	0.00	.	.	.
	1991	1	0	1	0	0.00	.	.	.
	1993	2	0	2	0	0.00	.	.	.
NITRATE/NITRITE	1990	22	0	20	2	9.09	0.20	0.70	0.45
	1991	43	0	26	17	39.53	0.03	0.30	0.09
	1992	67	6	49	12	19.67	0.03	0.30	0.08
	1993	57	0	39	18	31.58	0.01	0.23	0.08
	1994	1	0	1	0	0.00	.	.	.
NITRITE	1990	15	0	14	1	6.67	0.10	0.10	0.10
	1991	1	0	1	0	0.00	.	.	.
	1992	1	0	1	0	0.00	.	.	.
	1993	1	0	1	0	0.00	.	.	.
ORTHOPHOSPHATE	1990	23	0	23	0	0.00	.	.	.
	1991	43	0	41	2	4.65	0.02	0.04	0.03
	1992	67	0	67	0	0.00	.	.	.
	1993	55	0	54	1	1.82	0.02	0.02	0.02
	1994	1	0	1	0	0.00	.	.	.
SILICA	1990	26	0	23	3	11.54	0.43	30.20	11.21
	1991	43	0	42	1	2.33	0.19	0.19	0.19
	1992	61	2	42	17	28.81	0.10	0.60	0.27
	1993	66	0	56	10	15.15	0.05	0.58	0.16
	1994	2	0	1	1	50.00	0.14	0.14	0.14

Table A-14 (continued)
Equipment-Rinsate Results for Water-Quality Parameters

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(mg/l) Minimum	Maximum	Average
SULFATE	1990	25	0	25	0	0.00	.	.	.
	1991	43	1	37	5	11.90	3.00	6.00	3.96
	1992	67	0	66	1	1.49	5.90	5.90	5.90
	1993	61	0	54	7	11.48	0.02	5.00	0.74
	1994	1	0	1	0	0.00	.	.	.
TOTAL DISSOLVED SOLIDS	1990	25	0	21	4	16.00	11.00	32.00	20.00
	1991	44	0	42	2	4.55	0.00	13.00	6.50
	1992	67	0	58	9	13.43	17.00	270.00	88.67
	1993	61	0	52	9	14.75	11.00	45.00	18.89
	1994	1	0	1	0	0.00	.	.	.
TOTAL ORGANIC CARBON	1992	12	0	11	1	8.33	1.05	1.05	1.05
	1993	14	0	12	2	14.29	0.27	2.00	1.13
	1994	1	0	1	0	0.00	.	.	.
TOTAL SUSPENDED SOLIDS	1990	24	0	24	0	0.00	.	.	.
	1991	44	0	40	4	9.09	-11.00	210.00	53.50
	1992	67	0	66	1	1.49	6.00	6.00	6.00
	1993	61	0	54	7	11.48	4.00	38.00	15.86
	1994	1	0	1	0	0.00	.	.	.
pH	1992	2	0	0	2	100.00	6.20	6.20	6.20
Totals	1990	288	0	238	50	17.36			
	1991	481	2	399	80	16.63			
	1992	770	14	662	94	12.21			
	1993	704	0	595	109	15.48			
	1994	15	0	13	2	13.33			
	Overall	2258	16	1907	335	14.84			

Table A-15
Relative Percent Differences for Water-Quality Parameters

Analyte	Year	Number of Samples	Number Rejected	Nondetect Mismatch	Both are Nondets	Both are Detects	Average	Std Dev.	Minimum	Maximum
ALKALINITY AS CACO3	1991	0	0	0	0	0	.	.	.	.
	1992	2	0	0	0	2	4.13	5.84	0.00	8.26
	Overall	2	0	0	0	2	4.13	5.84	0.00	8.26
AMMONIA	1992	13	0	1	12	0	.	.	.	.
	1993	13	0	1	11	1	29.51	.	29.51	29.51
	1994	1	0	0	1	0	.	.	.	.
	* Overall	27	0	2	24	1	29.51	.	29.51	29.51
BICARBONATE AS CACO3	1990	45	0	0	0	45	6.27	13.97	0.00	75.00
	1991	43	0	0	0	43	8.31	30.14	0.00	198.45
	1992	65	0	0	0	65	5.88	8.84	0.00	56.41
	1993	66	0	0	1	65	5.53	8.23	0.00	49.79
	1994	1	0	0	0	1	0.00	.	0.00	0.00
	Overall	220	0	0	1	219	6.30	16.08	0.00	198.45
CARBONATE	1990	25	0	0	25	0	.	.	.	.
	1991	41	0	1	35	5	160.00	89.44	0.00	200.00
	1992	65	0	4	61	0	.	.	.	.
	1993	67	0	1	61	5	33.25	19.31	3.60	52.43
	1994	1	0	0	1	0	.	.	.	.
	* Overall	199	0	6	183	10	96.62	90.47	0.00	200.00
CHEMICAL OXYGEN DEMA	1992	13	0	5	2	6	30.26	18.27	11.76	59.46
	1993	14	0	4	6	4	11.93	12.58	0.00	28.57
	1994	1	0	0	1	0	.	.	.	.
	* Overall	28	0	9	9	10	22.93	18.10	0.00	59.46
CHLORIDE	1990	42	0	1	1	40	11.82	28.28	0.00	176.47
	1991	44	2	0	1	41	15.25	34.21	0.00	199.61
	1992	66	7	1	5	53	7.13	15.54	0.00	69.39
	1993	67	0	0	5	62	3.33	7.55	0.00	44.05
	1994	1	0	0	0	1	0.00	.	0.00	0.00
	Overall	220	9	2	12	197	8.54	22.38	0.00	199.61
CYANIDE	1990	37	0	2	30	5	19.28	15.62	0.00	40.00
	1991	44	0	2	39	3	16.93	15.00	0.00	28.57
	1992	65	7	6	48	4	43.50	22.15	19.05	71.53
	1993	58	2	8	46	2	47.55	41.54	18.18	76.92
	1994	1	0	0	1	0	.	.	.	.
	* Overall	205	9	18	164	14	29.73	23.30	0.00	76.92
FLUORIDE	1990	41	0	1	7	33	5.66	12.97	0.00	66.67
	1991	44	0	0	0	44	15.41	45.80	0.00	199.70
	1992	66	0	0	3	63	7.55	11.35	0.00	40.00
	1993	67	0	0	5	62	5.74	14.05	0.00	66.67
	1994	1	0	0	0	1	0.00	.	0.00	0.00
	Overall	219	0	1	15	203	8.36	24.23	0.00	199.70
NITRATE	1990	3	0	0	0	3	3.51	6.08	0.00	10.53
	1991	1	0	0	0	1	32.66	.	32.66	32.66
	1993	3	0	0	0	3	3.99	3.48	0.00	6.45
	Overall	7	0	0	0	7	7.88	11.66	0.00	32.66
NITRATE/NITRITE	1990	42	0	1	8	33	8.99	28.29	0.00	163.64
	1991	43	0	1	5	37	17.15	34.23	0.00	179.49
	1992	66	5	1	2	58	10.43	20.02	0.00	100.00
	1993	61	0	1	0	60	9.24	19.90	0.00	133.33
	1994	1	0	0	0	1	3.64	.	3.64	3.64
	Overall	213	5	4	15	189	11.08	24.82	0.00	179.49
NITRITE	1990	20	0	0	18	2	12.50	17.68	0.00	25.00
	1991	1	0	0	1	0	.	.	.	.
	1992	1	0	0	1	0	.	.	.	.
	1993	2	0	0	1	1	18.87	.	18.87	18.87
	Overall	24	0	0	21	3	14.62	13.03	0.00	25.00

Table A-15 (continued)
Relative Percent Differences for Water-Quality Parameters

Analyte	Year	Number of Samples	Number Rejected	Nondetect Mismatch	Both are Nondets	Both are Detects	Average	Std Dev.	Minimum	Maximum
ORTHOPHOSPHATE	1990	28	0	0	9	19	49.29	40.90	0.00	154.68
	1991	43	0	5	24	14	22.22	33.63	0.00	100.00
	1992	66	0	9	44	13	16.12	42.30	0.00	142.86
	1993	55	0	11	31	13	21.02	29.31	0.00	66.67
	1994	1	0	0	1	0	.	.	.	.
	* Overall	193	0	25	109	59	29.33	38.96	0.00	154.68
SILICA	1990	21	0	0	0	21	7.92	23.97	0.00	111.35
	1991	39	0	0	0	39	2.16	3.70	0.00	15.05
	1992	18	0	0	0	18	2.83	3.77	0.00	13.04
	Overall	78	0	0	0	78	3.86	12.86	0.00	111.35
SULFATE	1990	41	0	0	0	41	12.45	24.07	0.00	150.56
	1991	43	0	0	0	43	12.65	32.62	0.00	199.56
	1992	66	0	1	0	65	4.50	6.69	0.00	36.62
	1993	71	0	0	4	67	3.76	7.71	0.00	42.42
	1994	1	0	0	0	1	3.51	.	3.51	3.51
	Overall	222	0	1	4	217	7.38	19.04	0.00	199.56
TOTAL DISSOLVED SOLI	1990	46	0	0	0	46	5.88	9.34	0.00	50.00
	1991	44	0	0	0	44	8.98	29.99	0.00	199.62
	1992	66	0	1	0	65	9.25	15.94	0.00	88.24
	1993	67	0	0	0	67	5.69	8.18	0.00	41.86
	1994	1	0	0	0	1	9.52	.	9.52	9.52
	Overall	224	0	1	0	223	7.43	16.97	0.00	199.62
TOTAL ORGANIC CARBON	1992	12	0	1	1	10	13.33	10.02	0.00	31.58
	1993	15	0	2	5	8	18.32	18.38	0.00	40.00
	1994	1	0	0	1	0	.	.	.	.
	Overall	28	0	3	7	18	15.55	14.10	0.00	40.00
TOTAL SUSPENDED SOLI	1990	33	0	2	4	27	45.14	32.75	2.02	101.23
	1991	44	0	2	1	41	45.09	45.60	0.00	199.78
	1992	66	0	2	2	62	49.08	45.43	0.00	167.25
	1993	67	0	1	2	64	38.54	34.75	0.00	148.62
	1994	1	0	0	0	1	2.20	.	2.20	2.20
	* Overall	211	0	7	9	195	44.00	40.51	0.00	199.78
pH	1990	12	0	0	0	12	1.41	1.51	0.00	5.33
	1992	2	0	0	0	2	0.00	0.00	0.00	0.00
	Overall	14	0	0	0	14	1.21	1.48	0.00	5.33

Table A-16
Equipment-Rinsate Results for Semivolatiles

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(µg/l) Minimum	Maximum	Average
1,2,4-TRICHLOROBENZENE	1993	6	0	6	0	0.00	.	.	.
1,2-DICHLOROBENZENE	1993	6	0	6	0	0.00	.	.	.
1,3-DICHLOROBENZENE	1993	6	0	6	0	0.00	.	.	.
1,4-DICHLOROBENZENE	1993	6	0	6	0	0.00	.	.	.
2,4,5-TRICHLOROPHENOL	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
2,4,6-TRICHLOROPHENOL	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
2,4-DICHLOROPHENOL	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
2,4-DIMETHYLPHENOL	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
2,4-DINITROPHENOL	1992	5	1	4	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
2,4-DINITROTOLUENE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
2,6-DINITROTOLUENE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
2-CHLORONAPHTHALENE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
2-CHLOROPHENOL	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
2-METHYLNAPHTHALENE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
2-METHYLPHENOL	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
2-NITROANILINE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
2-NITROPHENOL	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
2-PENTANONE, 4-HYDROXY-4-MET	1992	1	0	0	1	100.00	13.00	13.00	13.00
	1993	1	0	0	1	100.00	18.00	18.00	18.00
3,3'-DICHLOROBENZIDINE	1992	5	0	5	0	0.00	.	.	.
	1993	6	3	3	0	0.00	.	.	.
3-NITROANILINE	1992	5	0	5	0	0.00	.	.	.
	1993	6	1	5	0	0.00	.	.	.
4,6-DINITRO-2-METHYLPHENOL	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
4-CHLORO-3-METHYLPHENOL	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
4-CHLOROANILINE	1992	5	0	5	0	0.00	.	.	.
	1993	6	3	3	0	0.00	.	.	.

Table A-16 (continued)
Equipment-Rinsate Results for Semivolatiles

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(µg/l) Minimum	Maximum	Average
4-CHLOROPHENYL PHENYL ETHER	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
4-METHYLPHENOL	1992	4	0	4	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
4-NITROANILINE	1992	5	0	5	0	0.00	.	.	.
	1993	6	1	5	0	0.00	.	.	.
4-NITROPHENOL	1992	5	0	5	0	0.00	.	.	.
	1993	6	1	5	0	0.00	.	.	.
ACENAPHTHENE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
ACENAPHTHYLENE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
ANTHRACENE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
BENZO(a)ANTHRACENE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
BENZO(a)PYRENE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
BENZO(b)FLUORANTHENE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
BENZO(ghi)PERYLENE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
BENZO(k)FLUORANTHENE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
BENZOIC ACID	1992	5	1	4	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
BENZYL ALCOHOL	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
BIS(2-CHLOROETHOXY)METHANE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
BIS(2-CHLOROETHYL)ETHER	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
BIS(2-CHLOROISOPROPYL)ETHER	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
BIS(2-ETHYLHEXYL)PHTHALATE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	5	1	16.67	2.00	2.00	2.00
BUTYL BENZYL PHTHALATE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
CHRYSENE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
DI-n-BUTYL PHTHALATE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.

Table A-16 (continued)
Equipment-Rinsate Results for Semivolatiles

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(µg/l) Minimum	Maximum	Average
DI-n-OCTYL PHTHALATE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
DIBENZO(a,h)ANTHRACENE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
DIBENZOFURAN	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
DIETHYL PHTHALATE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
DIMETHYL PHTHALATE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
FLUORANTHENE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
FLUORENE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
HEPTADECANE, 2,6,10,15-TETRA	1992	1	0	0	1	100.00	9.30	9.30	9.30
HEXACHLOROBENZENE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
HEXACHLOROBUTADIENE	1993	6	0	6	0	0.00	.	.	.
HEXACHLOROCYCLOPENTADIENE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
HEXACHLOROETHANE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
INDENO(1,2,3-cd)PYRENE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
ISOPHORONE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
N-NITROSO-DI-n-PROPYLAMINE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
N-NITROSODIPHENYLAMINE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
NAPHTHALENE	1993	6	0	6	0	0.00	.	.	.
NITROBENZENE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
OCTANE 2,4,6-TRIMETHYL	1992	1	0	0	1	100.00	23.00	23.00	23.00
PENTACHLOROPHENOL	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
PHENANTHRENE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
PHENOL	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
PYRENE	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.

Table A-16 (continued)
Equipment-Rinsate Results for Semivolatiles

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(µg/l) Minimum	Maximum	Average
UNDECANE 5,7-DIMETHYL	1992	1	0	0	1	100.00	21.00	21.00	21.00
UNKNOWN ALKANE	1993	1	0	0	1	100.00	23.00	23.00	23.00
p-BROMODIPHENYL ETHER	1992	5	0	5	0	0.00	.	.	.
	1993	6	0	6	0	0.00	.	.	.
Totals	1990	0	0	0	0	.			
	1991	0	0	0	0	.			
	1992	298	2	292	4	1.34			
	1993	392	9	380	3	0.76			
	1994	0	0	0	0	.			
	Overall	690	11	672	7	1.01			

Table A-17
Field-Blank Results for Volatiles

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(µg/l) Minimum	Maximum	Average
1,1,1-TRICHLOROETHANE	1990	35	0	35	0	0.00	.	.	.
	1991	10	0	10	0	0.00	.	.	.
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
1,1,2,2-TETRACHLOROETHANE	1990	35	0	35	0	0.00	.	.	.
	1991	10	0	10	0	0.00	.	.	.
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
1,1,2-TRICHLOROETHANE	1990	35	0	34	1	2.86	1.00	1.00	1.00
	1991	10	0	10	0	0.00	.	.	.
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
1,1-DICHLOROETHANE	1990	35	1	34	0	0.00	.	.	.
	1991	10	0	10	0	0.00	.	.	.
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
1,1-DICHLOROETHENE	1990	35	0	35	0	0.00	.	.	.
	1991	10	0	10	0	0.00	.	.	.
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
1,2-DICHLOROETHANE	1990	35	0	34	1	2.86	1.00	1.00	1.00
	1991	10	0	10	0	0.00	.	.	.
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
1,2-DICHLOROETHENE	1990	34	0	34	0	0.00	.	.	.
	1991	7	0	7	0	0.00	.	.	.
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
1,2-DICHLOROPROPANE	1990	35	0	35	0	0.00	.	.	.
	1991	10	0	10	0	0.00	.	.	.
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
2-BUTANONE	1990	35	4	29	2	6.45	2.00	5.00	3.50
	1991	10	1	9	0	0.00	.	.	.
	1993	7	5	2	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
2-CHLOROETHYL VINYL ETHER	1990	4	0	4	0	0.00	.	.	.
2-HEXANONE	1990	35	0	35	0	0.00	.	.	.
	1991	10	0	10	0	0.00	.	.	.
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
4-METHYL-2-PENTANONE	1990	35	0	35	0	0.00	.	.	.
	1991	10	0	10	0	0.00	.	.	.
	1993	7	1	6	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
ACETIC ACID, ETHYL ESTER	1990	1	0	0	1	100.00	4.30	4.30	4.30
ACETONE	1990	35	0	14	21	60.00	2.00	42.00	12.62
	1991	10	1	6	3	33.33	2.00	16.00	7.33
	1993	7	3	4	0	0.00	.	.	.
	1994	3	0	2	1	33.33	29.00	29.00	29.00

Table A-17 (continued)
Field-Blank Results for Volatiles

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(µg/l) Minimum	Maximum	Average
BENZENE	1990	35	0	35	0	0.00	.	.	.
	1991	10	0	10	0	0.00	.	.	.
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
BROMODICHLOROMETHANE	1990	35	0	35	0	0.00	.	.	.
	1991	10	0	10	0	0.00	.	.	.
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
BROMOFORM	1990	35	0	35	0	0.00	.	.	.
	1991	10	0	10	0	0.00	.	.	.
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
BROMOMETHANE	1990	35	0	35	0	0.00	.	.	.
	1991	10	0	10	0	0.00	.	.	.
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
CARBON DISULFIDE	1990	35	0	35	0	0.00	.	.	.
	1991	10	0	10	0	0.00	.	.	.
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
CARBON TETRACHLORIDE	1990	35	0	34	1	2.86	1.00	1.00	1.00
	1991	10	1	9	0	0.00	.	.	.
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
CHLOROBENZENE	1990	35	0	35	0	0.00	.	.	.
	1991	10	0	10	0	0.00	.	.	.
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
CHLOROETHANE	1990	35	0	35	0	0.00	.	.	.
	1991	10	1	9	0	0.00	.	.	.
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
CHLOROFORM	1990	35	0	32	3	8.57	9.00	20.00	13.67
	1991	10	0	10	0	0.00	.	.	.
	1993	7	0	6	1	14.29	4.00	4.00	4.00
	1994	3	0	3	0	0.00	.	.	.
CHLOROMETHANE	1990	35	0	34	1	2.86	3.00	3.00	3.00
	1991	10	1	9	0	0.00	.	.	.
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
DIBROMOCHLOROMETHANE	1990	35	0	35	0	0.00	.	.	.
	1991	10	0	10	0	0.00	.	.	.
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
ETHYLBENZENE	1990	35	0	35	0	0.00	.	.	.
	1991	10	0	10	0	0.00	.	.	.
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
METHYLENE CHLORIDE	1990	35	0	11	24	68.57	1.00	14.00	3.96
	1991	10	0	9	1	10.00	2.00	2.00	2.00
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.

Table A-17 (continued)
Field-Blank Results for Volatiles

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(µg/l) Minimum	Maximum	Average
STYRENE	1990	35	0	35	0	0.00	.	.	.
	1991	10	0	10	0	0.00	.	.	.
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
TETRACHLOROETHENE	1990	35	0	34	1	2.86	12.00	12.00	12.00
	1991	10	0	10	0	0.00	.	.	.
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
TOLUENE	1990	35	0	29	6	17.14	1.00	3.00	1.67
	1991	10	0	10	0	0.00	.	.	.
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	2	1	33.33	1.00	1.00	1.00
TOTAL XYLENES	1990	35	0	34	1	2.86	3.00	3.00	3.00
	1991	10	0	10	0	0.00	.	.	.
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
TRICHLOROETHENE	1990	35	0	33	2	5.71	2.00	2.00	2.00
	1991	10	0	10	0	0.00	.	.	.
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
VINYL ACETATE	1990	35	0	35	0	0.00	.	.	.
	1991	10	0	10	0	0.00	.	.	.
	1993	7	1	6	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
VINYL CHLORIDE	1990	35	0	35	0	0.00	.	.	.
	1991	10	0	10	0	0.00	.	.	.
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
cis-1,3-DICHLOROPROPENE	1990	35	0	35	0	0.00	.	.	.
	1991	10	0	10	0	0.00	.	.	.
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
o-XYLENE	1990	4	0	4	0	0.00	.	.	.
trans-1,2-DICHLOROETHENE	1990	1	0	1	0	0.00	.	.	.
	1991	3	0	3	0	0.00	.	.	.
trans-1,3-DICHLOROPROPENE	1990	35	0	35	0	0.00	.	.	.
	1991	10	1	9	0	0.00	.	.	.
	1993	7	0	7	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
Totals	1990	1199	5	1129	65	5.42			
	1991	340	6	330	4	1.18			
	1992	0	0	0	0	.			
	1993	238	10	227	1	0.42			
	1994	102	0	100	2	1.96			
	Overall	1879	21	1786	72	3.83			

Table A-18
Trip-Blank Results for Volatiles

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(µg/l) Minimum	Maximum	Average
1,1,1,2-TETRACHLOROETHANE	1993	3	0	3	0	0.00	.	.	.
1,1,1-TRICHLOROETHANE	1990	213	0	213	0	0.00	.	.	.
	1991	6	0	6	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
1,1,2,2-TETRACHLOROETHANE	1990	210	0	210	0	0.00	.	.	.
	1991	6	0	5	1	16.67	2.00	2.00	2.00
	1993	3	0	3	0	0.00	.	.	.
1,1,2-TRICHLORO-1,2,2-TRI-	1990	1	0	0	1	100.00	12.00	12.00	12.00
1,1,2-TRICHLOROETHANE	1990	213	0	213	0	0.00	.	.	.
	1991	6	0	5	1	16.67	1.00	1.00	1.00
	1993	3	0	3	0	0.00	.	.	.
1,1-DICHLOROETHANE	1990	213	0	213	0	0.00	.	.	.
	1991	6	0	6	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
1,1-DICHLOROETHENE	1990	213	0	213	0	0.00	.	.	.
	1991	6	0	6	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
1,1-DICHLOROPROPENE	1993	3	0	3	0	0.00	.	.	.
1,2,3-TRICHLOROBENZENE	1993	3	0	3	0	0.00	.	.	.
1,2,3-TRICHLOROPROPANE	1993	3	0	3	0	0.00	.	.	.
1,2,4-TRICHLOROBENZENE	1993	3	0	3	0	0.00	.	.	.
1,2-DIBROMOETHANE	1993	3	0	3	0	0.00	.	.	.
1,2-DICHLOROBENZENE	1993	3	0	3	0	0.00	.	.	.
1,2-DICHLOROETHANE	1990	213	0	213	0	0.00	.	.	.
	1991	6	0	6	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
1,2-DICHLOROETHENE	1990	211	0	211	0	0.00	.	.	.
	1991	6	0	6	0	0.00	.	.	.
	1993	2	0	2	0	0.00	.	.	.
1,2-DICHLOROPROPANE	1990	213	0	213	0	0.00	.	.	.
	1991	6	0	6	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
1,3-DICHLOROBENZENE	1993	3	0	3	0	0.00	.	.	.
1,3-DICHLOROPROPANE	1993	3	0	3	0	0.00	.	.	.
1,4-DICHLOROBENZENE	1993	3	0	3	0	0.00	.	.	.
2,2-DICHLOROPROPANE	1993	3	0	3	0	0.00	.	.	.
2-BUTANONE	1990	213	6	196	11	5.31	3.00	91.00	29.36
	1991	6	0	6	0	0.00	.	.	.
	1993	2	1	1	0	0.00	.	.	.
2-CHLOROETHYL VINYL ETHER	1990	17	0	17	0	0.00	.	.	.
2-HEXANONE	1990	213	0	205	8	3.76	1.00	6.00	2.87
	1991	6	0	6	0	0.00	.	.	.
	1993	2	0	2	0	0.00	.	.	.

Table A-18 (continued)
Trip-Blank Results for Volatiles

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(µg/l) Minimum	Maximum	Average
4-ISOPROPYLTOLUENE	1993	3	0	3	0	0.00	.	.	.
4-METHYL-2-PENTANONE	1990	213	1	212	0	0.00	.	.	.
	1991	6	0	6	0	0.00	.	.	.
	1993	2	0	2	0	0.00	.	.	.
ACETONE	1990	213	3	158	52	24.76	1.00	52.00	11.85
	1991	6	0	6	0	0.00	.	.	.
	1993	2	0	2	0	0.00	.	.	.
BENZENE	1990	213	0	213	0	0.00	.	.	.
	1991	6	0	6	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
BENZENE, 1,2,4-TRIMETHYL	1993	3	0	3	0	0.00	.	.	.
BENZENE, 1,3,5-TRIMETHYL-	1993	3	0	3	0	0.00	.	.	.
BENZENE, 1-PROPENYL-	1990	1	0	0	1	100.00	9.30	9.30	9.30
BROMOBENZENE	1993	3	0	3	0	0.00	.	.	.
BROMOCHLOROMETHANE	1993	3	0	3	0	0.00	.	.	.
BROMODICHLOROMETHANE	1990	213	0	212	1	0.47	1.00	1.00	1.00
	1991	6	0	6	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
BROMOFORM	1990	213	2	211	0	0.00	.	.	.
	1991	6	0	5	1	16.67	1.00	1.00	1.00
	1993	3	0	3	0	0.00	.	.	.
BROMOMETHANE	1990	213	0	213	0	0.00	.	.	.
	1991	6	0	6	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
CARBON DISULFIDE	1990	213	2	211	0	0.00	.	.	.
	1991	6	0	6	0	0.00	.	.	.
	1993	2	0	2	0	0.00	.	.	.
CARBON TETRACHLORIDE	1990	213	0	212	1	0.47	2.00	2.00	2.00
	1991	6	0	6	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
CHLOROBENZENE	1990	213	0	212	1	0.47	2.00	2.00	2.00
	1991	6	0	6	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
CHLOROETHANE	1990	213	0	213	0	0.00	.	.	.
	1991	6	0	6	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
CHLOROFORM	1990	213	0	177	36	16.90	1.00	29.00	11.06
	1991	6	0	6	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
CHLOROMETHANE	1990	213	0	213	0	0.00	.	.	.
	1991	6	0	6	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
DIBROMOCHLOROMETHANE	1990	213	0	213	0	0.00	.	.	.
	1991	6	0	6	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.

Table A-18 (continued)
Trip-Blank Results for Volatiles

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(µg/l) Minimum	Maximum	Average
DIBROMOMETHANE	1993	3	0	3	0	0.00	.	.	.
DICHLORODIFLUOROMETHANE	1993	3	0	3	0	0.00	.	.	.
ETHYL ESTER ACETIC ACID	1990	1	0	0	1	100.00	10.00	10.00	10.00
ETHYLBENZENE	1990	213	0	213	0	0.00	.	.	.
	1991	6	0	6	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
HEXACHLOROBUTADIENE	1993	3	0	3	0	0.00	.	.	.
HEXANE	1990	1	0	0	1	100.00	5.00	5.00	5.00
ISOPROPYLBENZENE	1993	3	0	3	0	0.00	.	.	.
METHYLENE CHLORIDE	1990	213	0	66	147	69.01	1.00	40.00	4.77
	1991	6	0	3	3	50.00	1.00	6.00	3.33
	1993	3	0	0	3	100.00	2.00	5.00	3.00
NAPHTHALENE	1993	3	0	3	0	0.00	.	.	.
PROPANE, 1,2-DIBROMO-3-CHLORO	1993	3	3	0	0	.	.	.	.
STYRENE	1990	213	0	213	0	0.00	.	.	.
	1991	6	0	6	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
TETRACHLOROETHENE	1990	213	0	210	3	1.41	1.00	5.00	2.67
	1991	6	0	6	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
TOLUENE	1990	213	0	198	15	7.04	1.00	2.00	1.33
	1991	6	0	6	0	0.00	.	.	.
	1993	3	0	2	1	33.33	0.20	0.20	0.20
TOTAL XYLENES	1990	212	1	211	0	0.00	.	.	.
	1991	6	0	6	0	0.00	.	.	.
	1993	2	0	2	0	0.00	.	.	.
TRICHLOROETHENE	1990	213	0	208	5	2.35	1.00	5.00	2.80
	1991	6	0	6	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
TRICHLOROFLUOROMETHANE	1993	3	0	2	1	33.33	1.00	1.00	1.00
VINYL ACETATE	1990	213	0	213	0	0.00	.	.	.
	1991	6	0	6	0	0.00	.	.	.
	1993	2	0	2	0	0.00	.	.	.
VINYL CHLORIDE	1990	213	0	212	1	0.47	2.00	2.00	2.00
	1991	6	0	6	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
cis-1,2-DICHLOROETHENE	1993	3	0	3	0	0.00	.	.	.
cis-1,3-DICHLOROPROPENE	1990	213	0	213	0	0.00	.	.	.
	1991	6	0	6	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
m+p XYLENE	1993	3	0	3	0	0.00	.	.	.
n-BUTYLBENZENE	1993	3	0	3	0	0.00	.	.	.

Table A-18 (continued)
Trip-Blank Results for Volatiles

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(µg/l) Minimum	Maximum	Average
n-PROPYLBENZENE	1993	3	0	3	0	0.00	.	.	.
o-CHLOROTOLUENE	1993	3	0	3	0	0.00	.	.	.
o-XYLENE	1990	14	0	14	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
p-CHLOROTOLUENE	1993	3	0	3	0	0.00	.	.	.
sec-BUTYLBENZENE	1993	3	0	3	0	0.00	.	.	.
tert-BUTYLBENZENE	1993	3	0	3	0	0.00	.	.	.
trans-1,2-DICHLOROETHENE	1990	2	0	2	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
trans-1,3-DICHLOROPROPENE	1990	213	0	213	0	0.00	.	.	.
	1991	6	0	6	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
Totals	1990	7273	15	6973	285	3.92			
	1991	204	0	198	6	2.94			
	1992	0	0	0	0	.			
	1993	193	4	184	5	2.59			
	1994	0	0	0	0	.			
	Overall	7670	19	7355	296	3.86			

Table A-19
Equipment-Rinsate Results for Volatiles

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(µg/l) Minimum	Maximum	Average
1,1,1,2-TETRACHLOROETHANE	1992	13	0	13	0	0.00	.	.	.
	1993	22	0	22	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
1,1,1-TRICHLOROETHANE	1990	24	0	24	0	0.00	.	.	.
	1991	44	2	41	1	2.38	2.00	2.00	2.00
	1992	66	1	62	3	4.62	0.12	2.00	0.94
	1993	67	0	64	3	4.48	0.30	1.00	0.57
	1994	3	0	3	0	0.00	.	.	.
1,1,2,2-TETRACHLOROETHANE	1990	24	0	24	0	0.00	.	.	.
	1991	44	1	43	0	0.00	.	.	.
	1992	66	0	66	0	0.00	.	.	.
	1993	67	0	67	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
1,1,2-TRICHLOROETHANE	1990	24	0	24	0	0.00	.	.	.
	1991	44	1	43	0	0.00	.	.	.
	1992	66	0	66	0	0.00	.	.	.
	1993	67	0	67	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
1,1-DICHLOROETHANE	1990	24	1	23	0	0.00	.	.	.
	1991	44	1	43	0	0.00	.	.	.
	1992	66	0	66	0	0.00	.	.	.
	1993	67	0	67	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
1,1-DICHLOROETHENE	1990	24	0	24	0	0.00	.	.	.
	1991	44	1	43	0	0.00	.	.	.
	1992	66	0	65	1	1.52	3.00	3.00	3.00
	1993	67	0	67	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
1,1-DICHLOROPROPENE	1992	13	0	13	0	0.00	.	.	.
	1993	22	0	22	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
1,2,3-TRICHLOROBENZENE	1992	13	0	13	0	0.00	.	.	.
	1993	22	0	22	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
1,2,3-TRICHLOROPROPANE	1992	13	1	12	0	0.00	.	.	.
	1993	22	1	21	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
1,2,4-TRICHLOROBENZENE	1992	13	0	13	0	0.00	.	.	.
	1993	21	0	21	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
1,2-DIBROMOETHANE	1992	13	0	13	0	0.00	.	.	.
	1993	22	0	22	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
1,2-DICHLOROBENZENE	1992	13	0	13	0	0.00	.	.	.
	1993	21	0	21	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
1,2-DICHLOROETHANE	1990	24	0	24	0	0.00	.	.	.
	1991	44	1	43	0	0.00	.	.	.
	1992	66	0	66	0	0.00	.	.	.
	1993	67	0	67	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.

Table A-19 (continued)
Equipment-Rinsate Results for Volatiles

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(µg/l) Minimum	Maximum	Average
1,2-DICHLOROETHENE	1990	23	0	23	0	0.00	.	.	.
	1991	40	3	37	0	0.00	.	.	.
	1992	53	0	53	0	0.00	.	.	.
	1993	47	0	47	0	0.00	.	.	.
1,2-DICHLOROPROPANE	1990	24	0	24	0	0.00	.	.	.
	1991	44	1	43	0	0.00	.	.	.
	1992	66	0	66	0	0.00	.	.	.
	1993	67	0	67	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
1,3-DICHLOROBENZENE	1992	13	0	13	0	0.00	.	.	.
	1993	21	0	21	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
1,3-DICHLOROPROPANE	1992	13	0	13	0	0.00	.	.	.
	1993	22	0	22	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
1,4-DICHLOROBENZENE	1992	13	0	13	0	0.00	.	.	.
	1993	21	0	21	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
1-HEPTENE, 5-METHYL-	1993	1	0	0	1	100.00	0.13	0.13	0.13
2,2-DICHLOROPROPANE	1992	13	7	6	0	0.00	.	.	.
	1993	22	0	22	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
2-BUTANONE	1990	24	3	20	1	4.76	1.00	1.00	1.00
	1991	44	15	29	0	0.00	.	.	.
	1992	53	24	29	0	0.00	.	.	.
	1993	47	27	20	0	0.00	.	.	.
2-CHLOROETHYL VINYL ETHER	1990	1	0	1	0	0.00	.	.	.
2-HEXANONE	1990	24	0	24	0	0.00	.	.	.
	1991	44	4	40	0	0.00	.	.	.
	1992	53	6	47	0	0.00	.	.	.
	1993	47	0	47	0	0.00	.	.	.
3-METHYLHEPTYL ACETATE	1993	3	0	0	3	100.00	0.11	1.10	0.50
4-ISOPROPYLTOLUENE	1992	13	0	13	0	0.00	.	.	.
	1993	22	0	22	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
4-METHYL-2-PENTANONE	1990	24	0	24	0	0.00	.	.	.
	1991	44	3	41	0	0.00	.	.	.
	1992	53	0	53	0	0.00	.	.	.
	1993	47	1	45	1	2.17	7.00	7.00	7.00
ACETONE	1990	24	0	11	13	54.17	4.00	25.00	9.85
	1991	44	4	35	5	12.50	2.00	15.00	9.00
	1992	53	0	44	9	16.98	1.00	13.00	4.67
	1993	47	3	43	1	2.27	6.00	6.00	6.00
BENZENE	1990	24	0	24	0	0.00	.	.	.
	1991	44	1	43	0	0.00	.	.	.
	1992	66	0	62	4	6.06	0.20	0.70	0.40
	1993	67	1	66	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.

Table A-19 (continued)
Equipment-Rinsate Results for Volatiles

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(µg/l) Minimum	Maximum	Average
BENZENE, 1,2,4-TRIMETHYL	1992	13	0	13	0	0.00	.	.	.
	1993	22	0	22	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
BENZENE, 1,3,5-TRIMETHYL-	1992	13	0	13	0	0.00	.	.	.
	1993	22	0	22	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
BROMOBENZENE	1992	13	0	13	0	0.00	.	.	.
	1993	22	0	22	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
BROMOCHLOROMETHANE	1992	13	2	11	0	0.00	.	.	.
	1993	22	1	21	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
BROMODICHLOROMETHANE	1990	24	0	24	0	0.00	.	.	.
	1991	44	2	42	0	0.00	.	.	.
	1992	66	0	66	0	0.00	.	.	.
	1993	67	0	67	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
BROMOFORM	1990	24	0	24	0	0.00	.	.	.
	1991	44	2	42	0	0.00	.	.	.
	1992	66	0	66	0	0.00	.	.	.
	1993	67	1	66	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
BROMOMETHANE	1990	24	0	24	0	0.00	.	.	.
	1991	44	7	37	0	0.00	.	.	.
	1992	66	5	61	0	0.00	.	.	.
	1993	67	0	67	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
CARBON DISULFIDE	1990	24	0	24	0	0.00	.	.	.
	1991	44	2	42	0	0.00	.	.	.
	1992	53	0	53	0	0.00	.	.	.
	1993	47	1	46	0	0.00	.	.	.
CARBON TETRACHLORIDE	1990	24	0	23	1	4.17	1.00	1.00	1.00
	1991	44	2	42	0	0.00	.	.	.
	1992	66	0	64	2	3.03	0.60	2.20	1.40
	1993	67	1	63	3	4.55	0.30	4.00	1.77
	1994	3	0	3	0	0.00	.	.	.
CHLOROBENZENE	1990	24	0	24	0	0.00	.	.	.
	1991	44	1	43	0	0.00	.	.	.
	1992	66	0	66	0	0.00	.	.	.
	1993	67	0	67	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
CHLORODIFLUOROMETHANE	1993	1	0	0	1	100.00	8.00	8.00	8.00
CHLOROETHANE	1990	24	0	24	0	0.00	.	.	.
	1991	44	3	41	0	0.00	.	.	.
	1992	66	0	66	0	0.00	.	.	.
	1993	67	0	67	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
CHLOROFORM	1990	24	0	23	1	4.17	1.00	1.00	1.00
	1991	44	1	43	0	0.00	.	.	.
	1992	66	0	65	1	1.52	0.10	0.10	0.10
	1993	67	2	64	1	1.54	0.60	0.60	0.60
	1994	3	0	3	0	0.00	.	.	.

Table A-19 (continued)
Equipment-Rinsate Results for Volatiles

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(µg/l) Minimum	Maximum	Average
CHLOROMETHANE	1990	24	1	22	1	4.35	5.00	5.00	5.00
	1991	44	1	40	3	6.98	2.00	7.00	5.33
	1992	66	3	56	7	11.11	0.70	12.00	3.47
	1993	67	0	65	2	2.99	11.00	13.00	12.00
	1994	3	0	3	0	0.00	.	.	.
DIBROMOCHLOROMETHANE	1990	24	0	24	0	0.00	.	.	.
	1991	44	1	43	0	0.00	.	.	.
	1992	66	0	66	0	0.00	.	.	.
	1993	67	0	67	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
DIBROMOMETHANE	1992	13	2	11	0	0.00	.	.	.
	1993	22	0	22	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
DICHLORODIFLUOROMETHANE	1992	13	3	10	0	0.00	.	.	.
	1993	22	0	22	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
ETHYLBENZENE	1990	24	0	24	0	0.00	.	.	.
	1991	44	1	43	0	0.00	.	.	.
	1992	66	0	66	0	0.00	.	.	.
	1993	67	0	67	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
HEXACHLOROBUTADIENE	1992	13	0	13	0	0.00	.	.	.
	1993	21	0	21	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
ISOPROPYLBENZENE	1992	13	0	13	0	0.00	.	.	.
	1993	22	0	22	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
METHANE, ISOCYANO-	1991	1	0	0	1	100.00	7.60	7.60	7.60
METHYLENE CHLORIDE	1990	24	0	9	15	62.50	1.00	8.00	3.40
	1991	44	0	40	4	9.09	1.00	4.00	2.00
	1992	66	1	59	6	9.23	1.00	2.00	1.37
	1993	67	0	64	3	4.48	0.30	1.00	0.63
	1994	3	0	3	0	0.00	.	.	.
NAPHTHALENE	1992	13	7	6	0	0.00	.	.	.
	1993	21	0	21	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
PROPANE, 1,2-DIBROMO-3-CHLORO	1992	13	5	8	0	0.00	.	.	.
	1993	22	17	5	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
STYRENE	1990	24	0	24	0	0.00	.	.	.
	1991	44	2	42	0	0.00	.	.	.
	1992	66	0	66	0	0.00	.	.	.
	1993	67	0	67	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
TETRACHLOROETHENE	1990	24	0	24	0	0.00	.	.	.
	1991	44	1	43	0	0.00	.	.	.
	1992	66	1	61	4	6.15	0.14	3.30	1.86
	1993	67	0	64	3	4.48	0.20	2.00	0.80
	1994	3	0	3	0	0.00	.	.	.
TOLUENE	1990	24	0	22	2	8.33	1.00	1.00	1.00
	1991	44	1	37	6	13.95	1.00	110.00	29.33
	1992	66	0	39	27	40.91	0.14	340.00	20.09
	1993	67	0	55	12	17.91	0.20	3.00	0.72
	1994	3	0	3	0	0.00	.	.	.

Table A-19 (continued)
Equipment-Rinsate Results for Volatiles

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(µg/l) Minimum	Maximum	Average
TOTAL XYLENES	1990	24	0	24	0	0.00	.	.	.
	1991	44	1	43	0	0.00	.	.	.
	1992	54	0	52	2	3.70	0.30	1.00	0.65
	1993	47	0	47	0	0.00	.	.	.
TRICHLOROETHENE	1990	24	0	23	1	4.17	2.00	2.00	2.00
	1991	44	1	43	0	0.00	.	.	.
	1992	66	2	60	4	6.25	0.56	4.00	1.56
	1993	67	0	62	5	7.46	0.20	26.00	6.74
	1994	3	0	3	0	0.00	.	.	.
TRICHLOROFLUOROMETHANE	1992	13	0	13	0	0.00	.	.	.
	1993	22	0	22	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
UNKNOWN	1992	2	0	0	2	100.00	0.30	6.00	3.15
	1993	5	0	0	5	100.00	0.14	1.30	0.48
	1994	2	0	0	2	100.00	0.16	0.18	0.17
UNKNOWN ALCOHOL	1993	1	0	0	1	100.00	0.24	0.24	0.24
UNKNOWN HYDROCARBON C8H16	1992	1	0	0	1	100.00	0.90	0.90	0.90
VINYL ACETATE	1990	24	0	24	0	0.00	.	.	.
	1991	44	6	38	0	0.00	.	.	.
	1992	52	9	43	0	0.00	.	.	.
	1993	46	1	45	0	0.00	.	.	.
VINYL CHLORIDE	1990	24	0	24	0	0.00	.	.	.
	1991	44	1	43	0	0.00	.	.	.
	1992	66	1	64	1	1.54	0.12	0.12	0.12
	1993	67	0	67	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
cis-1,2-DICHLOROETHENE	1992	13	0	13	0	0.00	.	.	.
	1993	22	0	22	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
cis-1,3-DICHLOROPROPENE	1990	24	0	24	0	0.00	.	.	.
	1991	44	1	43	0	0.00	.	.	.
	1992	65	0	65	0	0.00	.	.	.
	1993	62	0	62	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
m+p XYLENE	1992	8	0	7	1	12.50	0.15	0.15	0.15
	1993	22	0	22	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
m-XYLENE	1992	4	0	4	0	0.00	.	.	.
n-BUTYLBENZENE	1992	13	0	13	0	0.00	.	.	.
	1993	22	0	22	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
n-PROPYLBENZENE	1992	13	0	13	0	0.00	.	.	.
	1993	22	0	22	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
o-CHLOROTOLUENE	1992	13	0	13	0	0.00	.	.	.
	1993	22	0	22	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
o-XYLENE	1990	1	0	1	0	0.00	.	.	.
	1992	12	0	12	0	0.00	.	.	.
	1993	22	0	22	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.

Table A-19 (continued)
Equipment-Rinsate Results for Volatiles

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(µg/l) Minimum	Maximum	Average
p-CHLOROTOLUENE	1992	13	0	13	0	0.00	.	.	.
	1993	22	0	22	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
p-XYLENE	1992	3	0	3	0	0.00	.	.	.
sec-BUTYLBENZENE	1992	13	0	12	1	7.69	0.80	0.80	0.80
	1993	22	0	22	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
tert-BUTYLBENZENE	1992	13	0	13	0	0.00	.	.	.
	1993	22	0	22	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
trans-1,2-DICHLOROETHENE	1990	1	0	1	0	0.00	.	.	.
	1991	4	0	4	0	0.00	.	.	.
	1992	13	0	13	0	0.00	.	.	.
	1993	22	0	22	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
trans-1,3-DICHLOROPROPENE	1990	24	0	24	0	0.00	.	.	.
	1991	44	1	43	0	0.00	.	.	.
	1992	65	0	65	0	0.00	.	.	.
	1993	62	0	62	0	0.00	.	.	.
	1994	3	0	3	0	0.00	.	.	.
Totals	1990	818	5	778	35	4.28			
	1991	1497	76	1401	20	1.34			
	1992	2571	80	2415	76	2.96			
	1993	2838	57	2736	45	1.58			
	1994	179	0	177	2	1.12			
	Overall	7903	218	7507	178	2.25			

Table A-20
Relative Percent Differences for Pesticides and PCBs

Analyte	Year	Number of Samples	Number Rejected	Nondetect Mismatch	Both are Nondets	Both are Detects	Average	Std Dev.	Minimum	Maximum
4,4'-DDD	1992	5	0	0	5	0	.	.	.	.
	1993	4	0	0	4	0	.	.	.	.
	Overall	9	0	0	9	0	.	.	.	.
4,4'-DDE	1992	5	0	0	5	0	.	.	.	.
	1993	4	0	0	4	0	.	.	.	.
	Overall	9	0	0	9	0	.	.	.	.
4,4'-DDT	1992	5	0	0	5	0	.	.	.	.
	1993	4	0	0	4	0	.	.	.	.
	Overall	9	0	0	9	0	.	.	.	.
ALDRIN	1992	5	0	0	5	0	.	.	.	.
	1993	4	0	0	4	0	.	.	.	.
	Overall	9	0	0	9	0	.	.	.	.
AROCLOR-1016	1992	5	0	0	5	0	.	.	.	.
	1993	4	0	0	4	0	.	.	.	.
	Overall	9	0	0	9	0	.	.	.	.
AROCLOR-1221	1992	5	0	0	5	0	.	.	.	.
	1993	4	0	0	4	0	.	.	.	.
	Overall	9	0	0	9	0	.	.	.	.
AROCLOR-1232	1992	5	0	0	5	0	.	.	.	.
	1993	4	0	0	4	0	.	.	.	.
	Overall	9	0	0	9	0	.	.	.	.
AROCLOR-1242	1992	5	0	0	5	0	.	.	.	.
	1993	4	0	0	4	0	.	.	.	.
	Overall	9	0	0	9	0	.	.	.	.
AROCLOR-1248	1992	5	0	0	5	0	.	.	.	.
	1993	4	0	0	4	0	.	.	.	.
	Overall	9	0	0	9	0	.	.	.	.
AROCLOR-1254	1992	5	0	0	5	0	.	.	.	.
	1993	4	0	0	4	0	.	.	.	.
	Overall	9	0	0	9	0	.	.	.	.
AROCLOR-1260	1992	5	0	0	5	0	.	.	.	.
	1993	4	0	0	4	0	.	.	.	.
	Overall	9	0	0	9	0	.	.	.	.
DIELDRIN	1992	5	0	0	5	0	.	.	.	.
	1993	4	0	0	4	0	.	.	.	.
	Overall	9	0	0	9	0	.	.	.	.
ENDOSULFAN I	1992	5	0	0	5	0	.	.	.	.
	1993	4	0	0	4	0	.	.	.	.
	Overall	9	0	0	9	0	.	.	.	.
ENDOSULFAN II	1992	5	0	0	5	0	.	.	.	.
	1993	4	0	0	4	0	.	.	.	.
	Overall	9	0	0	9	0	.	.	.	.
ENDOSULFAN SULFATE	1992	5	0	0	5	0	.	.	.	.
	1993	4	0	0	4	0	.	.	.	.
	Overall	9	0	0	9	0	.	.	.	.
ENDRIN	1992	5	0	0	5	0	.	.	.	.
	1993	4	0	0	4	0	.	.	.	.
	Overall	9	0	0	9	0	.	.	.	.

Table A-20 (continued)
Relative Percent Differences for Pesticides and PCBs

Analyte	Year	Number of Samples	Number Rejected	Nondetect Mismatch	Both are Nondets	Both are Detects	Average	Std Dev.	Minimum	Maximum
ENDRIN KETONE	1992	5	0	0	5	0	.	.	.	.
	1993	4	0	0	4	0	.	.	.	.
	Overall	9	0	0	9	0	.	.	.	.
HEPTACHLOR	1992	5	0	0	5	0	.	.	.	.
	1993	4	0	0	4	0	.	.	.	.
	Overall	9	0	0	9	0	.	.	.	.
HEPTACHLOR EPOXIDE	1992	5	0	0	5	0	.	.	.	.
	1993	4	0	0	4	0	.	.	.	.
	Overall	9	0	0	9	0	.	.	.	.
METHOXYCHLOR	1992	5	0	0	5	0	.	.	.	.
	1993	4	0	0	4	0	.	.	.	.
	Overall	9	0	0	9	0	.	.	.	.
TOXAPHENE	1992	5	0	0	5	0	.	.	.	.
	1993	4	0	0	4	0	.	.	.	.
	Overall	9	0	0	9	0	.	.	.	.
alpha-BHC	1992	5	0	0	5	0	.	.	.	.
	1993	4	0	0	4	0	.	.	.	.
	Overall	9	0	0	9	0	.	.	.	.
alpha-CHLORDANE	1992	5	0	0	5	0	.	.	.	.
	1993	4	0	0	4	0	.	.	.	.
	Overall	9	0	0	9	0	.	.	.	.
beta-BHC	1992	5	0	0	5	0	.	.	.	.
	1993	4	0	0	4	0	.	.	.	.
	Overall	9	0	0	9	0	.	.	.	.
delta-BHC	1992	5	0	0	5	0	.	.	.	.
	1993	4	0	0	4	0	.	.	.	.
	Overall	9	0	0	9	0	.	.	.	.
gamma-BHC (LINDANE)	1992	5	0	0	5	0	.	.	.	.
	1993	4	0	0	4	0	.	.	.	.
	Overall	9	0	0	9	0	.	.	.	.
gamma-CHLORDANE	1992	5	0	0	5	0	.	.	.	.
	1993	4	0	0	4	0	.	.	.	.
	Overall	9	0	0	9	0	.	.	.	.

Table A-21
Equipment-Rinsate Results for Pesticides and PCBs

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(mg/l) Minimum	Maximum	Average
4,4'-DDD	1992	5	0	5	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
4,4'-DDE	1992	5	0	5	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
4,4'-DDT	1992	5	0	5	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
ALDRIN	1992	5	0	5	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
AROCLOR-1016	1992	5	0	5	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
AROCLOR-1221	1992	5	0	5	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
AROCLOR-1232	1992	5	0	5	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
AROCLOR-1242	1992	5	0	5	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
AROCLOR-1248	1992	5	0	5	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
AROCLOR-1254	1992	5	0	5	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
AROCLOR-1260	1992	5	0	5	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
DIELDRIN	1992	5	0	5	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
ENDOSULFAN I	1992	5	0	5	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
ENDOSULFAN II	1992	5	0	5	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
ENDOSULFAN SULFATE	1992	5	0	5	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
ENDRIN	1992	5	0	5	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
ENDRIN KETONE	1992	5	0	5	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
HEPTACHLOR	1992	5	0	5	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
HEPTACHLOR EPOXIDE	1992	5	0	5	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
METHOXYCHLOR	1992	5	0	5	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
TOXAPHENE	1992	5	0	5	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.

Table A-21 (continued)
Equipment-Rinsate Results for Pesticides and PCBs

Analyte	Year	Number Sampled	Number Rejected	Number Nondetected	Number Detected	Detect Percent	Detected Concentrations(mg/l) Minimum	Maximum	Average
alpha-BHC	1992	5	0	5	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
alpha-CHLORDANE	1992	5	0	5	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
beta-BHC	1992	5	0	5	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
delta-BHC	1992	5	0	5	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
gamma-BHC (LINDANE)	1992	5	0	5	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
gamma-CHLORDANE	1992	5	0	5	0	0.00	.	.	.
	1993	3	0	3	0	0.00	.	.	.
Totals	1990	0	0	0	0	.			
	1991	0	0	0	0	.			
	1992	135	0	135	0	0.00			
	1993	81	0	81	0	0.00			
	1994	0	0	0	0	.			
	Overall	216	0	216	0	0.00			

Dissolved Metals

Aluminum
Antimony
Arsenic
Barium
Beryllium
Cadmium
Calcium
Cesium
Chromium
Cobalt
Copper
Cyanide
Iron
Lead
Lithium
Magnesium
Manganese
Mercury
Molybdenum
Nickel
Phosphorus
Potassium
Selenium
Silicon
Silver
Sodium
Strontium
Thallium
Tin
Vanadium
Zinc

Total Metals

Aluminum
Antimony
Arsenic
Barium
Beryllium
Cadmium
Calcium
Cesium
Chromium
Cobalt
Copper
Cyanide
Iron
Lead
Lithium
Magnesium
Manganese
Mercury
Molybdenum
Nickel
Phosphorus
Potassium
Selenium
Silica, Dissolved
Silicon
Silver
Sodium
Strontium
Thallium
Tin
Vanadium
Zinc

Dissolved Radionuclides

Americium-241
Cesium-137
Gross Alpha, Dissolved
Gross Alpha - Suspended
Gross Alpha Particle Radioactivity
Gross Beta - Dissolved
Gross Beta - Suspended
Gross Beta Particle Radioactivity

Plutonium-239
Plutonium-239/240
Radium-226
Radium-228
Strontium-89
Strontium-89,90
Strontium-90
Total Radiocesium
Tritium
Uranium-233,-234
Uranium-235
Uranium-235/236
Uranium-238

Total Radionuclides

Americium-241
Cesium
Cesium-137
Gross Alpha - Dissolved
Gross Alpha - Suspended
Gross Alpha Particle Radioactivity
Gross Beta - Dissolved
Gross Beta - Suspended
Gross Beta Particle Radioactivity
Plutonium-238
Plutonium-239
Plutonium-239/240
Radium-226
Strontium-89
Strontium-89,90
Strontium-90
Total Radiocesium
Tritium
Uranium-233,-234
Uranium-235
Uranium-235/236
Uranium-238

Field Measurements

Alkalinity, Field Measured
Dissolved Oxygen
Silica, Field Measured
Specific Conductance
pH, Field Measured

Water Quality Parameters

Alkalinity as $CaCO_3$
Ammonia
Bicarbonate
Bicarbonate as $CaCO_3$
Carbonate
Carbonate as $CaCO_3$
Chemical Oxygen Demand
Chloride
Cyanide
Cyanides
Fluoride
Fluoride, Soluble
Hexavalent Chromium
Hydrocyanic Acid
Nitrate
Nitrate/Nitrite
Nitrite
Oil and Grease
Orthophosphate
Phosphate
Phosphorus
Silica, Dissolved
Silicon
Sodium Fluoride
Sodium Sulfate
Solids, Nonvolatile Suspended
Sulfate
Total Dissolved Solids
Total Organic Carbon
Total Solids

Total Suspended Solids
pH

Pesticides

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

PCBs

Aroclor-1016
Aroclor-1221
Aroclor-1232
Aroclor-1242
Aroclor-1248
Aroclor-1254
Aroclor-1260

ABN Compounds

1,2,4-Trichlorobenzene
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol
2,4-Dichlorophenol
2,4-Dimethylphenol
2,4-Dinitrophenol
2,4-Dinitrotoluene
2,6-Dinitrotoluene
2-Chloronaphthalene
2-Chlorophenol
2-Methylnaphthalene
2-Methylphenol
2-Nitroaniline
2-Nitrophenol
3,3'-Dichlorobenzidine
3-Nitroaniline
4,6-Dinitro-2-methylphenol
4-Bromophenyl Phenyl Ether
4-Chloro-3-methylphenol
4-Chloroaniline
4-Chlorophenyl Phenyl Ether
4-Methylphenol
4-Nitroaniline
4-Nitrophenol
Acenaphthene
Acenaphthylene
Anthracene
Benzo(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(ghi)perylene
Benzo(k)fluoranthene
Benzoic Acid
Benzyl Alcohol
Bis(2-chloroethoxy)methane
Bis(2-chloroethyl)ether

Bis(2-chloroisopropyl)ether
Bis(2-Ethylhexyl)phthalate
Butyl Benzyl Phthalate
Chrysene
Di-n-butyl Phthalate
Di-n-octyl Phthalate
Dibenzo(a,h)anthracene
Dibenzofuran
Diethyl Phthalate
Dimethyl Phthalate
Fluoroanthene
Fluorene
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Indeno(1,2,3-cd)pyrene
Isophorone
N-nitroso-di-n-propylamine
N-nitrosodiphenylamine
Naphthalene
Nitrobenzene
Pentachlorophenol
Phenanthrene
Phenol
Pyrene

Volatile Organic Compounds (VOCs)

1,1,1,2-Tetrachloroethane
1,1,1-Trichloroethane
1,1,2,2-Tetrachloroethane
1,1,2-Trichloroethane
1,1-Dichloroethane
1,1-Dichloroethene
1,1-Dichloropropene
1,2,3-Trichlorobenzene
1,2,3-Trichloropropane
1,2,4-Trichlorobenzene
1,2-Dibromoethane
1,2-Dichlorobenzene
1,2-Dichloroethane
1,2-Dichloroethene
1,2-Dichloropropane
1,2-Dimethylbenzene
1,3-Dichlorobenzene
1,3-Dichloropropane
1,3-Dimethylbenzene
1,4-Dichlorobenzene
2-Butanone
2-Chloroethyl Vinyl Ether
2-Hexanone
4-Methyl-2-pentanone
Acetone
Benzene
Benzene, 1,2,4-Trimethyl-
Benzene, 1,3,5-Trimethyl-
Bromobenzene
Bromochloromethane
Bromodichloromethane
Bromoform
Bromomethane
Carbon Disulfide
Carbon Tetrachloride
Chlorobenzene
Chloroethane
Chloroform
Chloromethane
Cumene
Dibromochloromethane
Dibromomethane
Dichlorodifluoromethane
Ethylbenzene
Hexachlorobutadiene
Methylene Chloride

Naphthalene
Propane, 1,2-Dibromo-3-chloro-
Styrene
Tetrachloroethene
Toluene
Total Xylenes
Trichloroethene
Trichlorofluoromethane
Vinyl Acetate
Vinyl Chloride
cis-1,2-Dichloroethene
cis-1,3-Dichloropropene
n-Butylbenzene
n-Propylbenzene
o-Chlorotoluene
p-Chlorotoluene
p-Cymene
p-Xylene
sec-Butylbenzene
sec-Dichloropropane
tert-Butylbenzene
trans-1,2-Dichloroethene
trans-1,3-Dichloropropene

Laboratory Data Qualifiers

Qualifier	Definition	Include in Data Analysis	Detected ("Hit")
+	inorganics: correlation coefficient for the matrix spike analysis is less than 0.995 (estimated value)	yes	yes
-	inorganics: duplicate analysis is not within control limits (estimated value)	yes	yes
A	organics: identifies tentatively identified compound (TIC) as a suspected aldol condensation product	yes remove to TIC table	no
B	organics: warns that analyte also detected in blank note: for common lab contaminants include as hit if blank result > 10 x det. limit; for all other organics include as hit if blank result > 5 x det. limit	yes	yes
	inorganics: reported value is less than CRDL but greater than IDL	yes	yes
	rads: constituent also detected in associated blank whose concentration was greater than CRDL and/or minimum detectable activity (estimated value)	yes	yes
C	organics: pesticide result confirmed by GC/MS	yes	yes
	rads: presence of high TDS in sample increased minimum detectable activity	yes	yes
D	organics: identified in an analysis at a secondary dilution	yes	yes
E	organics: compound exceeded calibration range of instrument, sample must be reanalyzed	no	no
	inorganics: value is an estimate due to interference (estimated value)	yes	yes
F	rads: for alpha spectrometry - FWHM exceeded acceptable limits (estimated value)	yes	yes
G	TOC: dilution result exceeded range of instrument, estimated result	yes	yes
H	rads: sample analysis performed outside of method-specified maximum holding time	yes	yes
I	organics: interference with target peak (estimated value)	yes	yes
JB	organics: result below detection limit and analyte detected in lab blank	yes	no
J	organics: MS data indicate presence of compound but below detection limit (estimated value)	yes	yes
	inorganics: value greater than IDL but control sample analysis not within control limits (estimated value)	yes	yes
L	undefined	no	no

Qualifier	Definition	Include in Data Analysis	Detected ("Hit")
N	organics: compound presumed present (TIC)	yes remove to TIC table	no
	inorganics: spiked sample recovery is not within control limits (estimated value)	yes	yes
N*	inorganics: spiked sample recovery and duplicate analysis are not within control limits (estimated value)	yes	yes
R	validation code for rejected data entered in lab qualifier field/unusable data	no	no
S	inorganics: the reported value determined by the method of standard additions	yes	yes
U	organics and inorganics: analyte analyzed but not detected at the quantitation limit	yes	no
UC	organics: pesticide result confirmed but below detection limit	yes	no
UE	rads: detection limit reported as result (?)	no	no
UJ	organics: analyzed but not above the detection limit, estimated value	yes	no
UN	organics: compound presumed present but below detection limit	yes (TICs)	no
	inorganics: spiked sample recovery not within control limits and sample result below detection limit	yes	no
UW	inorganics: post-digestion spike for GFAA analysis is out of control limits and sample result is below detection limit	yes	no
UX		yes	no
V	validation code for valid data entered into lab qualifier field	yes	yes
W	inorganics: post-digestion spike for GFAA analysis is out of control limits while sample absorbance < 50% of spike absorbance	yes	yes
X	organics (pre-1992): lab software flag (combines more than one qualifier) - not defined	no (unless accompanied by a validated result)	no
	inorganics (pre-1992): detection limit greater than normal, sample matrix interference	yes	yes
	other (OU7 RFI/RI samples): result by calculation defined in GRRASP	yes	yes
Y	rads: chemical yield exceeded acceptable limits (estimated value)	yes	yes

Note on use of X qualifiers: X is defined in the GRRASP as a result determined by calculation not by direct laboratory analysis. Therefore, for samples analyzed during the period that GRRASP has been in effect (since January 1992) the results qualified

by an X will be treated as estimated values (similar to J). For historic data, when GRRASP was not used by laboratories, an X qualifier has two definitions. For organics, the X is a flag entered manually by the laboratory, but is not defined in RFEDS. Therefore, organic results qualified by X are not considered usable data, unless a validated result is given. For inorganics, an X qualifier indicates that the detection limit for the analyte is higher than normal due to matrix interference. An inorganic qualified with an X will be treated like a J result. The X qualifier is sometimes also used with other qualifiers (i.e., UX, XJ). In these cases the meaning of X depends on the analyte and the date of the analysis.

Data Validation

EPA functional guidelines for data validation (EPA, 1988a; EPA, 1988b) were used for validating metals and organic data for CLP analytes. Non-CLP analytical data were validated using data-validation guidelines developed by the EMD, because such guidelines have not been published by EPA (EG&G, 1991). These non-CLP guidelines are based on EPA functional guidelines and tailored to non-CLP analytical methods. Data validation is performed by an independent, third-party subcontractor to ensure that the proper chemistry laboratory protocols are followed.

Data were validated at EPA Level IV or the equivalent for non-CLP analytes. Validated data are classified by EMD in one of three ways: (1) V = valid and usable without qualification, (2) A = acceptable for use with qualification, and (3) R = rejected (unacceptable for use). Data that have been rejected have not been used in any of the statistical computations or in the data-quality assessment. Data qualified as V or A are considered of equal utility, and both are used in the computations and assessment.

Validation Codes

Qualifier	Definition	Include in Data Analysis
A	acceptable result	yes
J	estimated result	yes
JA	acceptable result (for estimated value)	yes
R	rejected result	no
V	valid result	yes

References

EPA, 1988a, Laboratory Data Validation Functional Guidelines for Evaluating Organics Analyses: Prepared by EPA's Data Review Work Group for EPA's Hazardous Site Evaluation Division, U.S. Environmental Protection Agency, February 1988.

EPA, 1988b, Laboratory Data Validation Functional Guidelines for Evaluating Inorganics Analyses: Prepared by EPA's Data Review Work Group for EPA's

Attachment 3

Evaluating Groundwater Data Quality Using Cation–Anion Balances

Evaluating Groundwater Data Quality Using Cation–Anion Balances

Aqueous solutions are electrically neutral; the sum of the negative charges (anions) is equivalent to the sum of the positive charges (cations). Imbalances with respect to anion and cation proportions may be indicative of analytical or reporting errors in the concentration data or they may result from the presence of charged species in the solution which are not accounted for in the analysis of the water sample. Calculating the charge balance of a water analysis, therefore, provides another means to evaluate the quality of the concentration data.

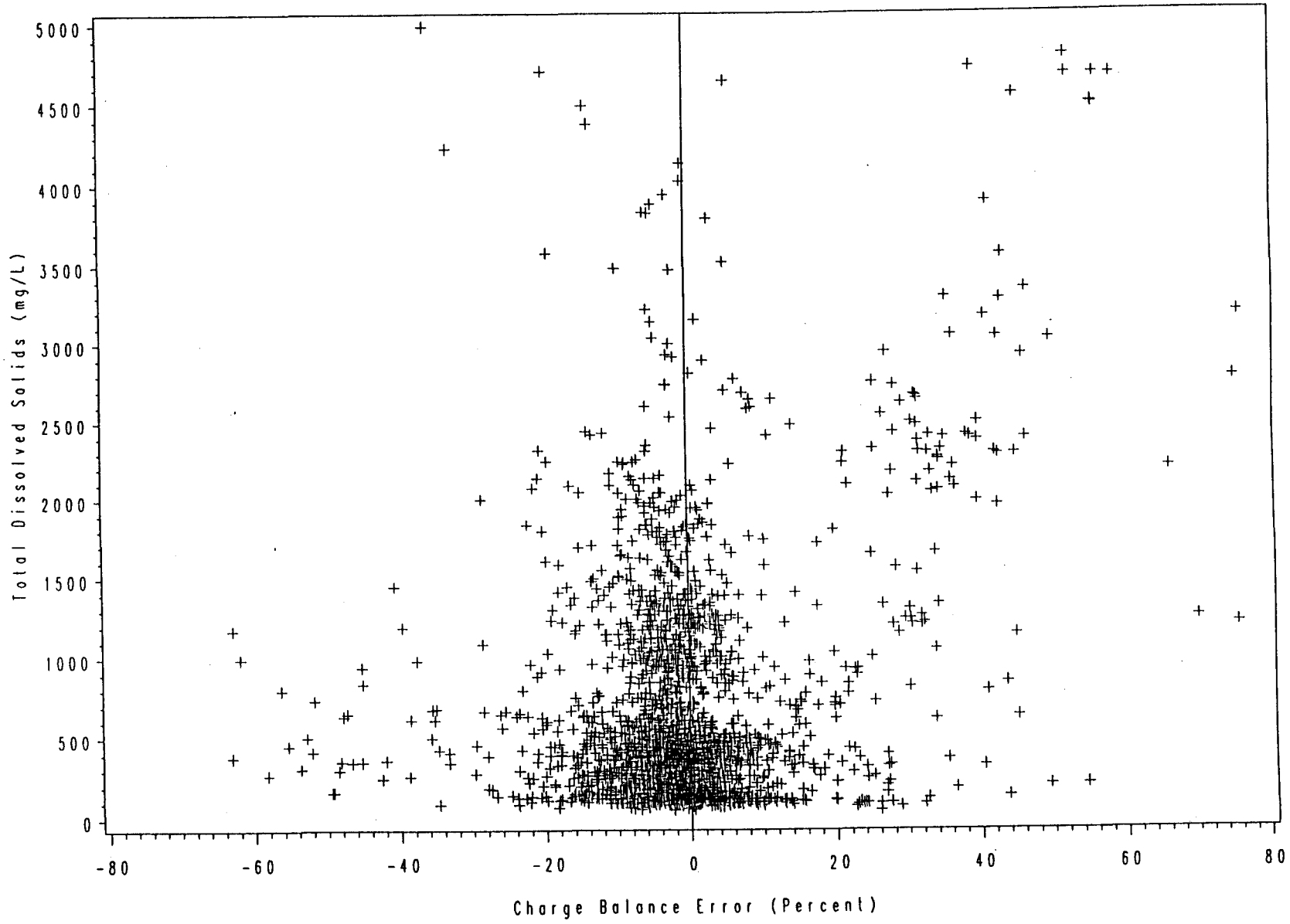
The following three plots present the calculated errors in the charge balances of groundwater samples from the Rocky Flats site. On each plot, the error in the charge balance is expressed as a percent error calculated using the following equation:

$$\frac{\sum \text{charges}}{\sum \text{ions in solution}} \times 100$$

Electrical neutrality is indicated by a vertical line at 0 percent error.

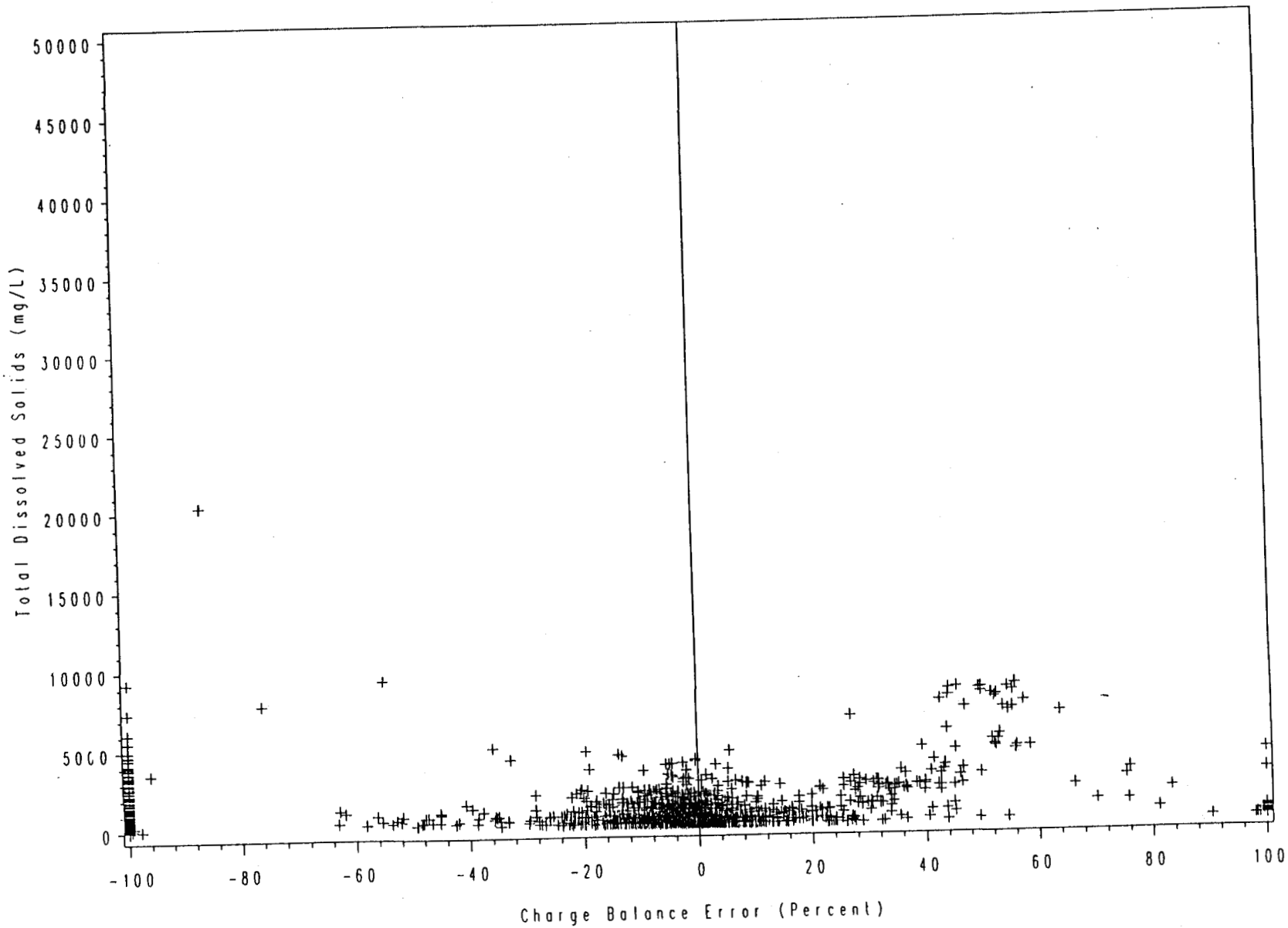
Total Dissolved Solids vs. Charge Balance

Ground Water



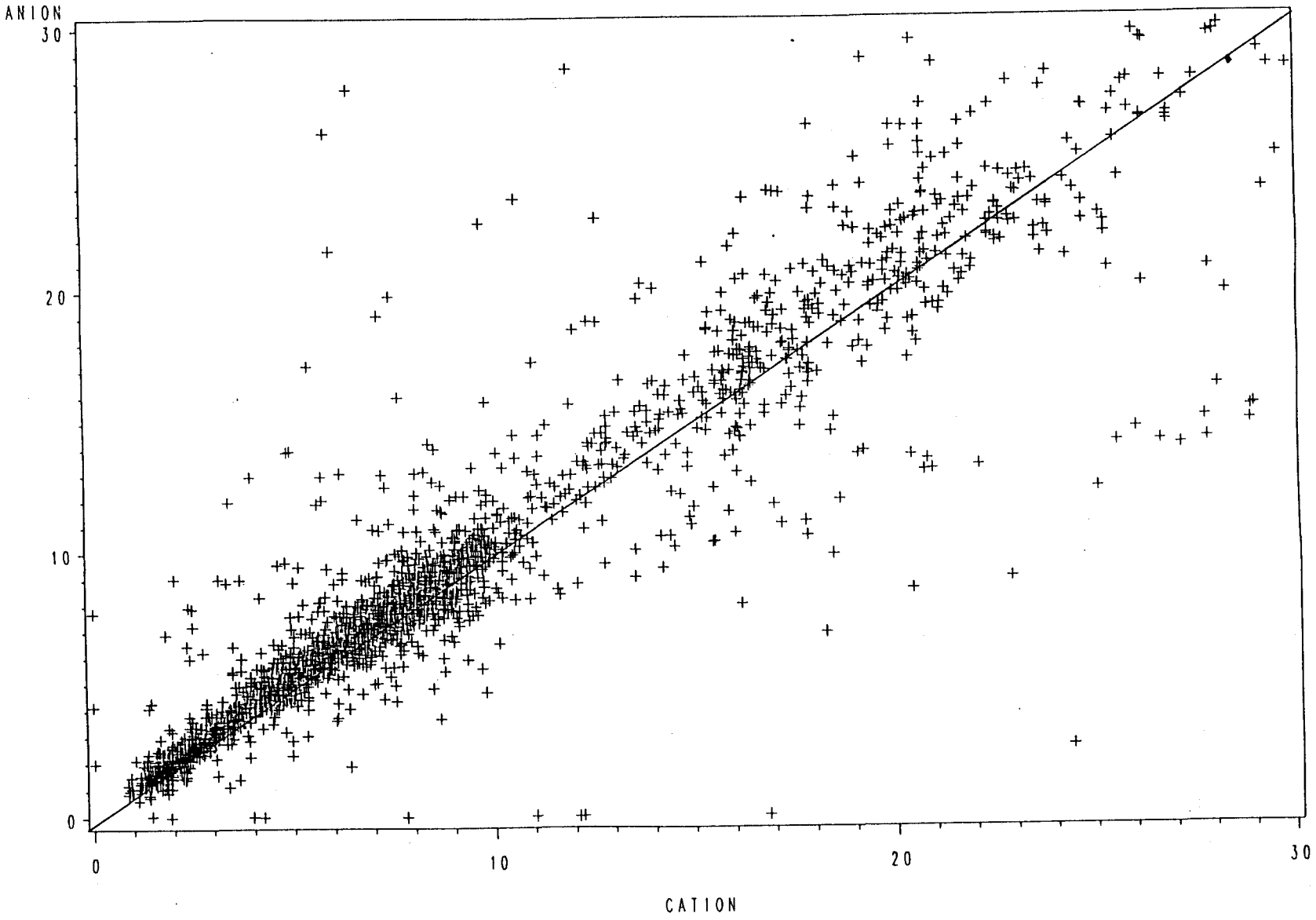
Total Dissolved Solids vs. Charge Balance

Ground Water



Total Dissolved Solids vs. Charge Balance

Ground Water



B. Summary Statistics (Sitewide)

The following tables of data provide summary statistics for all inorganic components analyzed in samples of groundwater collected from 1990 to 1994 at the Rocky Flats site. For these summary tables, no determinations of analyte distributions were made, and all non-detects were replaced with the value of 1/2 the reported detection limit, regardless of the percentage of non-detects for each specific analyte. The only exception to this treatment is for radionuclide data. In accordance with DOE Order 5400.1 X.X, all results for radionuclides have been treated as detects, including negative and zero results.

This summary is provided only to give the reader an overview of the types of components analyzed and the average concentrations or (in the case of radionuclides) activities of these components. Rigorous statistical evaluations have not been performed to produce these tables of summary statistics. Outlier tests were not conducted; therefore, "maximum" values should be viewed with caution and compared with the results for other samples collected from the same well to ensure that the result is representative of the chemistry of groundwater at that location, rather than representative of analytical or transcription errors.

The files are arranged by analytical suite (i.e., metals, radionuclides, and water-quality parameters). For metals and radionuclides, the summary statistics have also been calculated separately for data for filtered (dissolved) and unfiltered (total) samples. The number of records for that analyte (N Obs), the minimum and maximum values, the mean and standard deviation, the range, the standard error of the mean, and the coefficient of variation (CV) are included in the tables. The variable "Nmiss" indicates the number of records for which there was no value for the result. This should be = 0 for all analytes, but Nmiss = 4 for CARBONATE (of a total 3,509 records) and Nmiss = 1 for FLUORIDE (of 3,533 records). These five records should have been deleted during the data-cleanup process but were somehow overlooked. However, unintentional inclusion of these few records, out of thousands, will not have any noticeable impact on the mean values given in this appendix or conclusions of this report.

The actual data files used in this study are too voluminous (even as compressed files) to be contained on a floppy diskette for inclusion in this report. More than 200 megabytes (>350,000 records) of groundwater data (excluding stable-isotope data) were examined in the preparation of this report. The data are currently available as compressed SAS files that will fit on a Bernoulli 44 MB diskette. Other formats or subsets of the data files may be available upon request.

ANALYTE=ALUMINUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2823	5.0000000	13700.00	0	13695.00	104.6461204	447.7992600	8.4280661	427.9176888

ANALYTE=ANTIMONY

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2830	0.0250000	661.0000000	0	660.9750000	27.6818686	31.5931020	0.5938805	114.1292249

ANALYTE=ARSENIC

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2790	0.3500000	52.2000000	0	51.8500000	4.0075448	2.4159254	0.0457384	60.2844261

ANALYTE=BARIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2862	0.0100000	3260.00	0	3259.99	122.0405273	119.9452043	2.2420644	98.2830925

ANALYTE=BERYLLIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2783	0.1000000	2500.00	0	2499.90	2.9003557	47.3602775	0.8977546	1632.91

ANALYTE=BORON

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
12	31.1000000	218.0000000	0	186.9000000	99.4583333	54.2357222	15.6565044	54.5310990

ANALYTE=CADMIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2809	0.0500000	2500.00	0	2499.95	3.3662638	47.2097757	0.8907505	1402.44

ANALYTE=CALCIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2847	170.0000000	2380000.00	0	2379830.00	117122.44	207364.62	3886.34	177.0494309

ANALYTE=CESIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2602	1.0000000	1250.00	0	1249.00	412.4584358	219.0958429	4.2951713	53.1194961

ANALYTE=CHROMIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2825	1.0000000	202.0000000	0	201.0000000	6.6958704	11.4905341	0.2161877	171.6062794

ANALYTE=COBALT

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV

2831	0.0100000	200.0000000	0	199.9900000	18.0727361	11.0481875	0.2076448	61.1317921

ANALYTE=COPPER

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2841	0.5000000	1210.00	0	1209.50	12.3755192	42.7104762	0.8013067	345.1206820

ANALYTE=IRON

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2838	2.0000000	146000.00	0	145998.00	985.5446966	6860.64	128.7830601	696.1272116

ANALYTE=LEAD

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2819	0.4000000	2500.00	0	2499.60	3.2857414	55.0821638	1.0374411	1676.40

ANALYTE=LITHIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2828	1.0000000	2700.00	0	2699.00	72.3372496	172.7763541	3.2489618	238.8483872

ANALYTE=MAGNESIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2848	22.5000000	788000.00	0	787977.50	30595.42	70712.58	1325.03	231.1214167

ANALYTE=MANGANESE

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2839	0.5000000	10500.00	0	10499.50	184.8523329	650.5984223	12.2104118	351.9557542

ANALYTE=MERCURY

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2776	0.0100000	100.0000000	0	99.9900000	0.5806351	6.8220569	0.1294809	1174.93

ANALYTE=MOLYBDENUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2802	1.7500000	435.0000000	0	433.2500000	57.7321699	45.5630716	0.8607538	78.9214604

ANALYTE=NICKEL

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2829	0.0100000	4950.00	0	4949.99	24.6033097	117.5609761	2.2102770	477.8258606

ANALYTE=POTASSIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2855	5.0000000	580000.00	0	579995.00	4326.21	17252.73	322.8902122	398.7951644

ANALYTE=SELENIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2818	0.5000000	28200.00	0	28199.50	48.4190277	561.4545453	10.5765520	1159.57

ANALYTE=SILVER

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2809	1.0000000	217.0000000	0	216.0000000	4.5991648	4.5913848	0.0866299	99.8308375

ANALYTE=SODIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2846	111.0000000	2020000.00	0	2019889.00	100652.87	190607.93	3572.92	189.3715756

ANALYTE=STRONTIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2830	1.3000000	81700.00	0	81698.70	1056.35	2819.04	52.9918117	266.8666399

ANALYTE=THALLIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2821	0.0500000	50.0000000	0	49.9500000	4.0905884	3.0417286	0.0572689	74.3591931

ANALYTE=TIN

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2805	4.7000000	767.0000000	0	762.3000000	68.2207023	44.8822606	0.8474387	65.7897956

ANALYTE=VANADIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2831	0.6000000	146.0000000	0	145.4000000	14.8800551	11.7993105	0.2217618	79.2961477

ANALYTE=ZINC

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2850	0.8500000	9850.00	0	9849.15	44.5338477	376.8143387	7.0583793	846.1302089

Analysis Variable : RESULT2

ANALYTE=ALUMINUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1413	9.0000000	1460000.00	0	1459991.00	16240.39	59199.52	1574.88	364.5204146

ANALYTE=ANTIMONY

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1365	0.0250000	2060.00	0	2059.98	33.1755267	74.4810199	2.0159478	224.5059151

ANALYTE=ARSENIC

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1364	0.3500000	70.7000000	0	70.3500000	4.3408724	3.5325132	0.0956482	81.3779536

ANALYTE=BARIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1415	8.5000000	11300.00	0	11291.50	297.6539004	639.8859791	17.0107857	214.9765141

ANALYTE=BERYLLIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1382	0.1000000	160.0000000	0	159.9000000	3.0992533	7.0271057	0.1890264	226.7354473

ANALYTE=CADMIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1387	0.0500000	1720.00	0	1719.95	4.8063381	49.1533538	1.3198207	1022.68

ANALYTE=CALCIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1413	50.0000000	2380000.00	0	2379950.00	112246.70	178634.29	4752.19	159.1443655

ANALYTE=CESIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1295	1.0000000	500.0000000	0	499.0000000	417.1307336	151.6471502	4.2140469	36.3548255

ANALYTE=CHROMIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1410	1.0000000	5020.00	0	5019.00	48.8876376	221.3973231	5.8960724	452.8697520

ANALYTE=COBALT

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1399	0.0100000	1620.00	0	1619.99	23.2776026	55.6189351	1.4870097	238.9375577

ANALYTE=COPPER

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1428	1.0000000	7140.00	0	7139.00	51.2589888	299.9787442	7.9382794	585.2217361

ANALYTE=IRON

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1413	3.5000000	2020000.00	0	2019996.50	24966.42	109398.54	2910.32	438.1827656

ANALYTE=LEAD

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1402	0.4000000	3660.00	0	3659.60	18.7244551	108.4025174	2.8951119	578.9354994

ANALYTE=LITHIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1415	1.0000000	2190.00	0	2189.00	65.0464947	130.3814966	3.4660733	200.4435400

ANALYTE=MAGNESIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1412	1060.00	786000.00	0	784940.00	28321.21	56131.23	1493.78	198.1950262

ANALYTE=MANGANESE

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1411	1.0000000	24000.00	0	23999.00	538.5472225	1422.95	37.8814114	264.2201097

ANALYTE=MERCURY

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1395	0.1000000	4.7000000	0	4.6000000	0.1495842	0.2674865	0.0071617	178.8200001

ANALYTE=MOLYBDENUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1420	1.7500000	1600.00	0	1598.25	67.2558810	63.0115442	1.6721528	93.6892704

ANALYTE=NICKEL

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1419	0.0100000	2010.00	0	2009.99	46.8508182	134.7649773	3.5775511	287.6470093

ANALYTE=POTASSIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1416	243.0000000	235000.00	0	234757.00	5746.58	12575.95	334.2021891	218.8423906

ANALYTE=SELENIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1365	0.5500000	2200.00	0	2199.45	28.2475092	137.0185405	3.7086258	485.0641511

ANALYTE=SILICON

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
864	1080.00	916000.00	0	914920.00	32083.39	48034.34	1634.16	149.7171243

ANALYTE=SILVER

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1372	1.0000000	3040.00	0	3039.00	9.1732544	95.4919433	2.5780401	1040.98

ANALYTE=SODIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1411	2500.00	2010000.00	0	2007500.00	84547.03	159300.26	4240.85	188.4161419

ANALYTE=STRONTIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1396	46.3000000	23300.00	0	23253.70	926.3365809	1956.20	52.3564738	211.1758658

ANALYTE=THALLIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1403	0.4500000	5.6000000	0	5.1500000	3.9767356	1.7359594	0.0463458	43.6528753

ANALYTE=TIN

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1382	4.7000000	642.0000000	0	637.3000000	79.8056758	42.5522274	1.1446383	53.3198008

ANALYTE=VANADIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1418	1.3000000	3140.00	0	3138.70	44.6530487	131.4742032	3.4914227	294.4349986

ANALYTE=ZINC

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1415	1.5000000	686000.00	0	685998.50	652.2197703	18256.64	485.3360539	2799.15

Analysis Variable : RESULT

ANALYTE=AMERICIUM-241

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
138	-0.0080000	0.4706000	0	0.4786000	0.0107566	0.0424979	0.0036177	395.0866546

ANALYTE=CESIUM-134

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
66	-0.8000000	1.7600000	0	2.5600000	0.3478439	0.6475210	0.0797043	186.1527423

ANALYTE=CESIUM-137

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
316	-0.9100000	2.6000000	0	3.5100000	0.1942572	0.4320345	0.0243038	222.4033631

ANALYTE=GROSS ALPHA

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2636	-5.9200000	593.3000000	0	599.2200000	11.5709544	31.4739233	0.6130250	272.0080148

ANALYTE=GROSS BETA

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2701	-7.2000000	300.0000000	0	307.2000000	8.8240876	20.7846248	0.3999262	235.5441787

ANALYTE=PLUTONIUM-239/240

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
134	-0.0090000	0.6852000	0	0.6942000	0.0105604	0.0609166	0.0052624	576.8393956

ANALYTE=RADIUM-226

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
872	-0.0800000	8.0640000	0	8.1440000	0.6126510	0.7914916	0.0268033	129.1912603

ANALYTE=RADIUM-228

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
215	-0.5400000	14.3400000	0	14.8800000	2.2619715	2.7789286	0.1895214	122.8542739

ANALYTE=STRONTIUM-89,90

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2052	-1.7000000	15.4800000	0	17.1800000	0.4006504	0.8030999	0.0177289	200.4490778

ANALYTE=STRONTIUM-90

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
70	-0.2900000	4.1000000	0	4.3900000	0.2537249	0.5541783	0.0662370	218.4170450

ANALYTE=TOTAL RADIOCESIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
642	-13.0000000	7.3000000	0	20.3000000	0.4925560	0.9484612	0.0374328	192.5590543

ANALYTE=TRITIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1	90.0000000	90.0000000	0	0	90.0000000	.	.	.

ANALYTE=URANIUM-233,-234

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2670	-0.5210000	282.8140000	0	283.3350000	7.7913682	19.2356669	0.3722645	246.8843275

ANALYTE=URANIUM-235

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2673	-0.1703000	12.5442000	0	12.7145000	0.2691947	0.7052011	0.0136400	261.9669662

ANALYTE=URANIUM-238

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2655	-0.1830000	176.6420000	0	176.8250000	5.3797022	12.8144790	0.2486959	238.2005289

Analysis Variable : RESULT

ANALYTE=AMERICIUM-241

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2171	-0.4610000	46.5400000	0	47.0010000	0.1018393	1.4891923	0.0319610	1462.30

ANALYTE=CESIUM-134

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
5	-0.6080000	1.4890000	0	2.0970000	0.1667600	0.8089997	0.3617957	485.1281458

ANALYTE=CESIUM-137

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1247	-4.8600000	4.4990000	0	9.3590000	0.1027995	0.4510227	0.0127722	438.7402338

ANALYTE=GROSS ALPHA

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
260	-2.6910000	1600.00	0	1602.69	32.3272487	110.8389622	6.8739406	342.8654361

ANALYTE=GROSS BETA

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
246	-8.2000000	1300.00	0	1308.20	25.2945517	89.5730673	5.7109702	354.1200038

ANALYTE=PLUTONIUM-238

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
205	-0.0037490	0.0717590	0	0.0755080	0.0037846	0.0084303	0.000588797	222.7505927

ANALYTE=PLUTONIUM-239/240

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2277	-0.0240000	218.4000000	0	218.4240000	0.4886872	7.6479637	0.1602745	1565.00

ANALYTE=RADIUM-226

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
101	-0.0490000	9.2000000	0	9.2490000	1.4902178	1.8963677	0.1886956	127.2543968

ANALYTE=RADIUM-228

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
18	0.5900000	96.0000000	0	95.4100000	11.9222967	21.5365792	5.0762204	180.6411956

ANALYTE=STRONTIUM-89,90

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
171	-1.2000000	1.7000000	0	2.9000000	0.2401473	0.4077369	0.0311804	169.7862080

ANALYTE=STRONTIUM-90

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
88	-0.2860000	2.0000000	0	2.2860000	0.2777831	0.4328054	0.0461372	155.8069872

ANALYTE=TOTAL RADIOCESIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
50	-0.8900000	15.0000000	0	15.8900000	0.6004000	2.2190906	0.3138268	369.6020324

ANALYTE=TRITIUM

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
3076	-358.0000000	13850.00	0	14208.00	258.7361396	889.3106532	16.0346812	343.7133501

ANALYTE=URANIUM-233,-234

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
230	0	290.0000000	0	290.0000000	10.6239214	28.3284972	1.8679258	266.6482185

ANALYTE=URANIUM-235

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
230	-0.0200000	9.0000000	0	9.0200000	0.4297228	0.9642846	0.0635830	224.3968790

ANALYTE=URANIUM-238

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
246	-0.0100000	190.0000000	0	190.0100000	7.4745203	18.8666138	1.2028914	252.4123702

C. Overview of Organic Compounds in Groundwater at RFETS

The data presented in this appendix are given only as a general overview for the site; a listing of specific locations for the detected concentrations is not included here. The detection rates presented in the following set of tables are compiled from data for all wells sampled from 1990 to 1994. In general, detections of organic chemicals in groundwater are limited to the Industrial Area and other sites identified as potentially contaminated. Possible groundwater contamination at RFETS is being evaluated on an OU-by-OU basis under the Environmental Restoration Program at RFETS. The reader is referred to these OU-specific documents for a detailed evaluation of organic compounds in groundwater. Spatial distributions of detected organic compounds are presented in these OU-specific documents.

The reader should note that for production of the main set of tables in this appendix, records for which the result qualifier indicates that the compound was detected in the corresponding sample blank (i.e., B-qualified records) were not distinguished from other detections. For common laboratory contaminants such as acetone and methylene chloride, the percentage of B-qualified detections is greater than 50 percent of all detections. However, most organic compounds that have any B-qualified detections have from 0 to 10 percent B-qualifiers. Organic compounds in the data set for this report that have at least one B-qualified detection are listed in the following single-page summary table.

Information presented in the first set of tables includes the name of the compound as given in RFEDS; other names used by OSHA and DOT or other common names; the CAS number of the compound; the total number of records in the database for a given compound; the total number of those records indicate the compound was detected in a groundwater sample; and the corresponding detection rate (i.e., the number of detects for a given compound, divided by the total number of records for that compound, multiplied by 100 to give the rate as a percentage) for each compound.

Perusal of the following pages in this appendix should give the reader a "feel" for which organic compounds may be important in the assessment of groundwater at RFETS. For example, the reader will note that although 2,2-dichloropropane has been analyzed in 831 samples, it has never been detected at RFETS (0.0 percent detection rate). On the other hand, 1,2-dichloroethene has been detected 302 times out of 2,956 analyses, yielding a detection rate of 10.2 percent. The number of detects, combined with a significant detection rate, indicate that 1,2-dichloroethene is probably an organic chemical that may need to be assessed further at RFETS, whereas 2,2-dichloropropane probably is not.

SUMMARY TABLE OF B-QUALIFIED DETECTIONS FOR ORGANIC COMPOUNDS IN RFETS GROUNDWATER

Data for Groundwater Samples Collected Sitewide at RFETS, 1990 to 1994

Name of Organic Compound	No. of B-qualified Detections	Total No. of Detections	Percent B-qualified Detections
1,1,1-Trichloroethane	5	341	1.5 %
1,1-Dichloroethene	6	299	2.0 %
1,2,3-Trichlorobenzene	1	16	6.2 %
1,2,4-Trichlorobenzene	1	8	12.5 %
2-Butanone	13	33	39.4 %
2-Hexanone	6	11	54.5 %
4-Methyl-2-pentanone	2	35	5.7 %
Acetone	214	422	50.7 %
Benzene	1	106	0.9 %
Bis(2-ethylhexyl)phthalate	4	65	6.2 %
Carbon tetrachloride	7	697	1.0 %
Chlorobenzene	1	31	3.2 %
Chloroethane	1	22	4.5 %
Chloroform	25	785	3.2 %
Diethyl phthalate	2	37	5.4 %
Ethylbenzene	1	44	2.3 %
Hexachlorobutadiene	1	11	9.1 %
Methylene chloride	480	851	56.4 %
Naphthalene	2	38	5.3 %
Styrene	1	19	5.3 %
Tetrachloroethene	24	1045	2.3 %
Toluene	7	213	3.3 %
Total xylenes	5	80	6.2 %
Trichloroethene	21	1067	2.0 %
Vinyl chloride	1	78	1.3 %
sec-Butylbenzene	9	15	60.0 %

DETECTION RATES FOR ANALYZED ORGANIC COMPOUNDS

Data for Groundwater Samples Collected Sitewide at RFETS, 1990 to 1994

Name of Compound	Other Names	CAS Number	Total Number of Records	Total Number Detect Records	Percentage Detection Rate
1,1,1,2-TETRACHLOROETHANE	1,1,1,2-PCA	630-20-6	980	12	1.2 %
1,1,1-TRICHLOROETHANE	1,1,1-TCA Methyl chloroform	71-55-6	4015	341	8.5 %
1,1,2,2-TETRACHLOROETHANE	1,1,2,2-PCA Acetylene tetrachloride	79-34-5	4024	13	0.3 %
1,1,2-TRICHLOROETHANE	Vinyl trichloride Ethane trichloride	79-00-5	4031	29	0.8 %
1,1-DICHLOROETHANE	Ethylidene chloride	75-34-3	4035	225	5.6 %
1,1-DICHLOROETHENE	1,1-Dichloroethylene Vinylidene chloride	75-35-4	4026	299	7.4 %
1,1-DICHLOROPROPENE	1,1-Dichloropropylene	563-58-6	982	4	0.4 %
1,2,3-TRICHLOROBENZENE	1,2,3-TCB	87-61-6	979	16	1.6 %
1,2,3-TRICHLOROPROPANE	Allyl trichloride	96-18-4	912	3	0.3 %
1,2,4-TRICHLOROBENZENE	1,2,4-TCB	120-82-1	1092	8	0.7 %
1,2-DIBROMOETHANE	DBE Ethylene dibromide	106-93-4	981	2	0.2 %
1,2-DICHLOROBENZENE	DCB o-Dichlorobenzene	95-50-1	1100	1	0.1 %
1,2-DICHLOROETHANE	1,2-DCA Ethylene dichloride	107-06-2	4022	25	0.6 %
1,2-DICHLOROETHENE	1,2-DCE Acetylene dichloride	540-59-0	2956	302	10.2 %
1,2-DICHLOROPROPANE	Propylene dichloride	78-87-5	4033	34	0.9 %
1,3-DICHLOROBENZENE	m-Dichlorobenzene m-Phenylenedichloride	541-73-1	1099	5	0.5 %
1,3-DICHLOROPROPANE	Trimethylene dichloride	142-28-9	982	1	0.1 %
1,4-DICHLOROBENZENE	p-Dichlorobenzene 1,4-DCB	106-46-7	1100	3	0.3 %
2,2-DICHLOROPROPANE		594-20-7	831	0	0.0 %
2,4,5-TRICHLOROPHENOL	Phenachlor	95-95-4	294	1	0.3 %
2,4,6-TRICHLOROPHENOL	Phenachlor	88-06-2	294	0	0.0 %
2,4-DICHLOROPHENOL	2,4-DCP Dichlorohydroxybenzene	120-83-2	294	0	0.0 %
2,4-DIMETHYLPHENOL	m-Xylenol 2,4-Xylenol	105-67-9	294	4	0.1 %
2,4-DINITROPHENOL	Aldifen 2,4-DNP	51-28-5	274	0	0.0 %

Analytes for which there were three or fewer records in the database are not listed.

DETECTION RATES FOR ANALYZED ORGANIC COMPOUNDS

Data for Groundwater Samples Collected Sitewide at RFETS, 1990 to 1994

Name of Compound	Other Names	CAS Number	Total Number of Records	Total Number Detect Records	Percentage Detection Rate
2,4-DINITROTOLUENE	2,4-DNT 2,4-Dinitrotoluol	121-14-2	297	0	0.0 %
2,6-DINITROTOLUENE	2,6-DNT 2,6-Dinitrotoluol	606-20-2	297	1	0.3 %
2-BUTANONE	Ethyl methyl ketone Methyl acetone	78-93-3	2229	33	1.5 %
2-CHLOROETHYL VINYL ETHER	(2-chloroethoxy)ethene	110-75-8	35	0	0.0 %
2-CHLORONAPHTHALENE		91-58-7	297	0	0.0 %
2-CHLOROPHENOL	o-Chlorophenol	95-57-8	294	0	0.0 %
2-HEXANONE	Methyl n-butyl ketone MNBK	591-78-6	2916	11	0.4 %
2-METHYLNAPHTHALENE		91-57-6	297	1	0.3 %
2-METHYLPHENOL	o-Cresol o-Methylphenol	95-48-7	294	3	1.0 %
2-NITROANILINE	o-Nitroaniline 1-amino-2-nitrobenzene	88-74-4	297	0	0.0 %
2-NITROPHENOL	o-Nitrophenol	88-75-5	294	0	0.0 %
3,3'-DICHLOROBENZIDINE	DCB	91-94-1	245	0	0.0 %
3-NITROANILINE	m-Nitroaniline MNA	99-09-2	263	0	0.0 %
4,4'-DDD	Tetrachlorodiphenyl-ethane	72-54-8	9	0	0.0 %
4,4'-DDE	Dichlorodiphenyl-dichloroethylene	72-55-9	9	0	0.0 %
4,4'-DDT	Dichlorodiphenyl-trichloroethane	50-29-3	9	0	0.0 %
4,6-DINITRO-2-METHYLPHENOL	Dinitro-o-cresol Capsine	534-52-1	291	0	0.0 %
4-CHLORO-3-METHYLPHENOL	p-Chlorocresol	59-50-7	294	0	0.0 %
4-CHLOROANILINE	p-Chloroaniline 4-Chlorobenzamine	106-47-8	271	0	0.0 %
4-CHLOROPHENYL PHENYL ETHER	1-Chloro-4-phenoxy benzene	7005-72-3	297	0	0.0 %
4-ISOPROPYLTOLUENE	Cymene p-Methyl cumene	99-87-6	983	18	1.8 %
4-METHYL-2-PENTANONE	Isobutyl methyl ketone MIBK	108-10-1	2999	35	1.2 %
4-METHYLPHENOL	p-Cresol p-Toluol	106-44-5	285	12	4.2 %
4-NITROANILINE	p-Nitroaniline 1-amino-4-nitrobenzene	100-01-6	266	0	0.0 %

Analytes for which there were three or fewer records in the database are not listed.

DETECTION RATES FOR ANALYZED ORGANIC COMPOUNDS

Data for Groundwater Samples Collected Sitewide at RFETS, 1990 to 1994

Name of Compound	Other Names	CAS Number	Total Number of Records	Total Number Detect Records	Percentage Detection Rate
4-NITROPHENOL	p-Nitrophenol 4-Hydroxynitrobenzene	100-02-7	291	1	0.3 %
ACENAPHTHENE	Naphthyleneethylene	83-32-9	297	5	1.7 %
ACENAPHTHYLENE	Paranaphthalene	208-96-8	297	0	0.0 %
ACETONE	Methyl ketone 2-Propanone	67-64-1	2862	422	14.7 %
ALDRIN		309-00-2	9	0	0.0 %
ANTHRACENE	Paranaphthalene	120-12-7	297	0	0.0 %
AROCLOR-1016	Polychlorinated biphenyl (PCB)	12674-11-2	9	0	0.0 %
AROCLOR-1221	Polychlorinated biphenyl (PCB)	11104-28-2	9	0	0.0 %
AROCLOR-1232	Polychlorinated biphenyl (PCB)	11141-16-5	9	0	0.0 %
AROCLOR-1242	Polychlorinated biphenyl (PCB)	53469-21-9	9	0	0.0 %
AROCLOR-1248	Polychlorinated biphenyl (PCB)	12672-29-6	9	0	0.0 %
AROCLOR-1254	Polychlorinated biphenyl (PCB)	11097-69-1	9	0	0.0 %
AROCLOR-1260	Polychlorinated biphenyl (PCB)	11096-82-5	9	0	0.0 %
BENZENE		71-43-2	4034	106	2.6 %
BENZENE, 1,2,4-TRIMETHYL		95-63-6	983	7	0.7 %
BENZENE, 1,3,5-TRIMETHYL	TMB	108-67-8	984	6	0.6 %
BENZO(a)ANTHRACENE	BA Naphthanthracene	56-55-3	297	1	0.3 %
BENZO(a)PYRENE	BP B(a)P	50-32-8	297	0	0.0 %
BENZO(b)FLUORANTHENE	B(b)F	205-99-2	297	0	0.0 %
BENZO(ghi)PERYLENE	1,12-Benzoperylene B(ghi)P	191-24-2	297	0	0.0 %
BENZO(k)FLUORANTHENE		207-08-9	297	0	0.0 %
BENZOIC ACID	Carboxybenzene Benzoate	65-85-0	270	17	6.3 %
BENZYL ALCOHOL	Phenylmethanol Hydroxytoluene	100-51-6	289	0	0.0 %
BIS(2-CHLOROETHOXY)METHANE	Dichloroethyl formal	111-91-1	297	0	0.0 %

Analytes for which there were three or fewer records in the database are not listed.

DETECTION RATES FOR ANALYZED ORGANIC COMPOUNDS

Data for Groundwater Samples Collected Sitewide at RFETS, 1990 to 1994

Name of Compound	Other Names	CAS Number	Total Number of Records	Total Number Detect Records	Percentage Detection Rate
BIS(2-CHLOROETHYL)ETHER	Dichloroethyl ether	111-44-4	297	0	0.0 %
BIS(2-CHLOROISOPROPYL)ETHER	DCIP Dichloroisopropyl ether	108-60-1	283	0	0.0 %
BIS(2-ETHYLHEXYL)PHTHLATE	DEHP Di-sec-octyl phthalate	117-81-7	298	65	21.8 %
BROMOBENZENE		108-86-1	978	4	0.4 %
BROMOCHLOROMETHANE	Chlorobromomethane	74-97-5	954	4	0.4 %
BROMODICHLOROMETHANE	BDCM	75-27-4	4022	38	0.9 %
BROMOFORM	Tribromomethane Methyl tribromide	75-25-2	4011	11	0.3 %
BROMOMETHANE	Methyl bromide	74-83-9	3856	4	0.1 %
BUTYL BENZYL PHTHALATE		85-68-7	297	0	0.0 %
CARBON DISULFIDE	Carbon sulfide Carbon bisulfide	75-15-0	3034	56	1.8 %
CARBON TETRACHLORIDE	Tetrachloromethane Perchloromethane	56-23-5	3983	697	17.5 %
CHLOROBENZENE	Benzene chloride	108-90-7	4032	31	0.8 %
CHLOROETHANE	Ethyl chloride Chlorethyl	75-00-3	3984	22	0.6 %
CHLOROFORM	Trichloromethane Methyl trichloride	67-66-3	4001	785	19.6 %
CHLOROMETHANE	Methyl chloride	74-87-3	3948	10	0.3 %
CHRYSENE	1,2-Benzphenanthrene Benzo(a)phenanthrene	218-01-9	297	1	0.3 %
DI-n-BUTYL PHTHALATE	DBP Butyl phthalate	84-74-2	297	16	5.4 %
DI-n-OCTYL PHTHALATE	DNOP Dioctyl ester	117-84-0	297	1	0.3 %
DIBENZO(a,h)ANTHRACENE	DBA	53-70-3	297	0	0.0 %
DIBENZOFURAN	2,2'-Biphenylene oxide	132-64-9	297	0	0.0 %
DIBROMOCHLOROMETHANE	CDBM Chlorodibromomethane	124-48-1	4031	1	0.0 %
DIBROMOMETHANE	Methylene dibromide	74-95-3	941	0	0.0 %
DICHLORODIFLUOROMETHANE	Freon-12; Fluorocarbon-12	75-71-8	901	4	0.4 %
DIELDRIN	Insecticide number 497	60-57-1	9	0	0.0 %

Analytes for which there were three or fewer records in the database are not listed.

DETECTION RATES FOR ANALYZED ORGANIC COMPOUNDS

Data for Groundwater Samples Collected Sitewide at RFETS, 1990 to 1994

Name of Compound	Other Names	CAS Number	Total Number of Records	Total Number Detect Records	Percentage Detection Rate
DIETHYL PHTHALATE	DEP Diethyl ester	84-66-2	297	37	12.5 %
DIMETHYL PHTHALATE	DMP Dimethyl ester	131-11-3	297	0	0.0 %
ENDOSULFAN I		959-98-8	9	0	0.0 %
ENDOSULFAN II		33213-65-9	9	0	0.0 %
ENDOSULFAN SULFATE		1031-07-8	9	0	0.0 %
ENDRIN	Hexadrin	72-20-8	9	0	0.0 %
ENDRIN KETONE		53494-70-5	9	0	0.0 %
ETHYLBENZENE	EB Phenylethane	100-41-4	4027	44	1.1 %
FLUORANTHENE	Benzo(jk)fluorene 1,2-Benzacenaphthene	206-44-0	297	3	1.0 %
FLUORENE	o-Biphenylmethane Methylenebiphenyl	86-73-7	297	4	1.3 %
HEPTACHLOR	3-Chlorochlordene Heptachlorane	76-44-8	9	0	0.0 %
HEPTACHLOR EPOXIDE	HCE Epoxyheptachlor	1024-57-3	9	1	11.1 %
HEXACHLOROBENZENE	Perchlorobenzene Phenyl perchloryl	118-74-1	297	0	0.0 %
HEXACHLOROBUTADIENE	HCBD Perchlorobutadiene	87-68-3	1096	11	1.0 %
HEXACHLOROCYCLOPENTADIENE	HCCPD PCL	77-47-4	294	0	0.0 %
HEXACHLOROETHANE	Perchloroethane Ethylene hexachloride	67-72-1	297	1	0.3 %
INDENO(1,2,3-cd)PYRENE	o-Phenylenepyrene IP	193-39-5	297	0	0.0 %
ISOPHORONE	Trimethylcyclohexanone	78-59-1	297	0	0.0 %
ISOPROPYLBENZENE	Cumene (1-Methylethyl)benzene	98-82-8	982	0	0.0 %
METHOXYCHLOR	DMDT Dimethoxy-DT	72-43-5	9	0	0.0 %
METHYLENE CHLORIDE	Dichloromethane	75-09-2	3992	851	21.3 %
N-NITROSO-DI-n-PROPYLAMINE	NDPA; DPNA; DPN	621-64-7	297	0	0.0 %
N-NITROSODIPHENYLAMINE	Benzenamine NDPA	86-30-6	297	0	0.0 %
NAPHTHALENE	Moth balls	91-20-3	1009	38	3.8 %

Analytes for which there were three or fewer records in the database are not listed.

DETECTION RATES FOR ANALYZED ORGANIC COMPOUNDS

Data for Groundwater Samples Collected Sitewide at RFETS, 1990 to 1994

Name of Compound	Other Names	CAS Number	Total Number of Records	Total Number Detect Records	Percentage Detection Rate
NITROBENZENE	Mirbane oil	98-95-3	297	0	0.0 %
PENTACHLOROPHENOL		87-86-5	294	3	1.0 %
PHENANTHRENE	Phenatrin Phenanthren	85-01-8	297	6	2.0 %
PHENOL	Carbolic acid Hydroxybenzene	108-95-2	294	5	1.7 %
PROPANE, 1,2-DIBROMO-3-CHLORO	DBCP; BBC 12	96-12-8	449	2	0.4 %
PYRENE	Benzo(def)- phenanthrene	129-00-0	297	3	1.0 %
STYRENE	Vinyl benzene Phenylethylene	100-42-5	4022	19	4.7 %
TETRACHLOROETHENE	PERC; PCE Perchloroethylene	127-18-4	4023	1045	26.0 %
TOLUENE	Toluol Methylbenzene	108-88-3	4035	213	5.3 %
TOTAL XYLENES	Total dimethylbenzenes	1330-20-7	3138	80	2.5 %
TOXAPHENE	Chlorinated camphene Camphochlor	8001-35-2	9	0	0.0 %
TRICHLOROETHENE	TCE Ethylene trichloride	79-01-6	4025	1067	26.5 %
TRICHLOROFLUOROMETHANE	Freon-11 Fluorocarbon-11	75-69-4	981	14	1.4 %
VINYL ACETATE	1-Acetoxyethylene Ethenyl ester	108-05-4	2839	5	0.2 %
VINYL CHLORIDE	Chloroethene Chloroethylene	75-01-4	4007	78	13.8 %
alpha-BHC	alpha-Lindane Benzene hexachloride	319-84-6	9	0	0.0 %
alpha-CHLORDANE	cis-Chlordane	5103-71-9	9	0	0.0 %
beta-BHC	beta-Lindane Benzene hexachloride	319-85-7	9	0	0.0 %
cis-1,2-DICHLOROETHENE	cis-1,2-Dichloroethylene	156-59-2	979	282	28.8 %
cis-1,3-DICHLOROPROPENE	cis-1,3-Dichloropropylene	10061-01-5	3805	3	0.1 %
delta-BHC	delta-Lindane Benzene hexachloride	319-86-8	9	0	0.0 %
gamma-BHC	Lindane Benzene hexachloride	58-89-9	9	0	0.0 %
gamma-CHLORDANE	trans-Chlordane	5103-74-2	9	0	0.0 %
m+p XYLENE			716	5	0.7 %

Analytes for which there were three or fewer records in the database are not listed.

DETECTION RATES FOR ANALYZED ORGANIC COMPOUNDS

Data for Groundwater Samples Collected Sitewide at RFETS, 1990 to 1994

Name of Compound	Other Names	CAS Number	Total Number of Records	Total Number Detect Records	Percentage Detection Rate
m-XYLENE	m-Xylol m-Methyltoluene	108-38-3	184	5	2.7 %
n-BUTYLBENZENE	1-Phenylbutane	104-51-8	982	7	0.7 %
n-PROPYLBENZENE	Isocumene 1-Phenylpropane	103-65-1	982	0	0.0 %
o-CHLOROTOLUENE	2-Methylchloro-benzene	95-49-8	982	1	0.1 %
o-XYLENE	o-Xylol o-Methyltoluene	95-47-6	916	8	0.9 %
p-BROMODIPHENYL ETHER	p-Phenoxybromo-benzene	101-55-3	297	0	0.0 %
p-CHLOROTOLUENE	4-Chloro-1-methyl-benzene	106-43-4	983	2	0.2 %
p-XYLENE	p-Methyltoluene p-Xylol	106-42-3	125	2	1.6 %
sec-BUTYLBENZENE	2-Phenylbutane	135-98-8	981	15	1.5 %
tert-BUTYLBENZENE		98-06-6	983	4	0.4 %
trans-1,2-DICHLOROETHENE	trans-Dichloroethylene Acetylene dichloride	156-60-5	1077	31	2.9 %
trans-1,3-DICHLOROPROPENE	trans-1,3-Dichloro-propylene	10061-02-6	3777	3	0.1 %

Analytes for which there were three or fewer records in the database are not listed.

Analysis Variable : RESULT2

ANALYTE=(1,1'-BIPHENYL)-4-AMINE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	5.0000000	5.0000000	0	5.0000000	.	.	.

ANALYTE=1,1,1,2-TETRACHLOROETHANE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
980	0.0050000	6.0000000	5.9950000	0.1099694	0.2764026	0.0088294	251.3450690

ANALYTE=1,1,1-TRICHLOROETHANE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
4015	0.0050000	19000.00	19000.00	42.4826549	663.5152715	10.6397629	1561.85

ANALYTE=1,1,2,2-TETRACHLOROETHANE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
4024	0.0050000	2500.00	2500.00	2.8407815	40.5842381	0.6507027	1428.63

ANALYTE=1,1,2-TRICHLOROETHANE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
4031	0.0200000	2500.00	2499.98	2.9556252	40.6140905	0.6507632	1374.13

ANALYTE=1,1-DICHLOROETHANE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
4035	0.0150000	2500.00	2499.99	3.6829424	42.6298082	0.6821861	1157.49

ANALYTE=1,1-DICHLOROETHENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
4026	0.0200000	18000.00	17999.98	32.0978480	530.3492098	8.4989241	1652.29

ANALYTE=1,1-DICHLOROPROPENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
982	0.0100000	6.0000000	5.9900000	0.0668635	0.1983030	0.0063281	296.5787237

ANALYTE=1,2,3-TRICHLOROBENZENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
979	0.0250000	20.0000000	19.9750000	0.1517978	0.9314110	0.0297680	613.5868233

ANALYTE=1,2,3-TRICHLOROPROPANE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
912	0.0100000	5.0000000	4.9900000	0.1632895	0.1909970	0.0063245	116.9683210

ANALYTE=1,2,4,5-TETRACHLOROBENZENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	5.0000000	5.0000000	0	5.0000000	.	.	.

ANALYTE=1,2,4-TRICHLOROBENZENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1092	0.0300000	45.0000000	44.9700000	1.2125366	2.5091305	0.0759297	206.9323471

ANALYTE=1,2-DIBROMOETHANE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
981	0.0850000	13.0000000	12.9150000	0.1642661	0.5540504	0.0176895	337.2884383

ANALYTE=1,2-DICHLOROBENZENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1100	0.0150000	6.0000000	5.9850000	1.0896409	2.0098976	0.0606007	184.4550428

ANALYTE=1,2-DICHLOROETHANE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
4022	0.0150000	6000.00	5999.98	4.4338188	104.4264150	1.6751703	2355.23

ANALYTE=1,2-DICHLOROETHENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
2956	0.5000000	12000.00	11999.50	11.1521157	230.9268031	4.3363191	2070.70

ANALYTE=1,2-DICHLOROPROPANE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
4033	0.0150000	2500.00	2499.99	2.9059862	40.6905288	0.6516535	1400.23

ANALYTE=1,2-ETHANEDIAMINE, N,N-DIMETHYL-N'-2PYRI

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	12.5000000	12.5000000	0	12.5000000	.	.	.

ANALYTE=1,3,5-TRINITROBENZENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	50.0000000	50.0000000	0	50.0000000	.	.	.

ANALYTE=1,3-BENZODIOXOLE, 5-(1-PROPENYL)-

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	5.0000000	5.0000000	0	5.0000000	.	.	.

ANALYTE=1,3-DICHLOROBENZENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1099	0.0100000	7.0000000	6.9900000	1.1179163	2.0109698	0.0606606	179.8855411

ANALYTE=1,3-DICHLOROPROPANE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
982	0.0100000	6.0000000	5.9900000	0.0972811	0.1967888	0.0062798	202.2889146

ANALYTE=1,3-DINITROBENZENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	10.0000000	10.0000000	0	10.0000000	.	.	.

ANALYTE=1,4-DICHLOROBENZENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1100	0.0150000	9.0000000	8.9850000	1.1195182	2.0149275	0.0607524	179.9816695

ANALYTE=1,4-DIOXANE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	10.0000000	10.0000000	0	10.0000000	.	.	.

ANALYTE=1,4-NAPHTHOQUINONE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	25.0000000	25.0000000	0	25.0000000	.	.	.

ANALYTE=1-NAPHTHYLAMINE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	5.0000000	5.0000000	0	5.0000000	.	.	.

ANALYTE=2,2-DICHLOROPROPANE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
831	0.0250000	6.0000000	5.9750000	0.0751203	0.2125930	0.0073748	283.0032097

ANALYTE=2,3,4,6-TETRACHLOROPHENOL

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	5.0000000	5.0000000	0	5.0000000	.	.	.

ANALYTE=2,4,5-TRICHLOROPHENOL

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
294	3.0000000	30.0000000	27.0000000	24.8299320	1.8966439	0.1106145	7.6385384

ANALYTE=2,4,6-TRICHLOROPHENOL

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
294	4.0000000	6.0000000	2.0000000	5.0068027	0.1304546	0.0076083	2.6055477

ANALYTE=2,4-DICHLOROPHENOL

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
294	4.0000000	6.0000000	2.0000000	5.0068027	0.1304546	0.0076083	2.6055477

ANALYTE=2,4-DIMETHYLPHENOL

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
294	4.0000000	8.0000000	4.0000000	5.0408163	0.3226924	0.0188198	6.4015903

ANALYTE=2,4-DINITROPHENOL

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
274	12.5000000	30.0000000	17.5000000	24.8978102	1.4520904	0.0877240	5.8322014

ANALYTE=2,4-DINITROTOLUENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	4.0000000	6.0000000	2.0000000	5.0067340	0.1297937	0.0075314	2.5923816

ANALYTE=2,6-DICHLOROPHENOL

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	5.0000000	5.0000000	0	5.0000000	.	.	.

ANALYTE=2,6-DINITROTOLUENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	2.0000000	6.0000000	4.0000000	4.9966330	0.2174533	0.0126179	4.3519959

ANALYTE=2-BUTANONE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
2229	1.0000000	5000.00	4999.00	10.6080569	116.6209709	2.5388405	1099.36

ANALYTE=2-CHLOROETHYL VINYL ETHER

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
35	5.0000000	2500.00	2495.00	160.9375000	623.7500000	155.9375000	387.5728155

ANALYTE=2-CHLORONAPHTHALENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	4.0000000	6.0000000	2.0000000	5.0067340	0.1297937	0.0075314	2.5923816

ANALYTE=2-CHLOROPHENOL

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
294	4.0000000	6.0000000	2.0000000	5.0068027	0.1304546	0.0076083	2.6055477

ANALYTE=2-HEXANONE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
2916	1.0000000	5000.00	4999.00	7.6139627	95.8521248	1.8159805	1258.90

ANALYTE=2-METHYLNAPHTHALENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	1.0000000	6.0000000	5.0000000	4.9932660	0.2662714	0.0154506	5.3326095

ANALYTE=2-METHYLPHENOL

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
294	3.0000000	14.0000000	11.0000000	5.0476190	0.6246728	0.0364317	12.3755940

ANALYTE=2-NITROANILINE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	12.5000000	30.0000000	17.5000000	24.9057239	1.3948025	0.0809346	5.6003289

ANALYTE=2-NITROPHENOL

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
294	4.0000000	6.0000000	2.0000000	5.0068027	0.1304546	0.0076083	2.6055477

ANALYTE=2-PICOLINE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	5.0000000	5.0000000	0	5.0000000	.	.	.

ANALYTE=3,3'-DICHLOROBENZIDINE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
245	5.0000000	12.0000000	7.0000000	9.9551020	0.6123929	0.0391243	6.1515484

ANALYTE=3-CHLOROPROPENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	5.0000000	5.0000000	0	5.0000000	.	.	.

ANALYTE=3-NITROANILINE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
263	12.5000000	30.0000000	17.5000000	24.8935361	1.4821057	0.0913906	5.9537775

ANALYTE=4,4'-DDD

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
9	0.0500000	0.0500000	0	0.0500000	0	0	0

ANALYTE=4,4'-DDE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
9	0.0500000	0.0500000	0	0.0500000	0	0	0

ANALYTE=4,4'-DDT

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
9	0.0500000	0.0500000	0	0.0500000	0	0	0

ANALYTE=4,6-DINITRO-2-METHYLPHENOL

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
291	12.5000000	30.0000000	17.5000000	24.9037801	1.4090910	0.0826024	5.6581410

ANALYTE=4-CHLORO-3-METHYLPHENOL

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
294	4.0000000	6.0000000	2.0000000	5.0068027	0.1304546	0.0076083	2.6055477

ANALYTE=4-CHLOROANILINE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
271	4.0000000	6.0000000	2.0000000	5.0073801	0.1358818	0.0082542	2.7136297

ANALYTE=4-CHLOROPHENYL PHENYL ETHER

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	4.0000000	6.0000000	2.0000000	5.0067340	0.1297937	0.0075314	2.5923816

ANALYTE=4-ISOPROPYLTOLUENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
983	0.0100000	6.0000000	5.9900000	0.1067650	0.2307857	0.0073609	216.1622884

ANALYTE=4-METHYL-2-PENTANONE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
2999	1.0000000	5000.00	4999.00	8.7815652	100.0203230	1.8653886	1138.98

ANALYTE=4-METHYLPHENOL

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
285	4.0000000	2100.00	2096.00	20.2859649	167.1613504	9.9017838	824.0246451

ANALYTE=4-NITROANILINE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
266	12.5000000	30.0000000	17.5000000	24.8947368	1.4737356	0.0903605	5.9198683

ANALYTE=4-NITROPHENOL

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
291	12.5000000	61.0000000	48.5000000	25.0274914	2.5422499	0.1490293	10.1578296

ANALYTE=5-NITRO-o-TOLUIDINE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	10.0000000	10.0000000	0	10.0000000	.	.	.

ANALYTE=7,12-DIMETHYLBENZ(a)ANTHRACENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	10.0000000	10.0000000	0	10.0000000	.	.	.

ANALYTE=ACENAPHTHENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	2.0000000	6.0000000	4.0000000	4.9764310	0.2716007	0.0157599	5.4577410

ANALYTE=ACENAPHTHYLENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	4.0000000	6.0000000	2.0000000	5.0067340	0.1297937	0.0075314	2.5923816

ANALYTE=ACETAMIDE, N-(4-ETHOXYPHENYL)-

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	5.0000000	5.0000000	0	5.0000000	.	.	.

ANALYTE=ACETAMIDE, N-9H-FLUOREN-2-yl

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	10.0000000	10.0000000	0	10.0000000	.	.	.

ANALYTE=ACETONE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
2862	0.9000000	15000.00	14999.10	18.5775968	308.4014070	5.8671327	1660.07

ANALYTE=ACETONITRILE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	50.0000000	50.0000000	0	50.0000000	.	.	.

ANALYTE=ACROLEIN

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	250.0000000	250.0000000	0	250.0000000	.	.	.

ANALYTE=ACRYLONITRILE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	50.0000000	50.0000000	0	50.0000000	.	.	.

ANALYTE=ALDRIN

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
9	0.0250000	0.0250000	0	0.0250000	0	0	0

ANALYTE=ANTHRACENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	4.0000000	6.0000000	2.0000000	5.0067340	0.1297937	0.0075314	2.5923816

ANALYTE=AROCLOR-1016

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
9	0.2500000	0.2500000	0	0.2500000	0	0	0

ANALYTE=AROCLOR-1221

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
9	0.2500000	0.2500000	0	0.2500000	0	0	0

ANALYTE=AROCLOR-1232

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
9	0.2500000	0.2500000	0	0.2500000	0	0	0

ANALYTE=AROCLOR-1242

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
9	0.2500000	0.2500000	0	0.2500000	0	0	0

ANALYTE=AROCLOR-1248

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
9	0.2500000	0.2500000	0	0.2500000	0	0	0

ANALYTE=AROCLOR-1254

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
9	0.5000000	0.5000000	0	0.5000000	0	0	0

ANALYTE=AROCLOR-1260

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
9	0.5000000	0.5000000	0	0.5000000	0	0	0

ANALYTE=BENZAMIDE, 3,5-DICHLORO-N-(1,1-DIMETHYL-

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	5.0000000	5.0000000	0	5.0000000	.	.	.

ANALYTE=BENZENAMINE, N,N-DIMETHYL-4-(PEHNYLAZO)-

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	10.0000000	10.0000000	0	10.0000000	.	.	.

ANALYTE=BENZENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
4034	0.0050000	2500.00	2500.00	2.8091801	40.5091596	0.6489153	1442.03

ANALYTE=BENZENE, 1,2,4-TRIMETHYL

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
983	0.0100000	6.0000000	5.9900000	0.1056358	0.2187094	0.0069757	207.0409327

ANALYTE=BENZENE, 1,3,5-TRIMETHYL-

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
984	0.0150000	6.0000000	5.9850000	0.0993293	0.2230753	0.0071114	224.5815986

ANALYTE=BENZENEACETIC ACID, 4-CHLORO-alpha-(4-CH

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	5.0000000	5.0000000	0	5.0000000	.	.	.

ANALYTE=BENZENEETHANAMINE, alpha, alpha-DIMETHYL

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	25.0000000	25.0000000	0	25.0000000	.	.	.

ANALYTE=BENZO(a)ANTHRACENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	4.0000000	6.0000000	2.0000000	5.0033670	0.1423337	0.0082590	2.8447593

ANALYTE=BENZO(a)PYRENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	4.0000000	6.0000000	2.0000000	5.0067340	0.1297937	0.0075314	2.5923816

ANALYTE=BENZO(b)FLUORANTHENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	4.0000000	6.0000000	2.0000000	5.0067340	0.1297937	0.0075314	2.5923816

ANALYTE=BENZO(ghi)PERYLENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	4.0000000	6.0000000	2.0000000	5.0067340	0.1297937	0.0075314	2.5923816

ANALYTE=BENZO(k)FLUORANTHENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	4.0000000	6.0000000	2.0000000	5.0067340	0.1297937	0.0075314	2.5923816

ANALYTE=BENZOIC ACID

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
270	6.0000000	2900.00	2894.00	46.4870370	196.0760768	11.9328100	421.7865653

ANALYTE=BENZYL ALCOHOL

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
289	4.0000000	6.0000000	2.0000000	5.0069204	0.1315791	0.0077399	2.6279442

ANALYTE=BENZ[j]ACEANTHRYLENE, 1,2-DIHYDRO-3-METH

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	5.0000000	5.0000000	0	5.0000000	.	.	.

ANALYTE=BIS(2-CHLOROETHOXY)METHANE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	4.0000000	6.0000000	2.0000000	5.0067340	0.1297937	0.0075314	2.5923816

ANALYTE=BIS(2-CHLOROETHYL)ETHER

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	4.0000000	6.0000000	2.0000000	5.0067340	0.1297937	0.0075314	2.5923816

ANALYTE=BIS(2-CHLOROISOPROPYL)ETHER

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
283	4.0000000	6.0000000	2.0000000	5.0070671	0.1329676	0.0079041	2.6555979

ANALYTE=BIS(2-ETHYLHEXYL)PHTHALATE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
298	1.0000000	130.0000000	129.0000000	6.9597315	10.8378028	0.6278171	155.7215635

ANALYTE=BROMOBENZENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
978	0.0200000	6.0000000	5.9800000	0.0973722	0.2005523	0.0064130	205.9646892

ANALYTE=BROMOCHLOROMETHANE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
954	0.0050000	6.1000000	6.0950000	0.1950472	0.2873603	0.0093036	147.3286183

ANALYTE=BROMODICHLOROMETHANE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
4022	0.0500000	2500.00	2499.95	2.8054698	40.4894970	0.6496013	1443.23

ANALYTE=BROMOFORM

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
4011	0.0450000	2500.00	2499.96	2.8564972	40.6670544	0.6533756	1423.67

ANALYTE=BROMOMETHANE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
3856	0.0500000	5000.00	4999.95	5.7298361	82.8937321	1.3587311	1446.70

ANALYTE=BUTYL BENZYL PHTHALATE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	4.0000000	6.0000000	2.0000000	5.0067340	0.1297937	0.0075314	2.5923816

ANALYTE=CARBAMOTHIOIC ACID, BIS(1-METHYLETHYL)-S

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	5.0000000	5.0000000	0	5.0000000	.	.	.

ANALYTE=CARBAZOLE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
3	2.0000000	5.0000000	3.0000000	4.0000000	1.7320508	1.0000000	43.3012702

ANALYTE=CARBON DISULFIDE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
3034	0.1000000	2500.00	2499.90	3.8319655	46.9903649	0.8725892	1226.27

ANALYTE=CARBON TETRACHLORIDE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
3983	0.0100000	100000.00	99999.99	188.4195065	2432.36	39.0995966	1290.93

ANALYTE=CHLOROBENZENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
4032	0.0100000	2500.00	2499.99	2.8423415	40.5579112	0.6498631	1426.92

ANALYTE=CHLOROETHANE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
3984	0.0500000	5000.00	4999.95	5.7527294	81.6408393	1.3162742	1419.17

ANALYTE=CHLOROFORM

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
4001	0.0050000	64000.00	64000.00	60.5792107	1437.19	23.0637174	2372.41

ANALYTE=CHLOROMETHANE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
3948	0.0500000	18000.00	17999.95	10.5240357	302.8530427	4.9058297	2877.73

ANALYTE=CHRYSENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	4.0000000	6.0000000	2.0000000	5.0033670	0.1423337	0.0082590	2.8447593

ANALYTE=CYANIDE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
3	5.0000000	5.5500000	0.5500000	5.3666667	0.3175426	0.1833333	5.9169438

ANALYTE=DI-n-BUTYL PHTHALATE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	2.0000000	6.0000000	4.0000000	4.8905724	0.5489351	0.0318524	11.2243527

ANALYTE=DI-n-OCTYL PHTHALATE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	4.0000000	6.0000000	2.0000000	5.0101010	0.1420137	0.0082405	2.8345479

ANALYTE=DIBENZO(a,h)ANTHRACENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	4.0000000	6.0000000	2.0000000	5.0067340	0.1297937	0.0075314	2.5923816

ANALYTE=DIBENZOFURAN

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	4.0000000	6.0000000	2.0000000	5.0067340	0.1297937	0.0075314	2.5923816

ANALYTE=DIBROMOCHLOROMETHANE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
4031	0.0250000	2500.00	2499.98	2.8399268	40.5632744	0.6500324	1428.32

ANALYTE=DIBROMOMETHANE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
941	0.0500000	10.0000000	9.9500000	0.1457492	0.3775523	0.0123079	259.0424476

ANALYTE=DICHLORODIFLUOROMETHANE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
901	0.1000000	10.0000000	9.9000000	0.1579634	0.4206320	0.0140133	266.2845426

ANALYTE=DIELDRIN

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
9	0.0500000	0.0500000	0	0.0500000	0	0	0

ANALYTE=DIETHYL PHTHALATE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	2.0000000	310.0000000	308.0000000	6.7424242	18.2380140	1.0582769	270.4963870

ANALYTE=DIMETHYL PHTHALATE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	4.0000000	6.0000000	2.0000000	5.0067340	0.1297937	0.0075314	2.5923816

ANALYTE=DIPHENYLAMINE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	5.0000000	5.0000000	0	5.0000000	.	.	.

ANALYTE=ENDOSULFAN I

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
9	0.0250000	0.0250000	0	0.0250000	0	0	0

ANALYTE=ENDOSULFAN II

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
9	0.0500000	0.0500000	0	0.0500000	0	0	0

ANALYTE=ENDOSULFAN SULFATE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
9	0.0500000	0.0500000	0	0.0500000	0	0	0

ANALYTE=ENDRIN

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
9	0.0500000	0.0500000	0	0.0500000	0	0	0

ANALYTE=ENDRIN KETONE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
9	0.0500000	0.0500000	0	0.0500000	0	0	0

ANALYTE=ETHANE, PENTACHLORO-

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	10.0000000	10.0000000	0	10.0000000	.	.	.

ANALYTE=ETHANONE, 1-PHENYL

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	5.0000000	5.0000000	0	5.0000000	.	.	.

ANALYTE=ETHYL CYANIDE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	25.0000000	25.0000000	0	25.0000000	.	.	.

ANALYTE=ETHYL METHACRYLATE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	10.0000000	10.0000000	0	10.0000000	.	.	.

ANALYTE=ETHYLBENZENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
4027	0.0200000	2500.00	2499.98	3.1111694	41.2205207	0.6608195	1324.92

ANALYTE=FLUORANTHENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	1.0000000	6.0000000	5.0000000	4.9831650	0.2958943	0.0171695	5.9378797

ANALYTE=FLUORENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	1.0000000	6.0000000	5.0000000	4.9696970	0.3375552	0.0195869	6.7922685

ANALYTE=HEPTACHLOR

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
9	0.0250000	0.0250000	0	0.0250000	0	0	0

ANALYTE=HEPTACHLOR EPOXIDE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
9	0.0250000	0.0650000	0.0400000	0.0294444	0.0133333	0.0044444	45.2830189

ANALYTE=HEXACHLOROBENZENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	4.0000000	6.0000000	2.0000000	5.0067340	0.1297937	0.0075314	2.5923816

ANALYTE=HEXACHLOROBUTADIENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1096	0.0250000	6.0000000	5.9750000	1.1300912	1.9949581	0.0602599	176.5307103

ANALYTE=HEXACHLOROCYCLOPENTADIENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
294	4.0000000	6.0000000	2.0000000	5.0085034	0.1270396	0.0074091	2.5364774

ANALYTE=HEXACHLOROETHANE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	4.0000000	6.0000000	2.0000000	5.0033670	0.1423337	0.0082590	2.8447593

ANALYTE=HEXACHLOROPROPENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	10.0000000	10.0000000	0	10.0000000	.	.	.

ANALYTE=INDENO(1,2,3-cd)PYRENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	4.0000000	6.0000000	2.0000000	5.0067340	0.1297937	0.0075314	2.5923816

ANALYTE=ISOBUTYL ALCOHOL

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	1000.00	1000.00	0	1000.00	.	.	.

ANALYTE=ISOPHORONE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	4.0000000	6.0000000	2.0000000	5.0067340	0.1297937	0.0075314	2.5923816

ANALYTE=ISOPROPYLBENZENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
982	0.0100000	6.0000000	5.9900000	0.0970265	0.1967398	0.0062782	202.7691702

ANALYTE=METHACRYLONITRILE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	10.0000000	10.0000000	0	10.0000000	.	.	.

ANALYTE=METHANESULFONIC ACID, ETHYL ESTER

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	5.0000000	5.0000000	0	5.0000000	.	.	.

ANALYTE=METHOXYCHLOR

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
9	0.2500000	0.2500000	0	0.2500000	0	0	0

ANALYTE=METHYL METHACRYLATE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	10.0000000	10.0000000	0	10.0000000	.	.	.

ANALYTE=METHYL METHANESULFONATE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	5.0000000	5.0000000	0	5.0000000	.	.	.

ANALYTE=METHYLENE CHLORIDE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
3992	0.0050000	24000.00	24000.00	28.2822943	655.3123193	10.4920501	2317.04

ANALYTE=N-NITROSO-DI-n-PROPYLAMINE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	4.0000000	6.0000000	2.0000000	5.0067340	0.1297937	0.0075314	2.5923816

ANALYTE=N-NITROSODIBUTYLAMINE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	5.0000000	5.0000000	0	5.0000000	.	.	.

ANALYTE=N-NITROSODIETHYLAMINE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	5.0000000	5.0000000	0	5.0000000	.	.	.

ANALYTE=N-NITROSODIMETHYLAMINE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	5.0000000	5.0000000	0	5.0000000	.	.	.

ANALYTE=N-NITROSODIPHENYLAMINE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	4.0000000	6.0000000	2.0000000	5.0067340	0.1297937	0.0075314	2.5923816

ANALYTE=N-NITROSOMETHYLETHYLAMINE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	5.0000000	5.0000000	0	5.0000000	.	.	.

ANALYTE=N-NITROSOMORPHOLINE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	10.0000000	10.0000000	0	10.0000000	.	.	.

ANALYTE=N-NITROSOPIPERIDINE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	5.0000000	5.0000000	0	5.0000000	.	.	.

ANALYTE=N-NITROSOPYRROLIDINE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	25.0000000	25.0000000	0	25.0000000	.	.	.

ANALYTE=NAPHTHALENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1009	0.0100000	85.0000000	84.9900000	1.4692864	4.2904213	0.1350686	292.0071446

ANALYTE=NITROBENZENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	4.0000000	6.0000000	2.0000000	5.0067340	0.1297937	0.0075314	2.5923816

ANALYTE=PENTACHLOROBENZENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	5.0000000	5.0000000	0	5.0000000	.	.	.

ANALYTE=PENTACHLORONITROBENZENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	5.0000000	5.0000000	0	5.0000000	.	.	.

ANALYTE=PENTACHLOROPHENOL

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
294	4.0000000	62.0000000	58.0000000	24.9285714	2.9022764	0.1692642	11.6423694

ANALYTE=PHENANTHRENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	2.0000000	6.0000000	4.0000000	4.9646465	0.3693438	0.0214315	7.4394779

ANALYTE=PHENOL

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
294	2.0000000	130.0000000	128.0000000	5.8775510	8.9999226	0.5248861	153.1236833

ANALYTE=PHENOL, 2-(1-METHYLPROPYL)-4,6-DINITRO-

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	10.0000000	10.0000000	0	10.0000000	.	.	.

ANALYTE=PROPANE, 1,2-DIBROMO-3-CHLORO-

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
449	0.1000000	10.0000000	9.9000000	0.2005568	0.5175435	0.0244244	258.0533278

ANALYTE=PYRENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	2.0000000	6.0000000	4.0000000	4.9831650	0.2721028	0.0157890	5.4604419

ANALYTE=SAFROLE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	5.0000000	5.0000000	0	5.0000000	.	.	.

ANALYTE=SPECIAL ORGANIC

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	125.0000000	125.0000000	0	125.0000000	.	.	.

ANALYTE=STYRENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
4022	0.0500000	2500.00	2499.95	2.8365260	40.6061554	0.6513891	1431.55

ANALYTE=TETRACHLOROETHENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
4023	0.0100000	84000.00	83999.99	154.8693058	2371.03	37.8795401	1530.99

ANALYTE=TOLUENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
4035	0.0100000	2500.00	2499.99	3.8399233	44.0036284	0.7038104	1145.95

ANALYTE=TOTAL XYLENES

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
3138	0.1500000	2500.00	2499.85	4.6897663	50.8762337	0.9296437	1084.84

ANALYTE=TOXAPHENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
9	0.5000000	0.5000000	0	0.5000000	0	0	0

ANALYTE=TRICHLOROETHENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
4025	0.0150000	150000.00	149999.98	367.9219485	4654.14	74.3259955	1264.98

ANALYTE=TRICHLOROFLUOROMETHANE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
981	0.0500000	7.9000000	7.8500000	0.1429562	0.3542984	0.0113119	247.8371048

ANALYTE=VINYL ACETATE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
2839	1.0000000	5000.00	4999.00	7.4557571	96.8719161	1.8639558	1299.29

ANALYTE=VINYL CHLORIDE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
4007	0.0050000	5000.00	5000.00	7.5099884	86.5769482	1.3911646	1152.82

ANALYTE=[1,1'-BIPHENYL]-4,4'-DIAMINE, 3,3'-DIMET

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	10.0000000	10.0000000	0	10.0000000	.	.	.

ANALYTE=alpha-BHC

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
9	0.0250000	0.0250000	0	0.0250000	0	0	0

ANALYTE=alpha-CHLORDANE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
9	0.2500000	0.2500000	0	0.2500000	0	0	0

ANALYTE=beta-BHC

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
9	0.0250000	0.0250000	0	0.0250000	0	0	0

ANALYTE=beta-NAPHTHYLAMINE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	5.0000000	5.0000000	0	5.0000000	.	.	.

ANALYTE=cis-1,2-DICHLOROETHENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
979	0.0150000	2000.00	1999.99	18.2963739	130.6475300	4.1755132	714.0624204

ANALYTE=cis-1,3-DICHLOROPROPENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
3805	0.0300000	2500.00	2499.97	3.0006652	41.7891078	0.6899990	1392.66

ANALYTE=delta-BHC

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
9	0.0250000	0.0250000	0	0.0250000	0	0	0

ANALYTE=gamma-BHC (LINDANE)

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
9	0.0250000	0.0250000	0	0.0250000	0	0	0

ANALYTE=gamma-CHLORDANE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
9	0.2500000	0.2500000	0	0.2500000	0	0	0

ANALYTE=m+p CRESOL

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	7.0000000	7.0000000	0	7.0000000	.	.	.

ANALYTE=m+p XYLENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
716	0.0100000	12.0000000	11.9900000	0.1151816	0.5108360	0.0190908	443.5049815

ANALYTE=m-XYLENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
184	0.0100000	0.4000000	0.3900000	0.1093478	0.0900249	0.0066367	82.3289738

ANALYTE=n-BUTYLBENZENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
982	0.0150000	6.0000000	5.9850000	0.0964257	0.2025204	0.0064627	210.0275381

ANALYTE=n-PROPYLBENZENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
982	0.0150000	6.0000000	5.9850000	0.0980855	0.1962809	0.0062636	200.1119820

ANALYTE=o-CHLOROTOLUENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
982	0.0150000	6.0000000	5.9850000	0.1300764	0.1981314	0.0063226	152.3192475

ANALYTE=o-TOLUIDINE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	5.0000000	5.0000000	0	5.0000000	.	.	.

ANALYTE=o-XYLENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
916	0.0100000	1250.00	1249.99	1.5325416	41.6404445	1.3872443	2717.08

ANALYTE=p-BROMODIPHENYL ETHER

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
297	4.0000000	6.0000000	2.0000000	5.0067340	0.1297937	0.0075314	2.5923816

ANALYTE=p-CHLOROTOLUENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
983	0.0100000	6.0000000	5.9900000	0.1022991	0.1973434	0.0062943	192.9082407

ANALYTE=p-PHENYLENEDIAMINE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	10.0000000	10.0000000	0	10.0000000	.	.	.

ANALYTE=p-XYLENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
125	0.1000000	0.2500000	0.1500000	0.1496000	0.0702805	0.0062861	46.9789731

ANALYTE=sec-BUTYLBENZENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
981	0.0150000	230.0000000	229.9850000	0.5402141	9.3257176	0.2977472	1726.30

ANALYTE=tert-BUTYLBENZENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
983	0.0300000	6.0000000	5.9700000	0.1075381	0.1977270	0.0063065	183.8668518

ANALYTE=trans-1,2-DICHLOROETHENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1077	0.0150000	140.0000000	139.9850000	0.5414670	4.5935048	0.1399704	848.3443127

ANALYTE=trans-1,3-DICHLOROPROPENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
3777	0.0300000	2500.00	2499.97	3.0248132	41.9484710	0.6952891	1386.81

ANALYTE=trans-1,4-DICHLORO-2-BUTENE

N Obs	Minimum	Maximum	Range	Mean	Std Dev	Std Error	CV
1	10.0000000	10.0000000	0	10.0000000	.	.	.

Analysis Variable : RESULT2

ANALYTE=ALKALINITY AS CACO3

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
51	0	3151000.00	0	3151000.00	238713.73	437088.62	61204.65	183.1015876

ANALYTE=AMMONIA

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
165	15.0000000	284000.00	0	283985.00	1851.48	22101.72	1720.62	1193.73

ANALYTE=BICARBONATE AS CACO3

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
3546	500.0000000	2000000.00	0	1999500.00	249613.12	164942.06	2769.89	66.0790817

ANALYTE=BROMIDE

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
8	1000.00	5000.00	0	4000.00	2750.00	1101.95	389.5968612	40.0707756

ANALYTE=CARBONATE

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
3509	0	3000000.00	4	3000000.00	4065.79	52074.37	879.5894389	1280.79

ANALYTE=CHEMICAL OXYGEN DEMAND

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
191	0	300090.00	0	300090.00	12298.22	24029.58	1738.72	195.3907014

ANALYTE=CHLORIDE

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
3442	-760.0000000	3010000.00	0	3010760.00	83468.14	160742.90	2739.85	192.5799483

ANALYTE=CYANIDE

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2432	0.0100000	10000.00	0	9999.99	24.3022167	355.6756281	7.2122757	1463.55

ANALYTE=FLUORIDE

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
3533	25.0000000	25000.00	1	24975.00	850.2171574	1182.02	19.8890277	139.0253621

ANALYTE=NITRATE

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
127	10.0000000	1450000.00	0	1449990.00	27037.97	147075.30	13050.82	543.9582829

ANALYTE=NITRATE/NITRITE

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
3500	10.0000000	8260000.00	0	8259990.00	55846.74	365359.41	6175.70	654.2179802

ANALYTE=NITRITE

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
319	5.0000000	2500.00	0	2495.00	144.1630094	482.0490447	26.9895650	334.3777622

ANALYTE=OIL AND GREASE

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
4	600.0000000	5000.00	0	4400.00	1800.00	2135.42	1067.71	118.6342028

ANALYTE=ORTHOPHOSPHATE

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2594	2.1000000	8278.71	0	8276.61	74.7578984	328.4339947	6.4485655	439.3301600

ANALYTE=PETROLEUM HYDROCARBONS, TOTAL RECOVERABL

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
1	100.0000000	100.0000000	0	0	100.0000000	.	.	.

ANALYTE=SILICA

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
2907	1100.00	59000.00	0	57900.00	12719.67	6867.26	127.3681783	53.9892943

ANALYTE=SULFATE

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
3607	100.0000000	19000000.00	0	18999900.00	181277.41	506285.56	8429.90	279.2877209

ANALYTE=TOTAL DISSOLVED SOLIDS

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
3582	2500.00	88000000.00	0	87997500.00	1017109.30	2783969.47	46515.93	273.7138943

ANALYTE=TOTAL ORGANIC CARBON

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
220	400.0000000	111400.00	0	111000.00	3635.05	8174.11	551.0986442	224.8696465

ANALYTE=TOTAL ORGANIC HALOGENS (TOX)

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
104	7.3000000	92000.00	0	91992.70	4253.33	15737.80	1543.22	370.0108614

ANALYTE=TOTAL SUSPENDED SOLIDS

N Obs	Minimum	Maximum	Nmiss	Range	Mean	Std Dev	Std Error	CV
3384	500.0000000	47000000.00	0	46999500.00	677427.57	2324573.53	39960.24	343.1471684

ANALYTE=pH

D. Representative Stiff Plots for Groundwater

The Stiff plots contained in this appendix depict the major-ion chemistry of dissolved constituents in groundwater, as measured in samples obtained from groundwater wells from across the Rocky Flats site. Each plot is representative of the major-ion chemistry of groundwater at each sampling site. Two-hundred-eighty-seven wells are represented in this appendix.

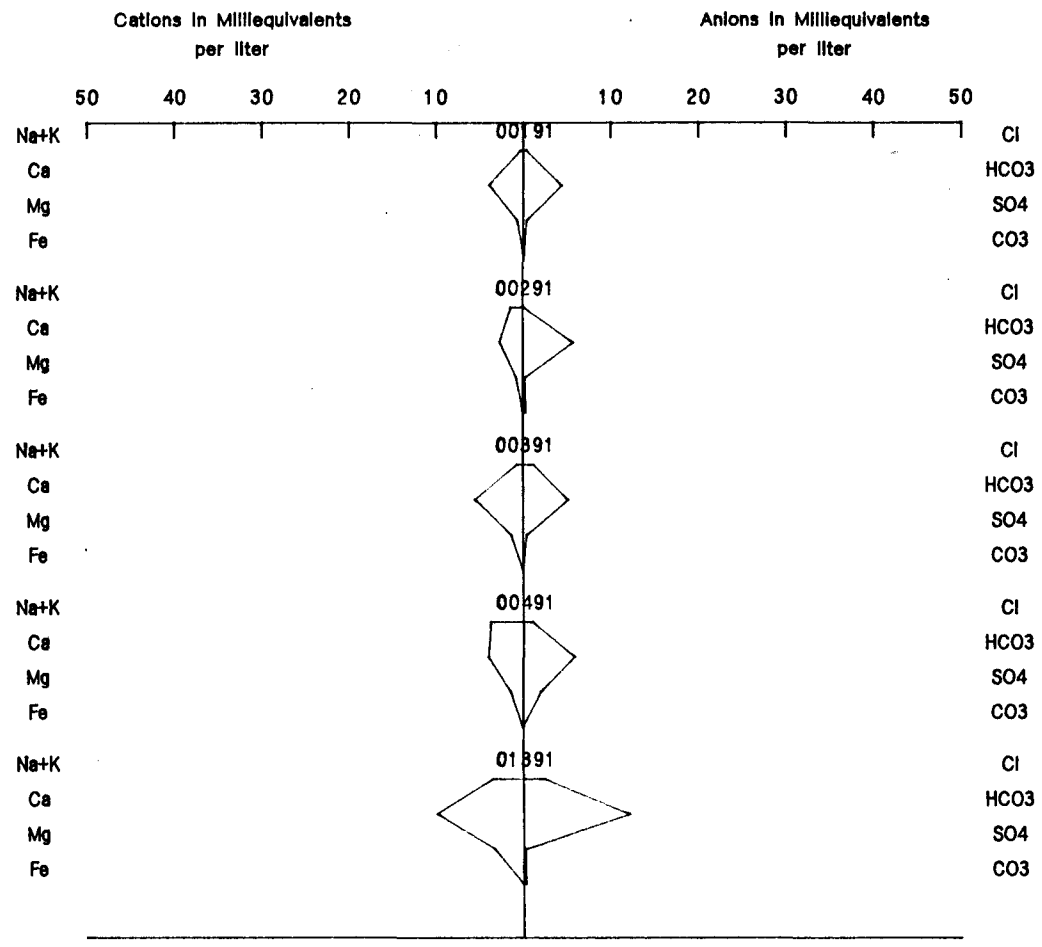
The relative sizes of Stiff diagrams are meaningful in that the higher the TDS content of the water, the larger the area of the diagram (providing that the scale of display remains constant). The shape of the Stiff diagram also conveys useful information, particularly for use as a pattern-recognition tool. The shape is determined by the concentrations of four major metals (Ca, Mg, K, Na) and four important anions (HCO_3, CO_3, Cl, SO_4), expressed in units of milliequivalents per liter (meq/L).

Stiff diagrams can be useful for understanding the evolution in major-ion chemistry along a groundwater flow path. There are a number of factors that affect groundwater chemistry along a flow path, including ion-exchange reactions, oxidation/reduction reactions, and mineral dissolution/precipitation processes. Also, in downgradient areas, some changes in chemistry may be the result of local groundwater contamination. In addition, the groundwaters in different hydrostratigraphic units may have different major-ion chemistries, hence different sizes and shapes of Stiff plots that allow for quick visual recognition of the various groundwaters.

Plotted Values

0.36	00191	0.34
3.99		4.40
0.73		0.35
0.00		0.03
1.38	00291	0.14
2.70		5.80
0.81		0.25
0.00		0.33
0.66	00391	1.24
5.44		5.20
1.32		0.50
0.00		0.03
3.67	00491	1.10
3.95		6.00
1.37		2.08
0.01		0.03
3.43	01391	2.51
9.83		12.20
3.29		0.29
0.00		0.33

Plotted values converted from mg/L to meq/L

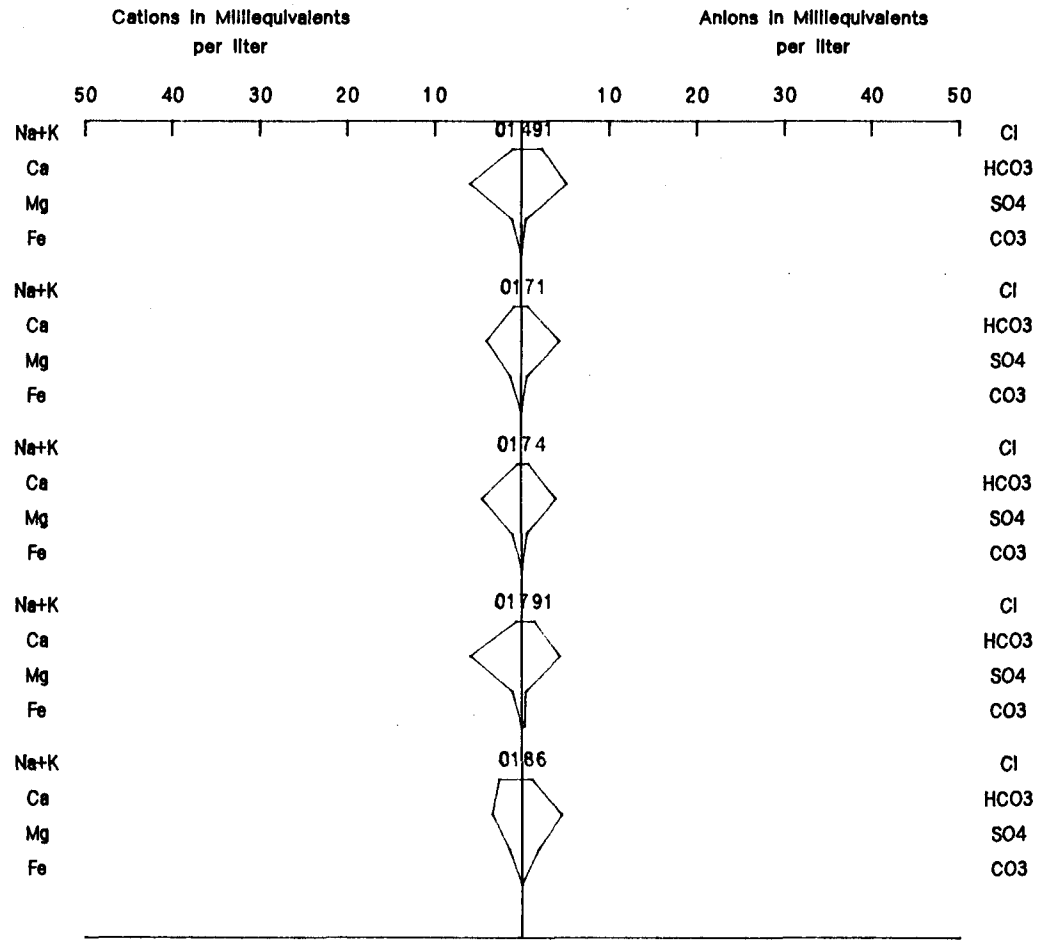


HC-GRAM 2.19

Plotted Values

1.03	01491	2.29
5.94		5.20
1.06		0.54
0.00		0.03
0.82	0171	0.71
4.02		4.40
1.27		0.67
0.00		0.03
0.39	0174	0.85
4.51		4.00
1.07		0.60
0.00		0.03
0.59	01791	1.47
5.89		4.40
1.04		0.46
0.00		0.33
2.62	0186	1.16
3.41		4.60
1.41		1.89
0.00		0.03

Plotted values converted from mg/L to meq/L

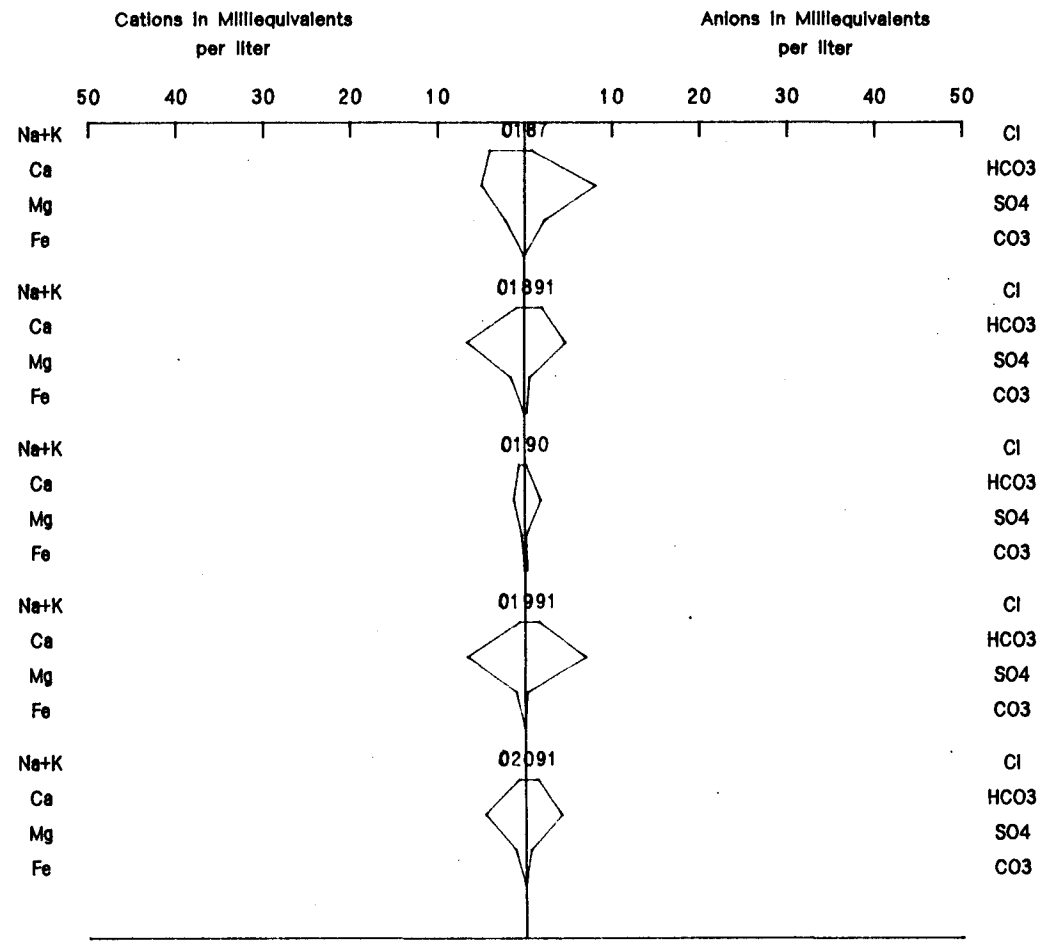


HC-GRAM 2.1 9

Plotted Values

3.96	01187	0.90
4.92		8.20
2.16		2.29
0.03		0.03
0.80	01891	2.06
6.54		4.80
1.51		0.65
0.00		0.33
0.58	01990	0.21
1.24		1.92
0.33		0.20
0.00		0.33
0.56	01991	1.69
6.59		7.00
0.96		0.33
0.00		0.03
0.71	02091	1.50
4.61		4.20
1.11		0.67
0.00		0.03

Plotted values converted from mg/L to meq/L

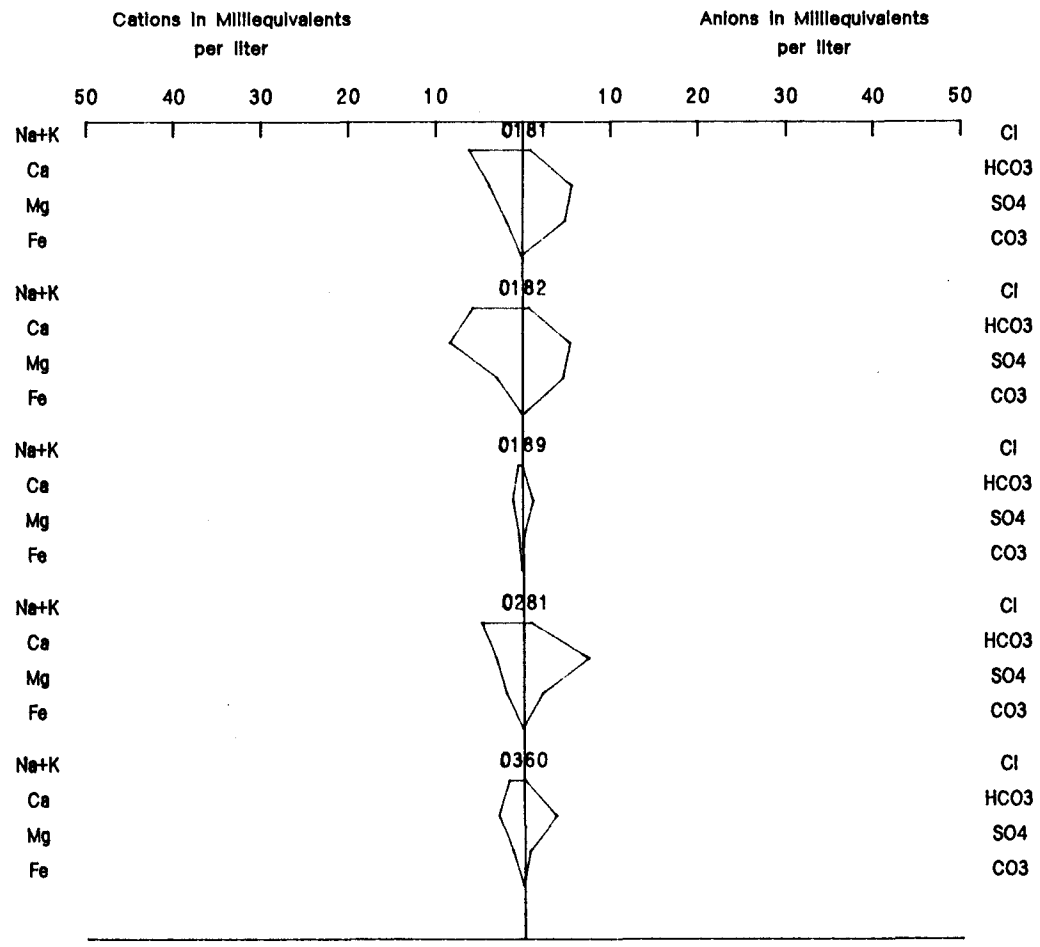


HC-GRAM 2.1 9

Plotted Values

6.00	0181	1.02
3.69		5.80
1.74		5.00
0.00		0.03
5.60	0182	0.85
8.18		5.60
2.80		4.79
0.00		0.40
0.33	0189	0.08
1.00		1.34
0.28		0.31
0.01		0.17
4.69	0281	1.04
3.03		7.60
1.84		2.29
0.00		0.03
1.60	0360	0.25
2.80		3.80
1.25		0.75
0.00		0.03

Plotted values converted from mg/L to meq/L

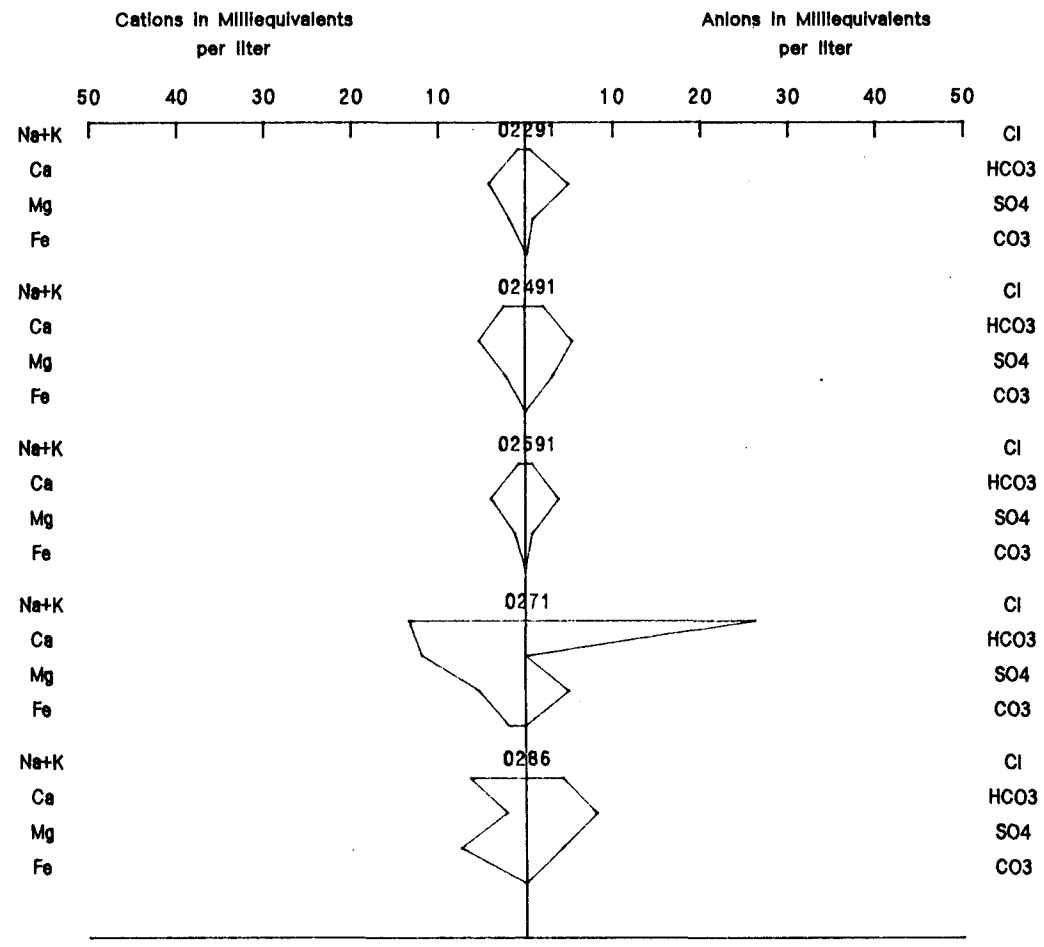


HC-GRAM 2.19

Plotted Values

0.92	02291	0.45
4.32		4.92
1.92		0.79
0.00		0.14
2.46	02491	2.06
5.34		5.40
2.25		3.12
0.00		0.05
0.73	02591	0.78
3.96		3.84
1.16		0.82
0.00		0.05
13.31	0271	26.24
11.83		0.08
5.31		5.00
1.91		0.03
6.32	0286	4.29
2.10		8.20
7.42		4.16
0.00		0.03

Plotted values converted from mg/L to meq/L

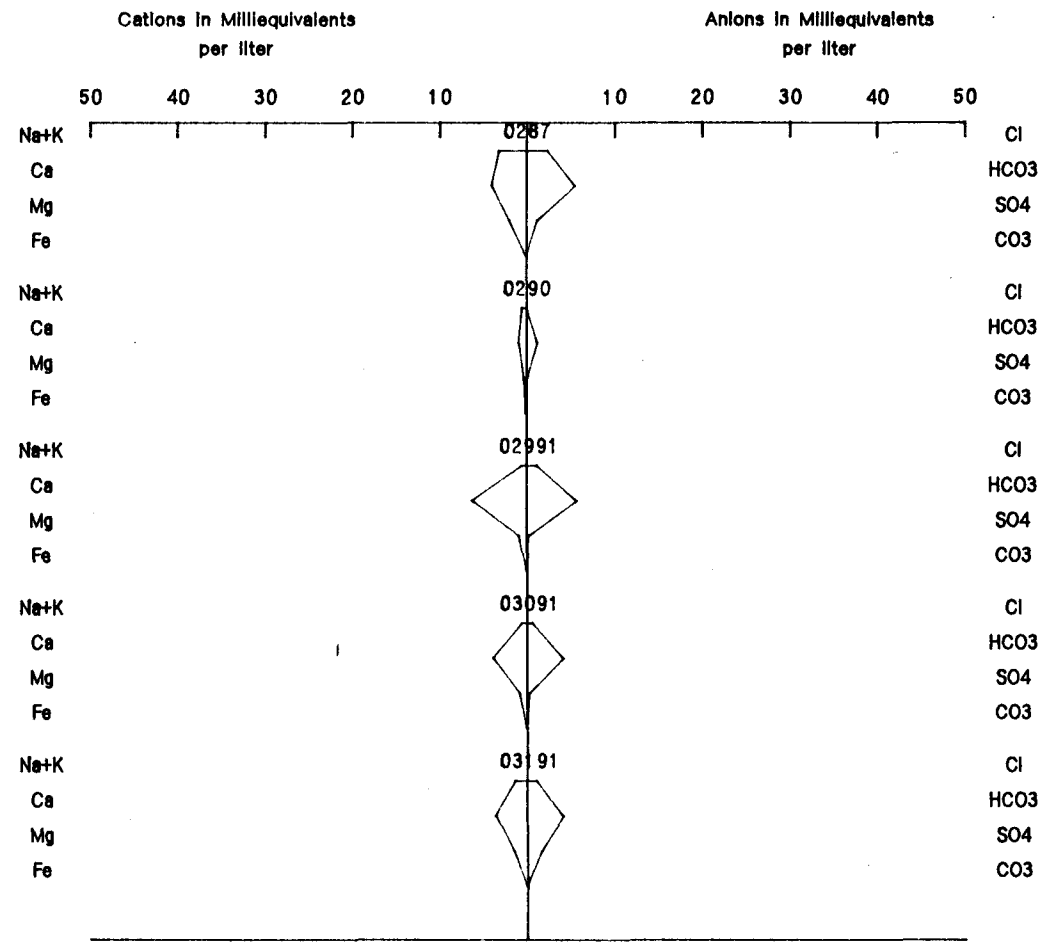


HC-GRAM 2.19

Plotted Values

3.10	0287	2.43
3.98		5.60
1.92		1.29
0.00		0.03
0.47	0290	0.01
0.85		1.32
0.25		0.12
0.00		0.03
0.51	02991	1.24
6.19		5.80
0.83		0.31
0.00		0.03
0.54	03091	0.68
3.84		4.20
0.78		0.35
0.00		0.03
1.34	03191	1.13
3.56		4.20
1.49		1.67
0.00		0.03

Plotted values converted from mg/L to meq/L

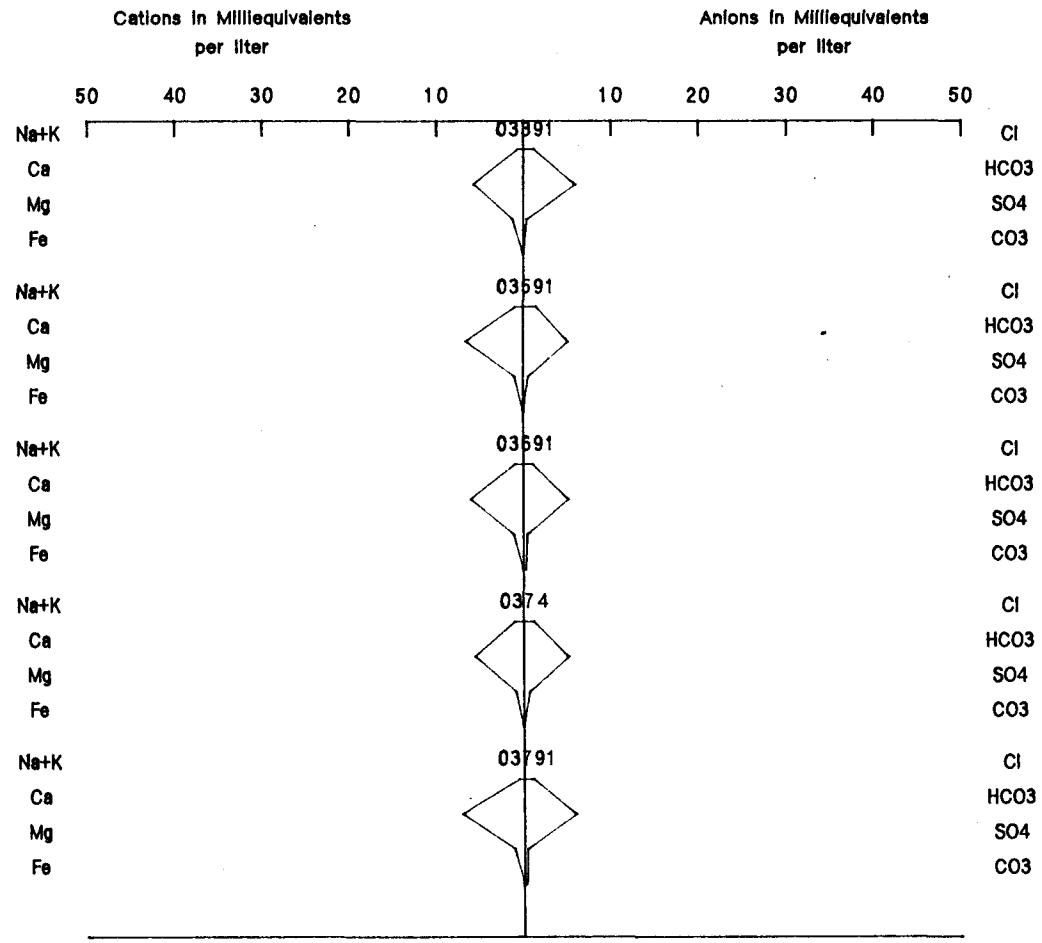


HC-GRAM 2.19

Plotted Values

0.60	03391	1.24
5.69		6.00
1.19		0.44
0.00		0.03
0.84	03591	1.55
6.59		5.20
0.96		0.62
0.00		0.03
0.91	03691	1.10
6.04		5.20
1.06		0.48
0.00		0.33
0.97	0374	1.24
5.54		5.20
0.87		0.73
0.00		0.03
0.55	03791	1.13
7.09		6.00
1.09		0.37
0.00		0.33

Plotted values converted from mg/L to meq/L

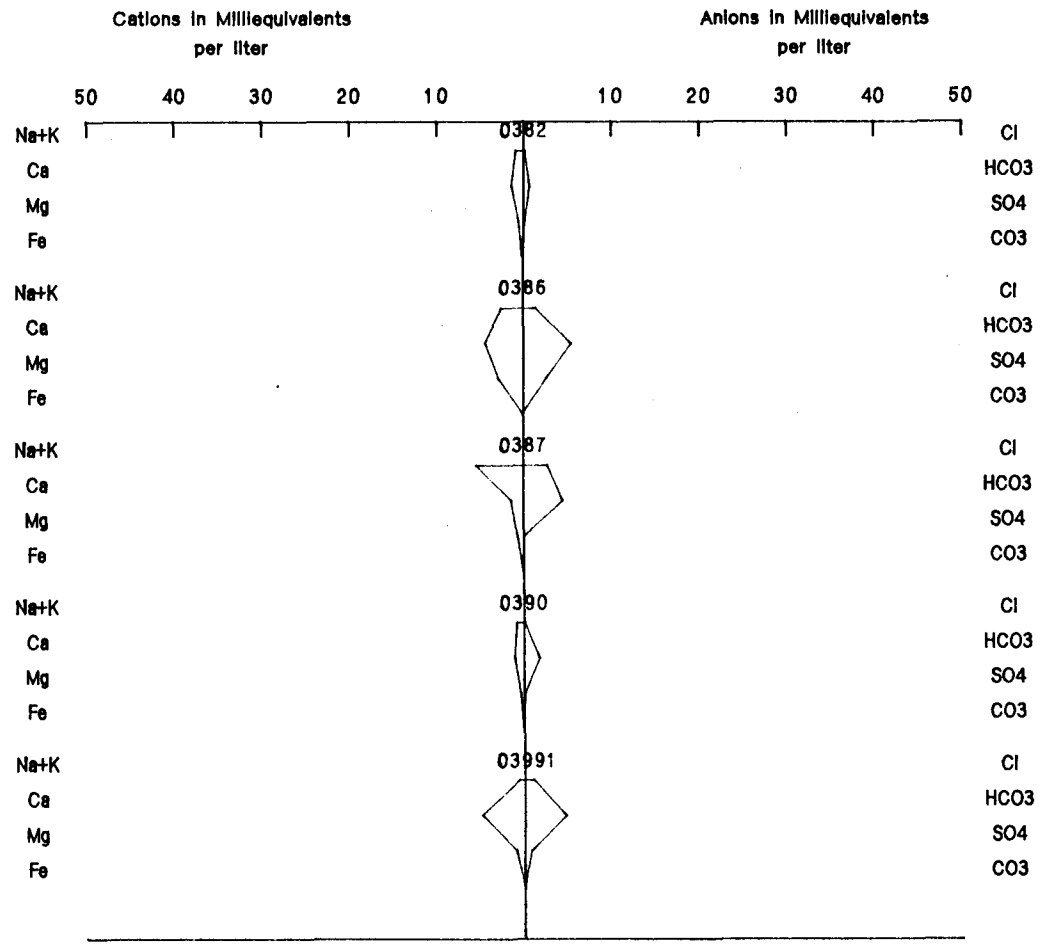


HC-GRAM 2.19

Plotted Values

0.73	0382	0.27
1.24		0.84
0.42		0.29
0.00		0.03
2.37	0386	1.58
4.27		5.60
2.71		2.71
0.00		0.03
5.28	0387	2.82
1.32		4.60
0.62		0.08
0.00		0.03
0.75	0390	0.08
1.02		1.84
0.36		0.15
0.00		0.03
0.58	03991	1.07
4.85		4.80
0.91		0.83
0.00		0.03

Plotted values converted from mg/L to meq/L

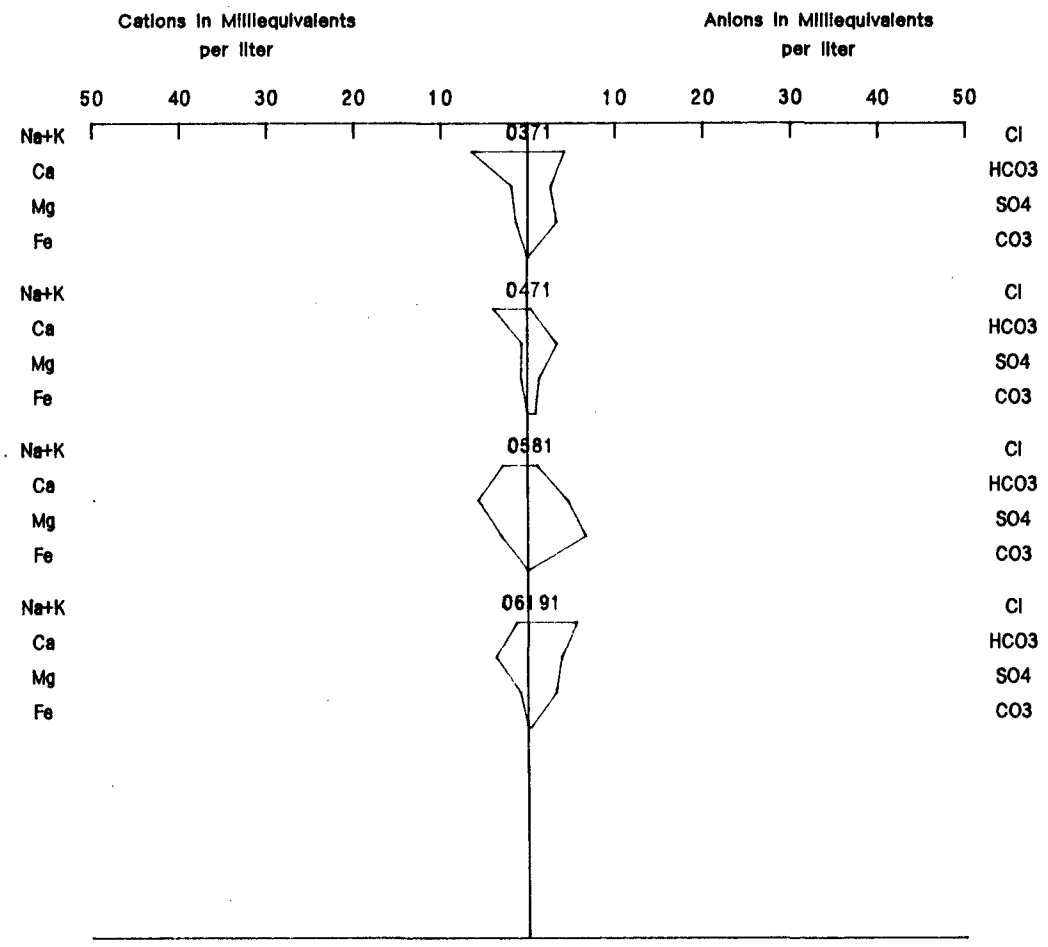


HC-GRAM 2.1 9

Plotted Values

6.44	0371	4.23
1.89		2.60
1.37		3.33
0.09		0.03
3.93	0471	0.37
0.65		3.40
0.72		1.33
0.00		0.93
2.89	0581	1.07
5.74		4.60
3.10		6.66
0.00		0.03
1.34	06191	5.56
3.68		3.90
0.90		3.25
0.00		0.33

Plotted values converted from mg/L to meq/L

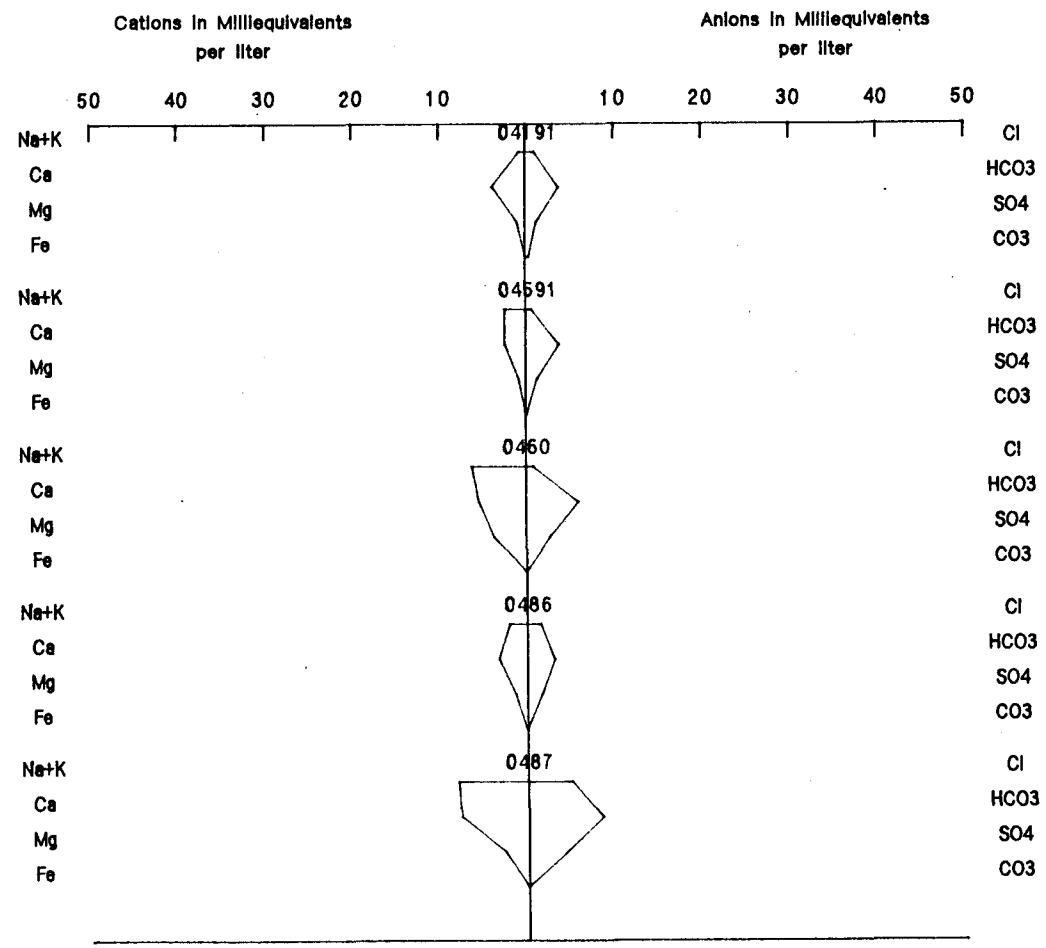


HC-GRAM 2.19

Plotted Values

0.78	04191	0.94
3.91		3.74
1.00		1.17
0.00		0.33
2.48	04591	0.57
2.48		3.78
0.81		1.24
0.00		0.07
6.22	0460	0.85
5.44		6.00
3.67		2.71
0.00		0.03
1.96	0486	1.58
3.27		3.20
1.32		1.71
0.00		0.03
7.93	0487	5.08
7.63		8.60
2.65		4.37
0.00		0.03

Plotted values converted from mg/L to meq/L

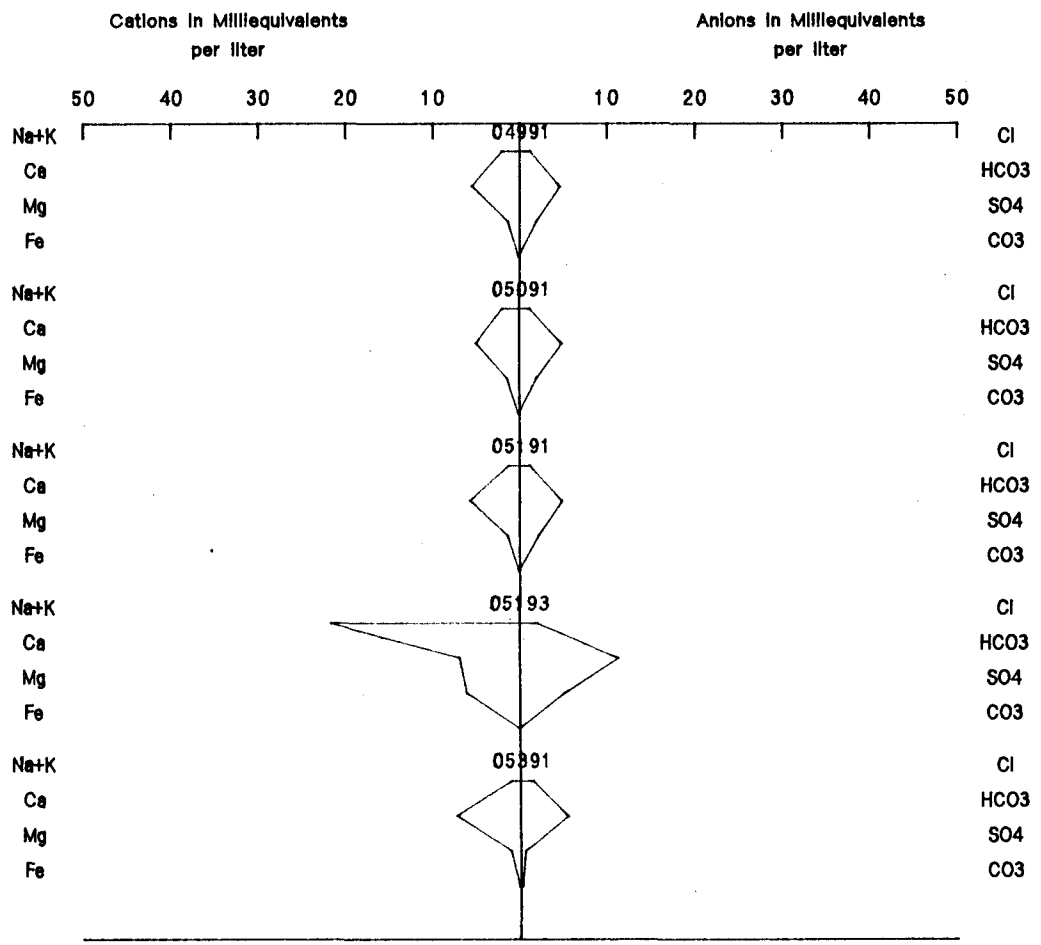


HC-GRAM 2.1 9

Plotted Values

1.91	04991	1.33
5.34		4.80
1.23		2.06
0.00		0.03
1.86	05091	1.31
4.84		5.00
1.31		2.08
0.00		0.03
1.15	05191	1.30
5.59		5.00
1.27		2.29
0.00		0.03
21.47	05193	2.16
6.79		11.42
5.98		5.19
0.00		0.06
0.89	05391	1.61
7.19		5.60
0.95		0.67
0.00		0.33

Plotted values converted from mg/L to meq/L

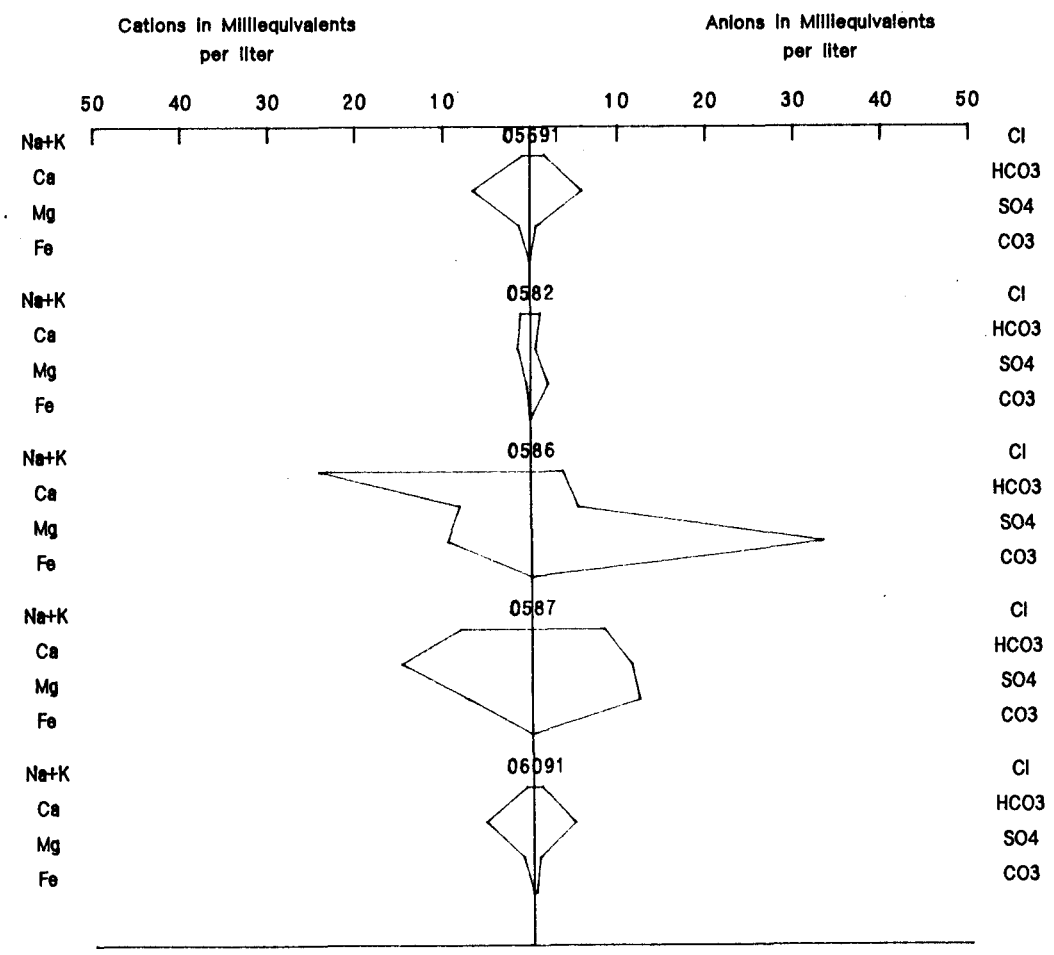


HC-GRAM 2.19

Plotted Values

0.83	05691	1.66
6.54		6.00
1.20		0.77
0.00		0.03
1.11	0582	1.13
1.48		0.60
0.45		2.08
0.00		0.03
24.10	0586	3.67
8.08		5.40
9.54		33.31
0.00		0.17
8.08	0587	8.29
14.82		11.40
7.21		12.28
0.00		0.03
0.76	06091	1.02
5.39		4.80
1.11		0.77
0.00		0.33

Plotted values converted from mg/L to meq/L

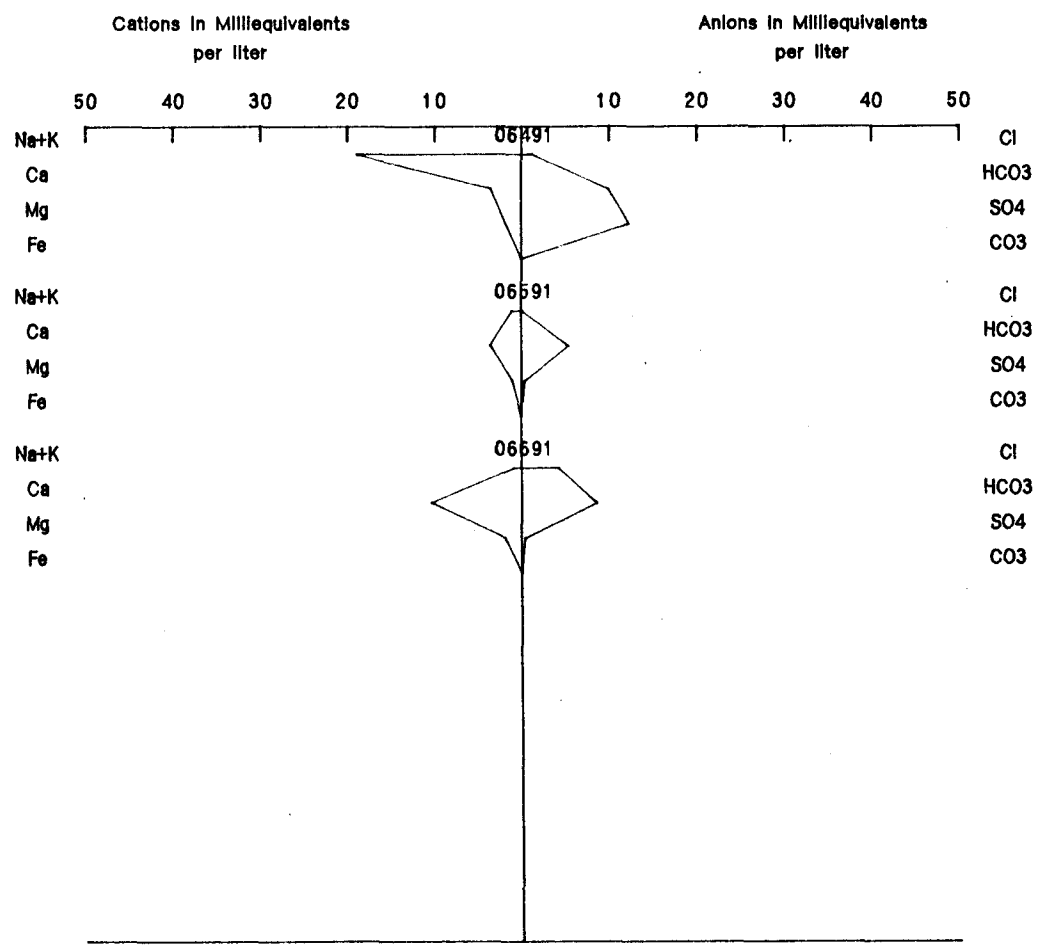


HC-GRAM 2.19

Plotted Values

18.86	06491	1.27
3.49		10.00
1.80		12.28
0.00		0.03
1.04	06591	0.14
3.60		5.40
1.04		0.40
0.00		0.03
0.85	06691	4.23
10.38		8.60
1.88		0.44
0.00		0.03

Plotted values converted from mg/L to meq/L

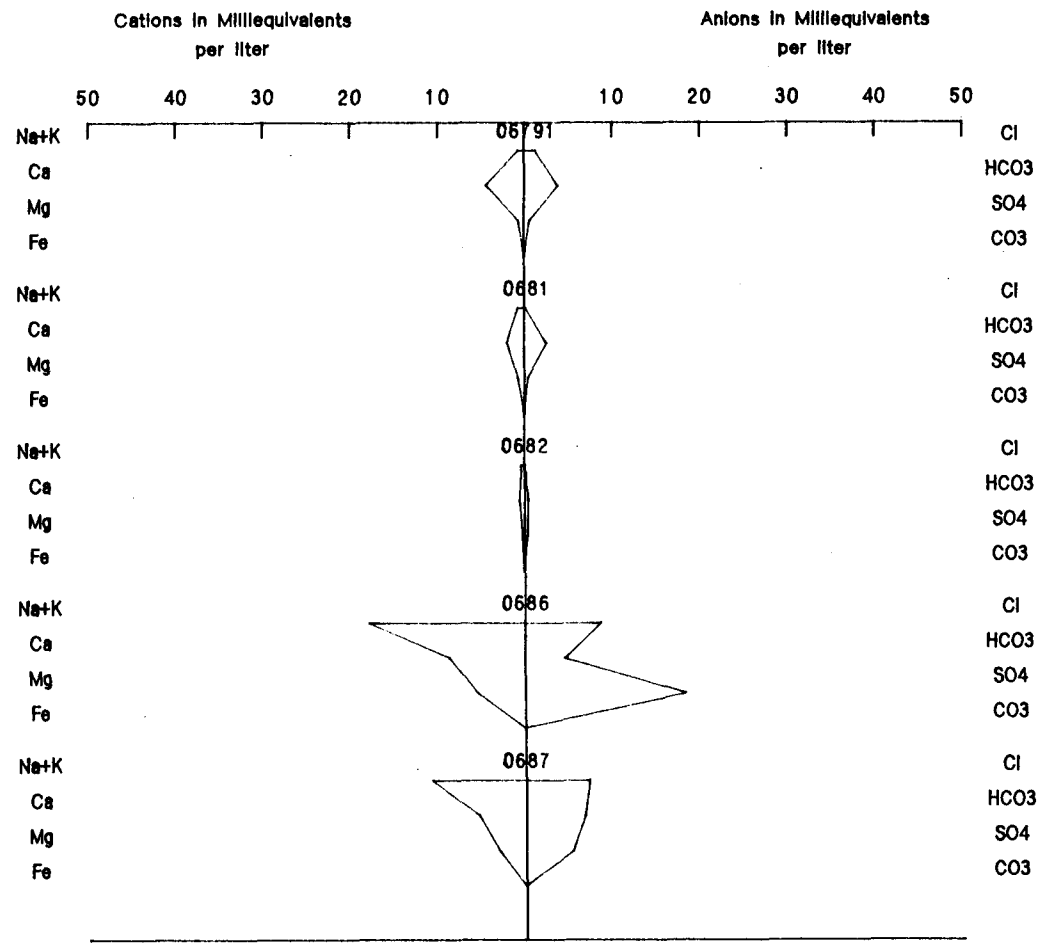


HC-GRAM 2.19

Plotted Values

0.68	06791	1.21
4.45		3.80
0.69		0.60
0.00		0.03
0.70	0681	0.14
1.97		2.60
0.71		0.42
0.00		0.03
0.26	0682	0.15
0.53		0.48
0.16		0.42
0.00		0.03
17.75	0686	8.75
8.58		4.60
5.43		18.32
0.00		0.03
10.66	0687	7.33
5.29		6.80
2.99		5.41
0.00		0.03

Plotted values converted from mg/L to meq/L

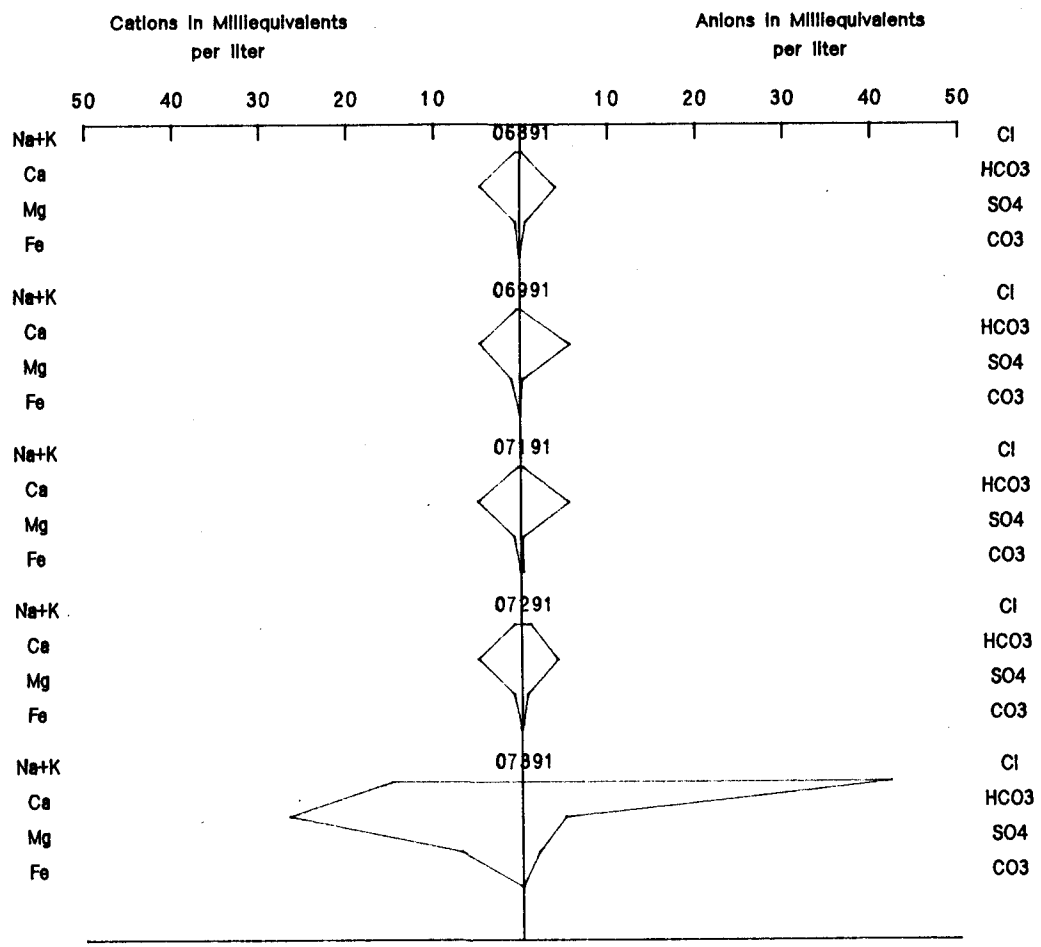


HC-GRAM 2.19

Plotted Values

0.49	06891	0.23
4.59		4.20
0.46		0.71
0.00		0.03
0.31	06991	0.08
4.60		5.80
0.95		0.31
0.00		0.03
0.29	07191	0.28
4.87		5.60
0.72		0.29
0.00		0.33
0.78	07291	1.08
4.93		4.20
0.87		0.69
0.00		0.06
14.82	07391	42.32
26.65		5.00
6.96		1.94
0.00		0.03

Plotted values converted from mg/L to meq/L

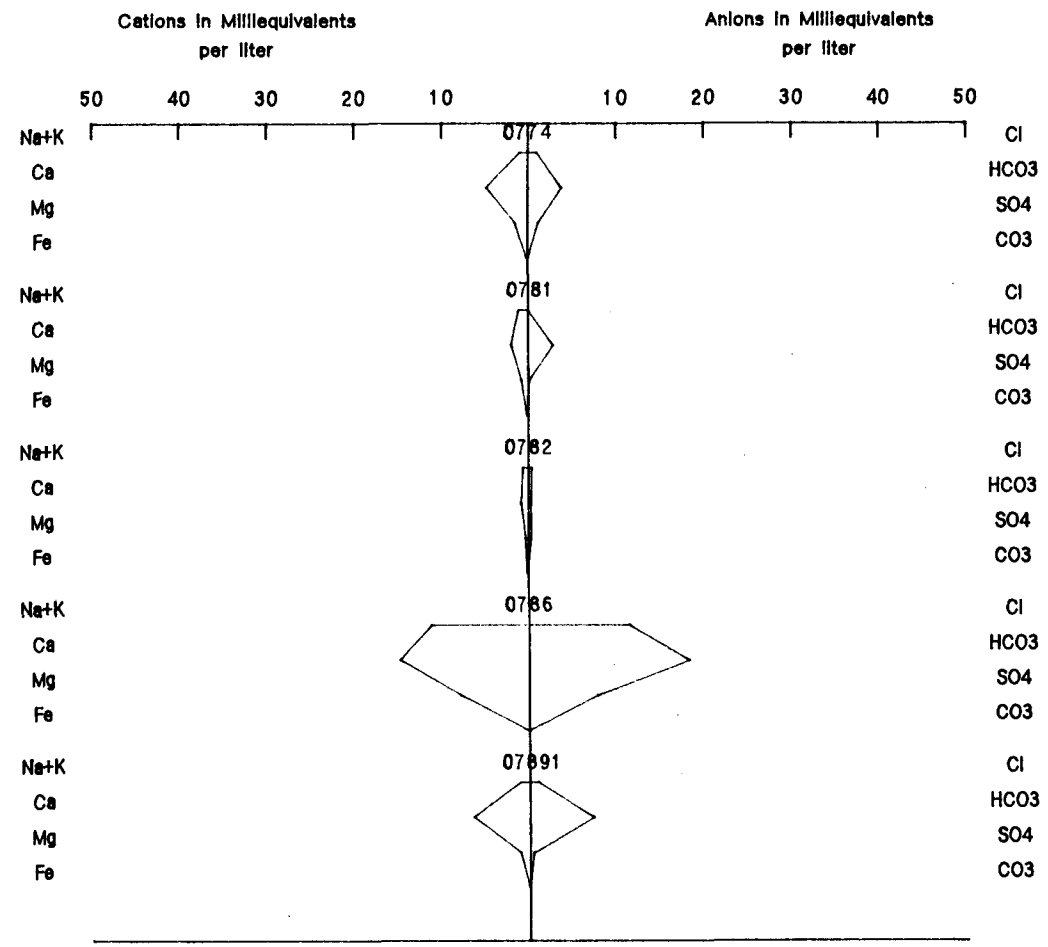


HC-GRAM 2.1 9

Plotted Values

0.81	0774	1.13
4.69		4.00
1.35		1.33
0.00		0.20
0.95	0781	0.14
1.86		3.00
0.65		0.27
0.00		0.03
0.49	0782	0.51
0.72		0.44
0.20		0.50
0.00		0.03
11.13	0786	11.57
14.72		18.40
7.79		7.91
0.13		0.17
1.04	07891	1.04
6.44		7.40
1.04		0.48
0.00		0.03

Plotted values converted from mg/L to meq/L

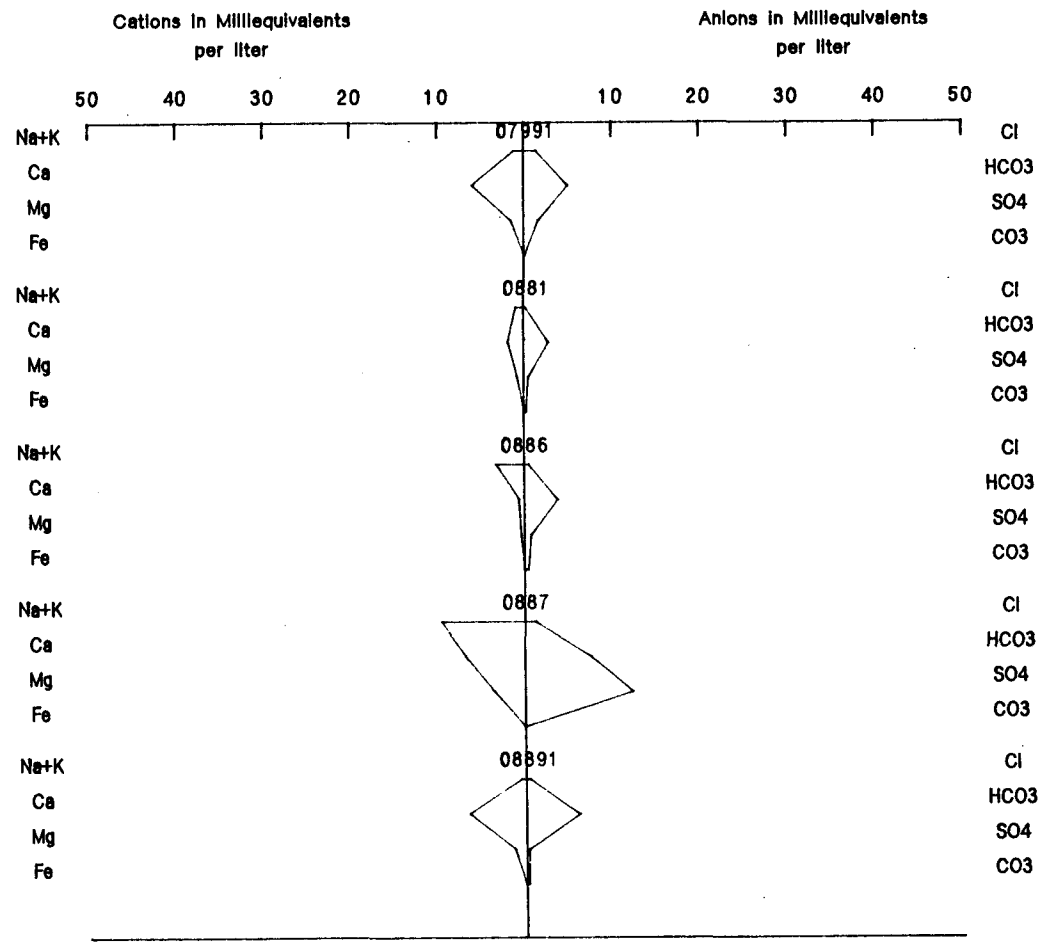


HC-GRAM 2.19

Plotted Values

1.20	07991	1.35
6.04		5.00
1.58		1.60
0.00		0.03
0.96	0881	0.14
1.92		2.80
0.82		0.46
0.01		0.20
3.28	0886	0.48
0.65		3.80
0.41		0.77
0.00		0.43
9.53	0887	1.27
6.79		7.60
3.49		12.28
0.00		0.03
0.47	08891	0.54
6.44		6.20
1.28		0.37
0.00		0.33

Plotted values converted from mg/L to meq/L

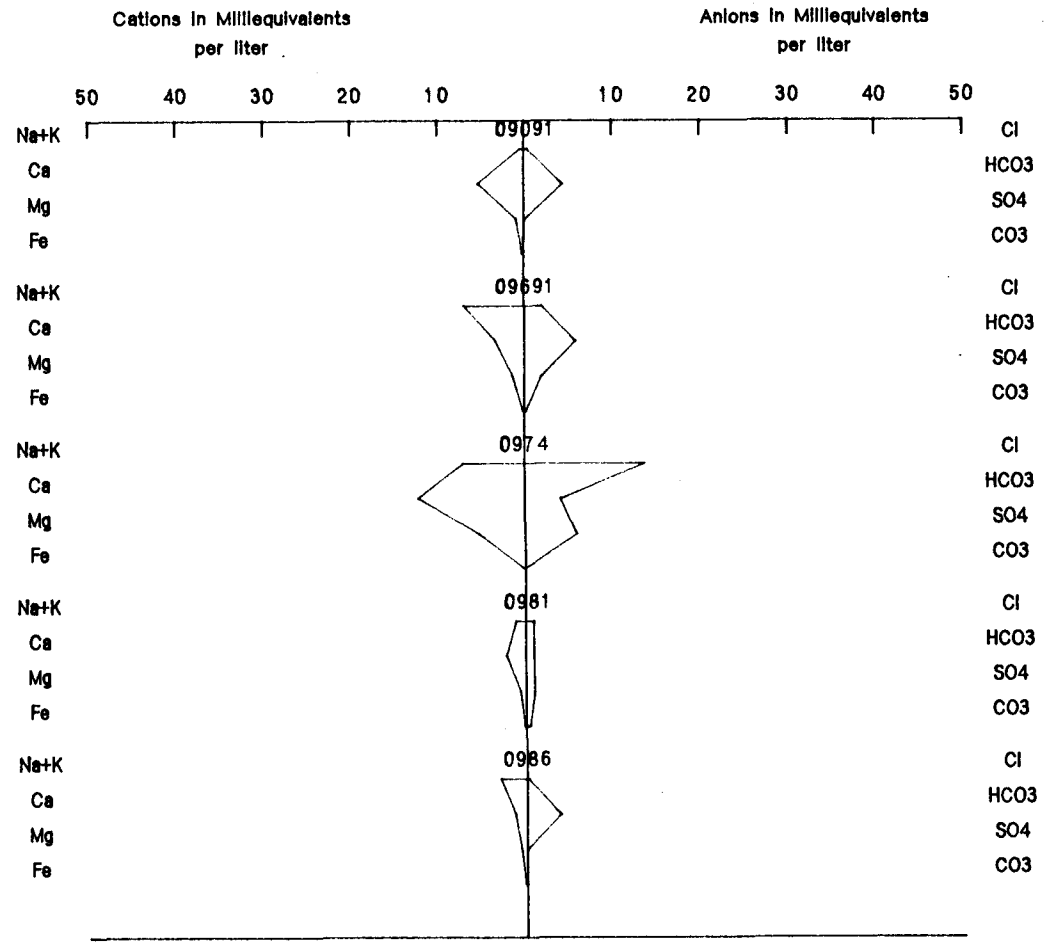


HC-GRAM 2.1 9

Plotted Values

0.28	09091	0.56
5.09		4.60
0.73		0.27
0.00		0.03
6.76	09691	2.17
3.21		6.00
1.20		2.08
0.00		0.33
6.94	0974	13.82
12.08		4.20
5.22		6.04
0.00		0.03
0.95	0981	1.07
2.08		1.10
0.50		1.17
0.00		0.60
2.86	0986	0.34
1.21		4.00
0.51		0.12
0.00		0.13

Plotted values converted from mg/L to meq/L

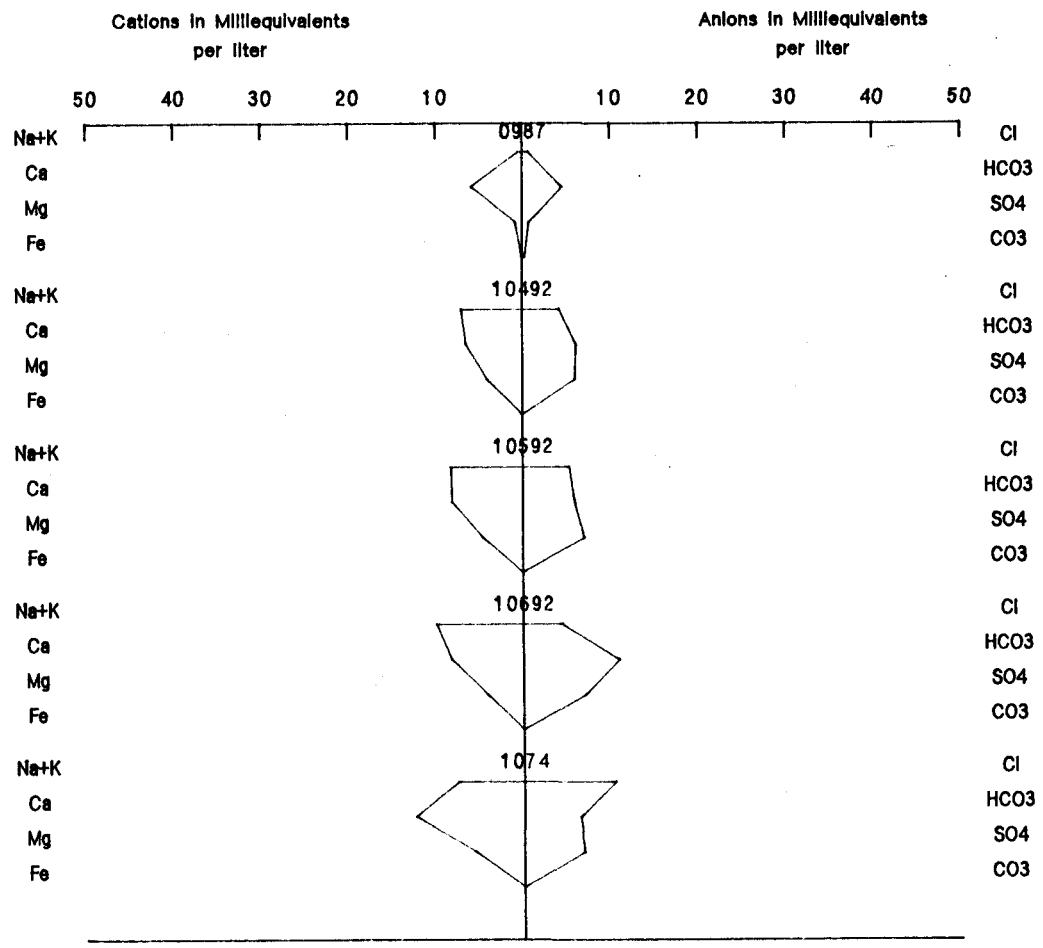


HC-GRAM 2.19

Plotted Values

0.42	0987	0.73
5.84		4.60
0.79		0.83
0.00		0.33
7.00	10492	4.23
6.44		6.20
4.03		6.04
0.00		0.03
8.23	10592	5.36
8.13		6.00
4.59		7.08
0.00		0.05
9.95	10692	4.51
8.23		11.00
4.14		7.08
0.00		0.03
7.58	1074	10.44
12.47		6.40
5.63		6.87
0.00		0.03

Plotted values converted from mg/L to meq/L

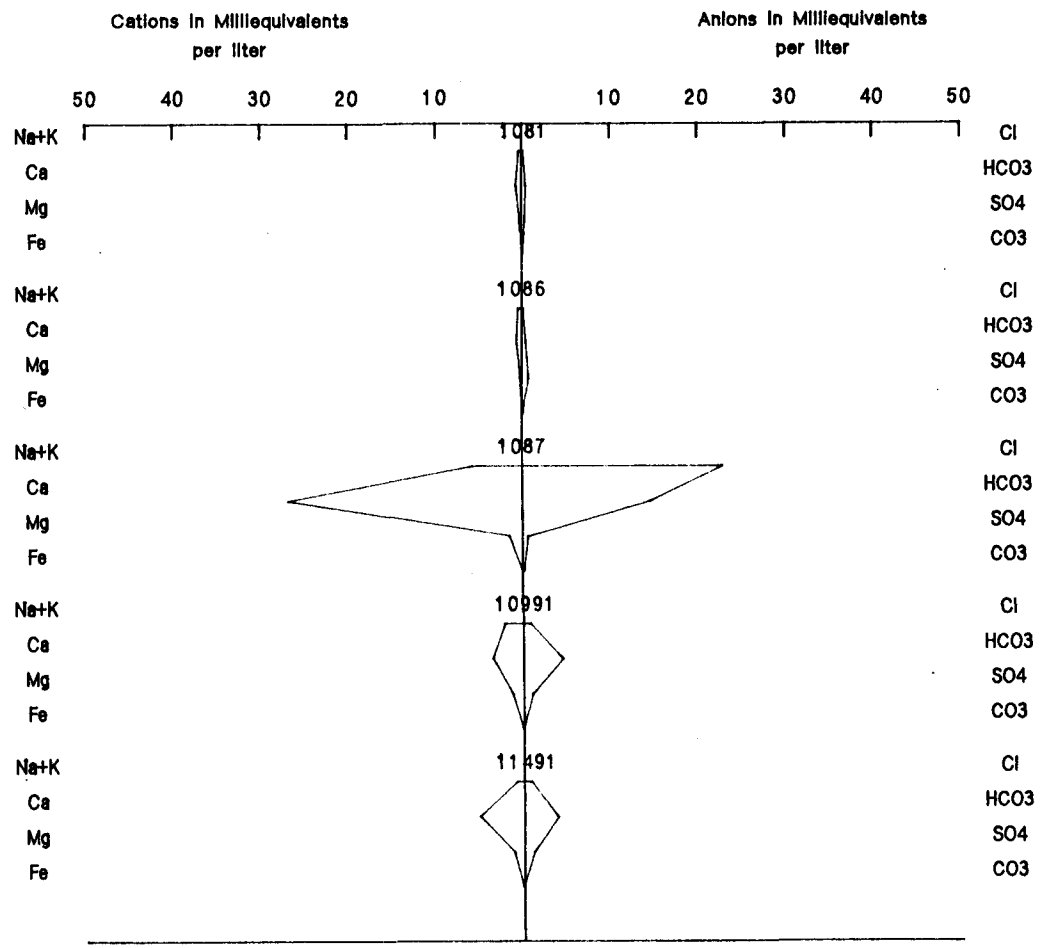


HC-GRAM 2.1 9

Plotted Values

0.34	1081	0.17
0.63		0.48
0.21		0.35
0.00		0.03
0.49	1086	0.08
0.62		0.44
0.23		0.75
0.00		0.03
5.68	1087	22.85
26.85		14.60
1.52		0.65
0.02		0.17
2.04	10991	0.87
3.47		4.60
1.21		1.10
0.00		0.03
0.68	11491	0.93
4.96		4.00
1.04		1.27
0.00		0.03

Plotted values converted from mg/L to meq/L

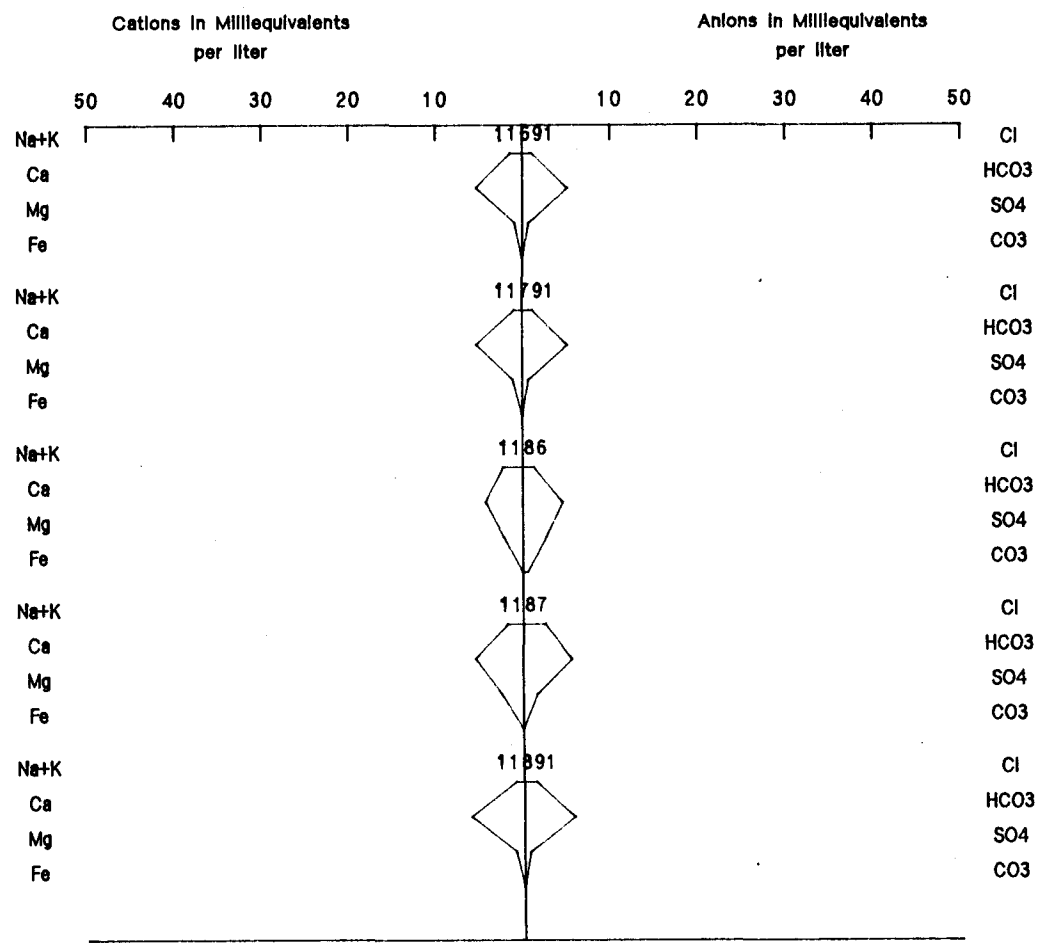


HC-GRAM 2.1 9

Plotted Values

1.35	11691	1.13
5.29		5.20
0.85		0.75
0.00		0.03
0.88	11791	1.16
5.24		5.20
1.08		0.73
0.01		0.03
2.22	1186	1.30
4.27		4.60
2.17		2.71
0.00		0.60
1.81	1187	2.51
5.44		5.60
2.48		1.62
0.00		0.00
0.91	11891	1.44
6.04		5.80
0.93		0.69
0.00		0.03

Plotted values converted from mg/L to meq/L

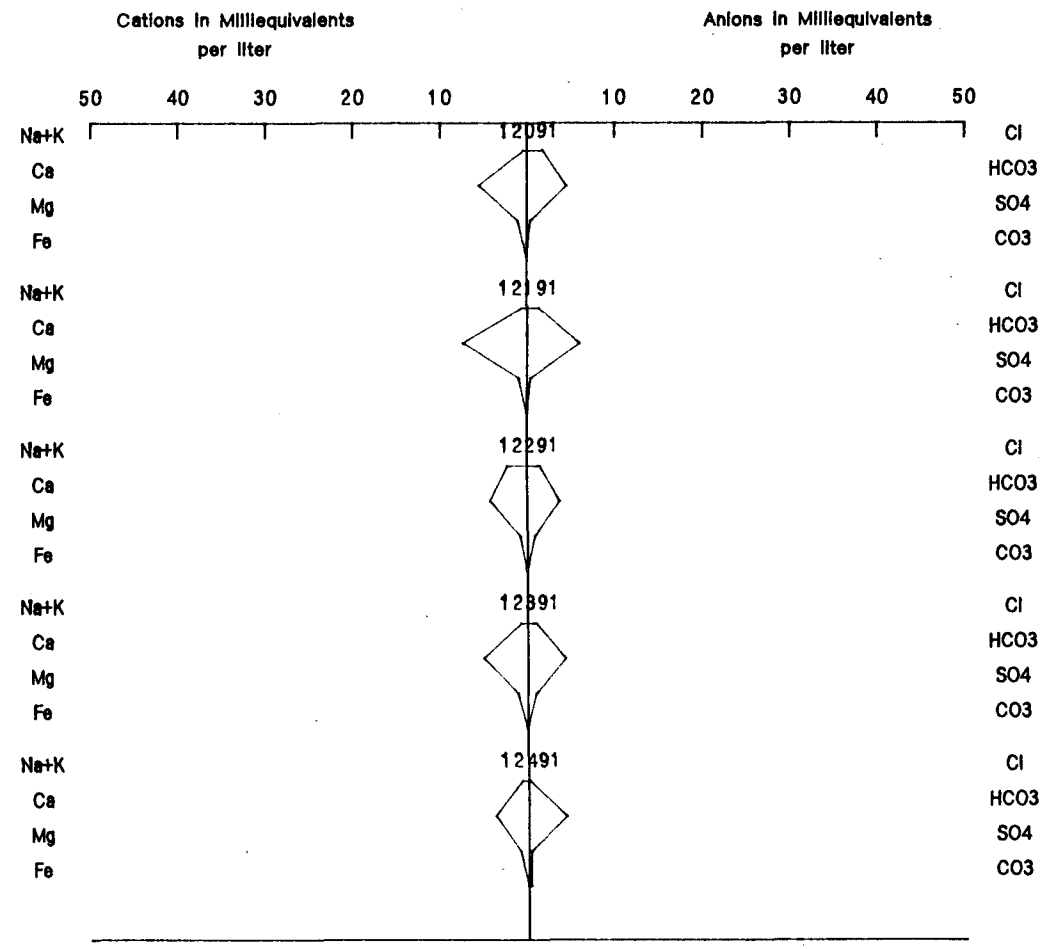


HC-GRAM 2.1 9

Plotted Values

0.38	12091	1.83
5.49		4.60
1.00		0.44
0.00		0.03
0.57	12191	1.39
7.29		6.11
0.91		0.45
0.00		0.04
2.20	12291	1.55
4.22		3.80
0.80		0.90
0.00		0.03
0.69	12391	1.07
4.97		4.40
1.08		1.02
0.00		0.03
0.69	12491	0.22
3.76		4.40
0.92		0.33
0.00		0.33

Plotted values converted from mg/L to meq/L

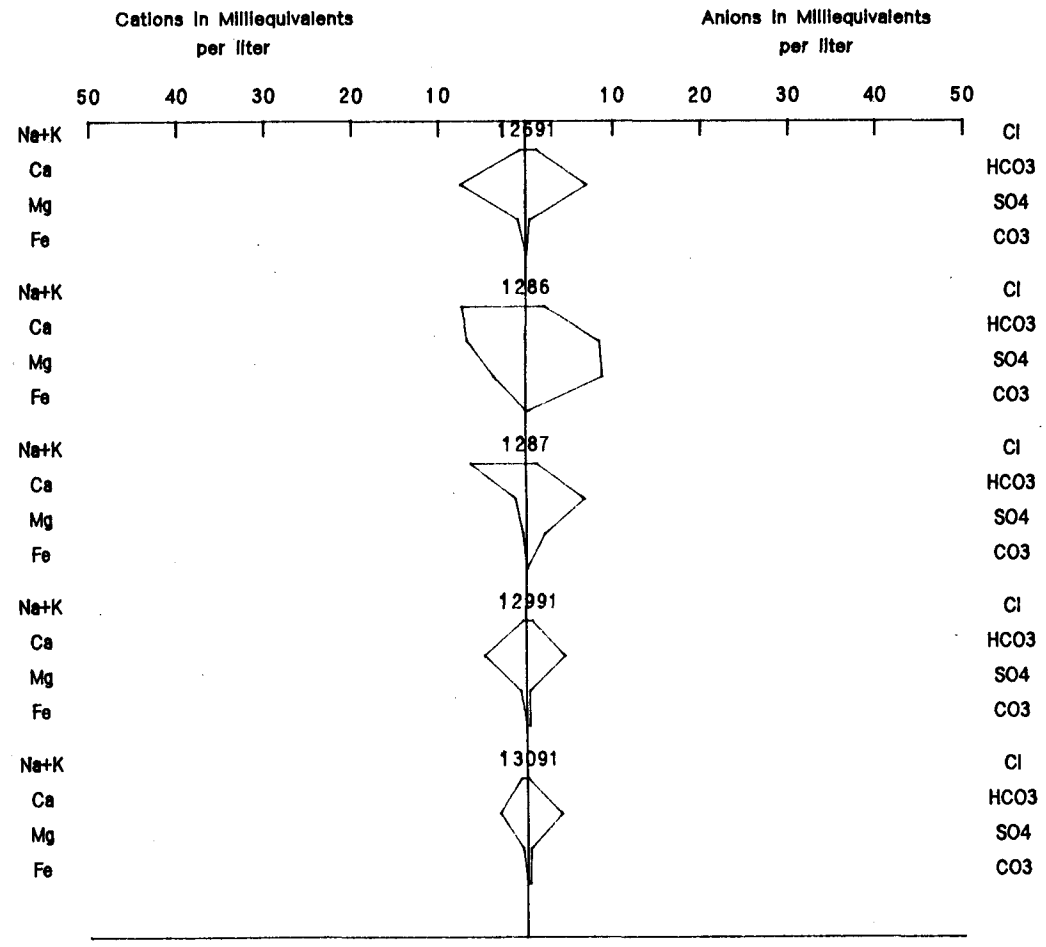


HC-GRAM 2.1 9

Plotted Values

0.63	12691	1.24
7.53		7.00
0.90		0.44
0.00		0.03
7.46	1286	2.09
6.79		8.40
3.73		8.74
0.00		0.03
6.42	1287	1.18
1.36		6.60
0.50		2.04
0.00		0.00
0.38	12991	0.65
4.85		4.40
0.71		0.33
0.00		0.33
0.63	13091	0.14
3.13		4.00
0.49		0.42
0.00		0.33

Plotted values converted from mg/L to meq/L

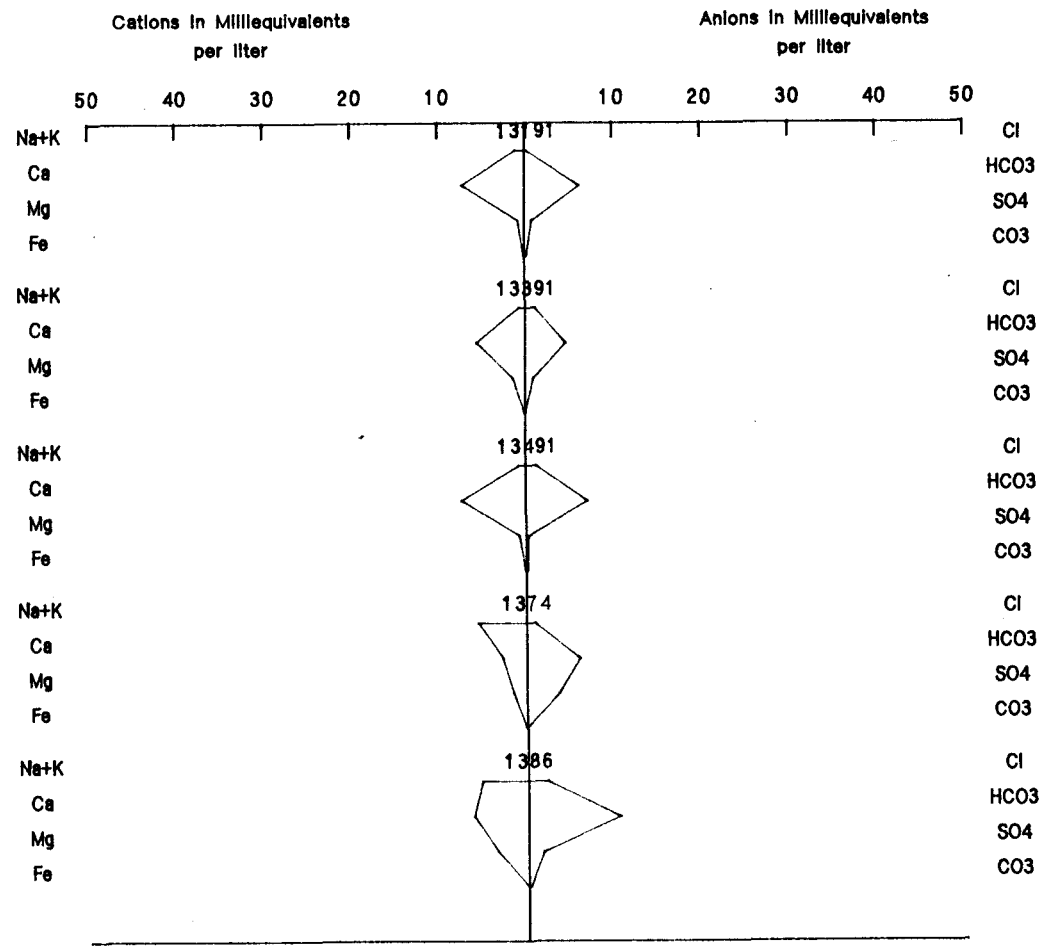


HC-GRAM 2.1 9

Plotted Values

1.00	13191	0.31
7.09		6.40
0.65		0.96
0.00		0.33
0.67	13391	1.19
5.49		4.80
1.34		1.08
0.00		0.07
0.67	13491	1.33
7.24		7.19
0.69		0.36
0.00		0.21
5.41	1374	1.04
2.66		6.20
1.46		3.75
0.00		0.03
5.17	1386	2.31
6.14		10.60
3.42		1.81
0.00		0.33

Plotted values converted from mg/L to meq/L

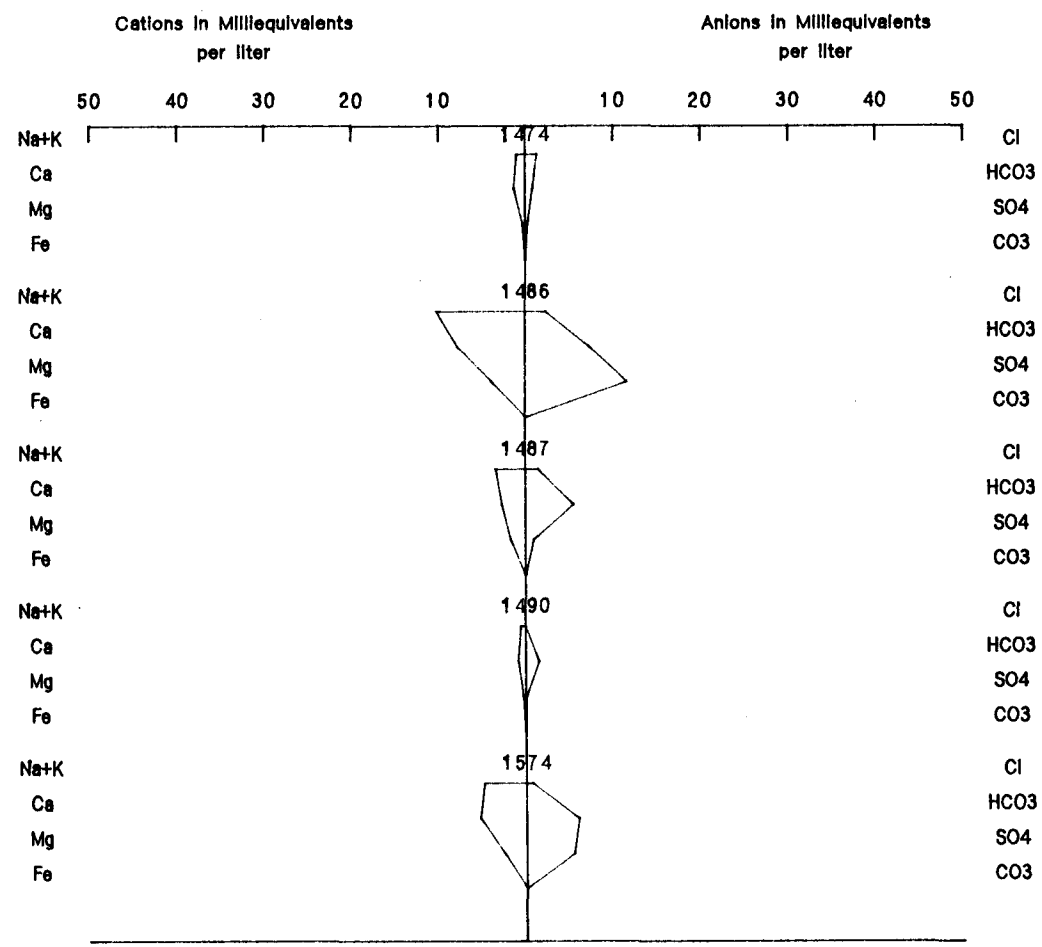


HC-GRAM 2.19

Plotted Values

0.95	1474	1.35
1.29		0.84
0.31		0.29
0.00		0.03
10.12	1486	2.37
7.78		7.40
3.83		11.66
0.00		0.33
3.38	1487	1.49
2.68		5.52
1.72		0.99
0.00		0.12
0.51	1490	0.04
0.81		1.56
0.26		0.12
0.00		0.03
4.82	1574	0.73
5.34		6.00
2.57		5.41
0.00		0.03

Plotted values converted from mg/L to meq/L

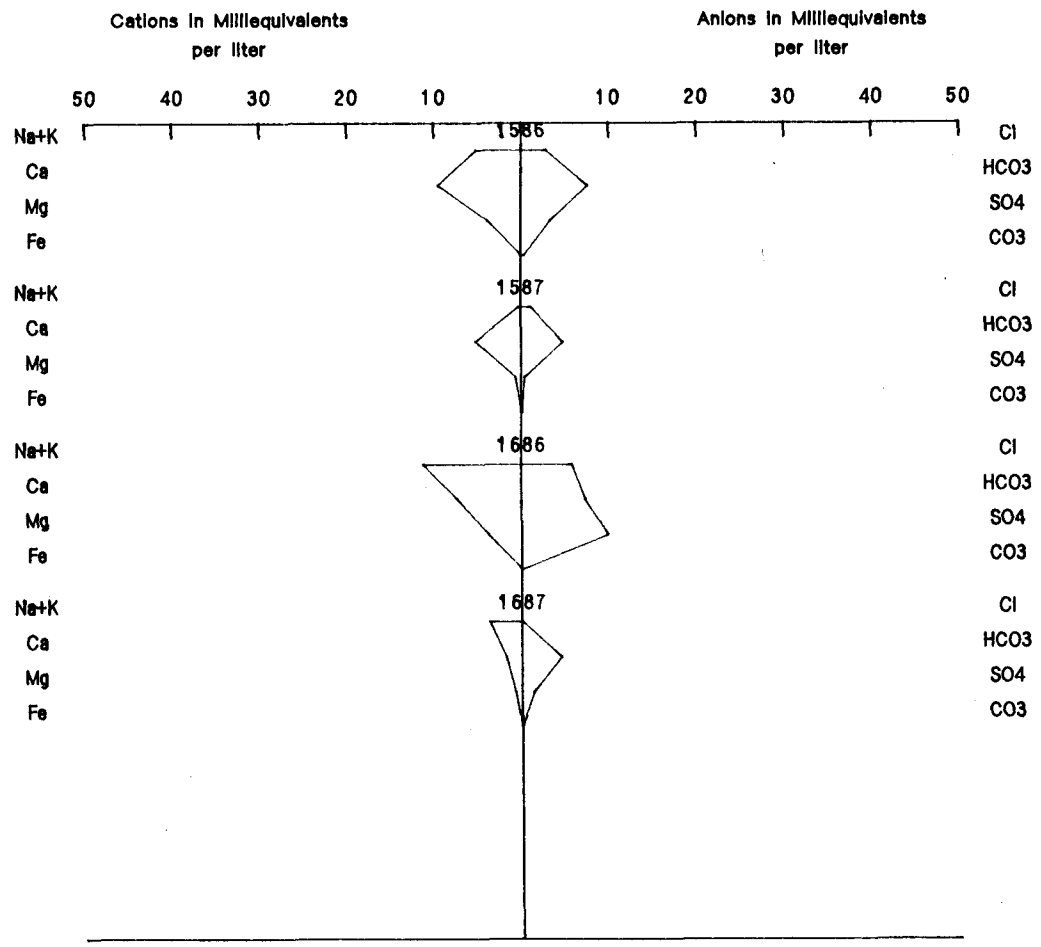


HC-GRAM 2.1 9

Plotted Values

5.23	1586	2.82
9.53		7.60
3.87		3.33
0.00		0.33
0.38	1587	1.11
5.34		4.70
0.74		0.33
0.00		0.05
11.25	1686	5.74
7.34		7.28
3.83		9.85
0.00		0.04
3.66	1687	0.11
1.83		4.60
0.68		1.42
0.00		0.03

Plotted values converted from mg/L to meq/L

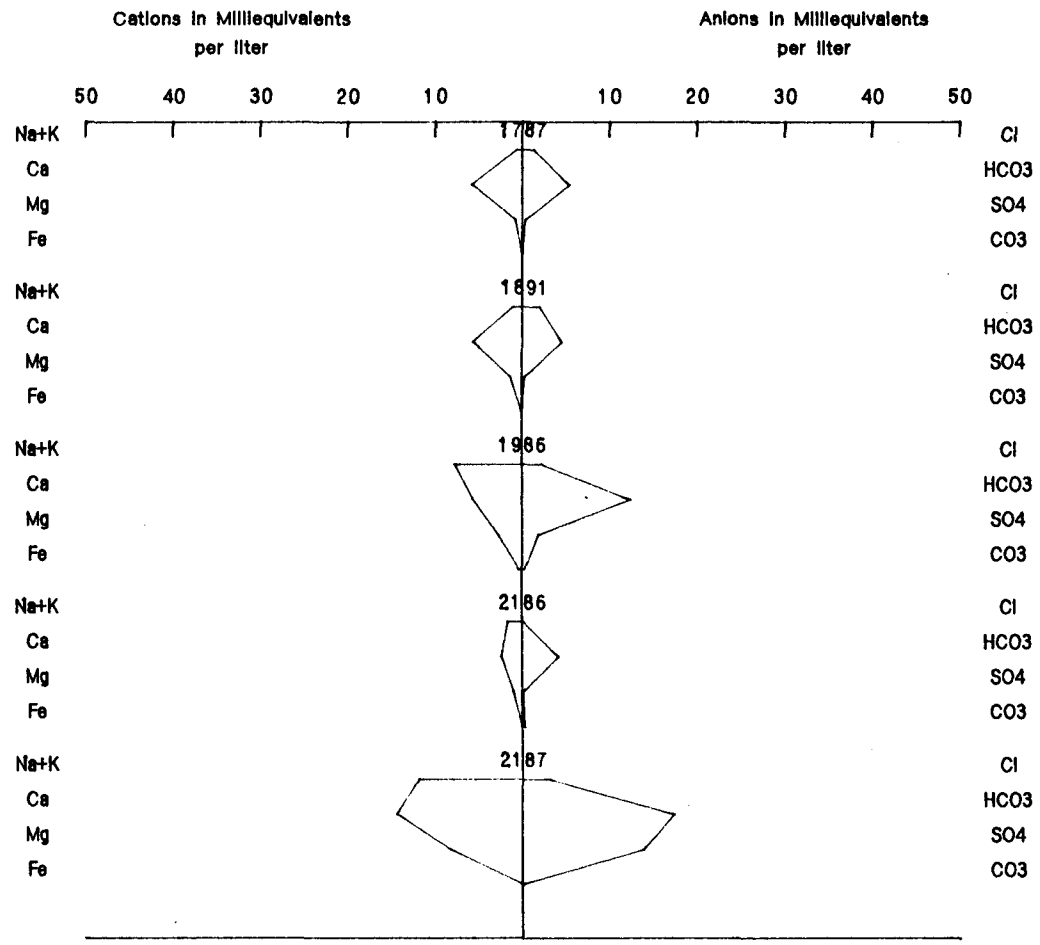


HC-GRAM 2.1 9

Plotted Values

0.65	1787	1.38
5.79		5.40
0.79		0.37
0.00		0.03
1.06	1891	2.06
5.64		4.60
1.30		0.35
0.00		0.03
7.66	1986	2.29
5.64		12.40
2.76		1.90
0.33		0.33
1.61	2186	0.14
2.37		4.20
0.98		0.15
0.00		0.33
11.87	2187	3.10
14.37		17.40
8.31		13.85
0.00		0.07

Plotted values converted from mg/L to meq/L

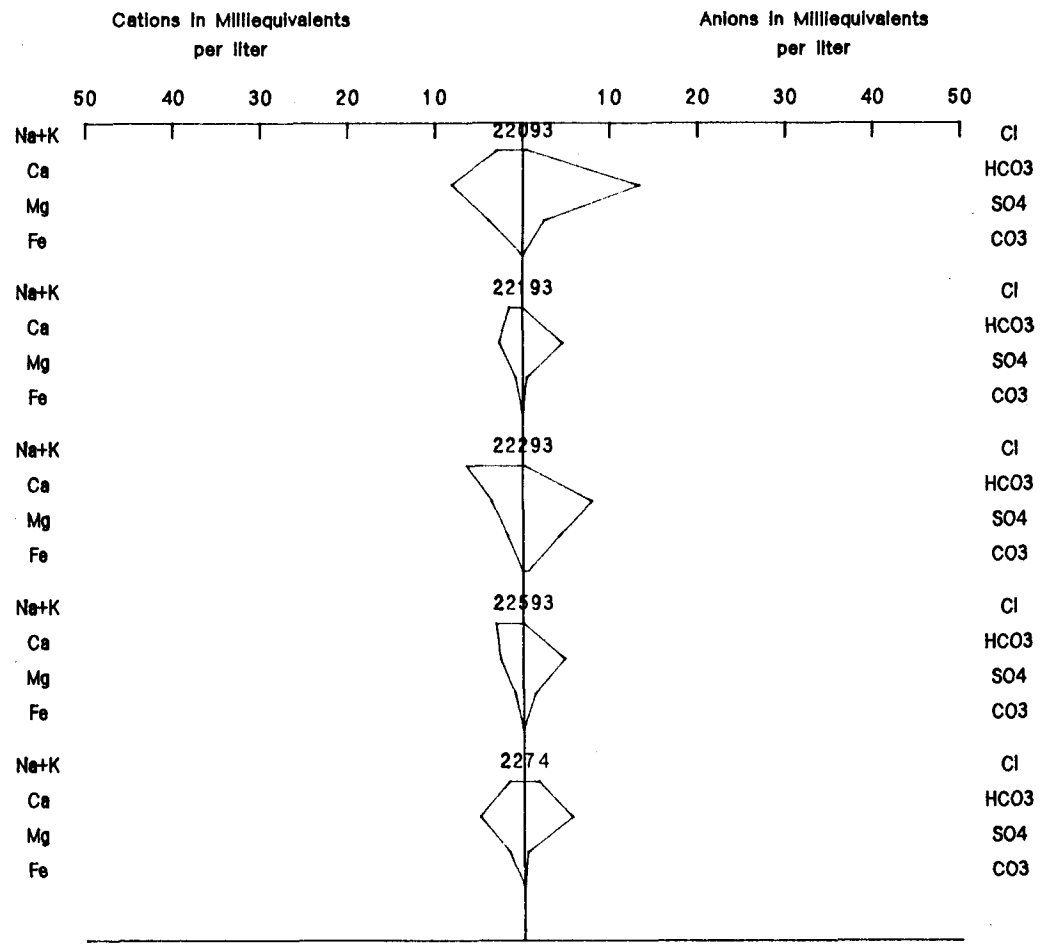


HC-GRAM 2.19

Plotted Values

2.89	22093	0.56
8.08		13.40
3.87		2.50
0.00		0.08
1.47	22193	0.07
2.69		4.60
0.79		0.48
0.00		0.03
6.28	22293	0.31
3.48		8.00
1.70		4.16
0.00		0.67
3.06	22593	0.13
2.54		4.84
0.90		1.37
0.00		0.04
1.64	2274	1.75
4.97		5.60
1.62		0.50
0.00		0.03

Plotted values converted from mg/L to meq/L

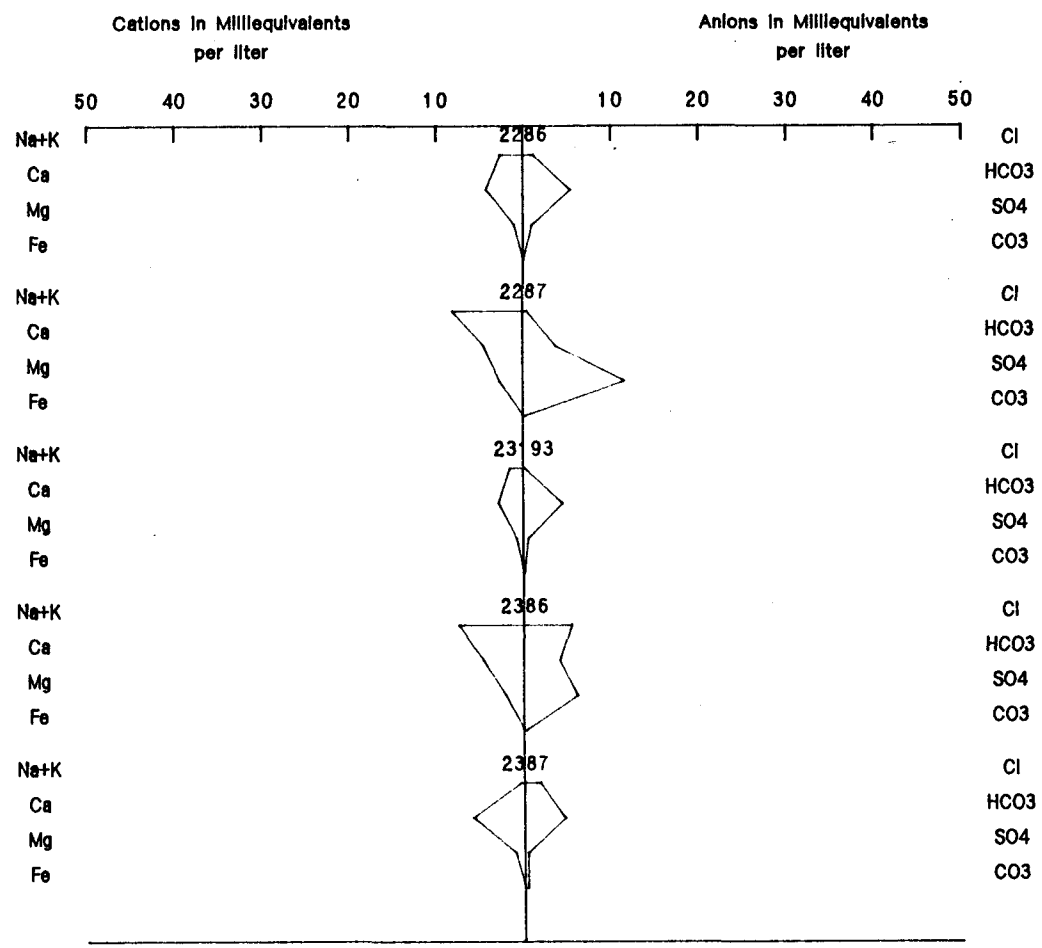


HC-GRAM 2.19

Plotted Values

2.63	2286	1.16
4.27		5.40
1.04		1.02
0.01		0.03
8.13	2287	0.37
4.58		3.71
2.75		11.48
0.00		0.05
1.64	23193	0.08
2.97		4.40
0.88		0.50
0.00		0.03
7.55	2386	5.36
4.70		4.00
2.15		6.04
0.02		0.17
0.47	2387	1.78
5.94		4.60
1.09		0.33
0.00		0.33

Plotted values converted from mg/L to meq/L

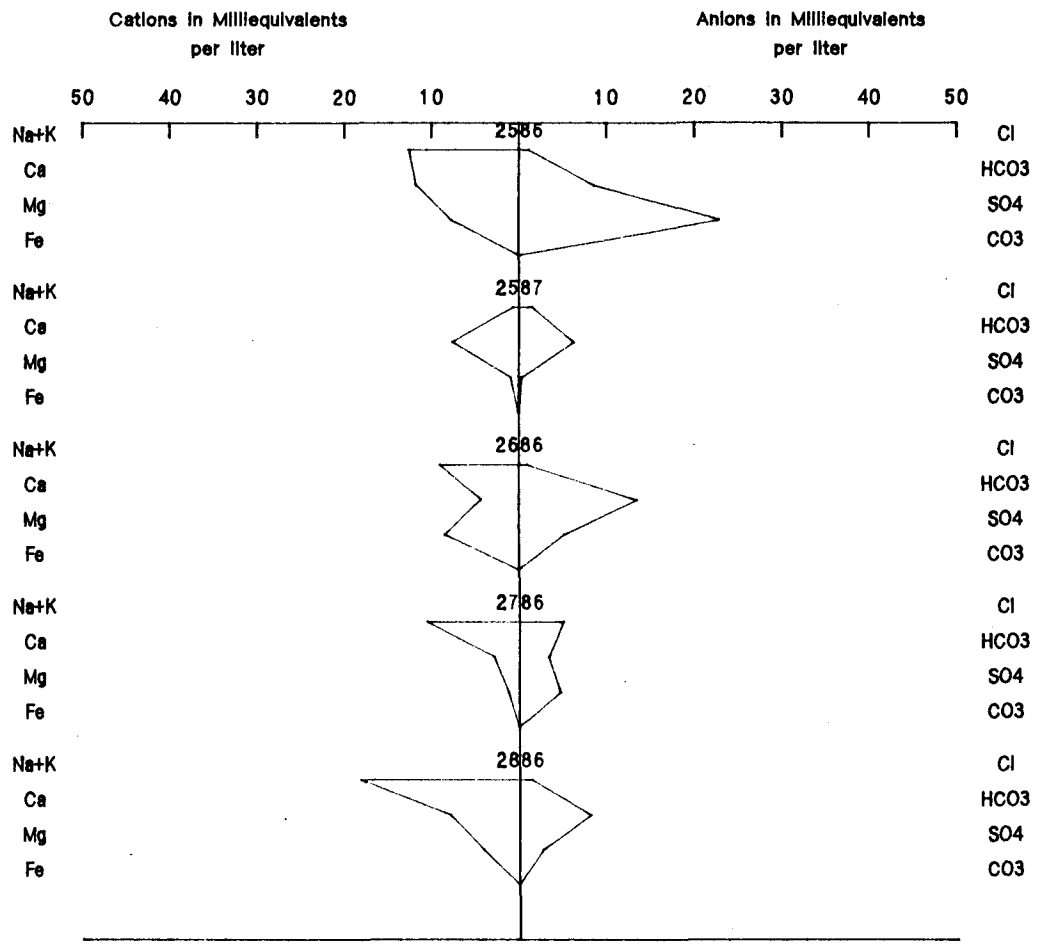


HC-GRAM 2.19

Plotted Values

12.59	2586	1.18
11.73		8.60
7.67		22.90
0.00		0.33
0.62	2587	1.59
7.53		6.37
0.87		0.42
0.00		0.10
8.93	2686	0.99
4.27		13.60
8.39		5.20
0.00		0.03
10.43	2786	5.08
2.83		3.40
1.20		4.79
0.00		0.03
18.07	2886	1.44
7.88		8.20
4.04		2.71
0.00		0.03

Plotted values converted from mg/L to meq/L

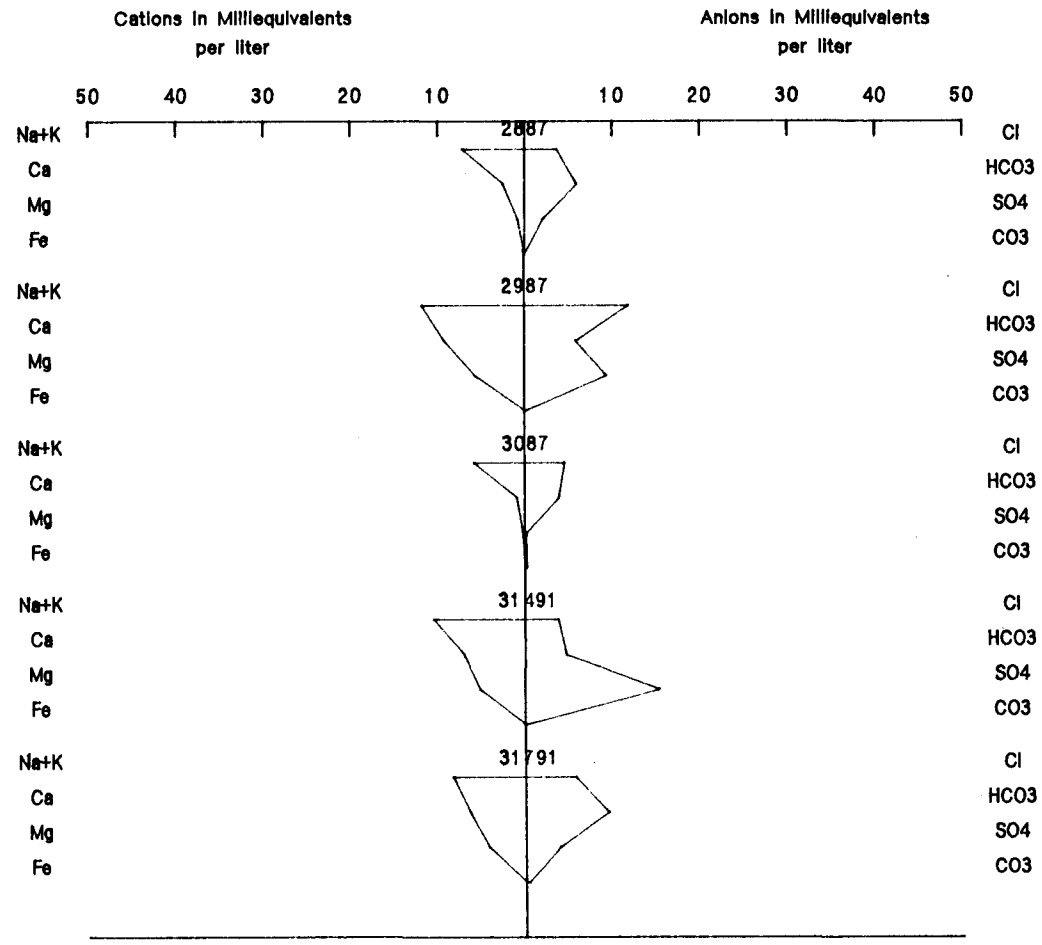


HC-GRAM 2.19

Plotted Values

	2887	
7.17		3.67
2.52		6.00
0.81		2.08
0.00		0.03
	2987	
11.80		11.81
9.28		5.80
5.75		9.26
0.00		0.06
	3087	
5.94		4.51
1.00		3.80
0.31		0.06
0.00		0.13
	31491	
10.52		3.67
7.14		4.60
5.24		15.20
0.00		0.03
	31791	
8.36		5.70
6.44		9.44
4.28		3.87
0.00		0.33

Plotted values converted from mg/L to meq/L

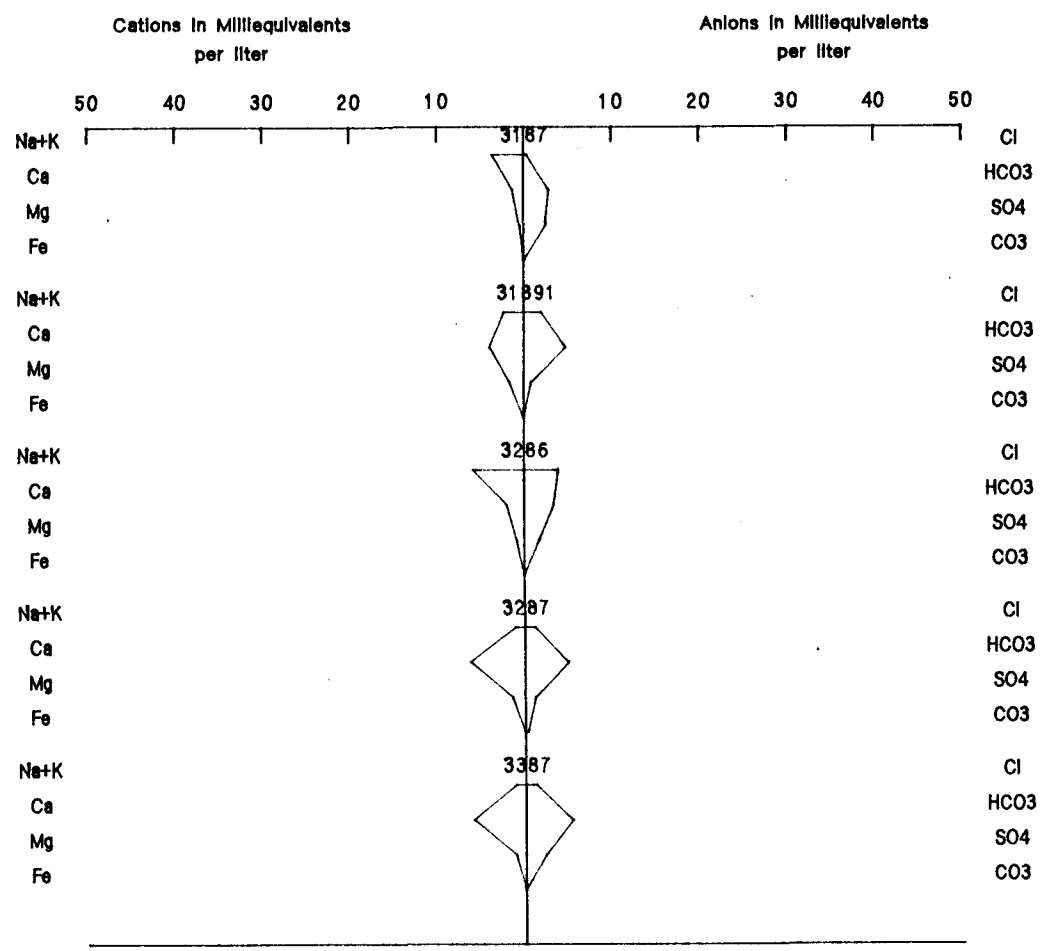


HC-GRAM 2.1 9

Plotted Values

3.67	3187	0.33
1.30		2.89
0.49		2.49
0.00		0.06
2.26	31891	2.00
3.96		4.80
1.63		0.87
0.00		0.03
5.82	3286	3.95
1.97		3.40
0.82		1.75
0.00		0.03
1.03	3287	1.16
6.24		5.00
1.41		1.23
0.00		0.33
1.06	3387	1.24
5.94		5.40
1.09		2.29
0.00		0.03

Plotted values converted from mg/L to meq/L

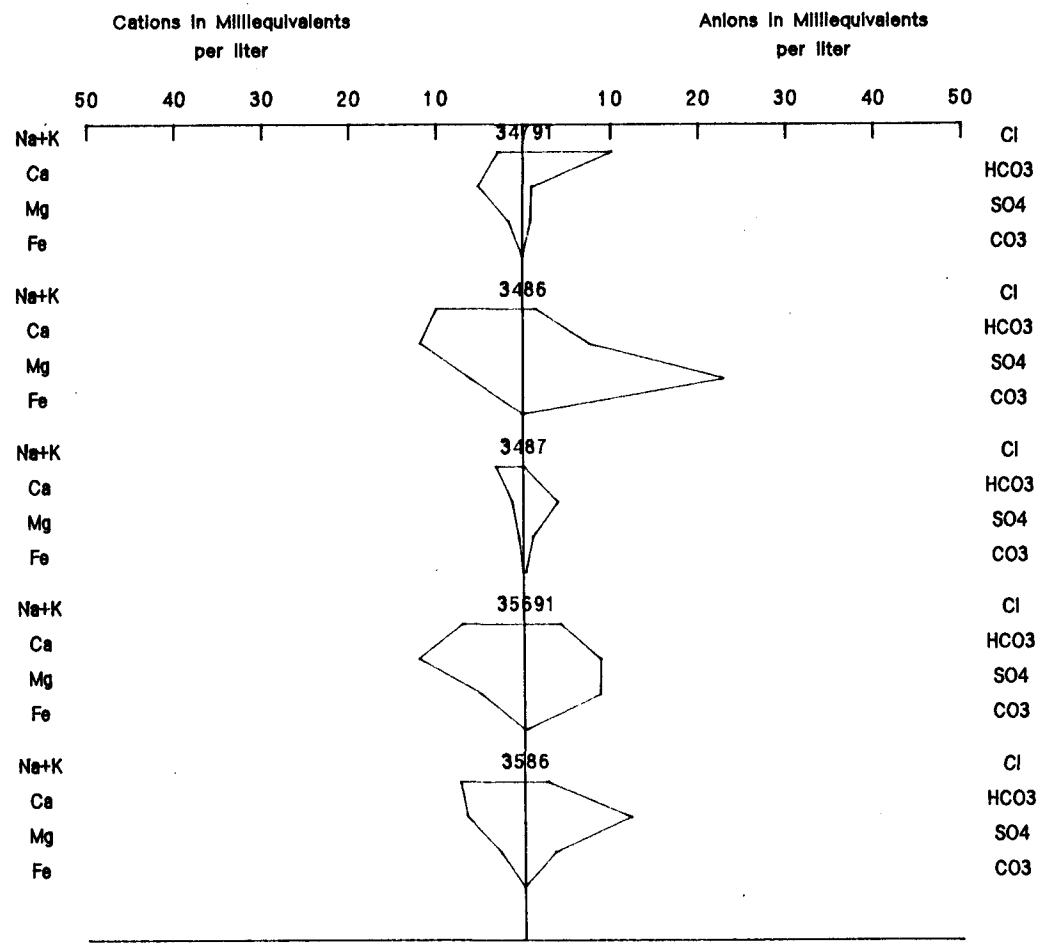


HC-GRAM 2.1 9

Plotted Values

2.84	34791	10.16
5.09		1.08
1.55		0.94
0.00		0.03
9.86	3486	1.52
11.73		7.60
6.00		22.90
0.06		0.03
3.14	3487	0.14
1.27		4.00
0.52		1.12
0.00		0.33
7.02	35691	4.23
12.03		8.80
4.86		8.74
0.00		0.33
7.32	3586	2.76
6.54		12.20
2.71		3.54
0.05		0.03

Plotted values converted from mg/L to meq/L

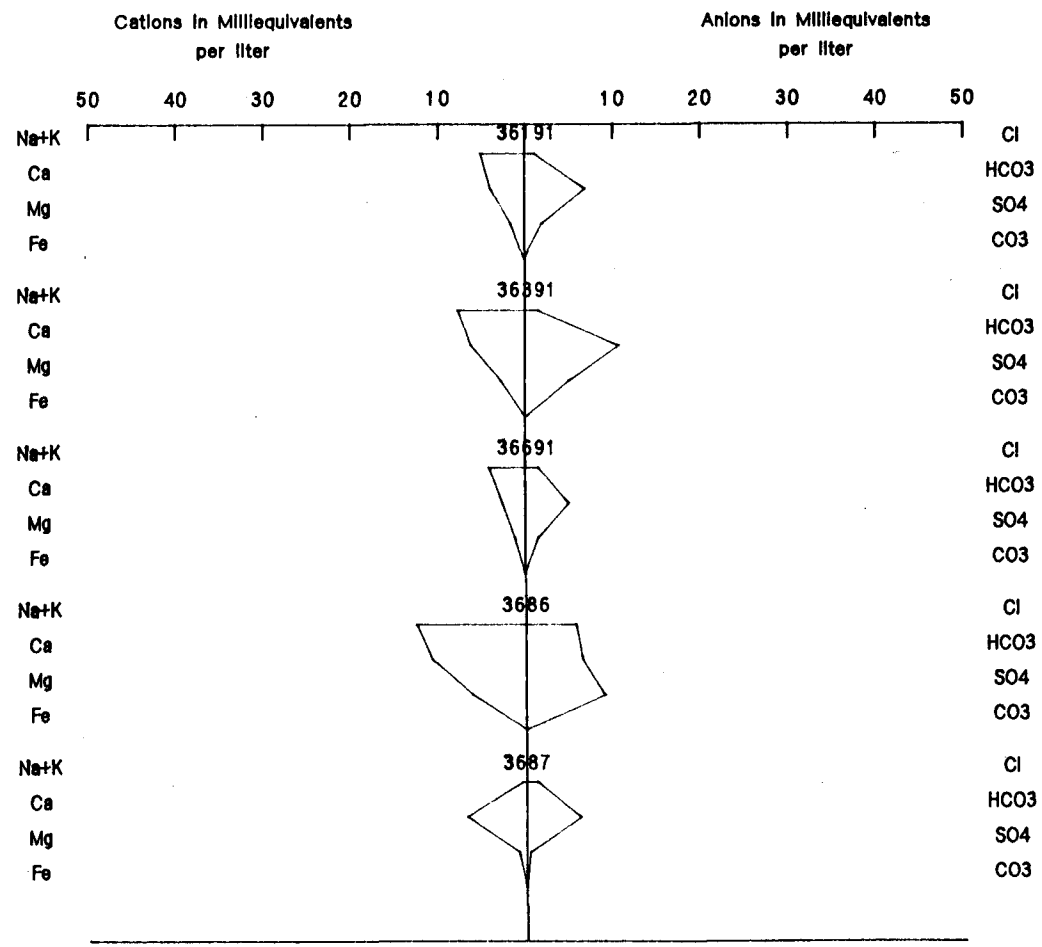


HC-GRAM 2.1 9

Plotted Values

4.93	36191	1.24
3.78		7.00
1.49		2.08
0.00		0.03
7.60	36391	1.57
6.09		10.78
2.66		5.08
0.00		0.33
4.11	36691	1.55
2.60		5.00
1.14		1.52
0.00		0.03
12.54	3686	5.64
10.73		6.40
6.09		8.95
0.00		0.03
0.46	3687	1.30
6.79		6.20
0.86		0.42
0.00		0.03

Plotted values converted from mg/L to meq/L

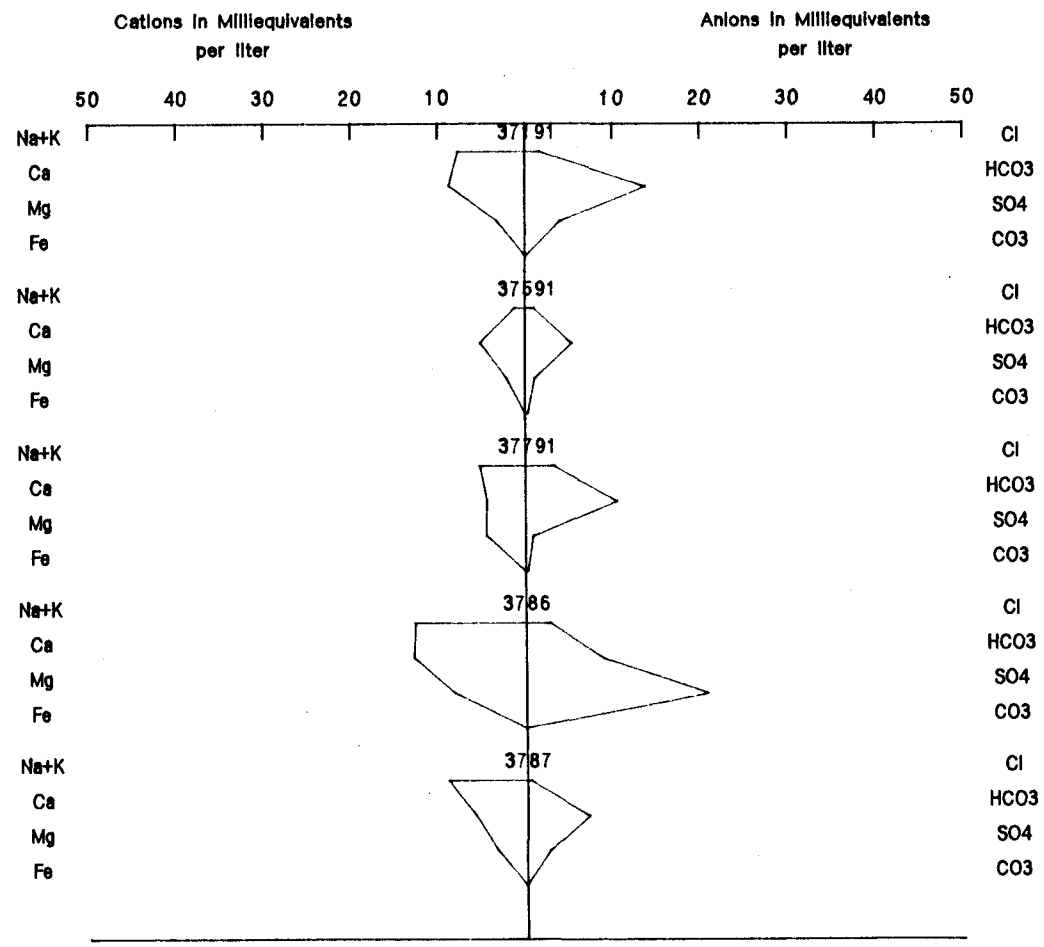


HC-GRAM 2.1 9

Plotted Values

7.67	37191	1.66
8.73		13.80
3.24		3.96
0.00		0.03
1.21	37591	1.02
5.14		5.40
2.08		1.12
0.00		0.33
5.18	37791	3.39
4.36		10.60
4.39		0.94
0.00		0.33
12.61	3786	2.82
12.77		9.00
8.13		20.82
0.00		0.00
8.87	3787	0.51
5.84		7.20
3.30		2.71
0.00		0.03

Plotted values converted from mg/L to meq/L

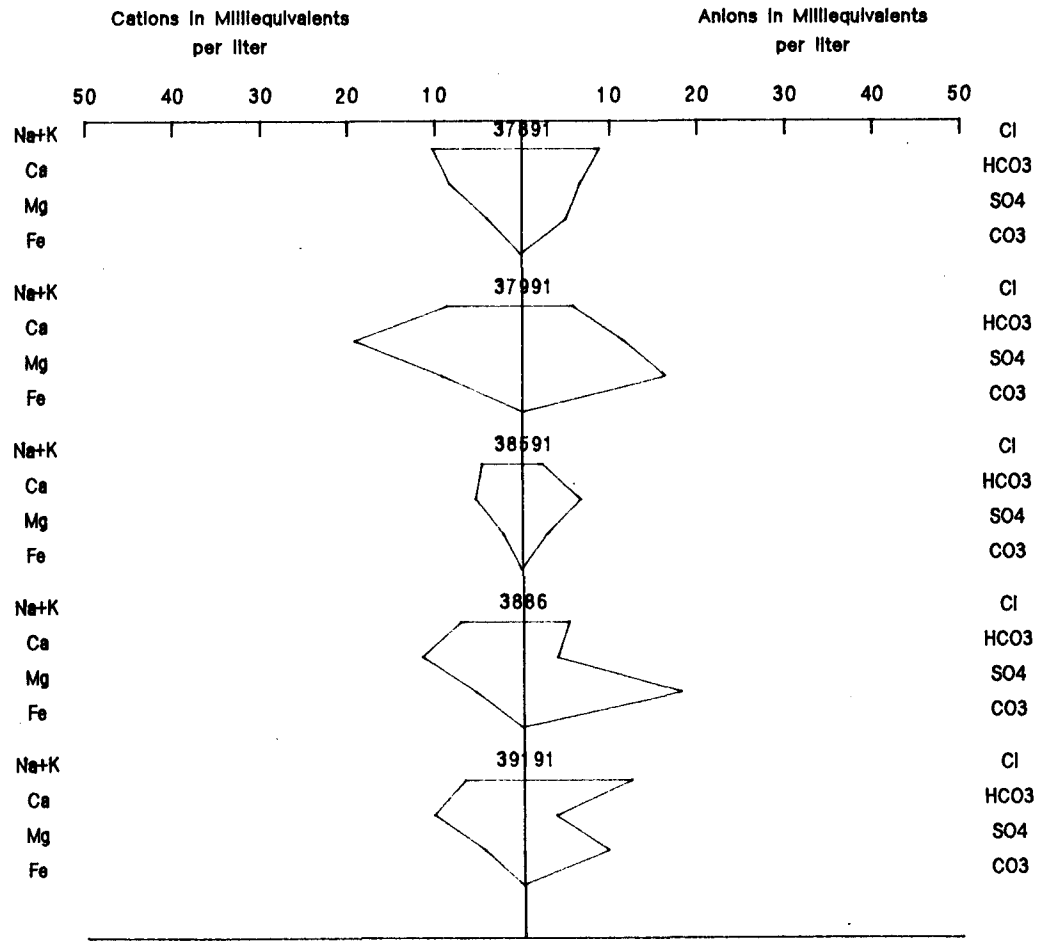


HC-GRAM 2.19

Plotted Values

10.09	37891	9.03
8.13		6.80
3.81		5.20
0.00		0.03
8.47	37991	5.92
19.06		11.80
9.05		16.45
0.00		0.33
4.48	38591	2.45
5.24		6.80
2.02		2.91
0.00		0.03
7.01	3886	5.36
11.43		4.00
5.26		18.11
0.04		0.03
6.58	39191	12.41
10.13		3.80
4.30		9.79
0.00		0.03

Plotted values converted from mg/L to meq/L

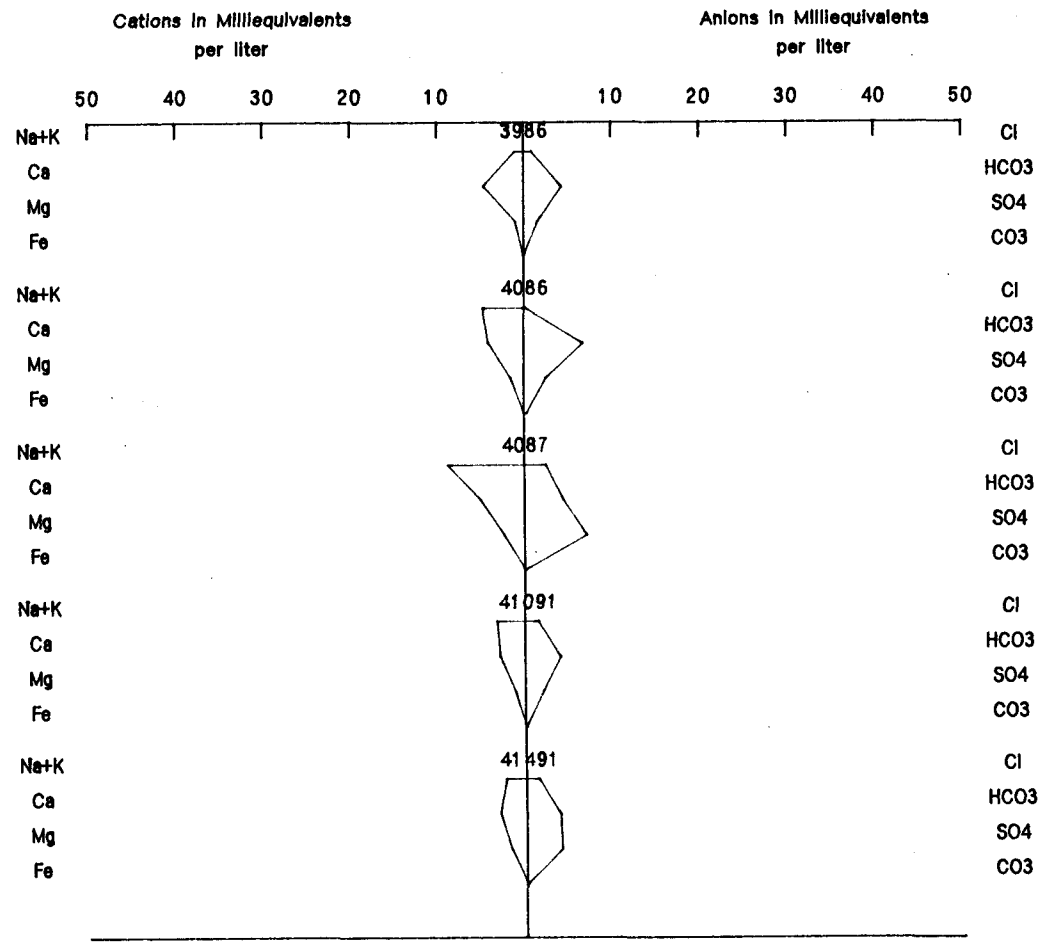


HC-GRAM 2.19

Plotted Values

0.98	3986	0.93
4.60		4.40
0.93		1.64
0.00		0.03
4.75	4086	0.21
4.11		6.80
1.53		2.50
0.00		0.33
8.85	4087	2.37
5.14		4.40
2.43		7.08
0.00		0.03
3.33	41091	1.44
3.01		4.00
1.24		1.96
0.00		0.03
2.34	41491	1.35
3.14		3.80
1.86		3.96
0.00		0.03

Plotted values converted from mg/L to meq/L

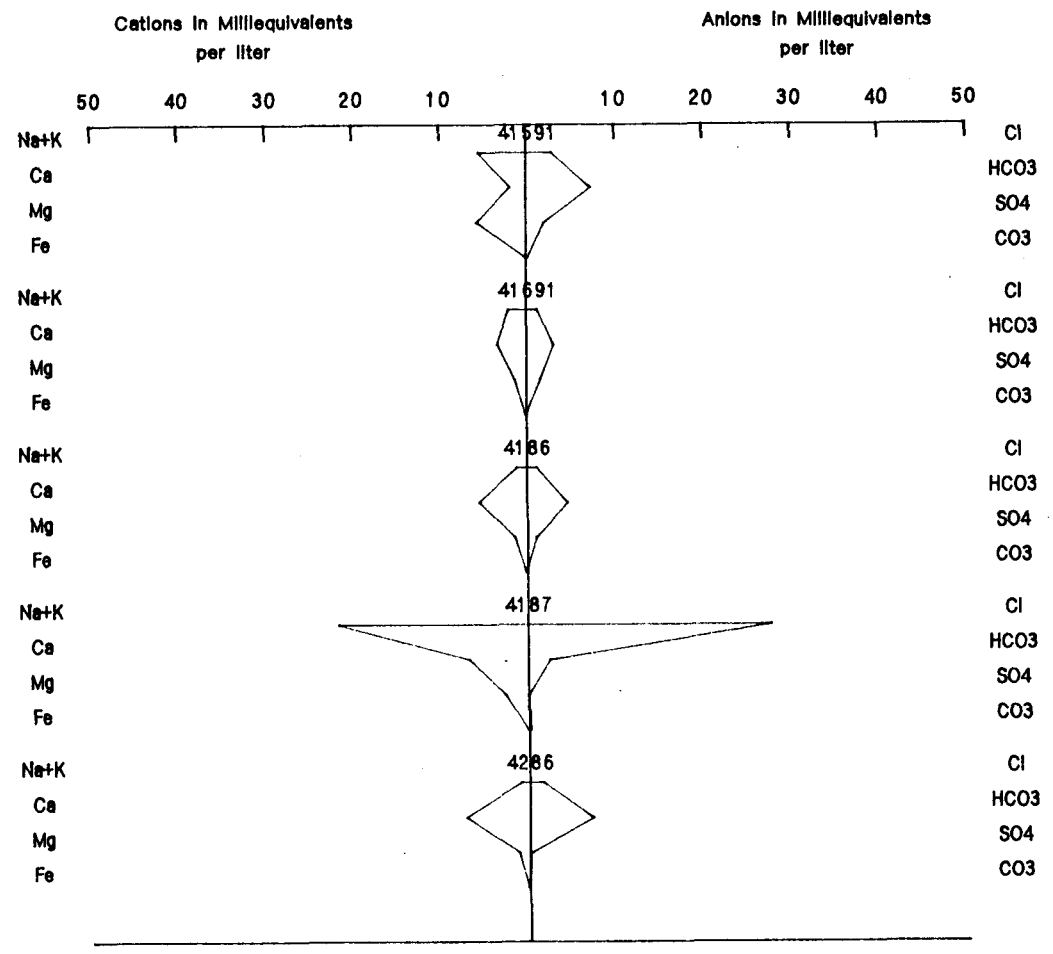


HC-GRAM 2.1 9

Plotted Values

5.41	41591	2.93
1.79		7.43
5.61		2.11
0.00		0.27
1.94	41691	1.38
3.28		3.22
1.23		1.68
0.00		0.04
1.03	4186	1.27
5.34		4.80
1.28		1.19
0.00		0.03
21.49	4187	27.93
6.64		2.60
2.52		0.18
0.01		0.33
0.82	4286	1.72
7.14		7.40
1.09		0.29
0.00		0.03

Plotted values converted from mg/L to meq/L

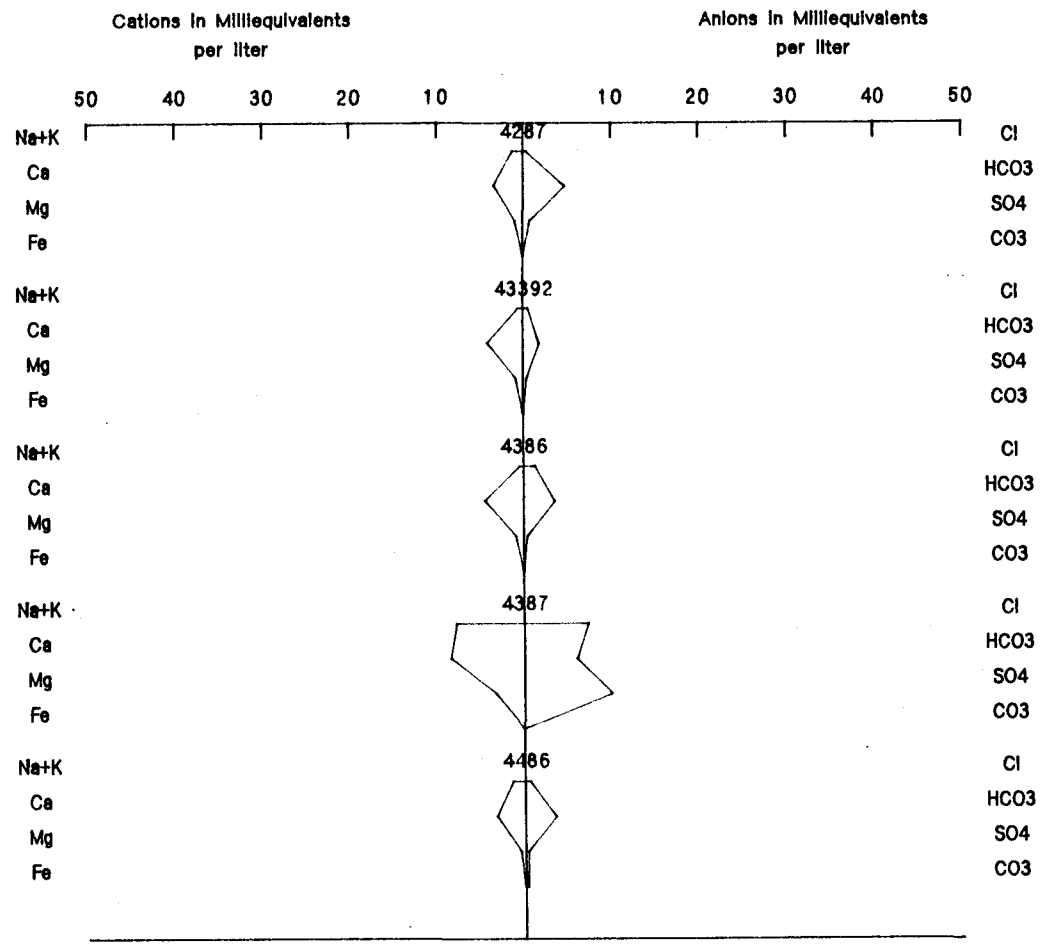


HC-GRAM 2.19

Plotted Values

1.19	4287	0.37
3.39		4.80
0.88		0.85
0.00		0.03
0.53	43392	0.60
4.12		1.91
0.86		0.45
0.00		0.02
0.42	4386	1.35
4.44		3.60
0.86		0.46
0.00		0.03
7.71	4387	7.33
8.43		6.00
3.27		9.99
0.00		0.03
1.35	4486	0.62
3.25		3.60
0.52		0.35
0.00		0.33

Plotted values converted from mg/L to meq/L

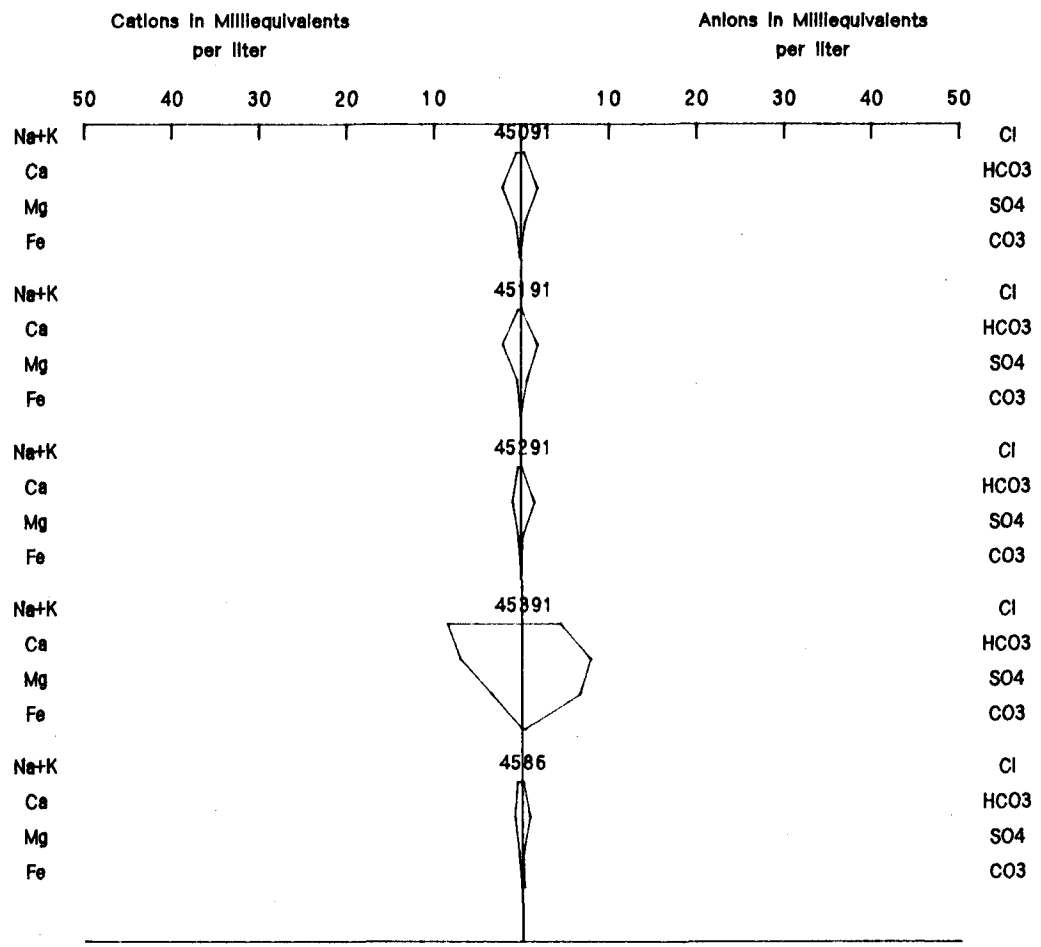


HC-GRAM 2.19

Plotted Values

0.47	45091	0.42
2.08		2.00
0.49		0.58
0.00		0.03
0.34	45191	0.08
2.09		1.96
0.45		0.75
0.00		0.03
0.36	45291	0.06
1.00		1.56
0.33		0.17
0.02		0.03
8.54	45391	4.40
7.04		7.88
3.44		6.62
0.00		0.33
0.49	4586	0.19
0.78		0.98
0.34		0.21
0.00		0.33

Plotted values converted from mg/L to meq/L

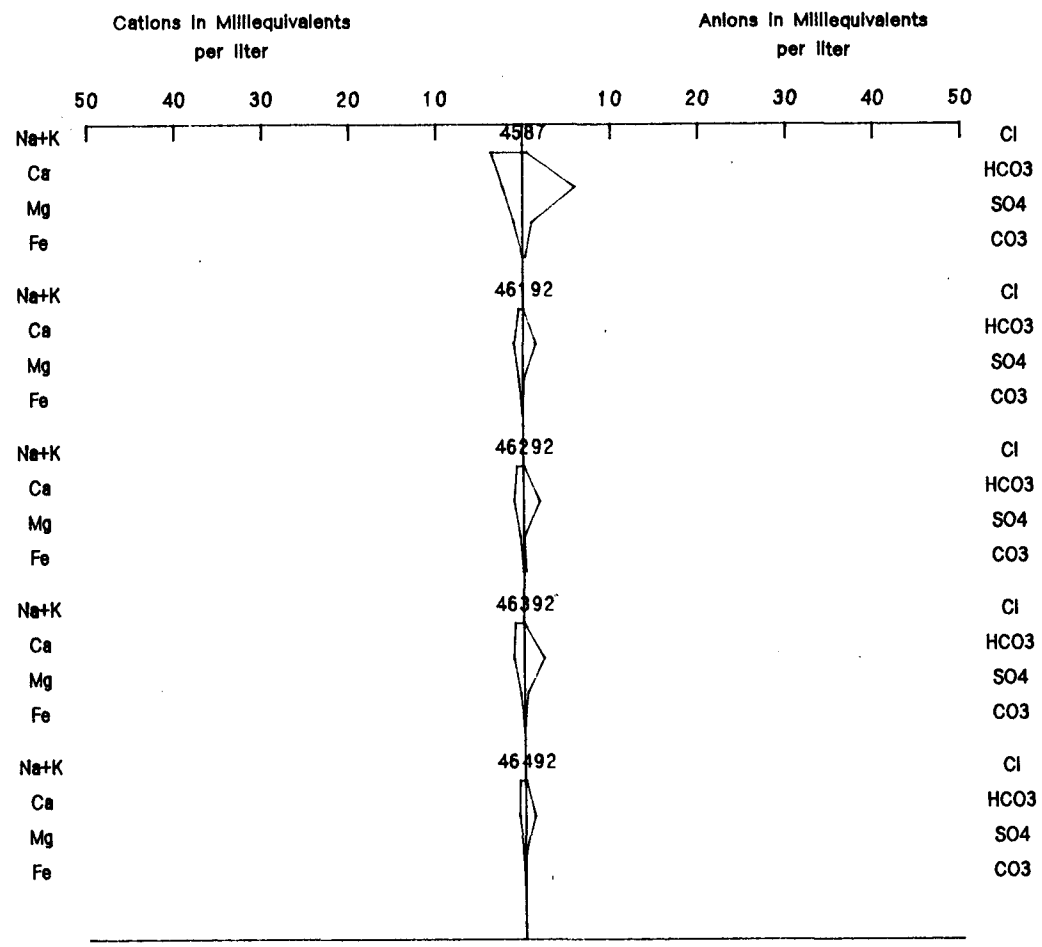


HC-GRAM 2.1 9

Plotted Values

3.61	4587	0.54
2.26		6.00
0.97		1.08
0.01		0.33
0.44	46192	0.06
0.95		1.56
0.39		0.19
0.00		0.03
0.66	46292	0.14
1.04		1.92
0.38		0.13
0.00		0.33
0.95	46392	0.06
1.15		2.30
0.43		0.42
0.00		0.03
0.58	46492	0.14
0.67		1.12
0.23		0.17
0.00		0.03

Plotted values converted from mg/L to meq/L

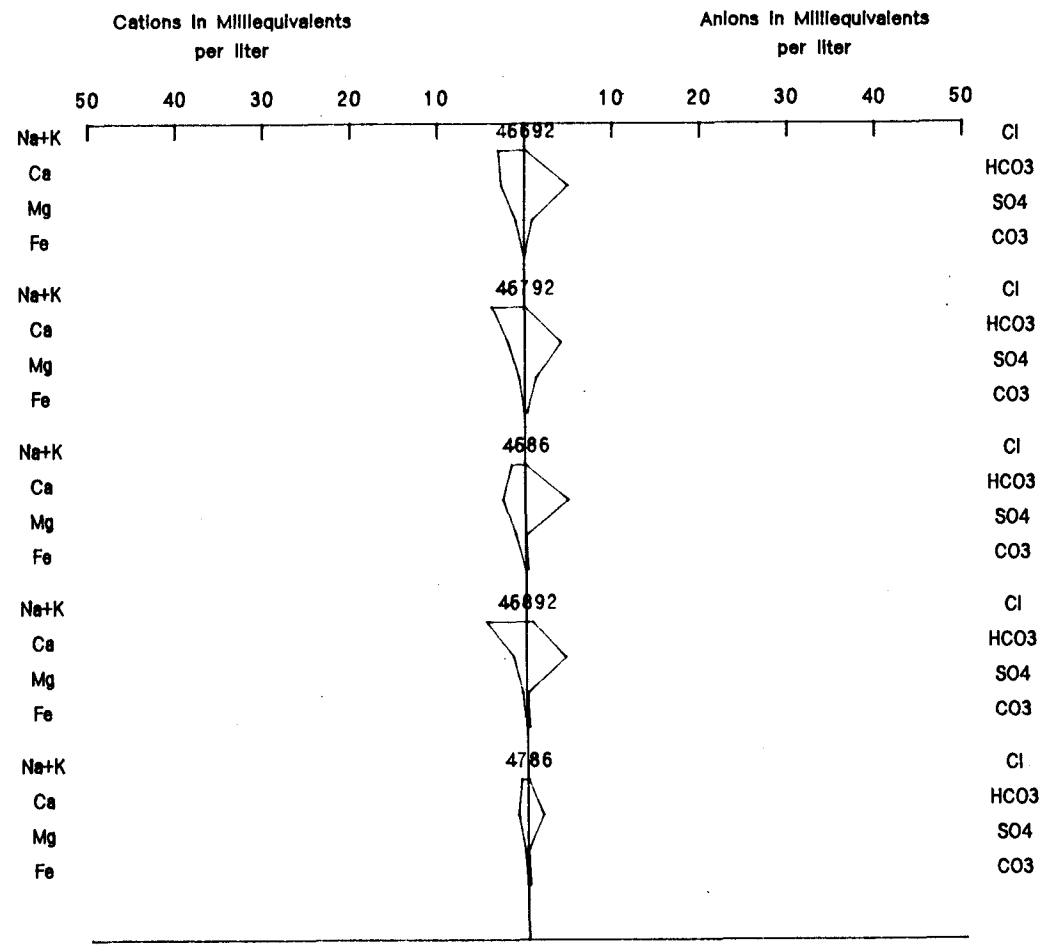


HC-GRAM 2.19

Plotted Values

2.93	46692	0.20
2.60		5.04
0.94		0.95
0.00		0.13
3.64	46792	0.16
1.89		4.20
0.61		1.35
0.00		0.33
1.46	4686	0.14
2.48		5.00
1.09		0.10
0.00		0.33
4.47	46892	0.79
1.40		4.60
0.41		0.29
0.00		0.33
0.65	4786	0.14
1.05		1.84
0.31		0.11
0.00		0.33

Plotted values converted from mg/L to meq/L

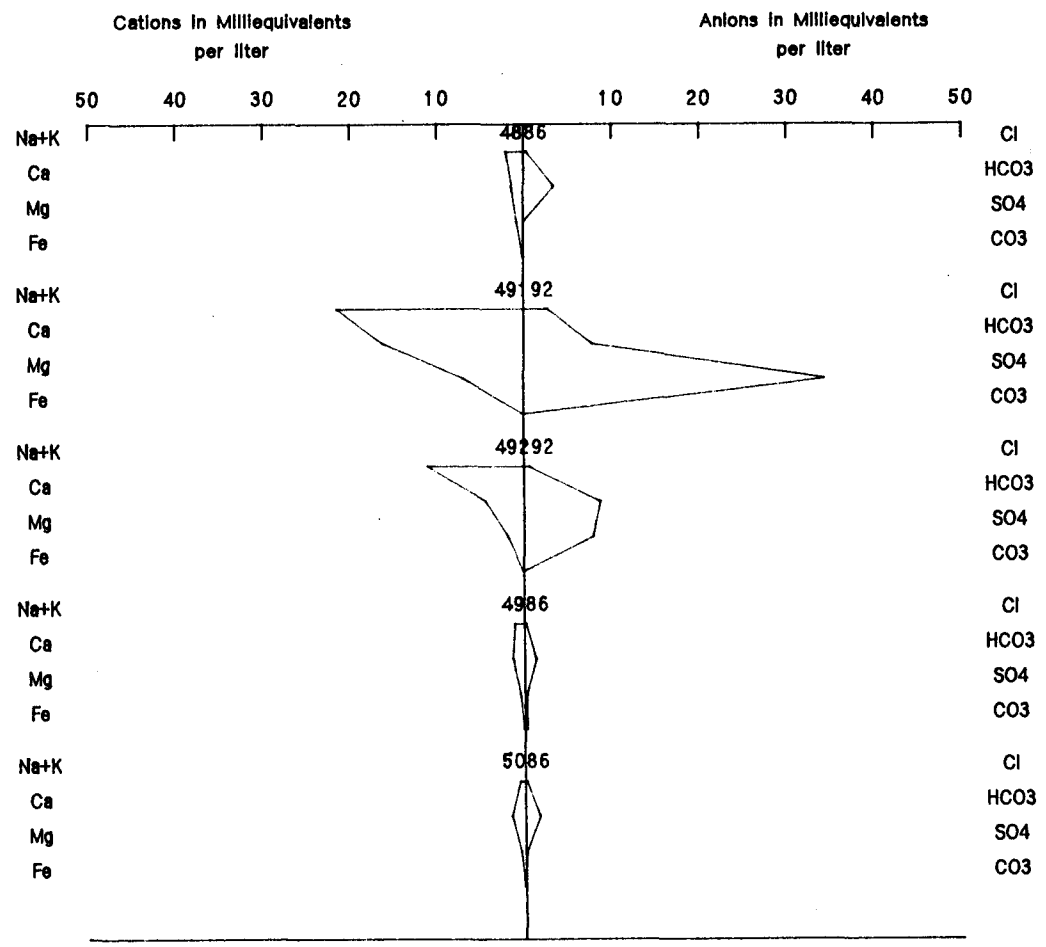


HC-GRAM 2.1 9

Plotted Values

1.97	4886	0.39
1.29		3.60
0.66		0.08
0.00		0.07
21.33	49192	2.80
16.12		7.85
6.84		34.48
0.02		0.03
10.95	49292	0.70
4.33		8.82
1.79		7.97
0.02		0.07
0.99	4986	0.27
1.25		1.42
0.42		0.33
0.00		0.33
0.44	5086	0.28
1.45		1.80
0.41		0.23
0.00		0.03

Plotted values converted from mg/L to meq/L

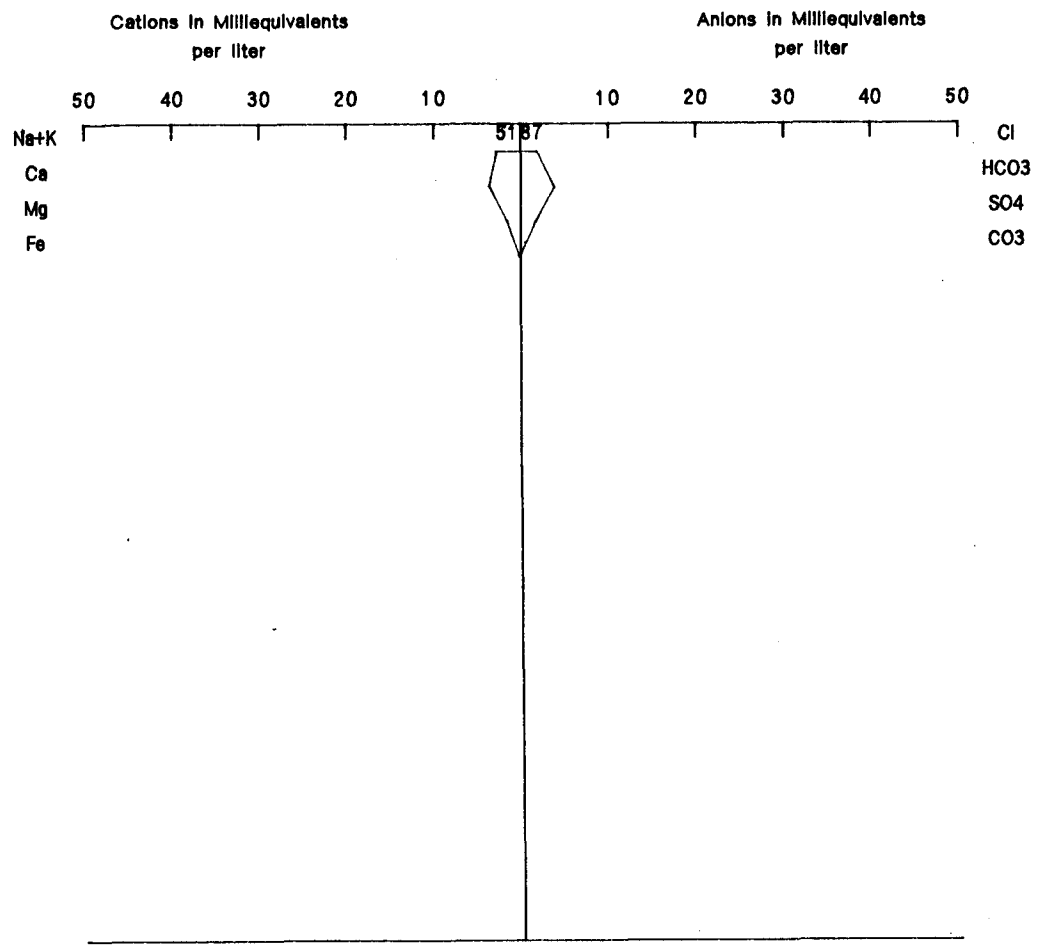


HC-GRAM 2.1 9

Plotted Values

	5187	
2.64		2.03
3.54		4.00
1.41		1.85
0.00		0.03

Plotted values converted from mg/L to meq/L

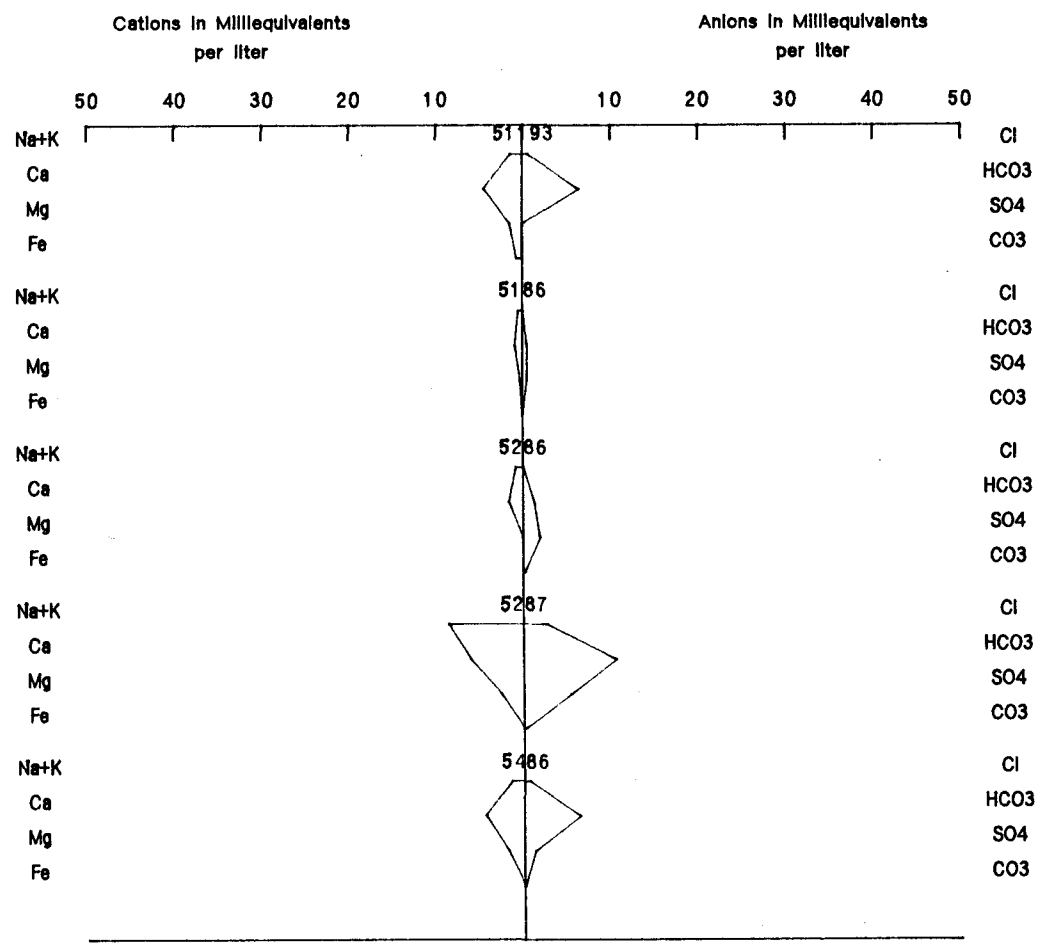


HC-GRAM 2.19

Plotted Values

1.29	51193	0.76
4.35		6.60
1.37		0.02
0.57		0.03
0.45	5186	0.08
0.84		0.56
0.27		0.56
0.00		0.03
0.84	5286	0.03
1.66		1.26
0.05		1.96
0.00		0.20
8.60	5287	2.70
6.14		10.57
2.62		5.35
0.00		0.10
1.52	5486	0.54
4.51		6.40
1.88		1.21
0.00		0.03

Plotted values converted from mg/L to meq/L

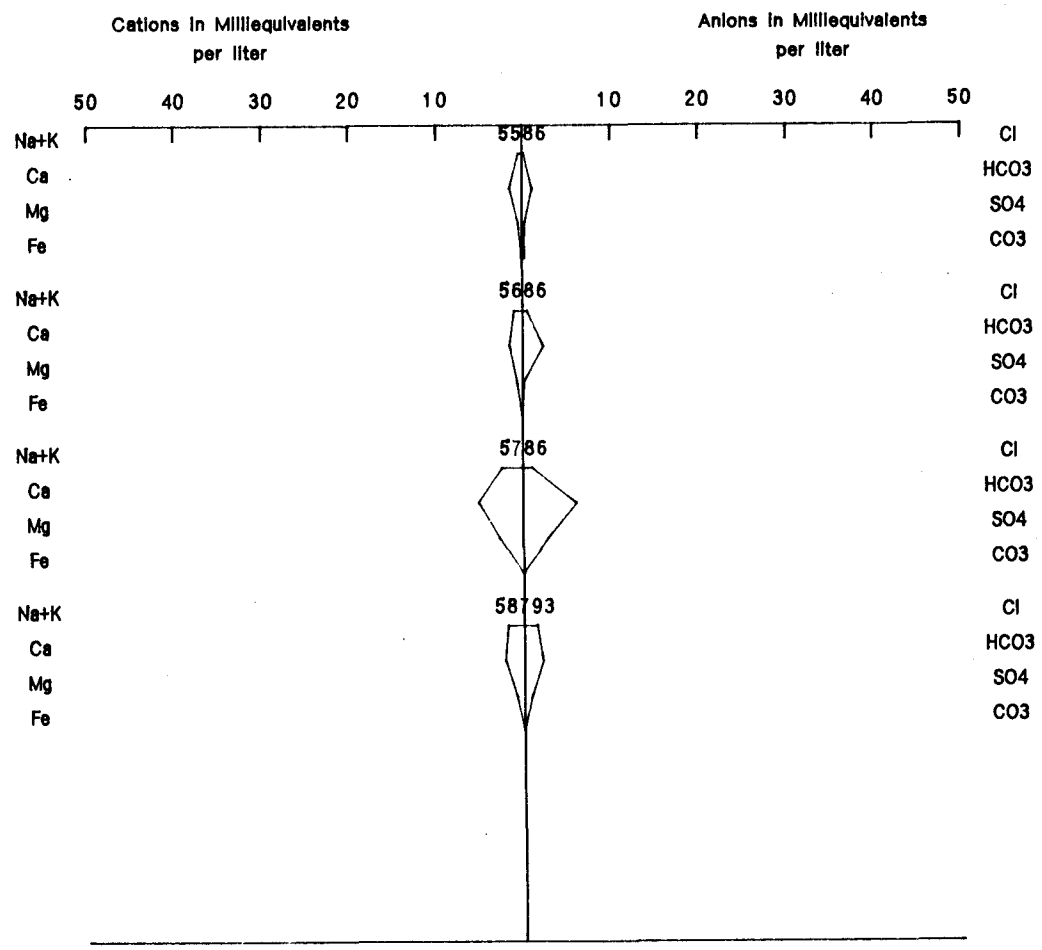


HC-GRAM 2.19

Plotted Values

0.41	5586	0.19
1.37		1.22
0.39		0.35
0.00		0.33
0.93	5686	0.56
1.50		2.40
0.62		0.25
0.00		0.00
2.38	5786	1.10
5.09		6.20
2.64		2.91
0.04		0.03
1.80	58793	1.52
2.16		2.20
0.86		0.92
0.00		0.03

Plotted values converted from mg/L to meq/L

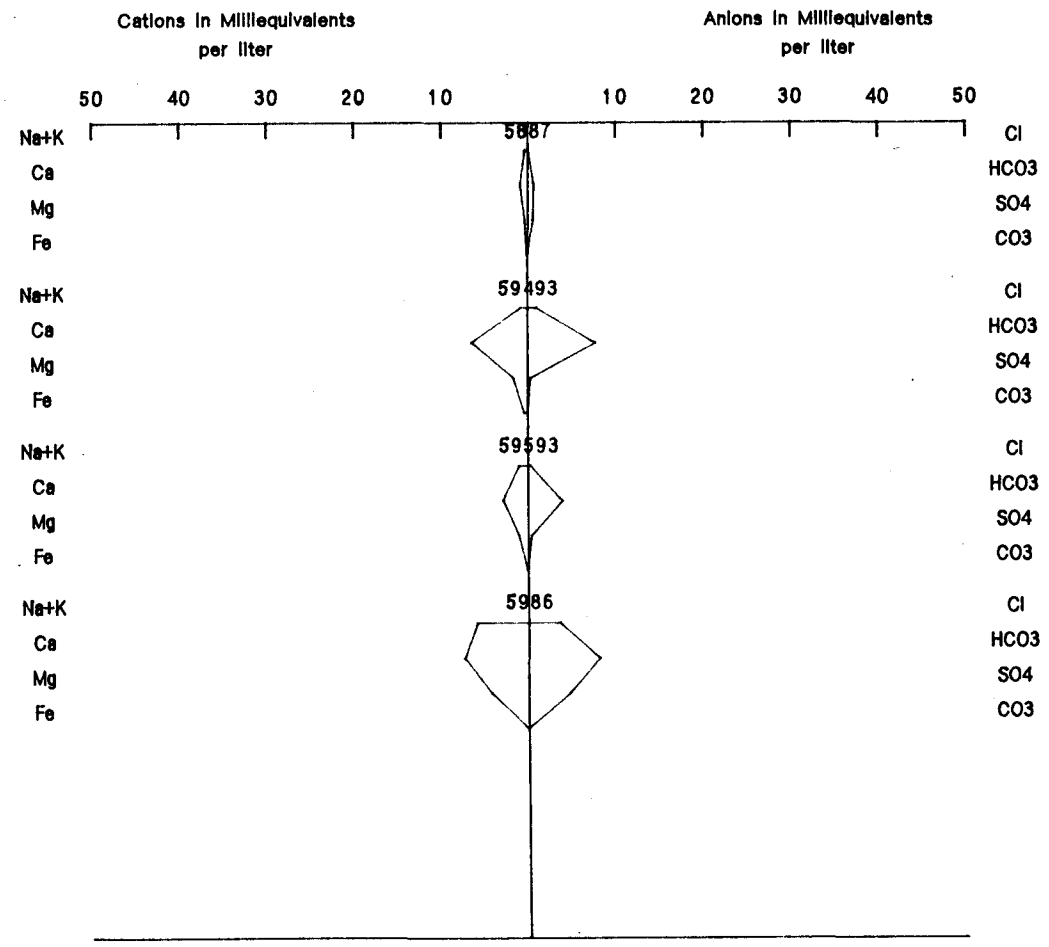


HC-GRAM 2.19

Plotted Values

0.27	5887	0.10
0.82		0.76
0.32		0.65
0.00		0.03
0.73	59493	1.07
6.39		7.80
1.63		0.35
0.36		0.03
0.95	59593	0.34
2.84		4.00
0.99		0.46
0.01		0.01
5.84	5986	3.67
7.29		8.20
4.15		4.79
0.00		0.03

Plotted values converted from mg/L to meq/L

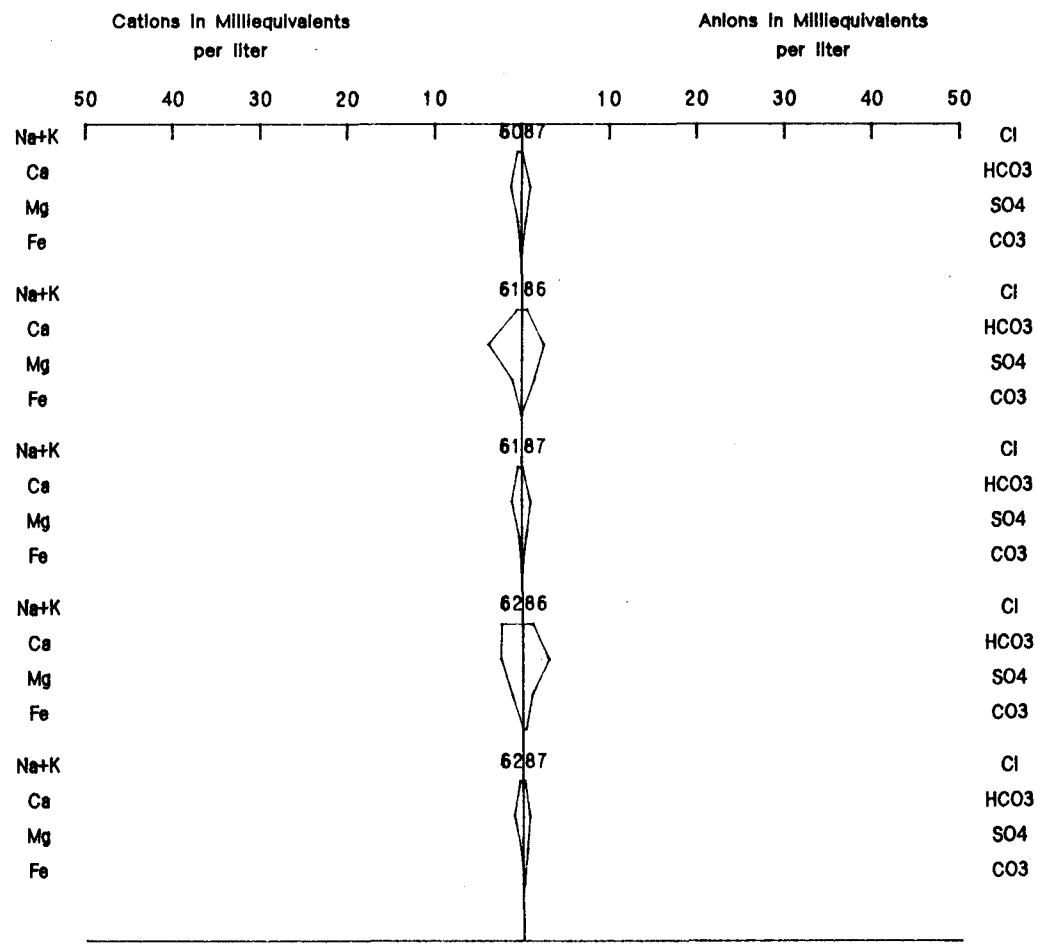


HC-GRAM 2.1 9

Plotted Values

0.47	6087	0.08
1.21		1.04
0.37		0.56
0.00		0.03
0.51	6186	0.65
3.77		2.60
1.02		1.48
0.00		0.03
0.42	6187	0.10
1.12		1.03
0.32		0.53
0.00		0.03
2.47	6286	1.13
2.56		3.00
1.29		1.06
0.00		0.33
0.45	6287	0.11
1.11		0.70
0.32		0.40
0.00		0.03

Plotted values converted from mg/L to meq/L

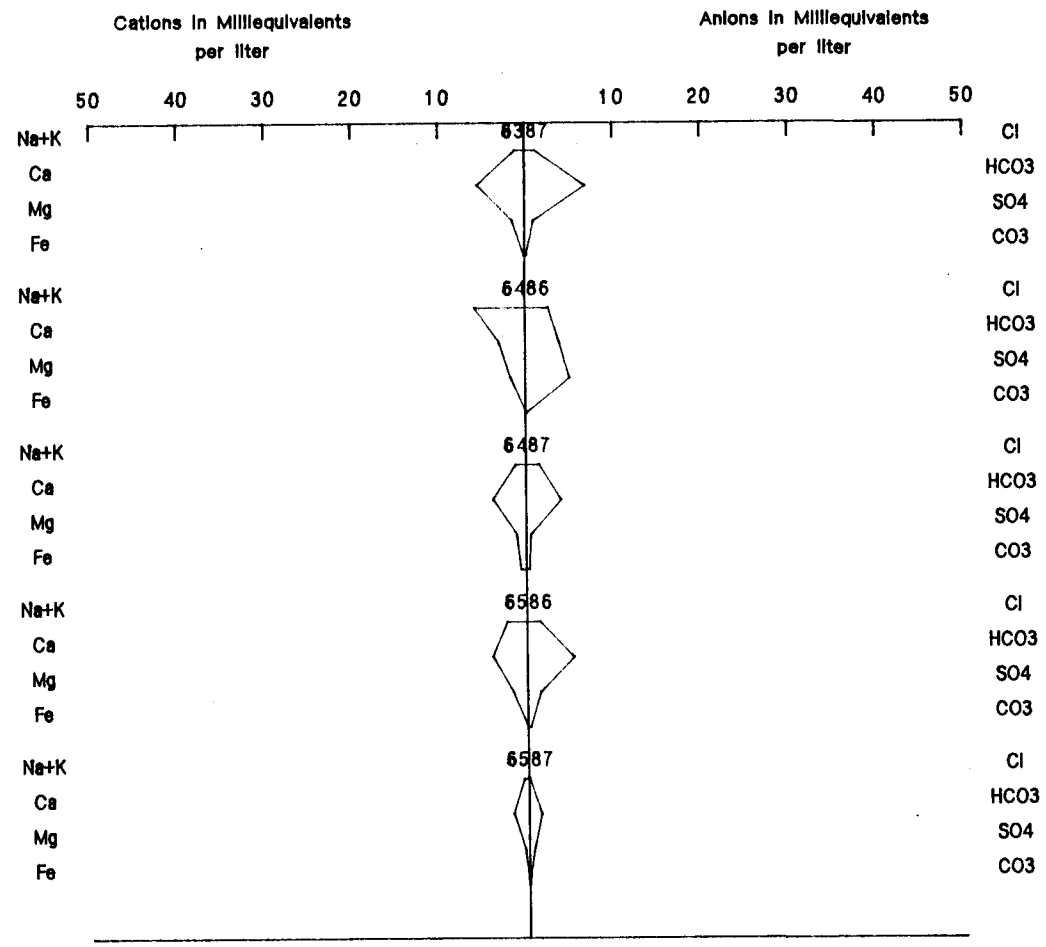


HC-GRAM 2.1 9

Plotted Values

1.26	6387	1.02
5.64		6.80
1.60		0.87
0.23		0.03
5.93	6486	2.54
3.13		3.80
1.81		5.00
0.00		0.03
1.25	6487	1.50
3.86		4.00
1.10		0.48
0.66		0.33
2.28	6586	1.52
3.96		5.40
1.64		1.54
0.00		0.33
0.51	6587	0.11
1.75		1.48
0.46		0.62
0.00		0.03

Plotted values converted from mg/L to meq/L

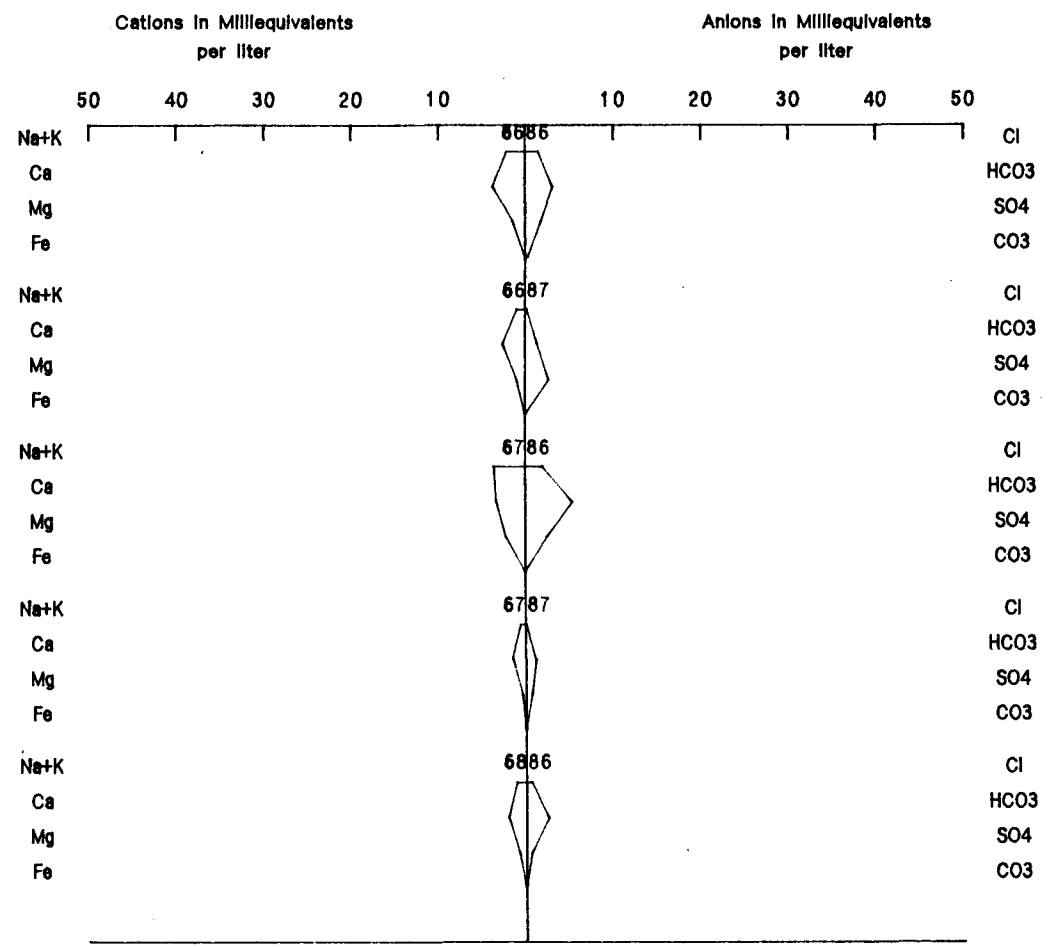


HC-GRAM 2.1 9

Plotted Values

2.10	6686	1.52
3.69		3.20
1.39		1.77
0.00		0.33
0.90	6687	0.17
2.60		1.40
0.96		2.71
0.00		0.03
3.59	6786	1.97
3.33		5.40
2.21		2.50
0.00		0.00
0.50	6787	0.14
1.48		1.20
0.35		0.73
0.00		0.03
1.03	6886	0.66
2.02		2.60
0.74		0.69
0.00		0.03

Plotted values converted from mg/L to meq/L

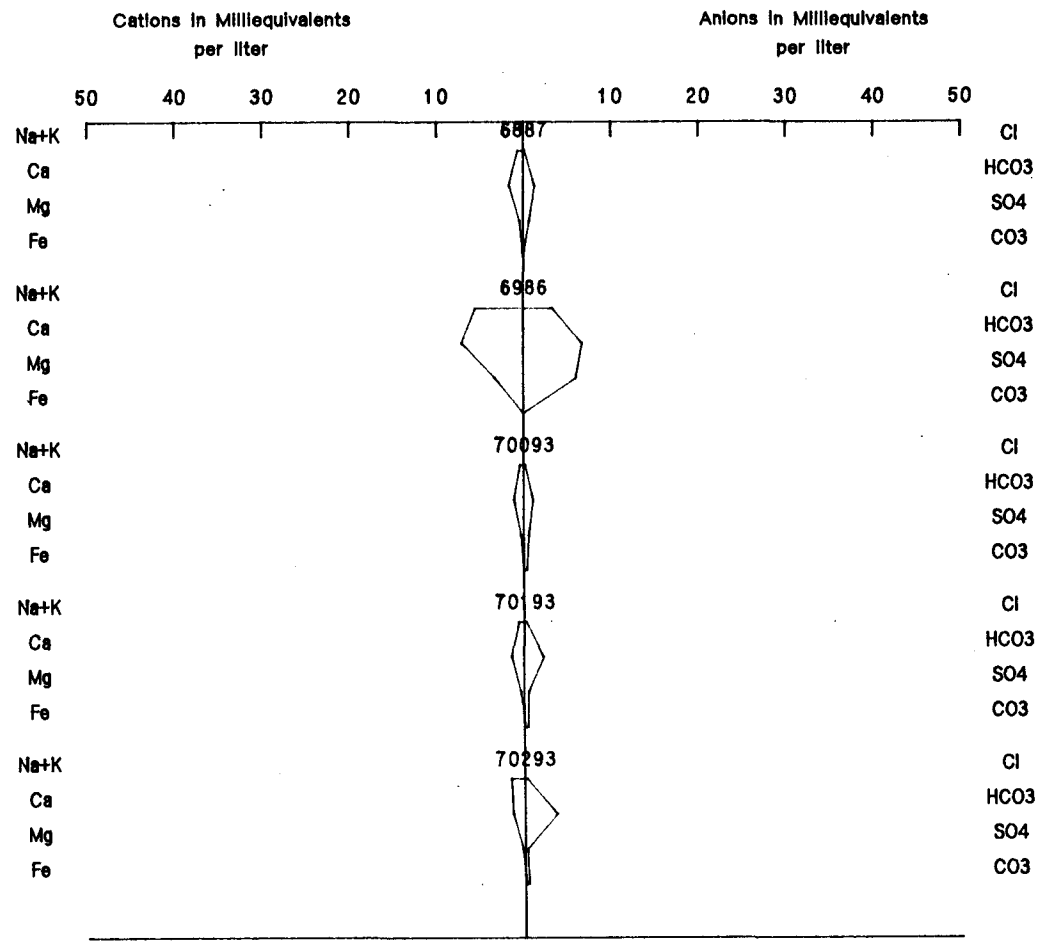


HC-GRAM 2.19

Plotted Values

0.59	6887	0.17
1.64		1.36
0.40		0.75
0.00		0.03
5.54	6986	3.39
7.09		6.80
3.23		6.04
0.00		0.03
0.47	70093	0.14
1.16		1.06
0.36		0.58
0.00		0.33
0.68	70193	0.14
1.54		2.20
0.49		0.42
0.00		0.33
1.70	70293	0.14
1.52		3.60
0.42		0.16
0.00		0.33

Plotted values converted from mg/L to meq/L

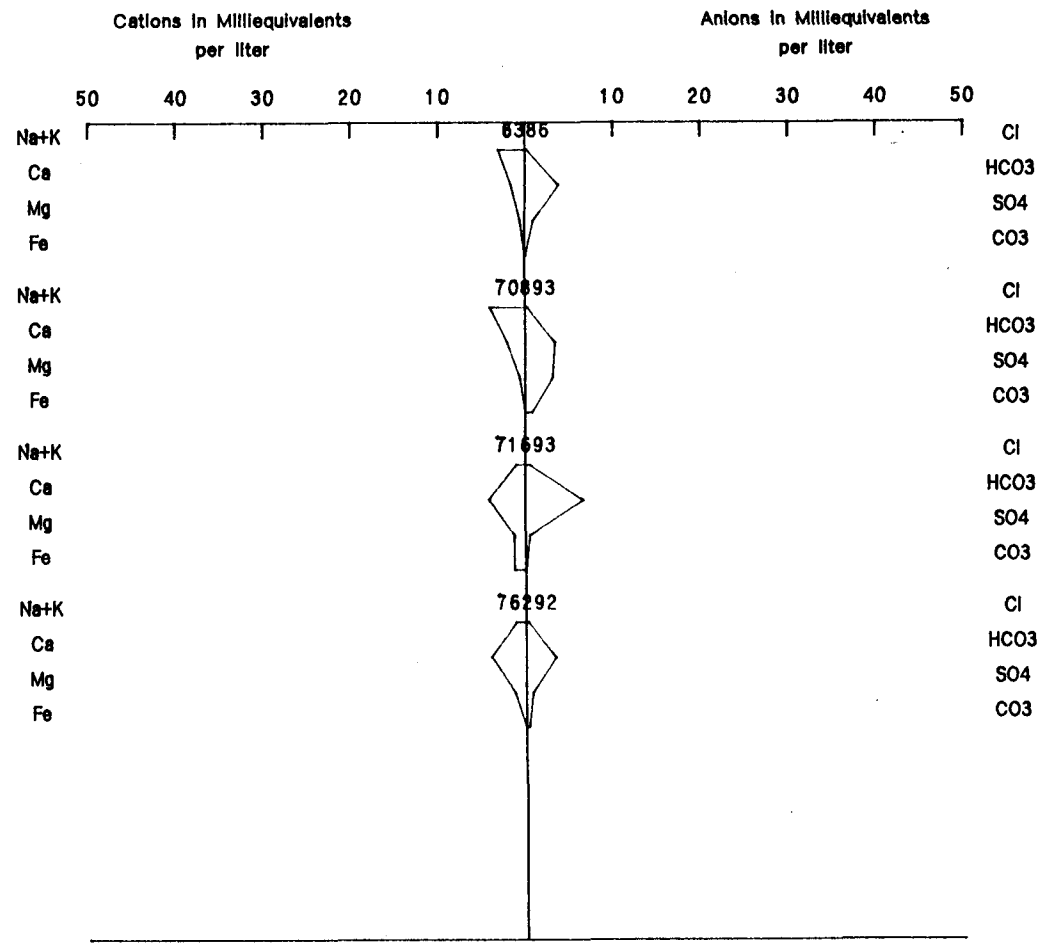


HC-GRAM 2.1 9

Plotted Values

3.16	6386	0.18
1.70		3.80
0.57		0.96
0.00		0.07
4.10	70893	0.20
2.11		3.40
0.64		3.12
0.00		0.80
1.03	71693	0.54
4.22		6.60
1.33		0.46
1.34		0.03
1.11	76292	0.28
3.98		3.40
1.31		0.79
0.00		0.33

Plotted values converted from mg/L to meq/L

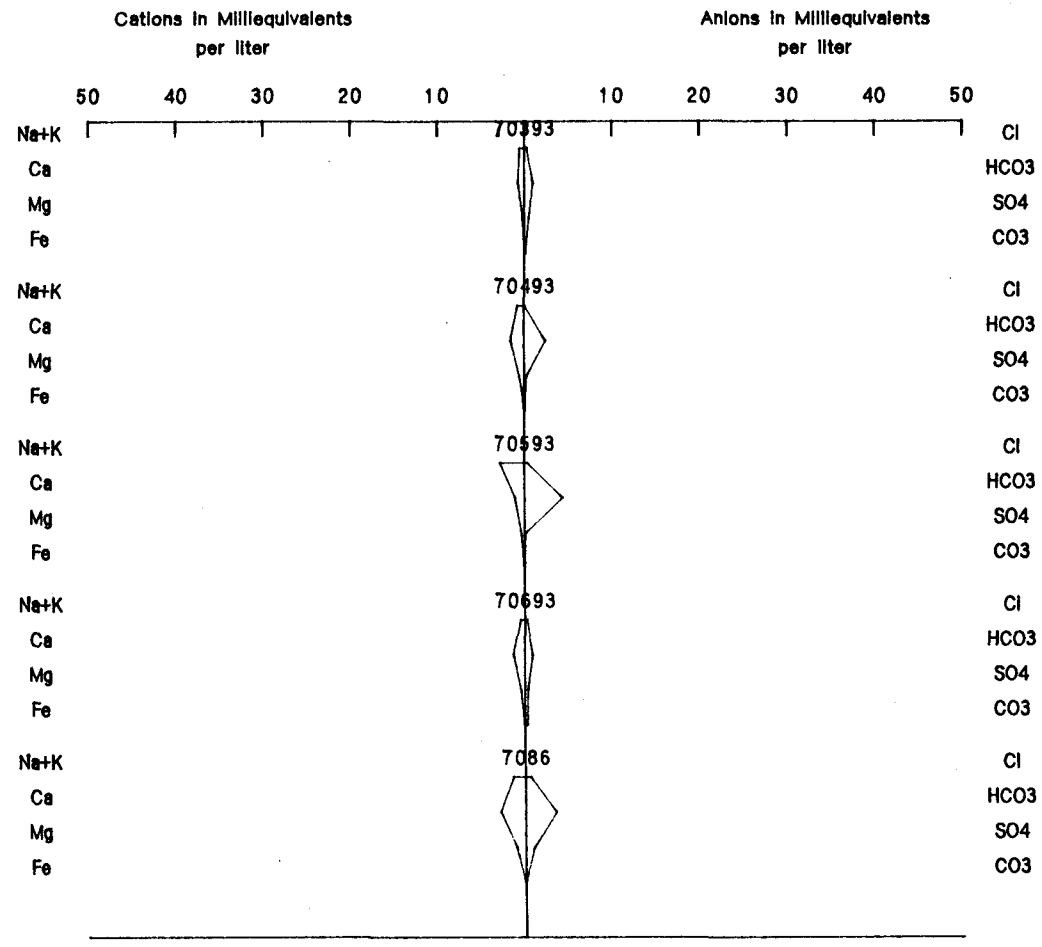


HC-GRAM 2.1 9

Plotted Values

0.60	70393	0.17
0.83		0.92
0.29		0.44
0.00		0.03
0.76	70493	0.02
1.63		2.40
0.61		0.27
0.00		0.03
2.81	70593	0.34
1.08		4.40
0.38		0.17
0.00		0.03
0.47	70693	0.27
1.28		0.96
0.43		0.40
0.02		0.33
1.33	7086	0.65
2.82		3.60
1.03		1.04
0.02		0.03

Plotted values converted from mg/L to meq/L

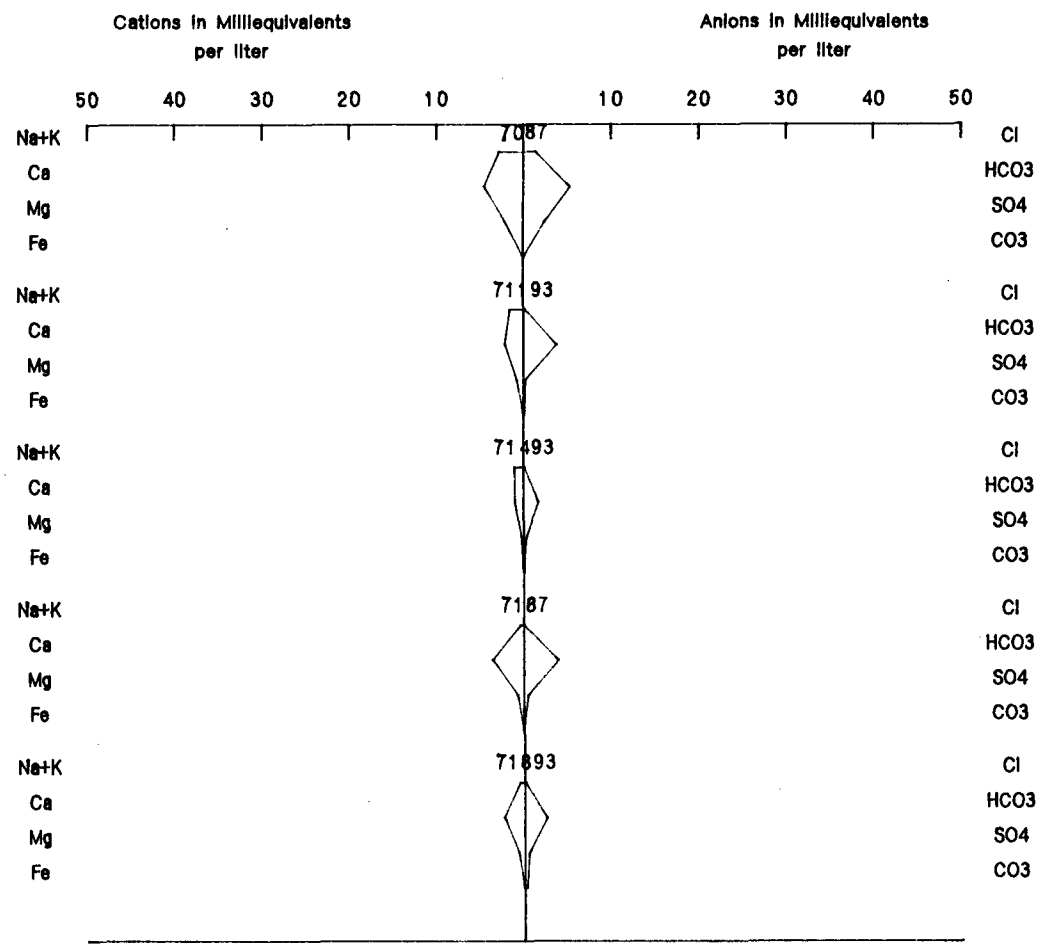


HC-GRAM 2.1 9

Plotted Values

2.81	7087	1.41
4.54		5.34
2.07		2.45
0.00		0.05
1.61	71193	0.20
2.14		3.80
0.78		0.27
0.00		0.13
1.01	71493	0.14
0.97		1.76
0.27		0.33
0.00		0.03
0.36	7187	0.07
3.56		4.00
0.66		0.56
0.00		0.03
0.52	71893	0.14
2.32		2.60
0.63		0.58
0.00		0.33

Plotted values converted from mg/L to meq/L

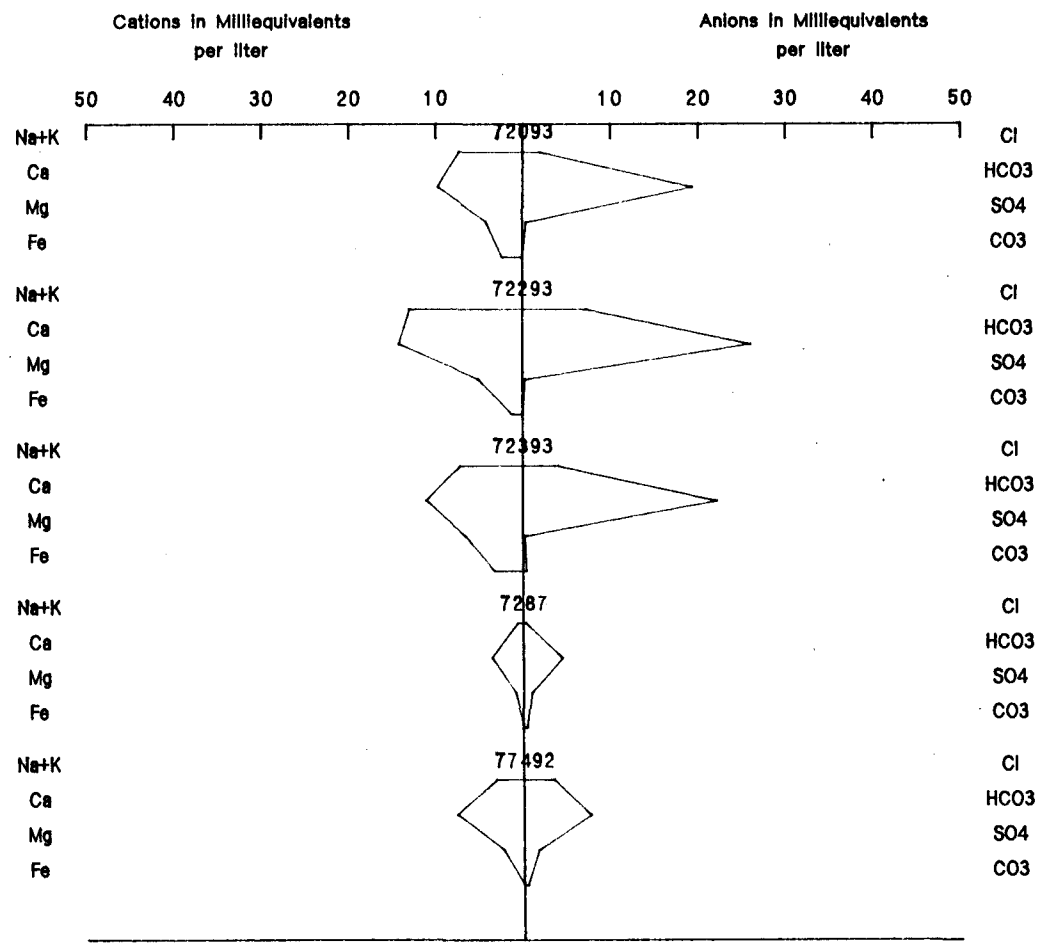


HC-GRAM 2.19

Plotted Values

7.28	72093	2.09
9.73		19.40
4.14		0.48
2.28		0.03
12.98	72293	7.33
14.22		25.99
5.12		0.25
1.25		0.03
7.28	72393	3.95
11.18		22.00
6.70		0.10
3.34		0.33
0.73	7287	0.19
3.72		4.38
1.00		0.84
0.00		0.33
3.25	77492	3.39
7.73		7.60
2.45		1.60
0.06		0.33

Plotted values converted from mg/L to meq/L

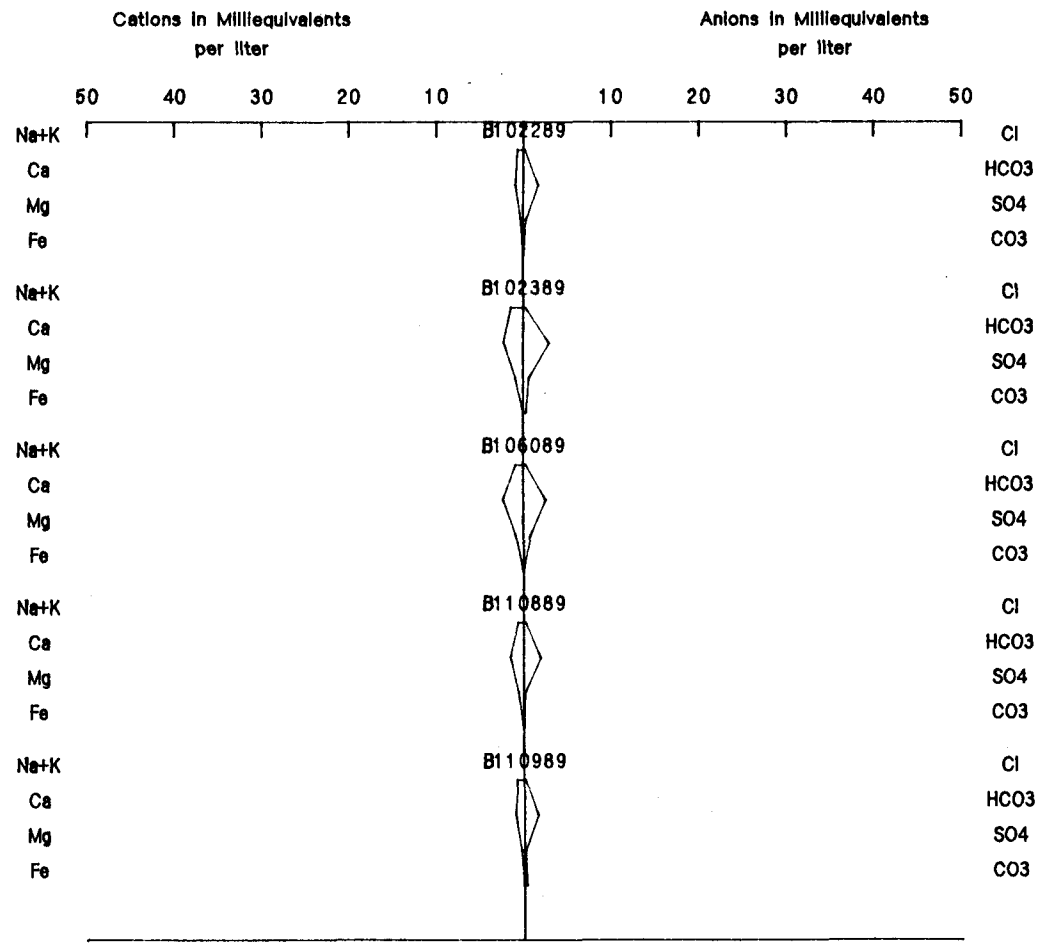


HC-GRAM 2.19

Plotted Values

0.72	B102289	0.08
0.95		1.68
0.33		0.27
0.00		0.03
1.41	B102389	0.25
2.28		3.00
0.92		0.67
0.00		0.33
0.84	B106089	0.28
2.33		2.60
0.86		0.85
0.04		0.03
0.58	B110889	0.25
1.52		2.00
0.54		0.21
0.00		0.03
0.70	B110989	0.18
0.99		1.60
0.33		0.16
0.00		0.33

Plotted values converted from mg/L to meq/L

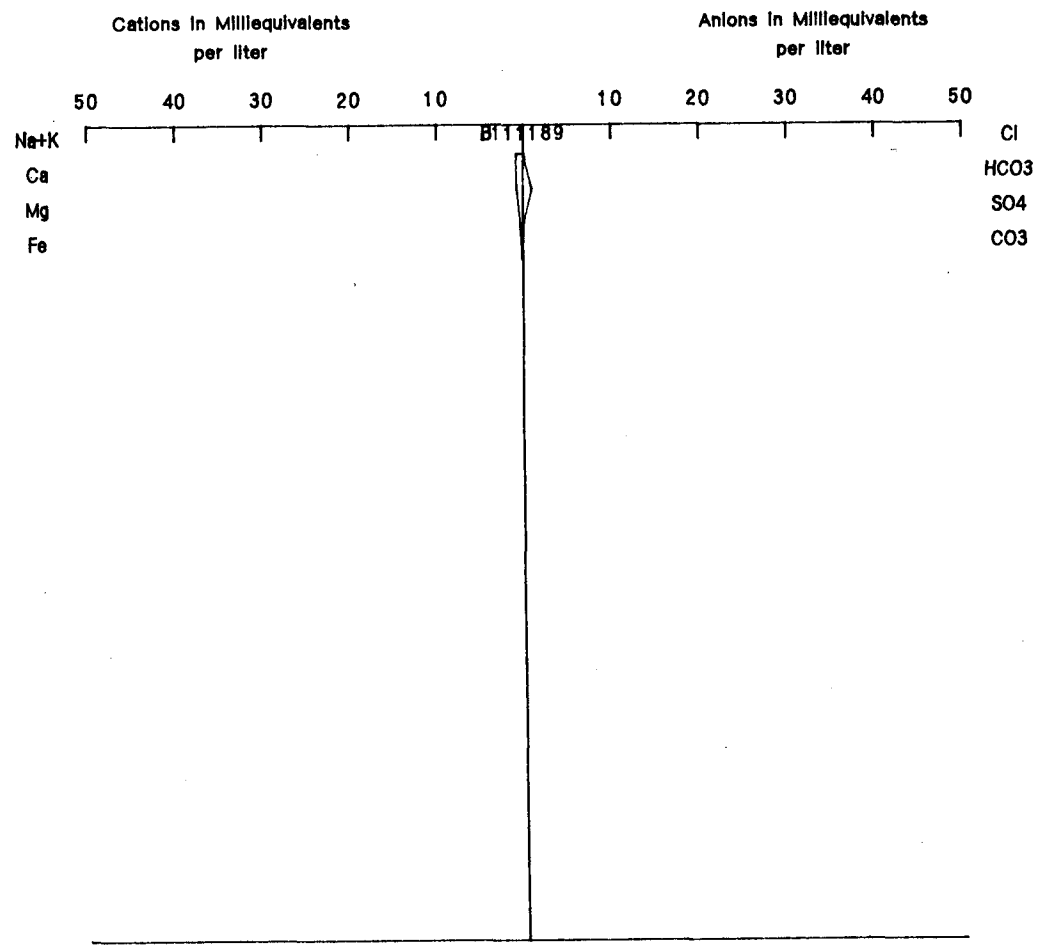


HC-GRAM 2.19

Plotted Values

	B111189	
0.71		0.14
0.60		1.16
0.21		0.19
0.00		0.03

Plotted values converted from mg/L to meq/L

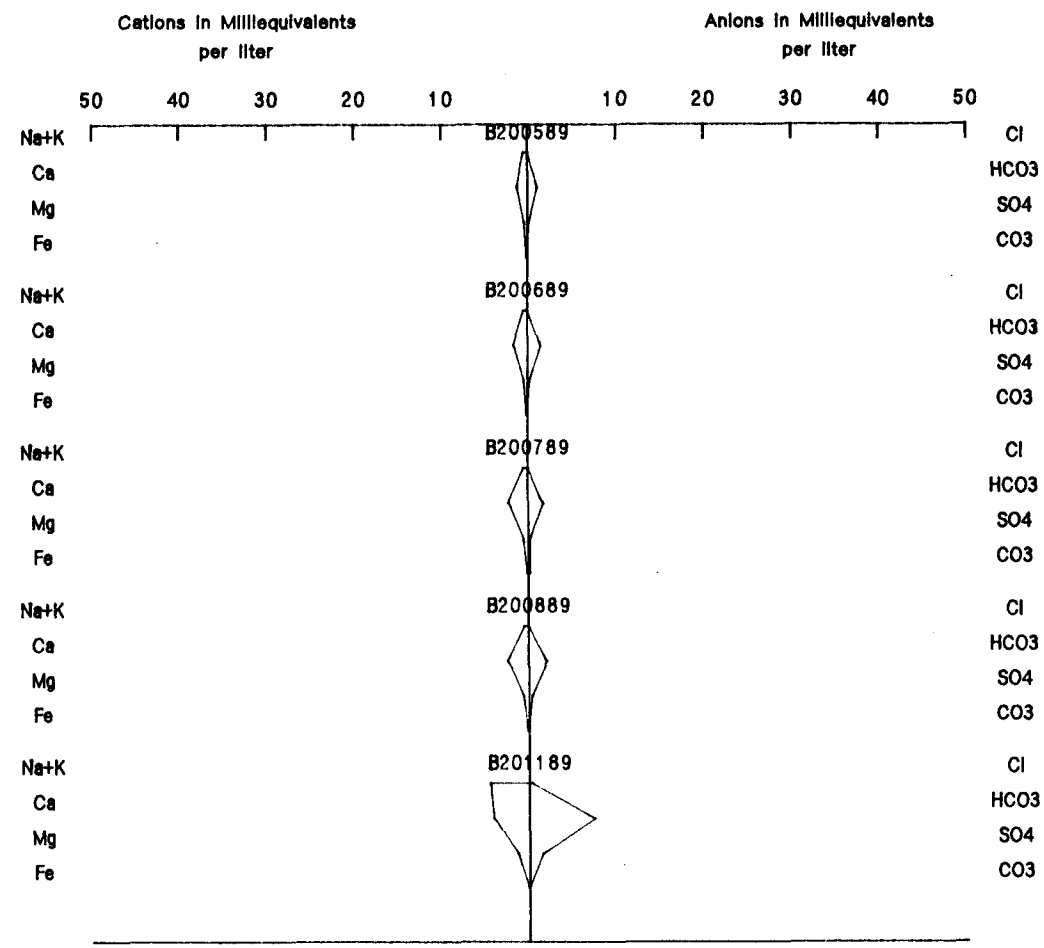


HC-GRAM 2.19

Plotted Values

0.39	B200589	0.14
1.16		1.20
0.29		0.29
0.00		0.03
0.33	B200689	0.11
1.55		1.60
0.33		0.33
0.00		0.03
0.37	B200789	0.14
2.17		1.82
0.45		0.35
0.00		0.33
0.37	B200889	0.11
2.27		2.20
0.50		0.48
0.00		0.03
4.50	B201189	0.39
4.05		7.60
1.29		1.56
0.00		0.03

Plotted values converted from mg/L to meq/L

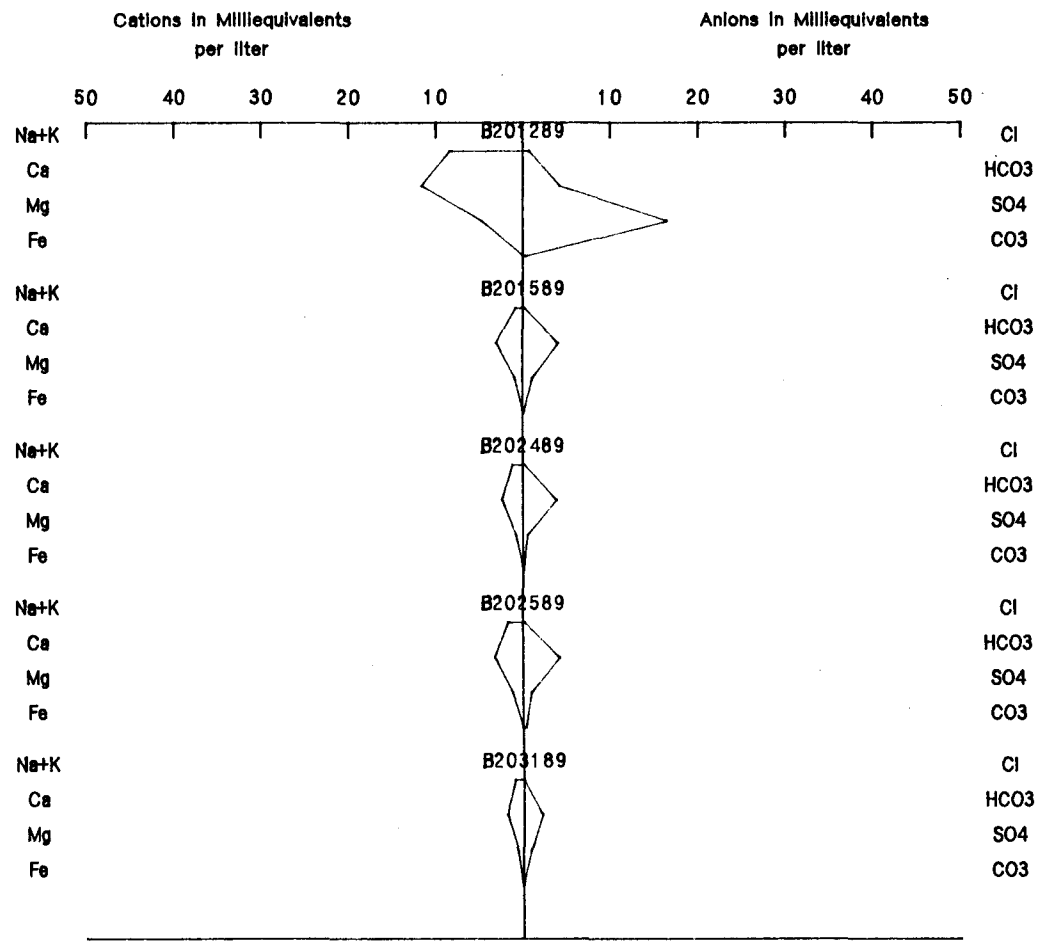


HC-GRAM 2.19

Plotted Values

8.44	B201289	0.65
11.68		4.20
4.75		16.45
0.00		0.33
0.93	B201589	0.10
3.15		4.00
1.00		1.04
0.00		0.03
1.24	B202489	0.14
2.49		3.80
0.89		0.46
0.00		0.03
1.70	B202589	0.19
3.30		4.20
1.22		0.96
0.00		0.33
0.94	B203189	0.05
1.86		2.20
0.61		0.98
0.00		0.07

Plotted values converted from mg/L to meq/L

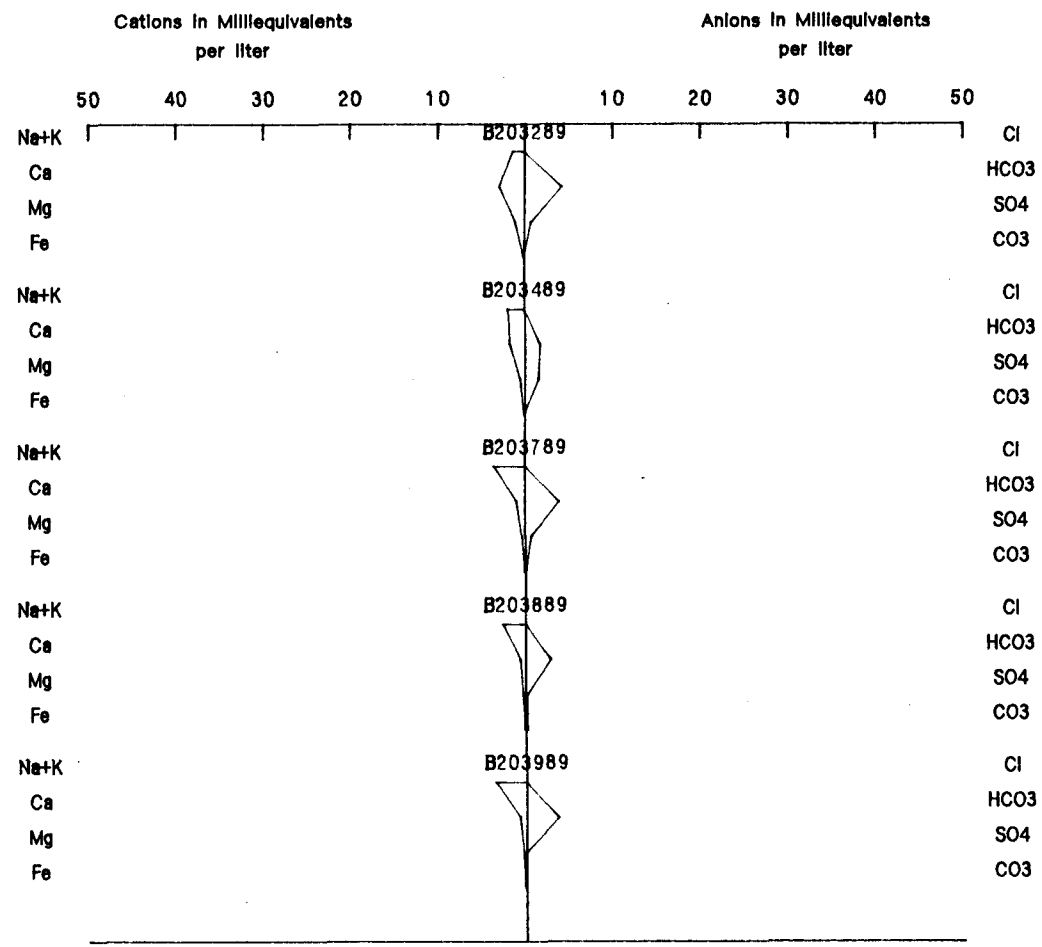


HC-GRAM 2.19

Plotted Values

1.29	B203289	0.06
2.84		4.40
0.97		0.87
0.00		0.03
1.86	B203489	0.06
1.68		1.84
0.47		1.67
0.00		0.03
3.49	B203789	0.15
0.88		4.00
0.30		0.77
0.00		0.13
2.51	B203889	0.14
0.51		3.00
0.18		0.31
0.00		0.33
3.42	B203989	0.11
0.63		3.80
0.20		0.06
0.00		0.03

Plotted values converted from mg/L to meq/L

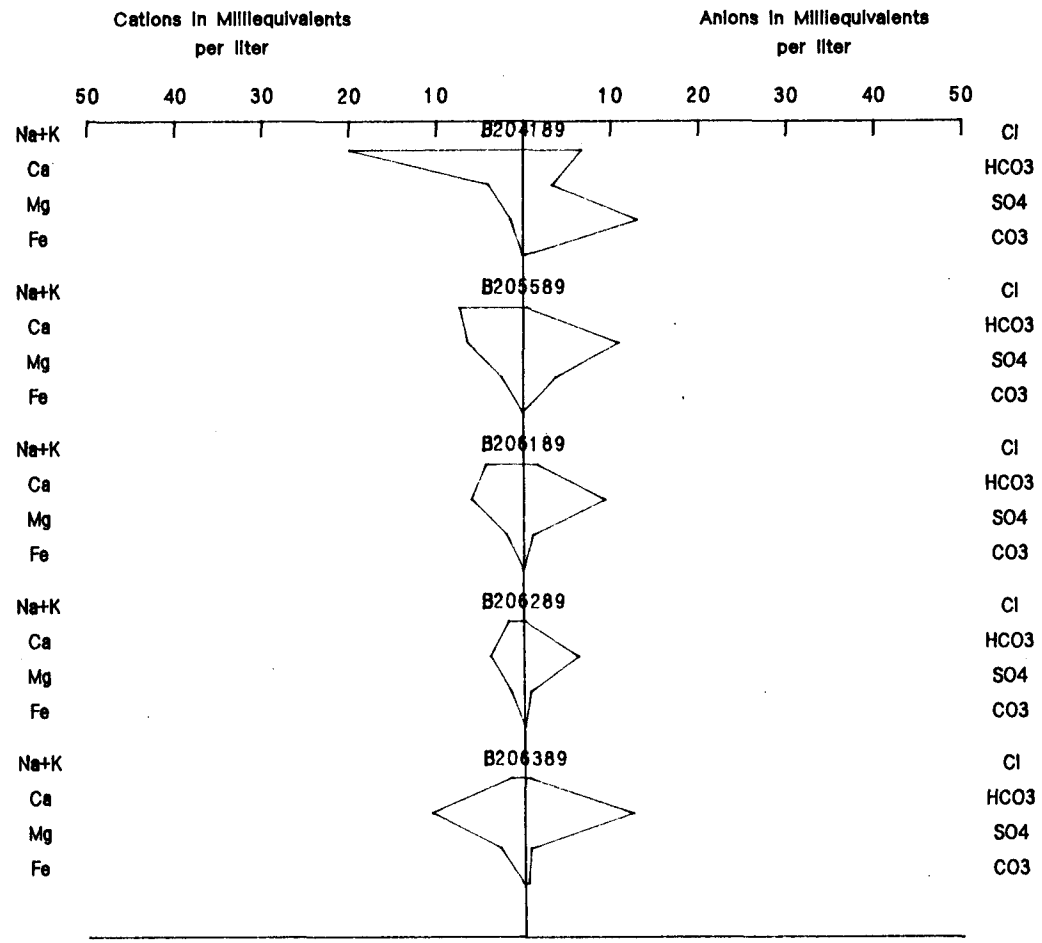


HC-GRAM 2.1 9

Plotted Values

19.80	B204189	6.77
3.96		3.40
1.35		13.12
0.00		0.33
7.25	B205589	0.48
6.34		11.00
2.39		3.75
0.00		0.03
4.26	B206189	1.66
5.99		9.40
1.94		1.10
0.00		0.03
1.78	B206289	0.11
3.88		6.25
1.56		0.74
0.00		0.08
1.64	B206389	0.48
10.68		12.40
2.89		0.62
0.29		0.33

Plotted values converted from mg/L to meq/L

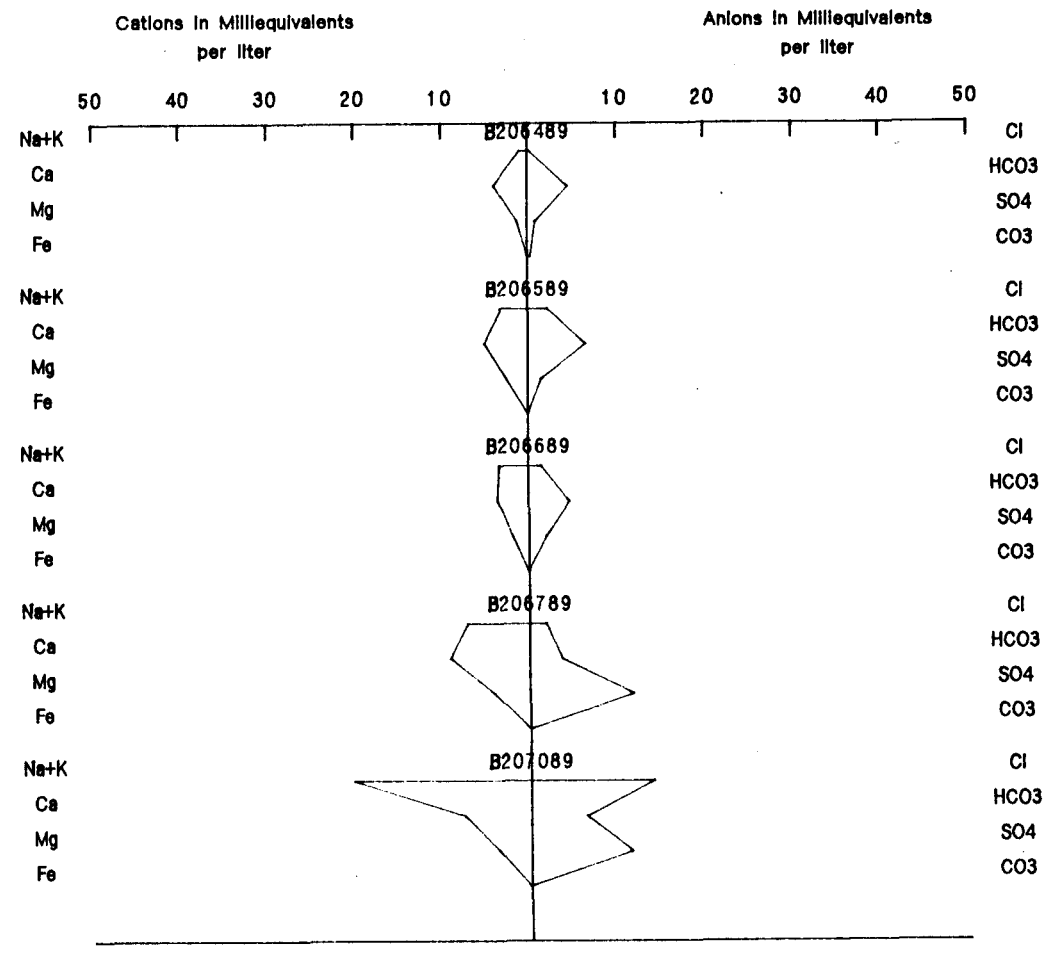


HC-GRAM 2.1 9

Plotted Values

0.93	B206489	0.19
3.90		4.60
1.21		0.90
0.00		0.33
3.08	B206589	2.29
4.99		6.60
2.43		1.56
0.00		0.03
3.26	B206689	1.55
3.54		4.80
1.81		2.08
0.00		0.03
7.02	B206789	2.00
8.98		3.80
4.00		11.87
0.00		0.33
20.08	B207089	14.07
7.53		6.42
3.56		11.58
0.00		0.03

Plotted values converted from mg/L to meq/L

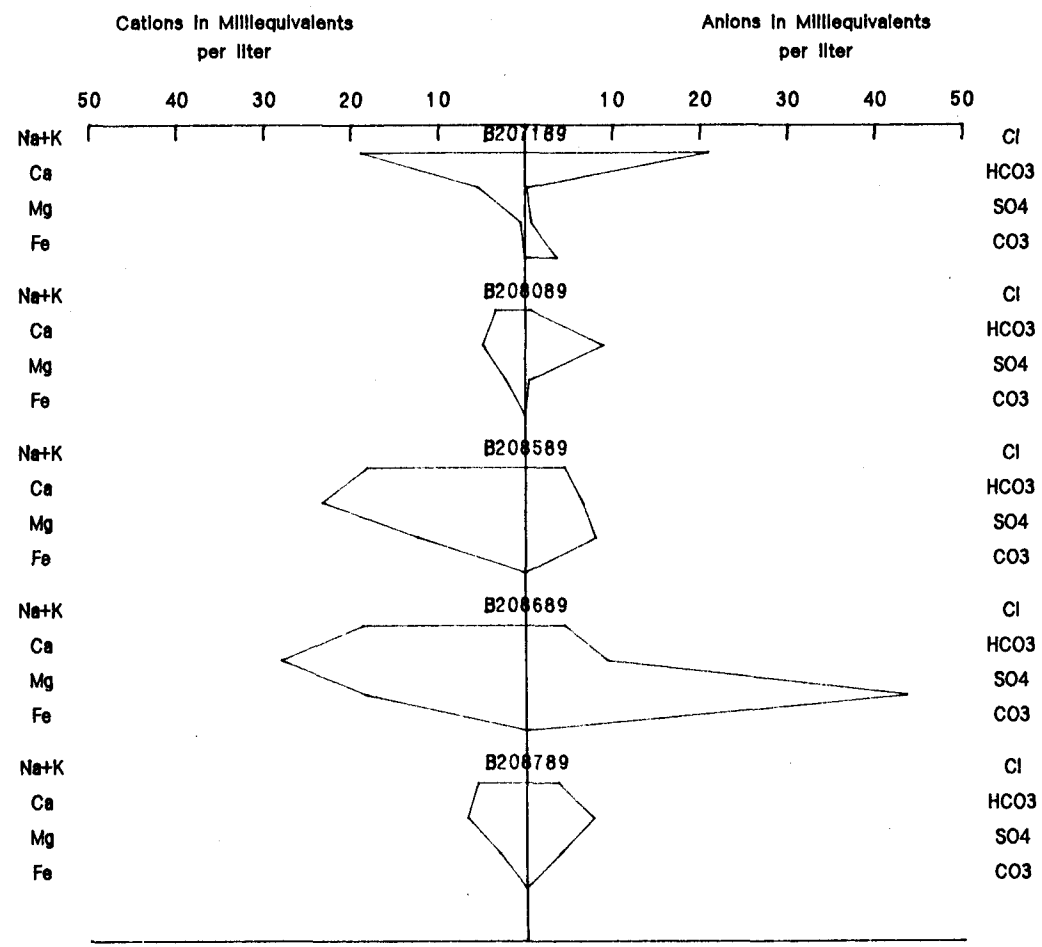


HC-GRAM 2.19

Plotted Values

18.69	B207189	21.02
5.39		0.20
0.51		0.72
0.00		3.70
3.35	B208089	0.68
4.89		9.00
2.13		0.52
0.00		0.03
18.05	B208589	4.51
23.25		6.60
12.26		8.12
0.00		0.03
18.54	B208689	4.51
27.99		9.40
18.18		43.72
0.00		0.33
5.50	B208789	3.67
6.69		7.80
2.99		3.96
0.00		0.03

Plotted values converted from mg/L to meq/L

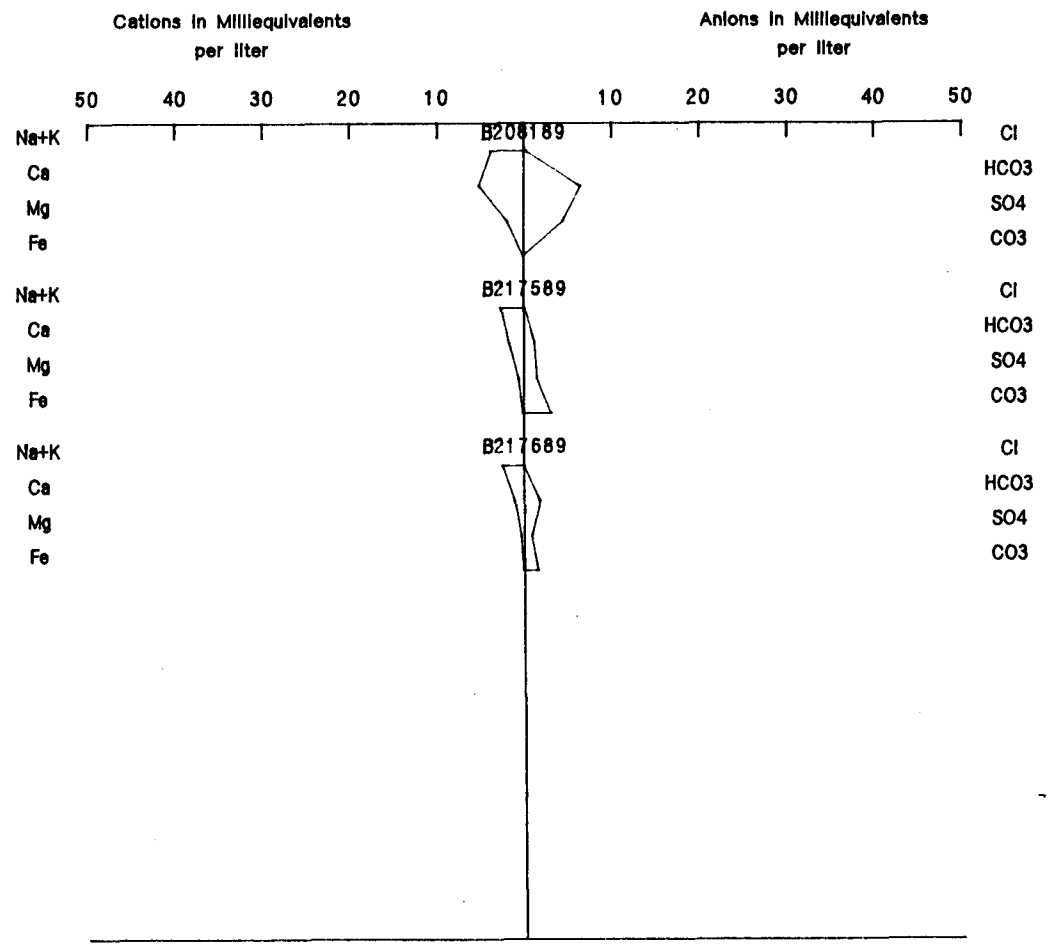


HC-GRAM 2.1 9

Plotted Values

3.69	B208189	0.34
5.04		6.60
1.83		4.58
0.00		0.03
2.55	B217589	0.23
1.67		1.30
0.52		1.58
0.00		3.27
2.35	B217689	0.10
1.00		1.96
0.27		0.94
0.00		1.67

Plotted values converted from mg/L to meq/L

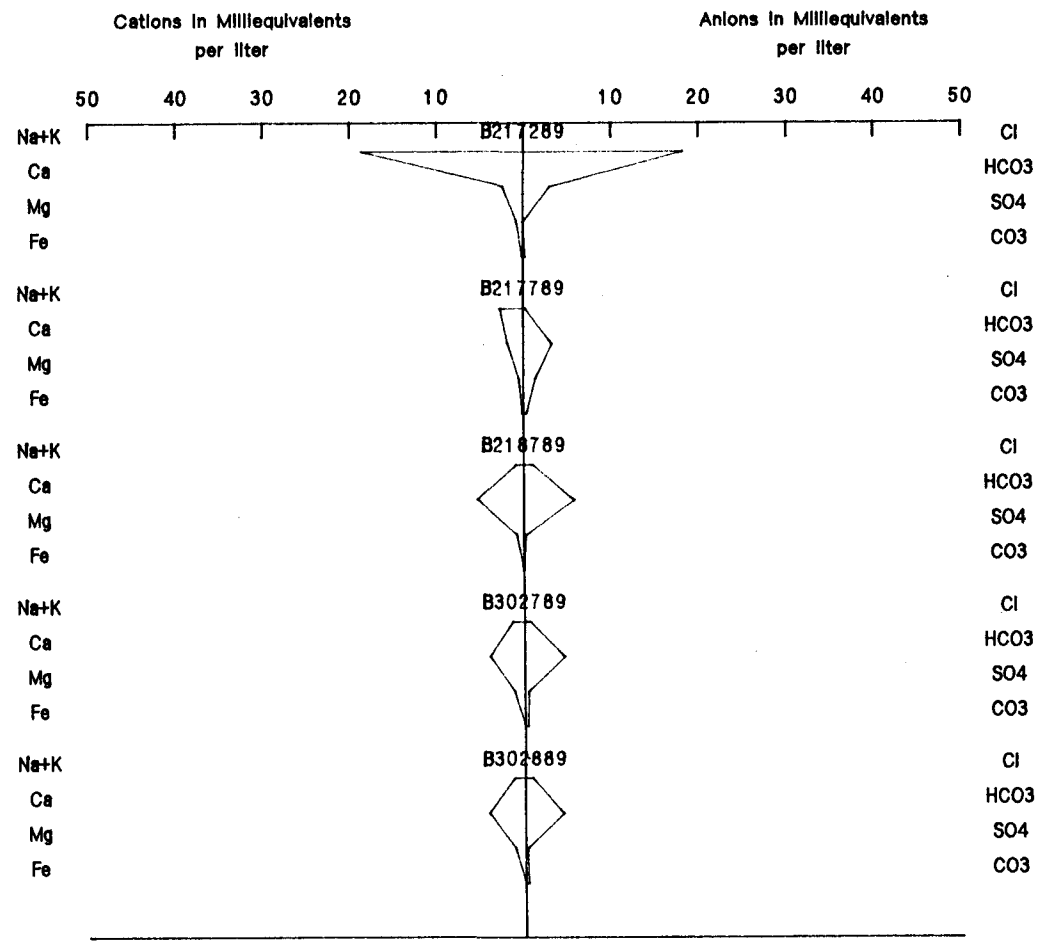


HC-GRAM 2.1 9

Plotted Values

18.49	B217289	18.34
2.23		3.20
0.63		0.10
0.00		0.33
2.60	B217789	0.34
1.77		3.40
0.44		1.52
0.00		0.47
0.88	B218789	1.07
5.29		5.80
0.78		0.27
0.00		0.03
1.41	B302789	0.68
3.99		4.60
1.22		0.42
0.00		0.33
1.24	B302889	0.87
4.16		4.40
1.18		0.23
0.00		0.33

Plotted values converted from mg/L to meq/L

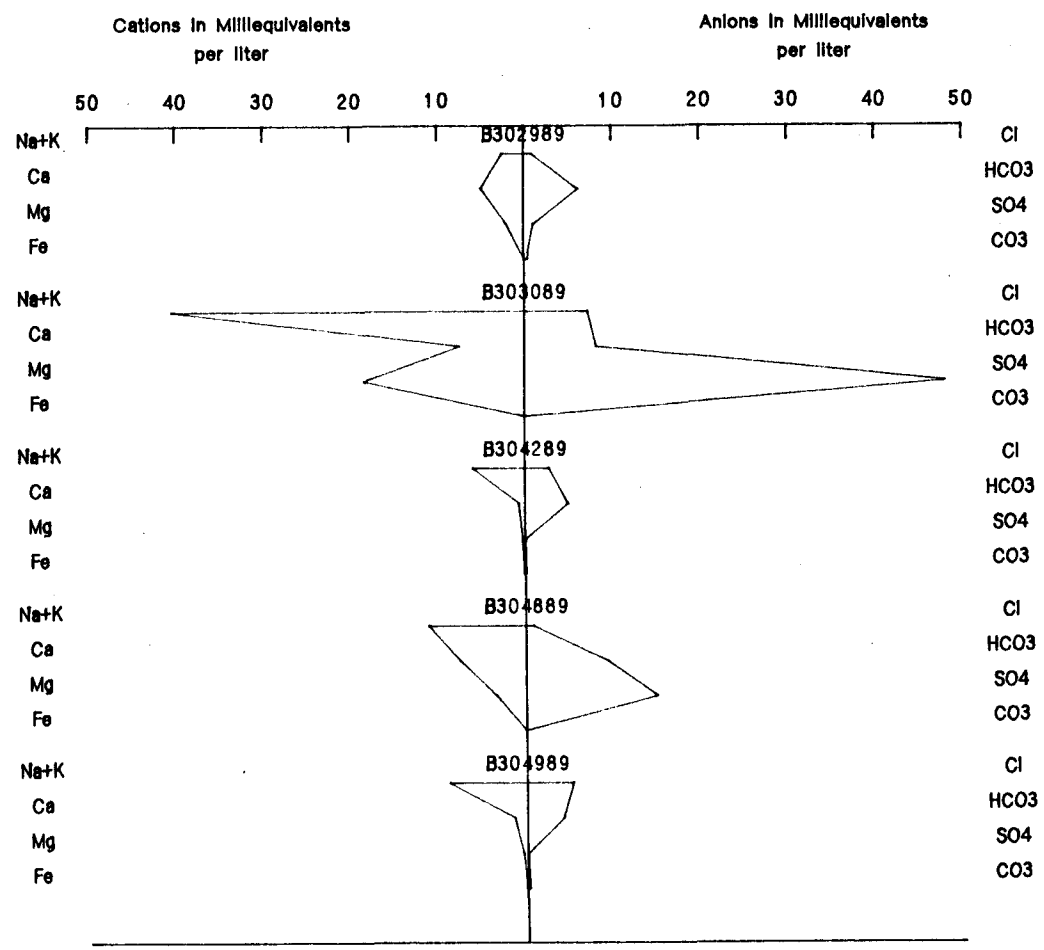


HC-GRAM 2.19

Plotted Values

2.55	B302989	0.87
4.93		6.20
1.99		1.08
0.00		0.33
40.28	B303089	7.22
7.44		8.20
18.34		48.09
0.00		0.07
5.90	B304289	2.82
0.64		5.00
0.22		0.17
0.00		0.20
11.02	B304889	0.96
7.49		9.40
3.35		14.99
0.01		0.03
8.80	B304989	5.36
1.43		4.20
0.43		0.13
0.00		0.33

Plotted values converted from mg/L to meq/L

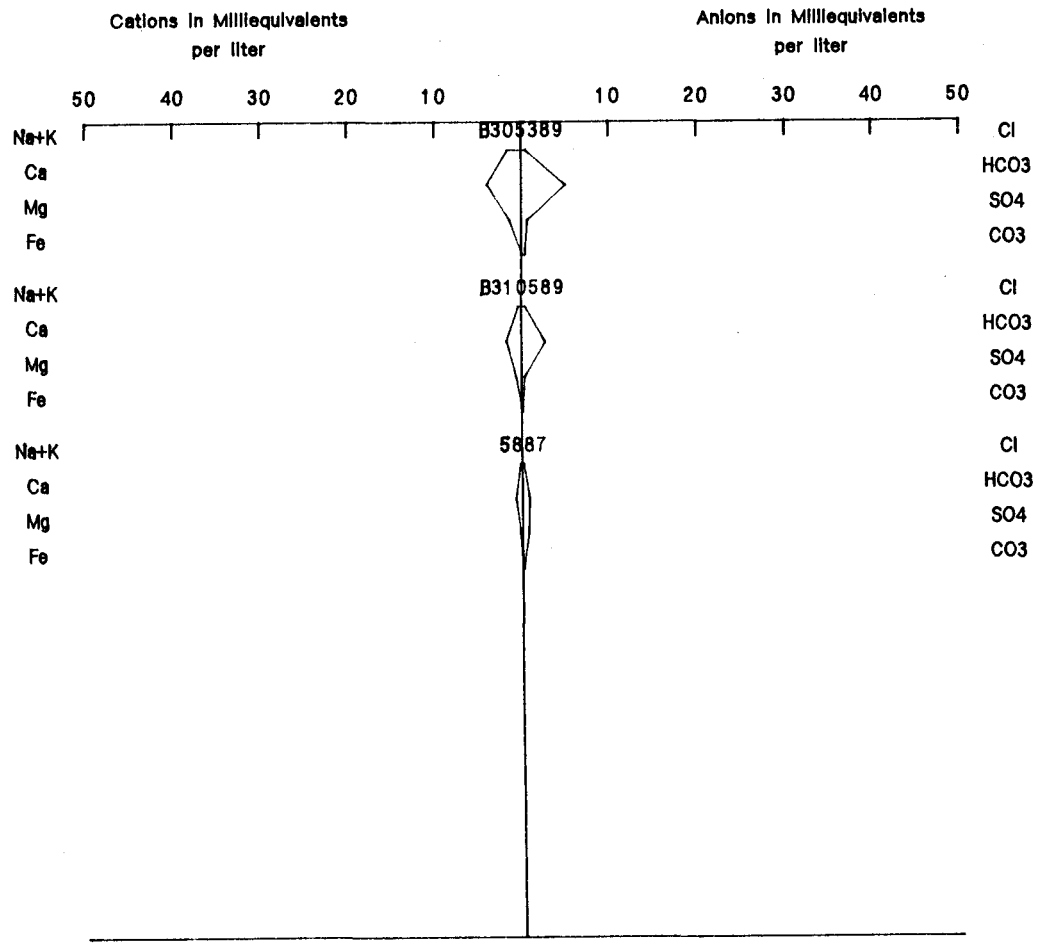


HC-GRAM 2.1 9

Plotted Values

1.69	B305389	0.42
4.03		5.00
1.46		0.65
0.00		0.33
0.48	B310589	0.31
1.86		2.60
0.78		0.25
0.00		0.03
0.27	5887	0.10
0.82		0.76
0.32		0.65
0.00		0.03

Plotted values converted from mg/L to meq/L

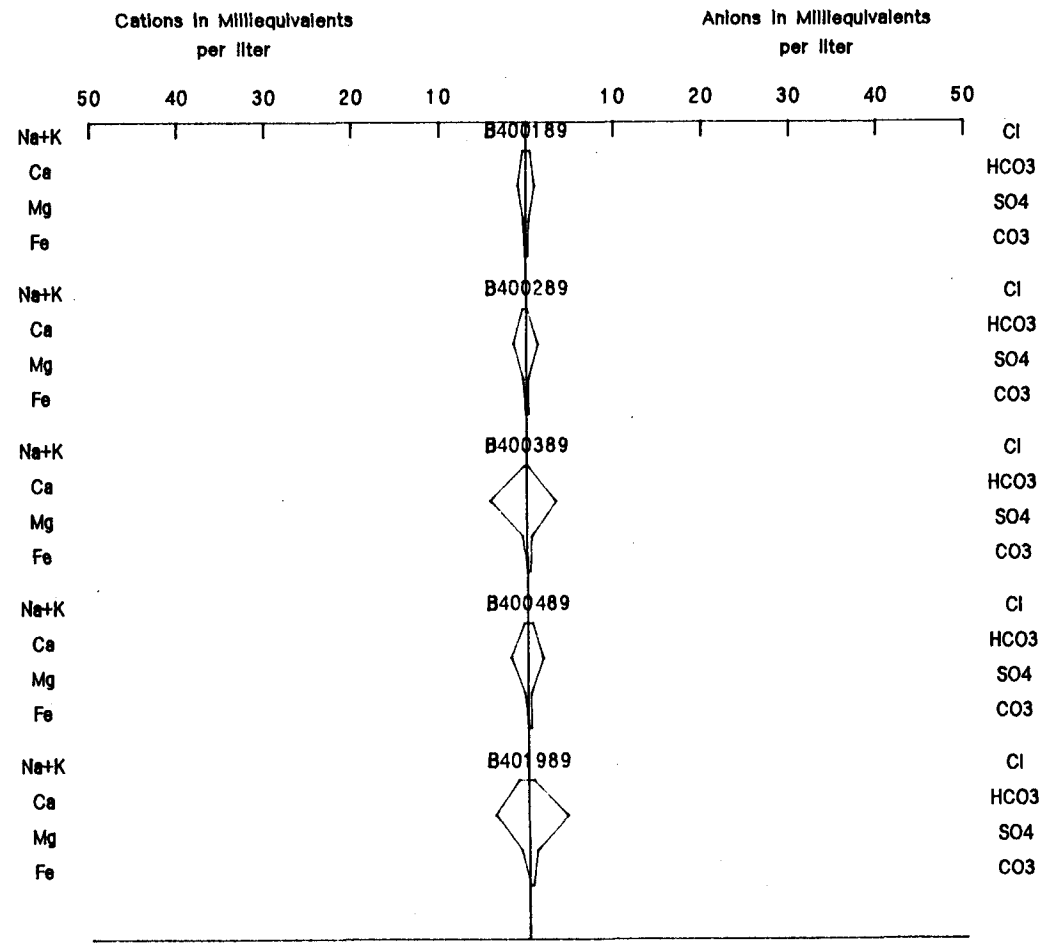


HC-GRAM 2.1 9

Plotted Values

0.32	B400189	0.56
0.87		1.06
0.22		0.41
0.00		0.33
0.38	B400289	0.14
1.42		1.44
0.32		0.31
0.00		0.33
0.26	B400389	0.14
4.20		3.40
0.48		0.60
0.00		0.33
0.48	B400489	0.48
2.03		1.72
0.46		0.31
0.00		0.33
1.26	B401989	0.51
3.92		4.40
1.00		0.81
0.00		0.33

Plotted values converted from mg/L to meq/L

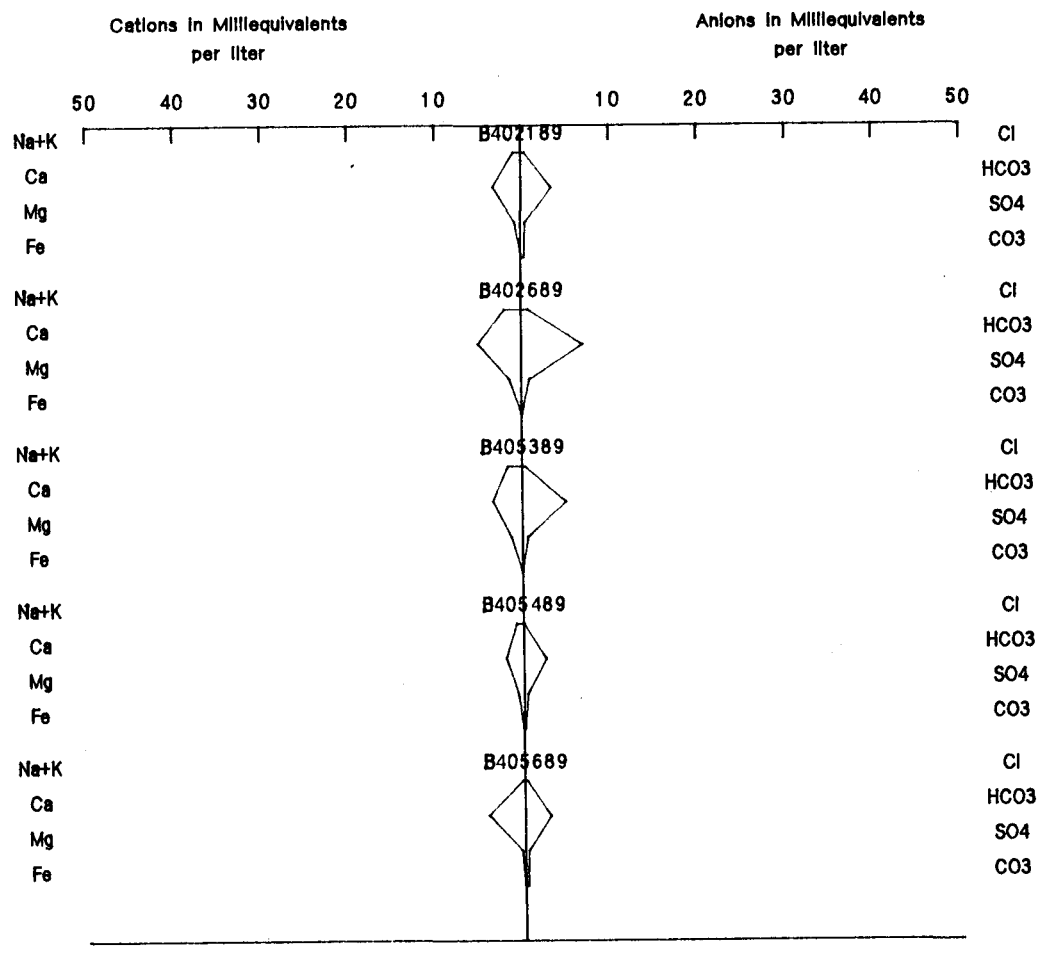


HC-GRAM 2.1 9

Plotted Values

0.95	B402189	0.31
3.33		3.40
0.78		0.44
0.00		0.33
1.95	B402689	0.79
4.99		7.00
1.41		0.90
0.00		0.03
1.64	B405389	0.37
3.37		5.00
1.29		0.69
0.00		0.03
0.75	B405489	0.08
2.01		2.60
0.63		0.46
0.00		0.20
0.22	B405689	0.31
4.12		3.00
0.36		0.42
0.00		0.33

Plotted values converted from mg/L to meq/L

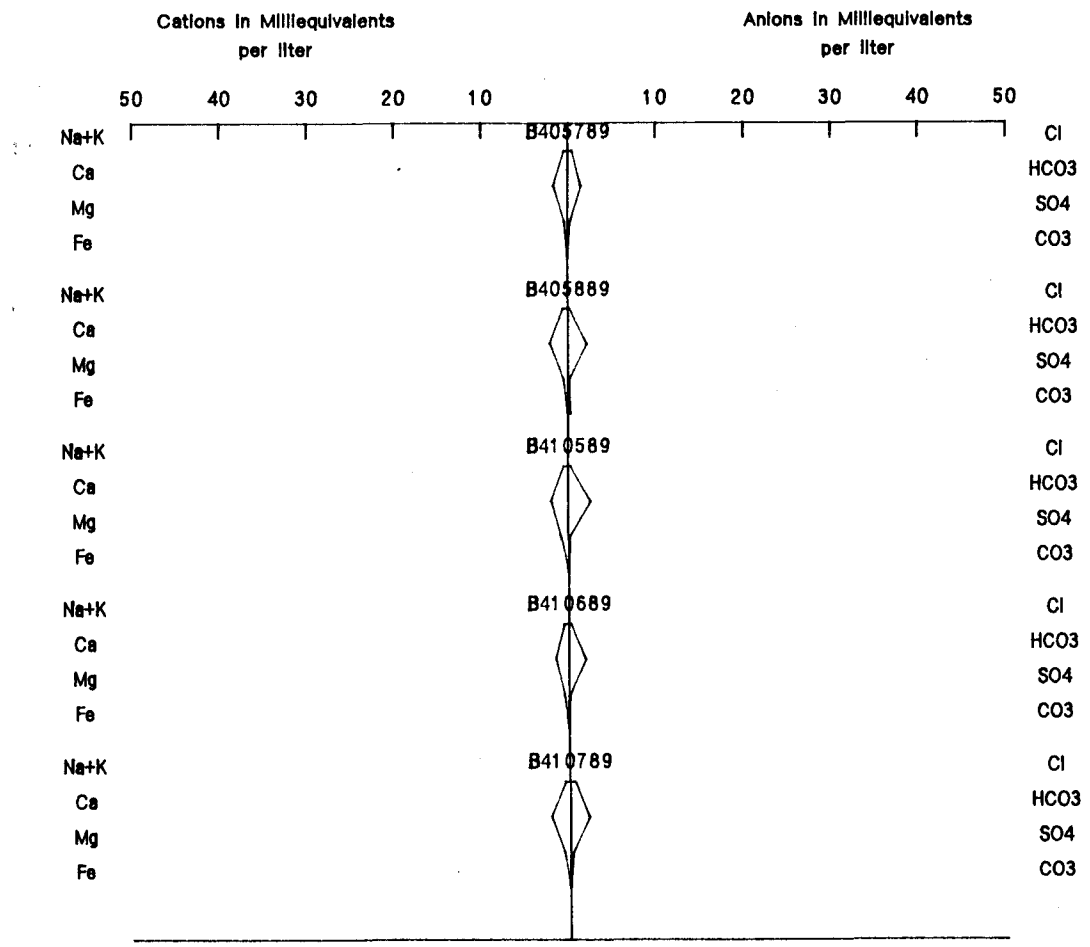


HC-GRAM 2.1 9

Plotted Values

0.43	B405789	0.51
1.65		1.56
0.41		0.33
0.00		0.03
0.56	B405889	0.18
2.06		2.20
0.50		0.23
0.00		0.33
0.49	B410589	0.28
1.94		2.60
0.80		0.25
0.00		0.03
0.48	B410689	0.28
1.46		2.00
0.50		0.21
0.00		0.03
0.53	B410789	0.59
2.16		2.20
0.66		0.37
0.00		0.03

Plotted values converted from mg/L to meq/L

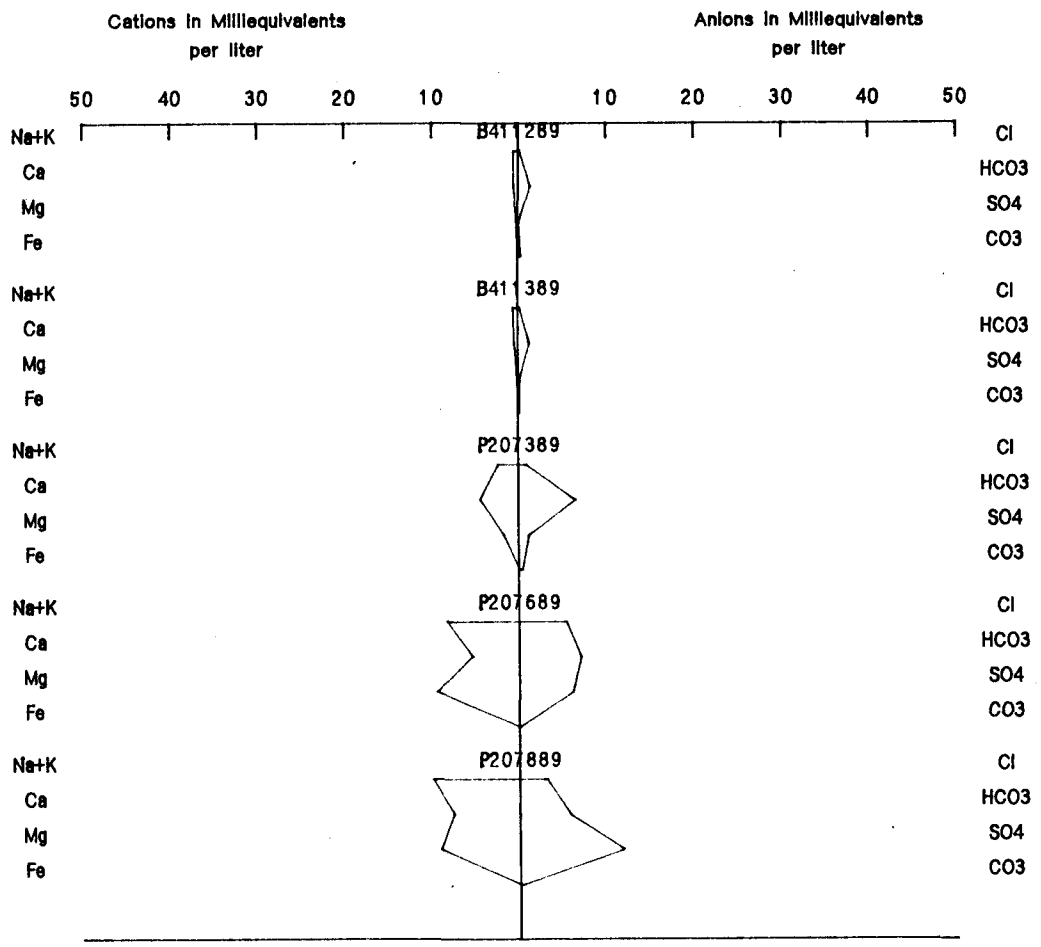


HC-GRAM 2.1 9

Plotted Values

0.57	B411289	0.14
0.56		1.36
0.18		0.10
0.00		0.33
0.65	B411389	0.11
0.53		1.20
0.17		0.12
0.00		0.03
2.47	P207389	0.79
4.57		6.40
1.84		1.08
0.00		0.33
8.33	P207689	5.36
5.44		7.00
9.54		6.04
0.00		0.03
9.94	P207889	3.10
7.53		5.80
9.05		11.87
0.00		0.33

Plotted values converted from mg/L to meq/L

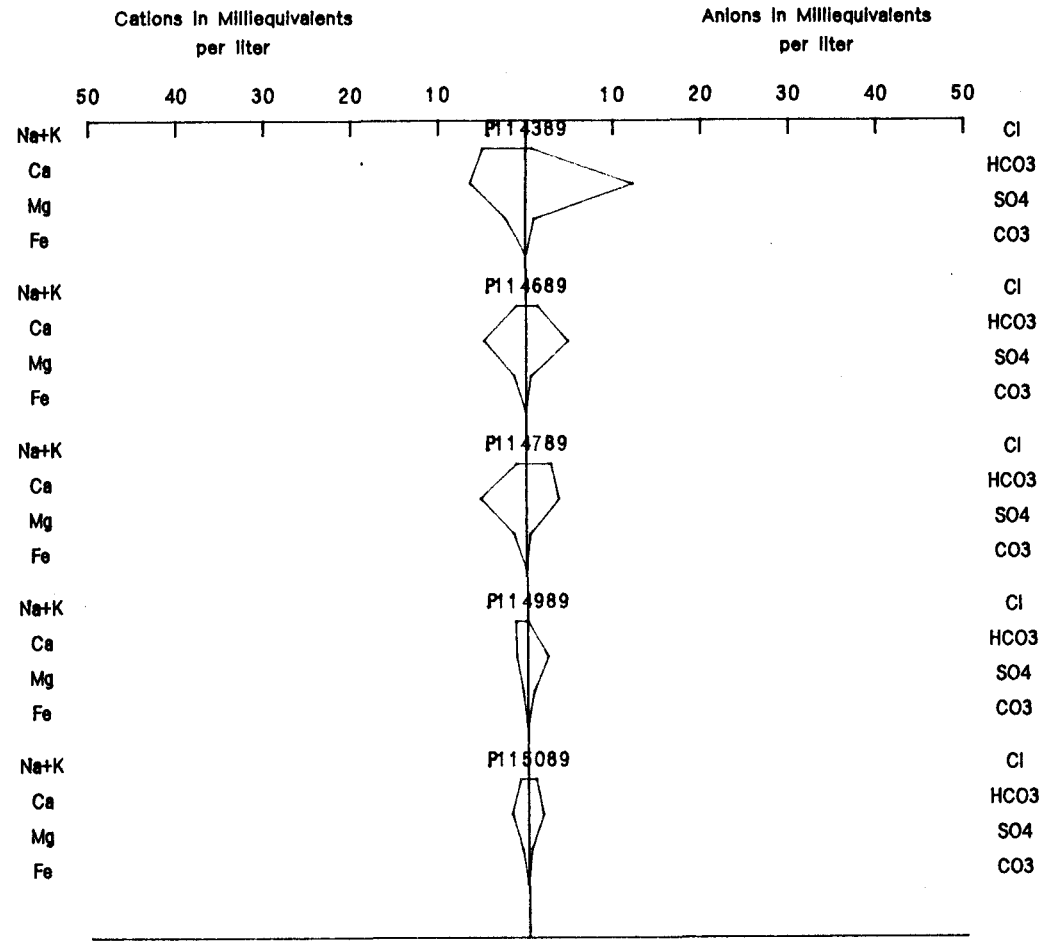


HC-GRAM 2.19

Plotted Values

4.89	P114389	0.71
6.29		12.38
2.25		1.01
0.00		0.16
1.09	P114689	1.33
4.79		4.89
1.31		0.62
0.00		0.04
1.09	P114789	2.88
5.19		3.79
1.37		0.50
0.00		0.02
1.33	P114989	0.08
1.25		2.40
0.49		0.79
0.00		0.03
0.85	P115089	0.93
1.86		1.76
0.62		0.43
0.00		0.01

Plotted values converted from mg/L to meq/L

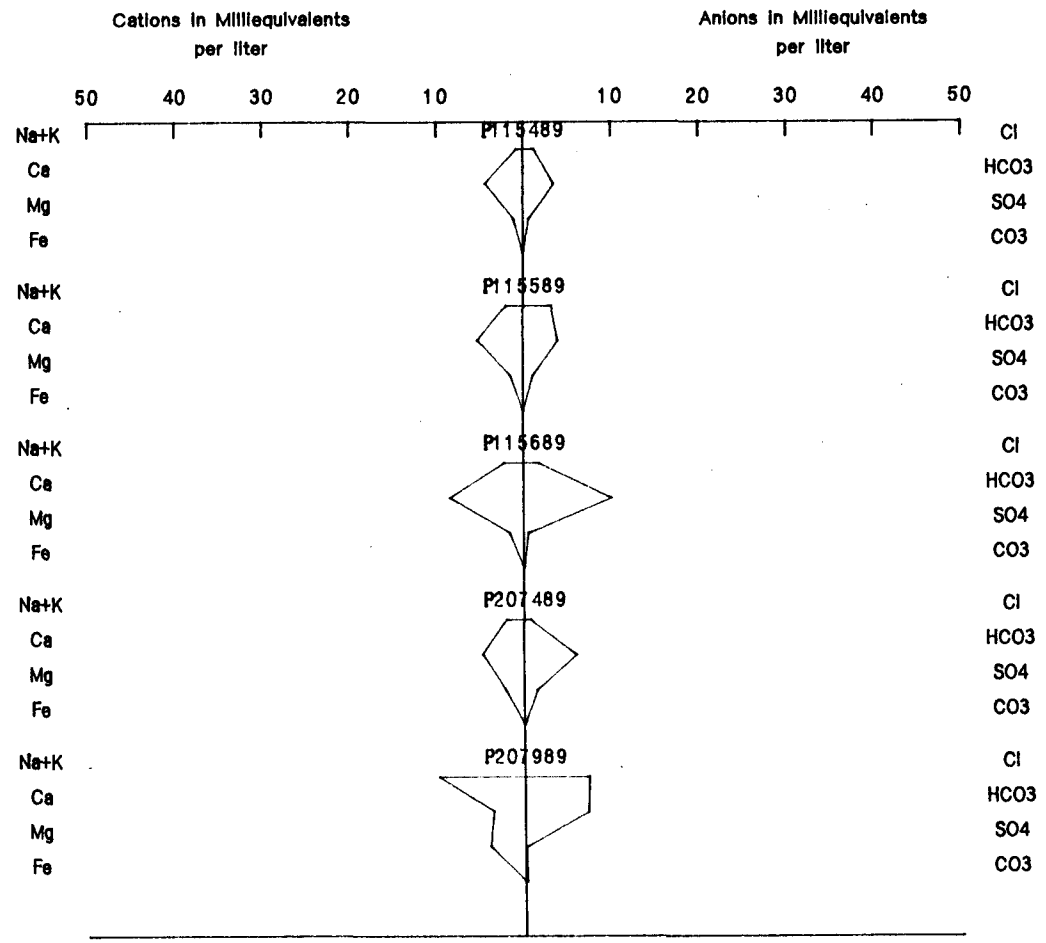


HC-GRAM 2.19

Plotted Values

0.72	P115489	1.25
4.36		3.57
1.06		0.71
0.00		0.03
1.99	P115589	3.24
5.24		4.03
1.44		1.13
0.00		0.03
2.20	P115689	1.74
8.48		10.09
1.65		0.56
0.00		0.07
2.02	P207489	0.73
4.77		6.00
2.15		1.50
0.00		0.03
9.86	P207989	7.33
3.61		7.20
4.01		0.08
0.00		0.17

Plotted values converted from mg/L to meq/L

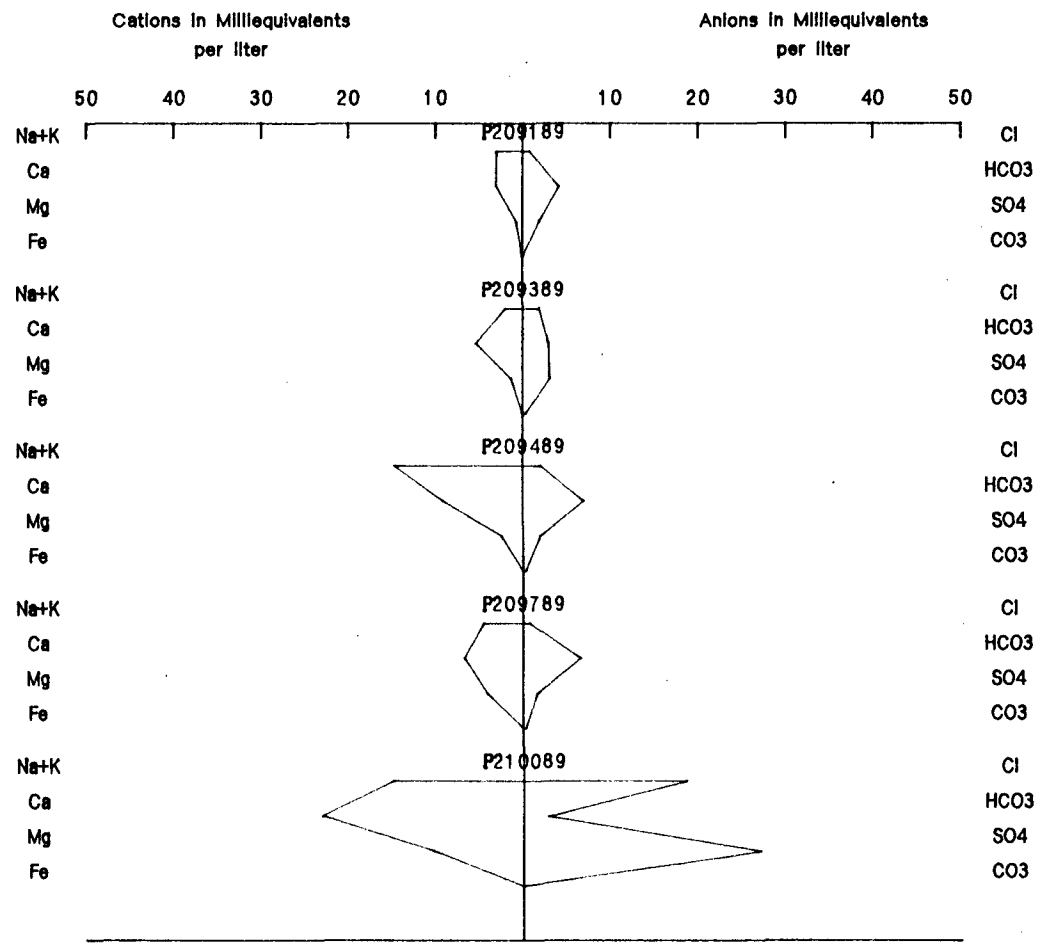


HC-GRAM 2.19

Plotted Values

2.98	P209189	0.79
3.02		4.20
0.68		1.94
0.02		0.03
1.97	P209389	1.86
5.34		3.00
1.31		3.12
0.00		0.33
14.60	P209489	2.00
9.13		7.00
2.47		1.98
0.00		0.33
4.46	P209789	0.79
6.69		6.60
4.03		1.67
0.00		0.33
14.88	P210089	18.62
23.00		2.80
10.20		27.07
0.00		0.03

Plotted values converted from mg/L to meq/L

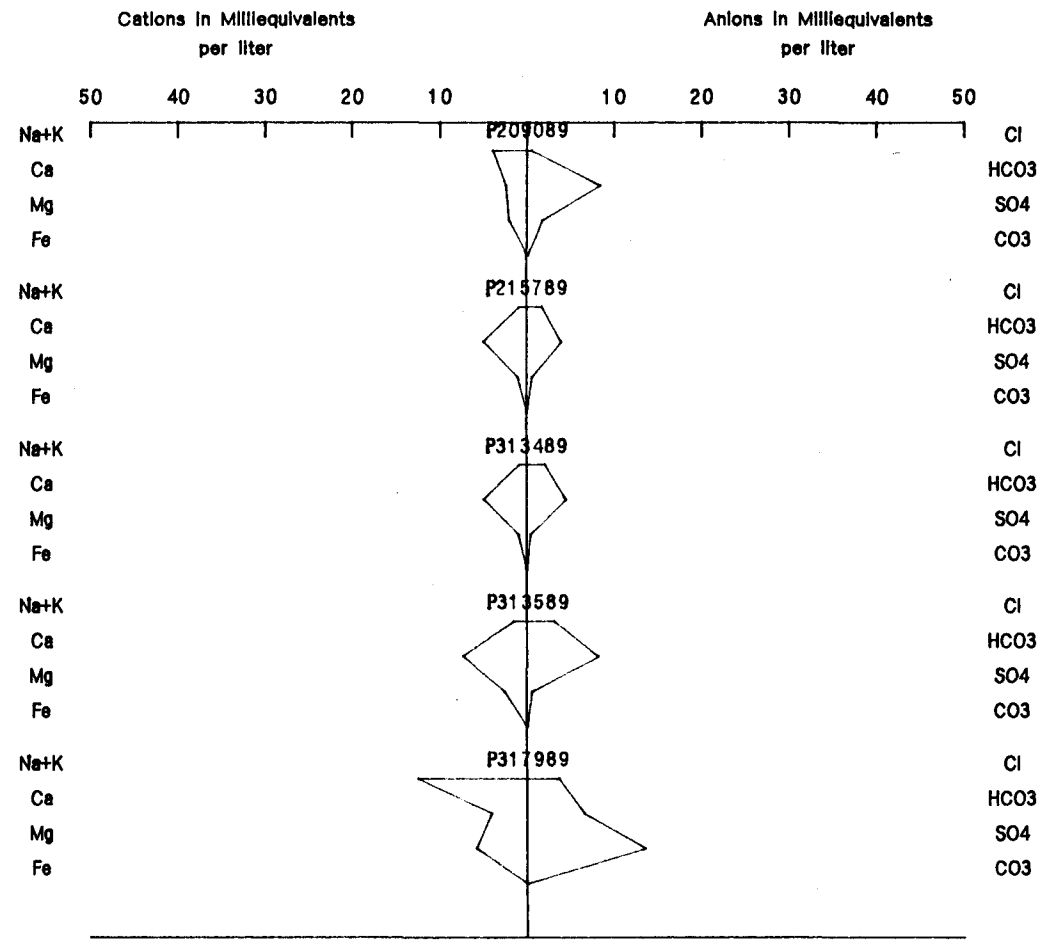


HC-GRAM 2.19

Plotted Values

4.01	P209089	0.54
2.50		8.40
2.11		1.75
0.00		0.17
0.92	P215789	1.72
5.04		3.95
1.06		0.59
0.00		0.01
0.92	P313489	2.07
4.99		4.50
0.98		0.45
0.00		0.05
1.56	P313589	3.15
7.39		8.22
2.58		0.65
0.00		0.09
12.37	P317989	3.67
4.03		6.60
5.81		13.53
0.00		0.17

Plotted values converted from mg/L to meq/L

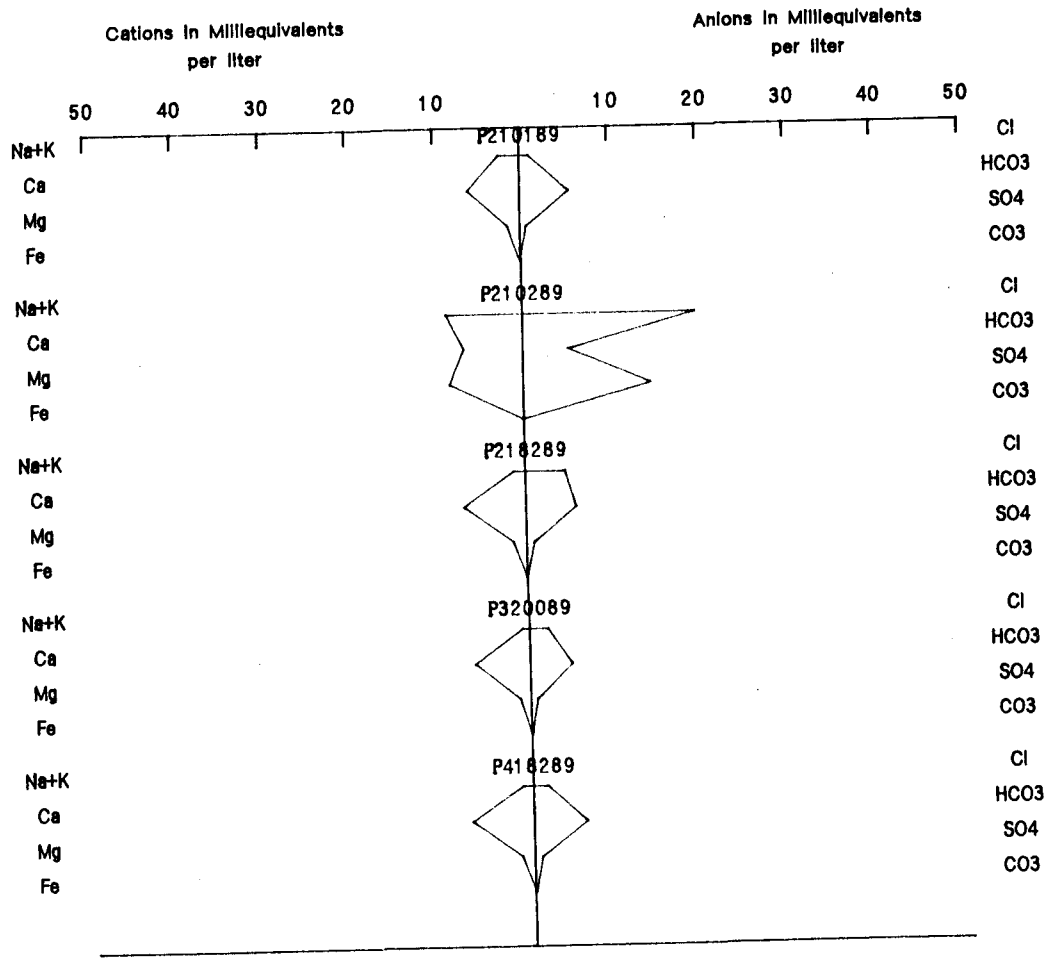


HC-GRAM 2.19

Plotted Values

2.39	P210189	1.15
5.94		5.71
1.37		0.83
0.00		0.03
8.72	P210289	19.75
6.69		5.20
8.39		14.57
0.00		0.03
1.35	P218289	4.57
7.09		5.80
1.50		0.96
0.00		0.03
0.87	P320089	2.06
6.29		4.80
1.27		0.75
0.00		0.02
1.29	P418289	1.61
7.09		6.00
1.51		0.83
0.00		0.03

Plotted values converted from mg/L to meq/L

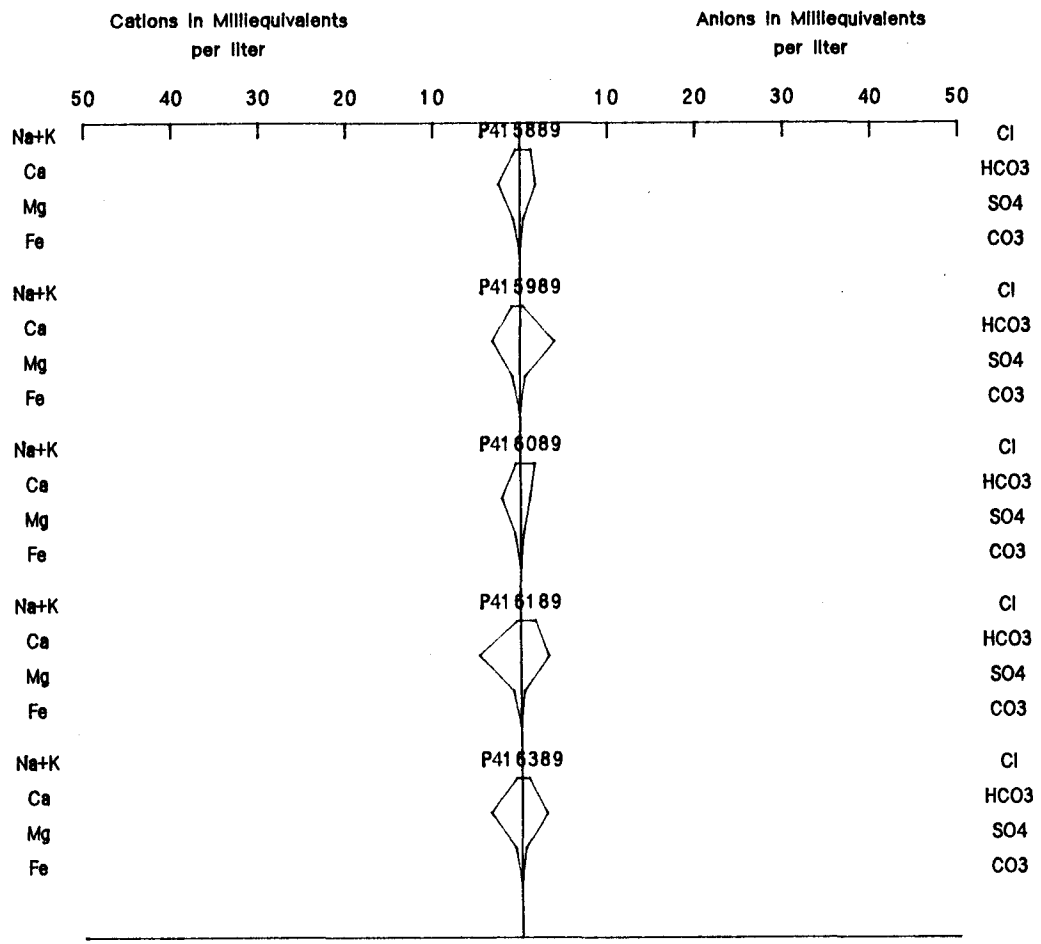


HC-GRAM 2.19

Plotted Values

0.50	P415889	1.28
2.46		1.82
0.73		0.40
0.00		0.01
0.90	P415989	0.32
3.18		4.00
0.86		0.62
0.02		0.01
0.52	P416089	1.69
2.13		1.12
0.63		0.37
0.00		0.03
0.37	P416189	1.73
4.74		3.28
0.82		0.42
0.00		0.01
0.56	P416389	0.85
3.53		2.93
0.63		0.52
0.00		0.02

Plotted values converted from mg/L to meq/L

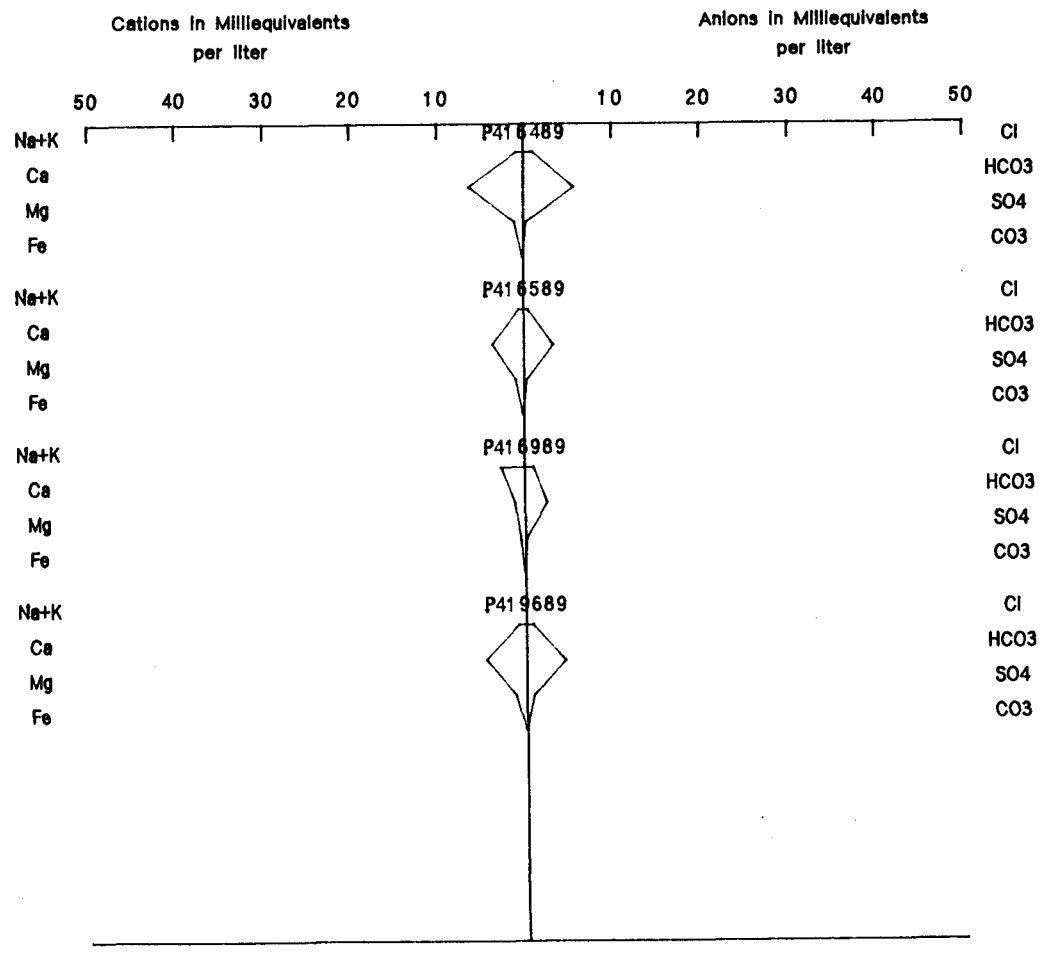


HC-GRAM 2.1 9

Plotted Values

0.66	P41 6489	1.20
6.1 4		5.91
0.89		0.45
0.00		0.1 0
0.43	P41 6589	0.61
3.53		3.47
0.82		0.44
0.00		0.01
2.61	P41 6989	1.1 2
1.05		2.69
0.45		0.29
0.00		0.05
0.7 2	P41 9689	0.87
4.50		4.60
1.1 1		0.98
0.00		0.03

Plotted values converted from mg/L to meq/L

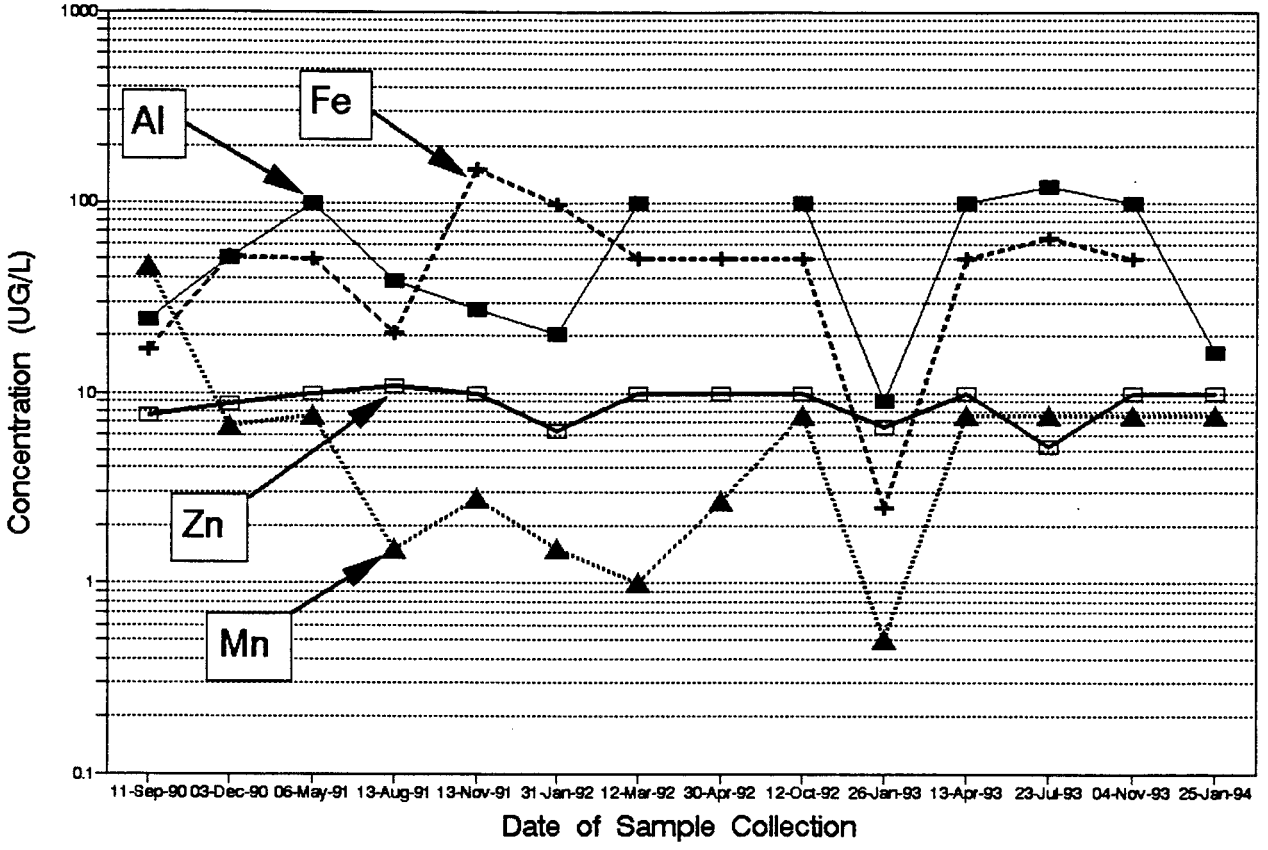


HC-GRAM 2.1 9

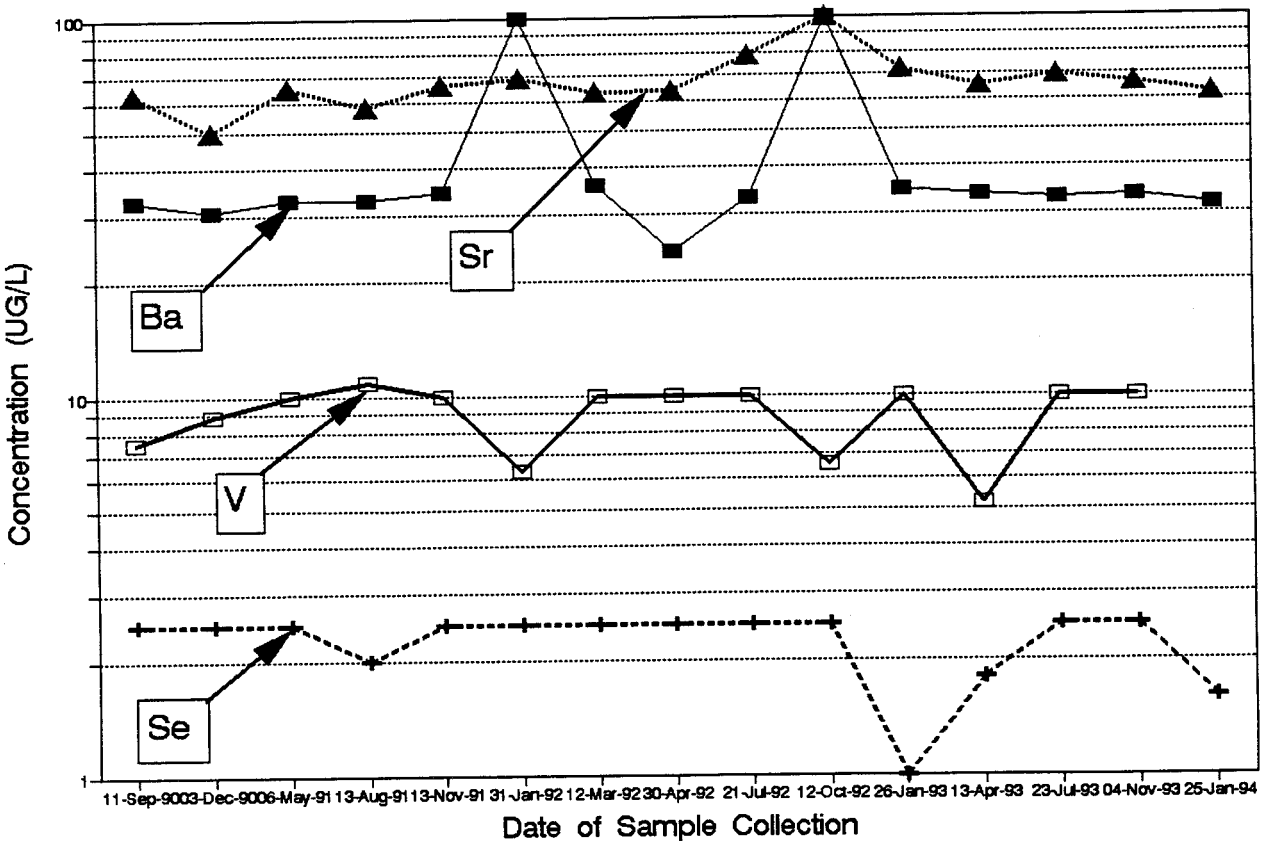
E. Time-Series Plots

Groundwater constituents selected for display as time-series plots include TDS, major ions (bicarbonate, chloride, nitrate, sulfate, calcium, potassium, magnesium, sodium), silica, and minor ions (aluminum, barium, iron, manganese, selenium, strontium, vanadium, and zinc). Time-series plots for 36 UHSU wells were generated using data from 1990 through 1993. The selected wells are along the four flow paths identified in this study: the Rock Creek flow path, the Industrial Area flow path, the Woman Creek flow path, and the Southern flow path.

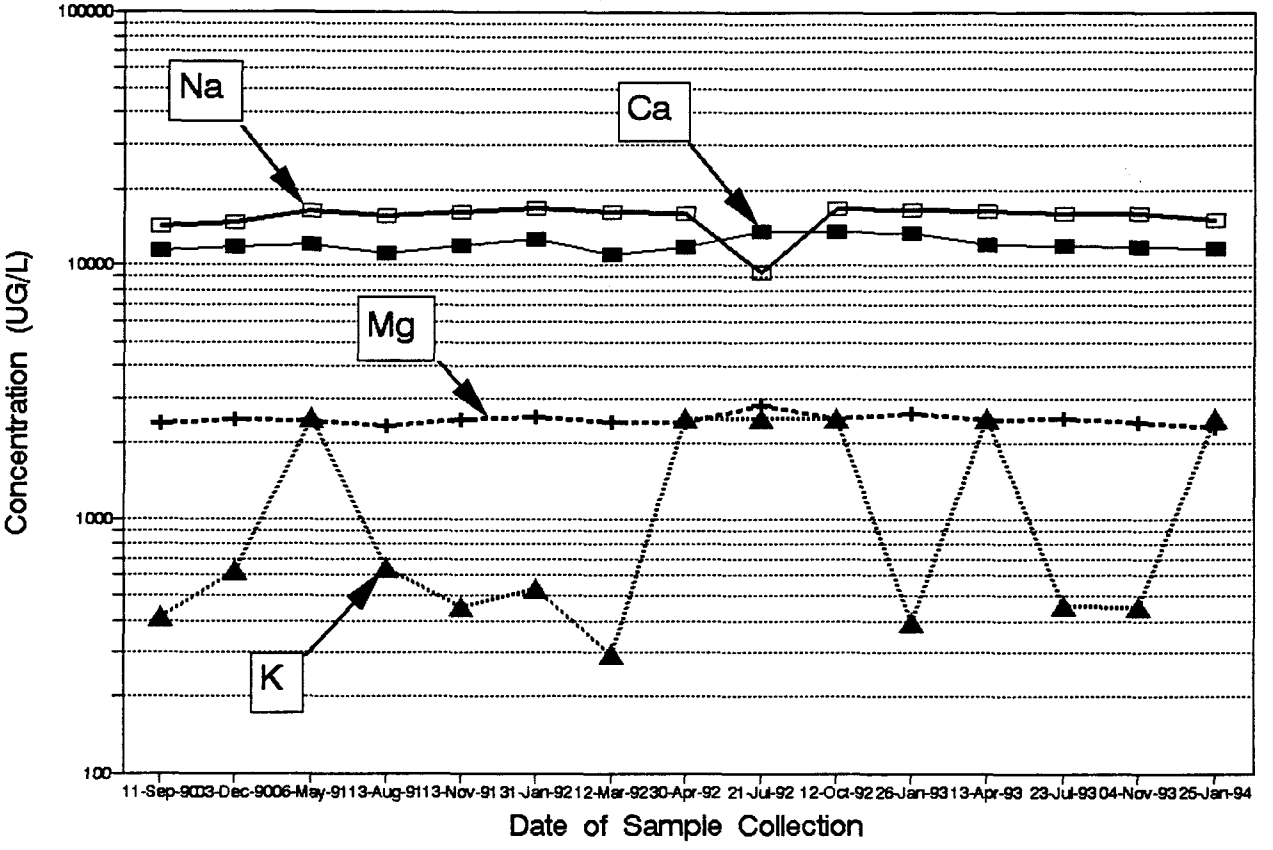
Well B111189 - Rock Creek flow path



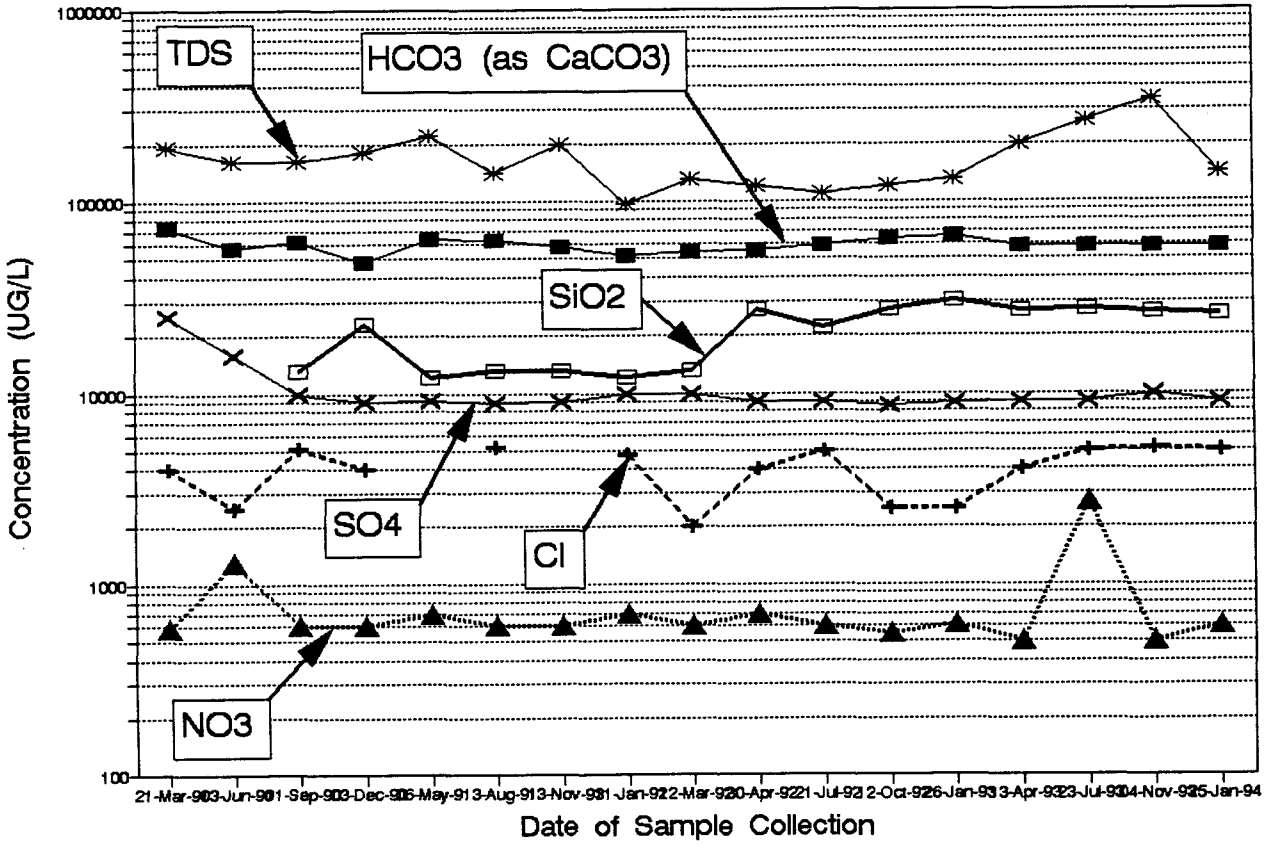
Well B111189 - Rock Creek flow path



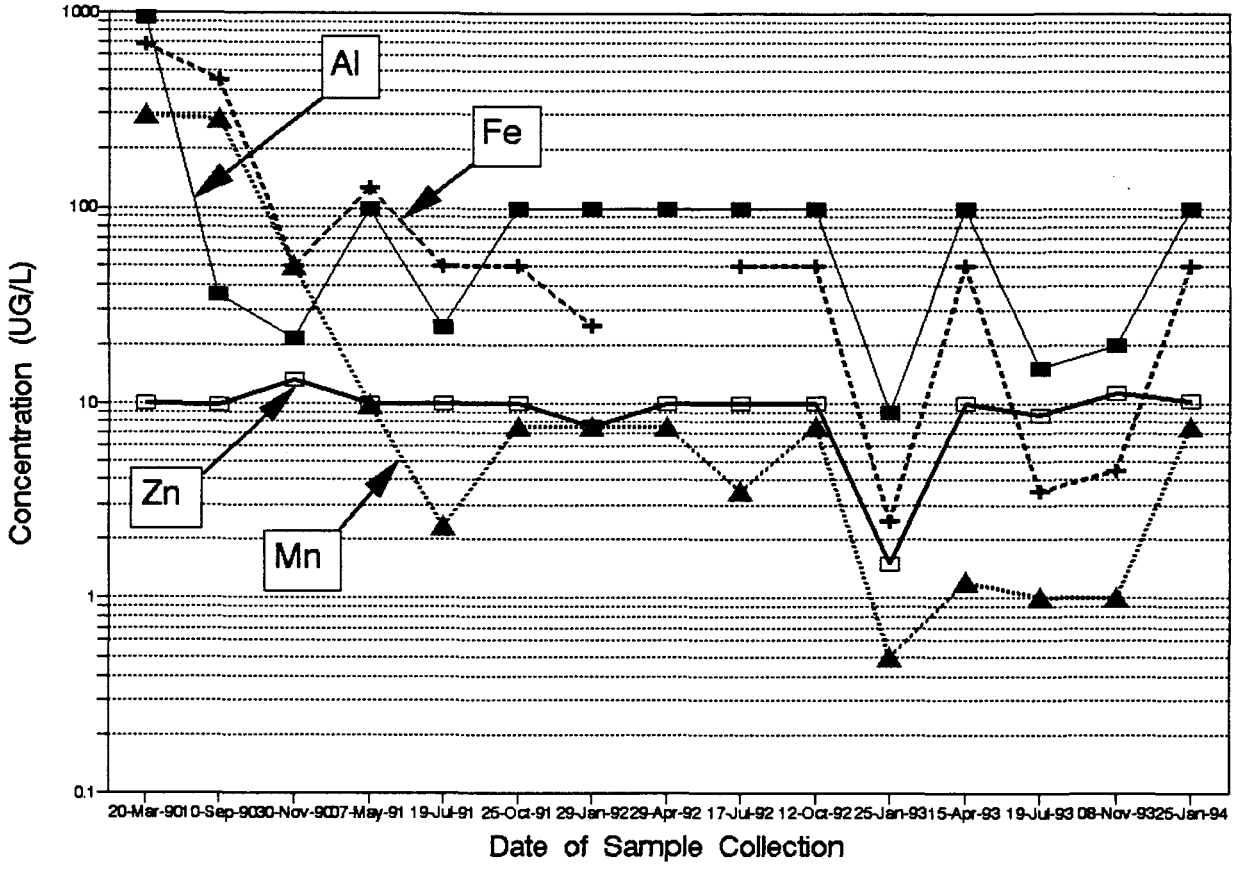
Well B111189 - Rock Creek flow path



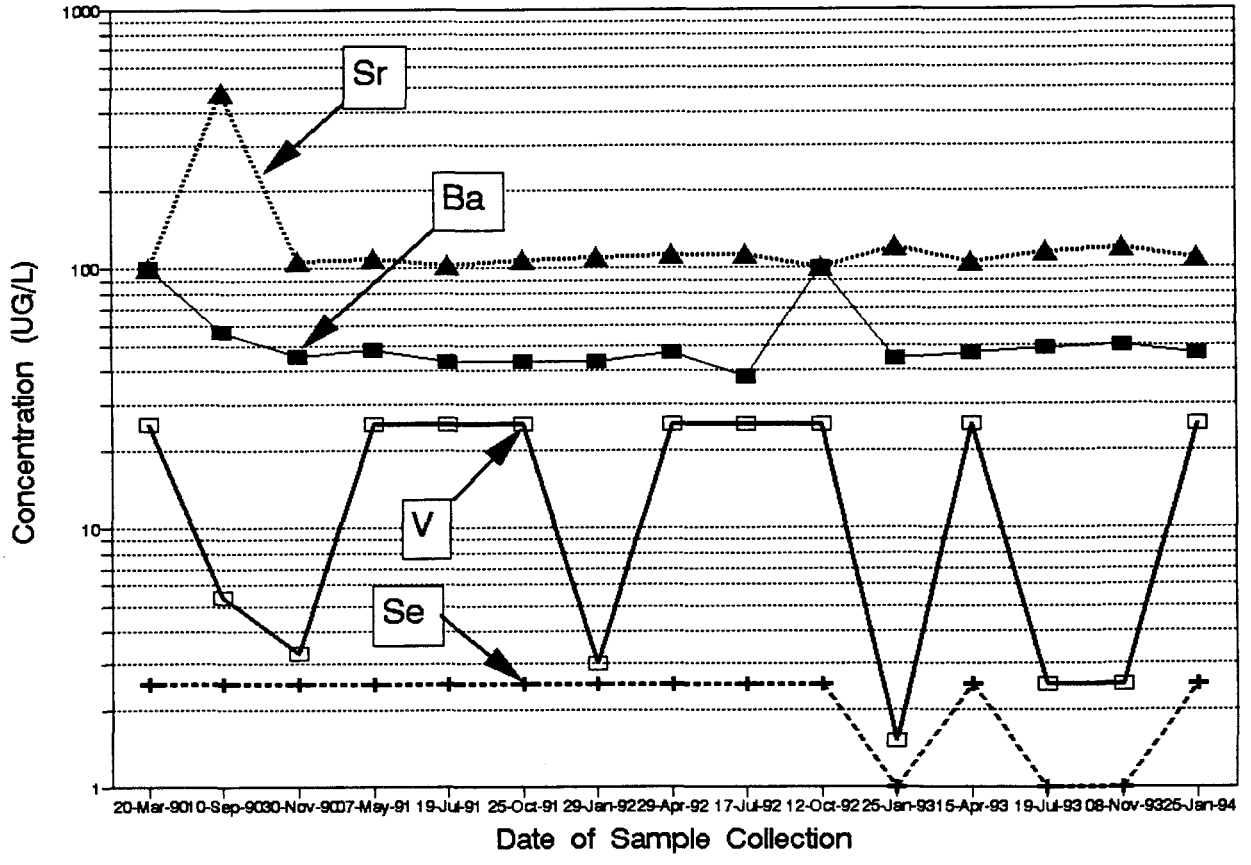
Well B111189 - Rock Creek flow path



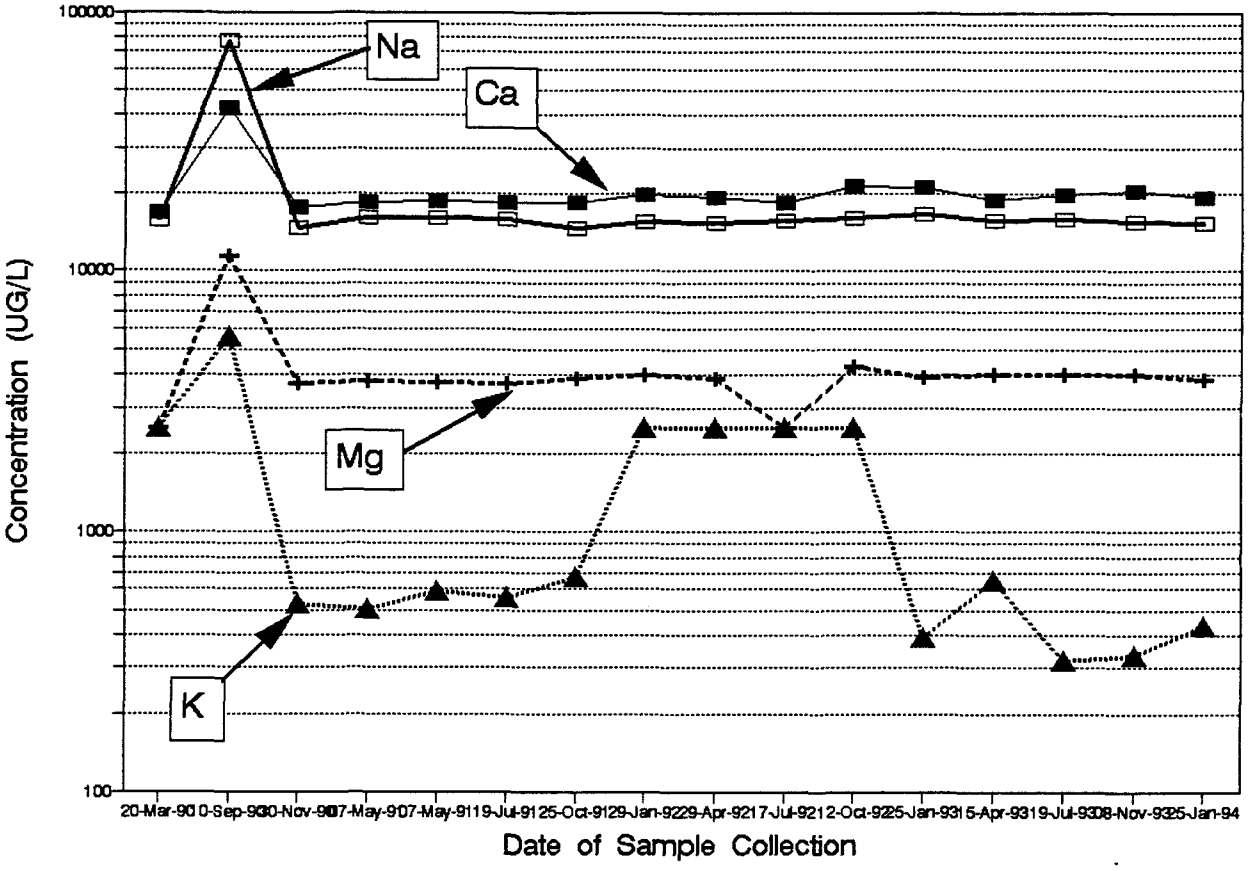
Well B110989 - Rock Creek flow path



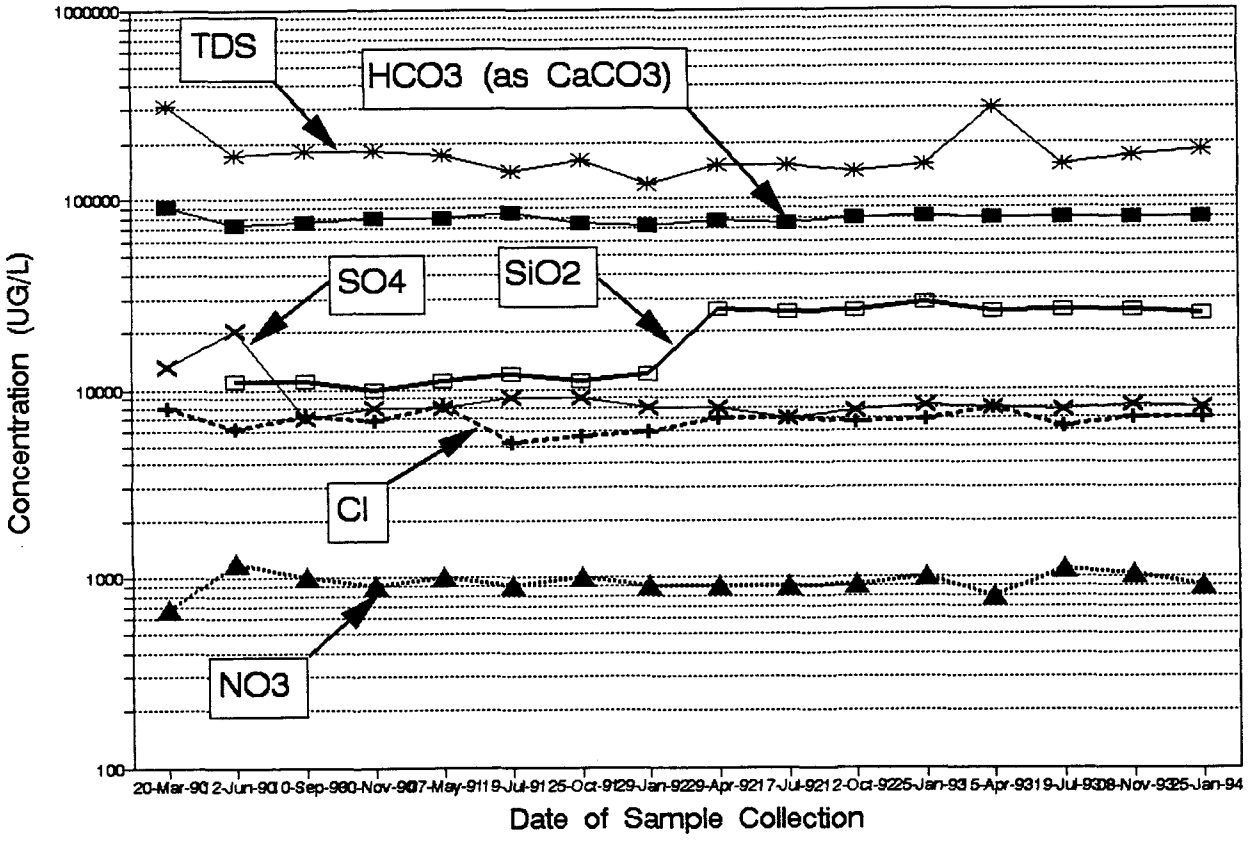
Well B110989 - Rock Creek flow path



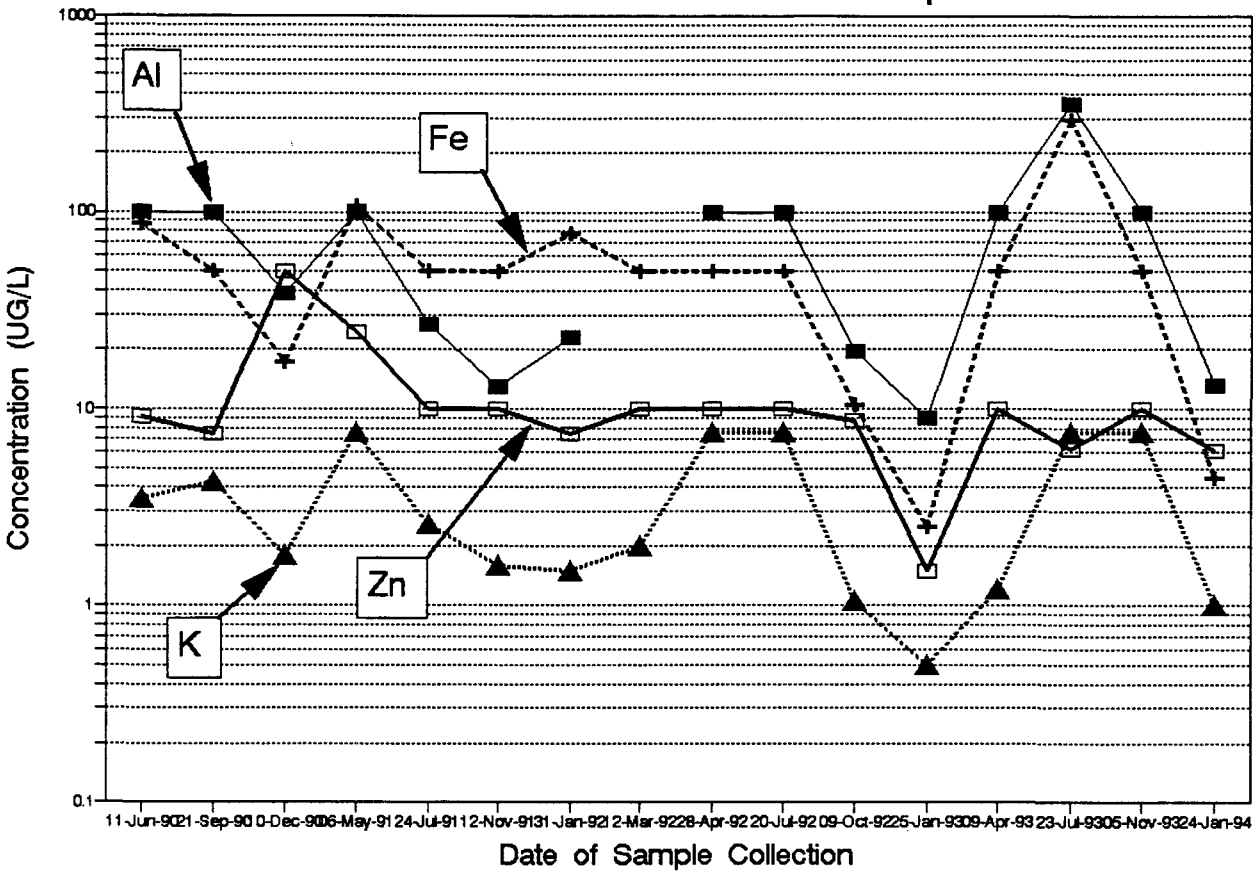
Well B110989 - Rock Creek flow path



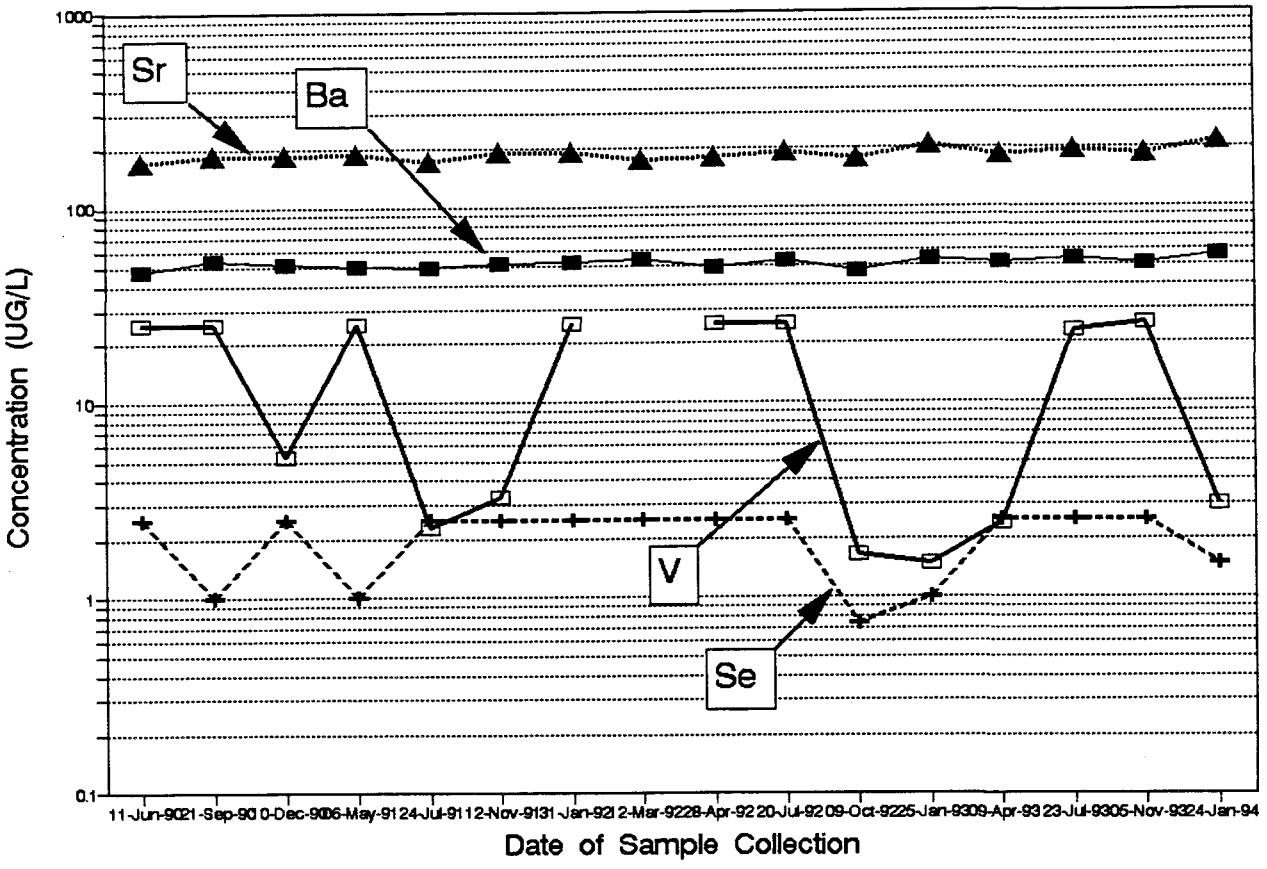
Well B110989 - Rock Creek flow path



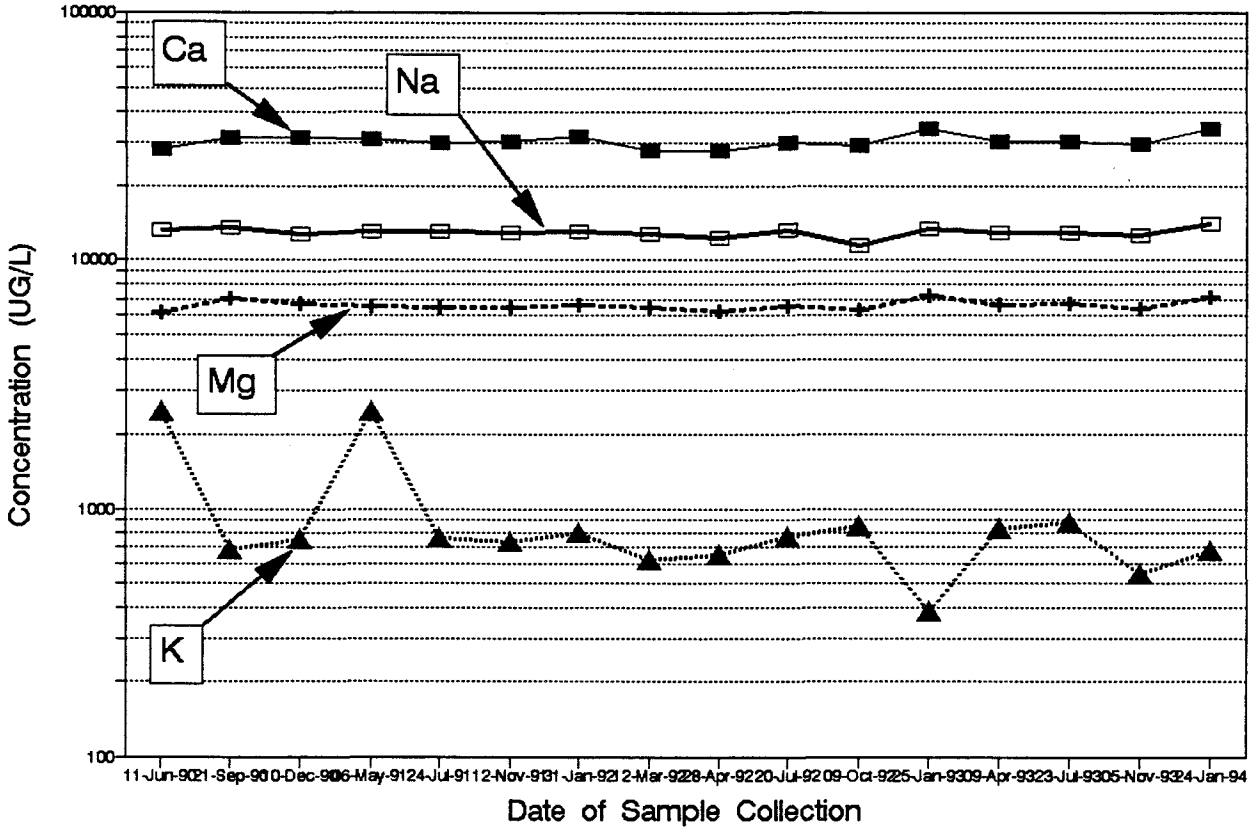
Well B110889 - Rock Creek flow path



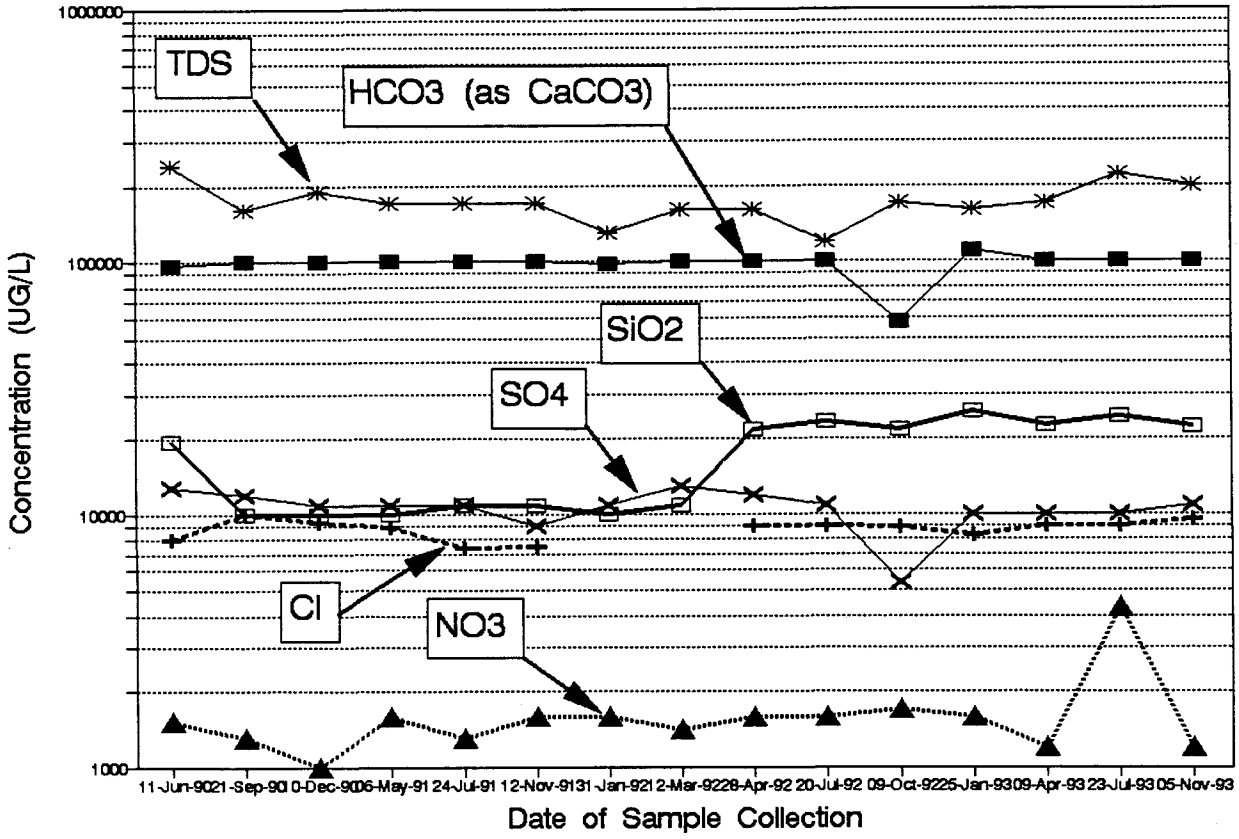
Well B110889 - Rock Creek flow path



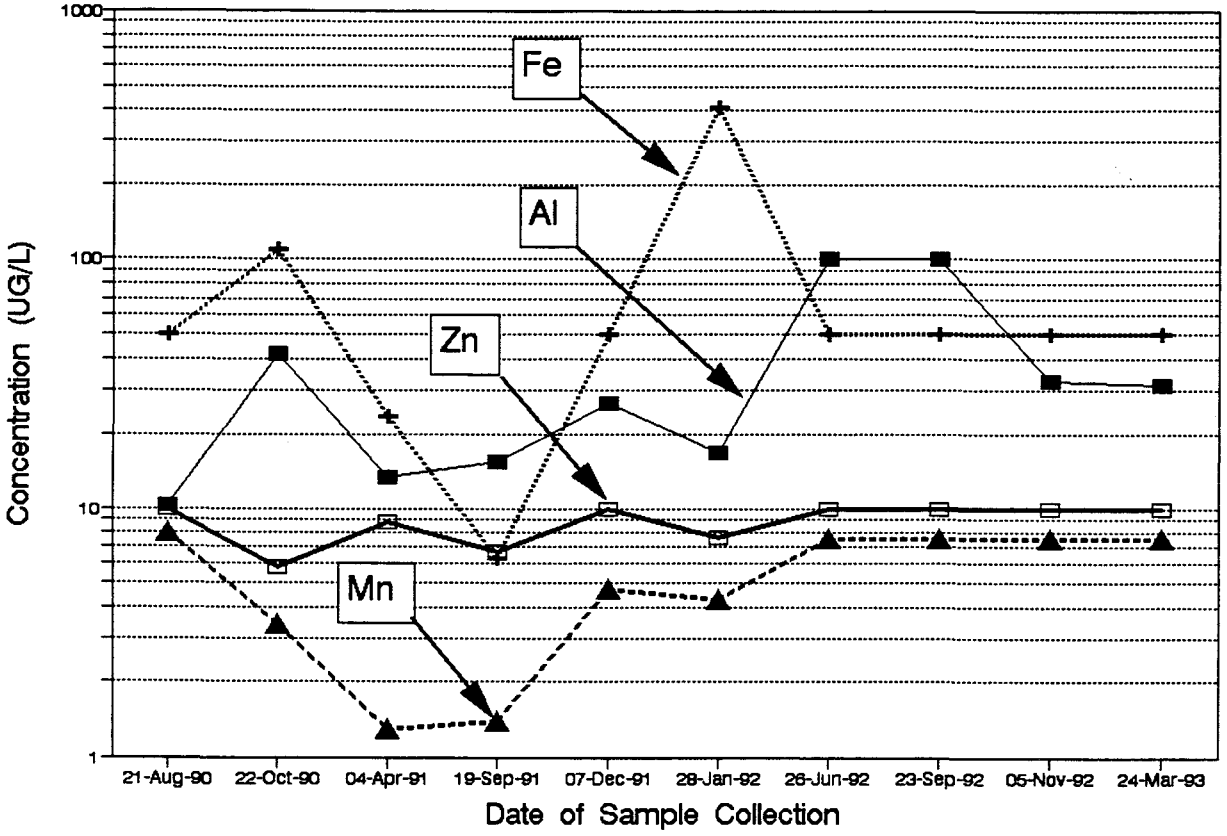
Well B110889 - Rock Creek flow path



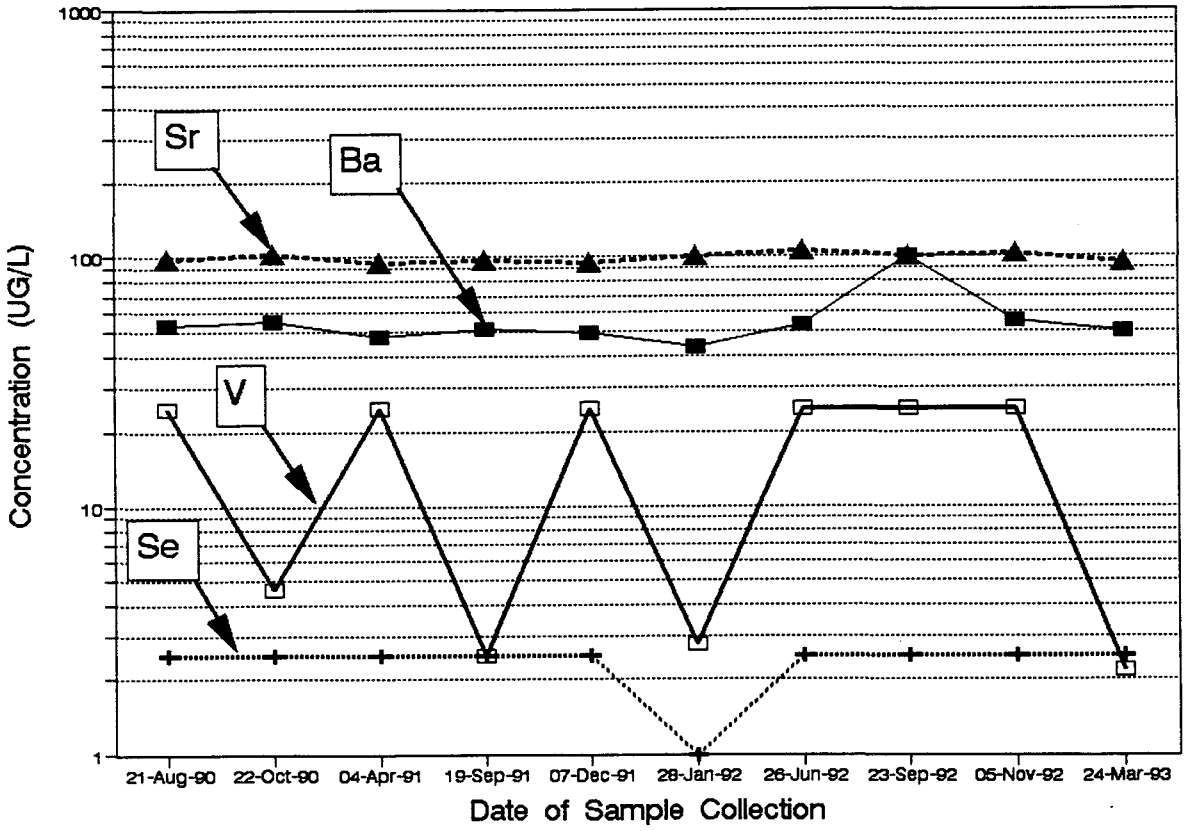
Well B110889 - Rock Creek flow path



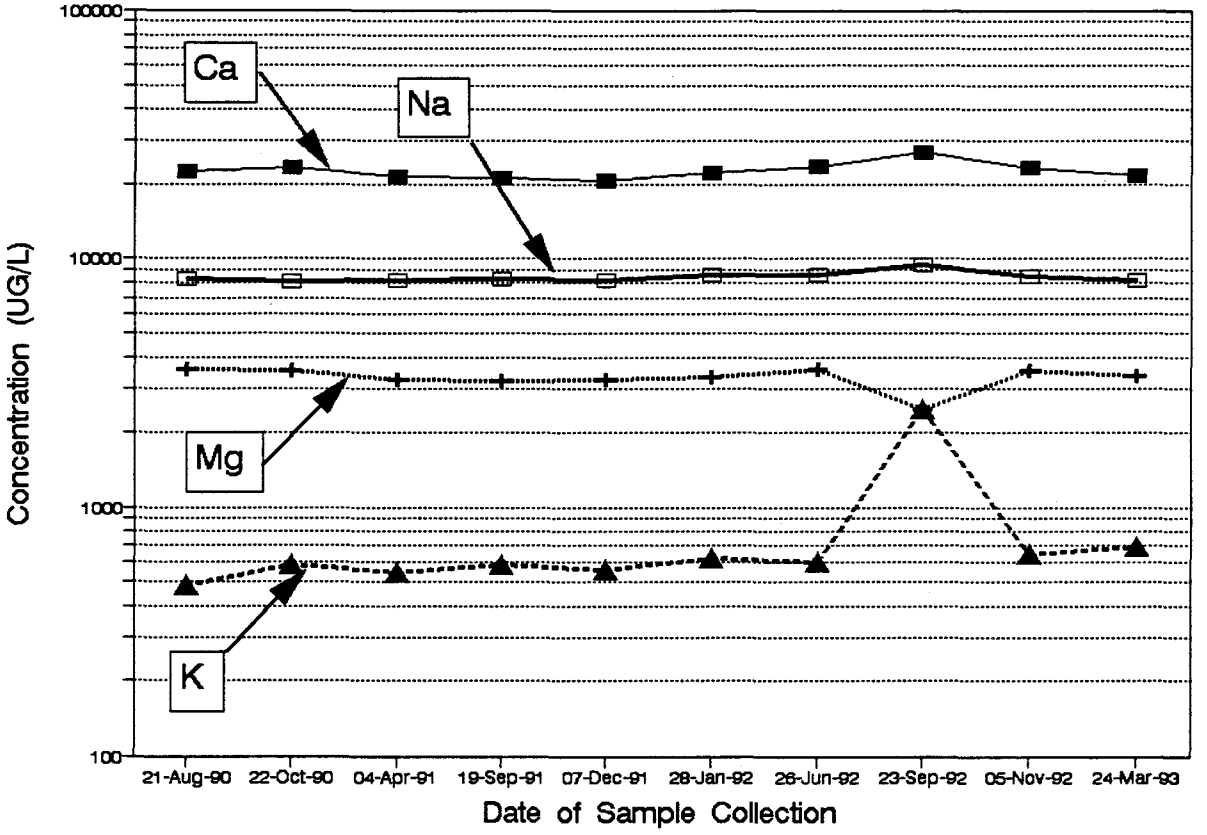
Well B200589 - Rock Creek flow path



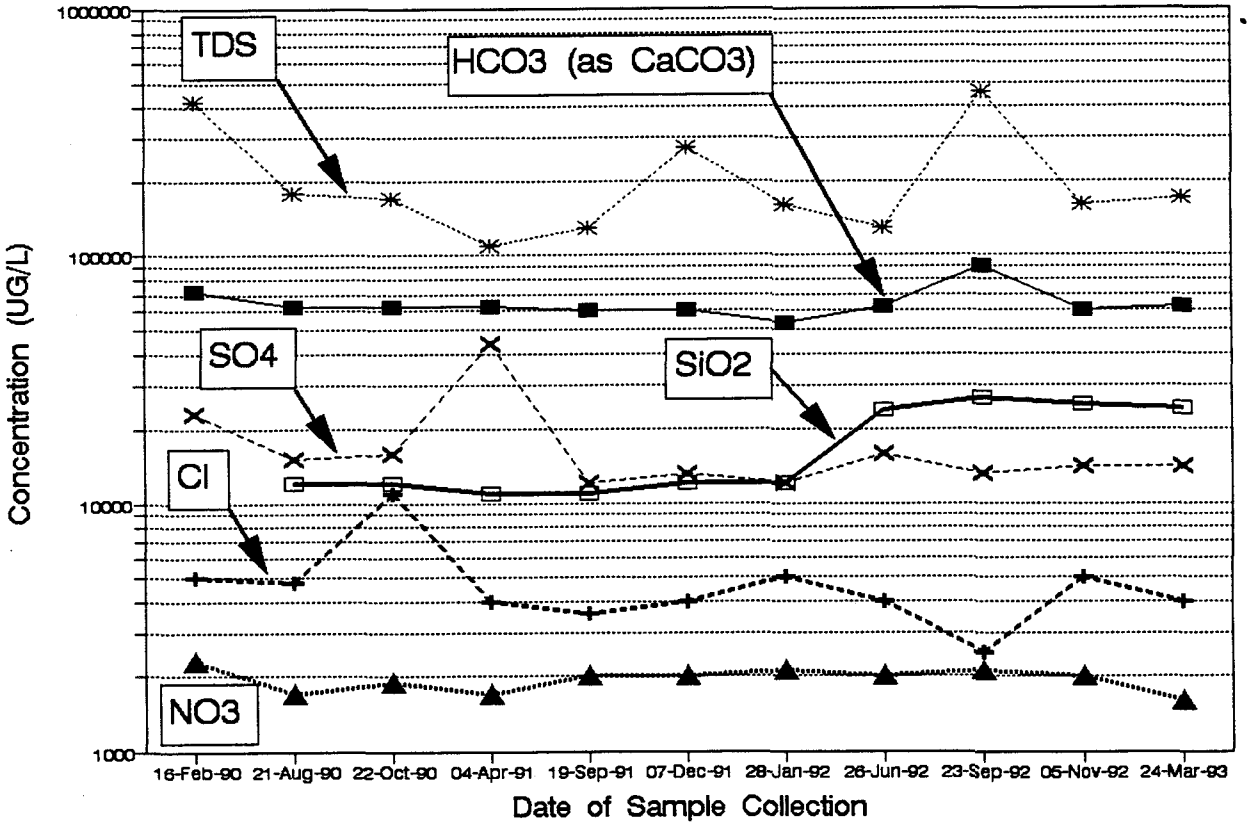
Well B200589 - Rock Creek flow path

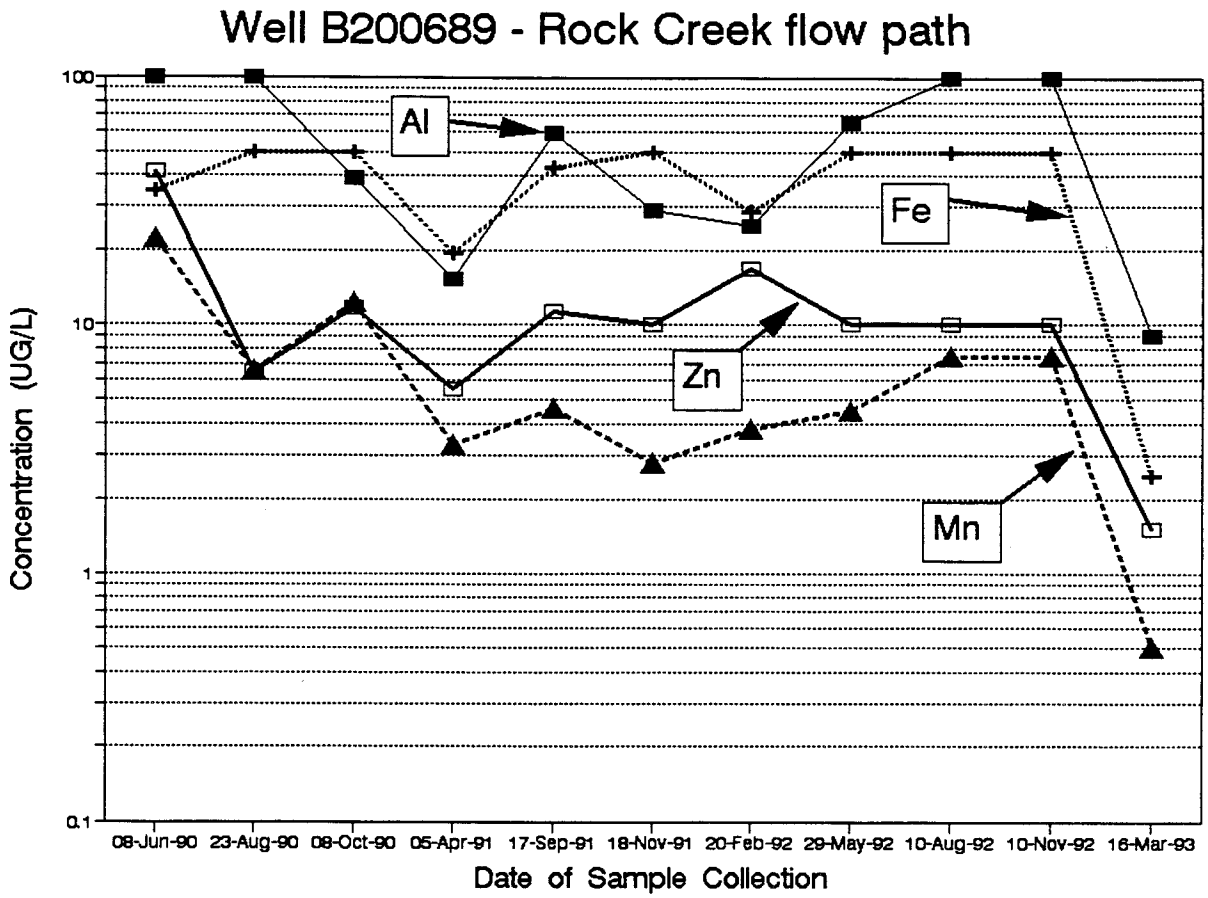


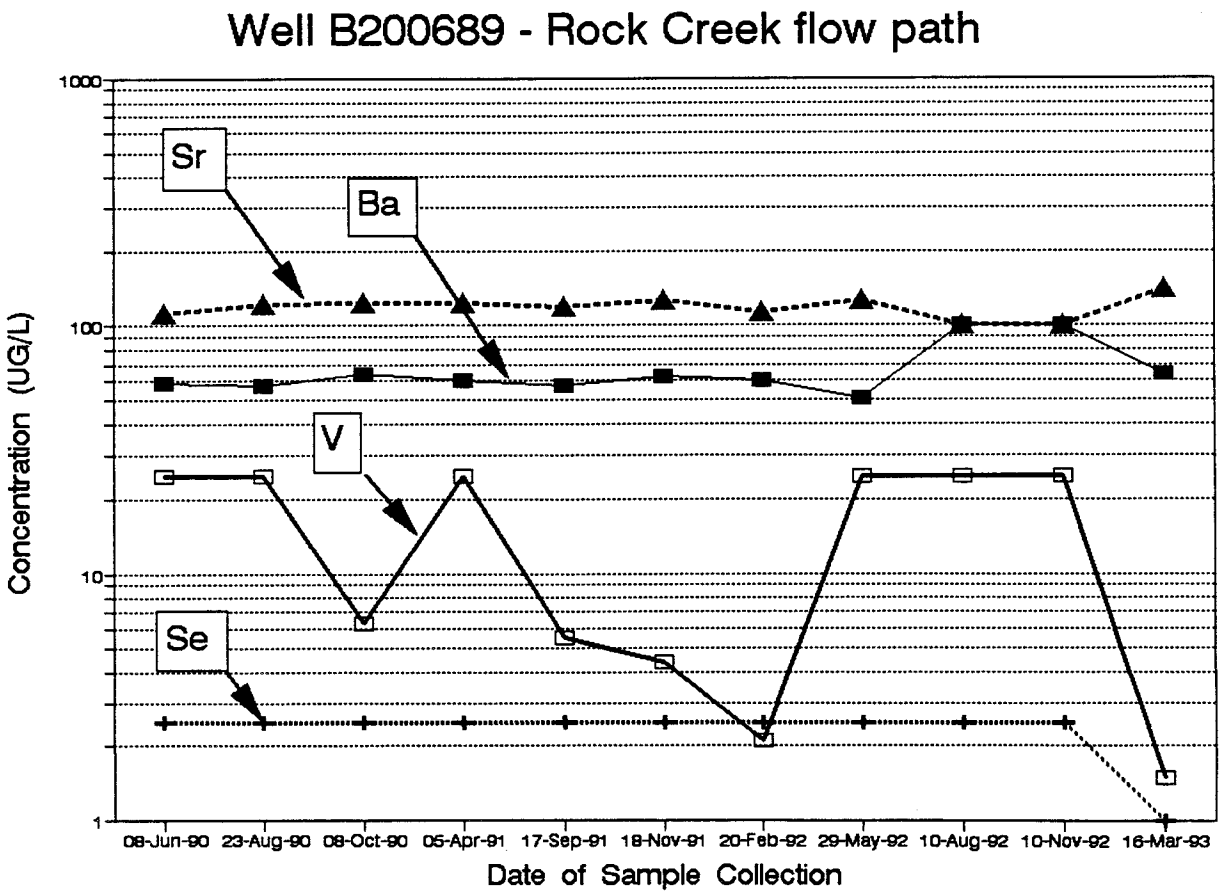
Well B200589 - Rock Creek flow path



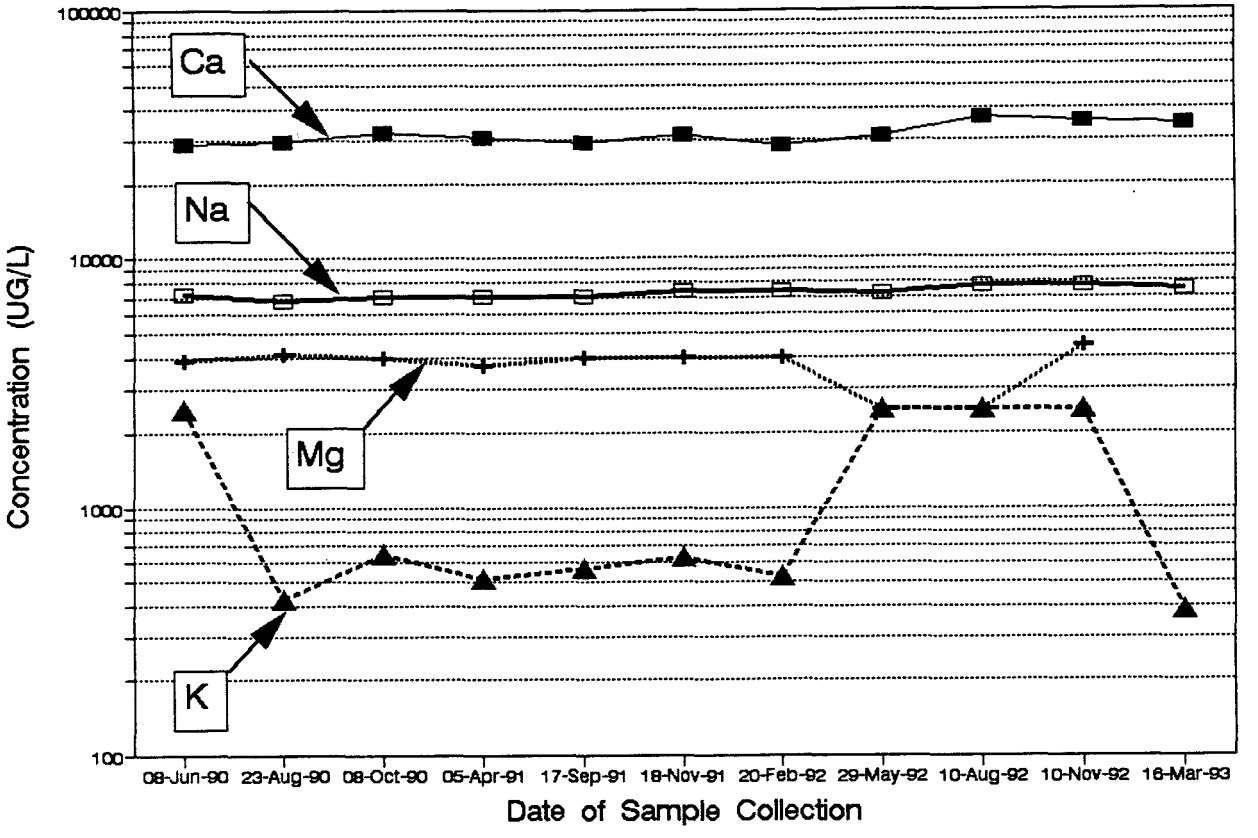
Well B200589 - Rock Creek flow path



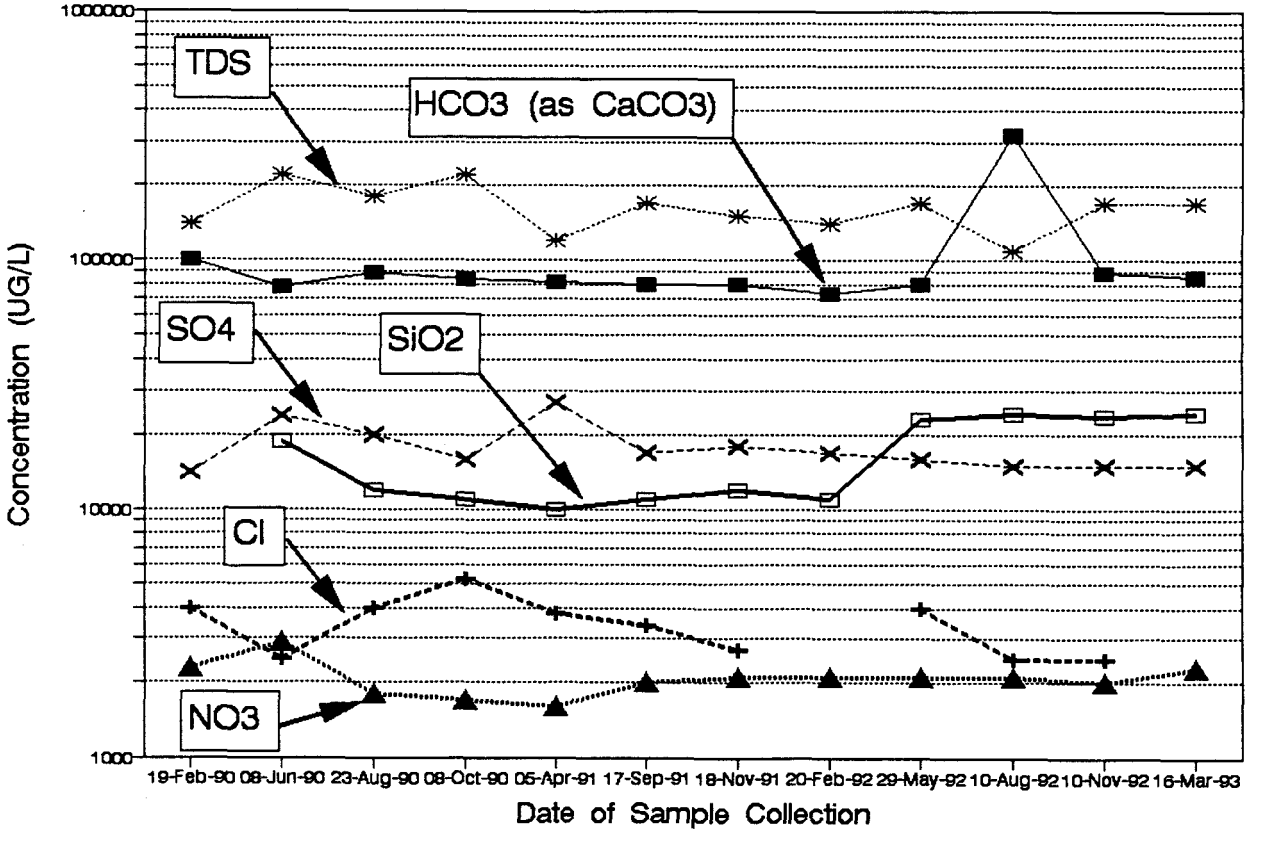

Well B200689 - Rock Creek flow path
Al
Fe
Zn
Mn
Concentration (UG/L)
100
10
1
0.1
08-Jun-90
23-Aug-90
08-Oct-90
05-Apr-91
17-Sep-91
18-Nov-91
20-Feb-92
29-May-92
10-Aug-92
10-Nov-92
16-Mar-93
Date of Sample Collection


Well B200689 - Rock Creek flow path
Sr
Ba
V
Se
Concentration (UG/L)
1000
100
10
1
08-Jun-90
23-Aug-90
08-Oct-90
05-Apr-91
17-Sep-91
18-Nov-91
20-Feb-92
29-May-92
10-Aug-92
10-Nov-92
16-Mar-93
Date of Sample Collection

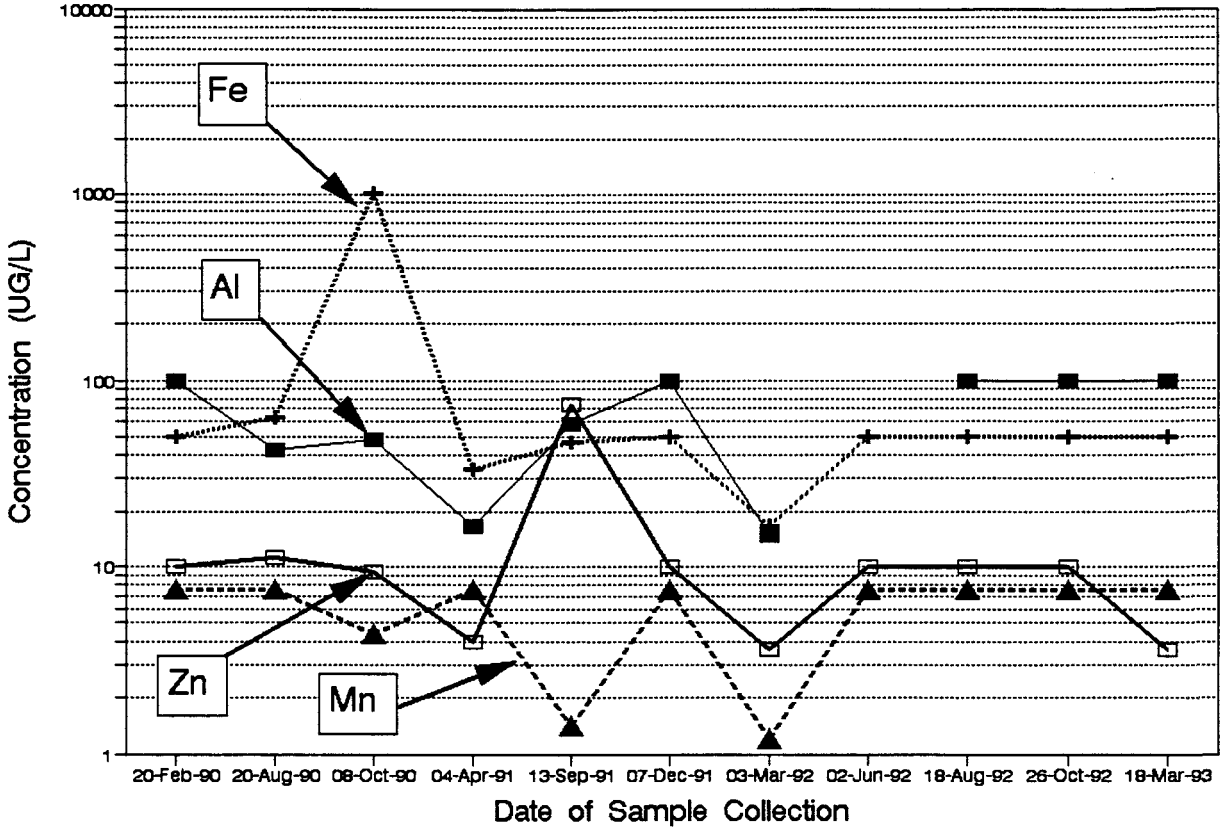
Well B200689 - Rock Creek flow path



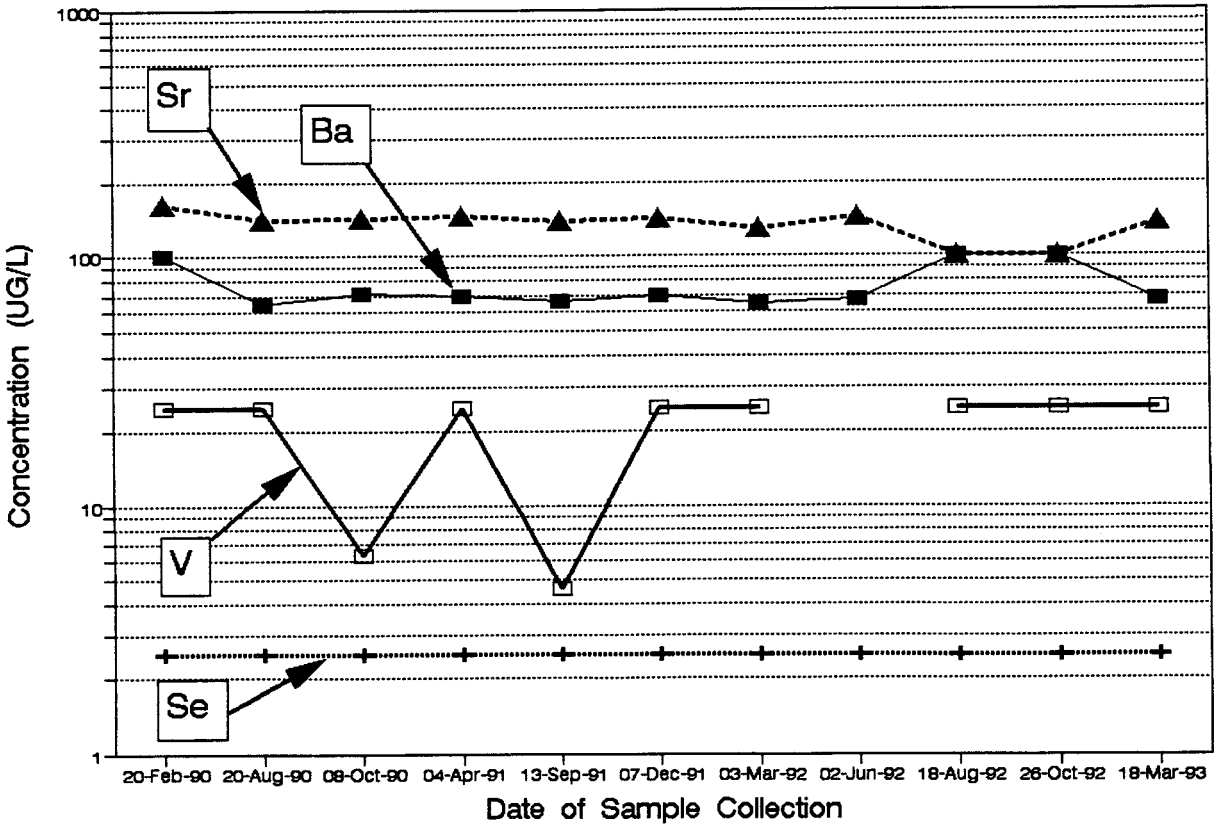
Well B200689 - Rock Creek flow path



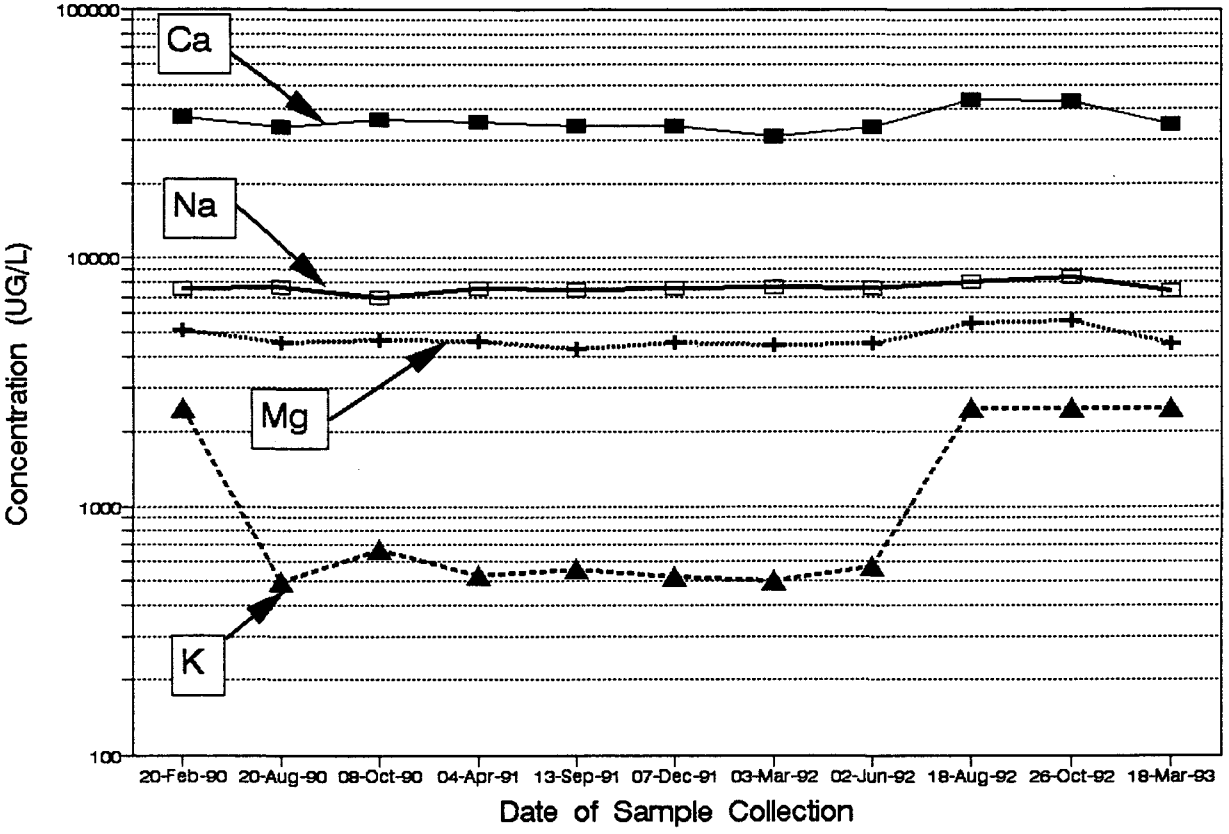
Well B200789 - Rock Creek flow path



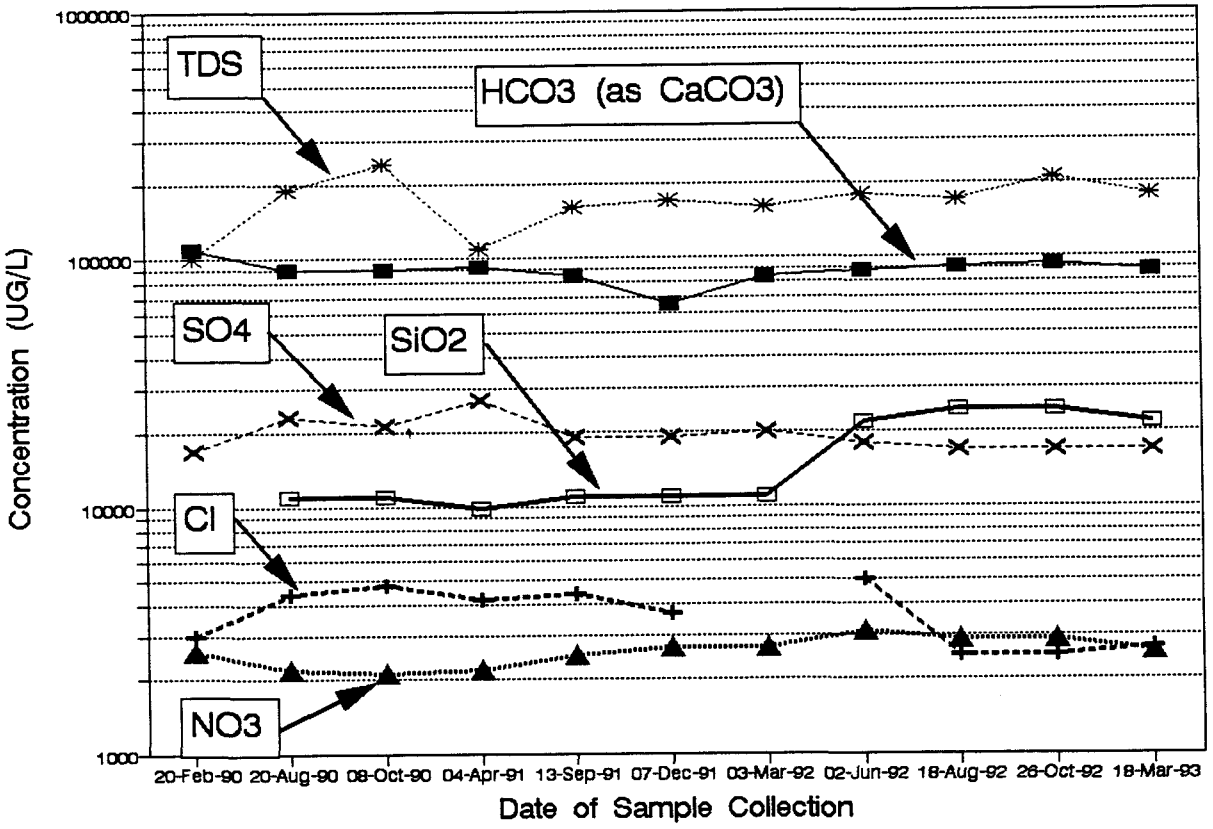
Well B200789 - Rock Creek flow path



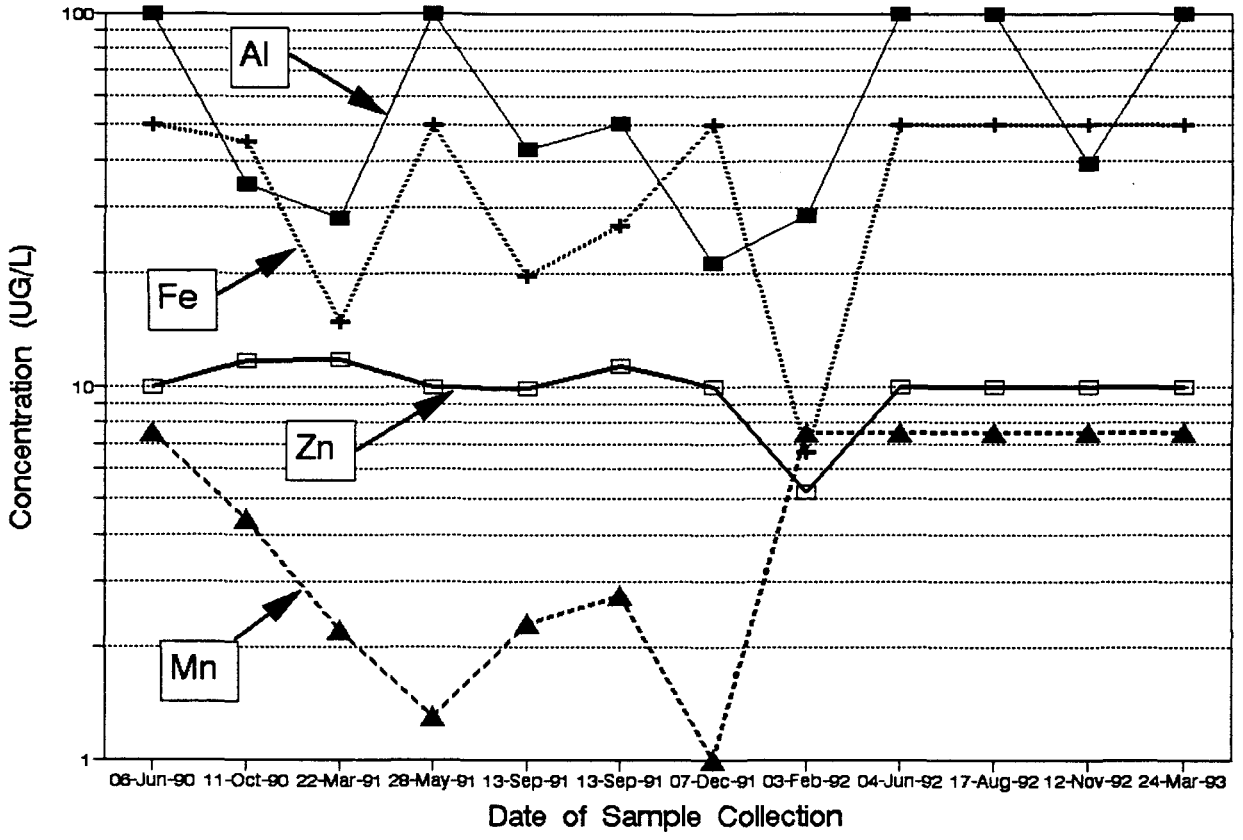
Well B200789 - Rock Creek flow path



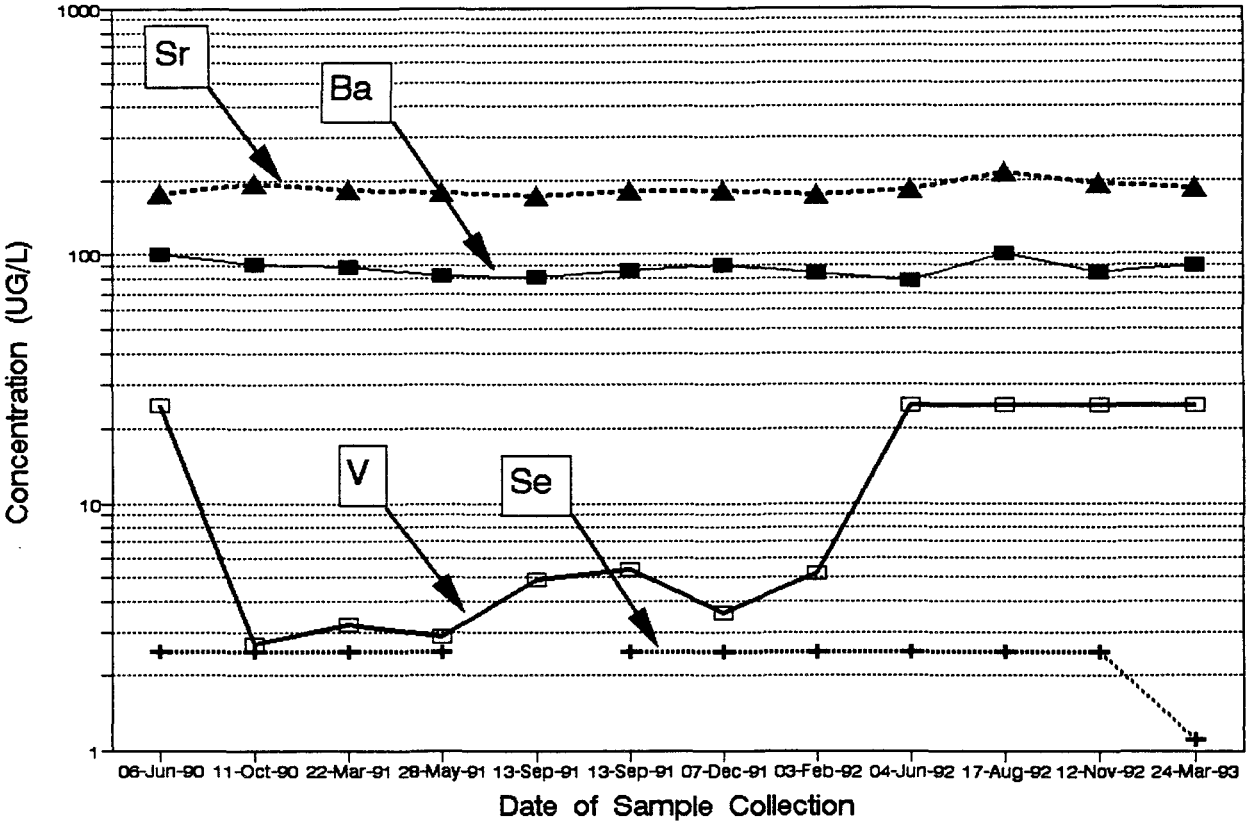
Well B200789 - Rock Creek flow path



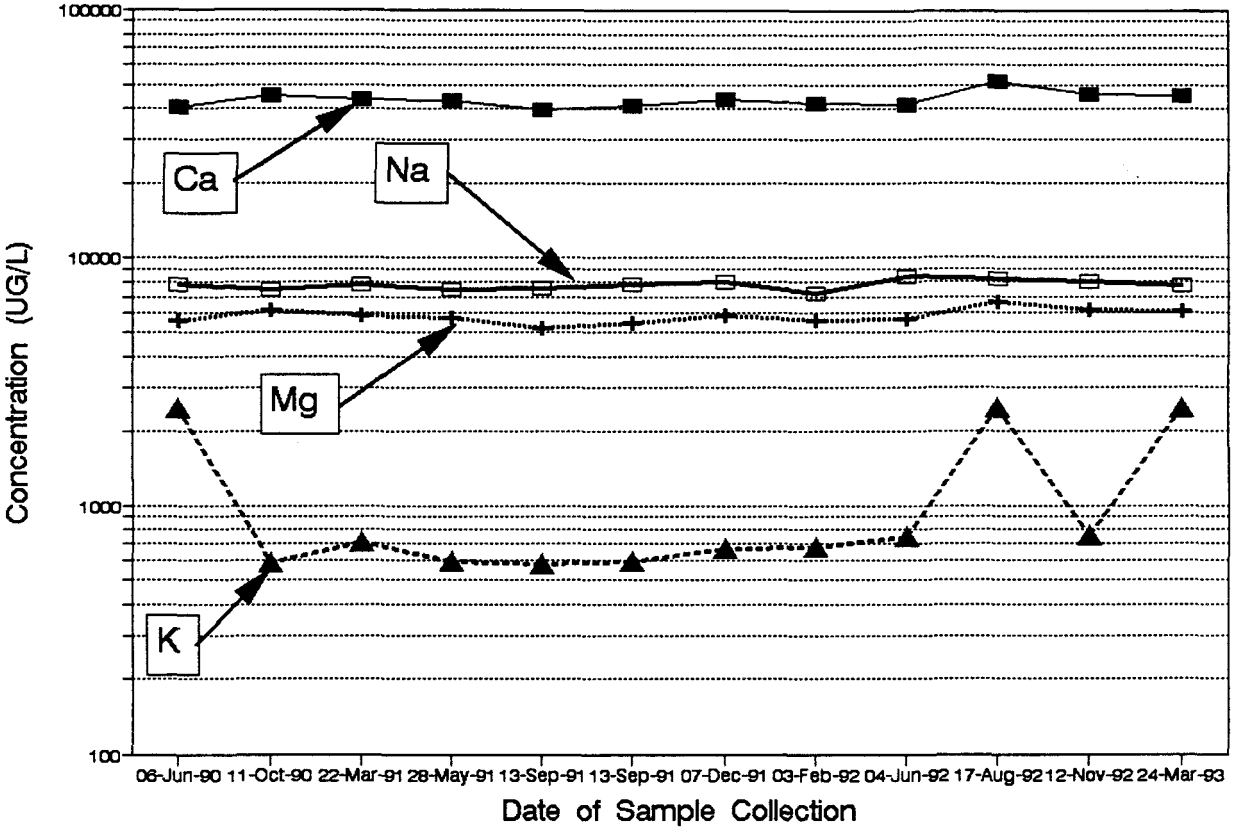
Well B200889 - Rock Creek flow path



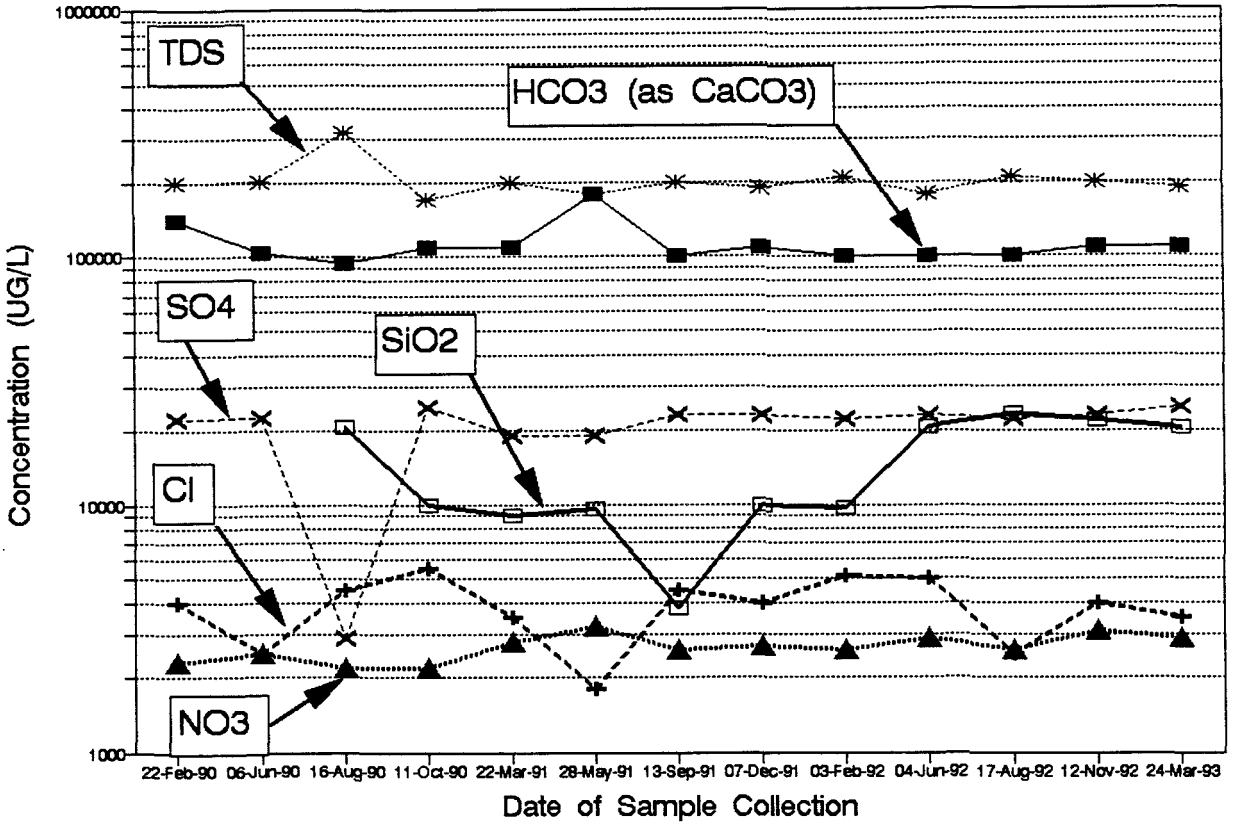
Well B200889 - Rock Creek flow path



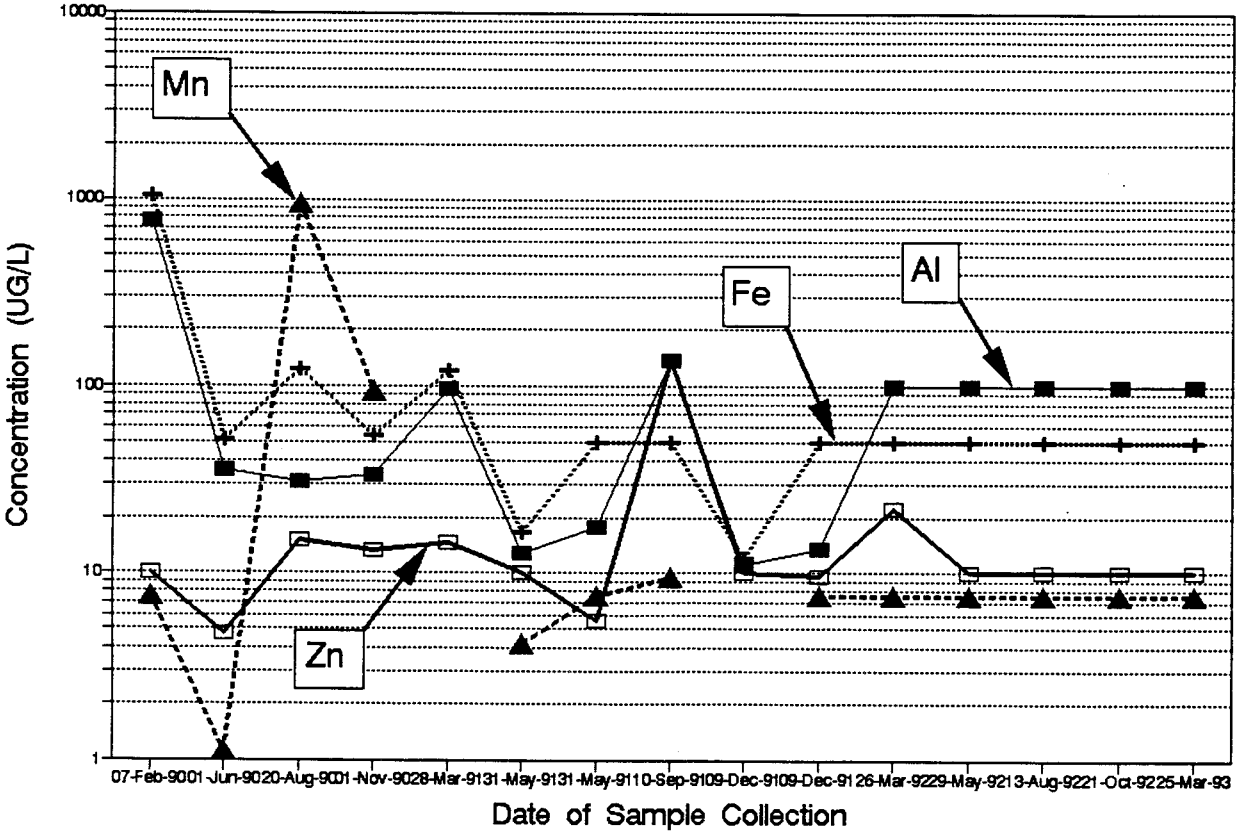
Well B200889 - Rock Creek flow path



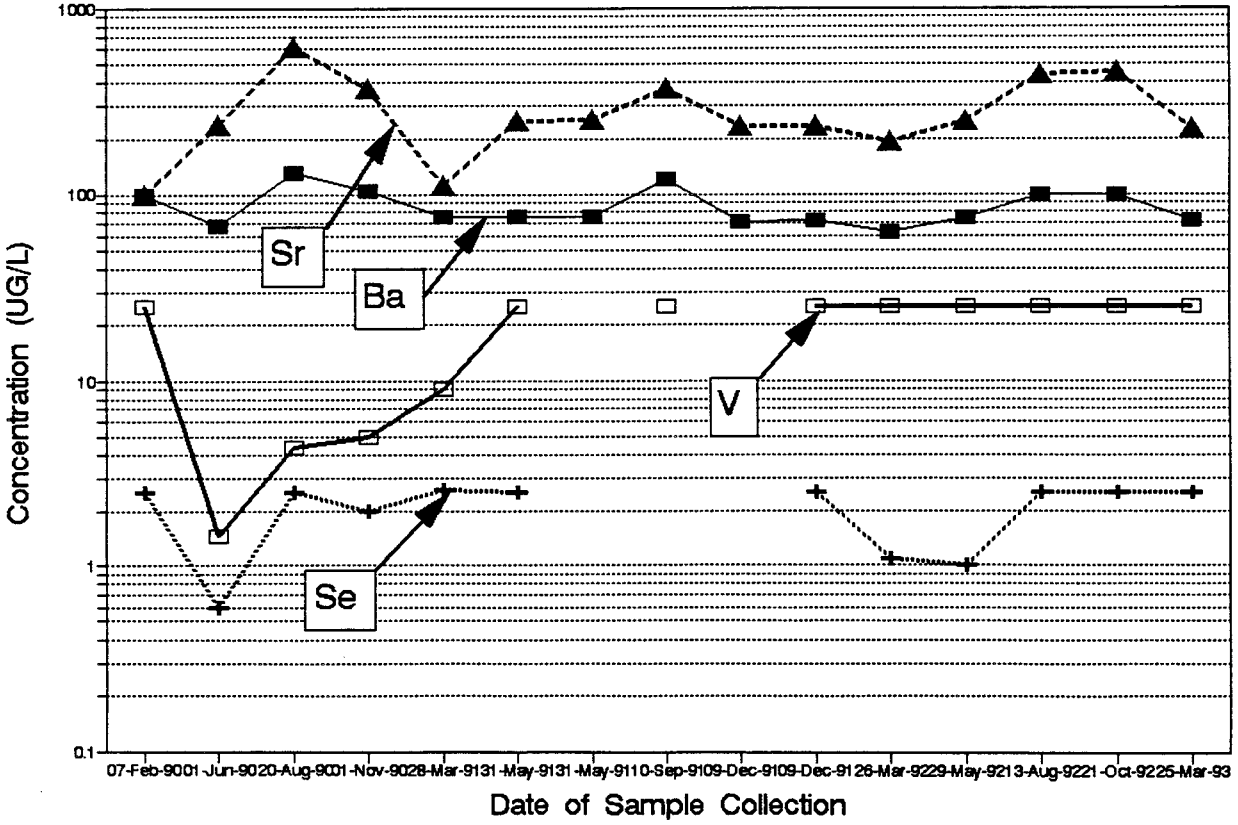
Well B200889 - Rock Creek flow path



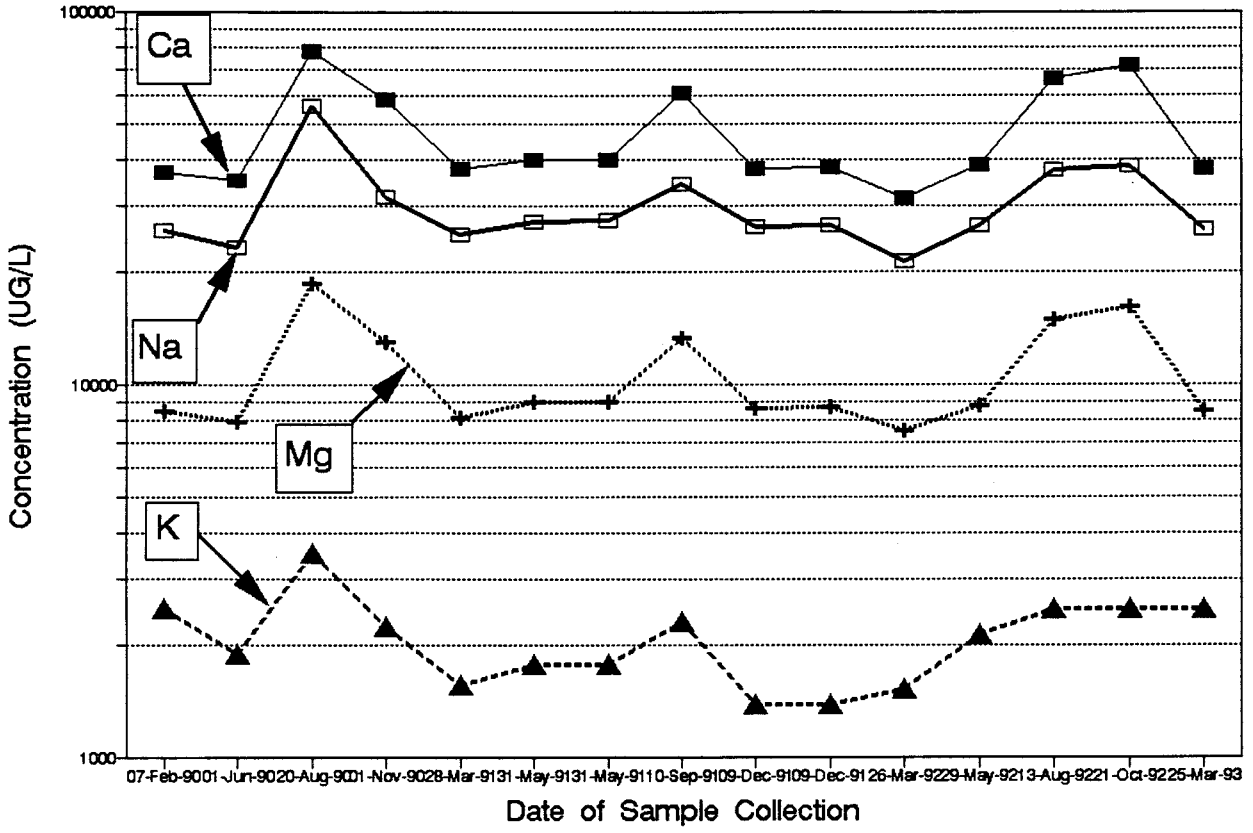
Well B202589 - Rock Creek flow path



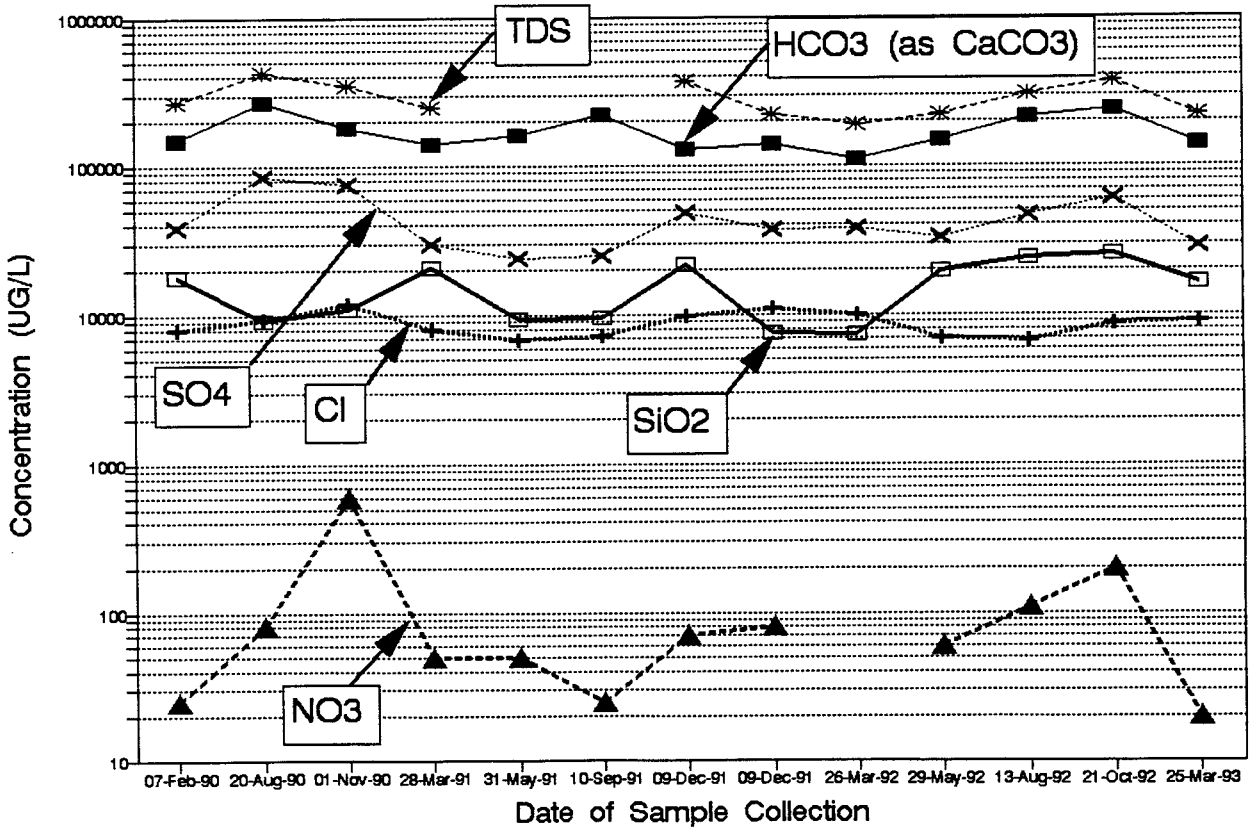
Well B202589 - Rock Creek flow path

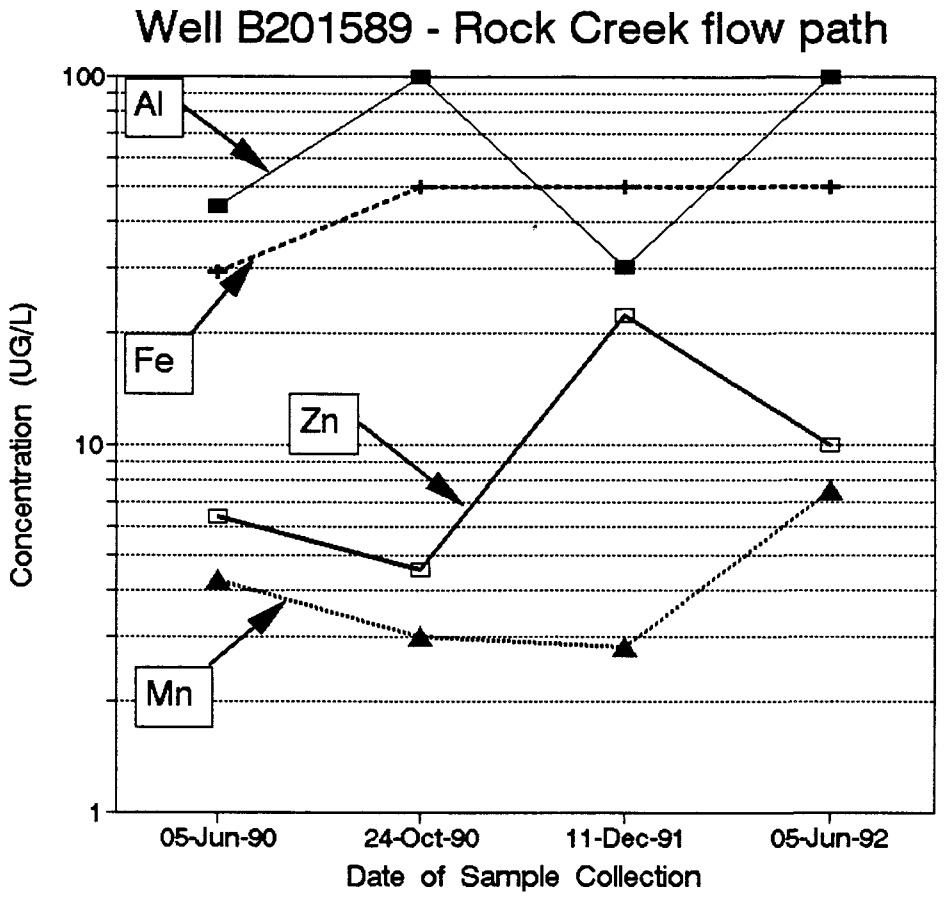


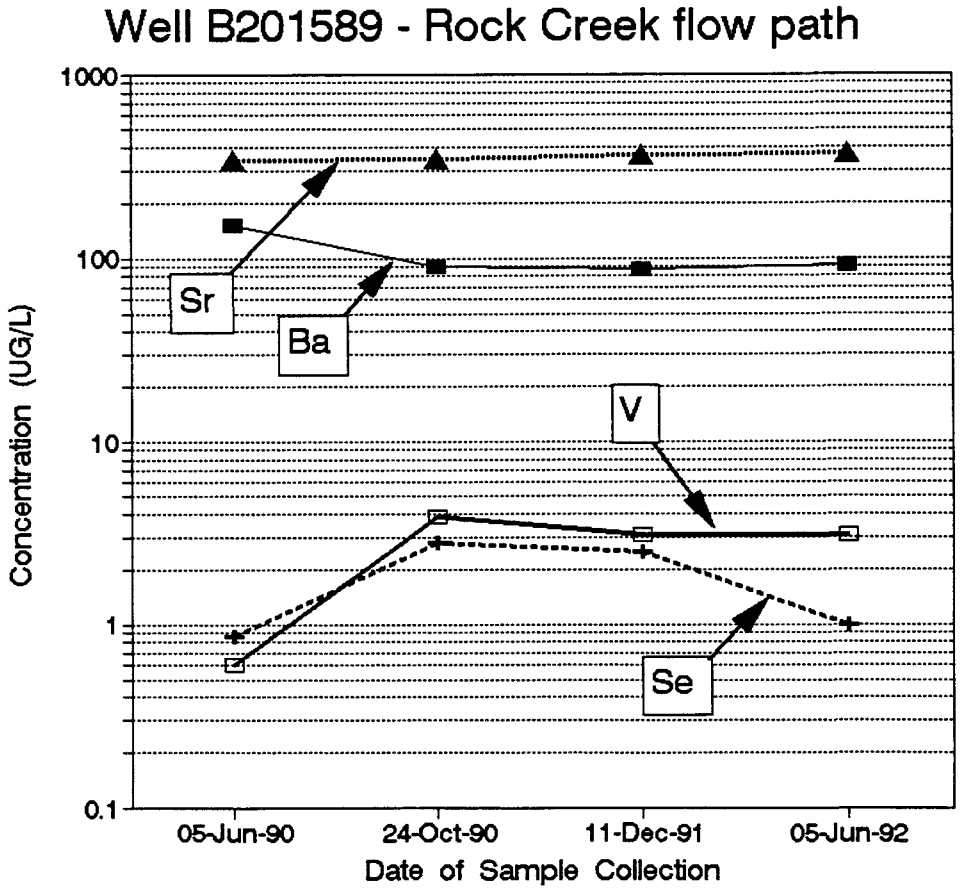
Well B202589 - Rock Creek flow path

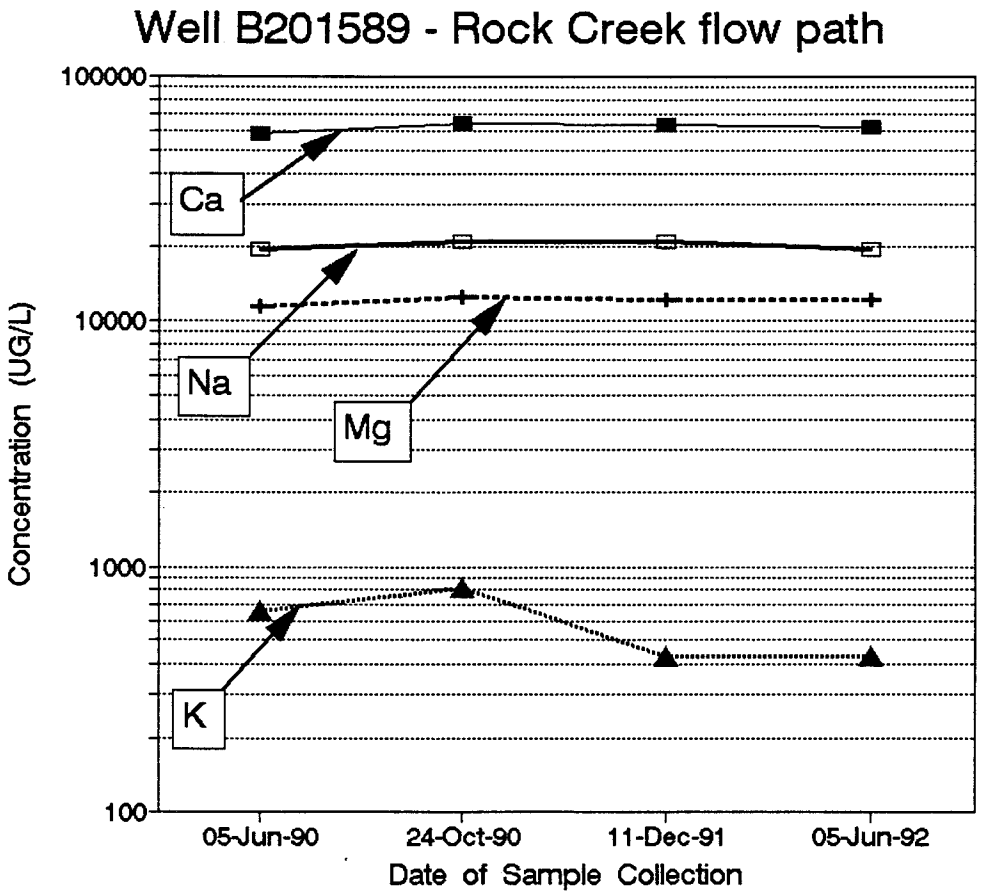


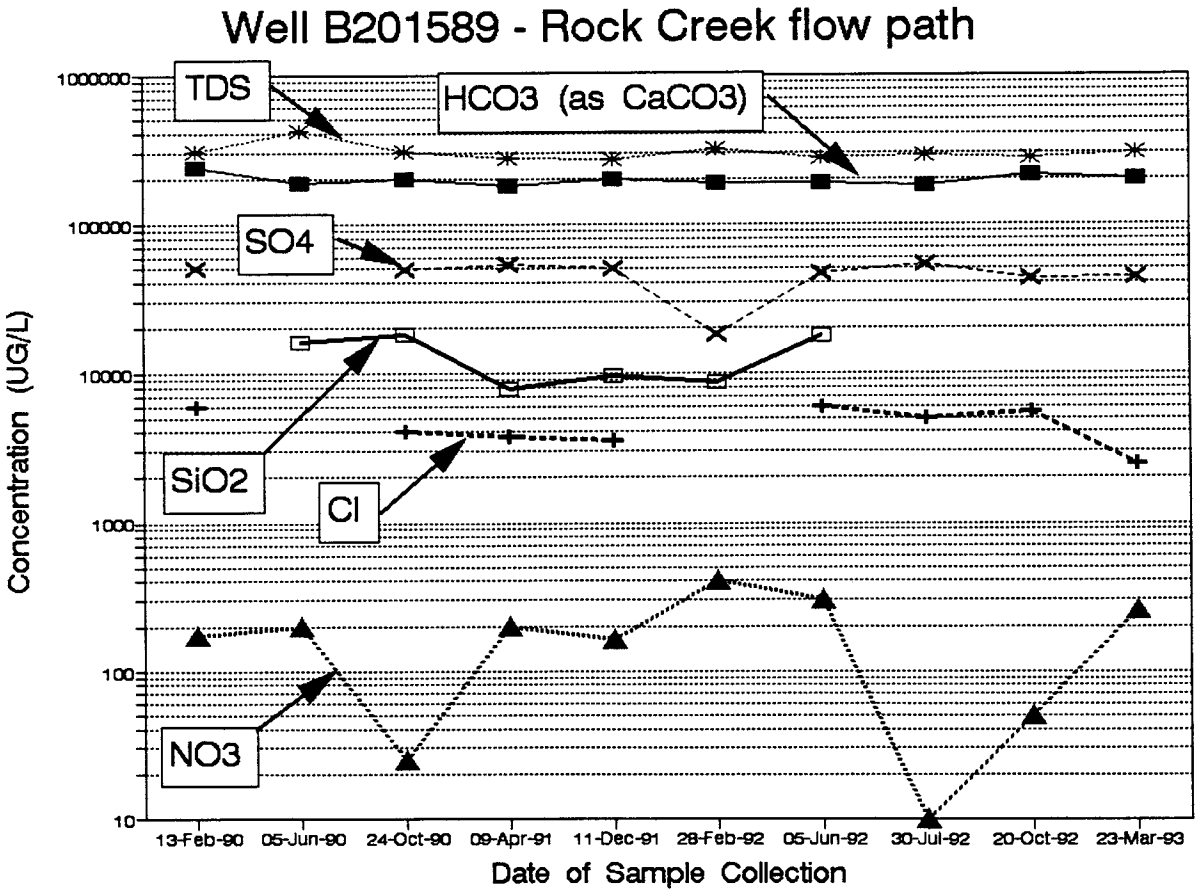
Well B202589 - Rock Creek flow path



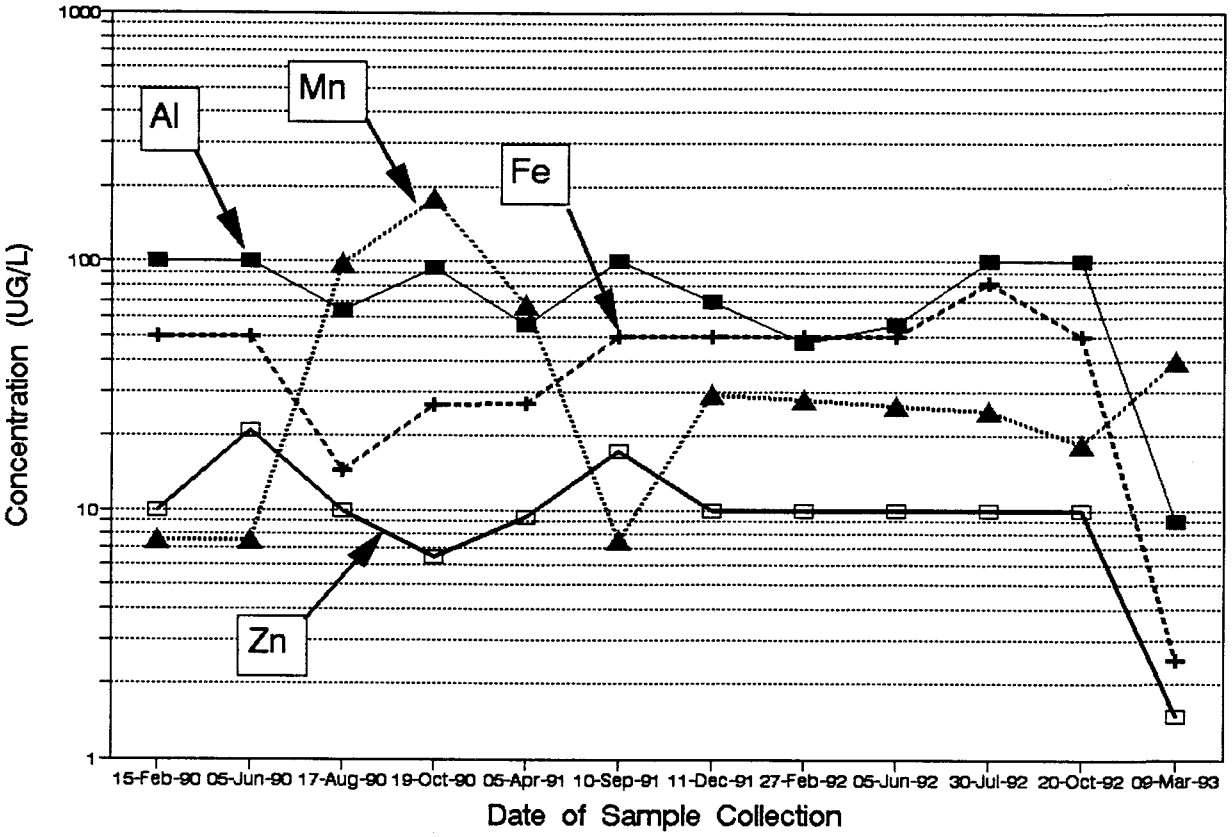

Well B201589 - Rock Creek flow path
100
10
1
Concentration (UG/L)
Al
Fe
Zn
Mn
05-Jun-90
24-Oct-90
11-Dec-91
05-Jun-92
Date of Sample Collection


Well B201589 - Rock Creek flow path
1000
100
10
1
0.1
Concentration (UG/L)
Sr
Ba
V
Se
05-Jun-90
24-Oct-90
11-Dec-91
05-Jun-92
Date of Sample Collection

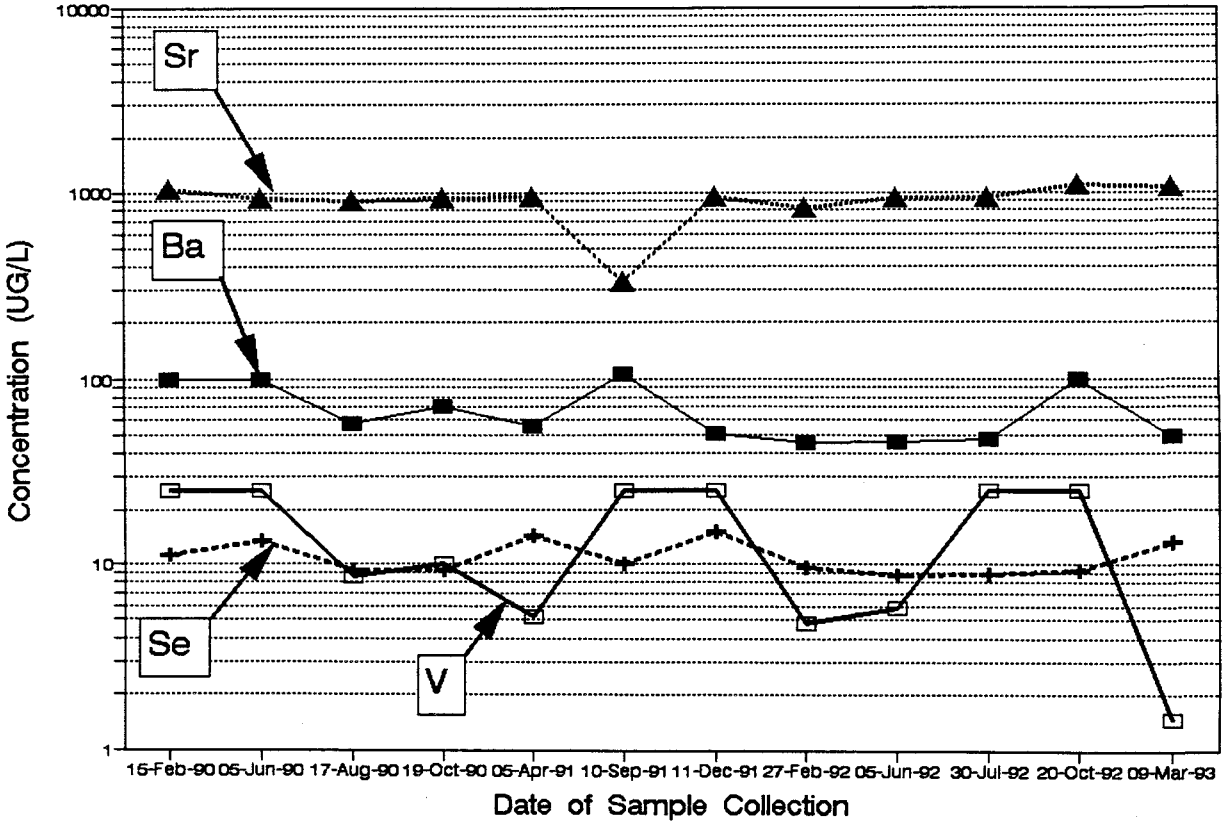

Well B201589 - Rock Creek flow path
100000
10000
1000
100
Concentration (UG/L)
Ca
Na
Mg
K
05-Jun-90
24-Oct-90
11-Dec-91
05-Jun-92
Date of Sample Collection


Well B201589 - Rock Creek flow path
1000000
100000
10000
1000
100
10
Concentration (UG/L)
TDS
HCO3 (as CaCO3)
SO4
SiO2
Cl
NO3
13-Feb-90
05-Jun-90
24-Oct-90
09-Apr-91
11-Dec-91
28-Feb-92
05-Jun-92
30-Jul-92
20-Oct-92
23-Mar-93
Date of Sample Collection

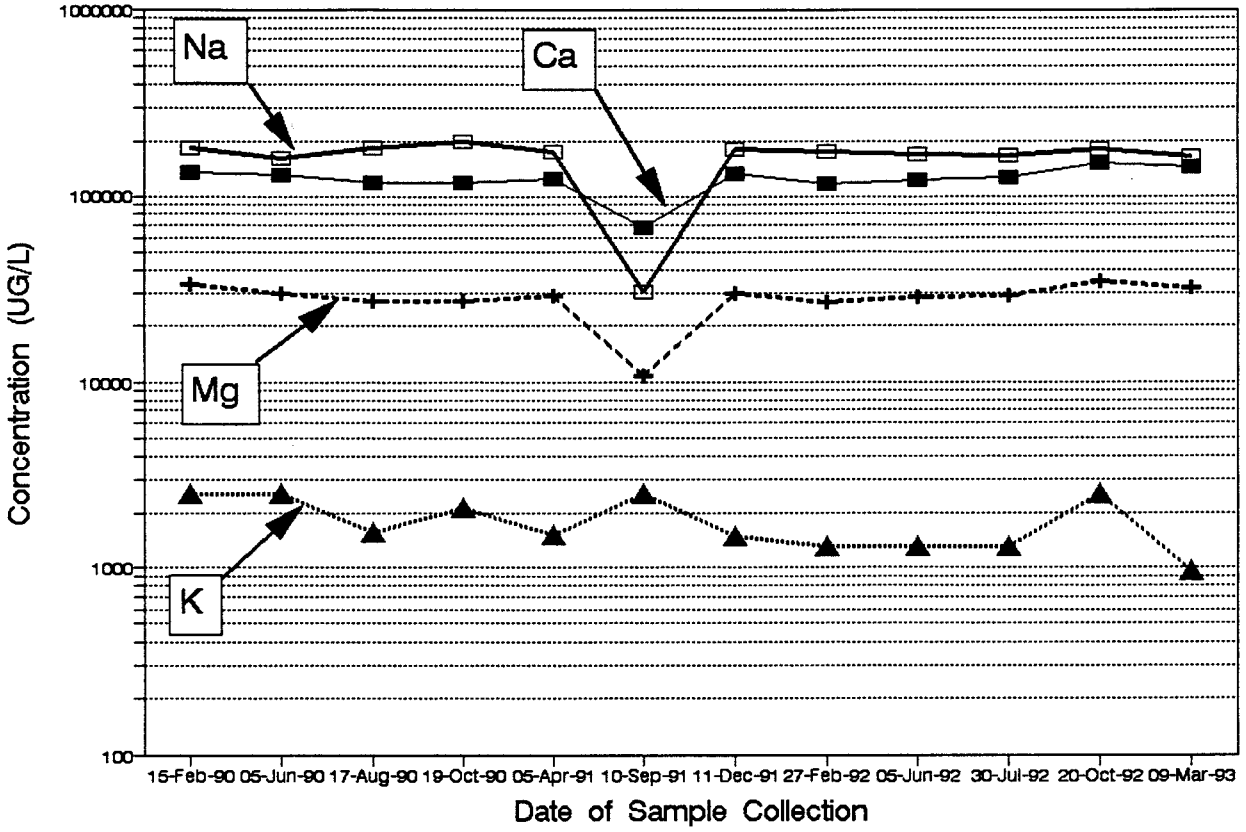
Well B205589 - Rock Creek flow path



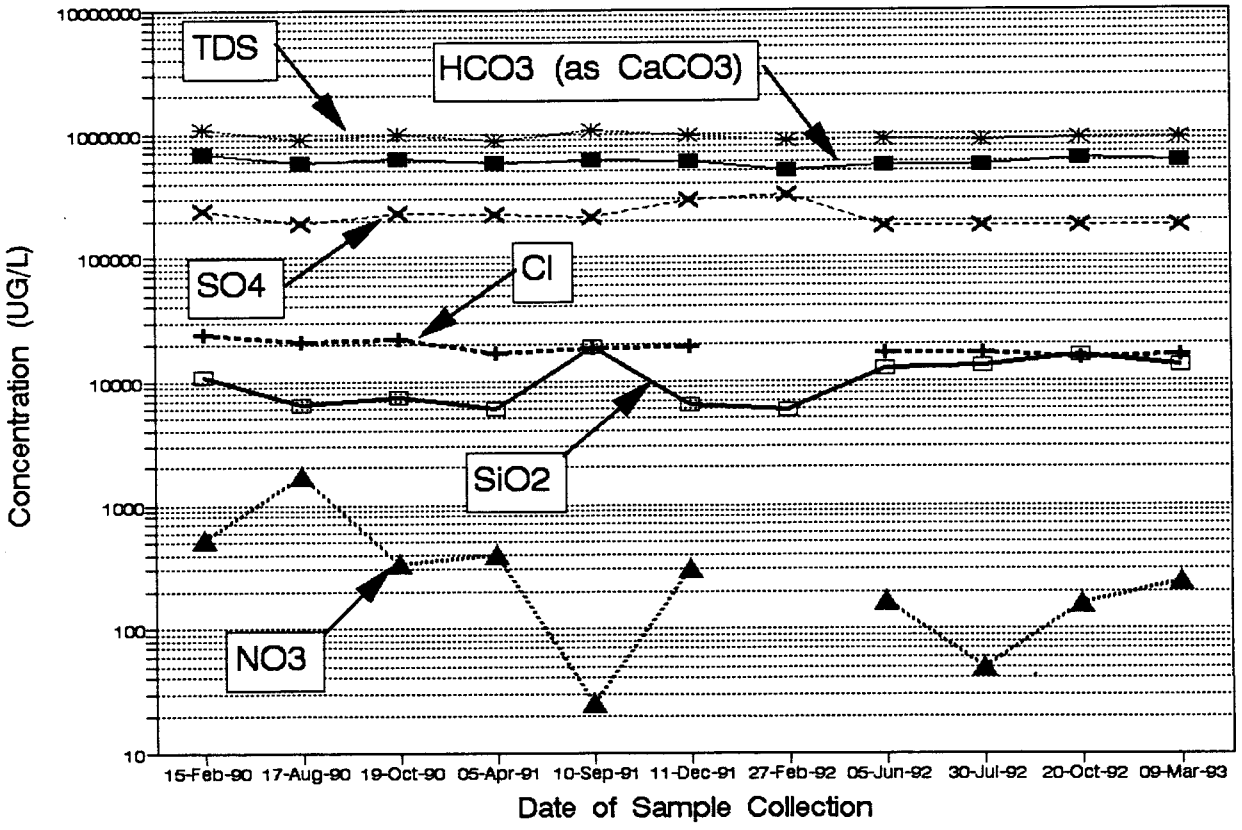
Well B205589 - Rock Creek flow path



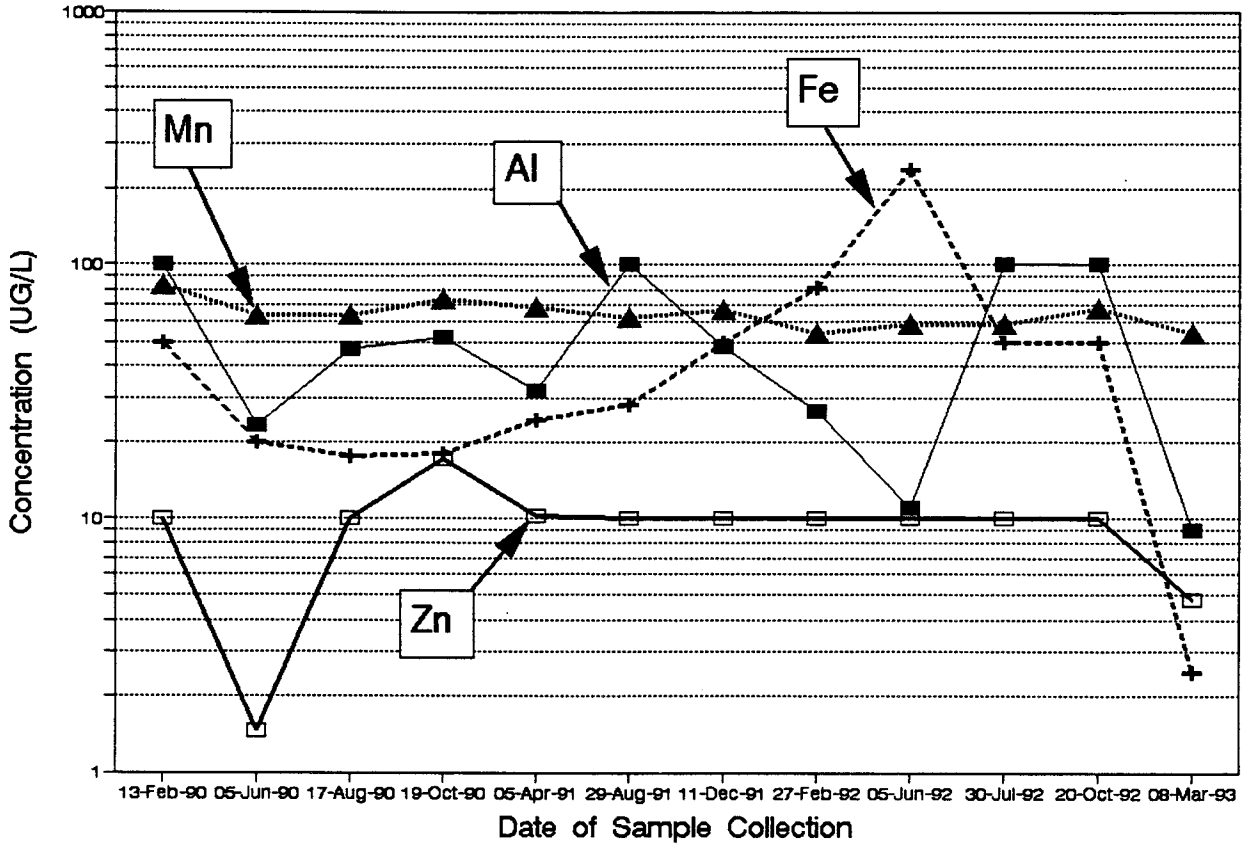
Well B205589 - Rock Creek flow path



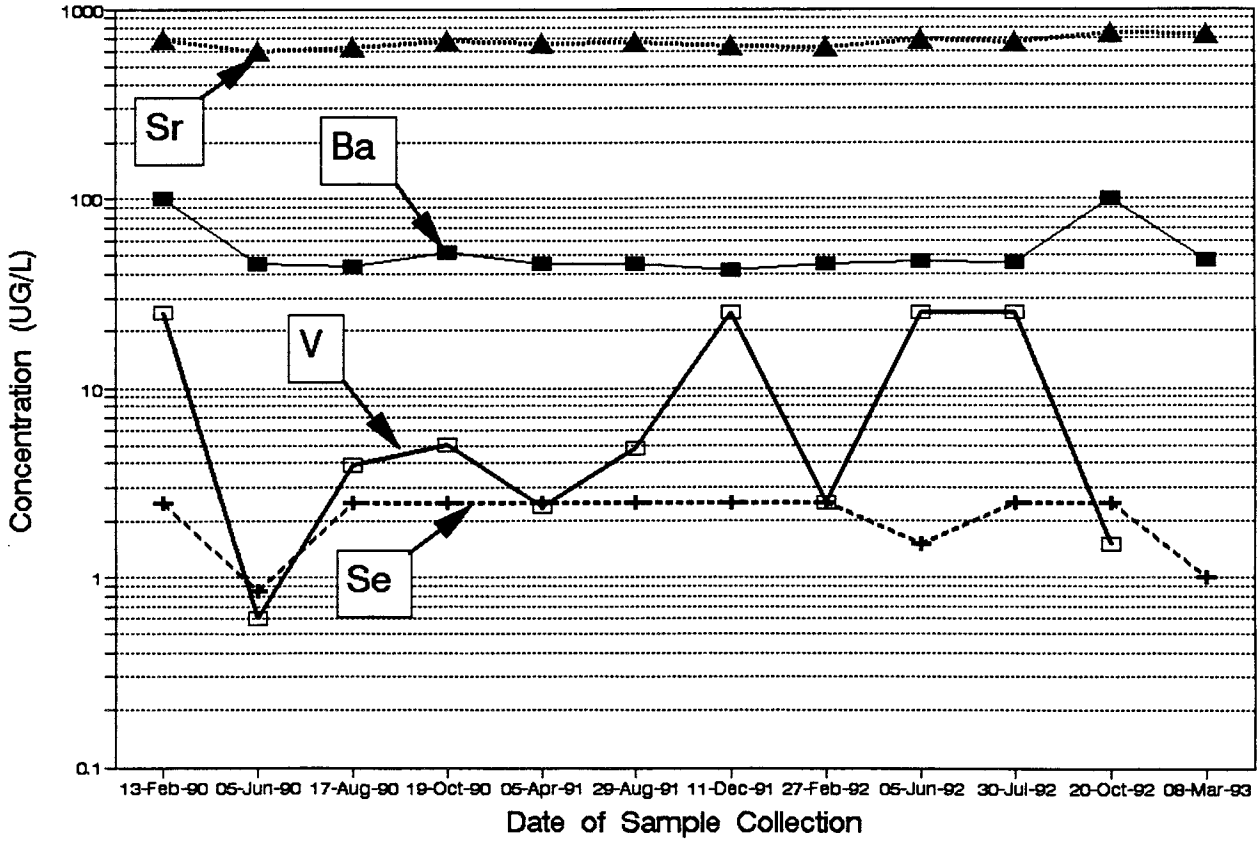
Well B205589 - Rock Creek flow path



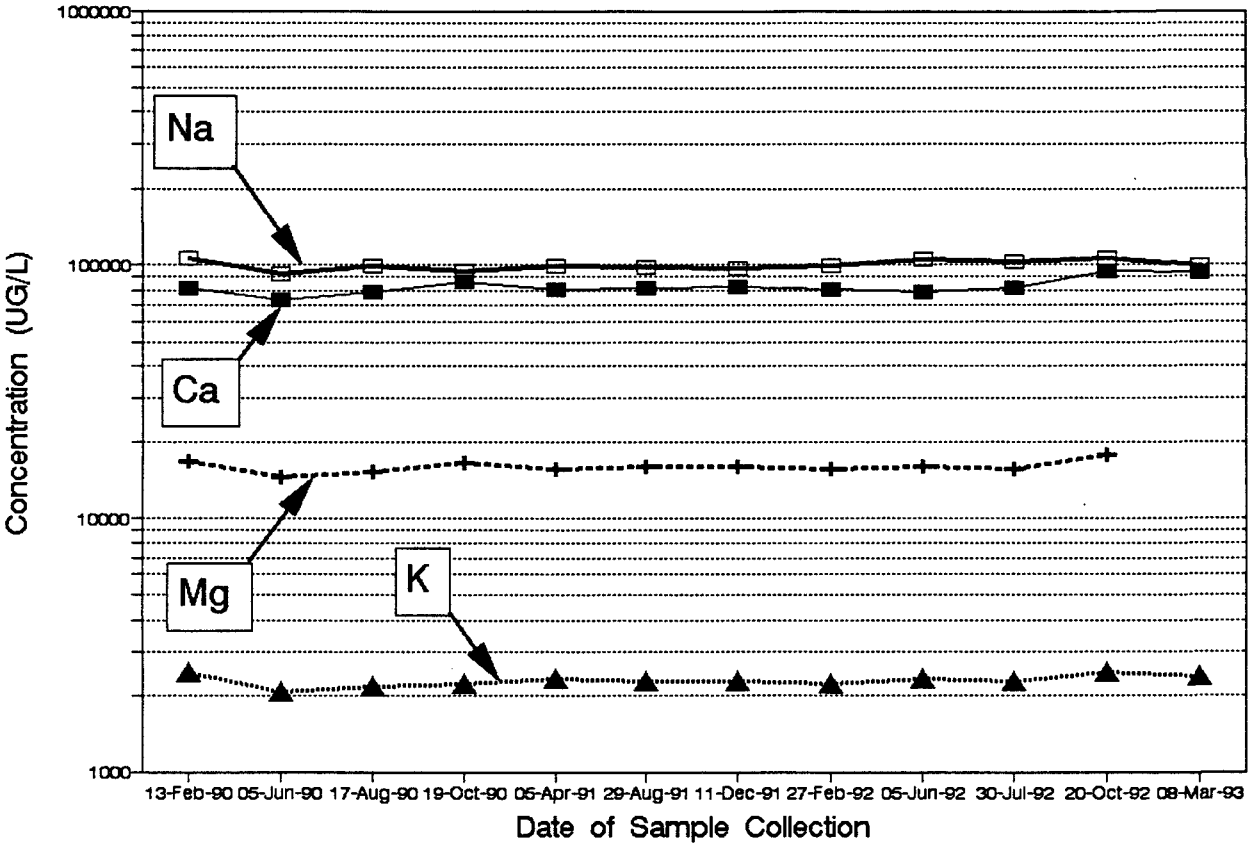
Well B201189 - Rock Creek flow path



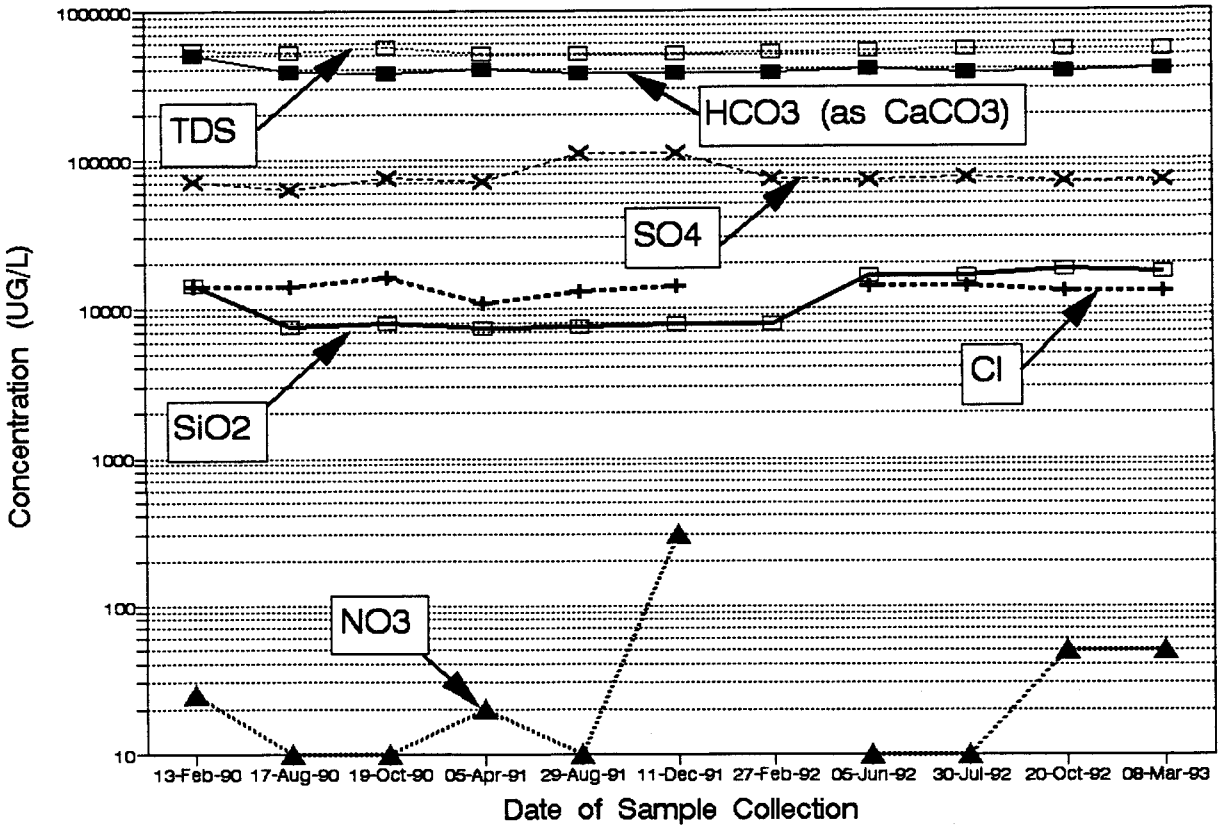
Well B201189 - Rock Creek flow path



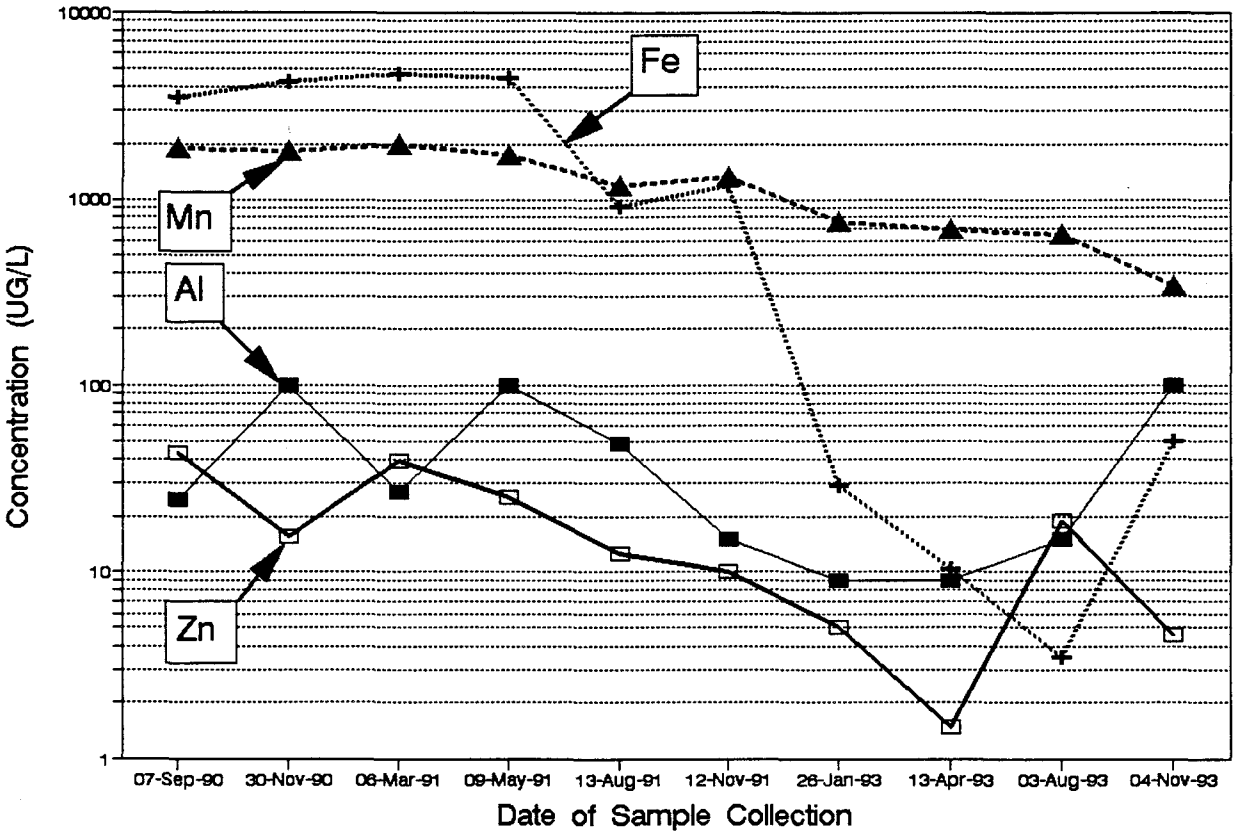
Well B201189 - Rock Creek flow path



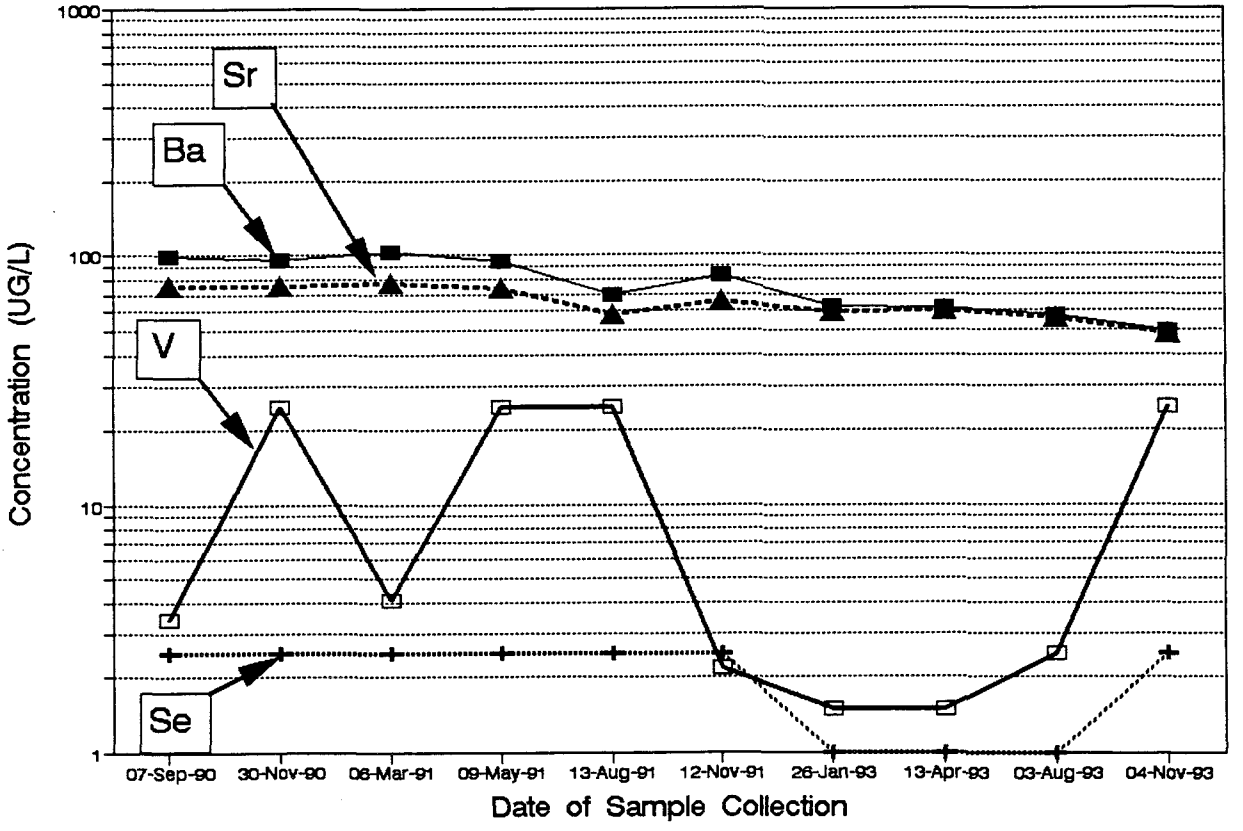
Well B201189 - Rock Creek flow path



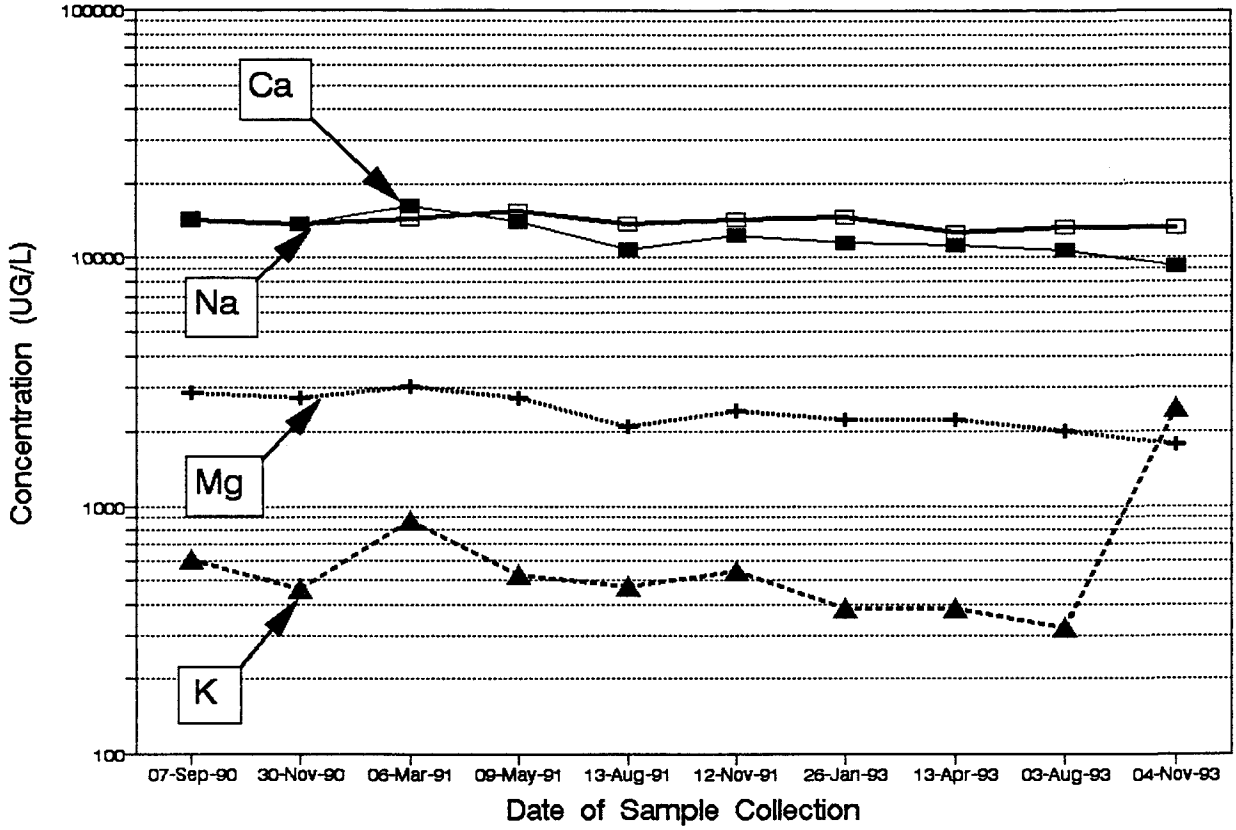
Well B411289 - Industrial Area path



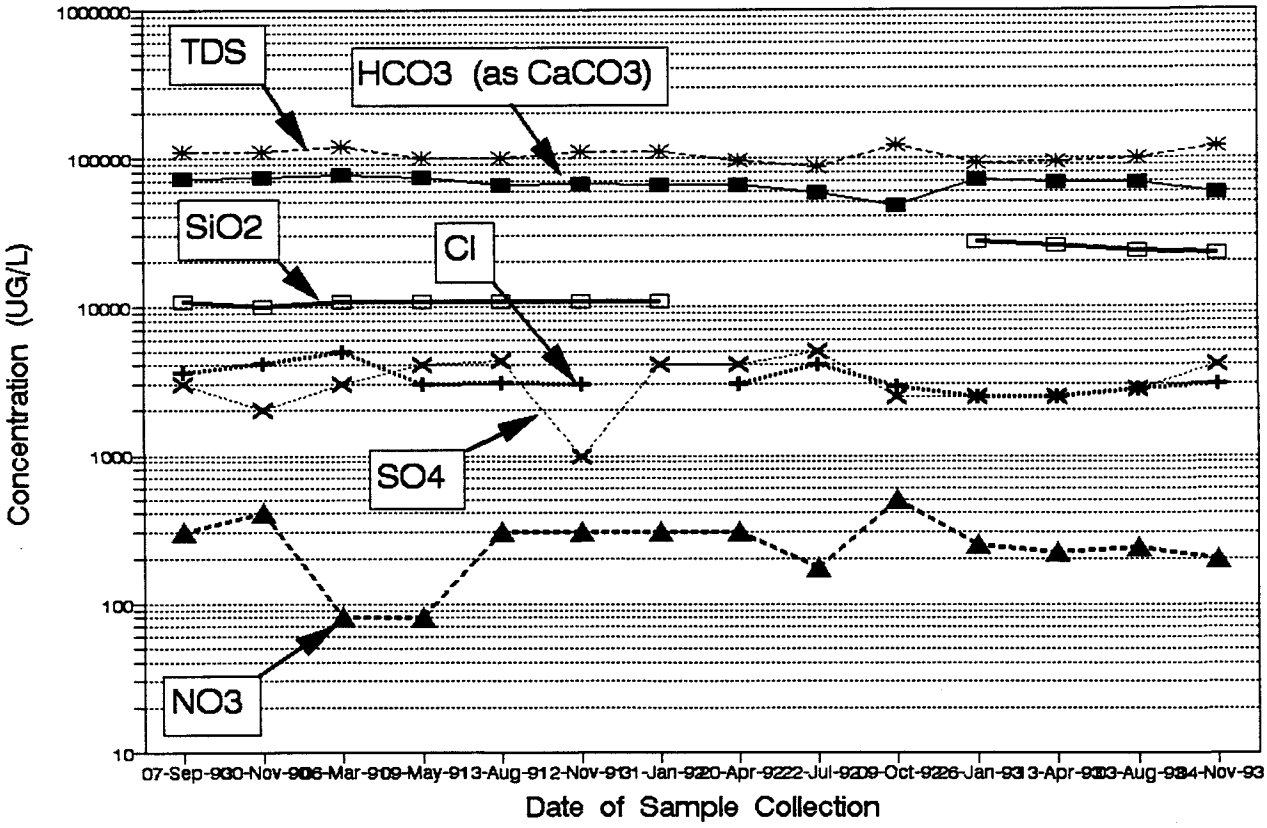
Well B411289 - Industrial Area path



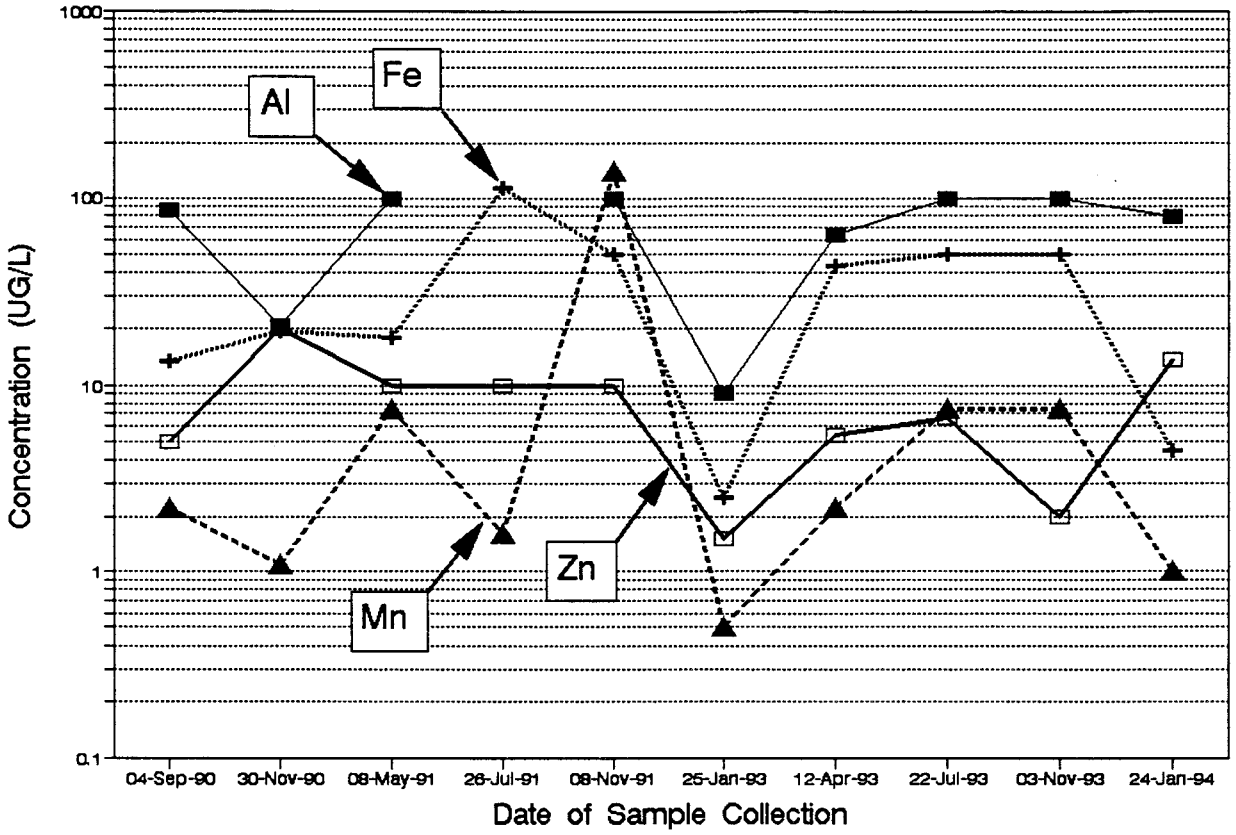
Well B411289 - Industrial Area path



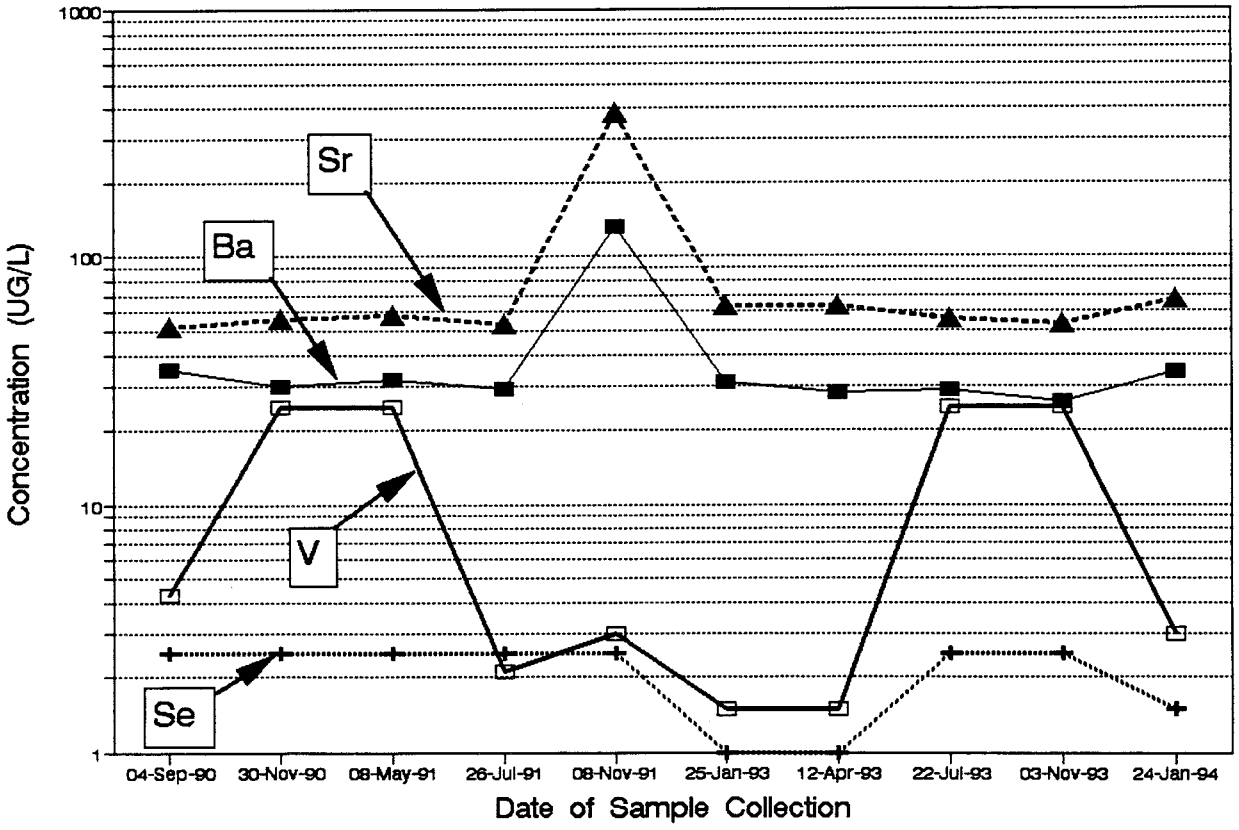
Well B411289 - Industrial Area path



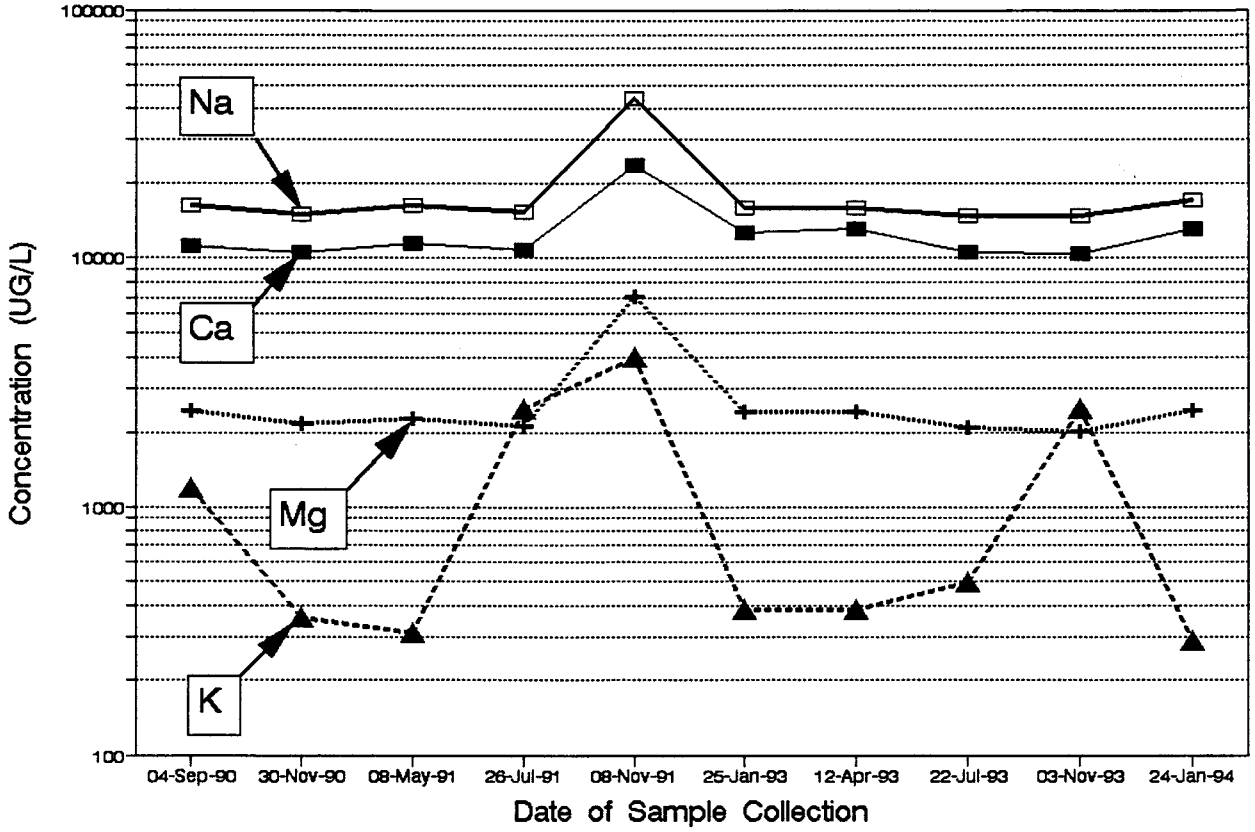
Well B411389 - Industrial Area path



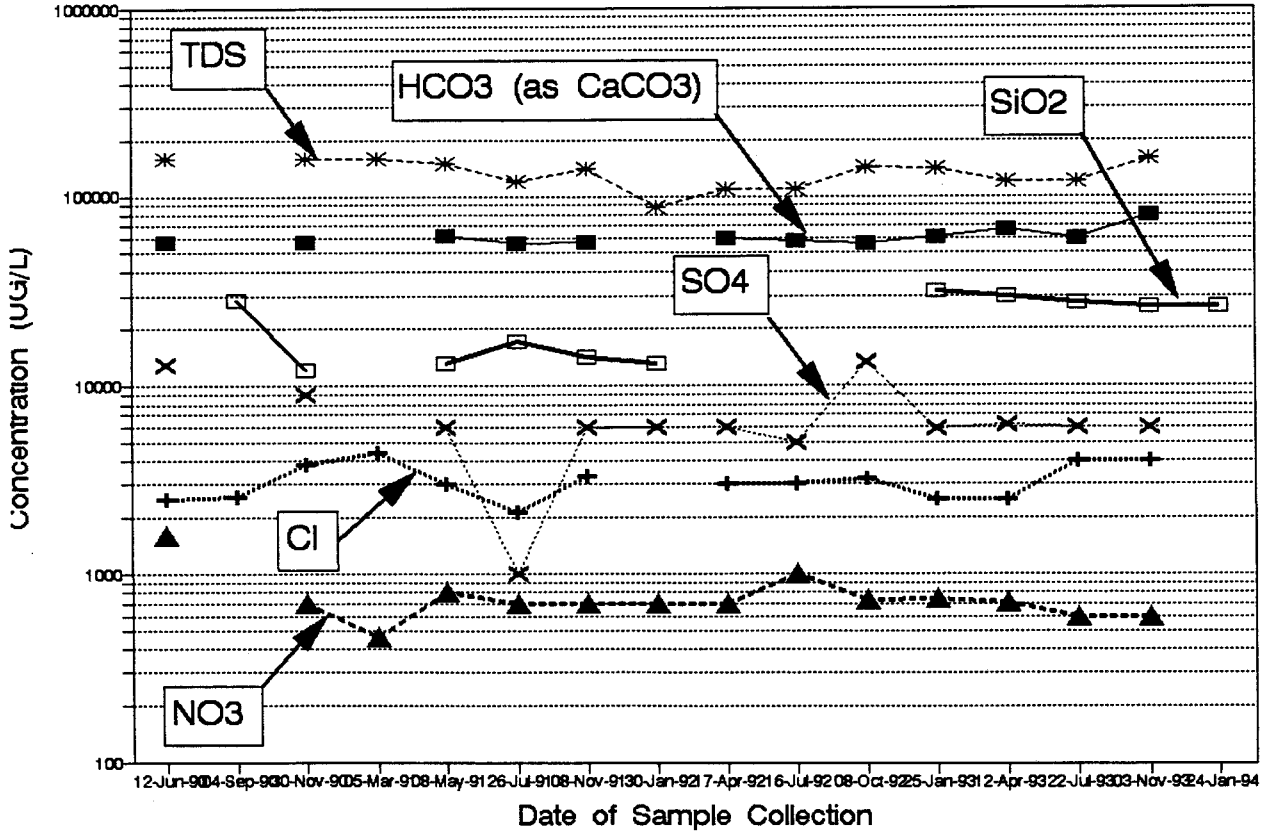
Well B411389 - Industrial Area path



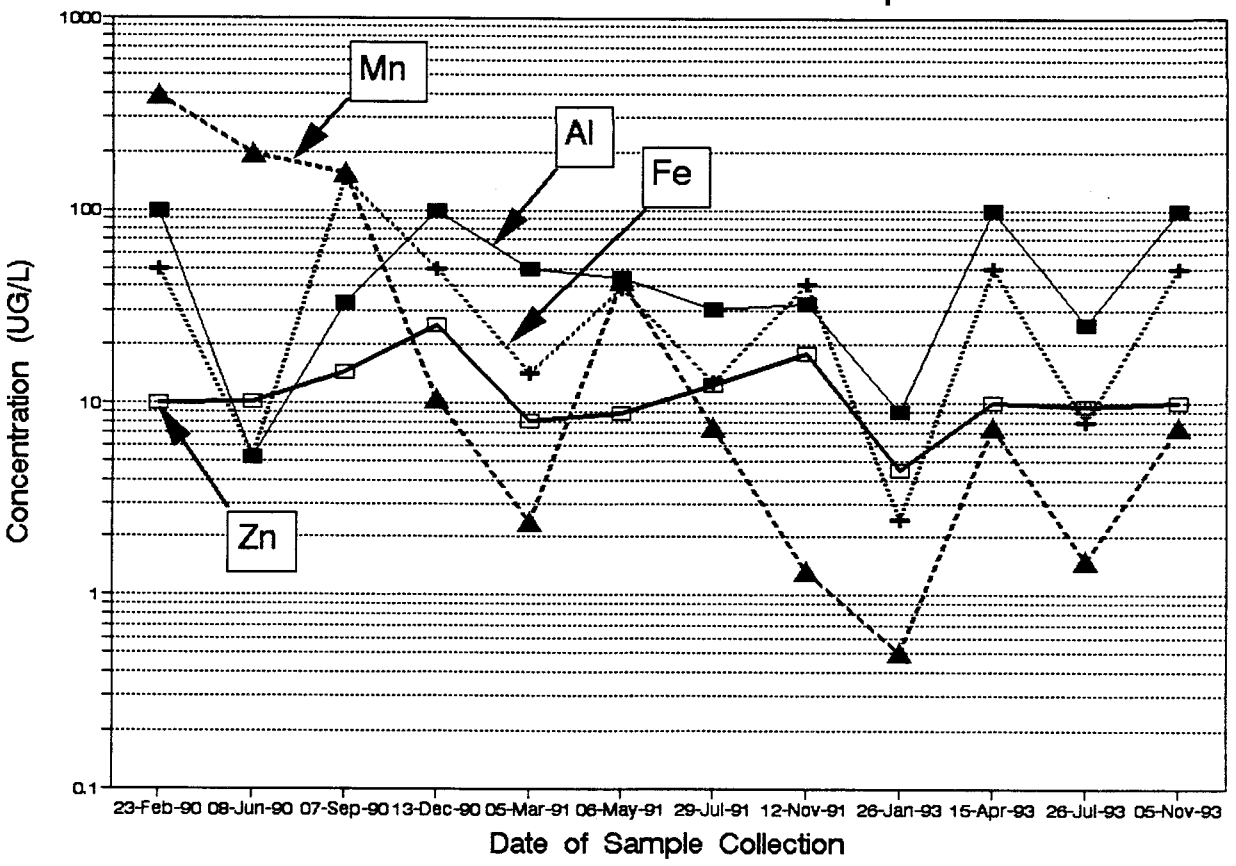
Well B411389 - Industrial Area path



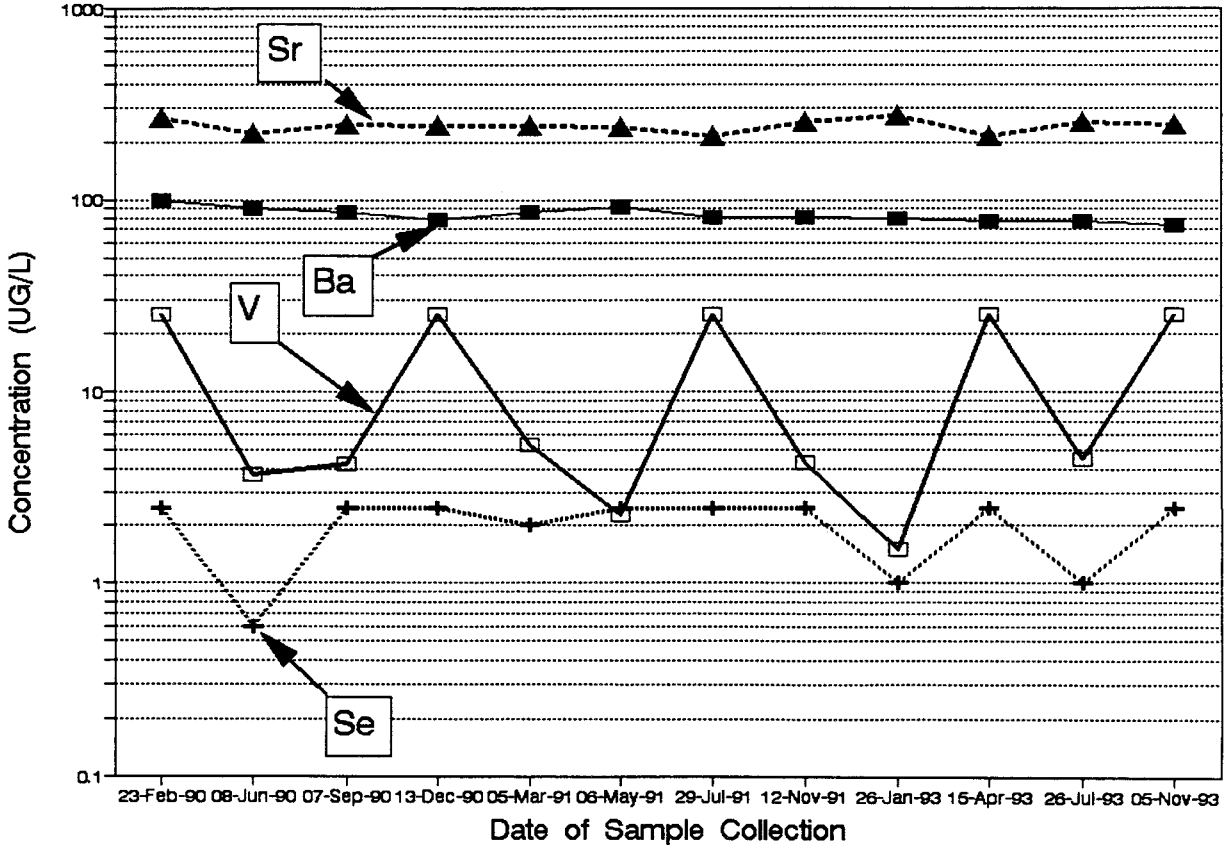
Well B411389 - Industrial Area path



Well B410789 - Industrial Area path



Well B410789 - Industrial Area path



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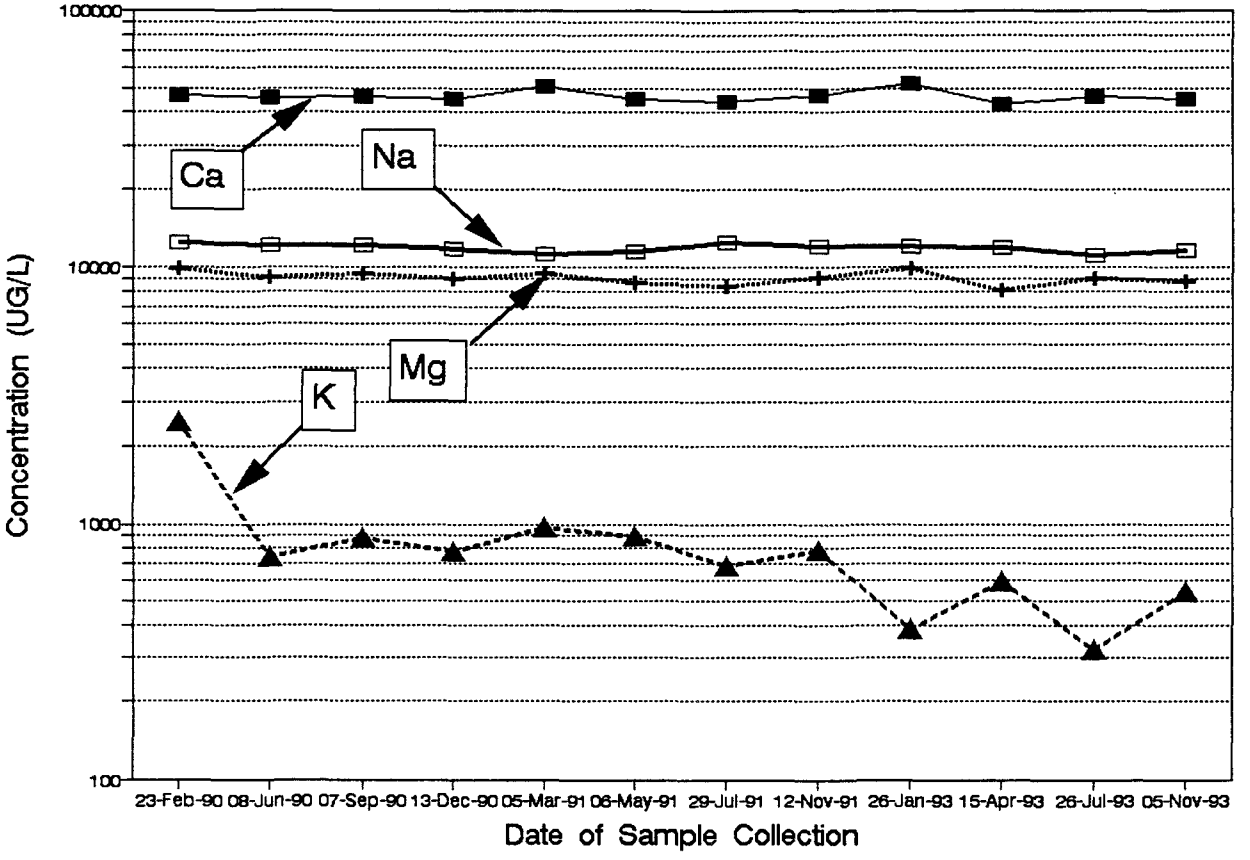
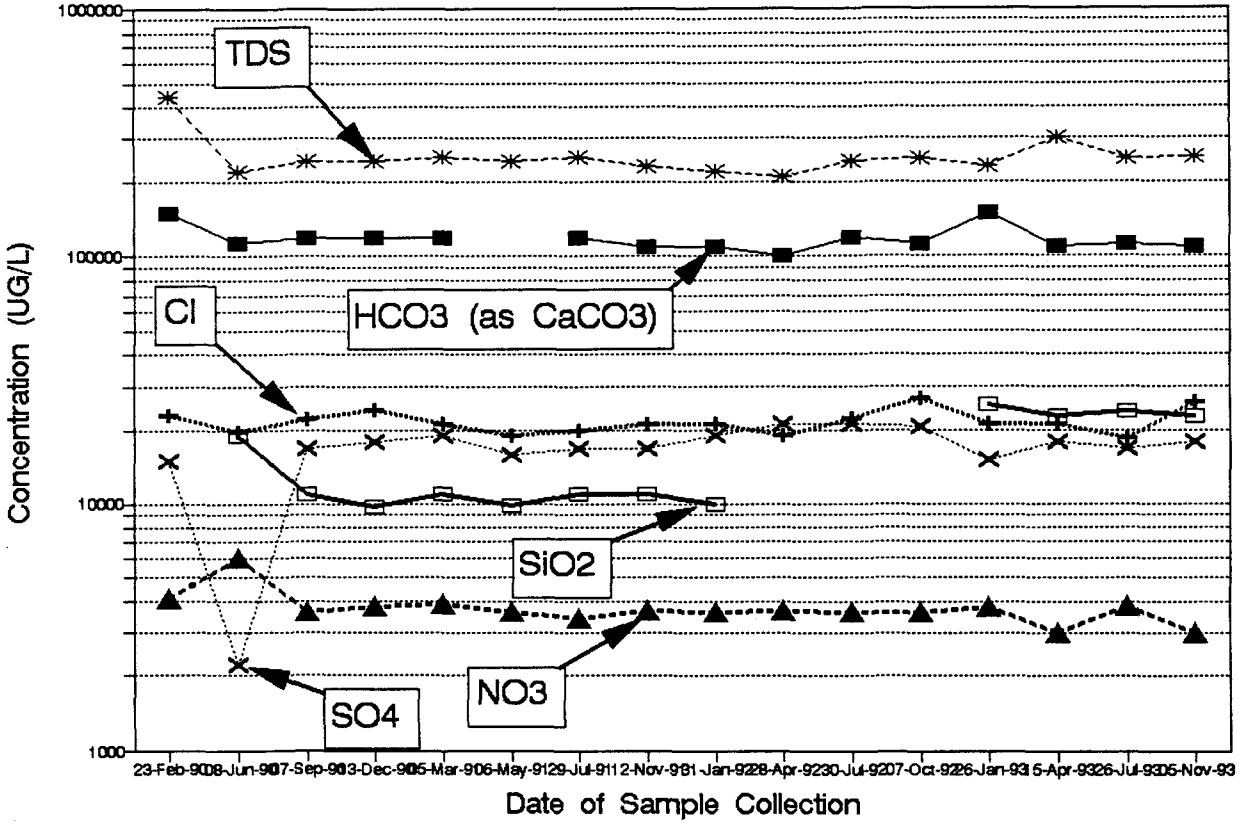
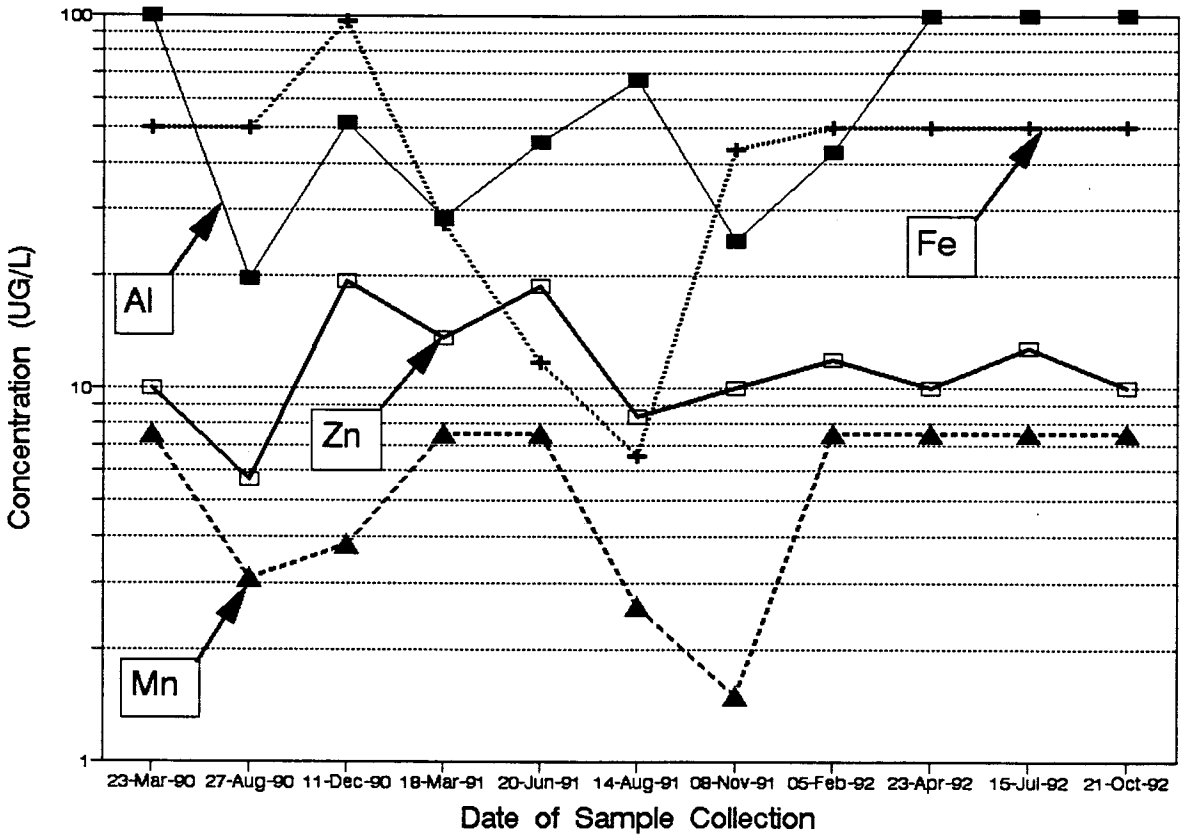


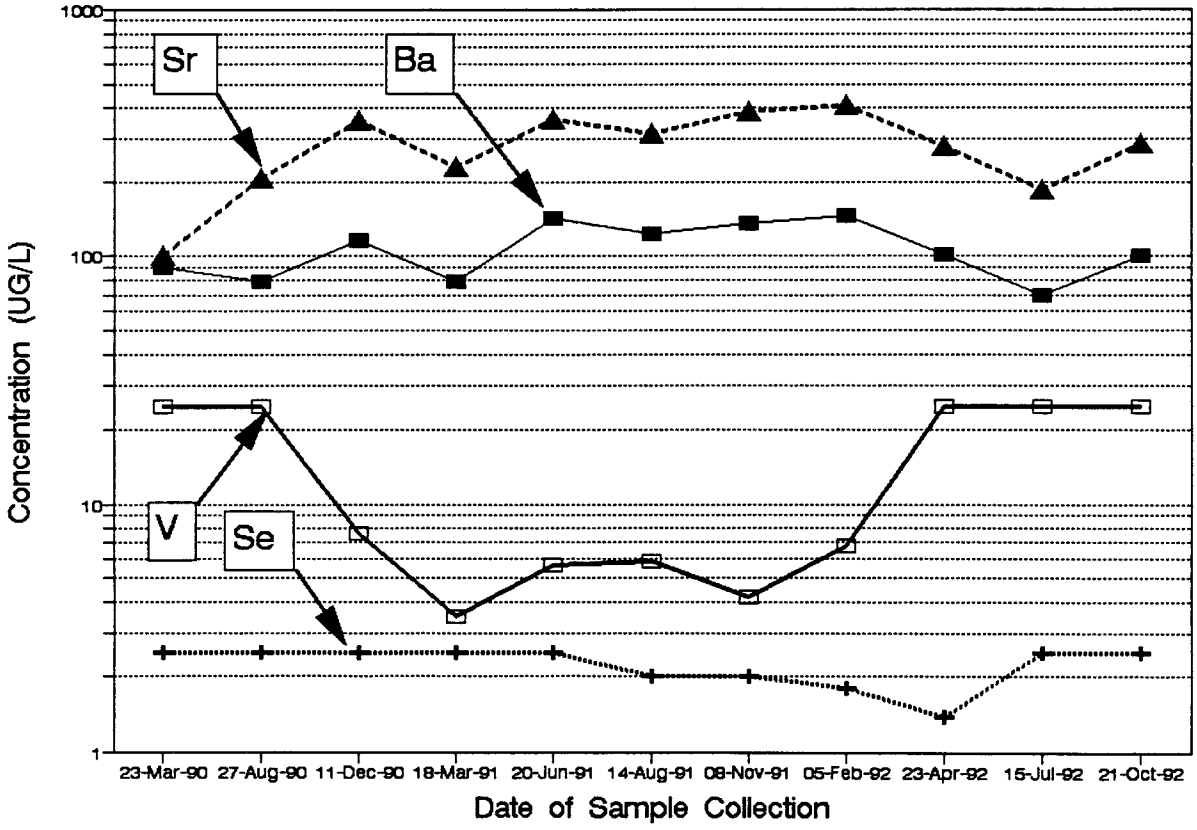
Well B410789 - Industrial Area path



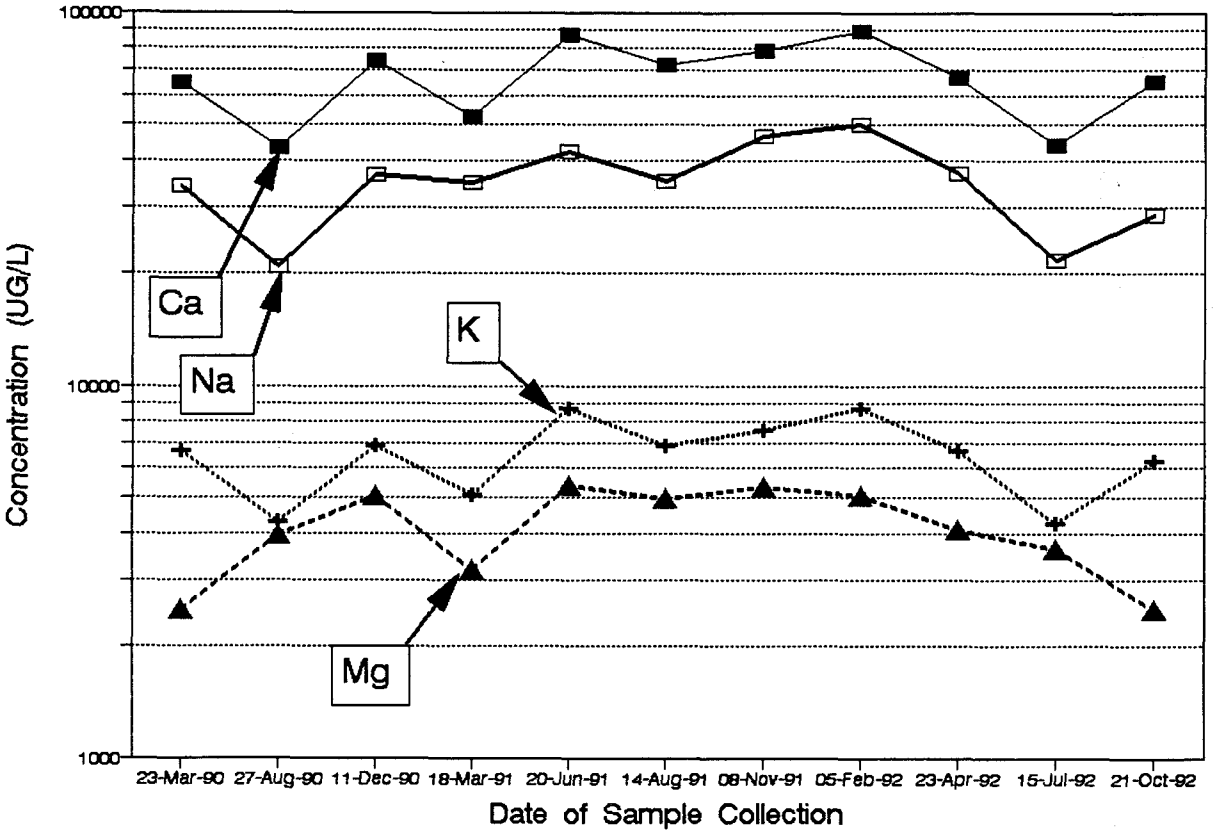
Well 4486 - Industrial Area flow path



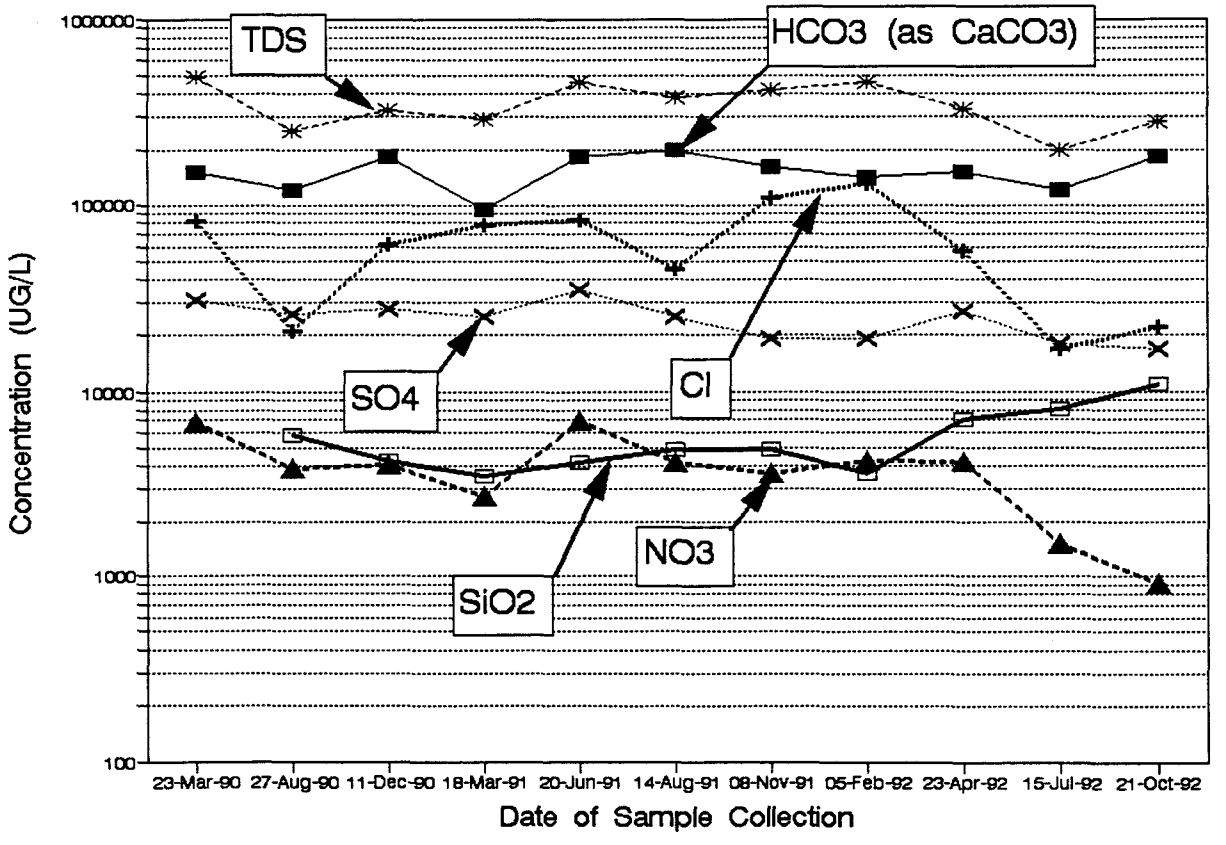
Well 4486 - Industrial Area flow path



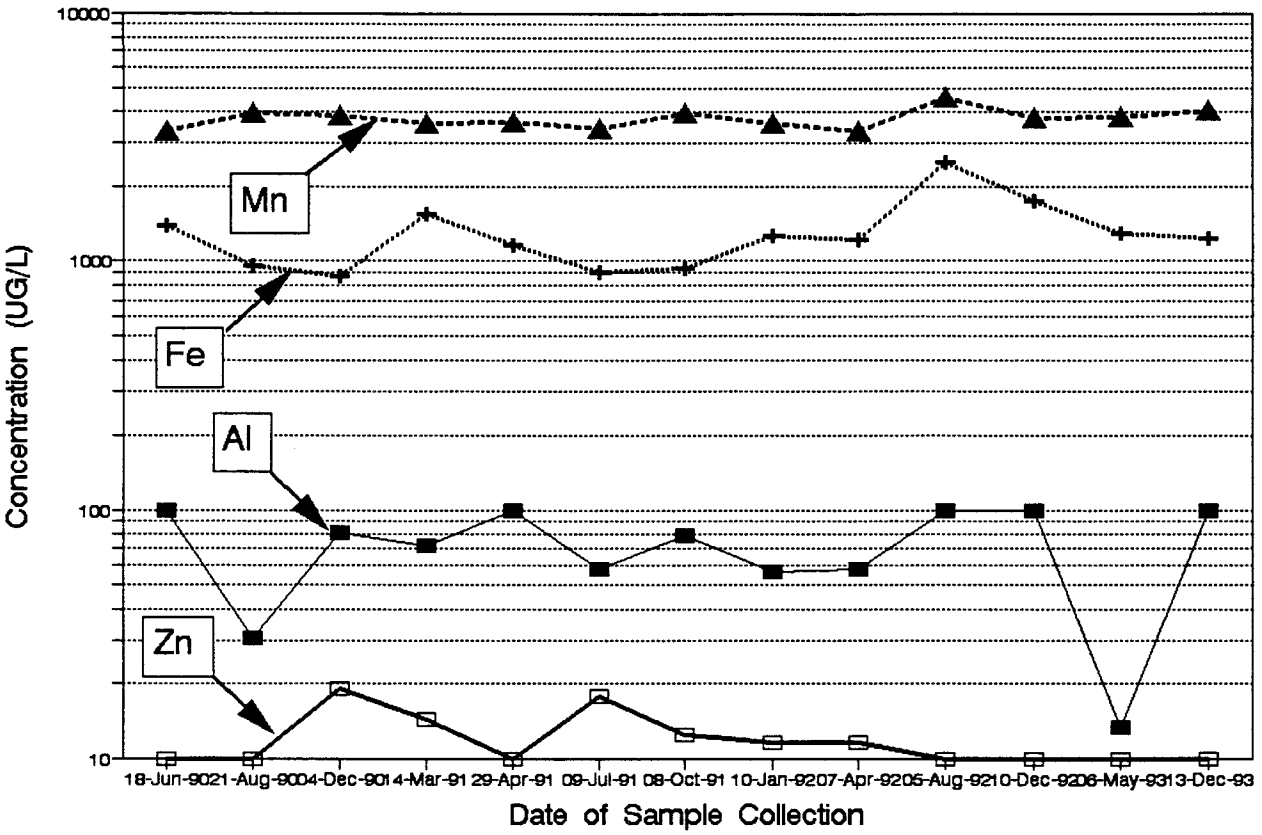
Well 4486 - Industrial Area flow path



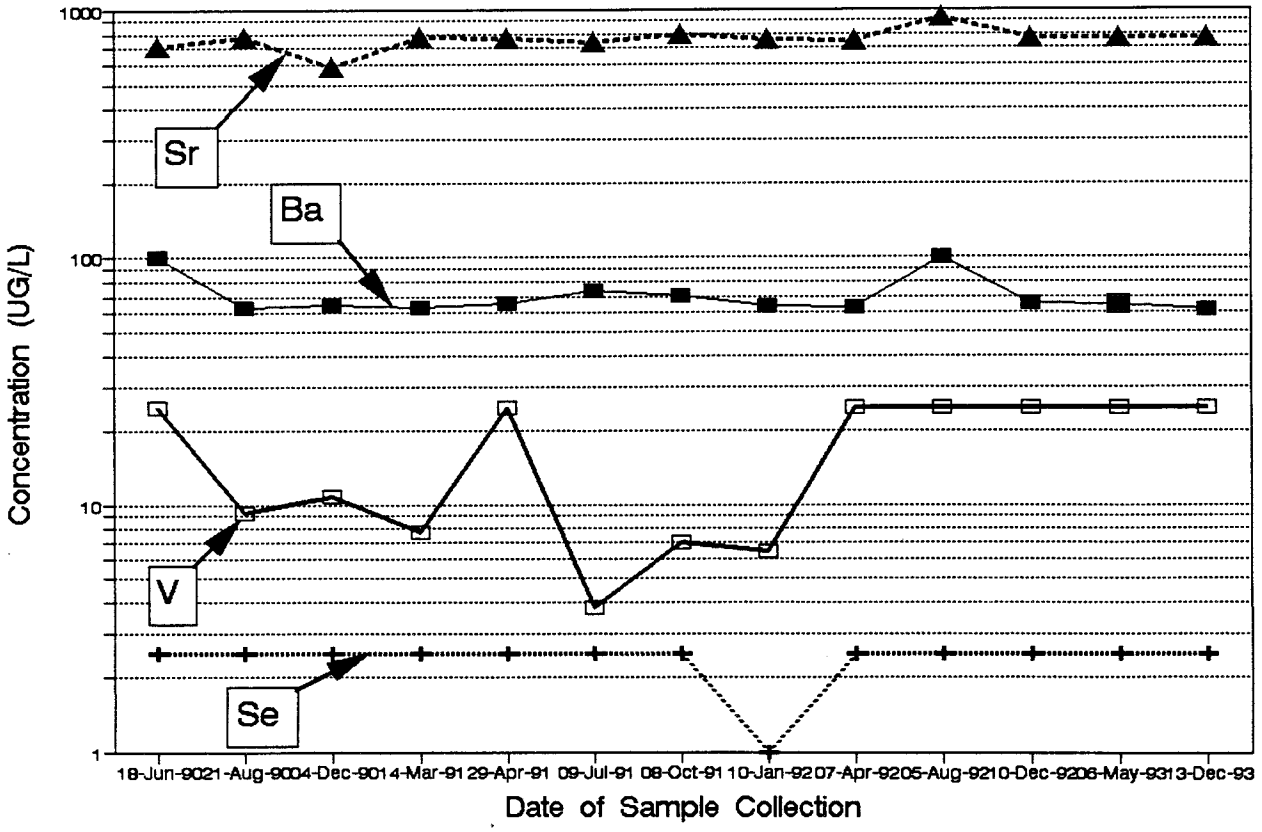
Well 4486 - Industrial Area flow path



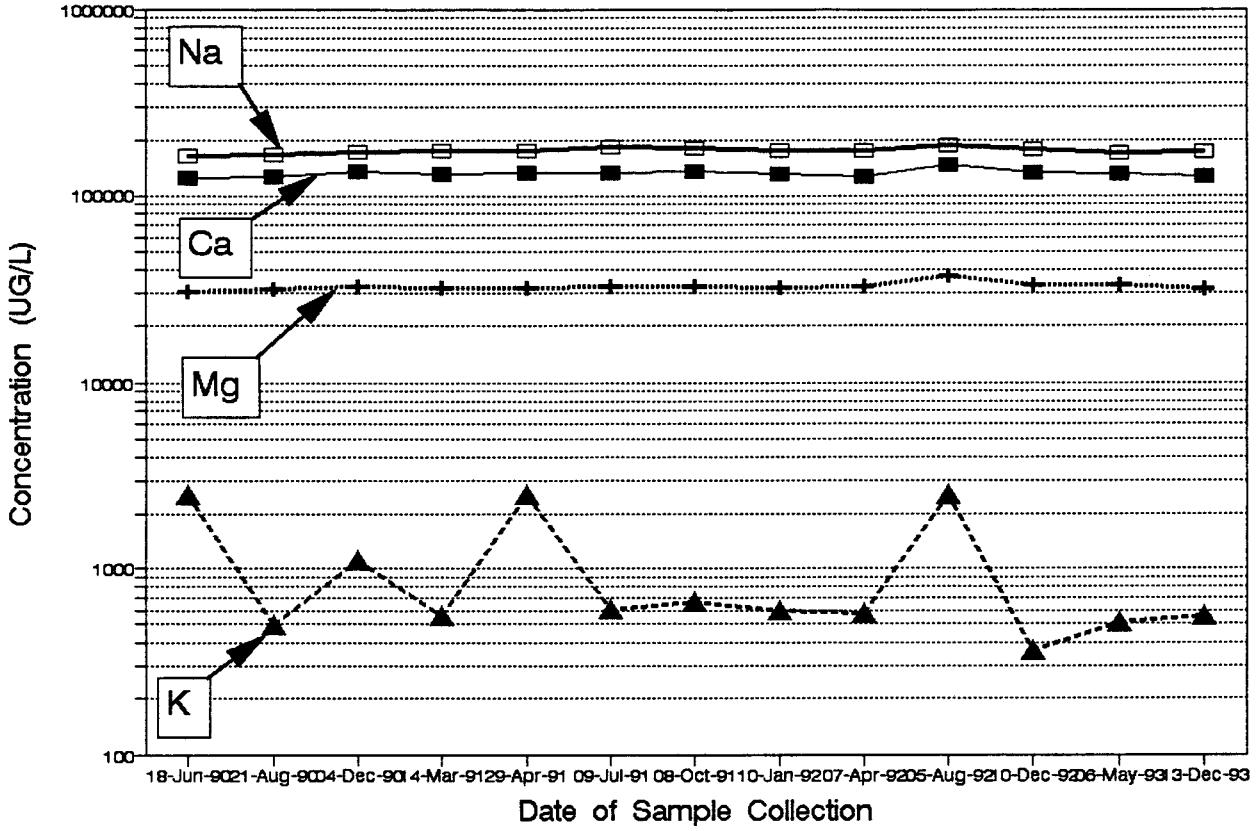
Well 3586 - Industrial Area flow path



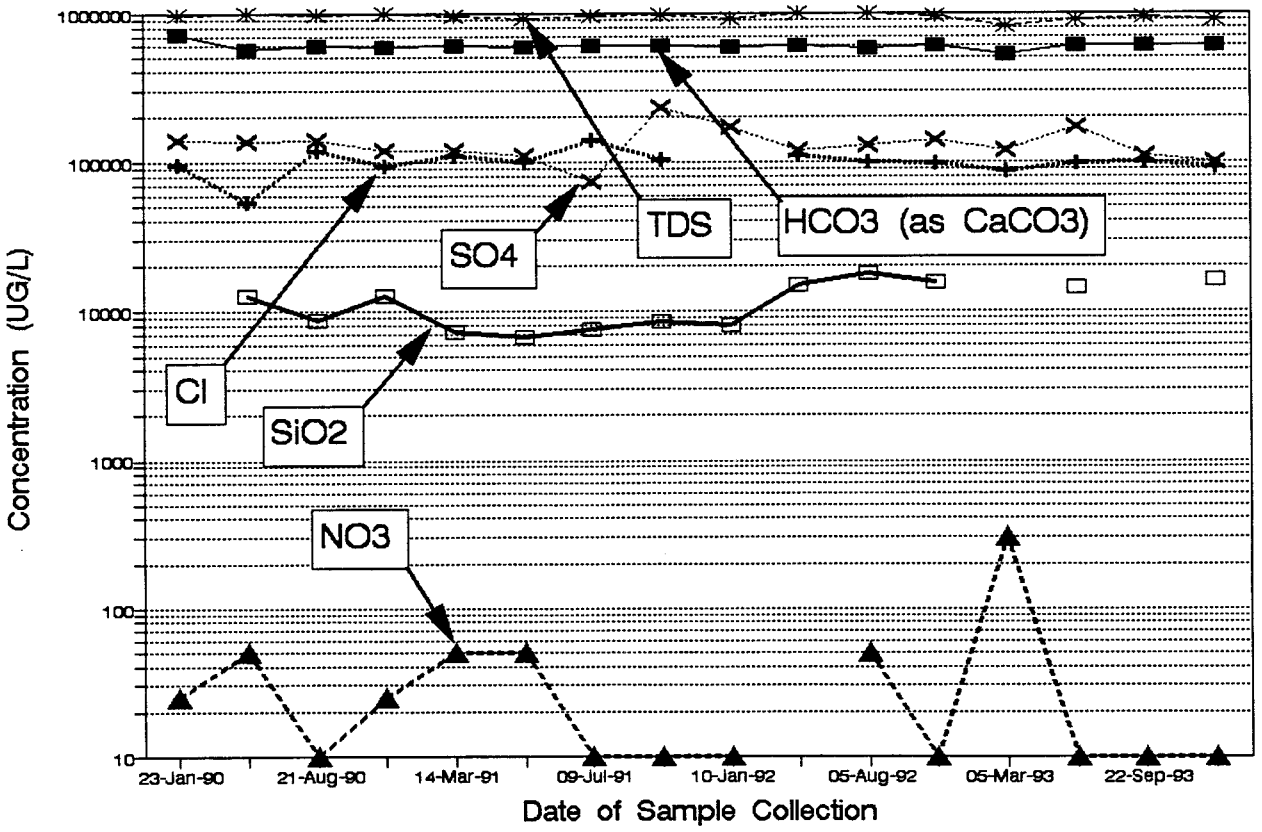
Well 3586 - Industrial Area flow path



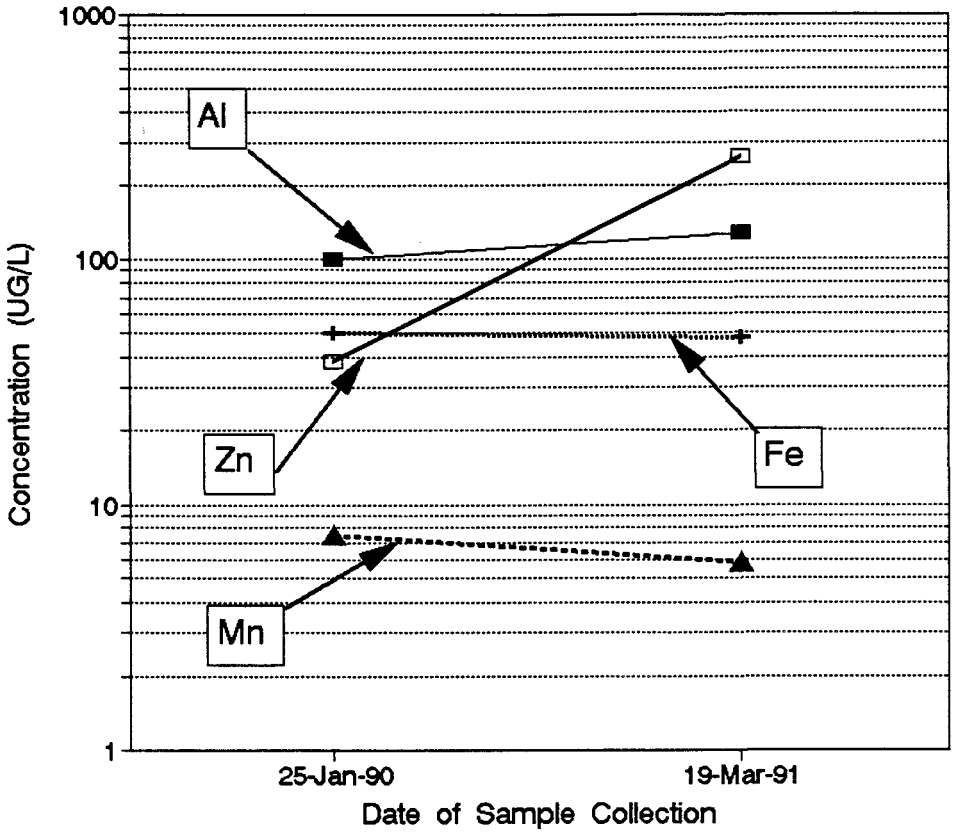
Well 3586 - Industrial Area flow path



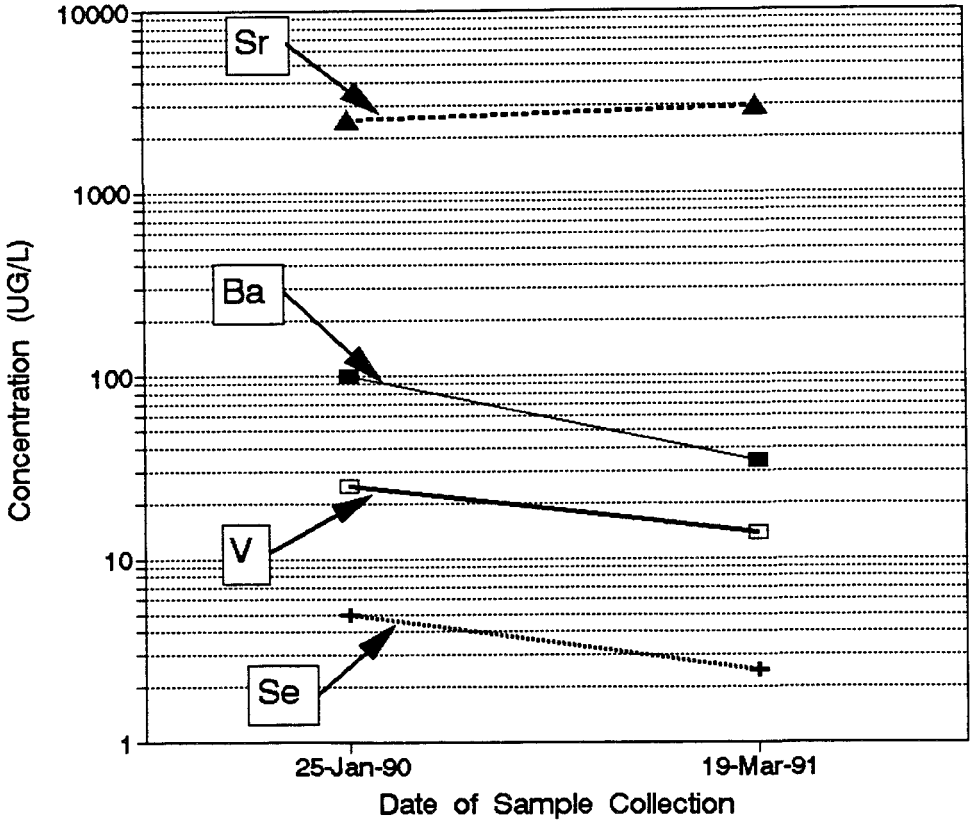
Well 3586 - Industrial Area flow path



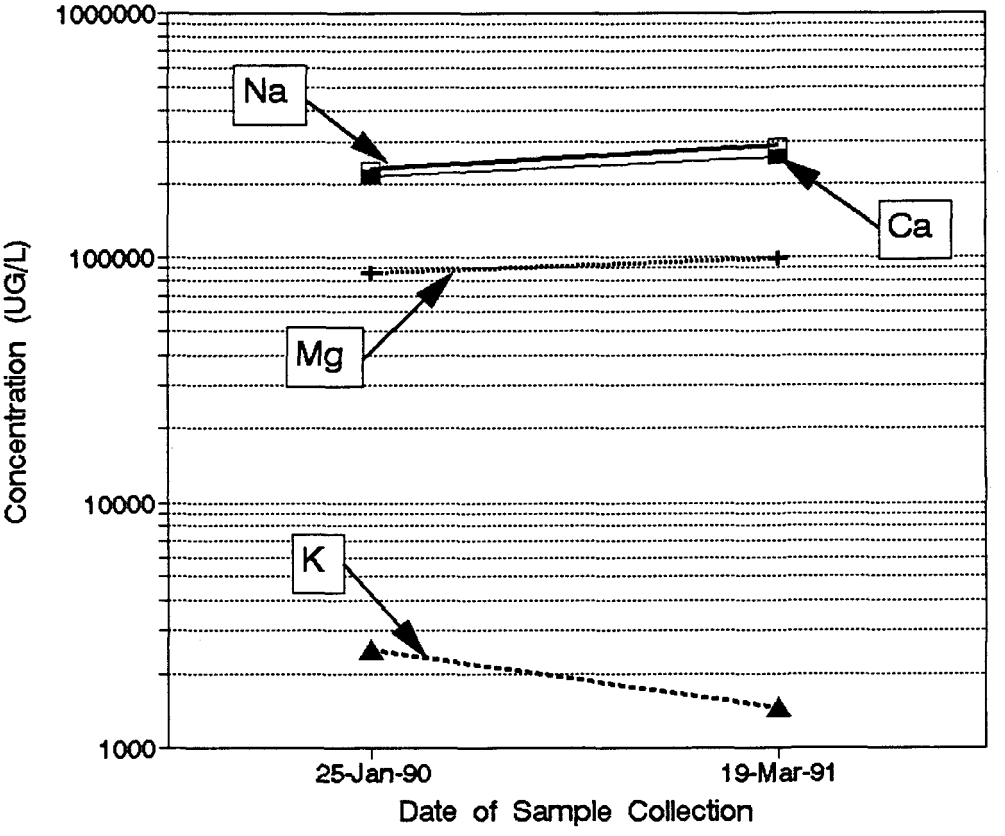
Well 3786 - Industrial Area flow path



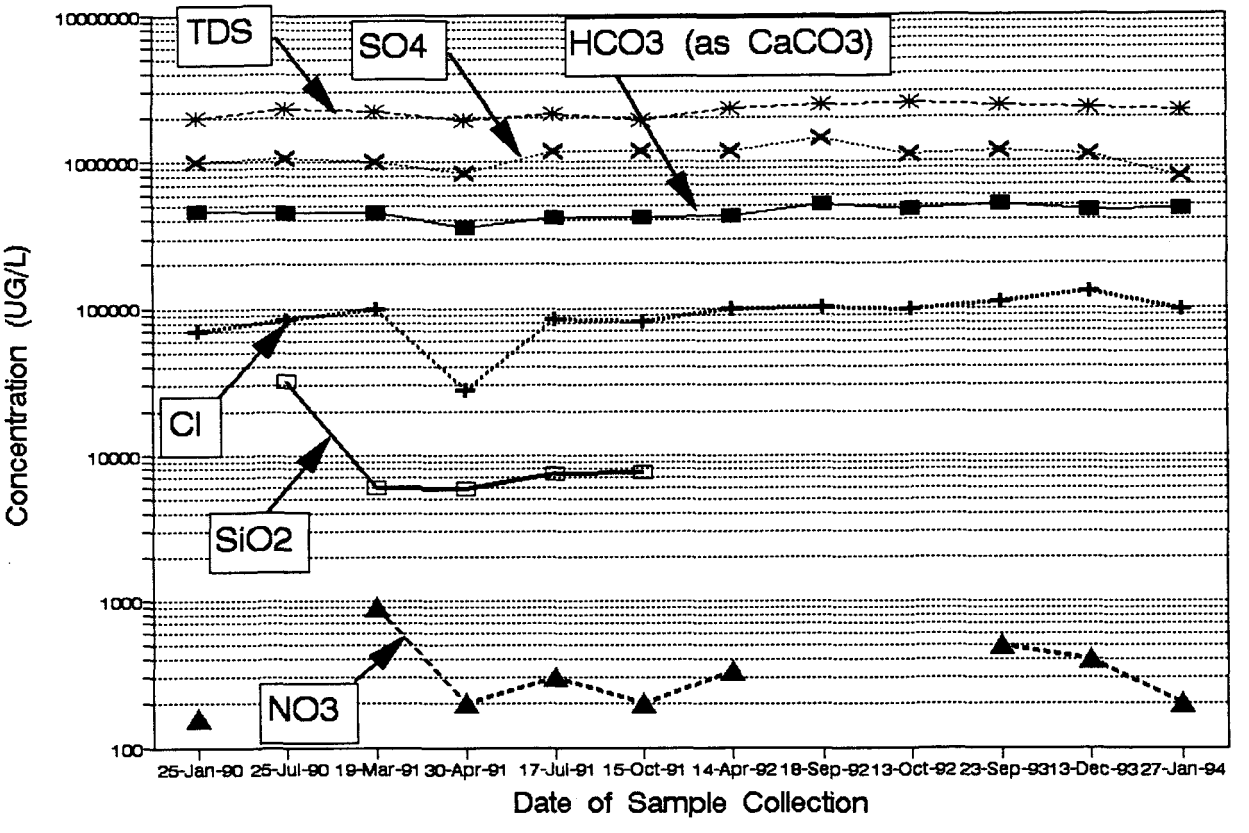
Well 3786 - Industrial Area flow path



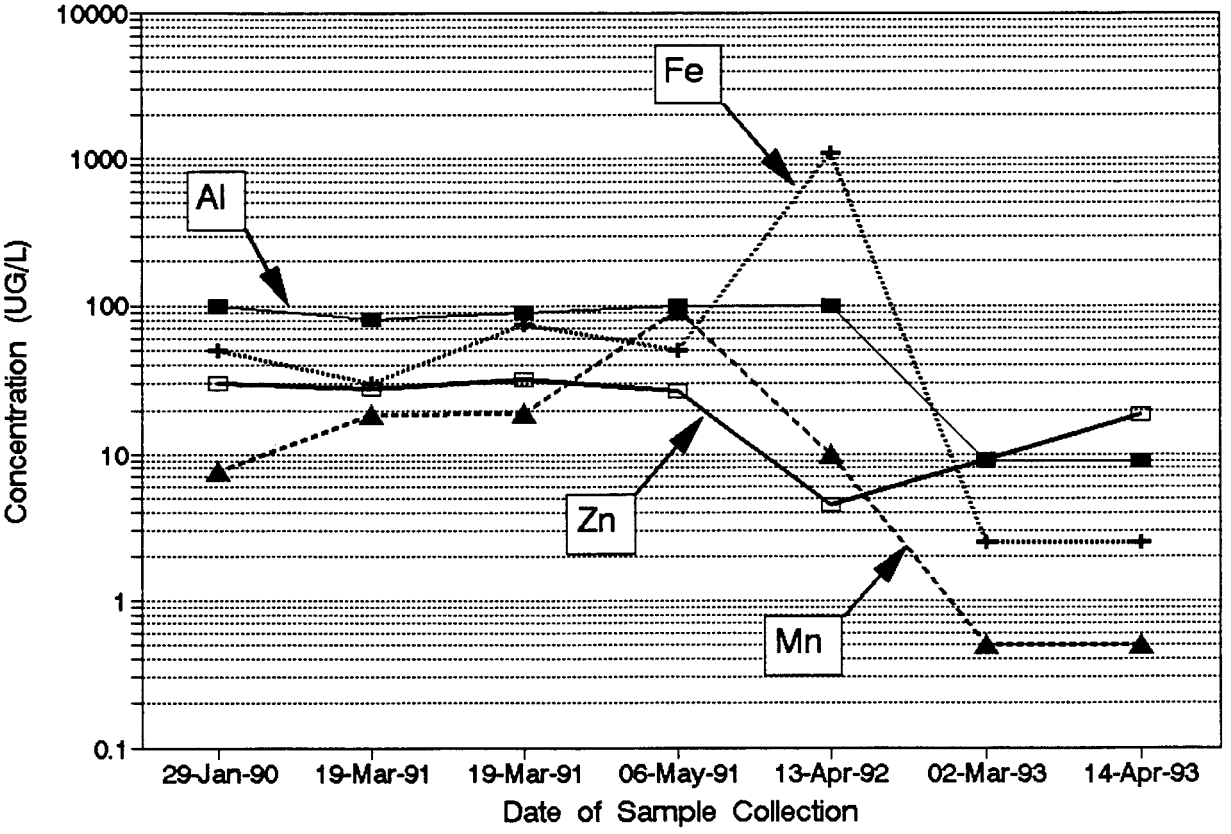
Well 3786 - Industrial Area flow path



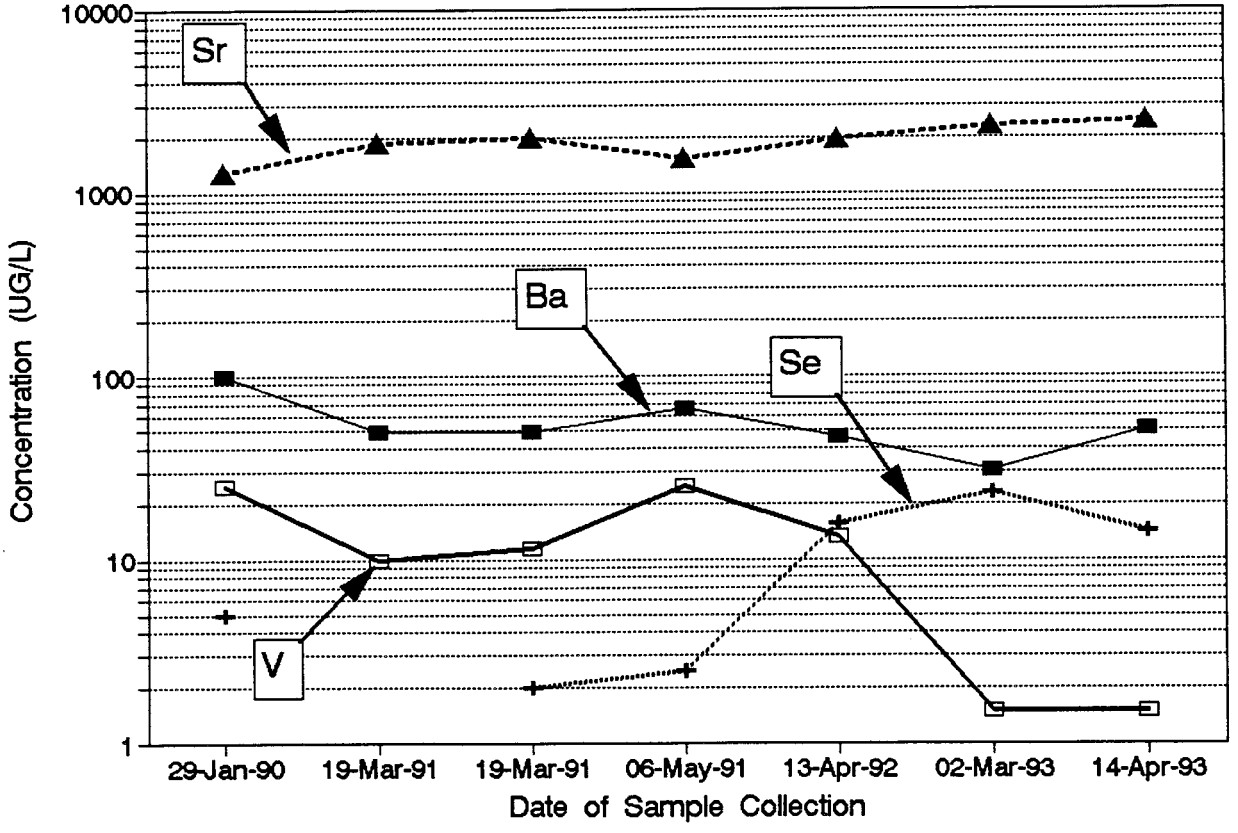
Well 3786 - Industrial Area flow path



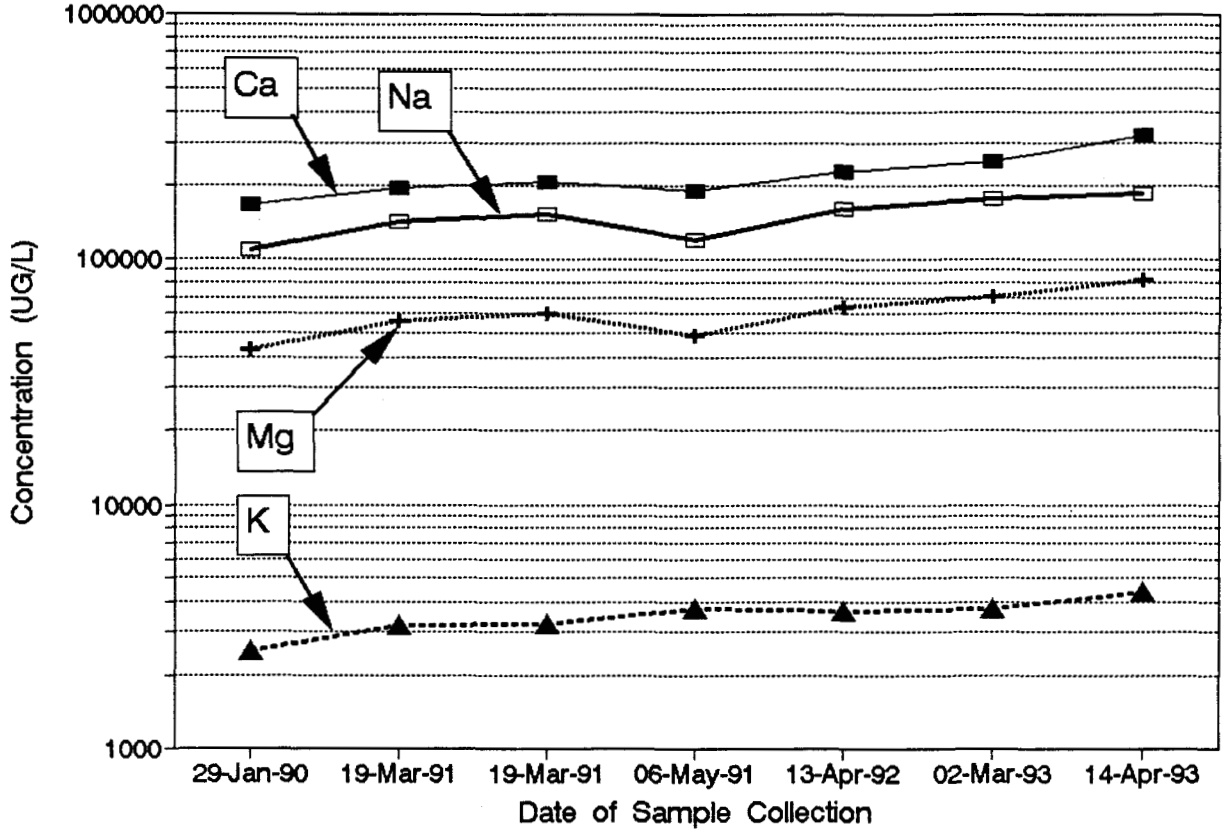
Well 3886 - Industrial Area flow path



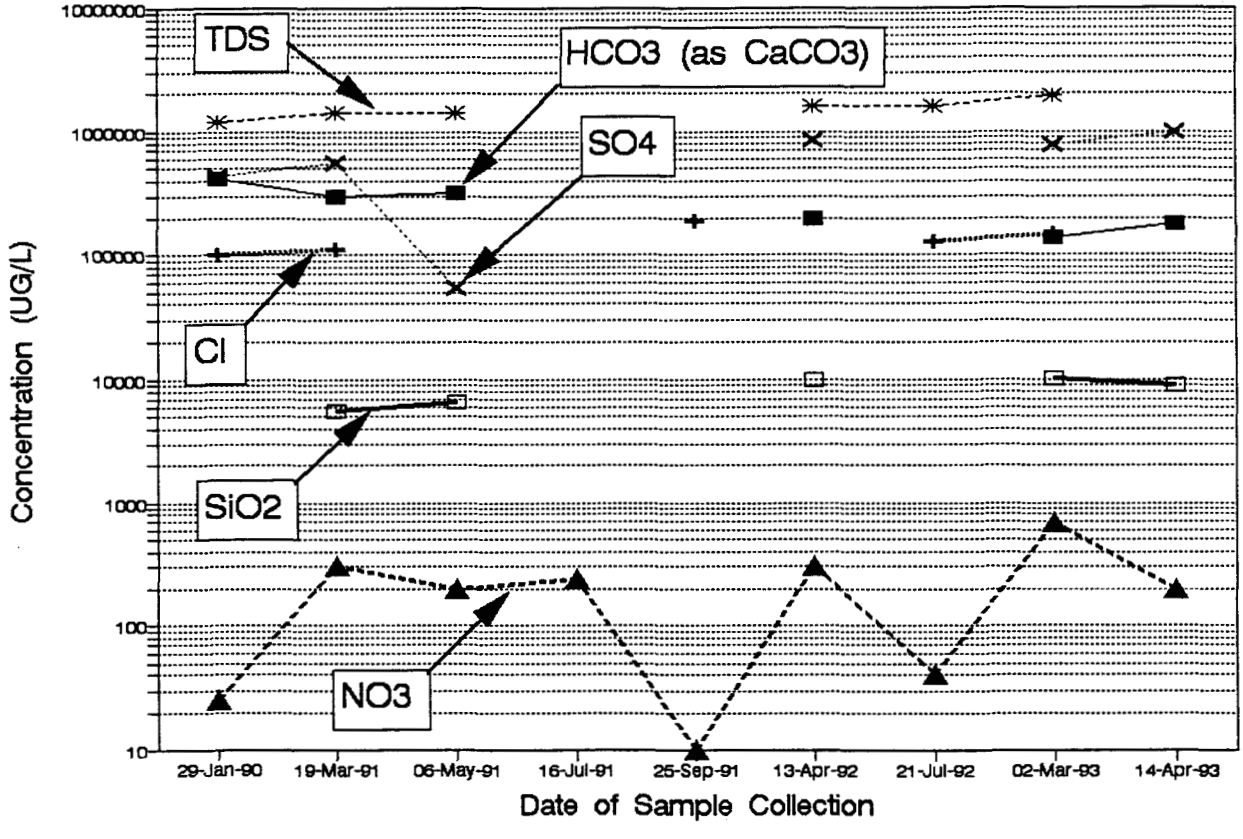
Well 3886 - Industrial Area flow path

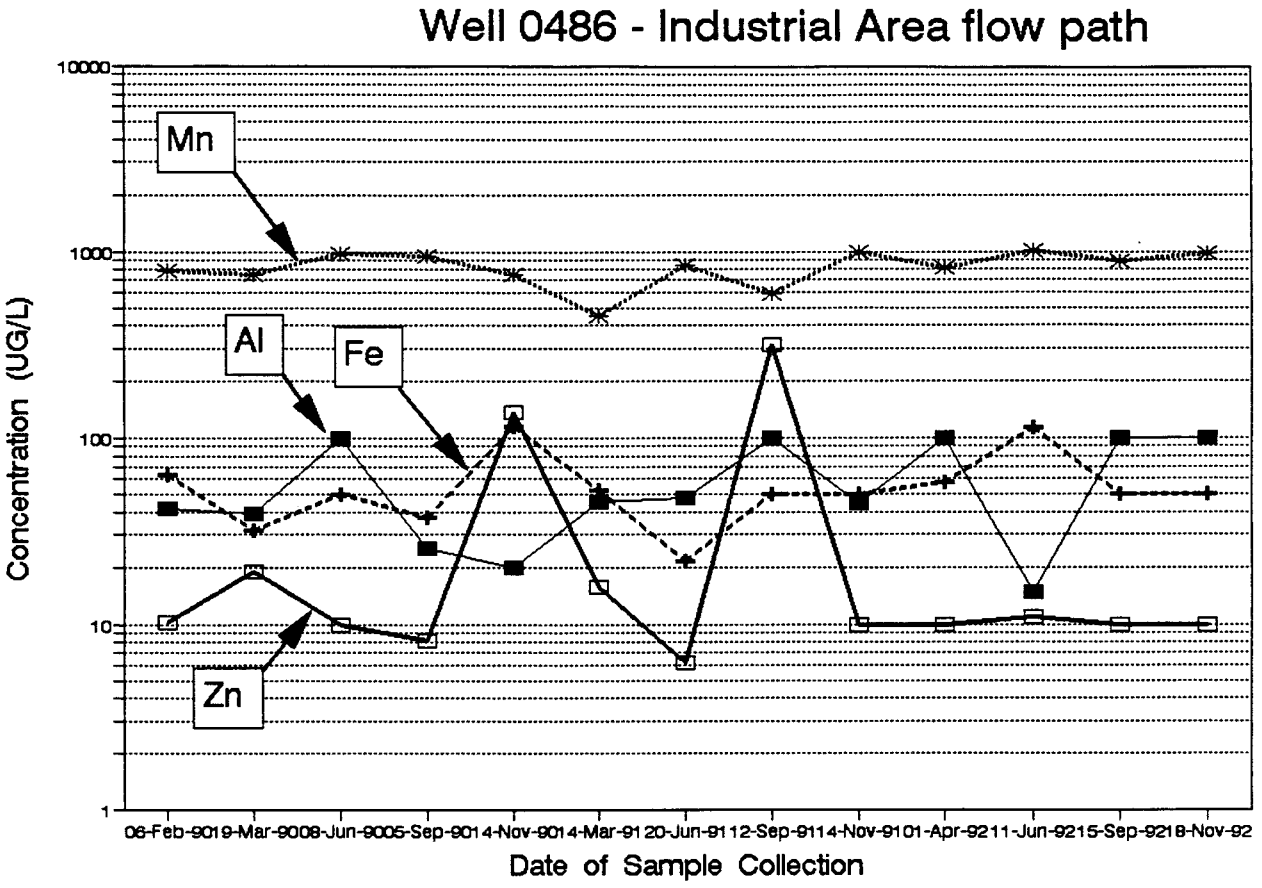


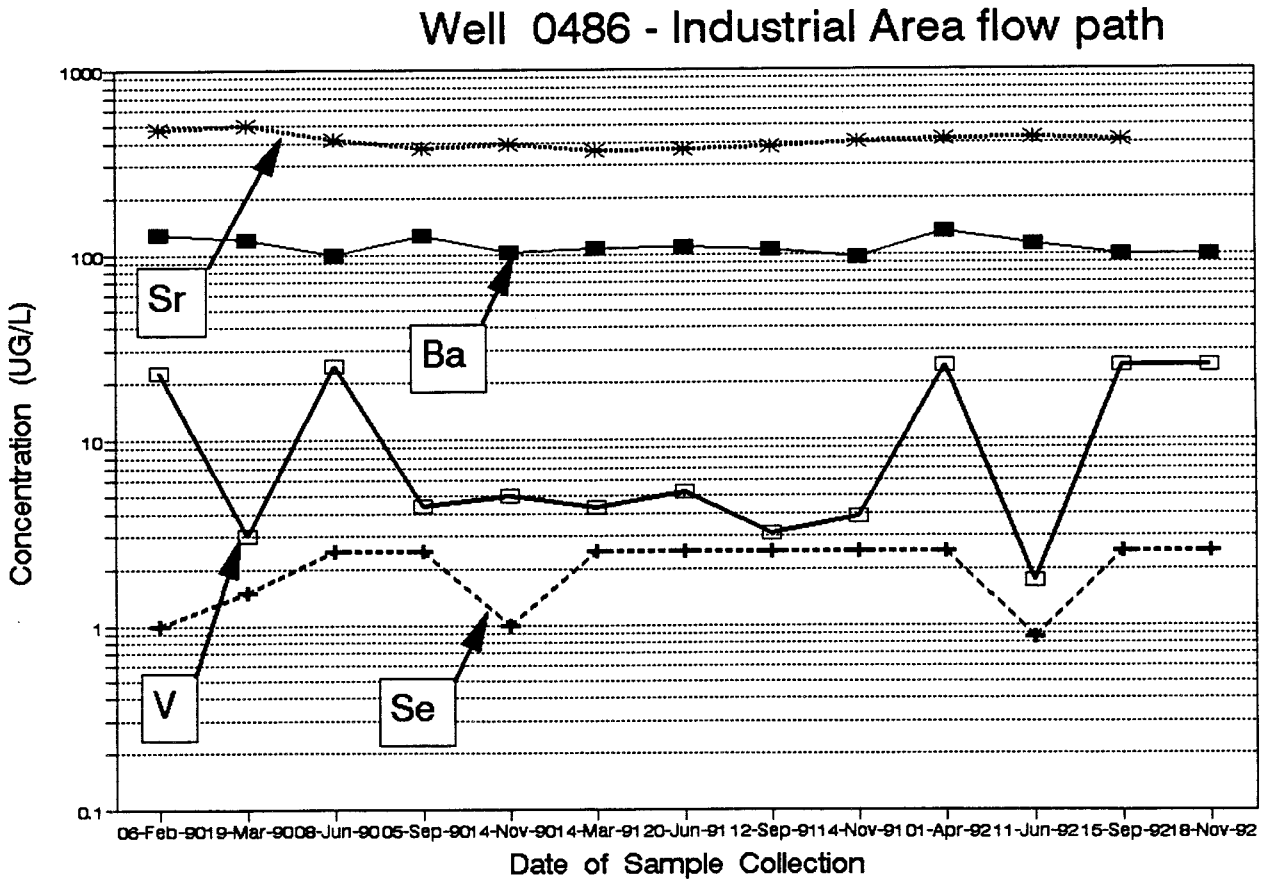
Well 3886 - Industrial Area flow path

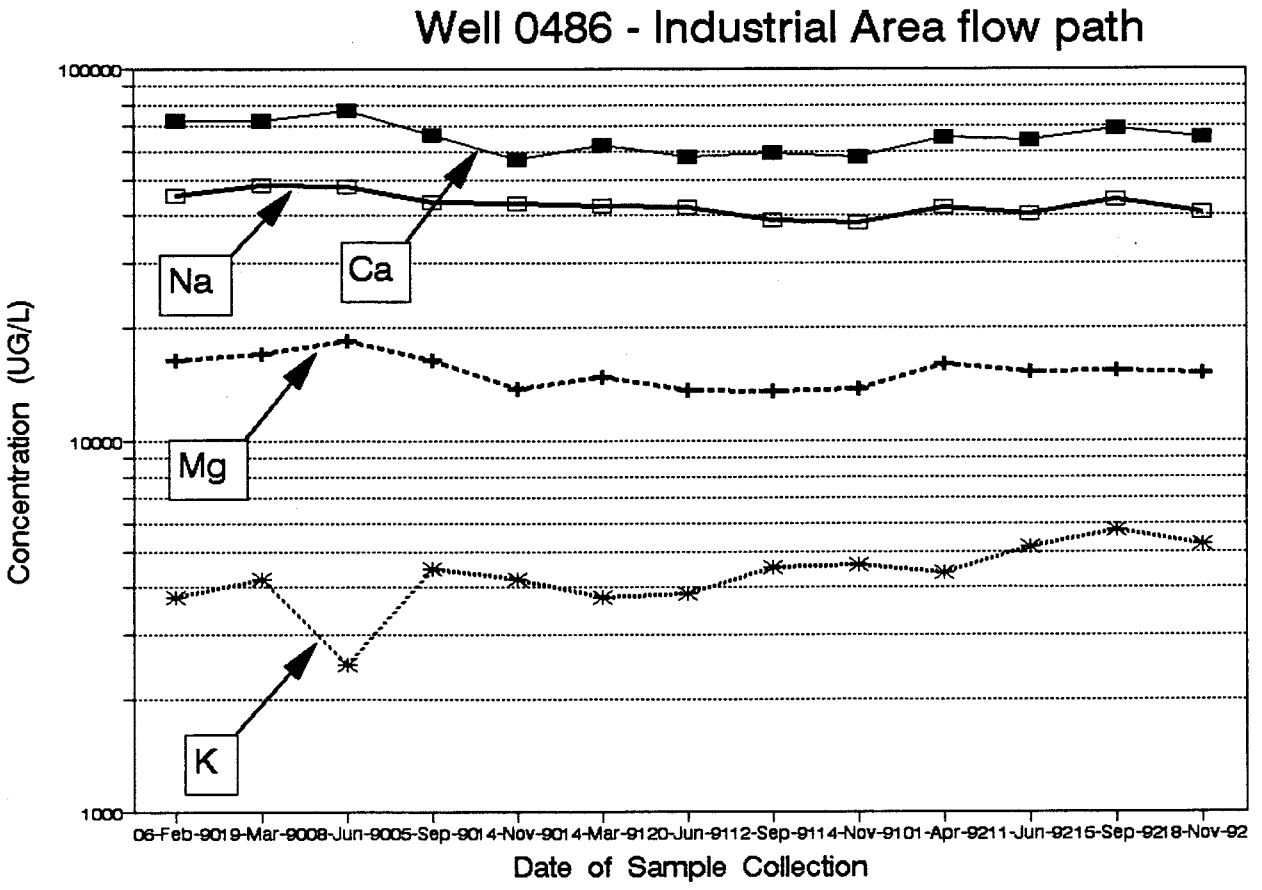


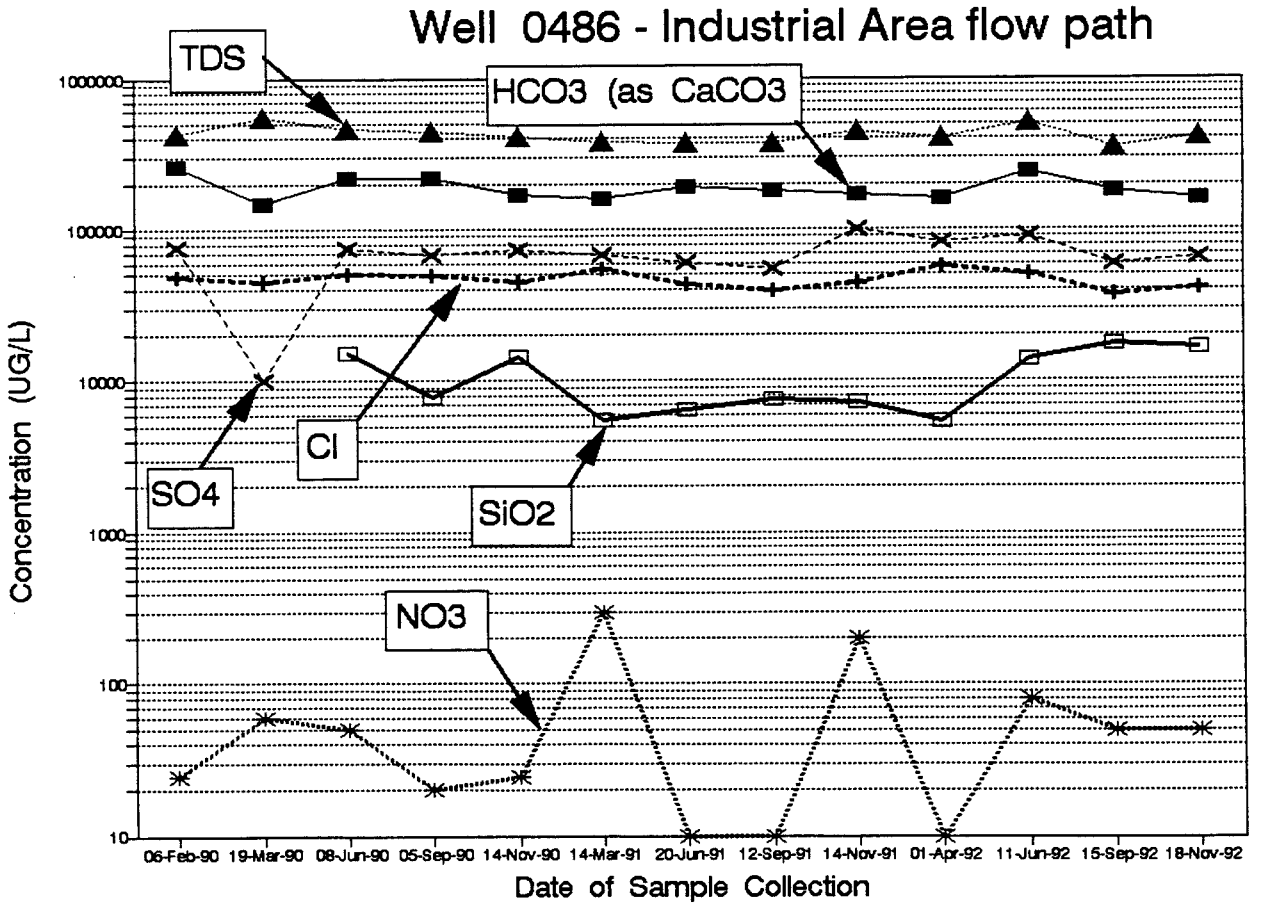
Well 3886 - Industrial Area flow path



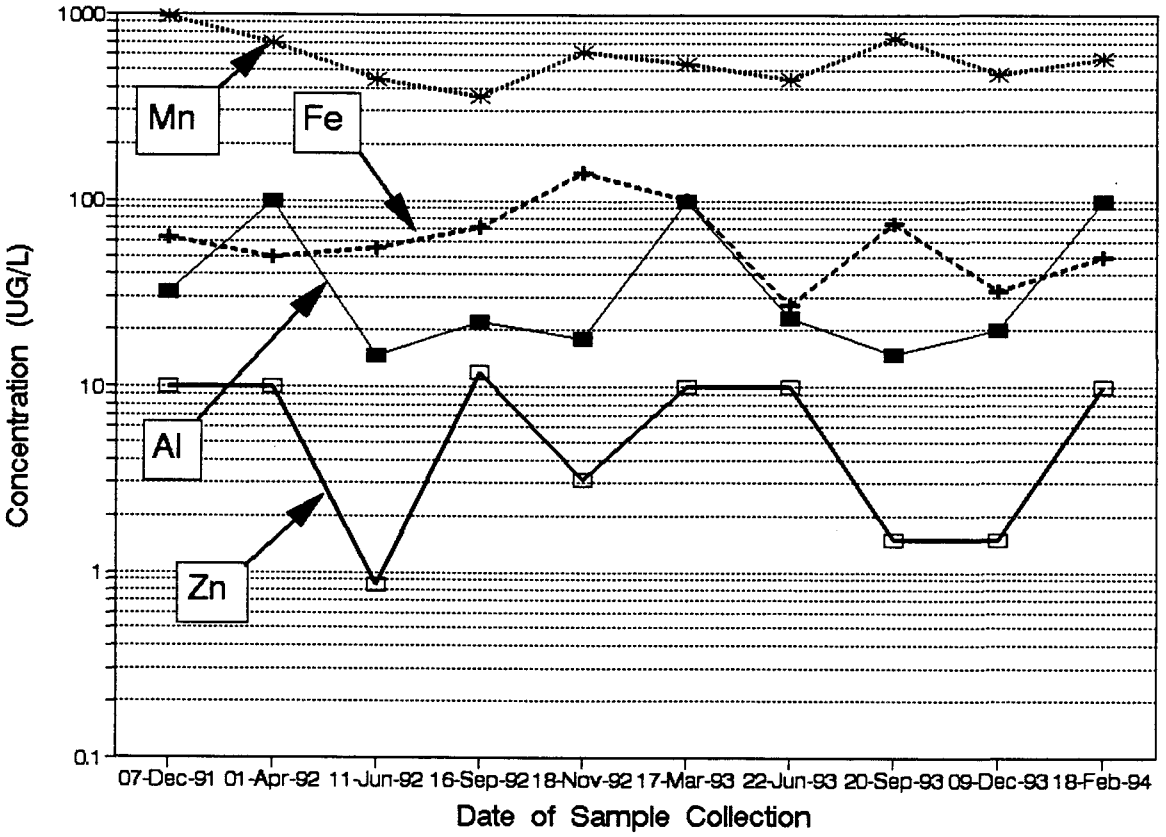

Well 0486 - Industrial Area flow path
Mn
Al
Fe
Zn
Concentration (UG/L)
10000
1000
100
10
1
06-Feb-90
19-Mar-90
08-Jun-90
05-Sep-90
14-Nov-90
14-Mar-91
20-Jun-91
12-Sep-91
14-Nov-91
01-Apr-92
11-Jun-92
15-Sep-92
18-Nov-92
Date of Sample Collection


Well 0486 - Industrial Area flow path
Sr
Ba
V
Se
Concentration (UG/L)
1000
100
10
1
0.1
06-Feb-90
19-Mar-90
08-Jun-90
05-Sep-90
14-Nov-90
14-Mar-91
20-Jun-91
12-Sep-91
14-Nov-91
01-Apr-92
11-Jun-92
15-Sep-92
18-Nov-92
Date of Sample Collection

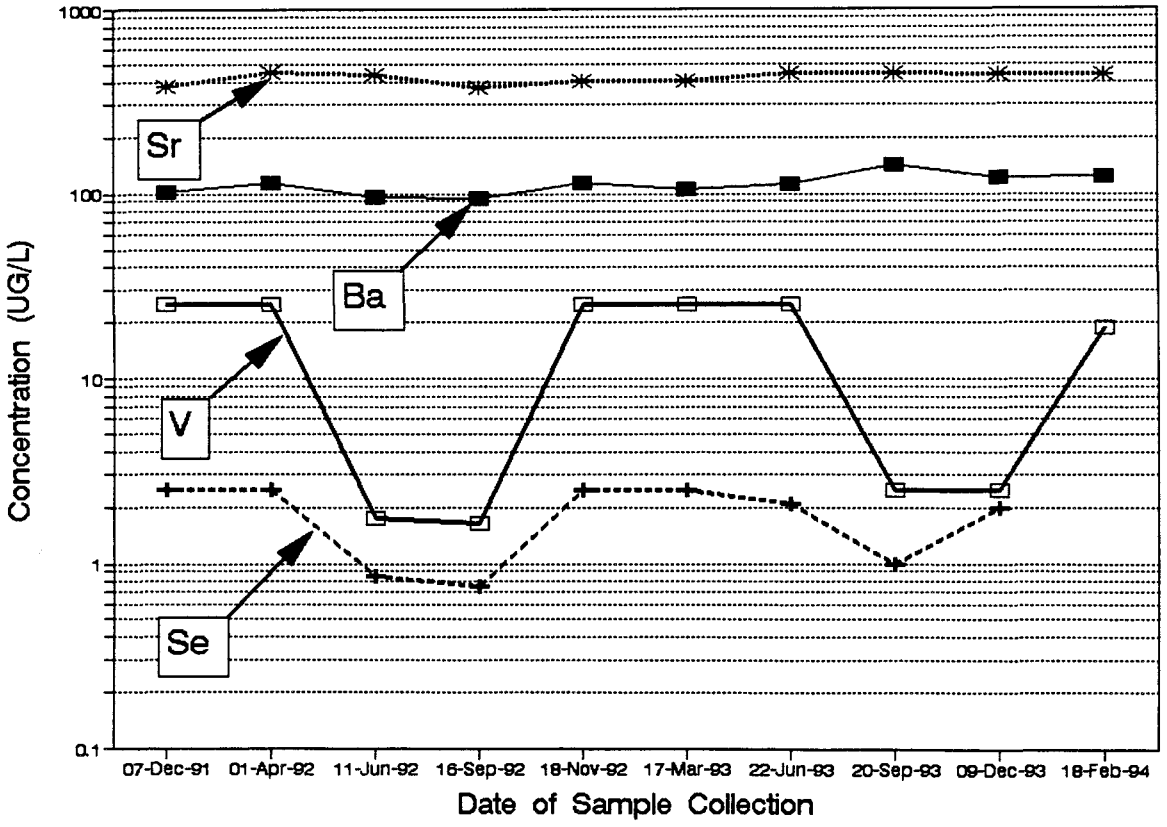

Well 0486 - Industrial Area flow path
Na
Ca
Mg
K
Concentration (UG/L)
100000
10000
1000
06-Feb-90
19-Mar-90
08-Jun-90
05-Sep-90
14-Nov-90
14-Mar-91
20-Jun-91
12-Sep-91
14-Nov-91
01-Apr-92
11-Jun-92
15-Sep-92
18-Nov-92
Date of Sample Collection

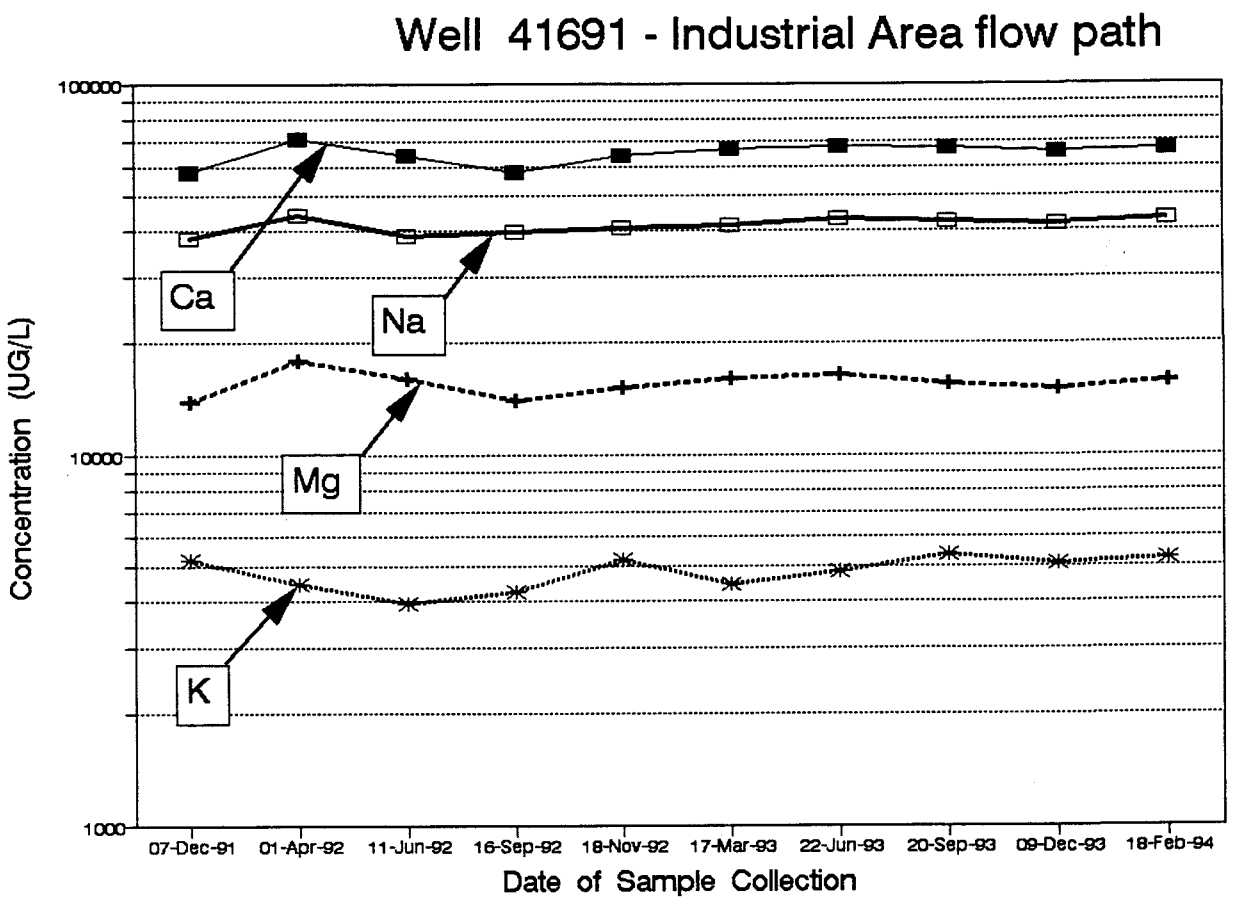

Well 0486 - Industrial Area flow path
TDS
HCO3 (as CaCO3
SO4
Cl
SiO2
NO3
Concentration (UG/L)
1000000
100000
10000
1000
100
10
06-Feb-90
19-Mar-90
08-Jun-90
05-Sep-90
14-Nov-90
14-Mar-91
20-Jun-91
12-Sep-91
14-Nov-91
01-Apr-92
11-Jun-92
15-Sep-92
18-Nov-92
Date of Sample Collection

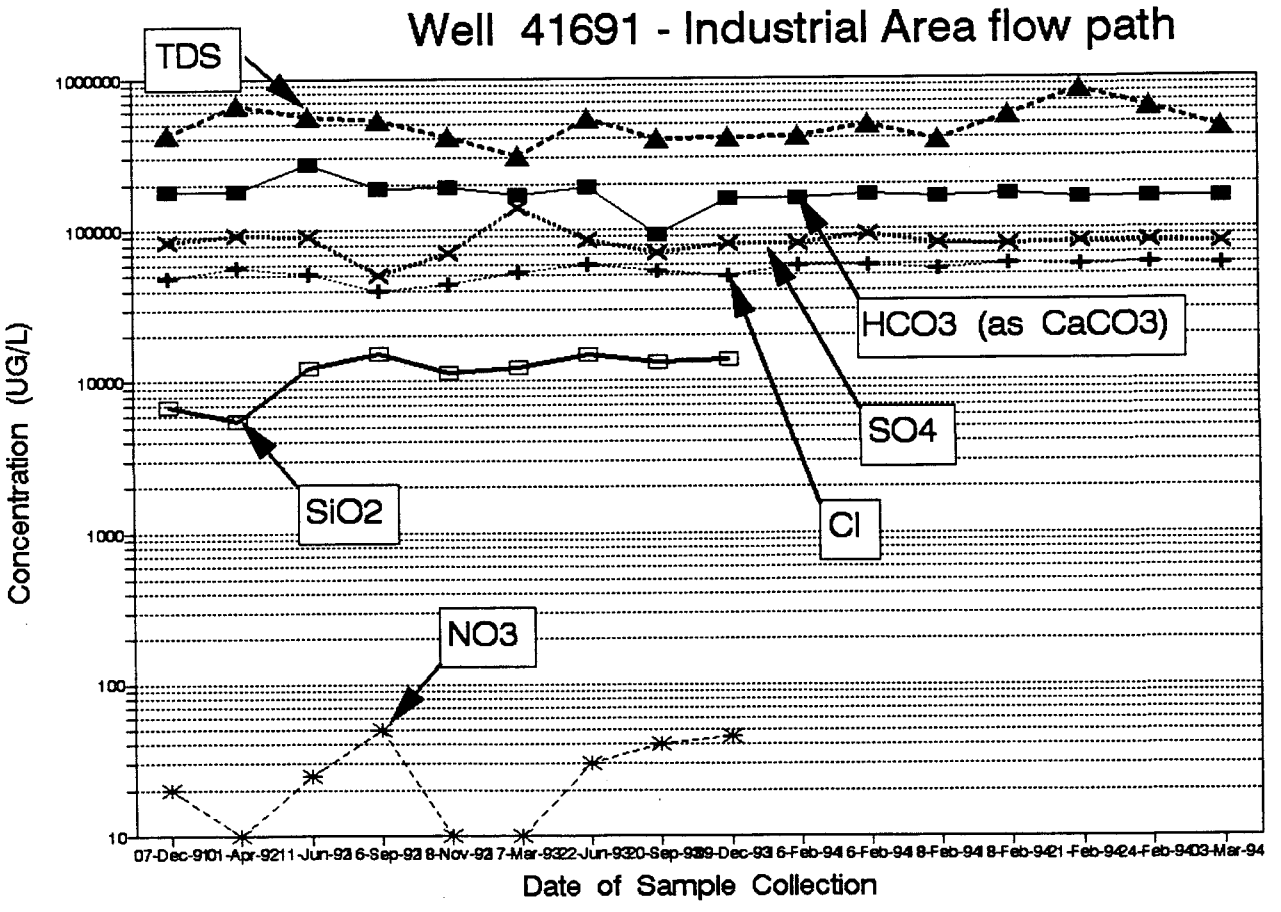
Well 41691 - Industrial Area flow path



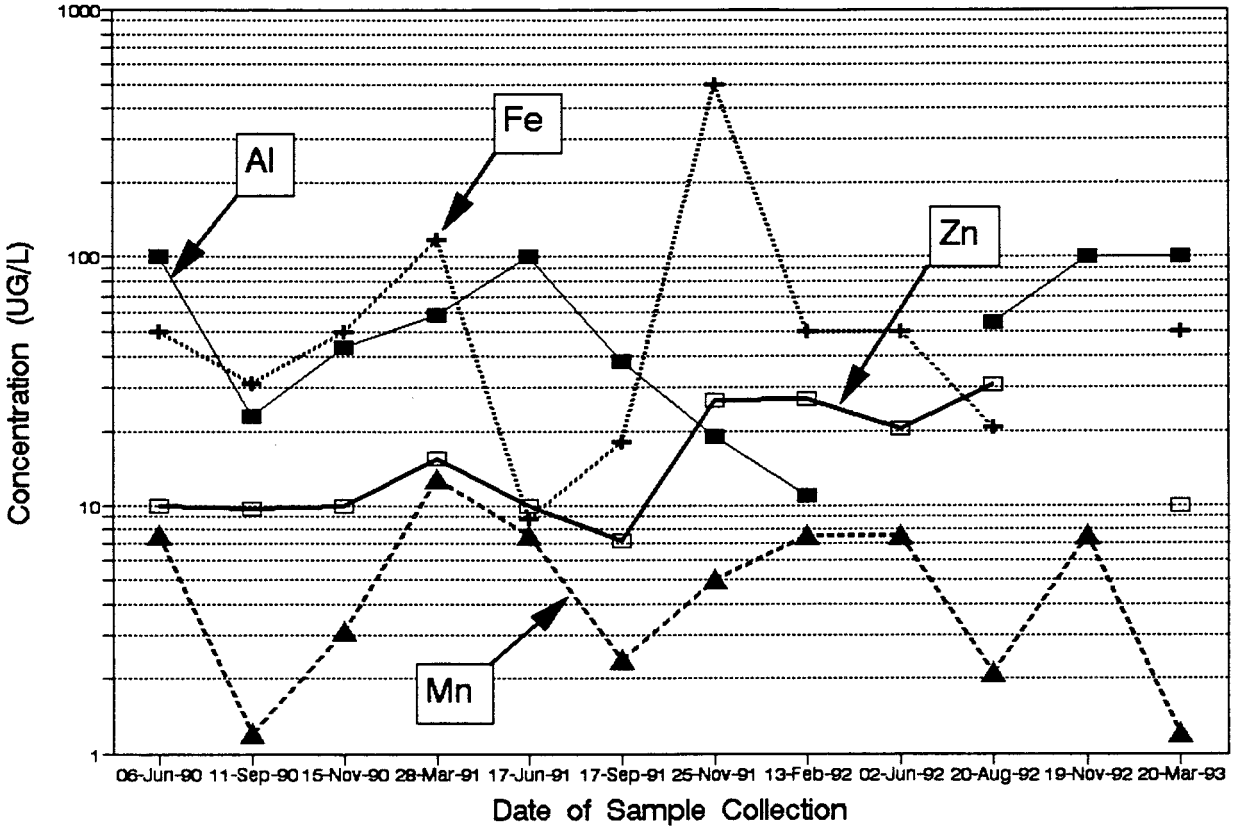
Well 41691 - Industrial Area flow path



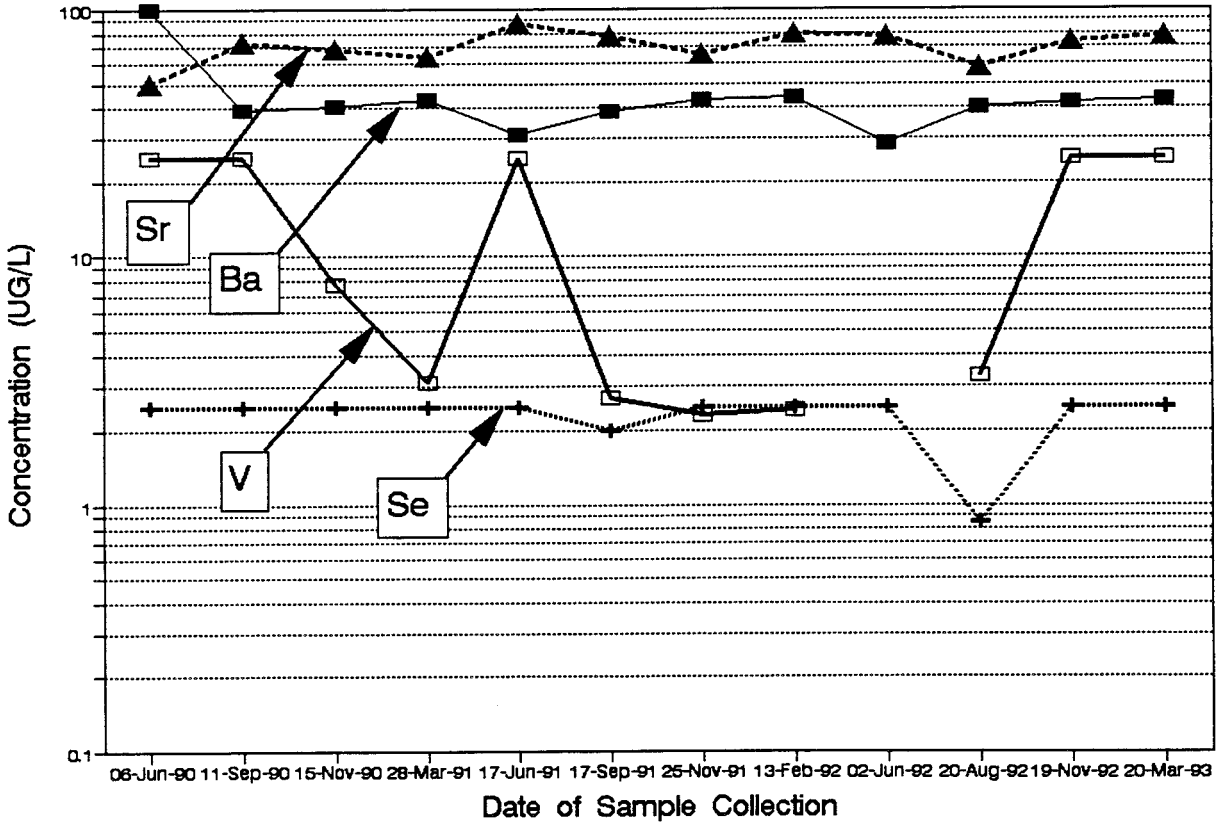

Well 41691 - Industrial Area flow path
Concentration (UG/L)
100000
10000
1000
Ca
Na
Mg
K
07-Dec-91
01-Apr-92
11-Jun-92
16-Sep-92
18-Nov-92
17-Mar-93
22-Jun-93
20-Sep-93
09-Dec-93
18-Feb-94
Date of Sample Collection


Well 41691 - Industrial Area flow path
Concentration (UG/L)
1000000
100000
10000
1000
100
10
TDS
HCO3 (as CaCO3)
SO4
Cl
SiO2
NO3
Date of Sample Collection

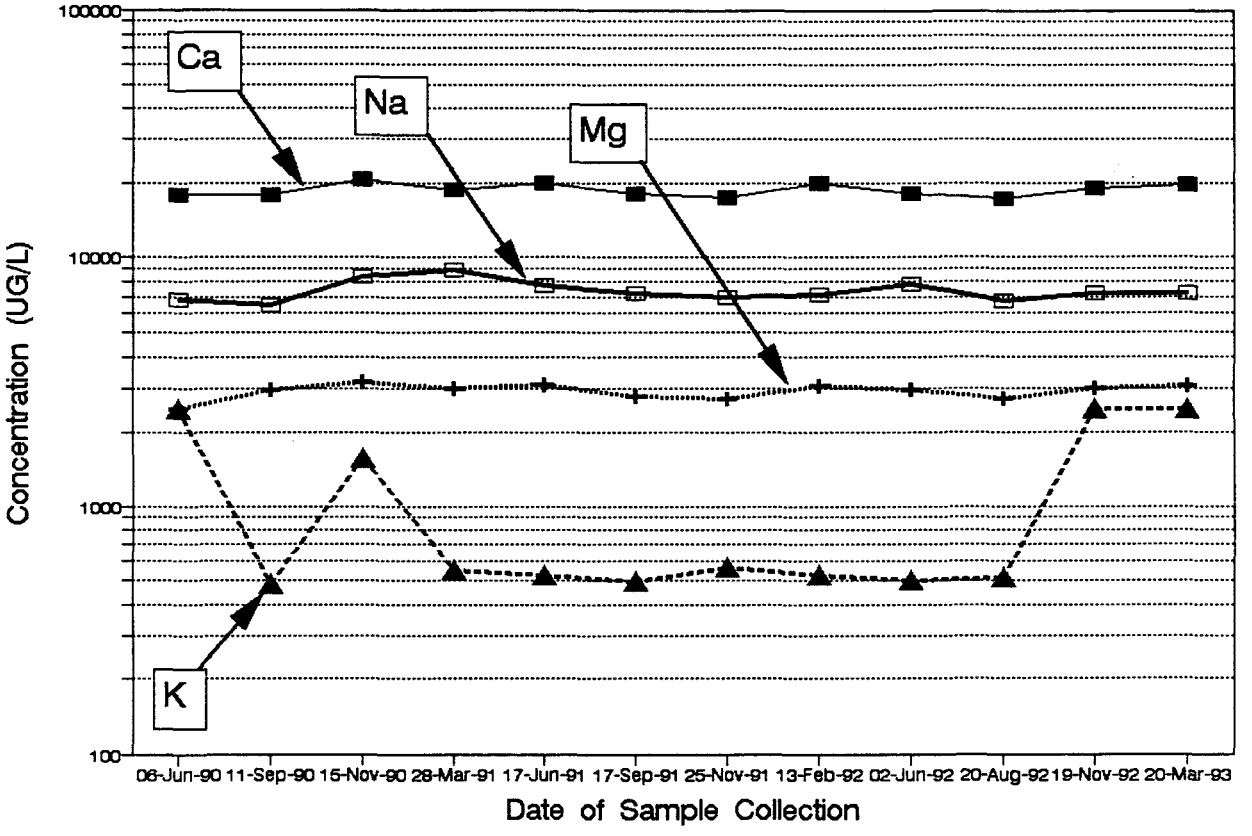
Well B400189 - Woman Creek flow path



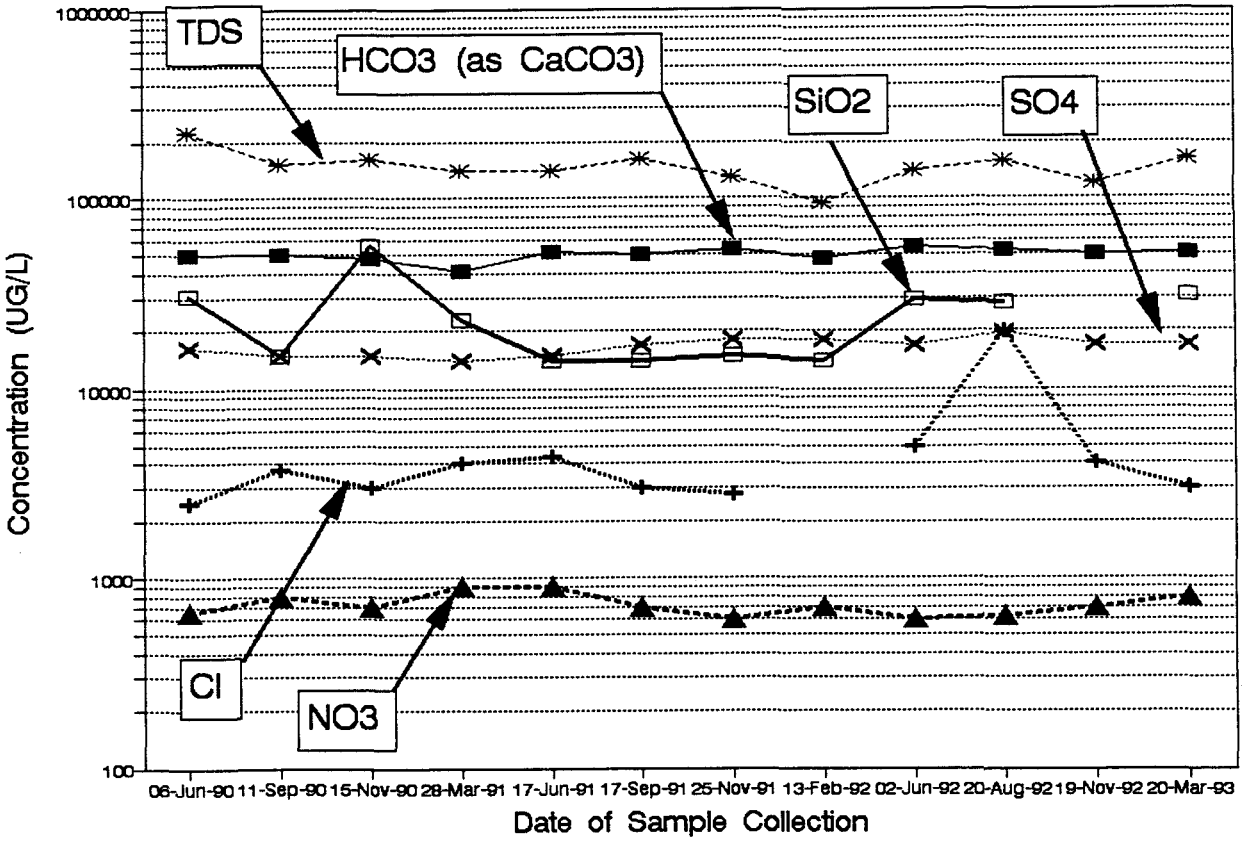
Well B400189 - Woman Creek flow path



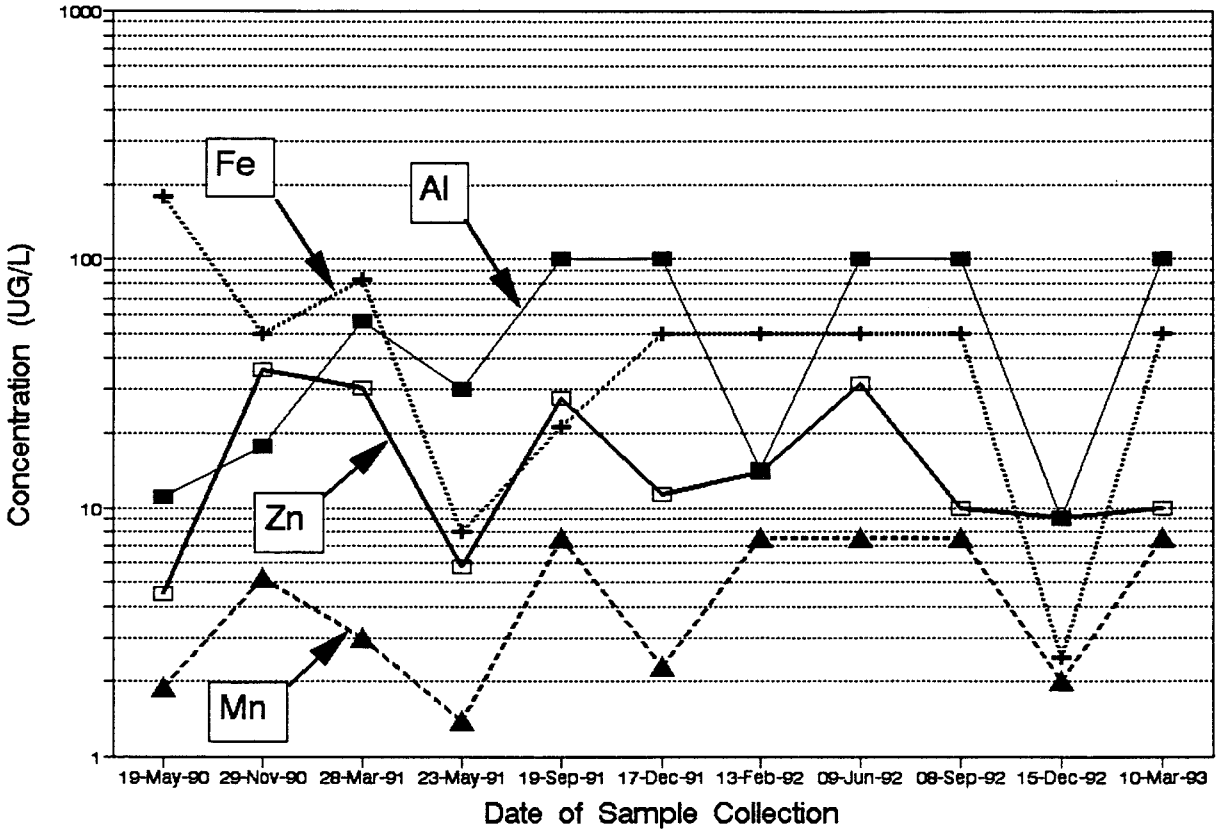
Well B400189 - Woman Creek flow path



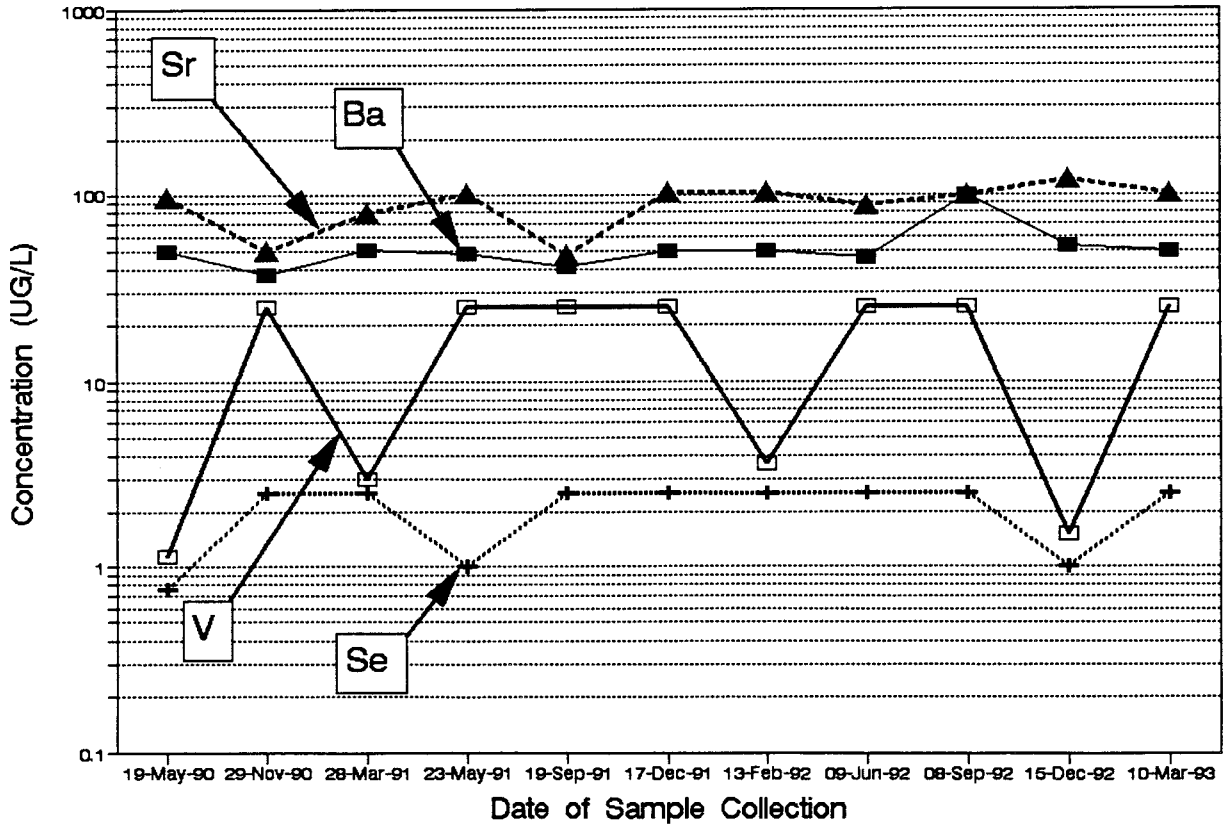
Well B400189 - Woman Creek flow path



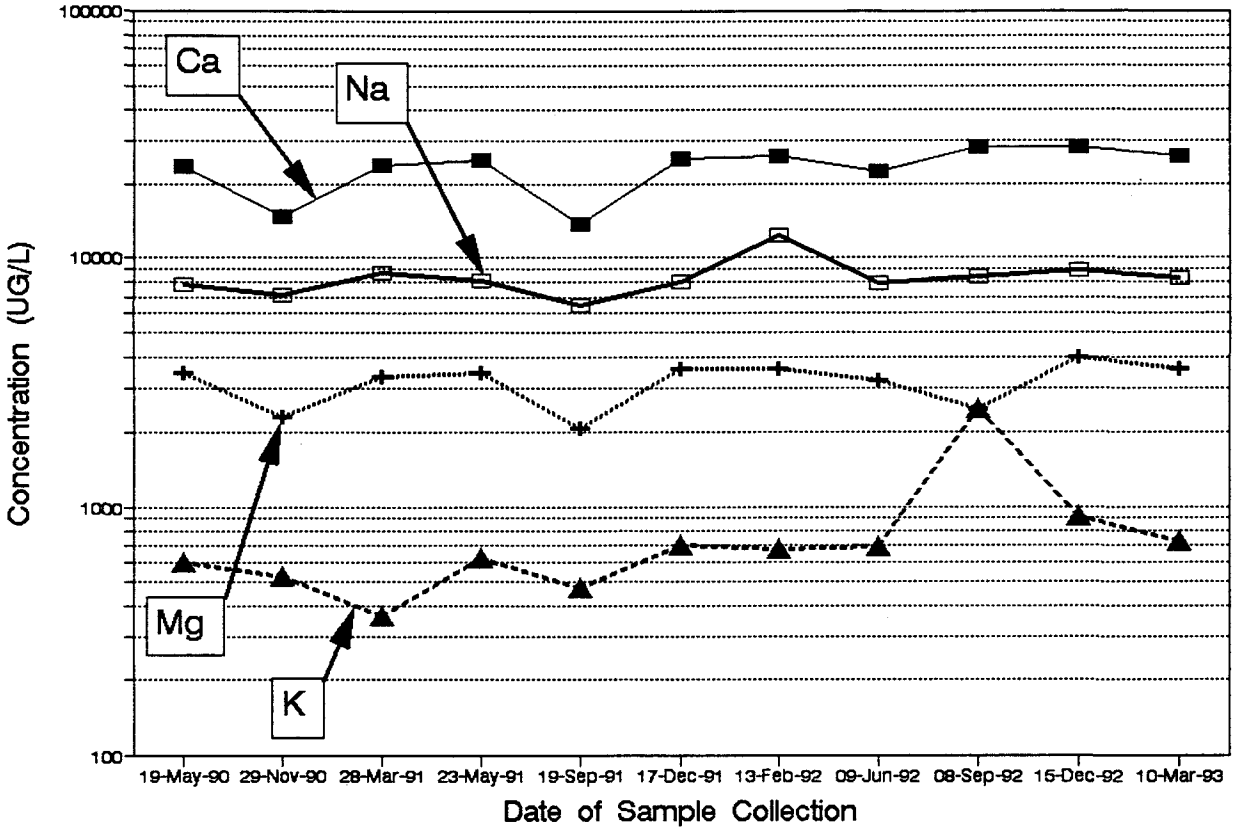
Well B400289 - Woman Creek flow path



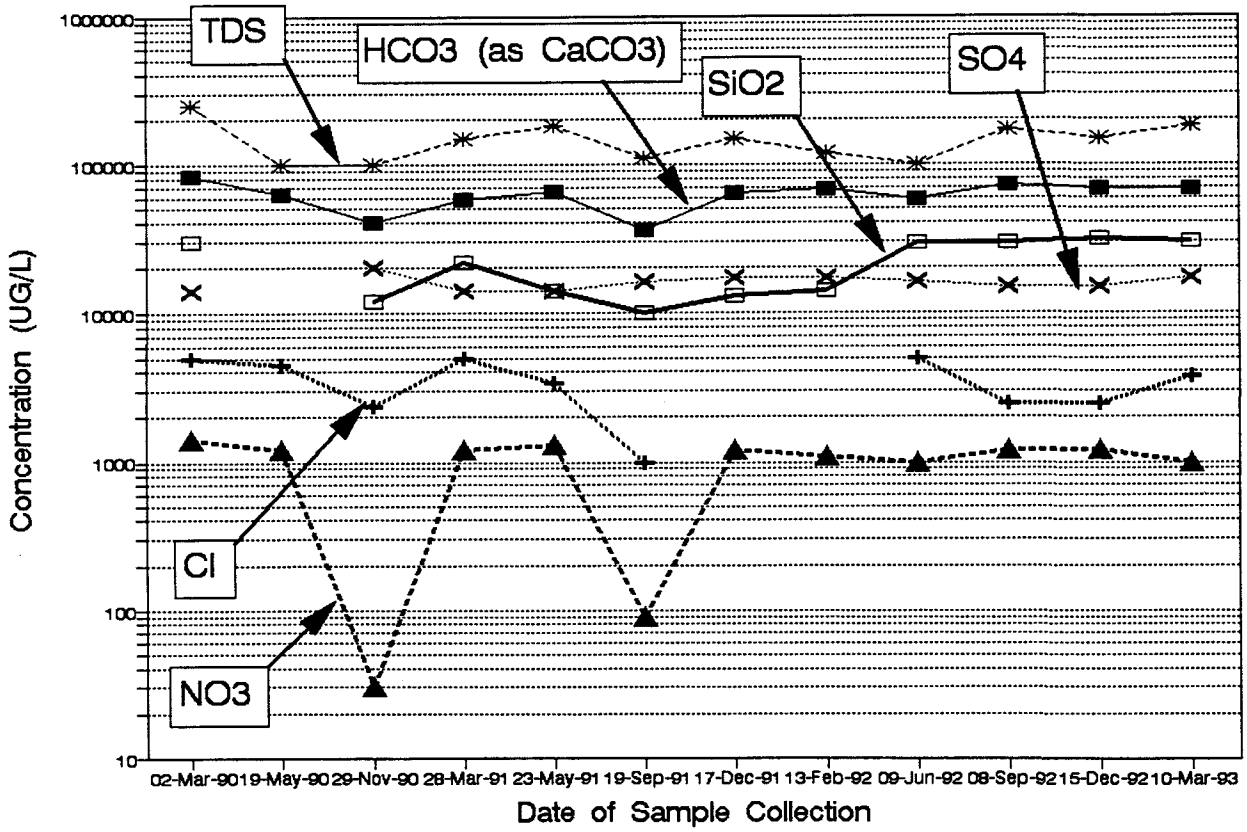
Well B400289 - Woman Creek flow path



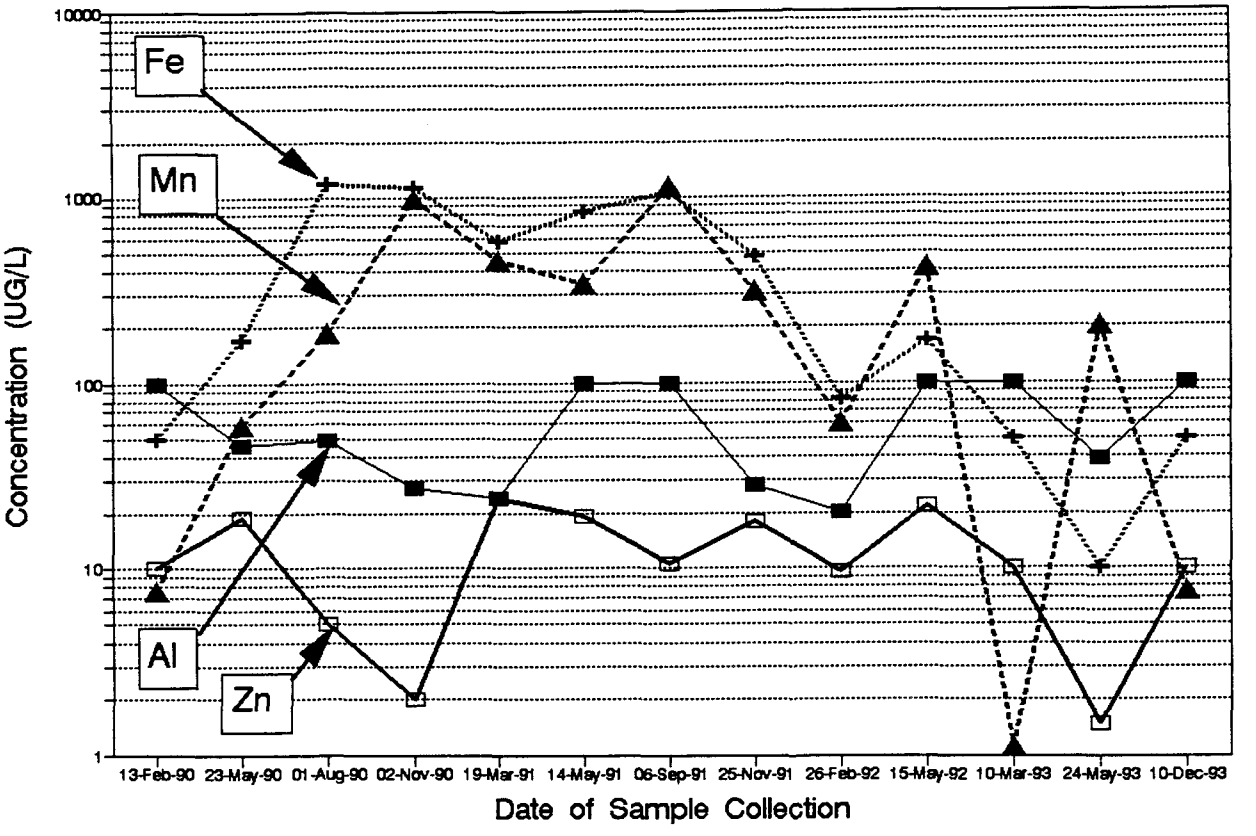
Well B400289 - Woman Creek flow path



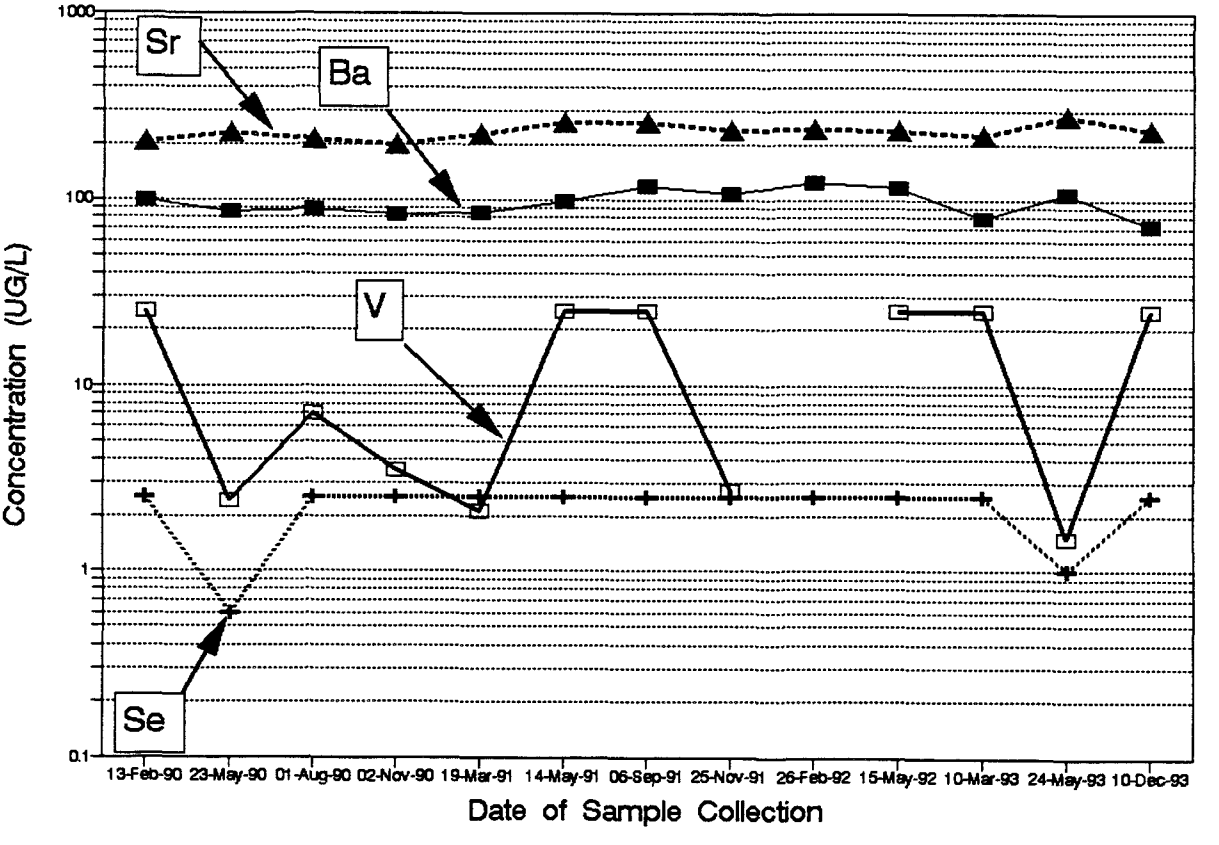
Well B400289 - Woman Creek flow path



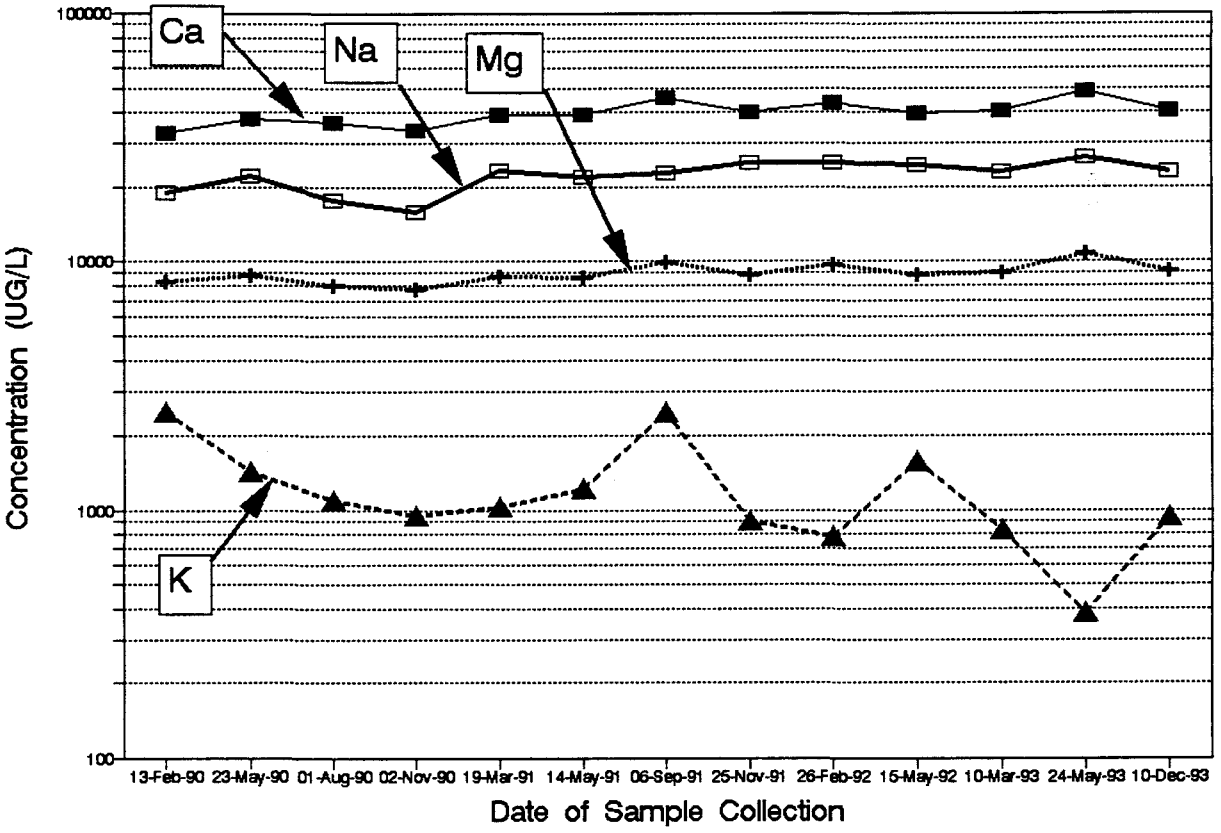
Well 6886 - Woman Creek flow path



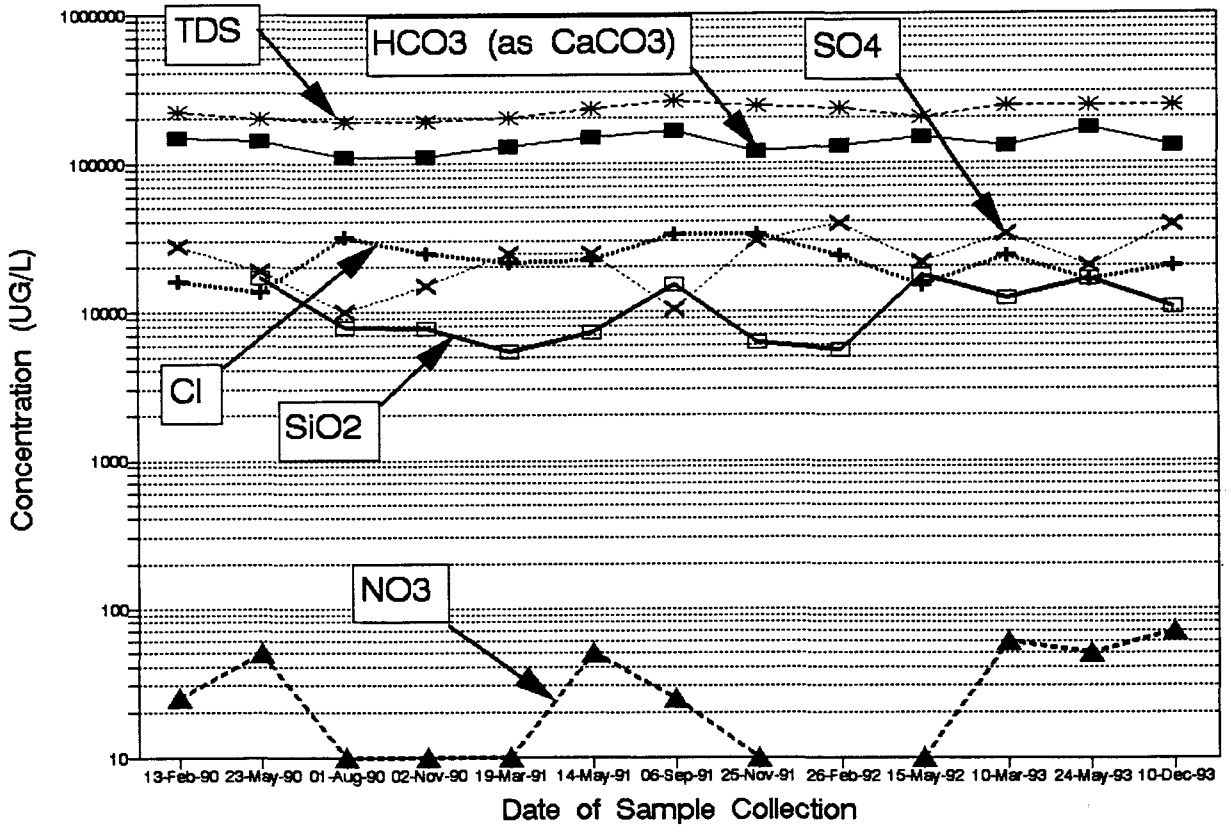
Well 6886 - Woman Creek flow path



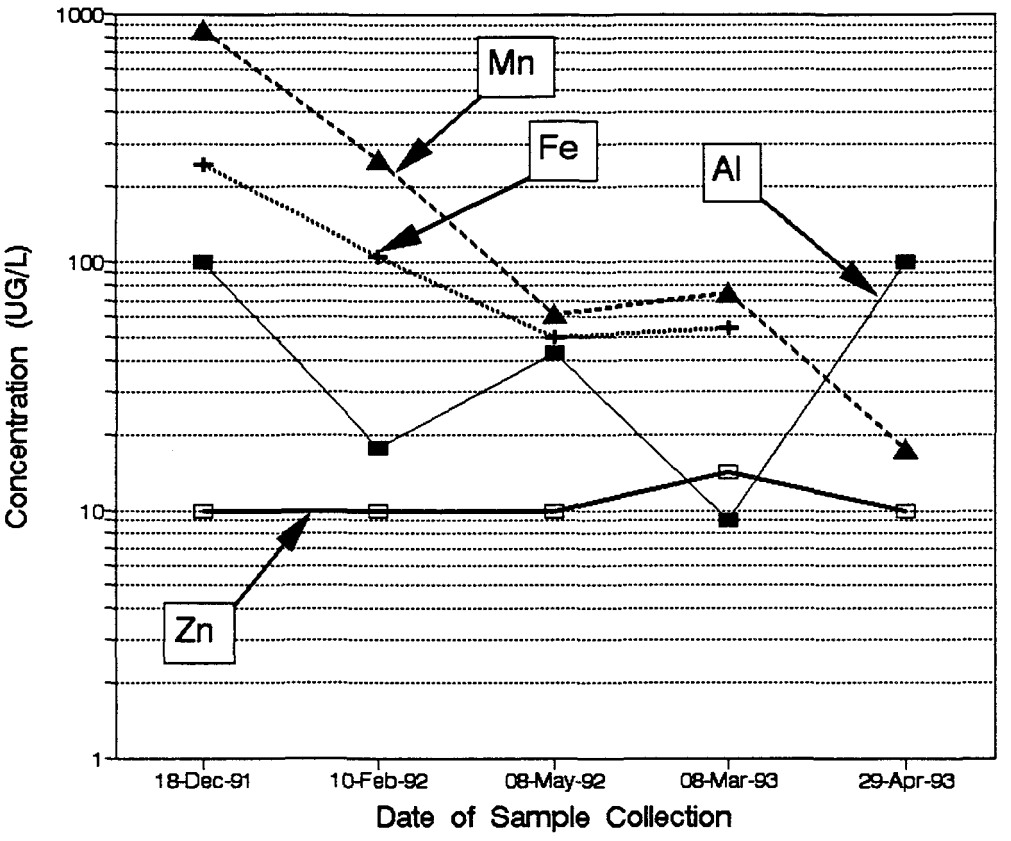
Well 6886 - Woman Creek flow path



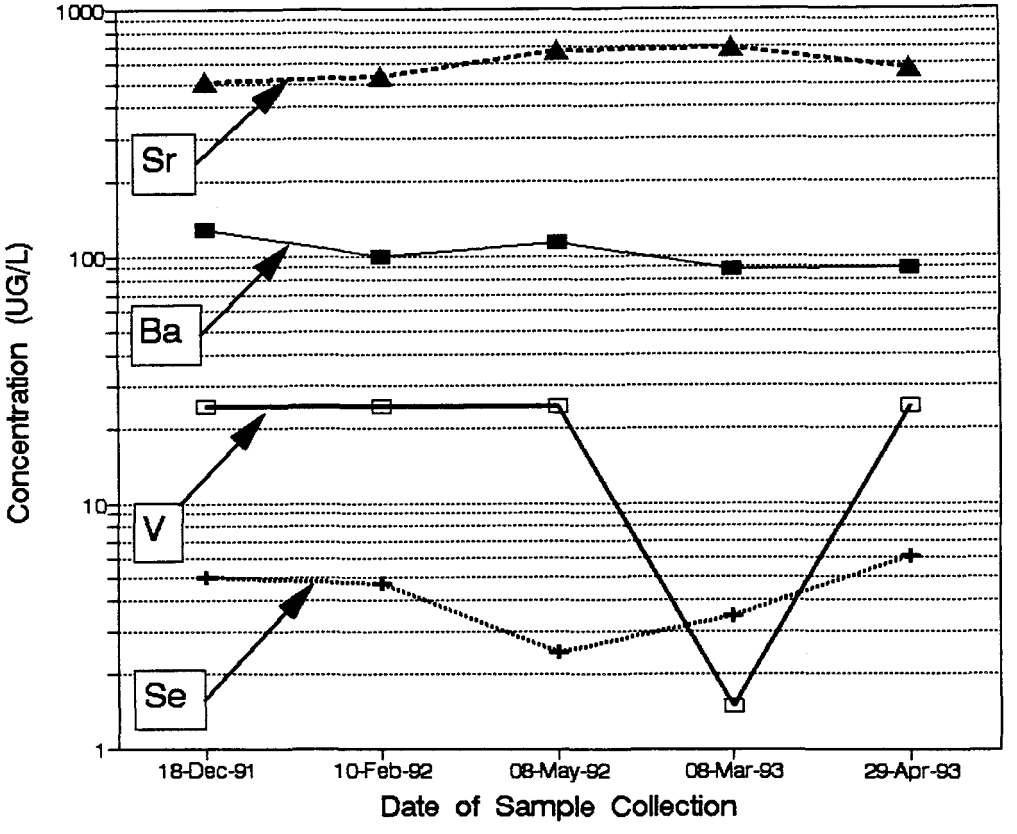
Well 6886 - Woman Creek flow path



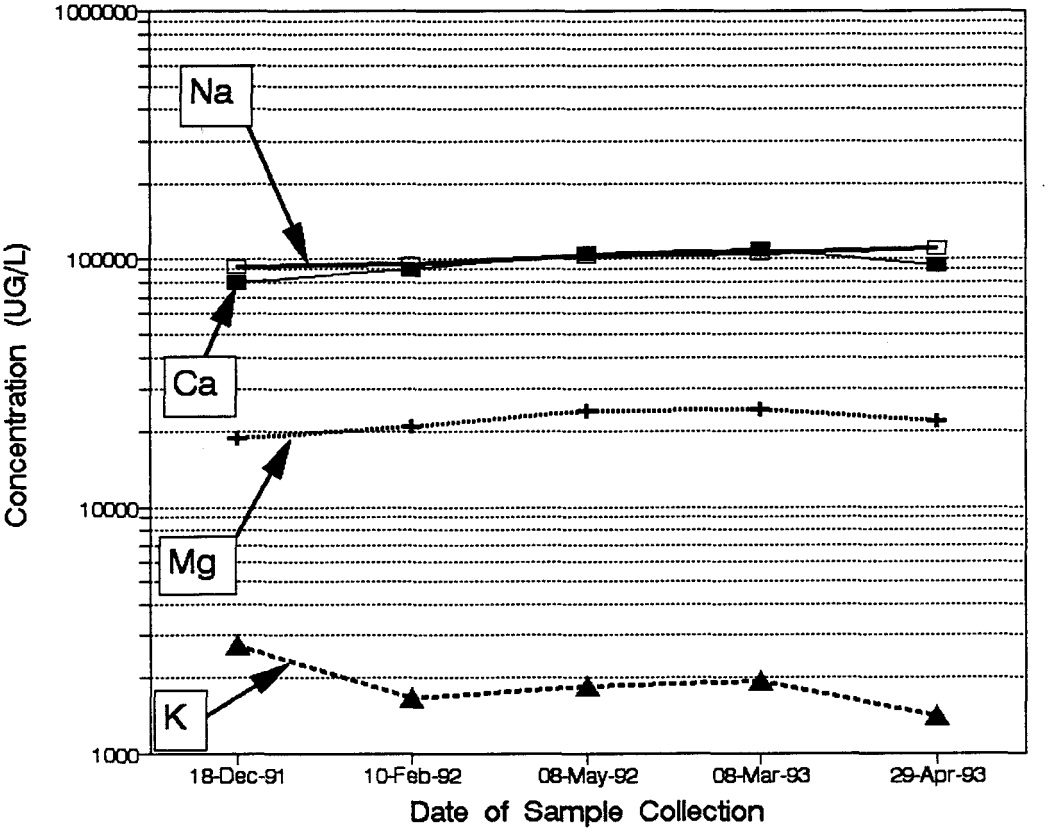
Well 38591 - Woman Creek flow path



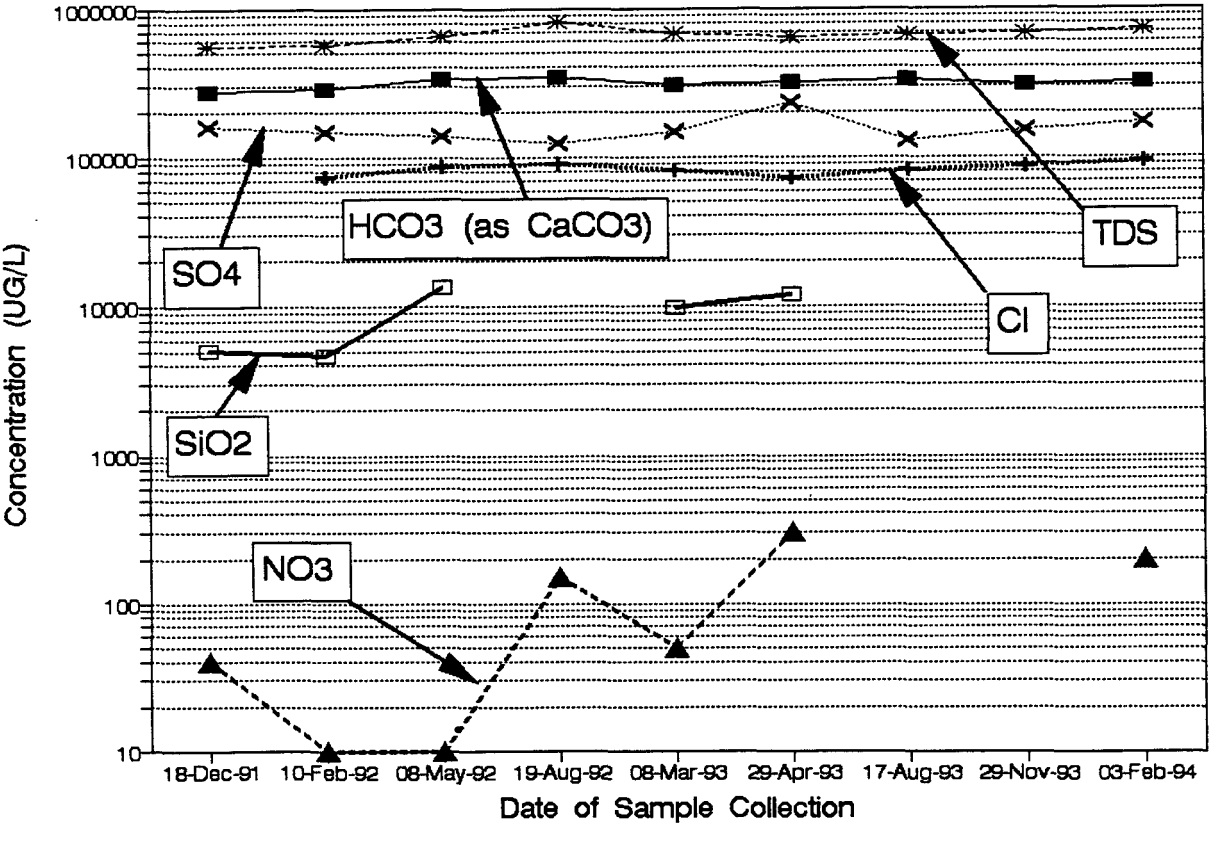
Well 38591 - Woman Creek flow path



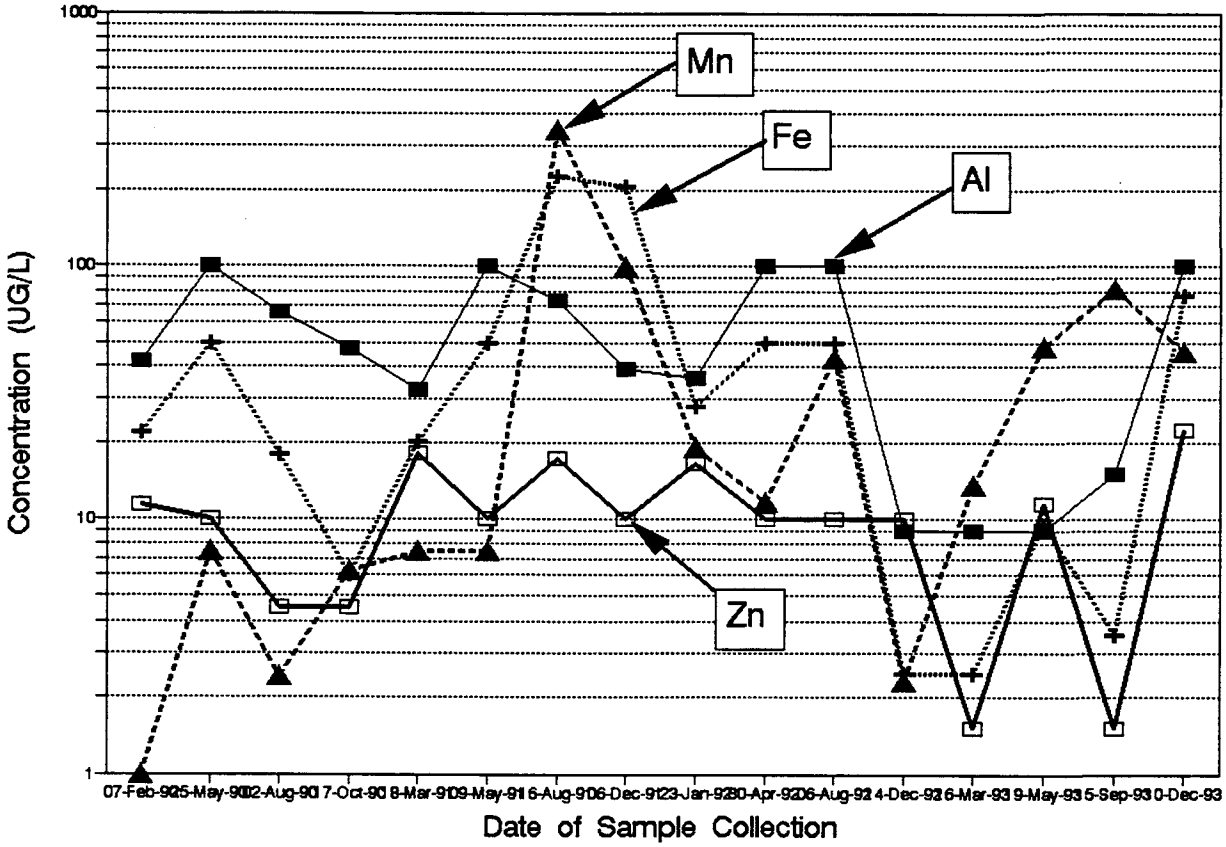
Well 38591 - Woman Creek flow path



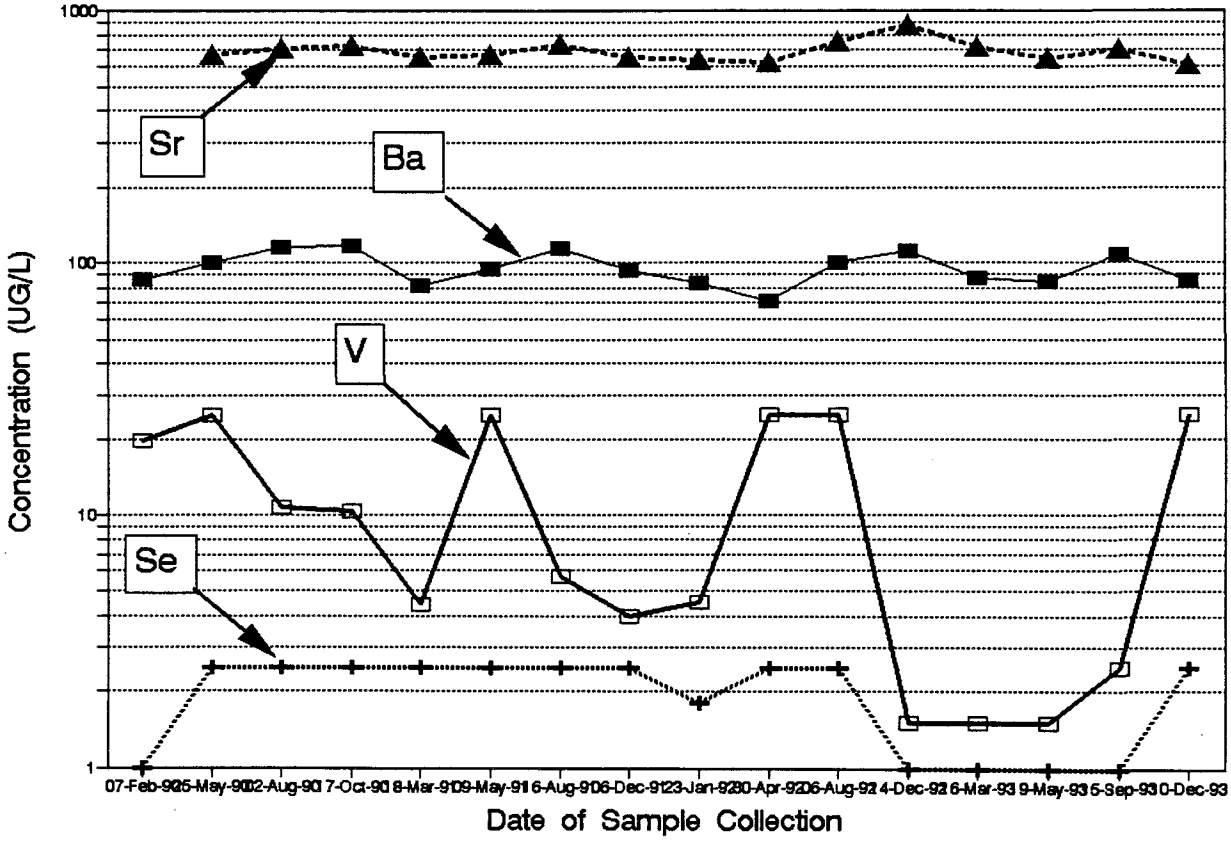
Well 38591 - Woman Creek flow path

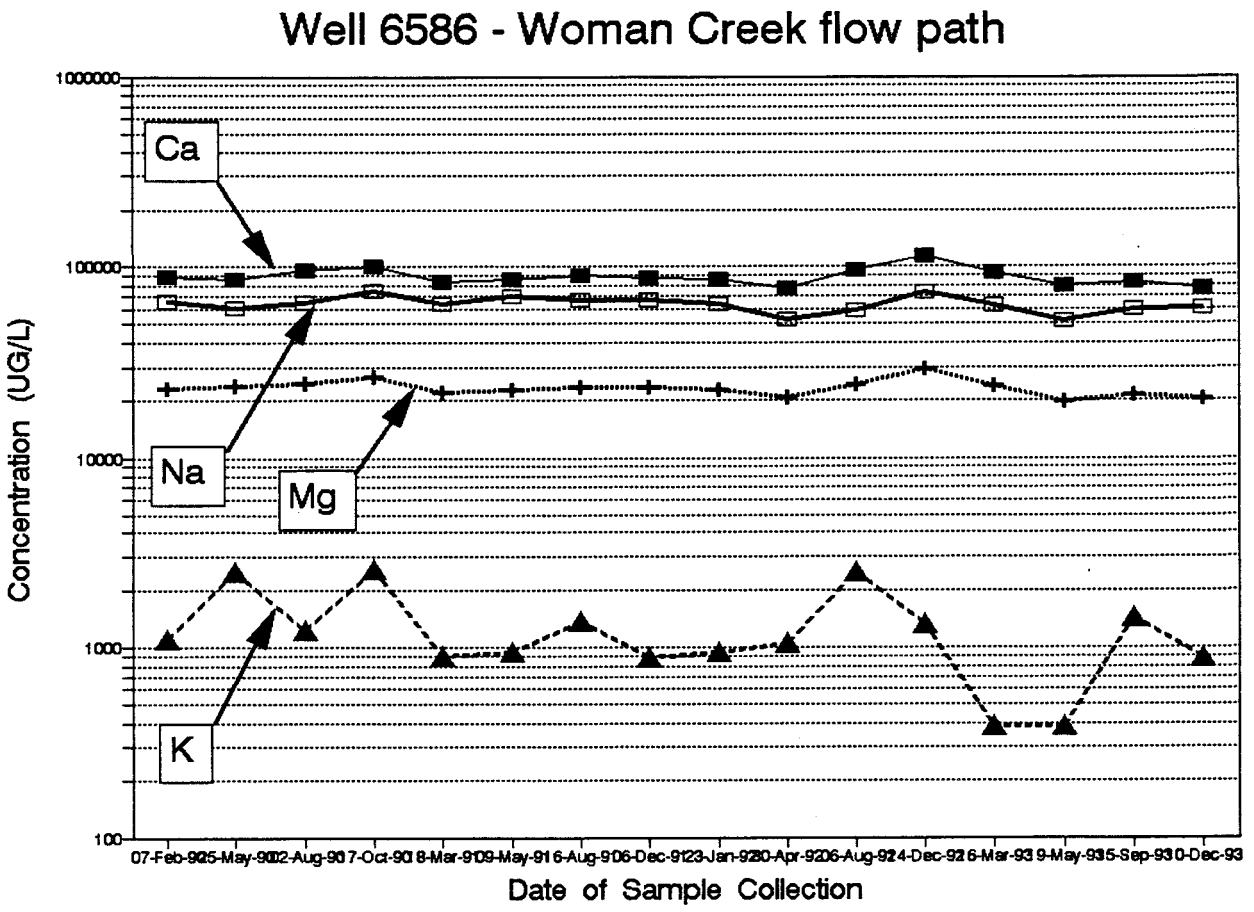


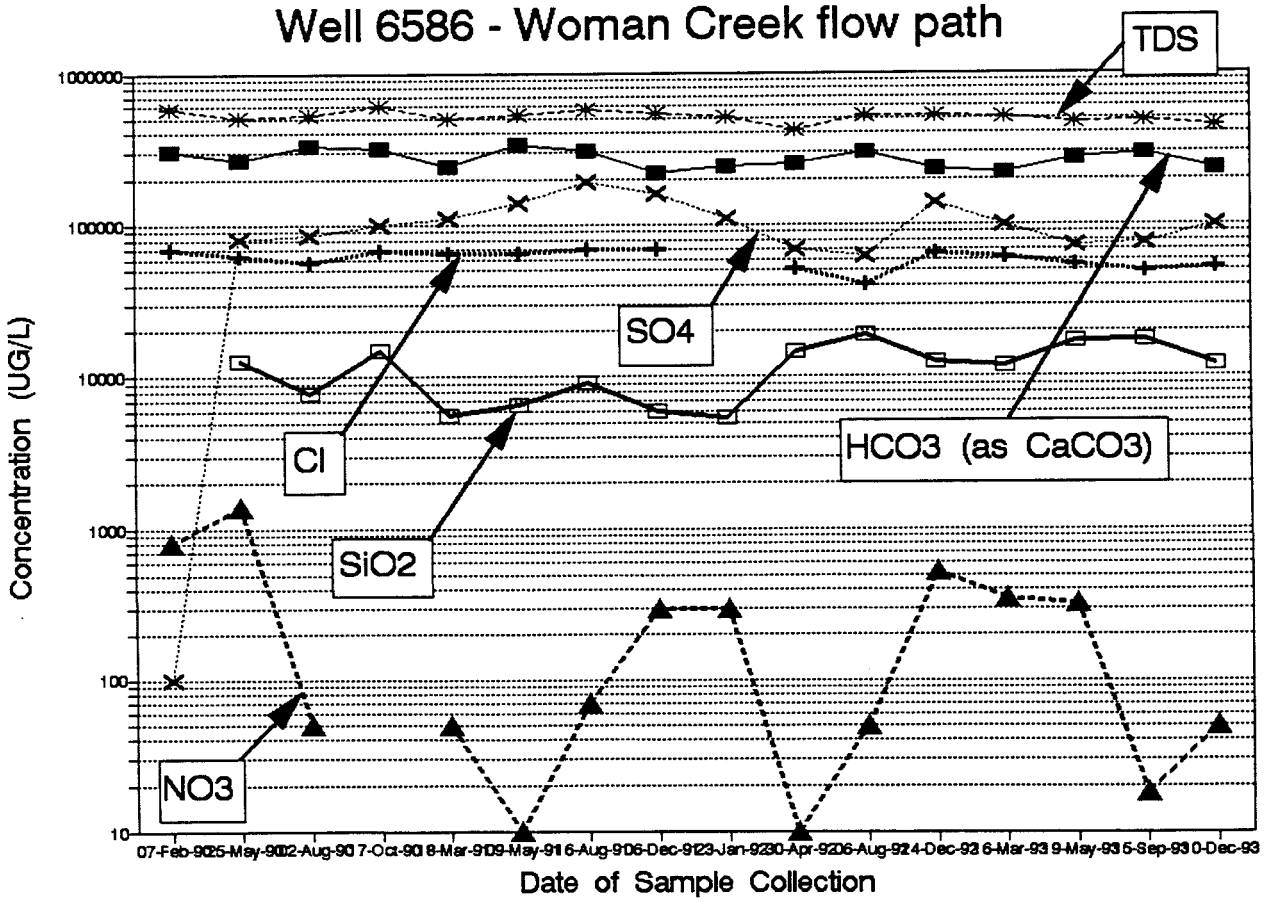
Well 6586 - Woman Creek flow path



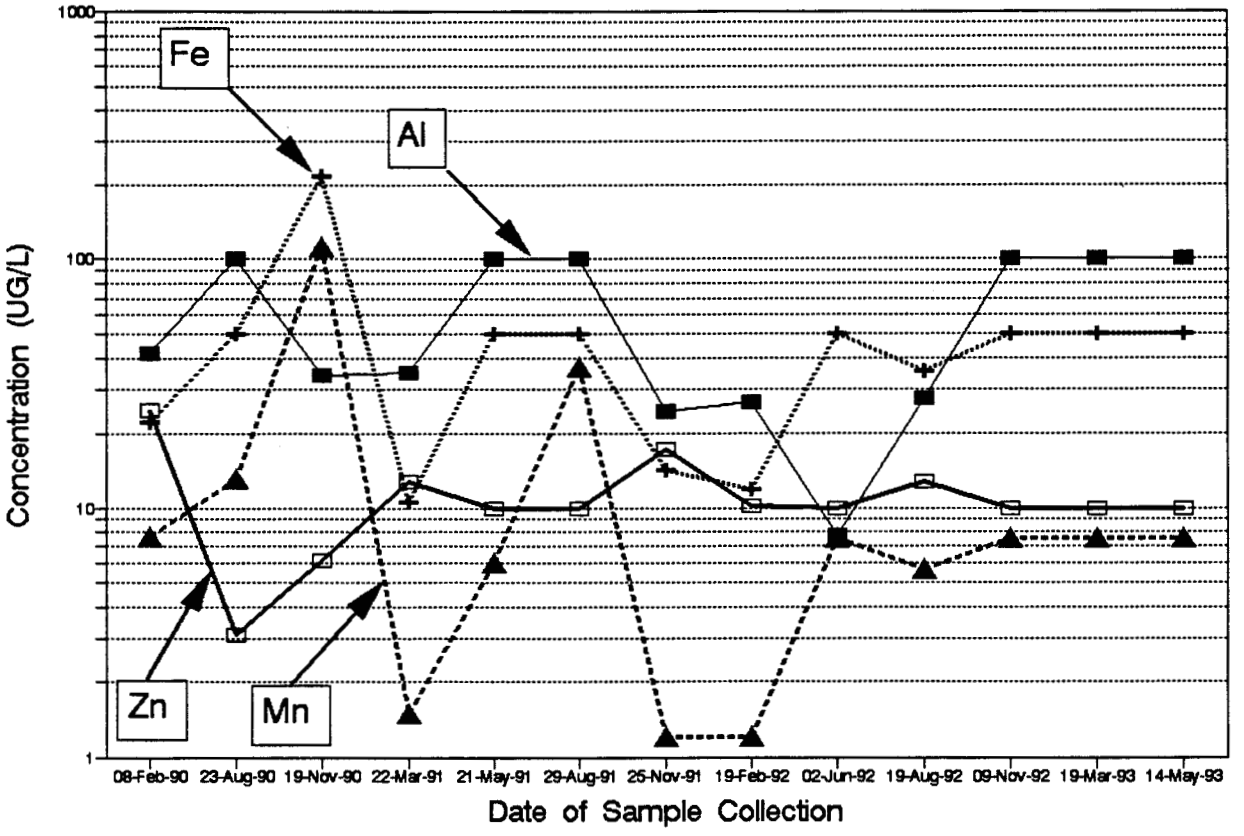
Well 6586 - Woman Creek flow path



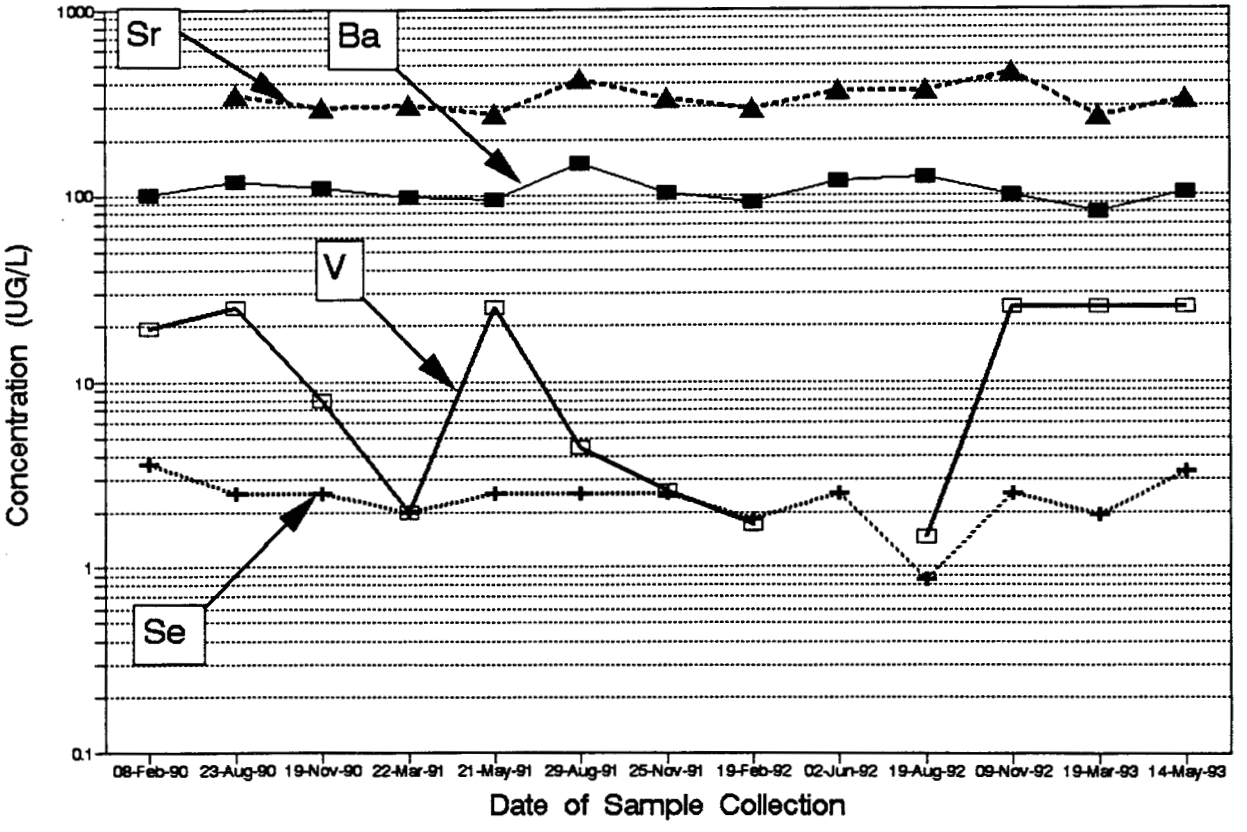

Well 6586 - Woman Creek flow path
Ca
Na
Mg
K
Concentration (UG/L)
1000000
100000
10000
1000
100
07-Feb-90
25-May-90
02-Aug-90
7-Oct-90
8-Mar-91
09-May-91
6-Aug-91
06-Dec-91
23-Jan-92
30-Apr-92
06-Aug-92
4-Dec-92
6-Mar-93
9-May-93
5-Sep-93
0-Dec-93
Date of Sample Collection


Well 6586 - Woman Creek flow path
TDS
SO4
Cl
HCO3 (as CaCO3)
SiO2
NO3
Concentration (UG/L)
1000000
100000
10000
1000
100
10
07-Feb-90
25-May-90
02-Aug-90
7-Oct-90
8-Mar-91
09-May-91
6-Aug-91
06-Dec-91
23-Jan-92
30-Apr-92
06-Aug-92
4-Dec-92
6-Mar-93
9-May-93
5-Sep-93
0-Dec-93
Date of Sample Collection

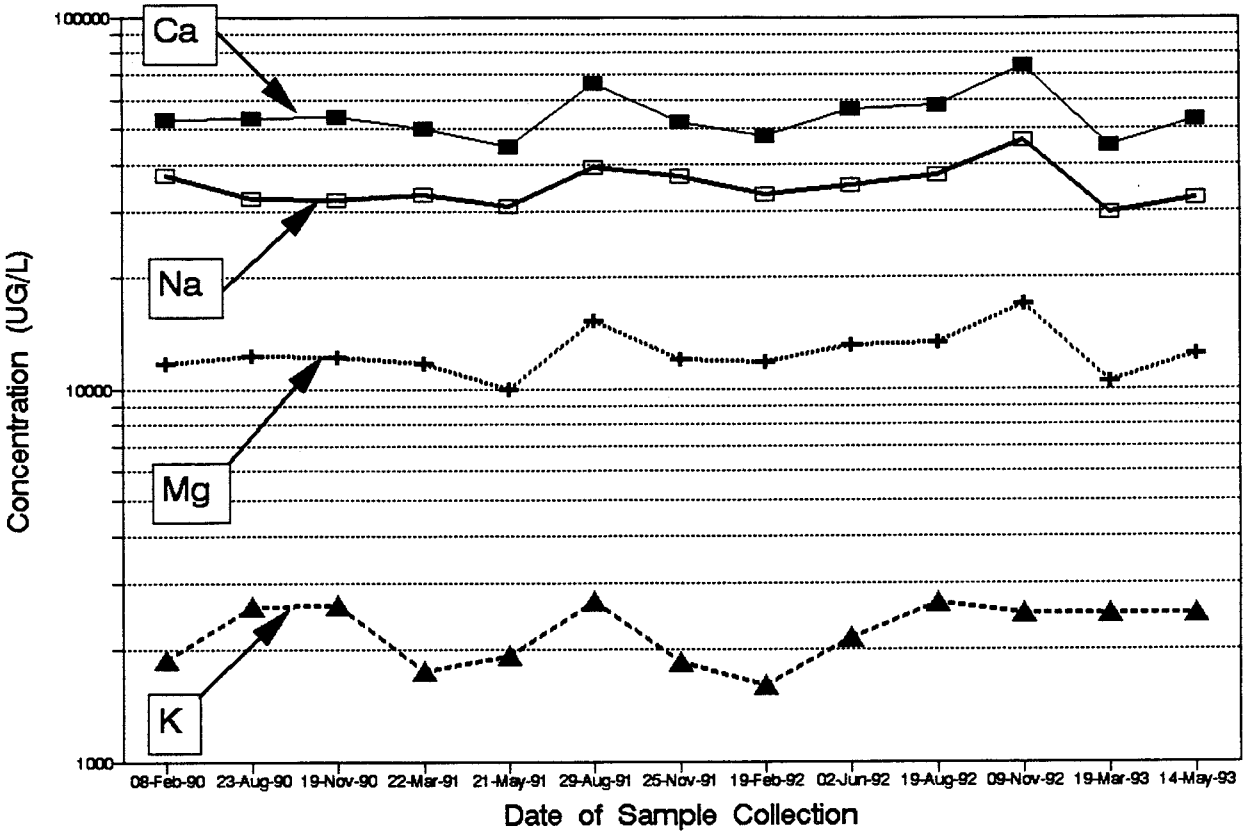
Well 6686 - Woman Creek flow path



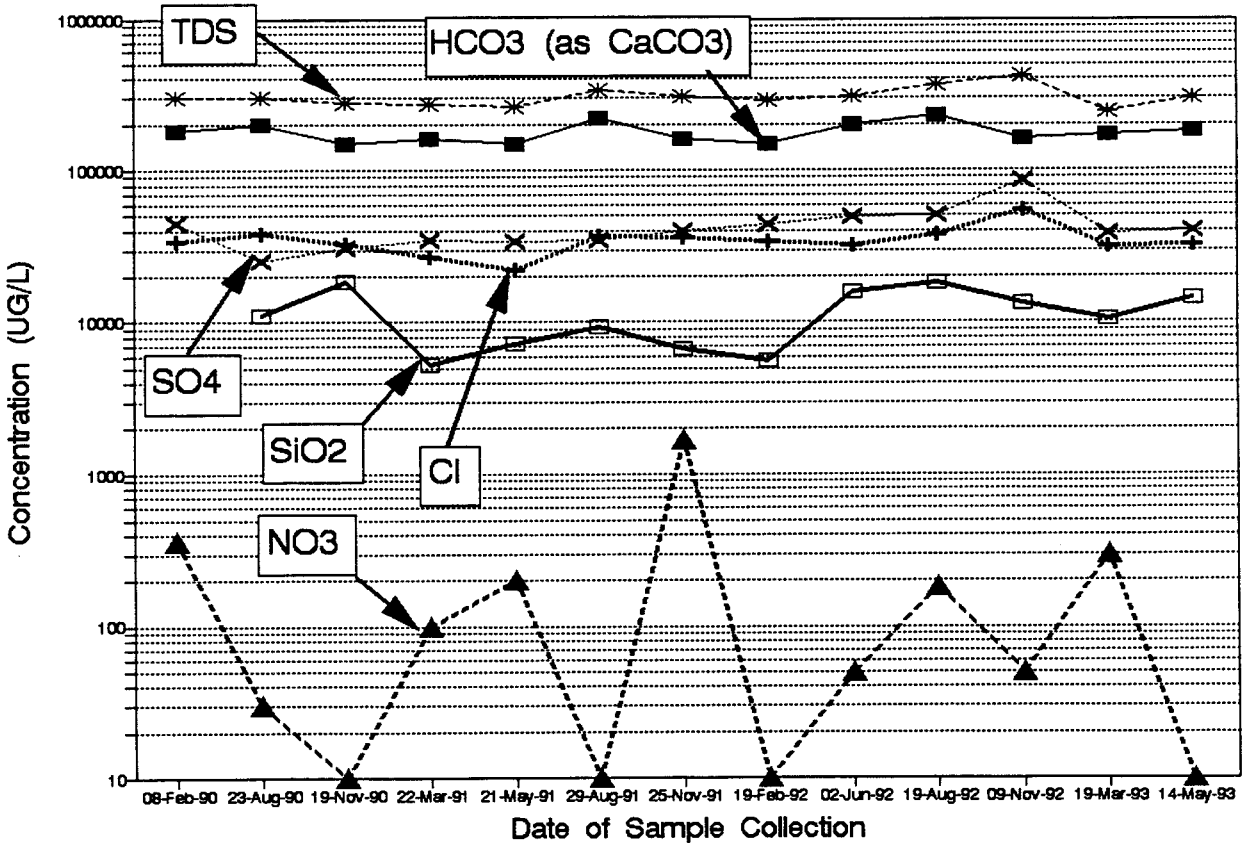
Well 6686 - Woman Creek flow path

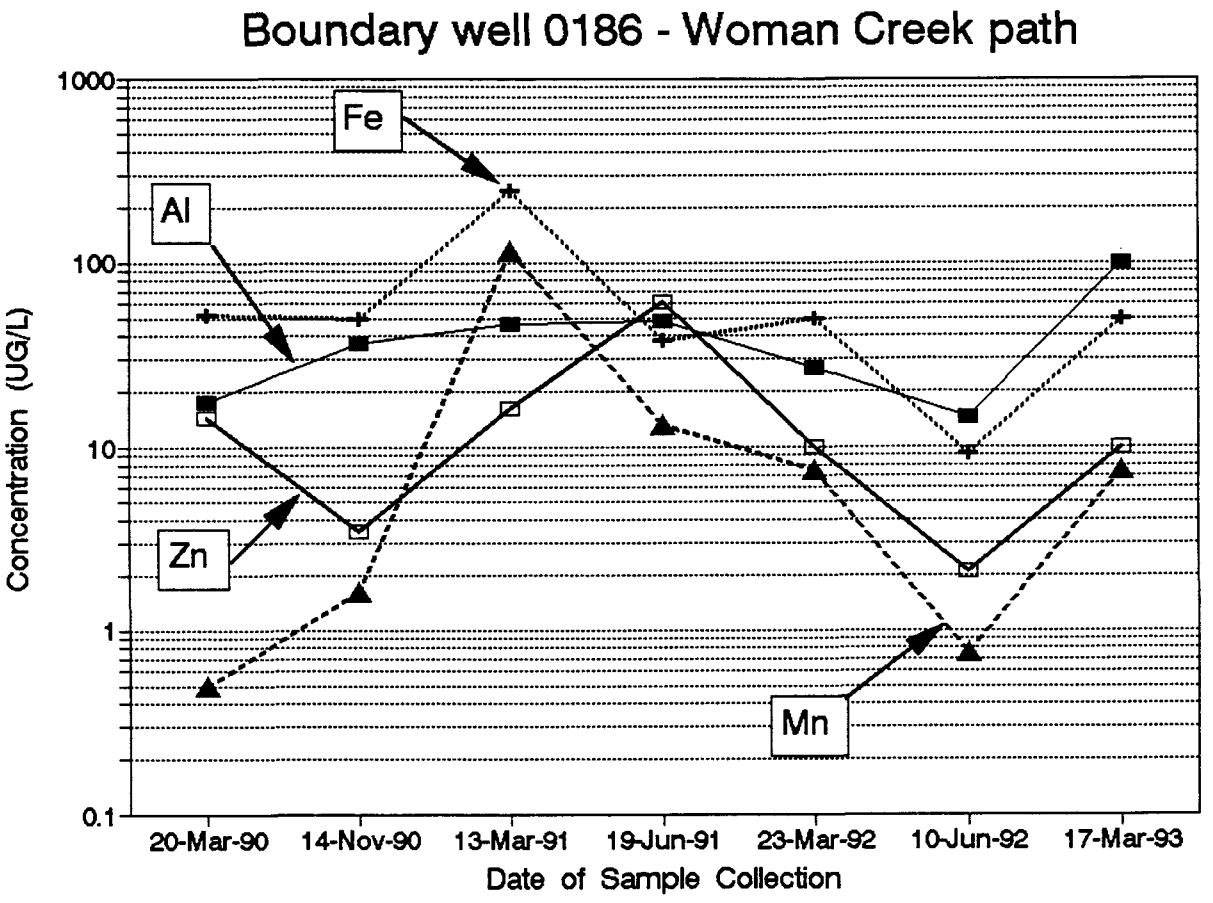


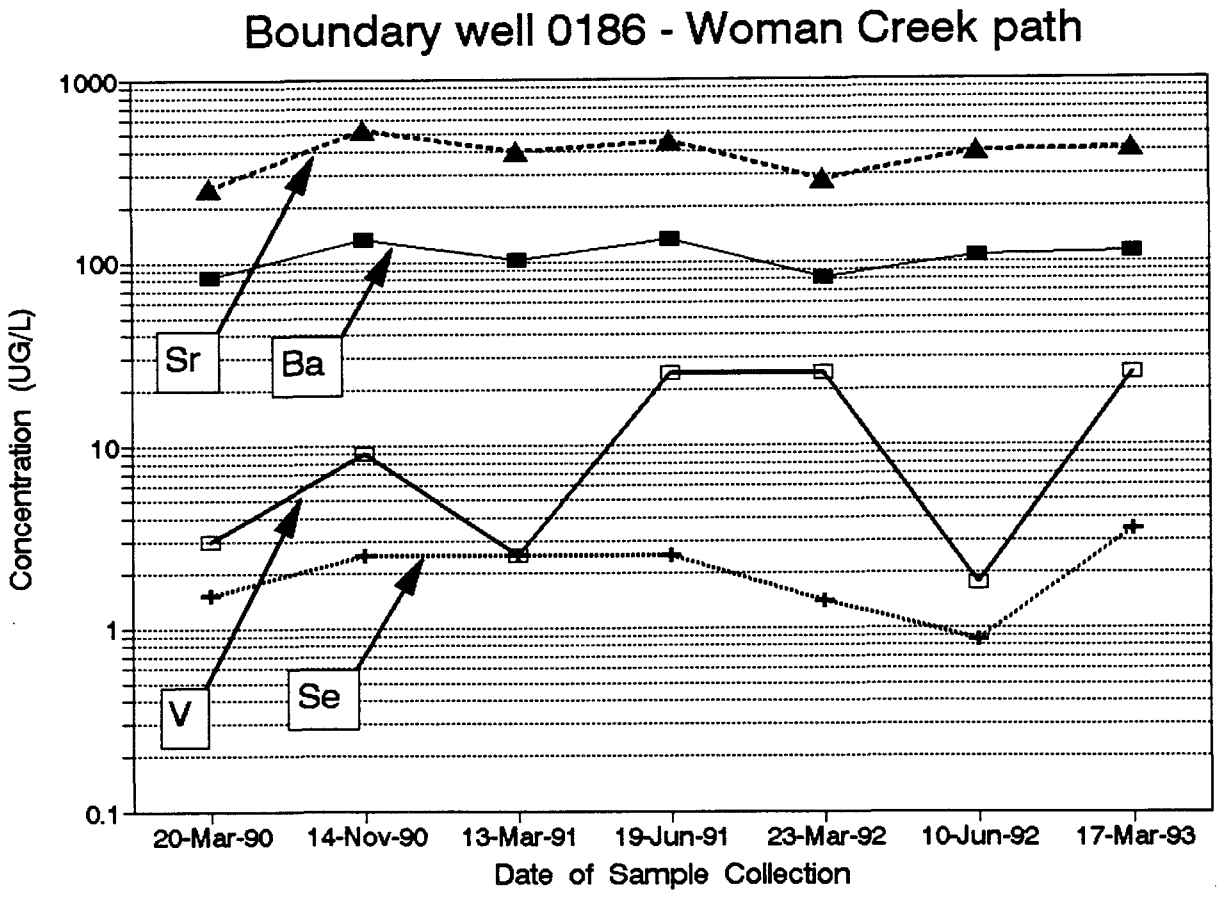
Well 6686 - Woman Creek flow path

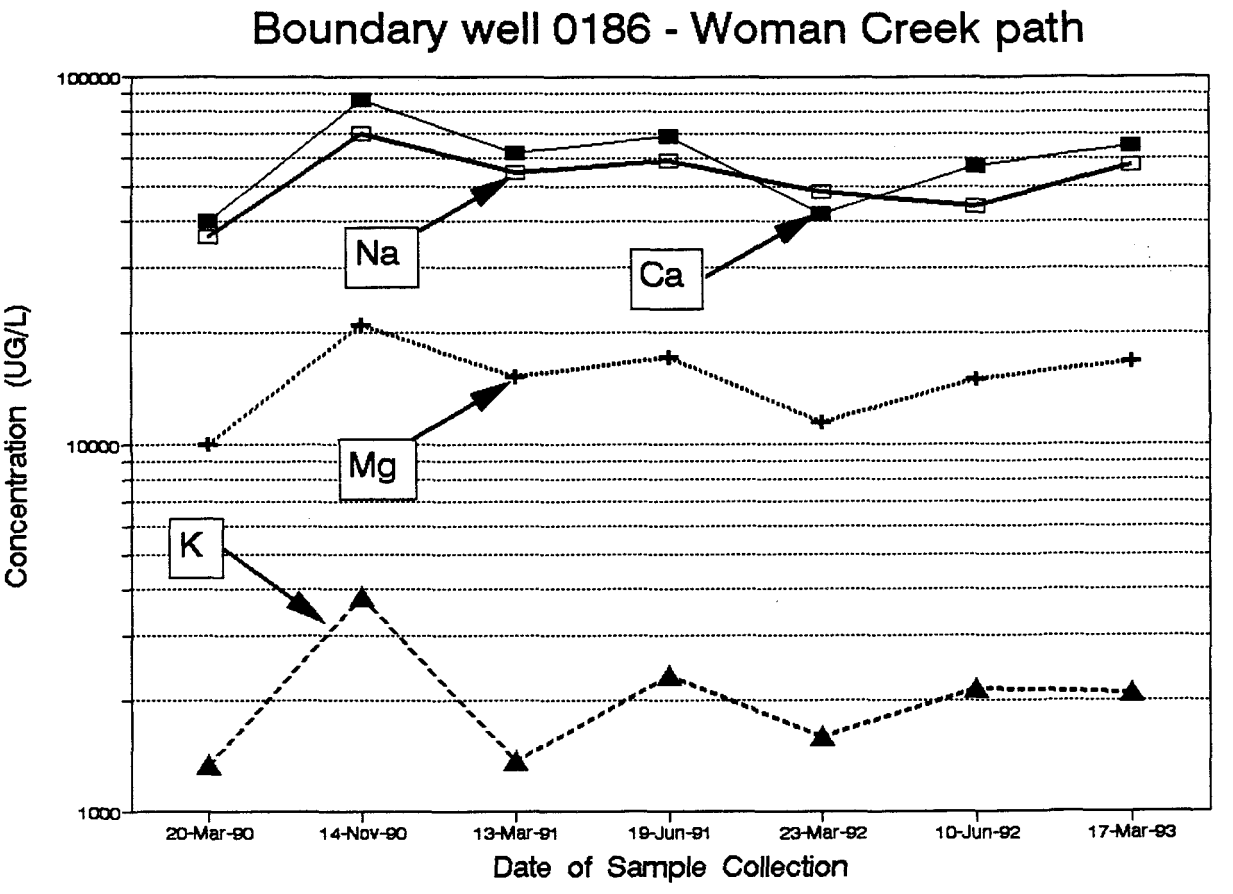


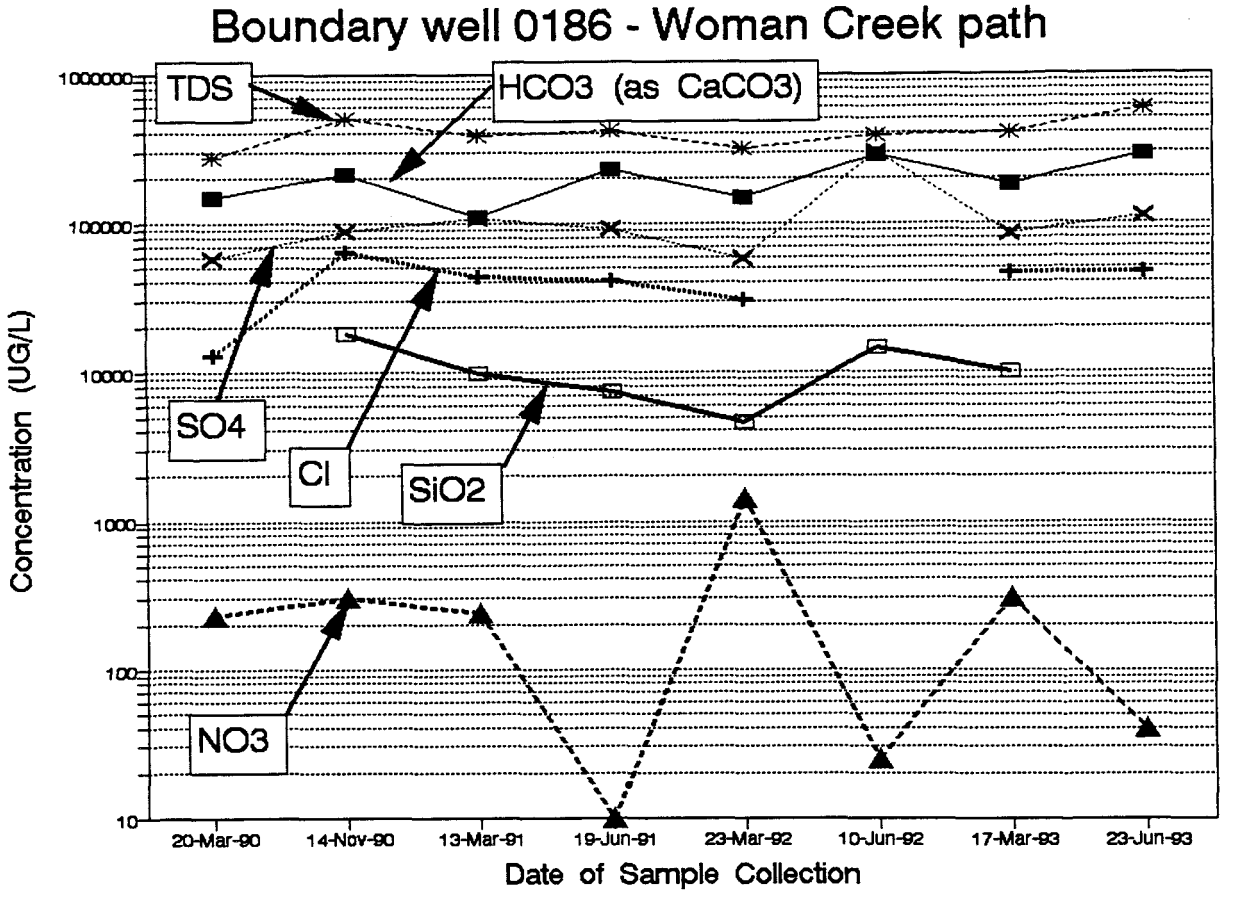
Well 6686 - Woman Creek flow path

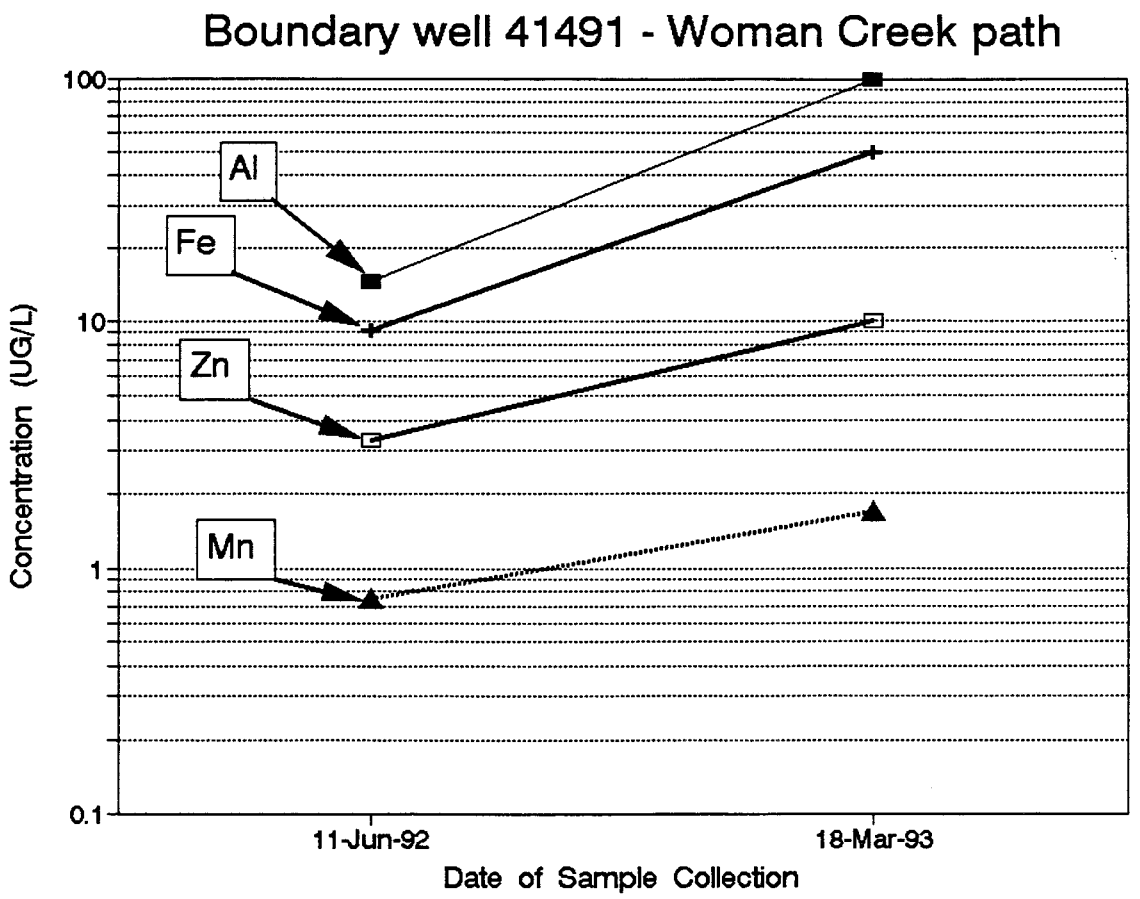


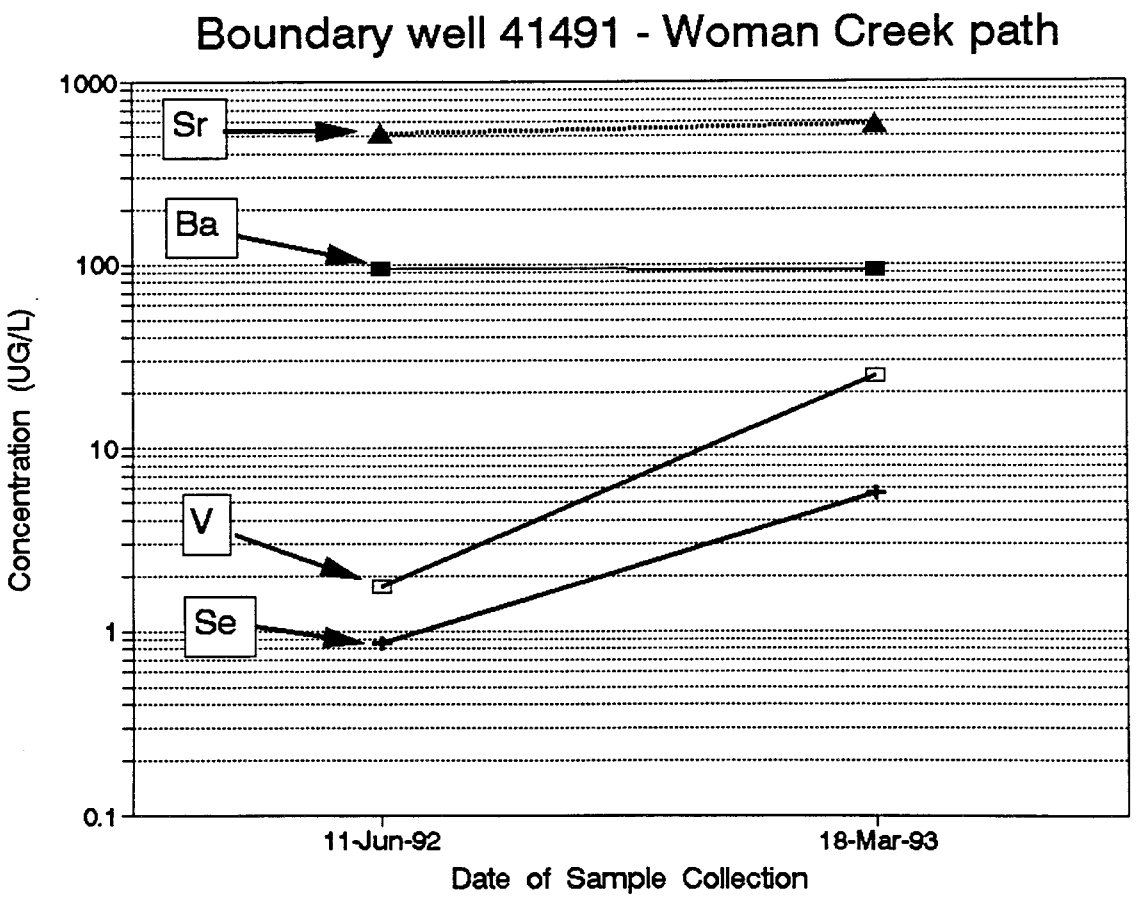

Boundary well 0186 - Woman Creek path
Fe
Al
Zn
Mn
1000
100
10
1
0.1
Concentration (UG/L)
20-Mar-90
14-Nov-90
13-Mar-91
19-Jun-91
23-Mar-92
10-Jun-92
17-Mar-93
Date of Sample Collection

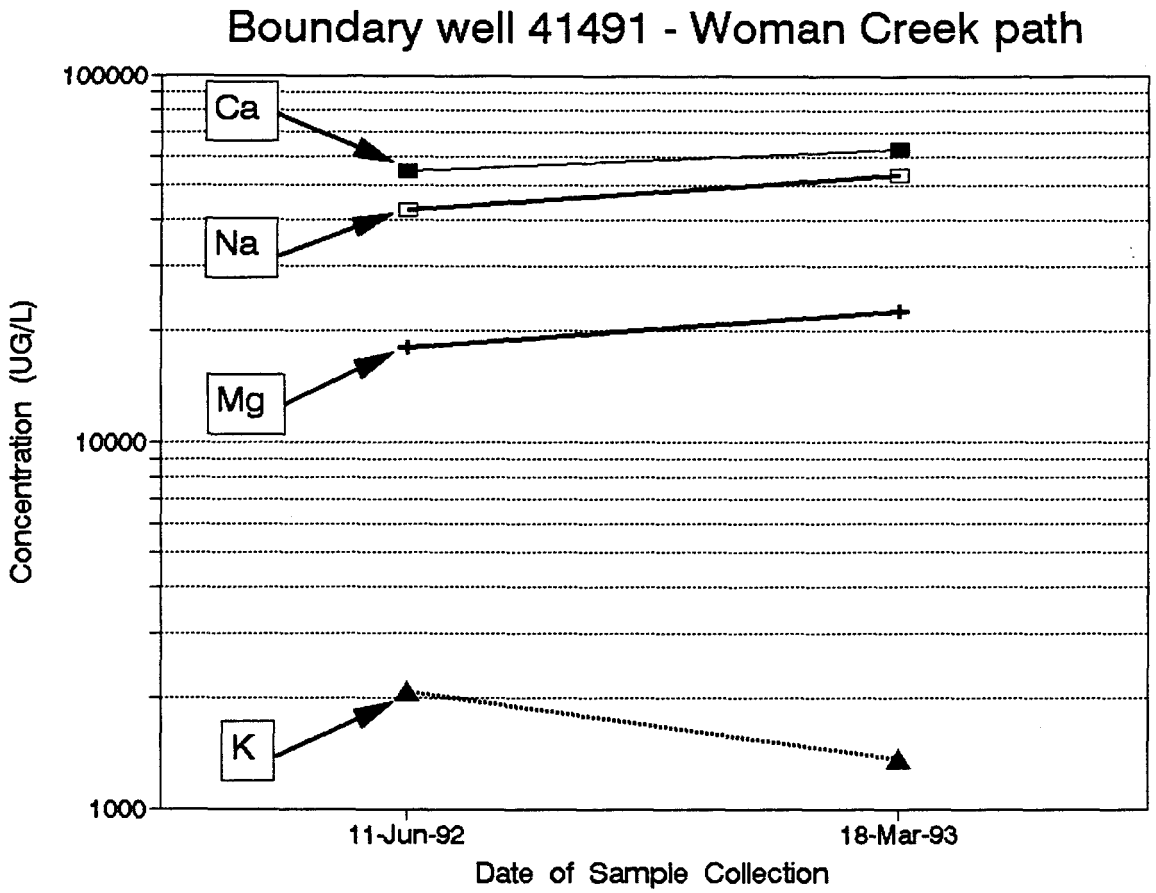

Boundary well 0186 - Woman Creek path
Sr
Ba
V
Se
1000
100
10
1
0.1
Concentration (UG/L)
20-Mar-90
14-Nov-90
13-Mar-91
19-Jun-91
23-Mar-92
10-Jun-92
17-Mar-93
Date of Sample Collection

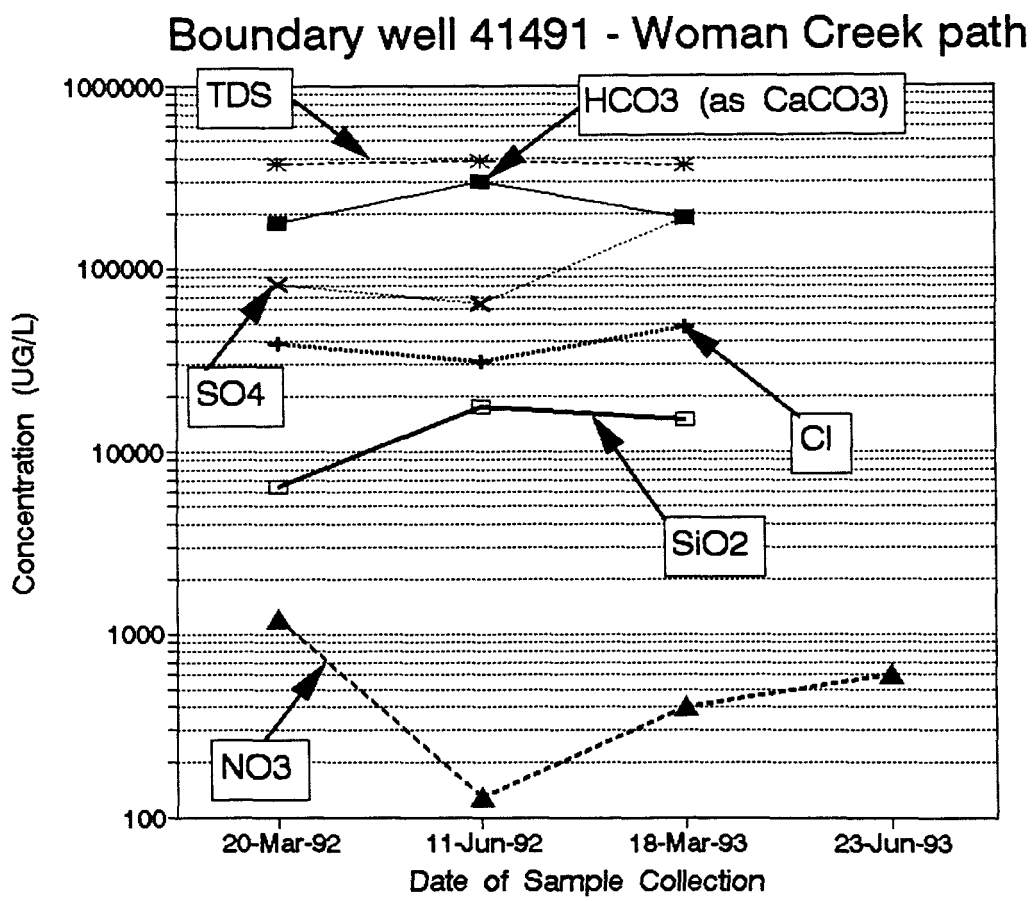

Boundary well 0186 - Woman Creek path
Concentration (UG/L)
100000
10000
1000
Na
Ca
Mg
K
20-Mar-90
14-Nov-90
13-Mar-91
19-Jun-91
23-Mar-92
10-Jun-92
17-Mar-93
Date of Sample Collection


Boundary well 0186 - Woman Creek path
Concentration (UG/L)
1000000
100000
10000
1000
100
10
TDS
HCO3 (as CaCO3)
SO4
Cl
SiO2
NO3
20-Mar-90
14-Nov-90
13-Mar-91
19-Jun-91
23-Mar-92
10-Jun-92
17-Mar-93
23-Jun-93
Date of Sample Collection

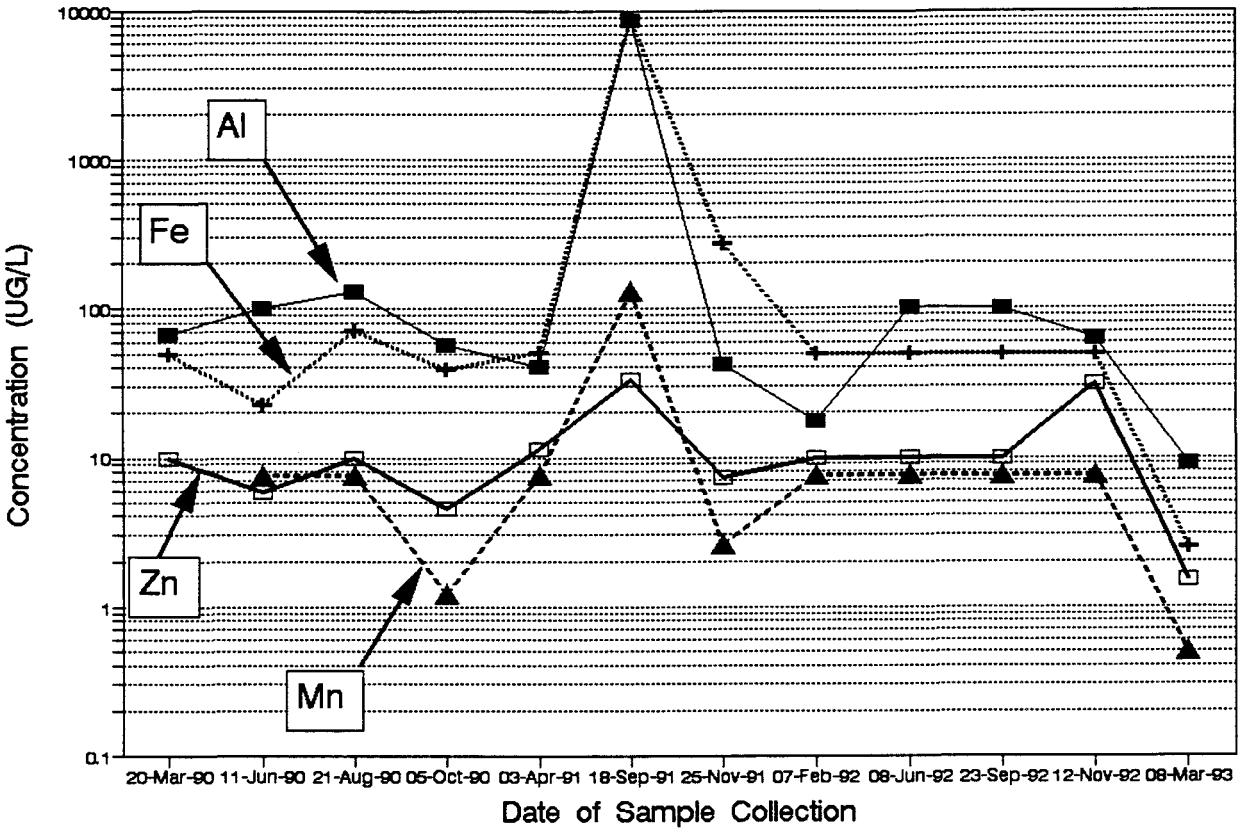

Boundary well 41491 - Woman Creek path
100
10
1
0.1
Concentration (UG/L)
Al
Fe
Zn
Mn
11-Jun-92
18-Mar-93
Date of Sample Collection


Boundary well 41491 - Woman Creek path
1000
100
10
1
0.1
Concentration (UG/L)
Sr
Ba
V
Se
11-Jun-92
18-Mar-93
Date of Sample Collection

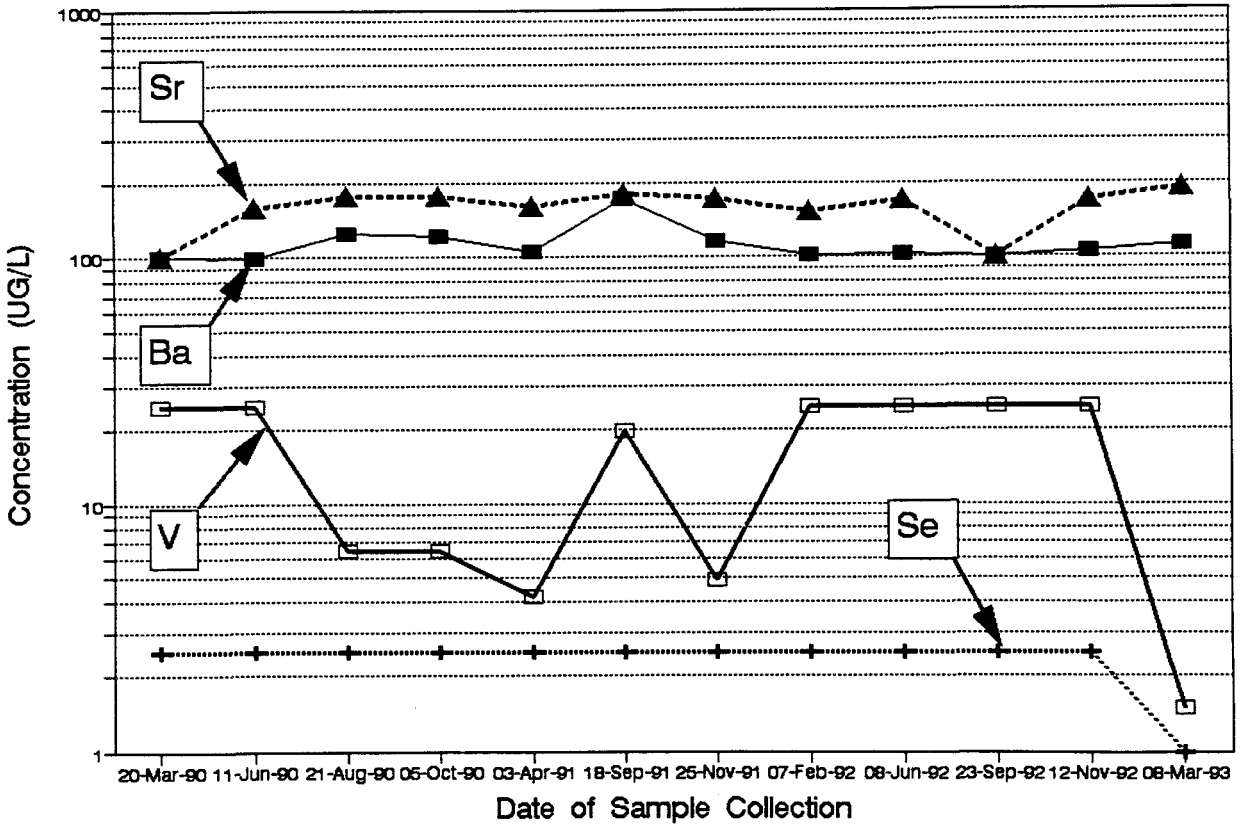

Boundary well 41491 - Woman Creek path
100000
10000
1000
Concentration (UG/L)
Ca
Na
Mg
K
11-Jun-92
18-Mar-93
Date of Sample Collection


Boundary well 41491 - Woman Creek path
1000000
100000
10000
1000
100
Concentration (UG/L)
TDS
HCO3 (as CaCO3)
SO4
Cl
SiO2
NO3
20-Mar-92
11-Jun-92
18-Mar-93
23-Jun-93
Date of Sample Collection

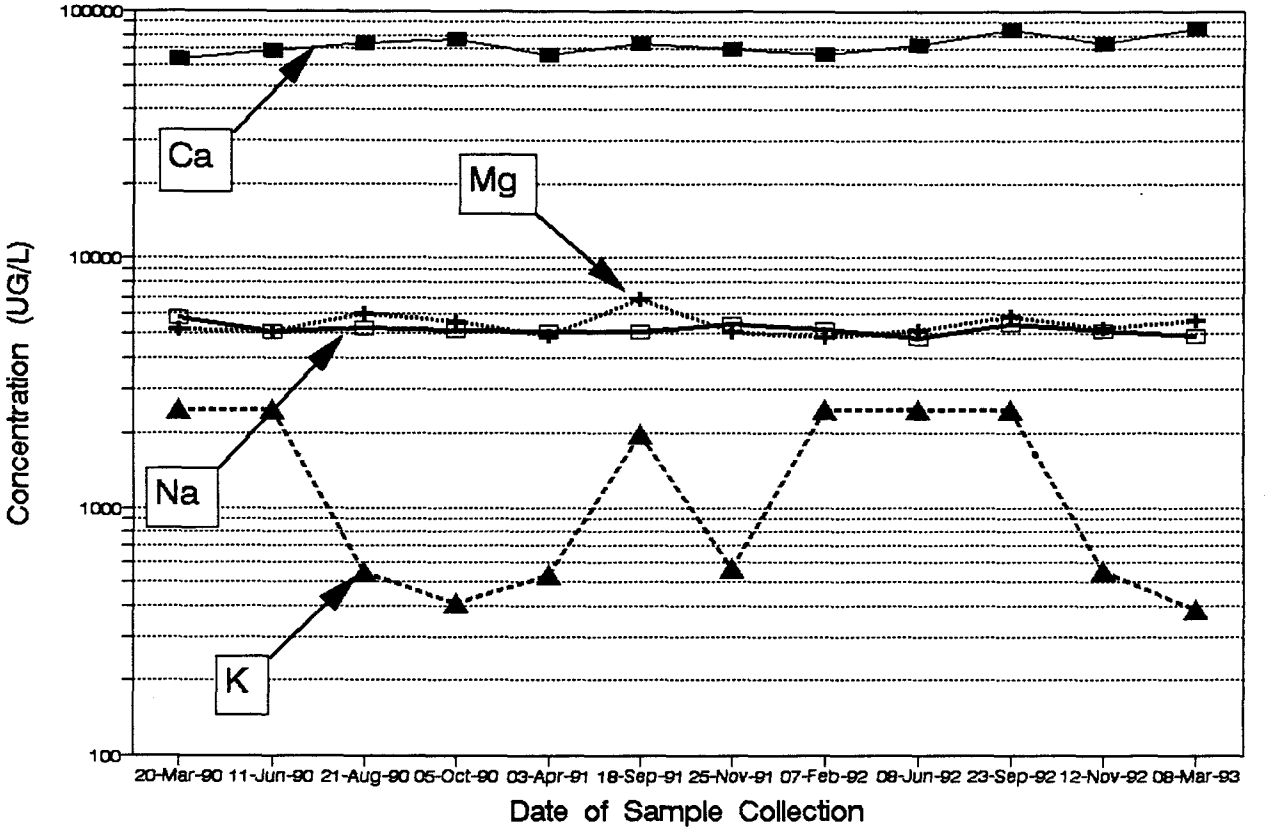
Well B400389 - Southern flow path



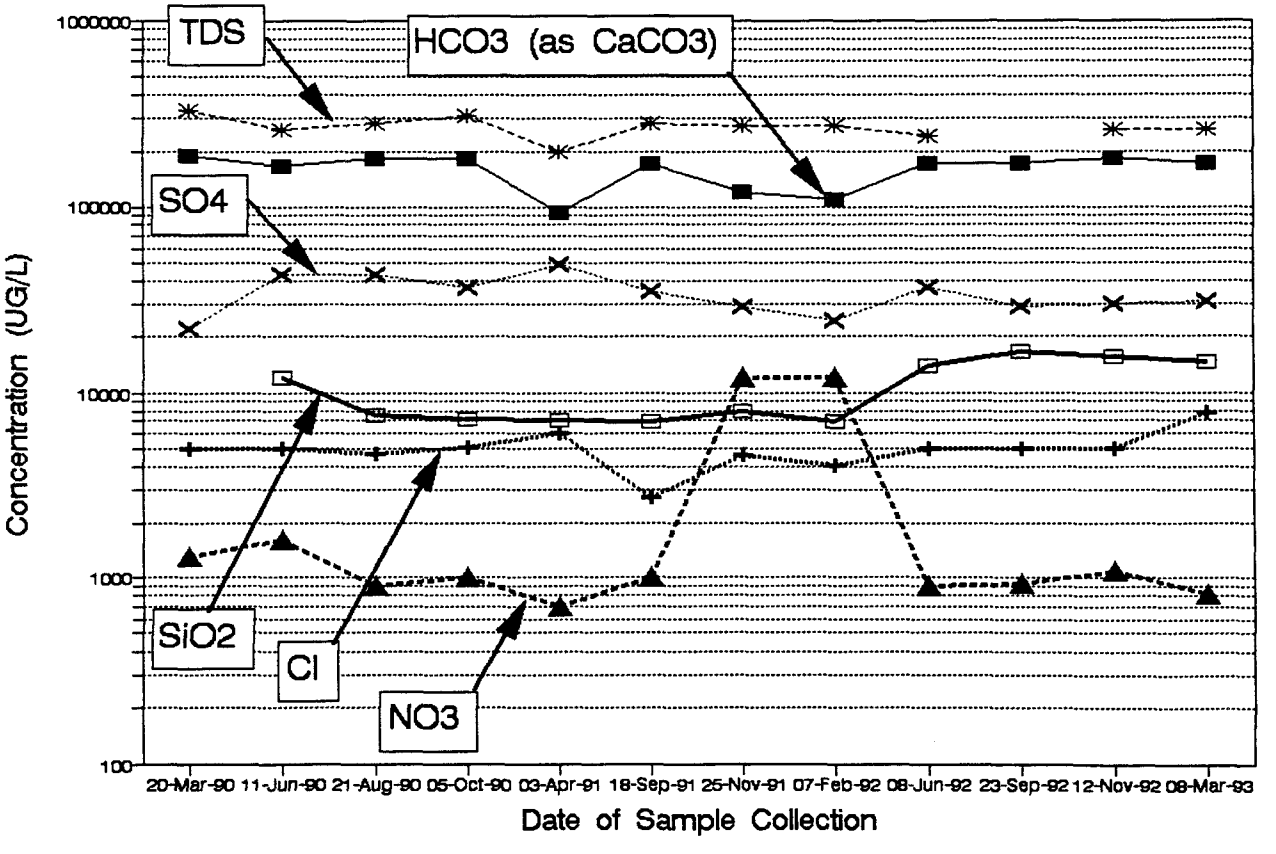
Well B400389 - Southern flow path



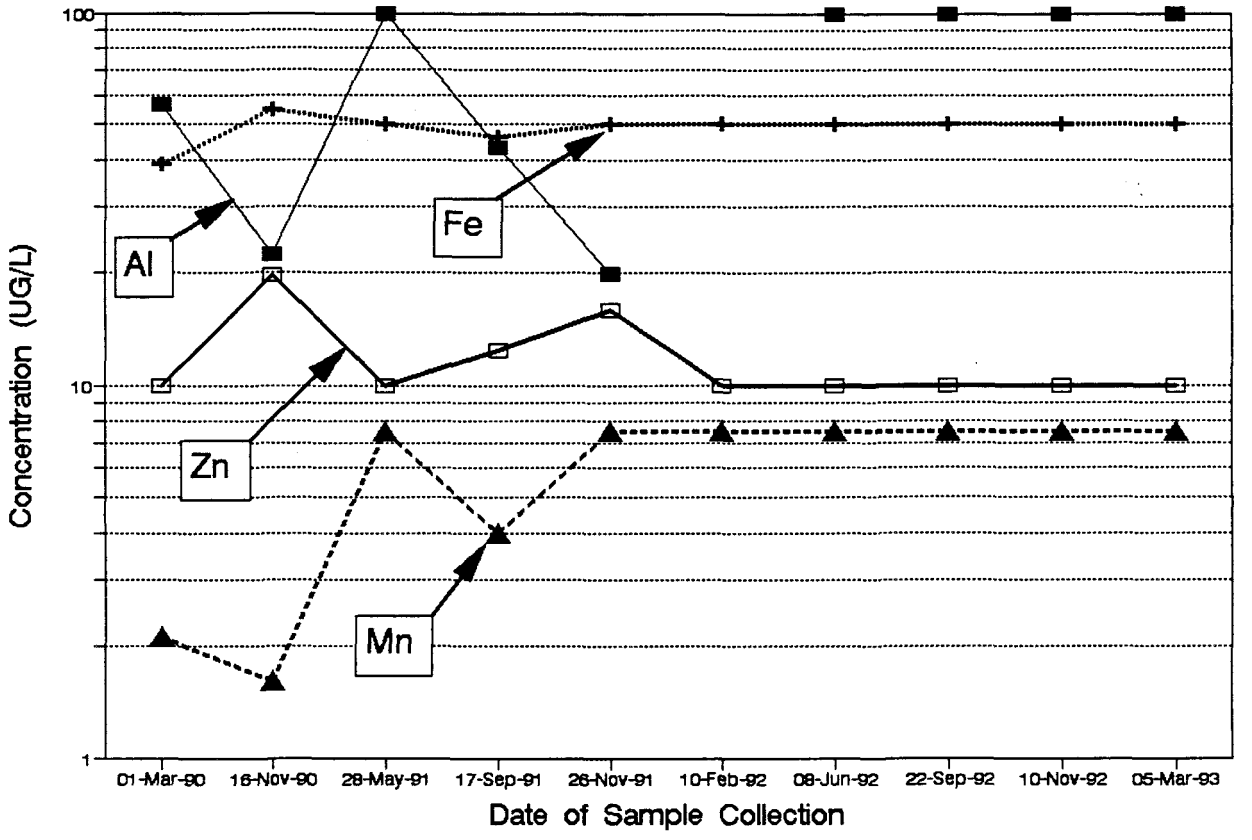
Well B400389 - Southern flow path



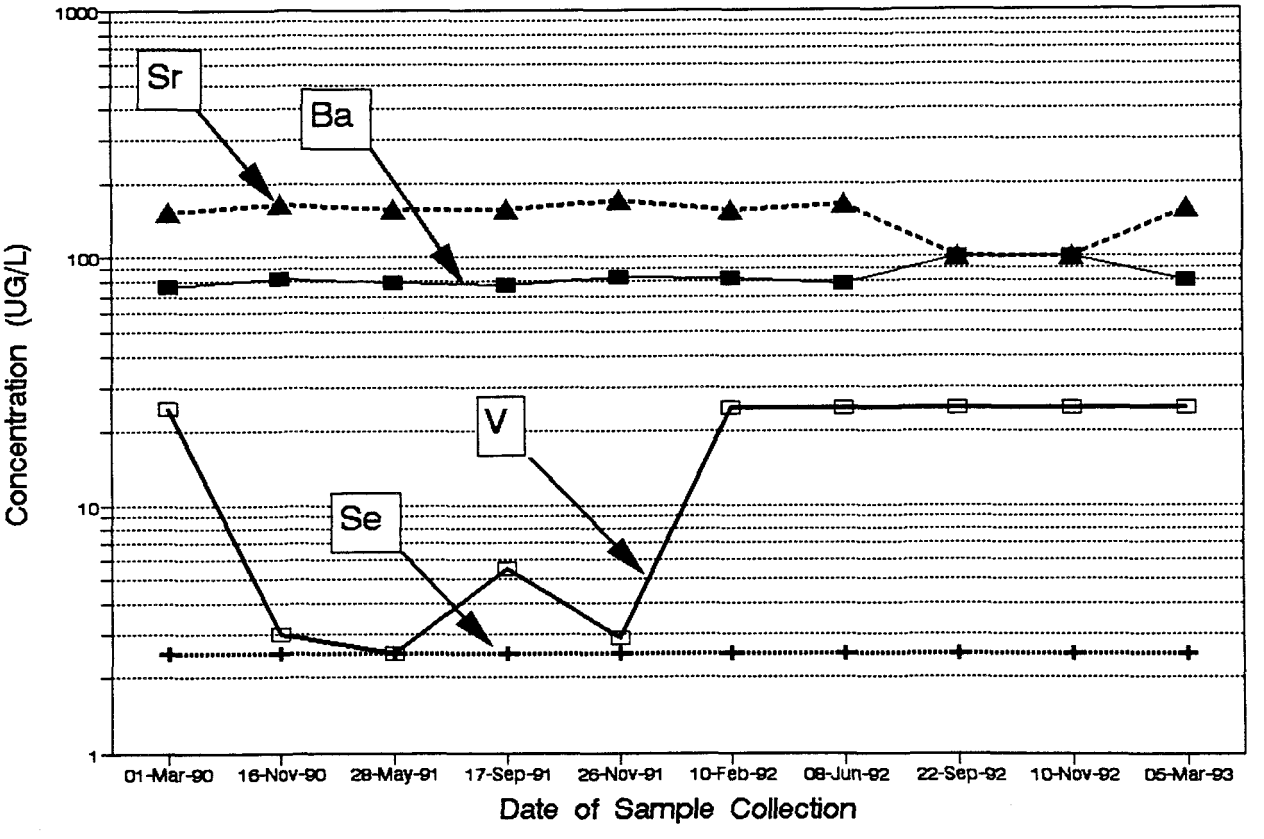
Well B400389 - Southern flow path



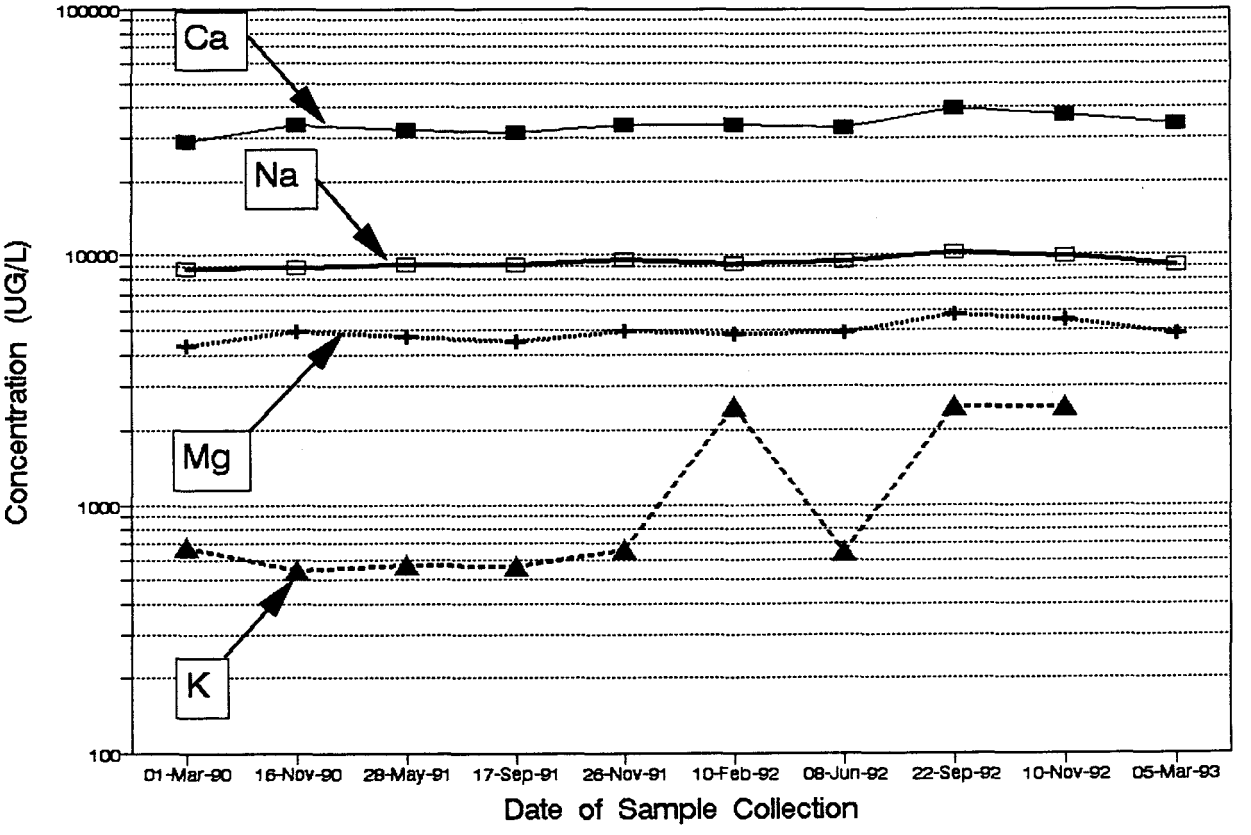
Well B405789 - Southern flow path



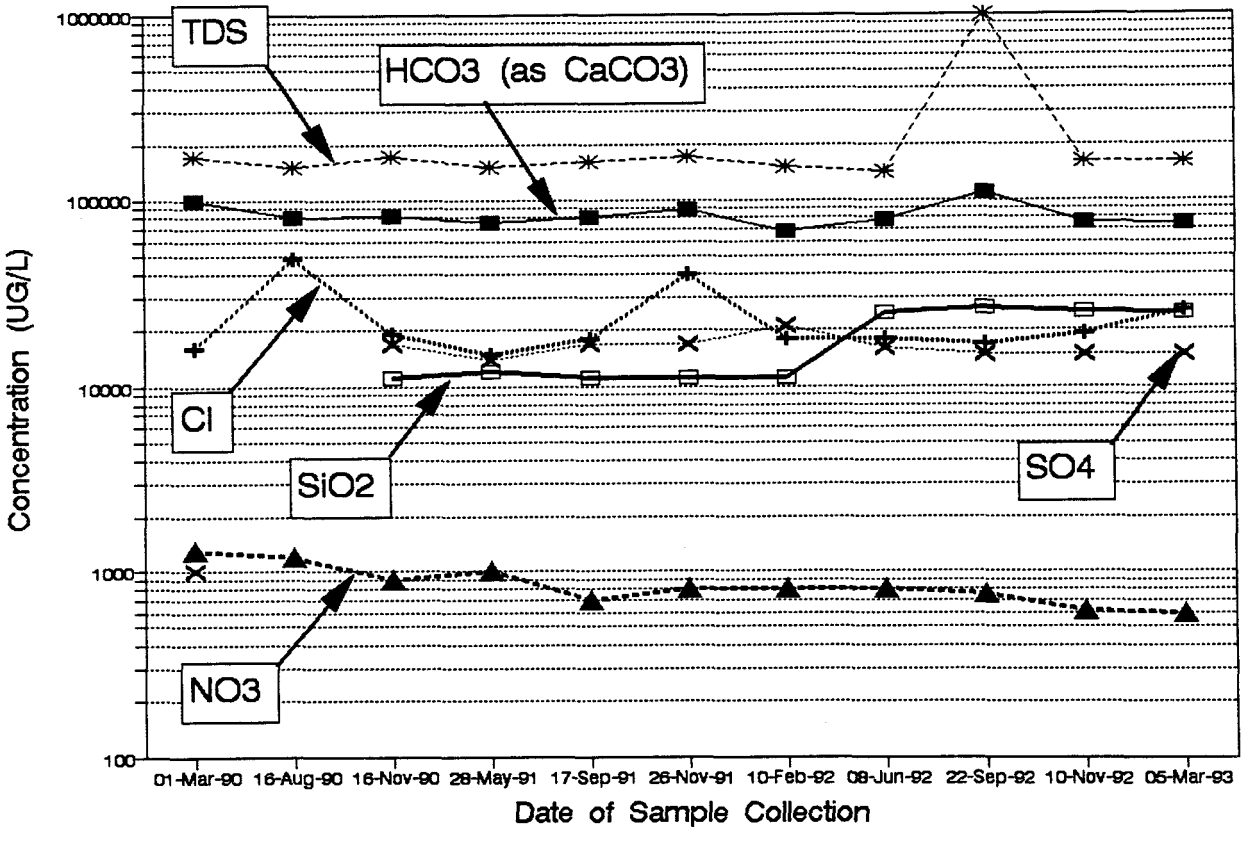
Well B405789 - Southern flow path



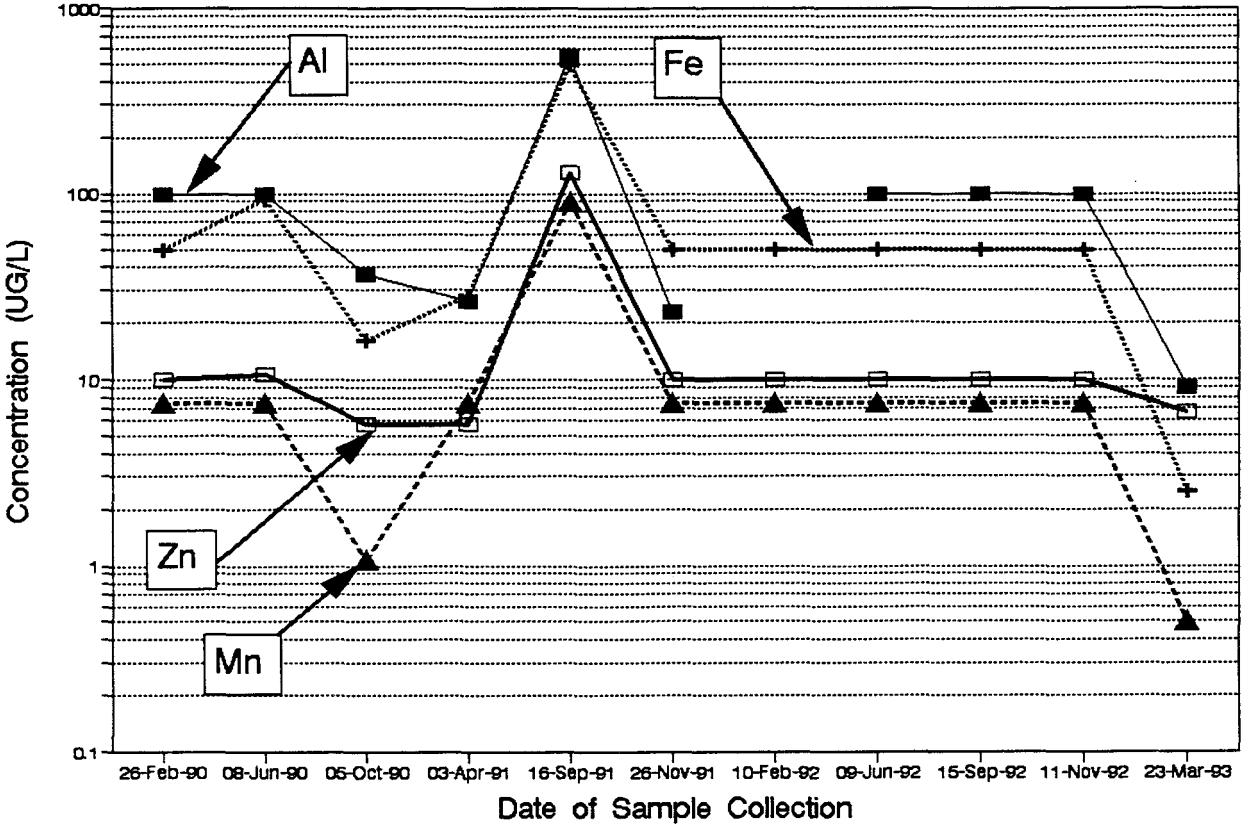
Well B405789 - Southern flow path



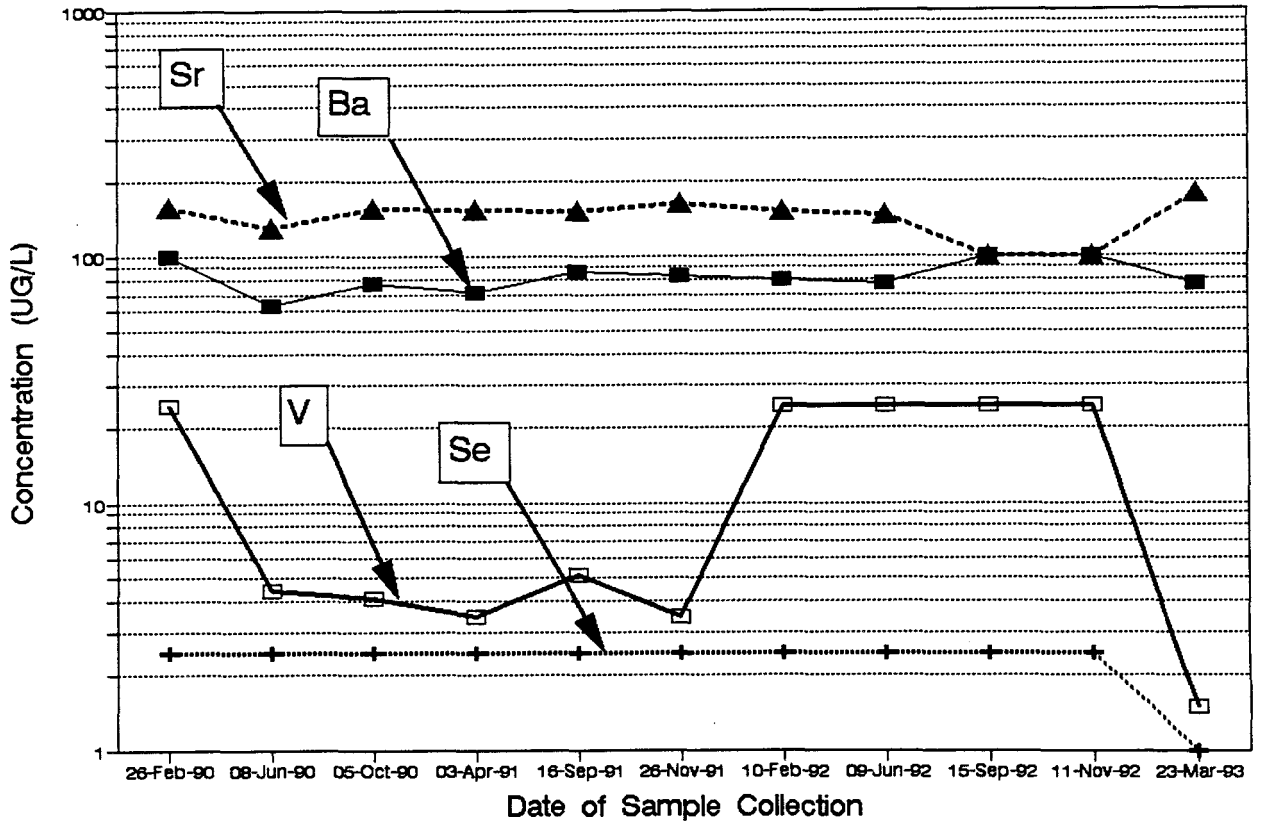
Well B405789 - Southern flow path



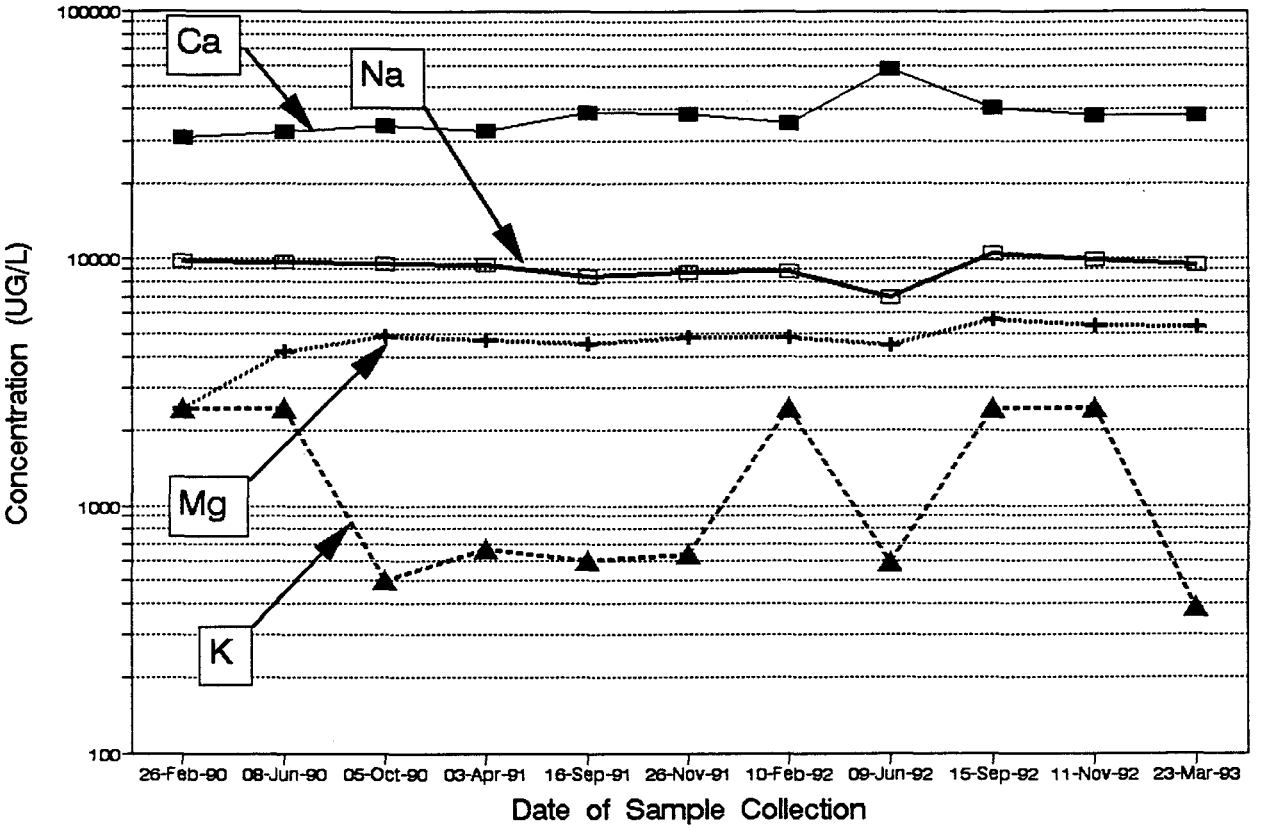
Well B400489 - Southern flow path



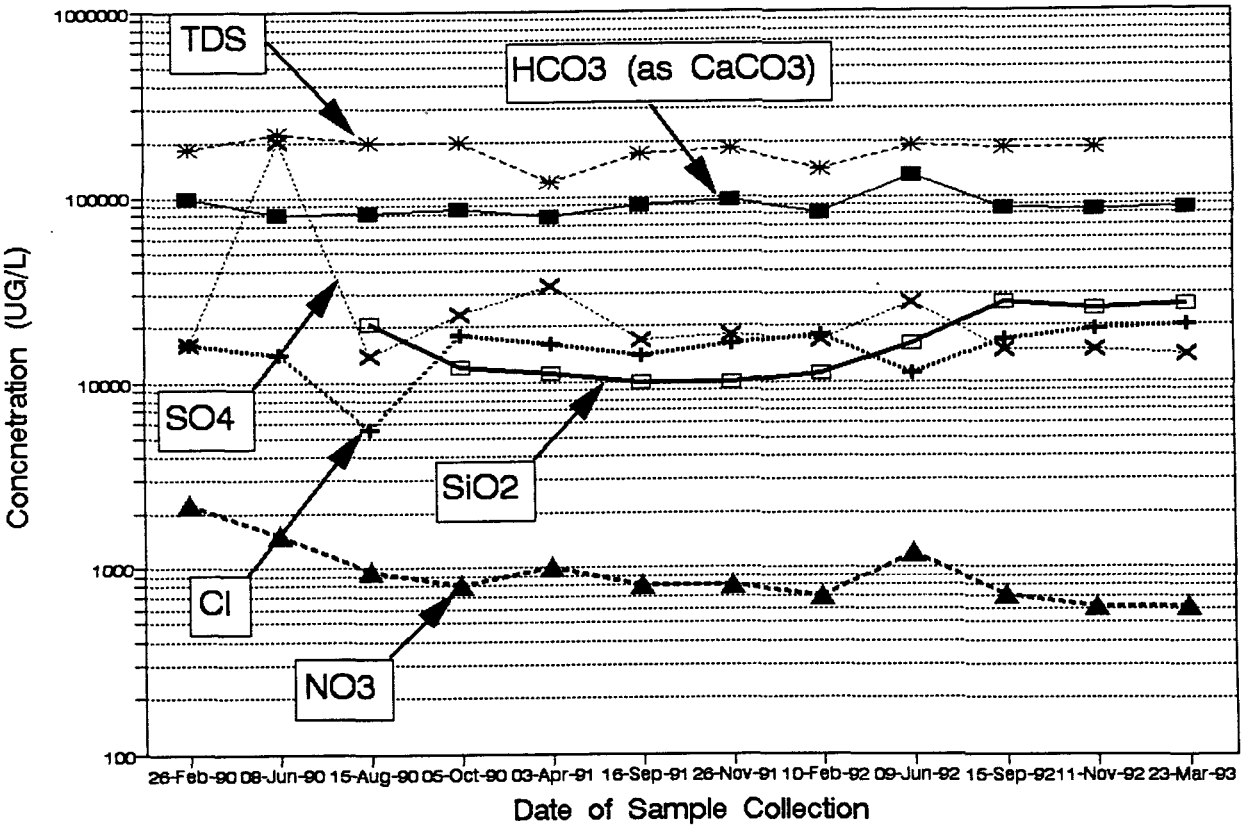
Well B400489 - Southern flow path

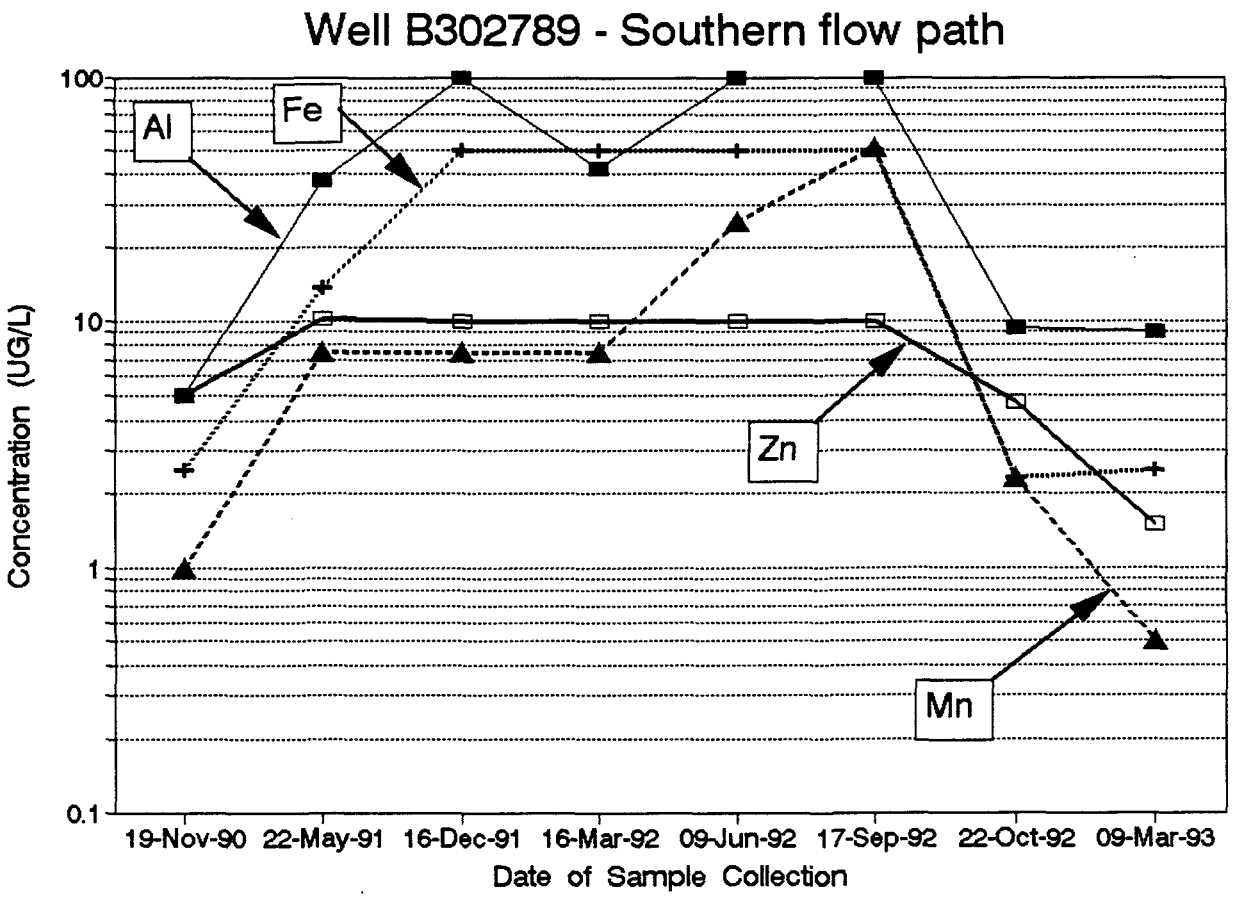


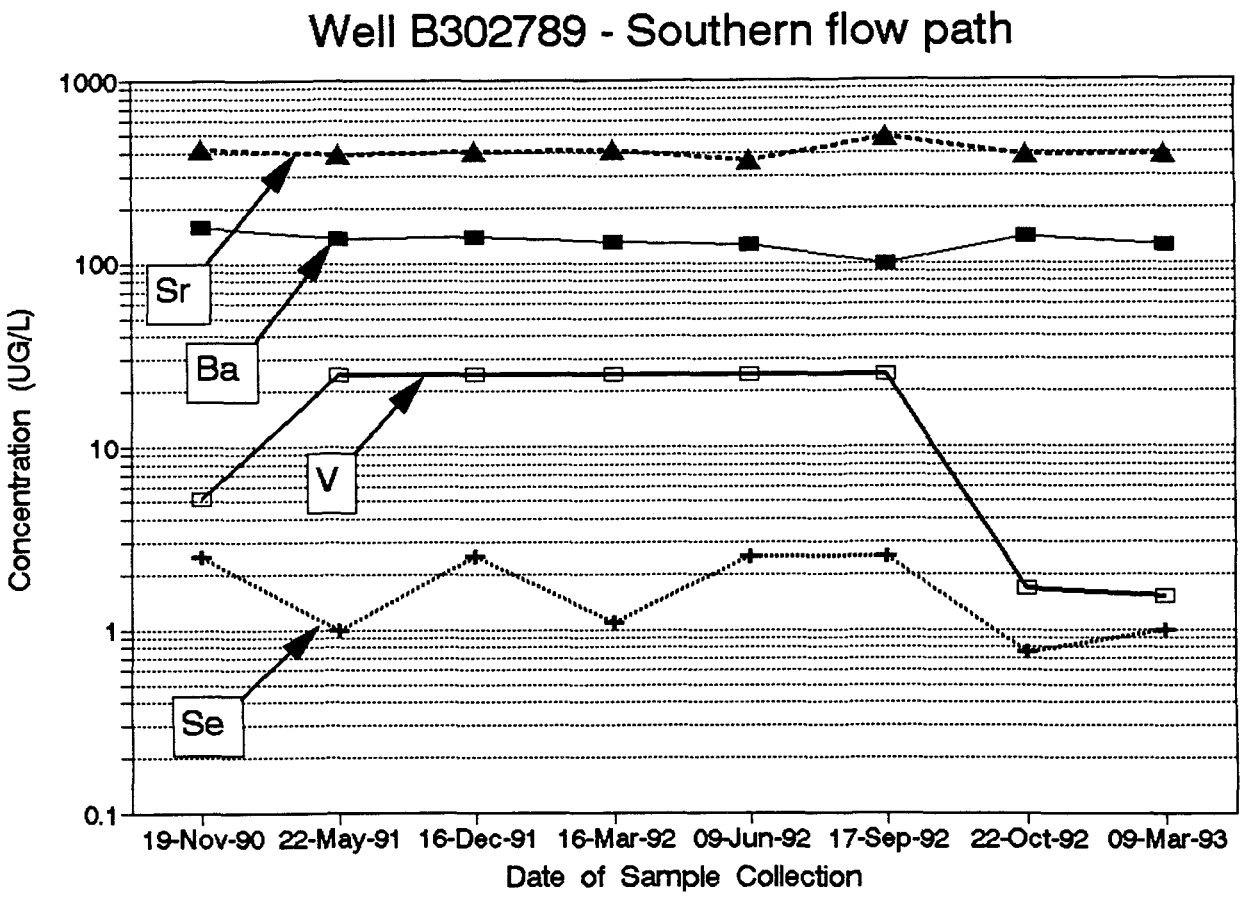
Well B400489 - Southern flow path



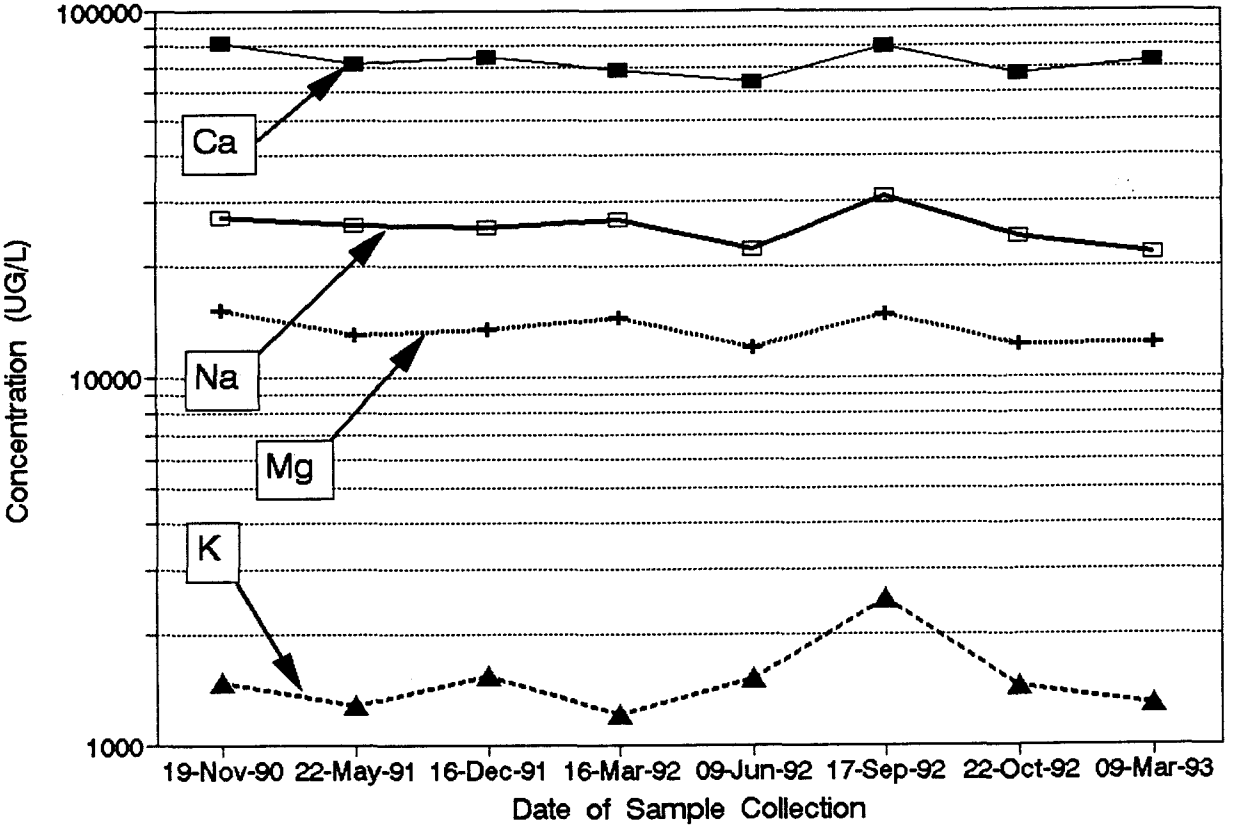
Well B400489 - Southern flow path



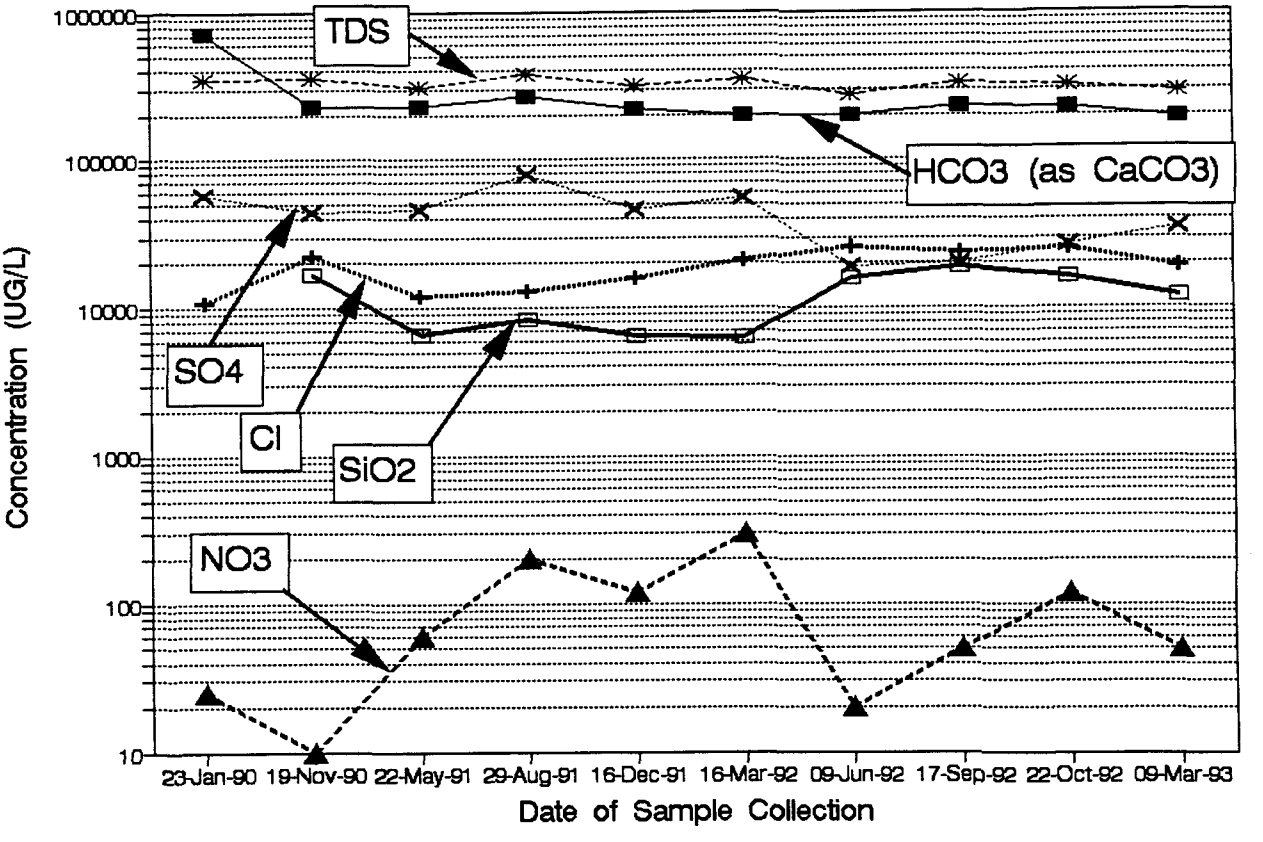

Well B302789 - Southern flow path
Al
Fe
Zn
Mn
100
10
1
0.1
Concentration (UG/L)
19-Nov-90
22-May-91
16-Dec-91
16-Mar-92
09-Jun-92
17-Sep-92
22-Oct-92
09-Mar-93
Date of Sample Collection


Well B302789 - Southern flow path
Sr
Ba
V
Se
1000
100
10
1
0.1
Concentration (UG/L)
19-Nov-90
22-May-91
16-Dec-91
16-Mar-92
09-Jun-92
17-Sep-92
22-Oct-92
09-Mar-93
Date of Sample Collection

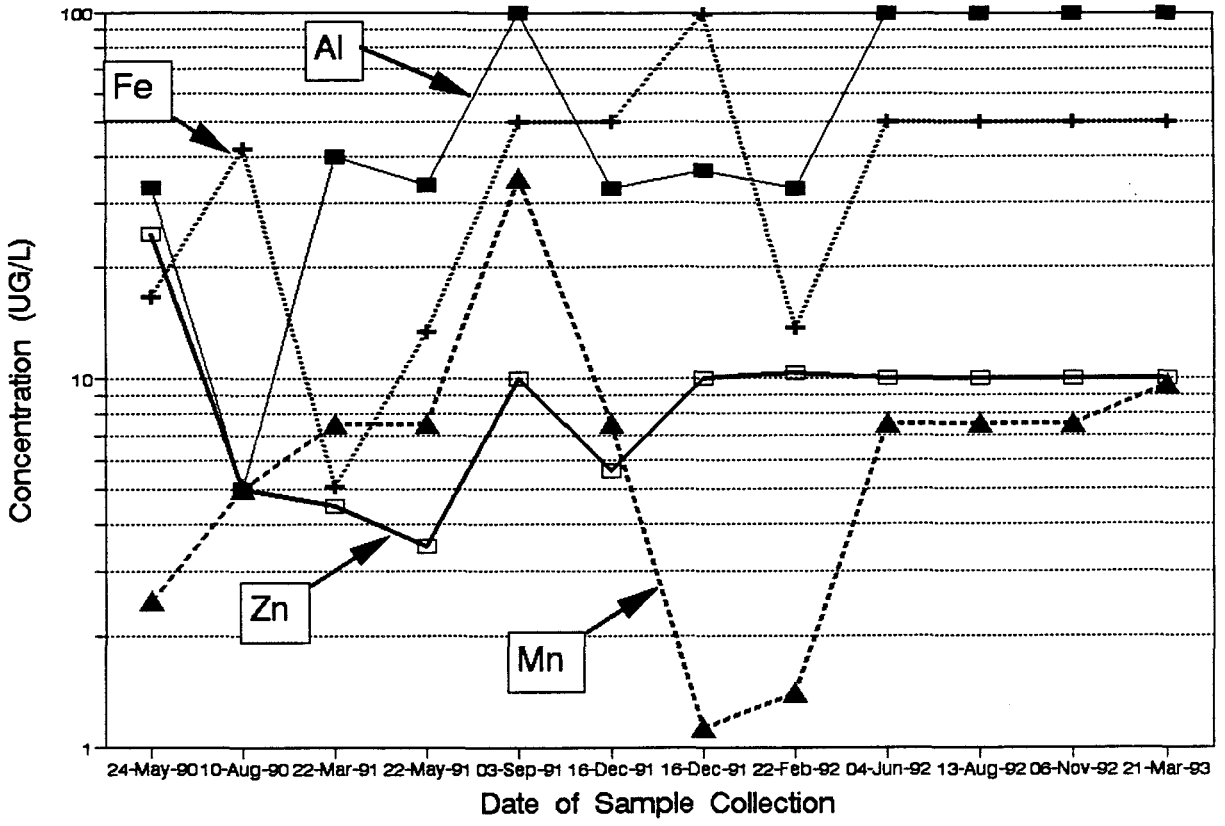
Well B302789 - Southern flow path



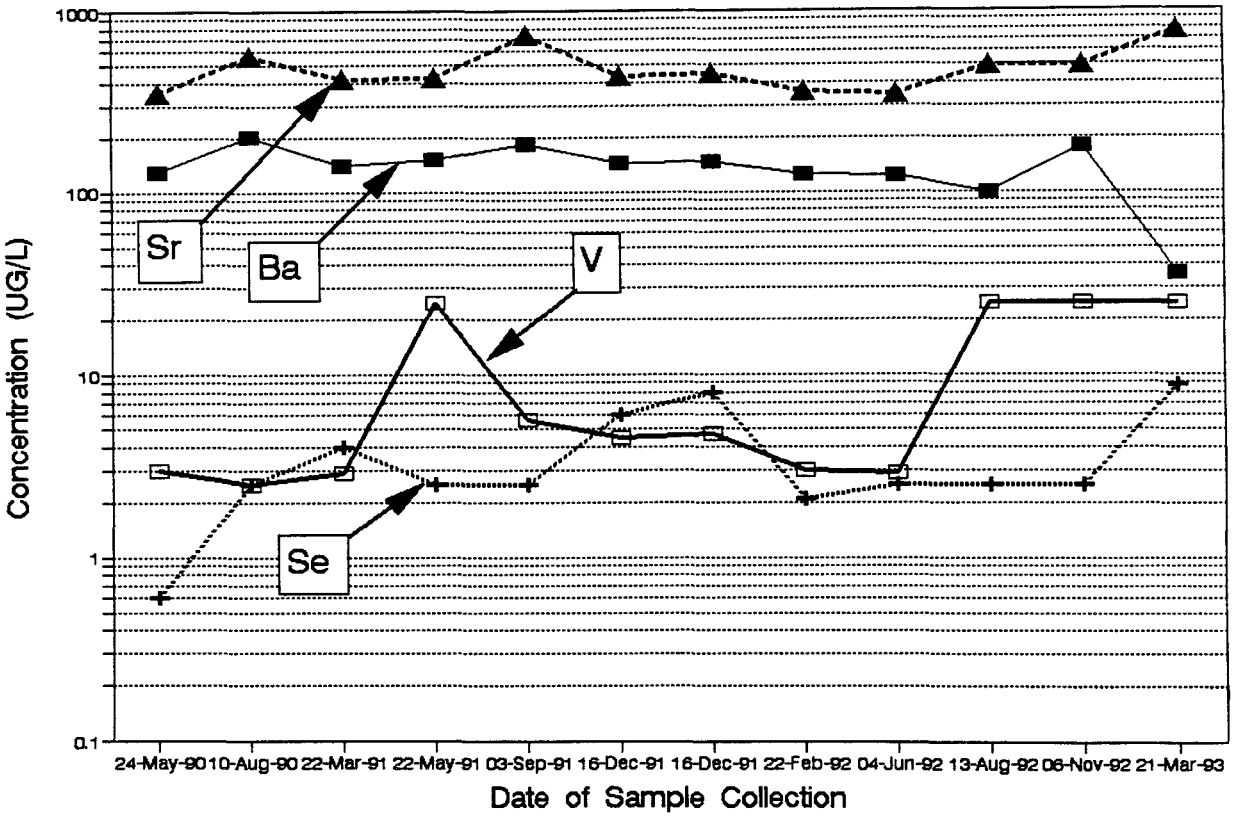
Well B302789 - Southern flow path

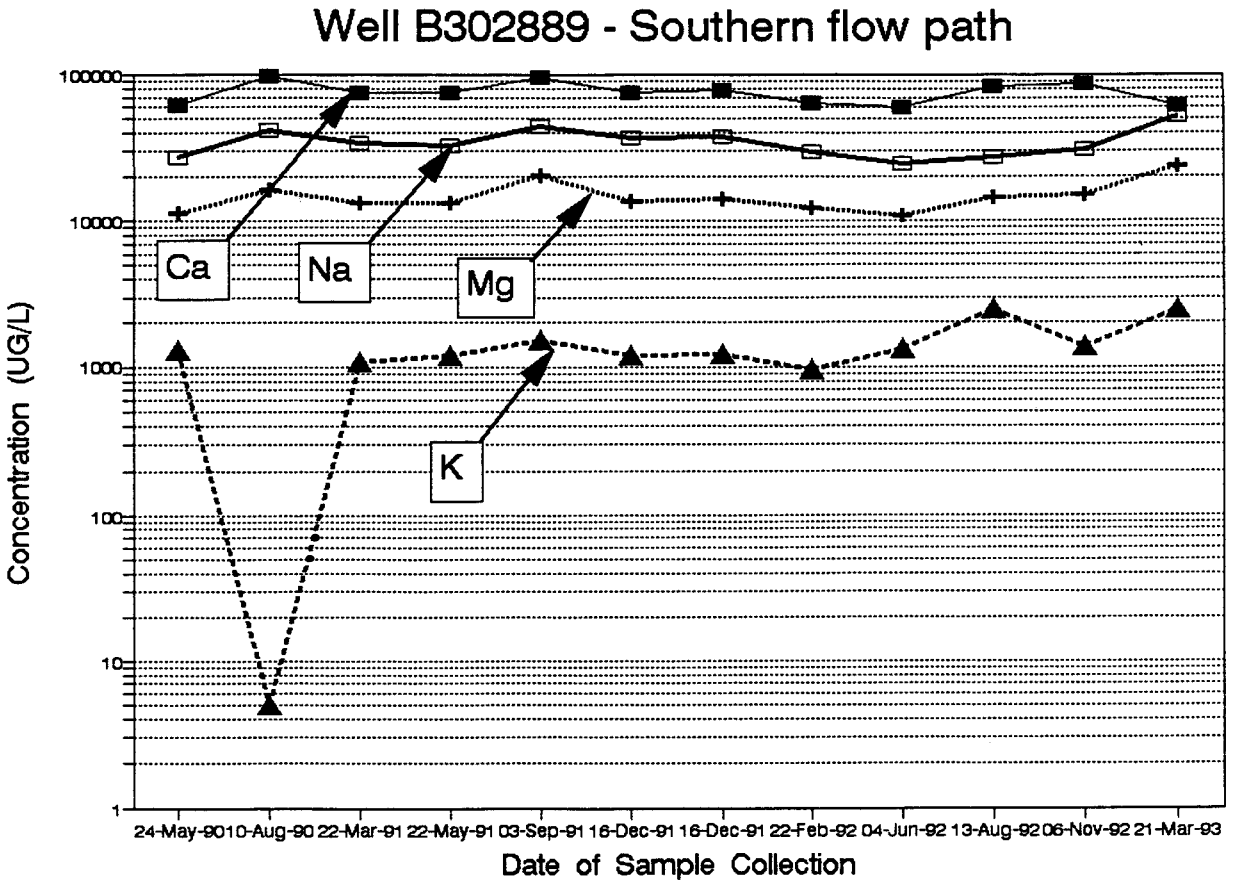


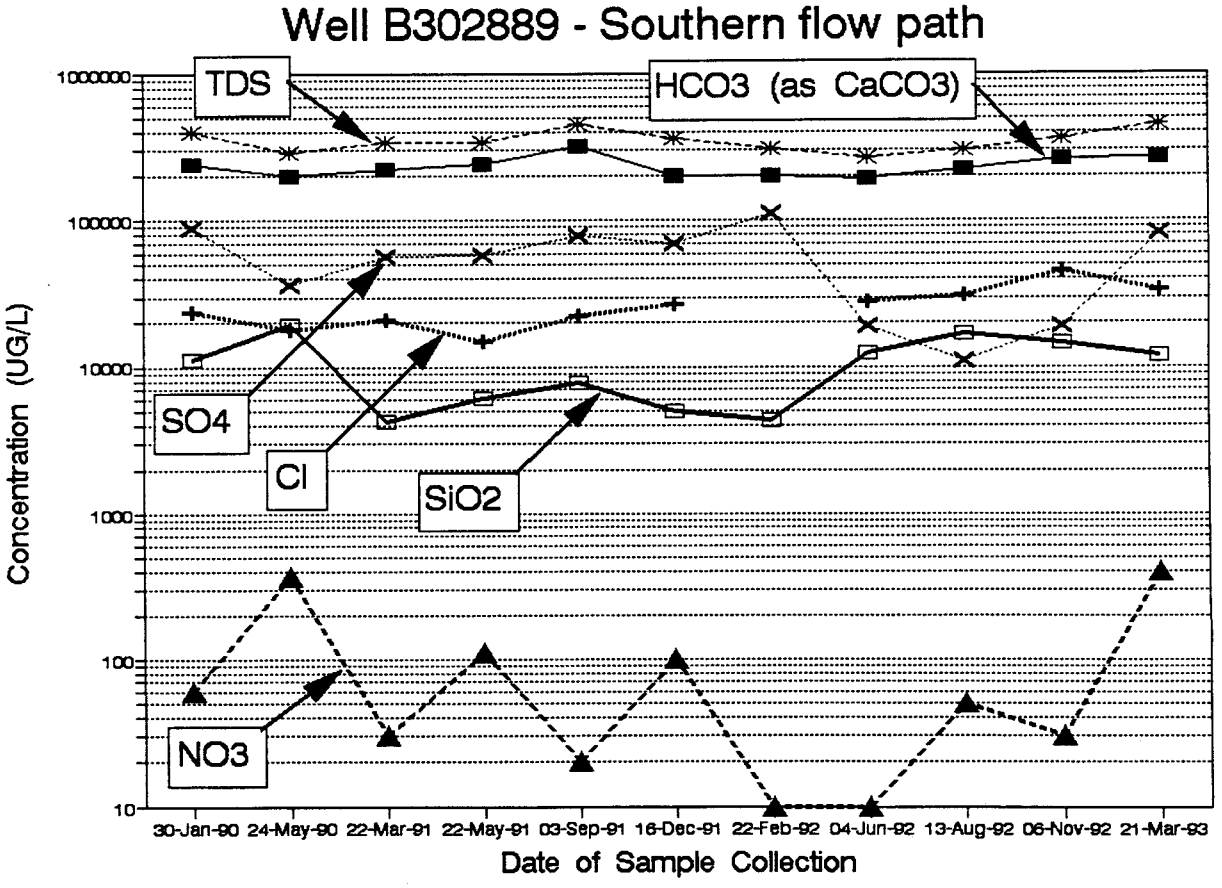
Well B302889 - Southern flow path

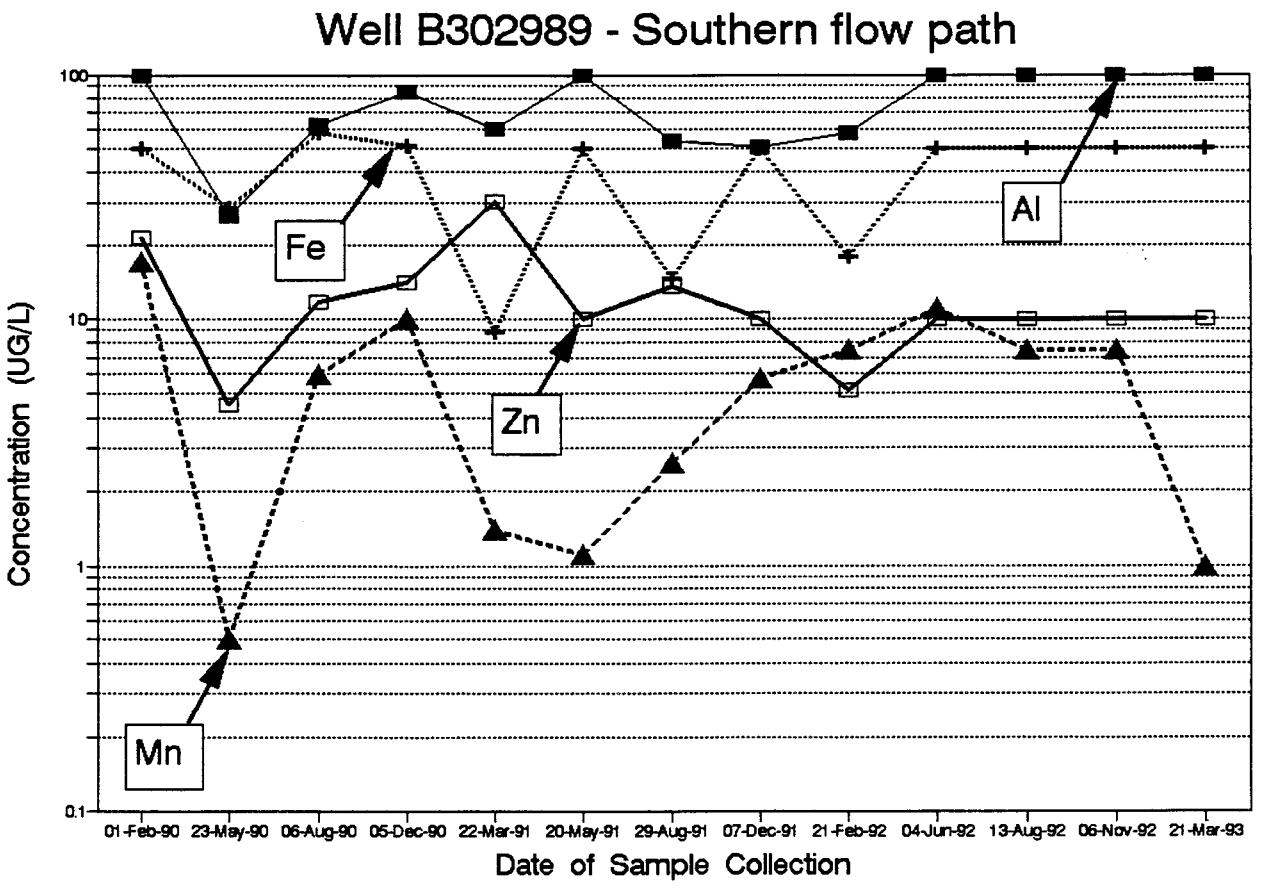


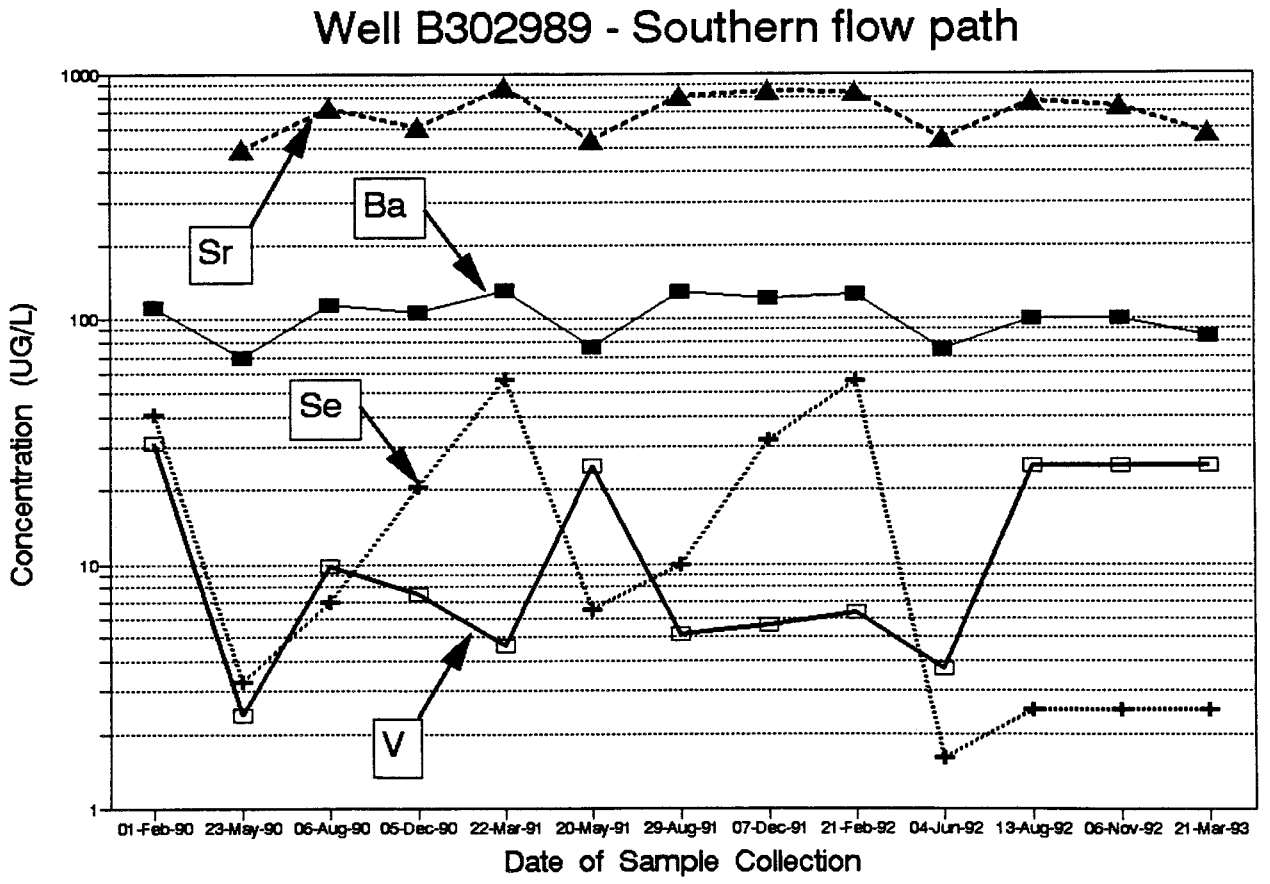
Well B302889 - Southern flow path

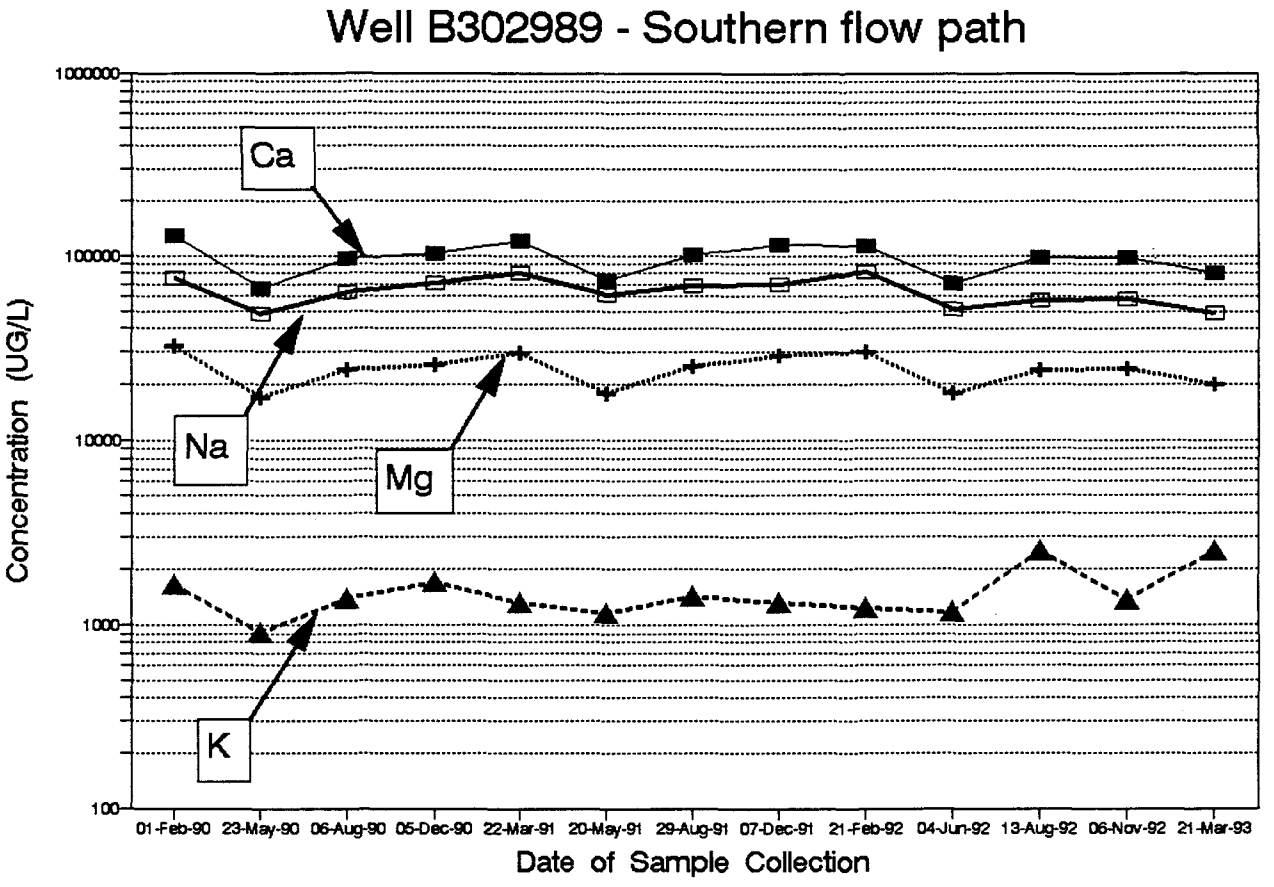



Well B302889 - Southern flow path
Concentration (UG/L)
100000
10000
1000
100
10
1
Ca
Na
Mg
K
24-May-90
10-Aug-90
22-Mar-91
22-May-91
03-Sep-91
16-Dec-91
16-Dec-91
22-Feb-92
04-Jun-92
13-Aug-92
06-Nov-92
21-Mar-93
Date of Sample Collection


Well B302889 - Southern flow path
Concentration (UG/L)
1000000
100000
10000
1000
100
10
TDS
HCO3 (as CaCO3)
SO4
Cl
SiO2
NO3
30-Jan-90
24-May-90
22-Mar-91
22-May-91
03-Sep-91
16-Dec-91
22-Feb-92
04-Jun-92
13-Aug-92
06-Nov-92
21-Mar-93
Date of Sample Collection


Well B302989 - Southern flow path
Concentration (UG/L)
100
10
1
0.1
Fe
Al
Zn
Mn
01-Feb-90
23-May-90
06-Aug-90
05-Dec-90
22-Mar-91
20-May-91
29-Aug-91
07-Dec-91
21-Feb-92
04-Jun-92
13-Aug-92
06-Nov-92
21-Mar-93
Date of Sample Collection


Well B302989 - Southern flow path
Concentration (UG/L)
1000
100
10
1
Ba
Sr
Se
V
01-Feb-90
23-May-90
06-Aug-90
05-Dec-90
22-Mar-91
20-May-91
29-Aug-91
07-Dec-91
21-Feb-92
04-Jun-92
13-Aug-92
06-Nov-92
21-Mar-93
Date of Sample Collection


Well B302989 - Southern flow path
Ca
Na
Mg
K
Concentration (UG/L)
1000000
100000
10000
1000
100
01-Feb-90
23-May-90
06-Aug-90
05-Dec-90
22-Mar-91
20-May-91
29-Aug-91
07-Dec-91
21-Feb-92
04-Jun-92
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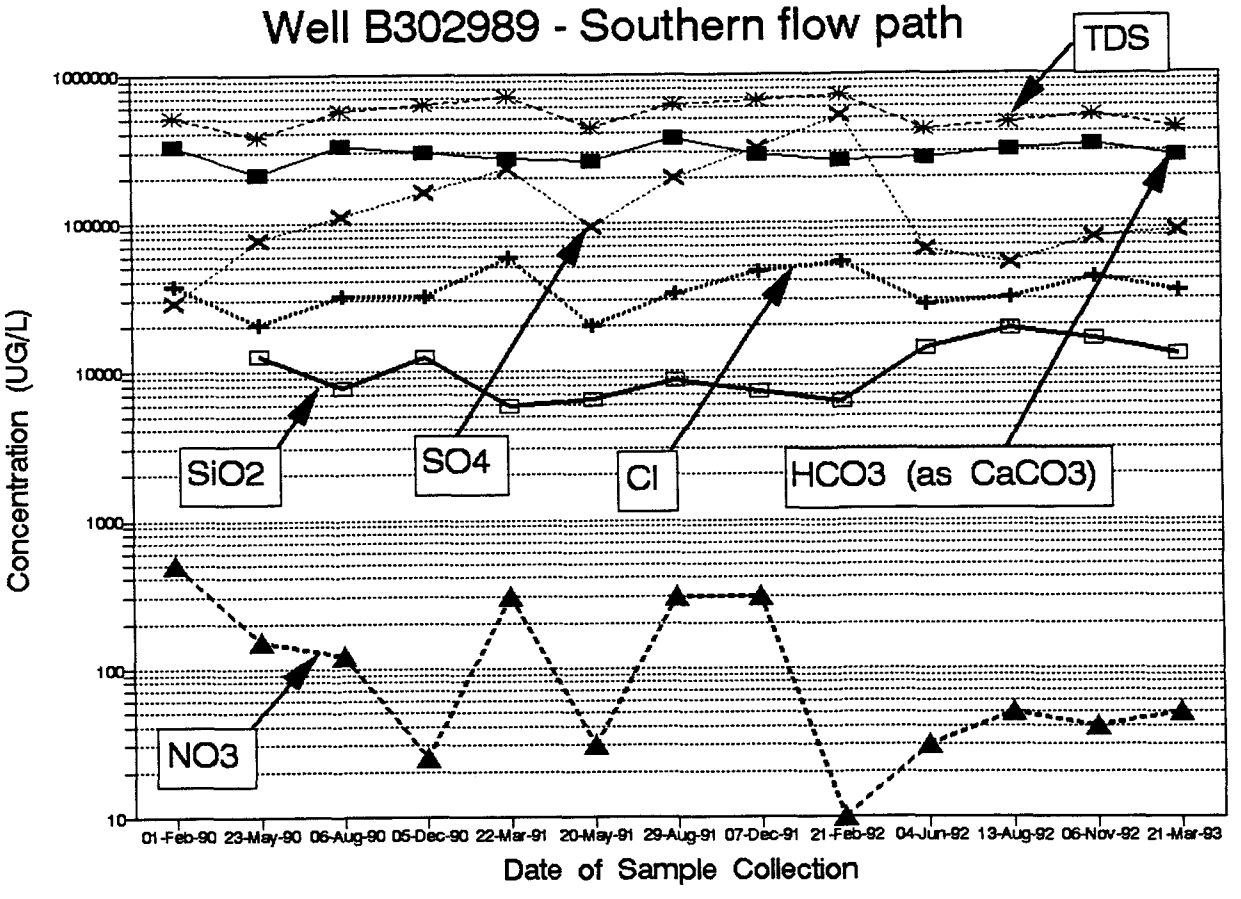
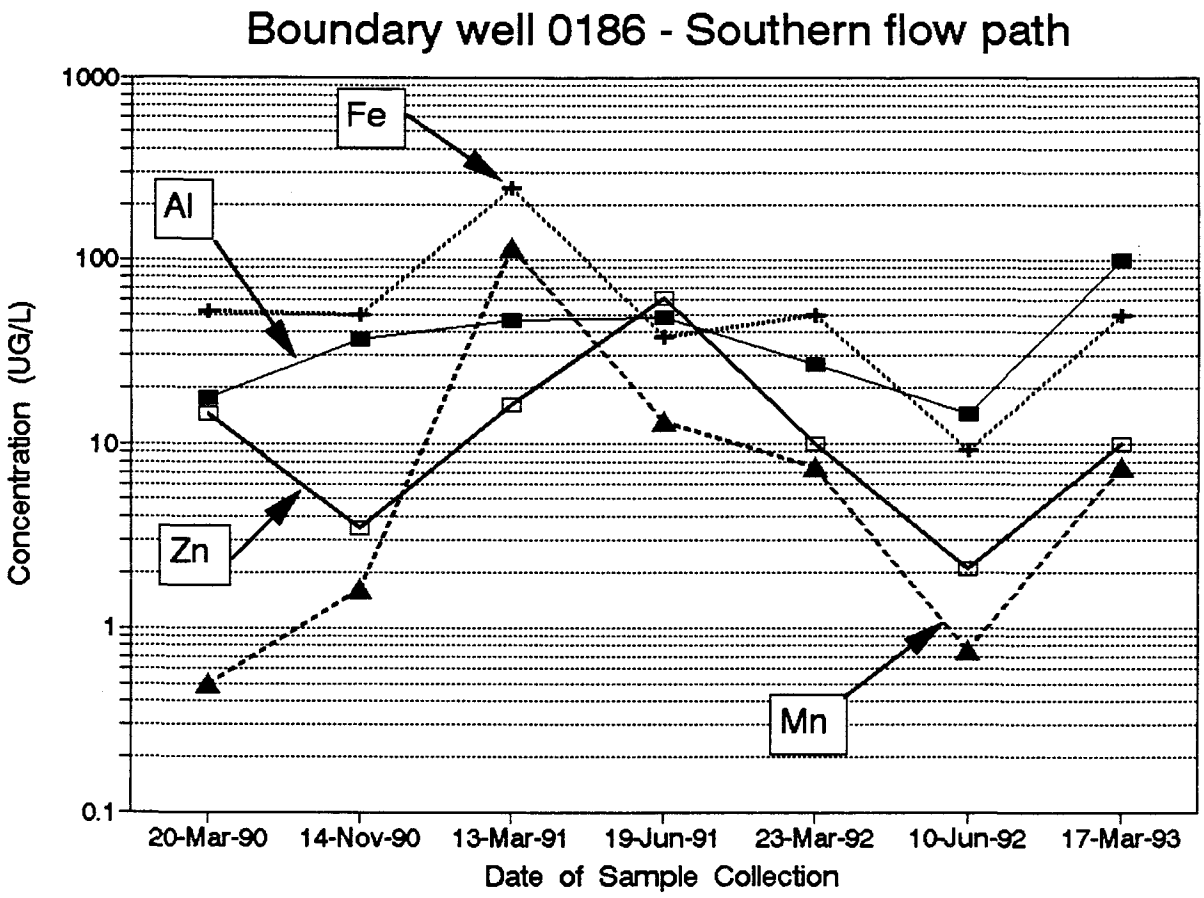
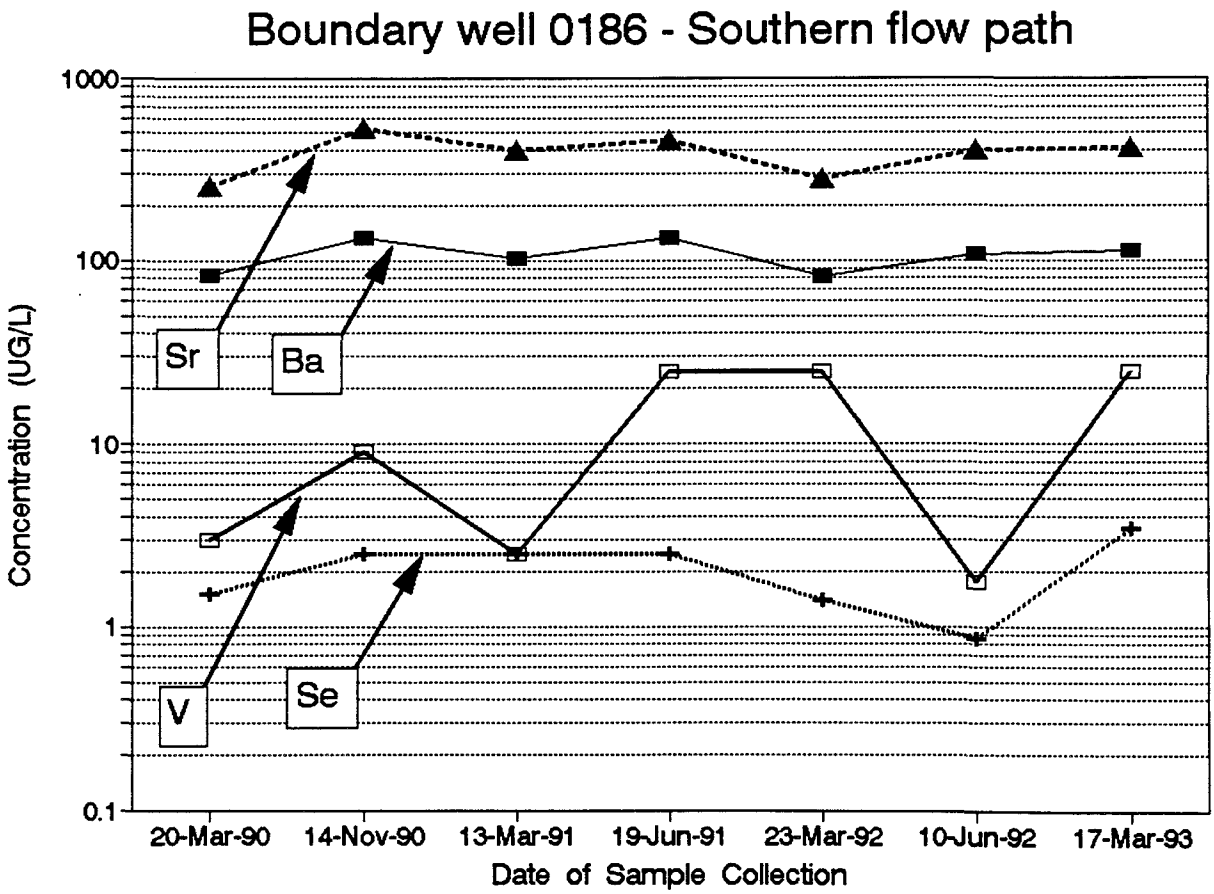
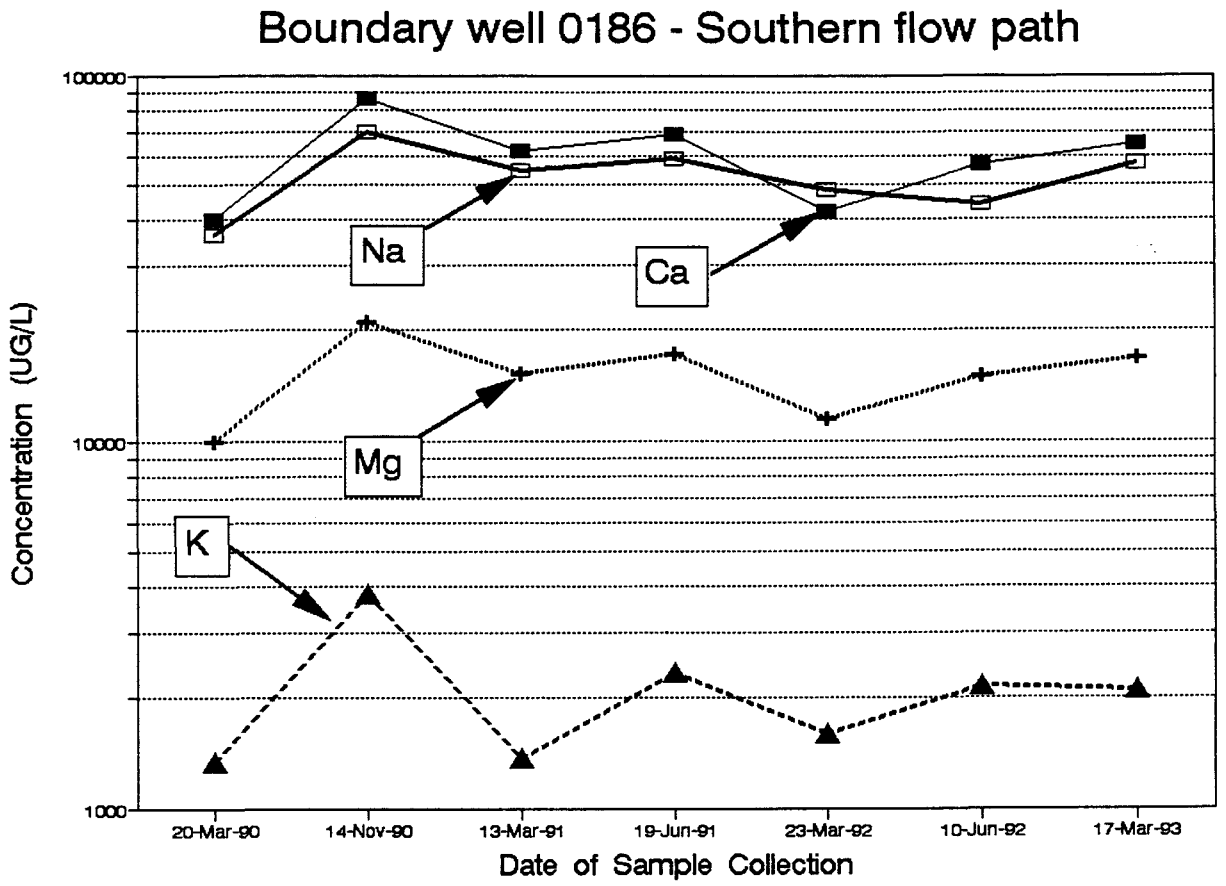
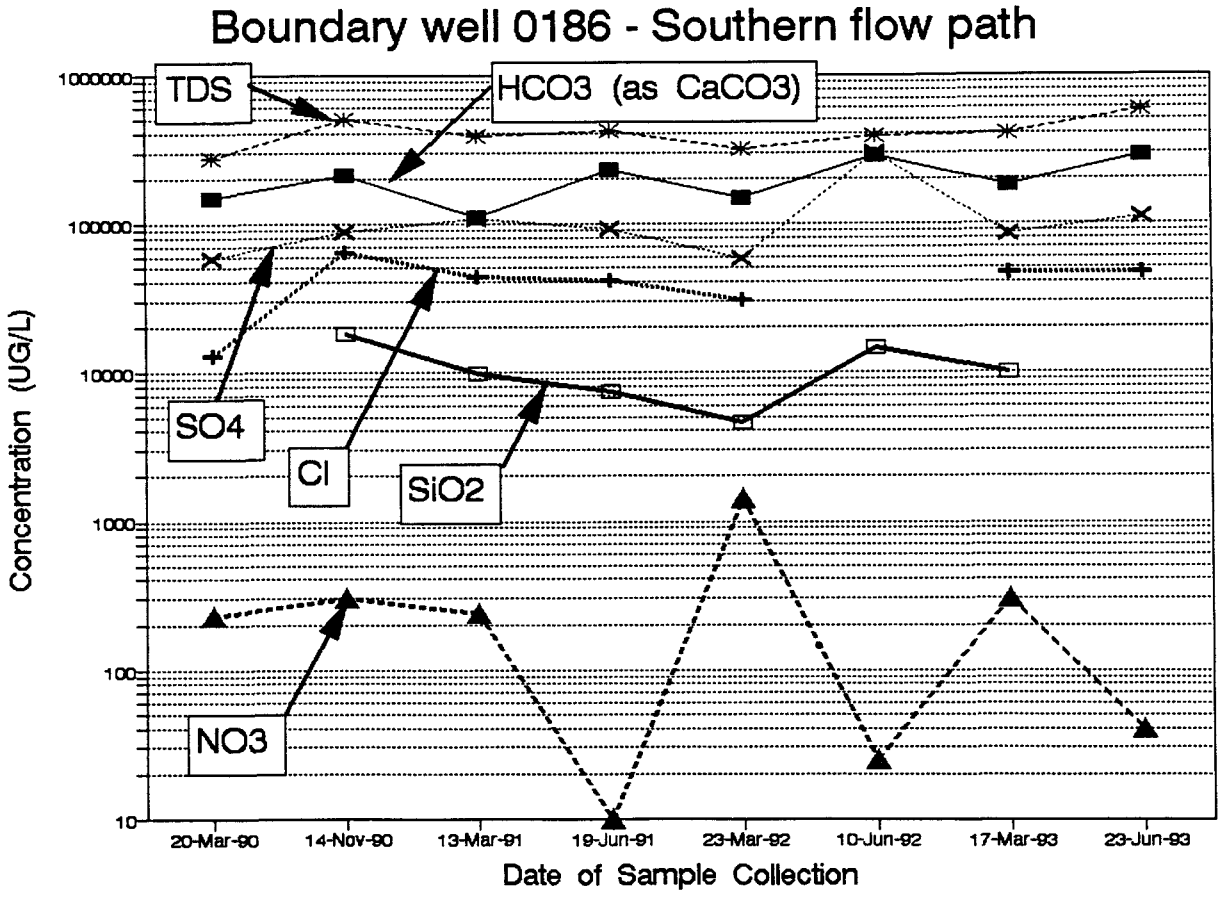
06-Nov-92
21-Mar-93
Date of Sample Collection

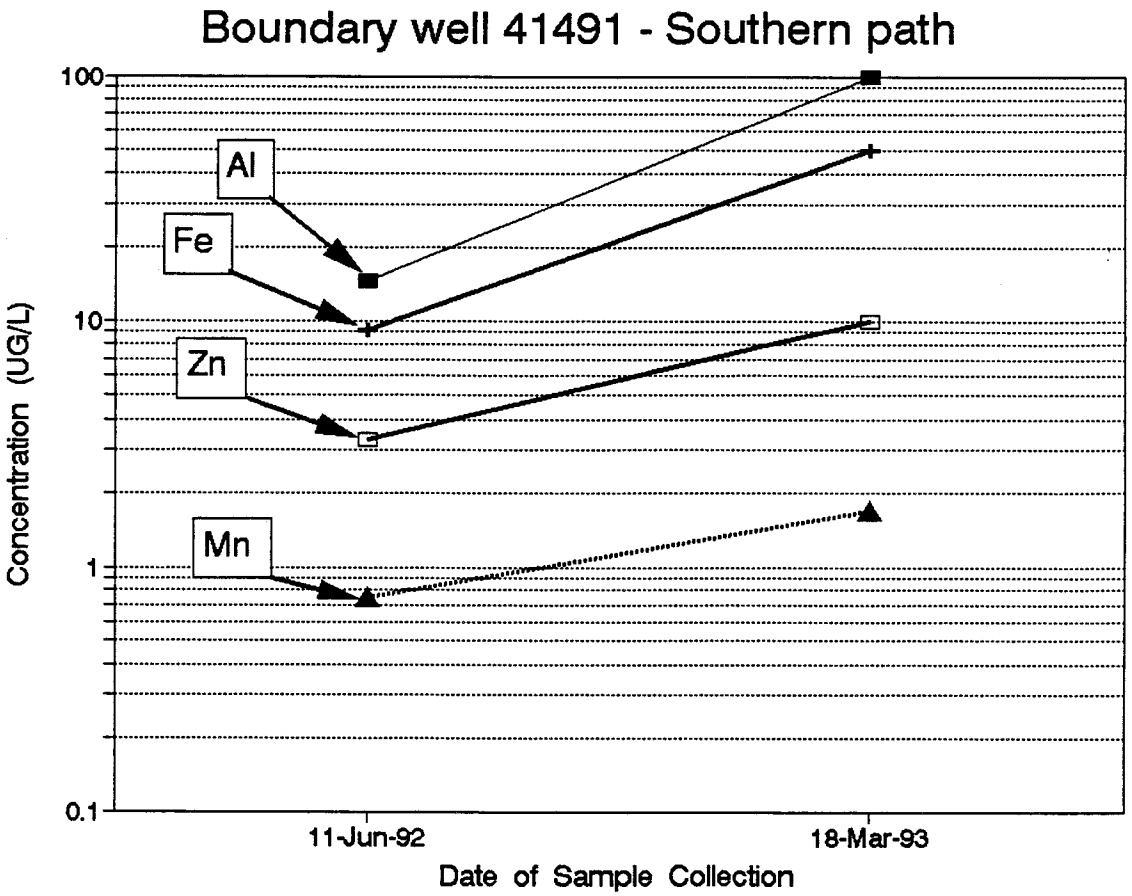

Well B302989 - Southern flow path
TDS
SiO2
SO4
Cl
HCO3 (as CaCO3)
NO3
Concentration (UG/L)
1000000
100000
10000
1000
100
10
01-Feb-90
23-May-90
06-Aug-90
05-Dec-90
22-Mar-91
20-May-91
29-Aug-91
07-Dec-91
21-Feb-92
04-Jun-92
13-Aug-92
06-Nov-92
21-Mar-93
Date of Sample Collection

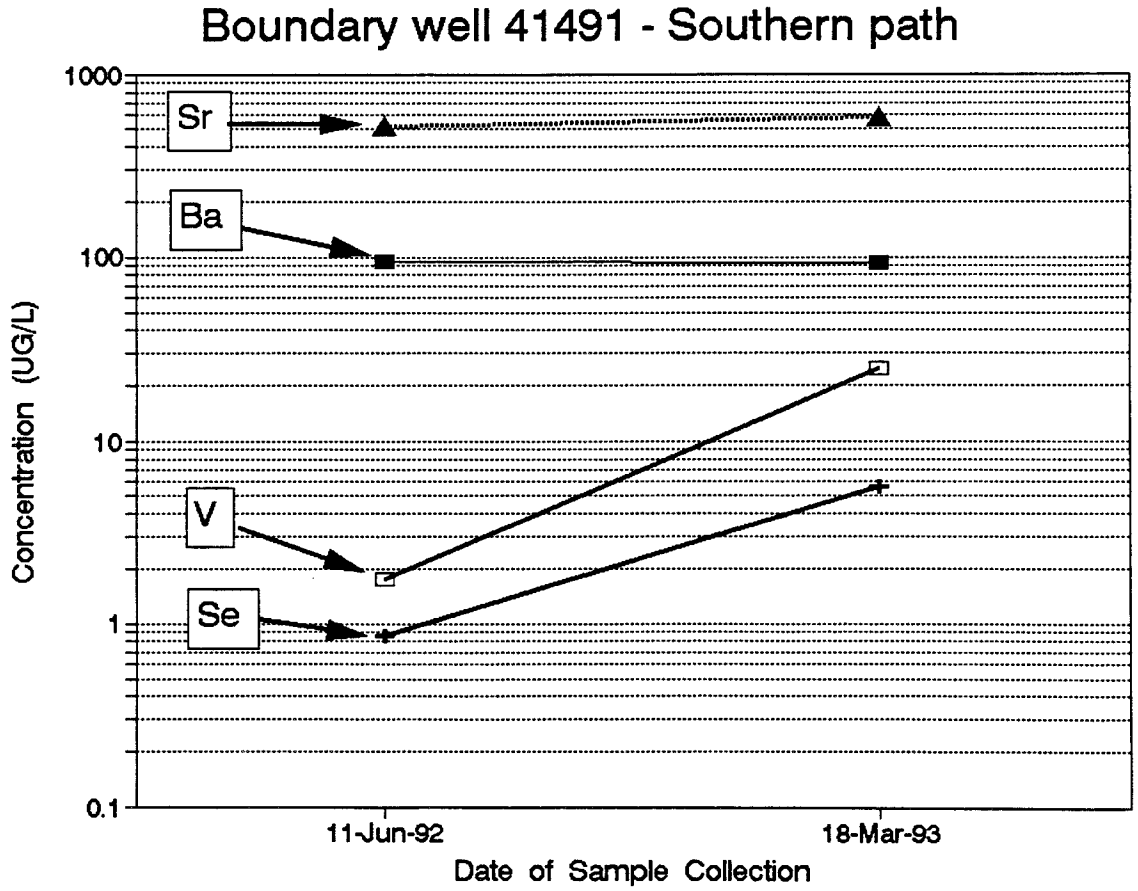

Boundary well 0186 - Southern flow path
Fe
Al
Zn
Mn
1000
100
10
1
0.1
Concentration (UG/L)
20-Mar-90
14-Nov-90
13-Mar-91
19-Jun-91
23-Mar-92
10-Jun-92
17-Mar-93
Date of Sample Collection

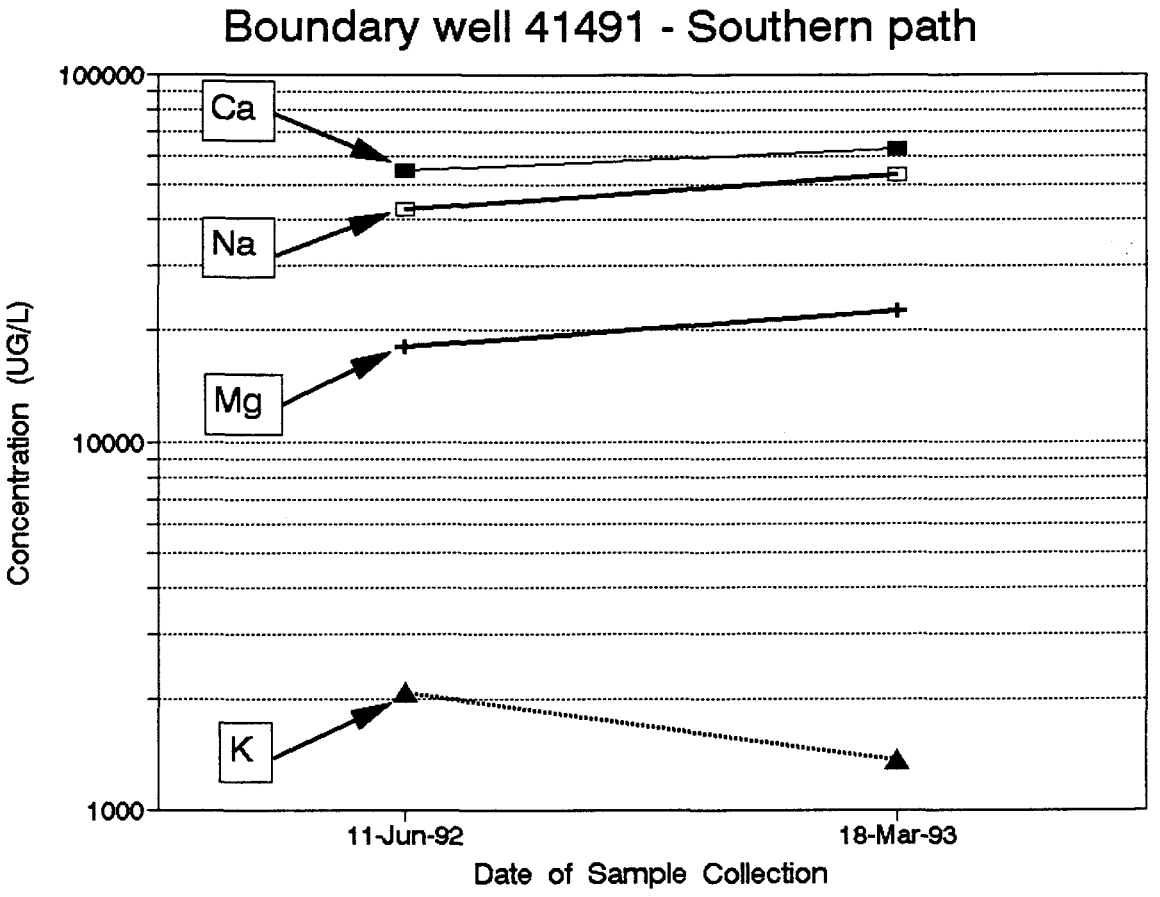

Boundary well 0186 - Southern flow path
Sr
Ba
V
Se
1000
100
10
1
0.1
Concentration (UG/L)
20-Mar-90
14-Nov-90
13-Mar-91
19-Jun-91
23-Mar-92
10-Jun-92
17-Mar-93
Date of Sample Collection

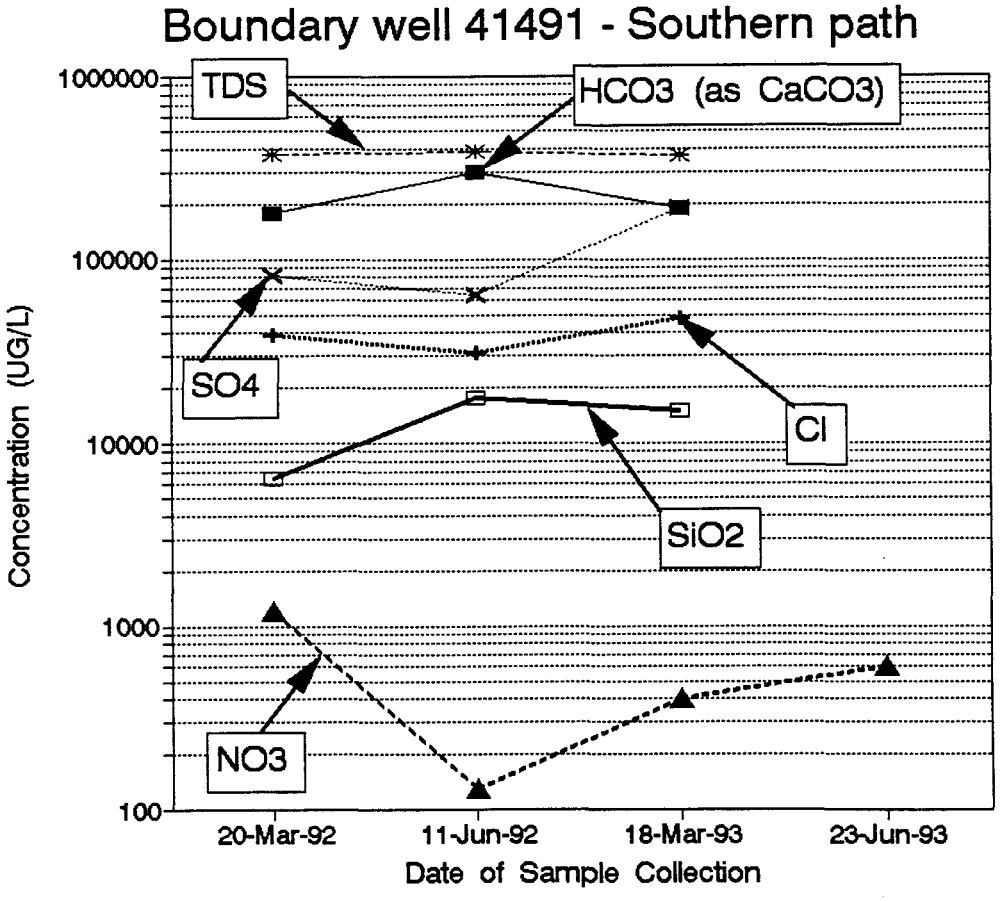

Boundary well 0186 - Southern flow path
100000
10000
1000
Concentration (UG/L)
Na
Ca
Mg
K
20-Mar-90
14-Nov-90
13-Mar-91
19-Jun-91
23-Mar-92
10-Jun-92
17-Mar-93
Date of Sample Collection


Boundary well 0186 - Southern flow path
1000000
100000
10000
1000
100
10
Concentration (UG/L)
TDS
HCO3 (as CaCO3)
SO4
Cl
SiO2
NO3
20-Mar-90
14-Nov-90
13-Mar-91
19-Jun-91
23-Mar-92
10-Jun-92
17-Mar-93
23-Jun-93
Date of Sample Collection


Boundary well 41491 - Southern path
100
10
1
0.1
Concentration (UG/L)
Al
Fe
Zn
Mn
11-Jun-92
18-Mar-93
Date of Sample Collection


Boundary well 41491 - Southern path
1000
100
10
1
0.1
Concentration (UG/L)
Sr
Ba
V
Se
11-Jun-92
18-Mar-93
Date of Sample Collection


Boundary well 41491 - Southern path
100000
10000
1000
Concentration (UG/L)
Ca
Na
Mg
K
11-Jun-92
18-Mar-93
Date of Sample Collection


Boundary well 41491 - Southern path
1000000
100000
10000
1000
100
Concentration (UG/L)
TDS
HCO3 (as CaCO3)
SO4
Cl
SiO2
NO3
20-Mar-92
11-Jun-92
18-Mar-93
23-Jun-93
Date of Sample Collection

F1. Geostatistical Analyses of Mean-Concentration Data for Groundwater

Kriging was used to evaluate the spatial variations in mean-concentration values for select analytes in groundwater (i.e., the mean concentration at each monitoring well location). Kriging is a linear-estimation technique that interpolates between the linear combinations of the random variables, in this case the mean concentration of an analyte in groundwater. The predicted or estimated values account for the uncertainty and configuration of the random variables and the spatial continuity of these measurements. Geostatistical analysis of the random variables (concentration values) was used to construct isoconcentration maps through the following steps: (1) evaluate the probabilistic nature of the random variables (i.e., determine the distribution of the mean concentrations), (2) determine the spatial correlation of the random variables, (3) perform a structural analysis of the spatially distributed data, (4) perform the linear interpolation technique known as ordinary kriging to simulate the estimated concentrations, and (5) present the simulations in the form of contour maps. The first four steps were performed using the Geostatistical Software Library (GSLIB) software package (Deutsch and Journel, 1992; Dovala and Ellerbroek, 1994). The SURFER™ software package was used to contour the simulated output from GSLIB.

F1.1 Step 1: Probalistic Nature of the Random Variables

The probabilistic nature of the random variables (Zx) was achieved by constructing histograms of the mean concentrations to determine the probability distribution. The histograms indicated that the selected ions were lognormally distributed. Kriging requires a normal distribution of the random variables; therefore, the data were normalized by a log-transformation (Cooper *et al.*, 1988).

Negative and zero values made log-transformations of uranium-235 measurements impossible; therefore, these measurements were normalized using a normal score transformation (Deutsch and Journel, 1992).

F1.2 Step 2: Spatial Correlation of the Random Variables

The spatial continuity of the data changes as a function of distance and direction. These relationships were analyzed with an omnidirectional semivariogram (only for isotropic cases), which assumes that the direction of the separation vector $h_{(i,j)}$ (the vector between two points in space) is inconsequential. The omnidirectional semivariogram $\Upsilon_{(h)}$ generally defines the average of the various directions of $h_{(i,j)}$. The magnitude of $h_{(i,j)}$ becomes important in the estimation of the experimental semivariogram $\Upsilon^*_{(h)}$ for isotropic cases. A more detailed discussion of experimental

semivariograms is given by Cooper *et al.* (1988), Deutsch and Journel (1992), and Isaaks and Srivastava (1989).

F1.3 Step 3: Structural Analysis

The structural analysis was conducted by fitting a spherical mathematical model or function to the experimental semivariogram. The spatial offset from the origin observed on the semivariograms is termed the nugget effect. This spatial discontinuity at the origin is generally caused by sampling/measurement error and/or "short" scale variability. The separation distance $h_{(i,j)}$ where the semivariogram begins to plateau is defined as the range. The range is the point on the semivariogram where the data lose spatial correlation. The sill is defined as the plateau value at which the semivariogram reaches the range (Isaaks and Srivastava, 1989). Generally, a structural analysis of the concentration data from the LHSU could not be performed due to the asymmetrical distribution and lack of spatial continuity of the data. This may be attributed to the discontinuous nature of the LHSU sandstone units being monitored (EG&G, 1994). Calcium and magnesium were the only LHSU analytes that showed a symmetrical distribution and adequate spatial correlation required for kriging. The necessary input parameters for the structural analysis are presented on the model semivariograms.

F1.4 Step 4: Ordinary Kriging

The fitted spherical model was used in the ordinary kriging analysis. Specifically, the nugget, range, and sill were important input parameters for this linear-estimation technique. Ordinary kriging is theoretically "unbiased" because of the numerical attempt to reduce the mean residuals or errors to zero and to minimize the variance of the errors. Point estimates were used to generate the simulated values (Isaaks and Srivastava, 1989). The log-transformed values $Y_{(x)}$ were backtransformed by taking the exponential of $Y_{(x)}$ plus half the estimated variance s^2 where

$Z_{(x)} = \exp. [Y_{(x)} + s^2]$ (Cooper *et al.*, 1988).

The normal score back transformation $Z_{(x)}$ of the "standard normal deviate" y_i is given by

$$Z_{(x)} = F^1 (G(y_i))$$

where $F_{(x)}$ is the declustered cumulative distribution function (cdf) of the data and $G(y_i)$ being the standard normal cdf (Deutsch and Journel, 1992). Below are the input parameters used in GSLIB for the ordinary kriging analysis.

2-D Ordinary Kriging: Input Parameters

Min. and Max.	Debug Options
Min: -100,000	Debugging Level: 1
Max: 100,000	Debug File: __

Radius: 40,000
Nugget: "Based on Structural Analysis"

Block Dimensions

X Block Size: 1	Min. # Data: 5
Y Block Size: 1	Max. # Data: 10

Grid Dimensions - UHSU

X: 50	X-Intercept: 2076000	X Spacing: 363
Y: 50	Y-Intercept: 741900	Y Spacing: 326

Grid Dimensions - LHSU

X: 50	X-Intercept: 2078000	X Spacing: 323
Y: 50	Y-Intercept: 2094150	Y Spacing: 244

(grid dimensions reported in state plane coordinates)

F1.5 Step 5: Contouring of the Simulated Values

The simulated estimates generated from the ordinary kriging analysis were contoured using the SURFER™ software package. For optimal unbiased results (i.e., prohibited reestimation of the simulated values by the SURFER™ gridding), the following gridding procedures were followed: (1) the grid size in SURFER™ was identical to the grid dimensions used in GSLIB (50 x 50), (2) the nearest number of search points was set to one, (3) the Inverse Distance Method with a weighted power function set to one was chosen, and (4) the Octant Search Method was used. The above procedure provides a SURFER™ grid file identical to the simulated output from GSLIB. The SURFER™ grid file was contoured using the SURFER™ TOPO module. This procedure is described in greater detail by Shan and Stephens (1994).

F1.6 References

Cooper, Richard M., and Jonathan D. Istok, 1988, Geostatistics Applied to Groundwater Contamination. I: Methodology. Journal of Environmental Engineering, Vol. 114, No. 2. April, 1988. p. 270-285.

Deutsch, Clayton V., and Andre G. Journel, 1992, GSLIB: Geostatistical Software Library and User's Guide: Oxford University Press, New York, NY. 340 p.

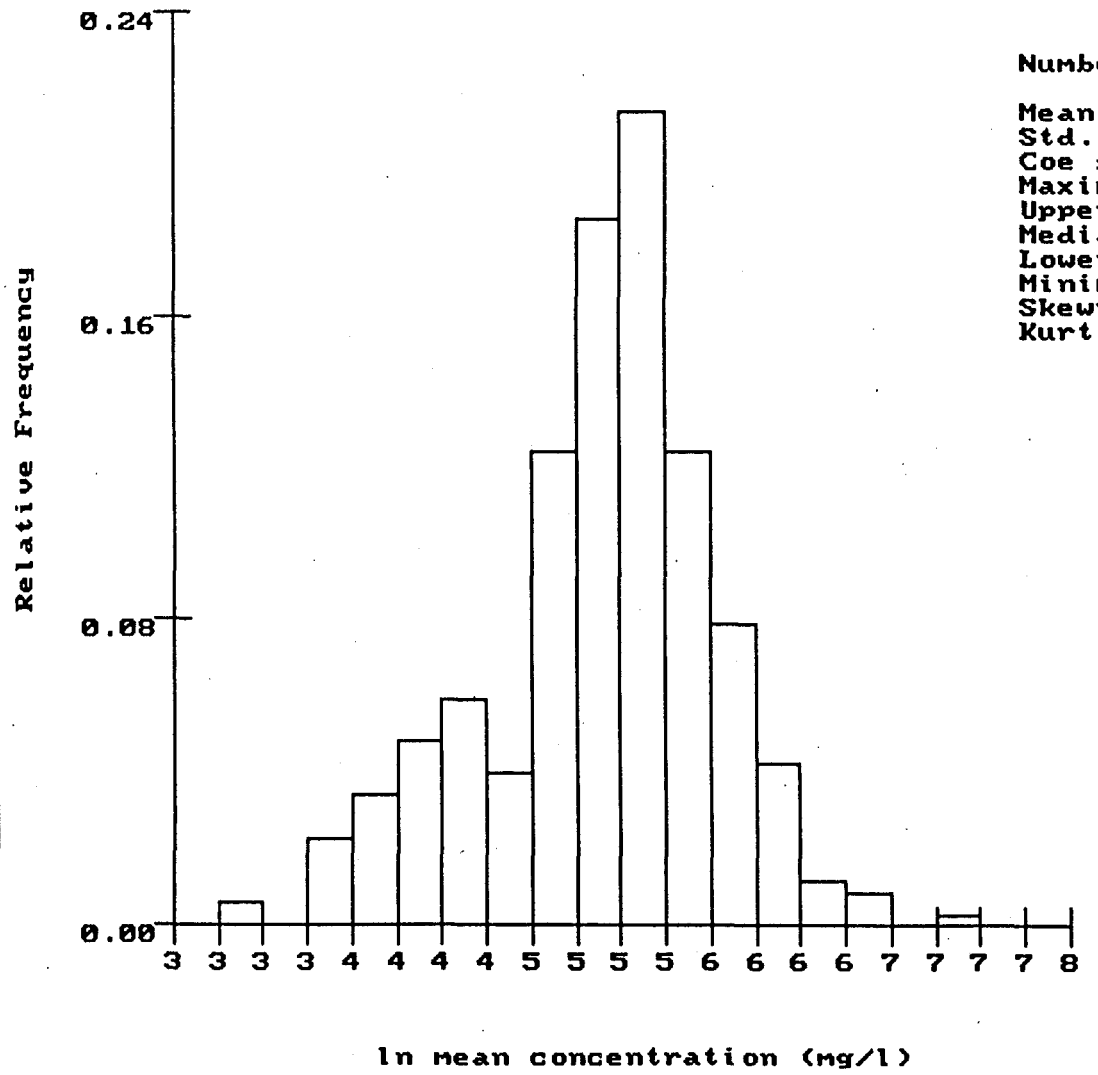
Dovala, Erika, and David Ellerbroek, 1994, GSLIB: Geostatistical Software Library Menu Interface User's Guide: S.M. Stoller Corporation, Boulder, CO. 122 p.

EG&G, 1994, Geologic Characterization Report - Draft: EG&G Rocky Flats, Inc., Golden, CO.

Isaaks, Edward H., and R. Mohan Srivastava, 1989, An Introduction to Applied Geostatistics: Oxford University Press, New York, NY. 551 p.

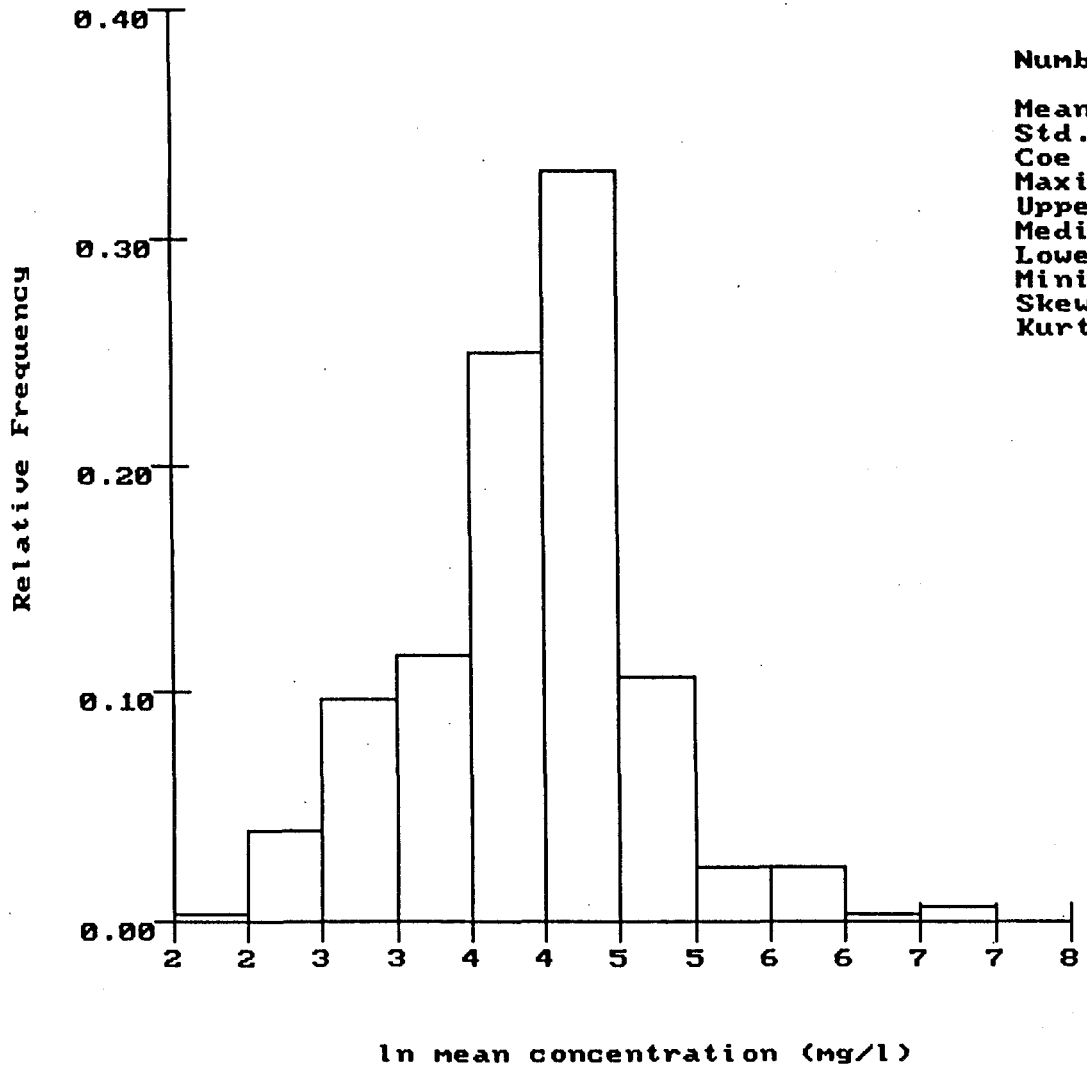
Shan, Chao, and Daniel B. Stephens, 1994, Recommendations for Usage of SURFER to Gridding Model Results: Ground Water, Vol. 32, No. 3. May-June 1994, p. 503-506.

UHSU BICARBONATE MEAN ln CONCENTRATION



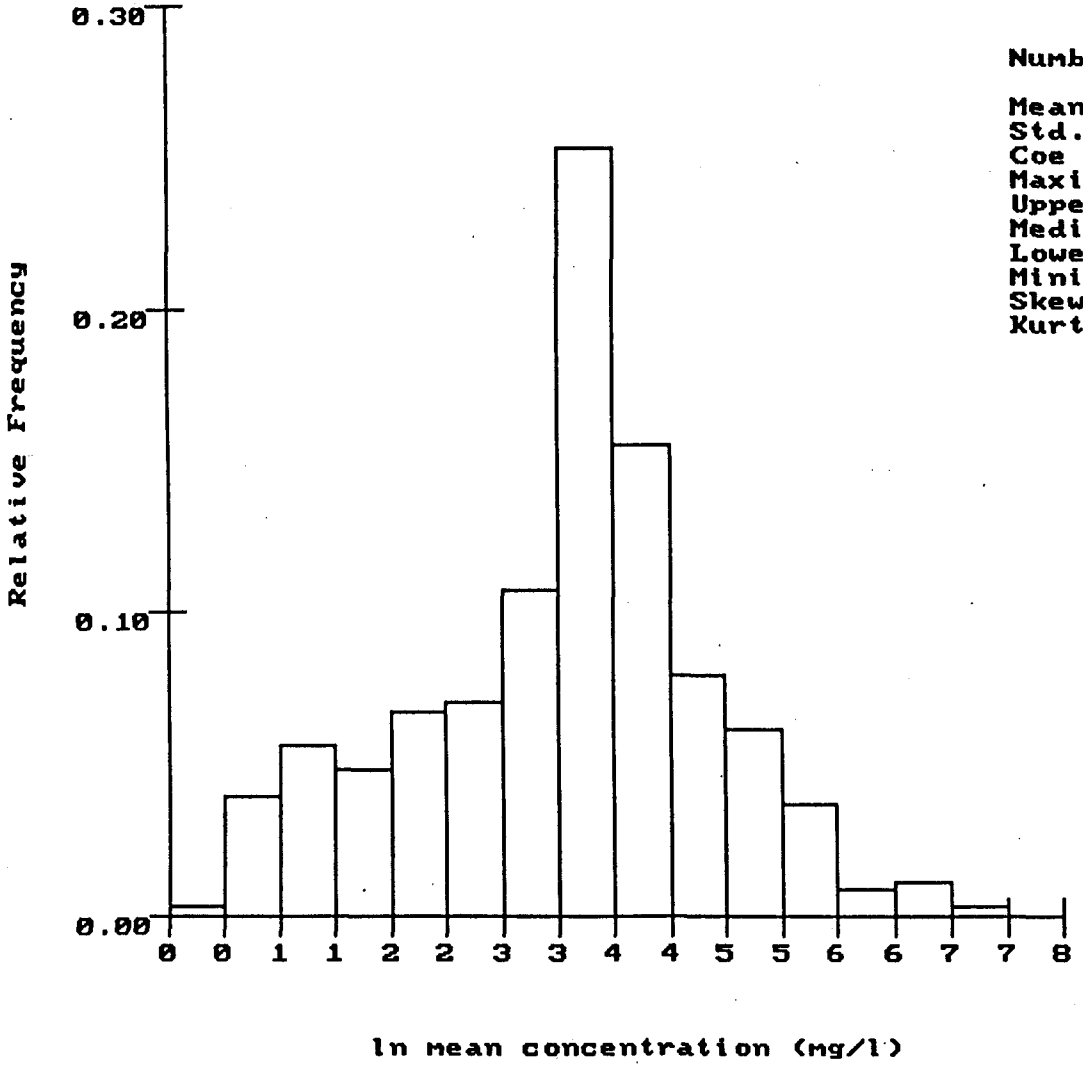
Number of Data	355
Mean	5.387
Std. Dev.	.635
Coe f. of Var	.118
Maximum	7.270
Upper Quartile	5.760
Median	5.460
Lower Quartile	5.110
Minimum	3.280
Skewness	.957
Kurtosis	2.420

UHSU CALCIUM LN MEAN CONCENTRATION



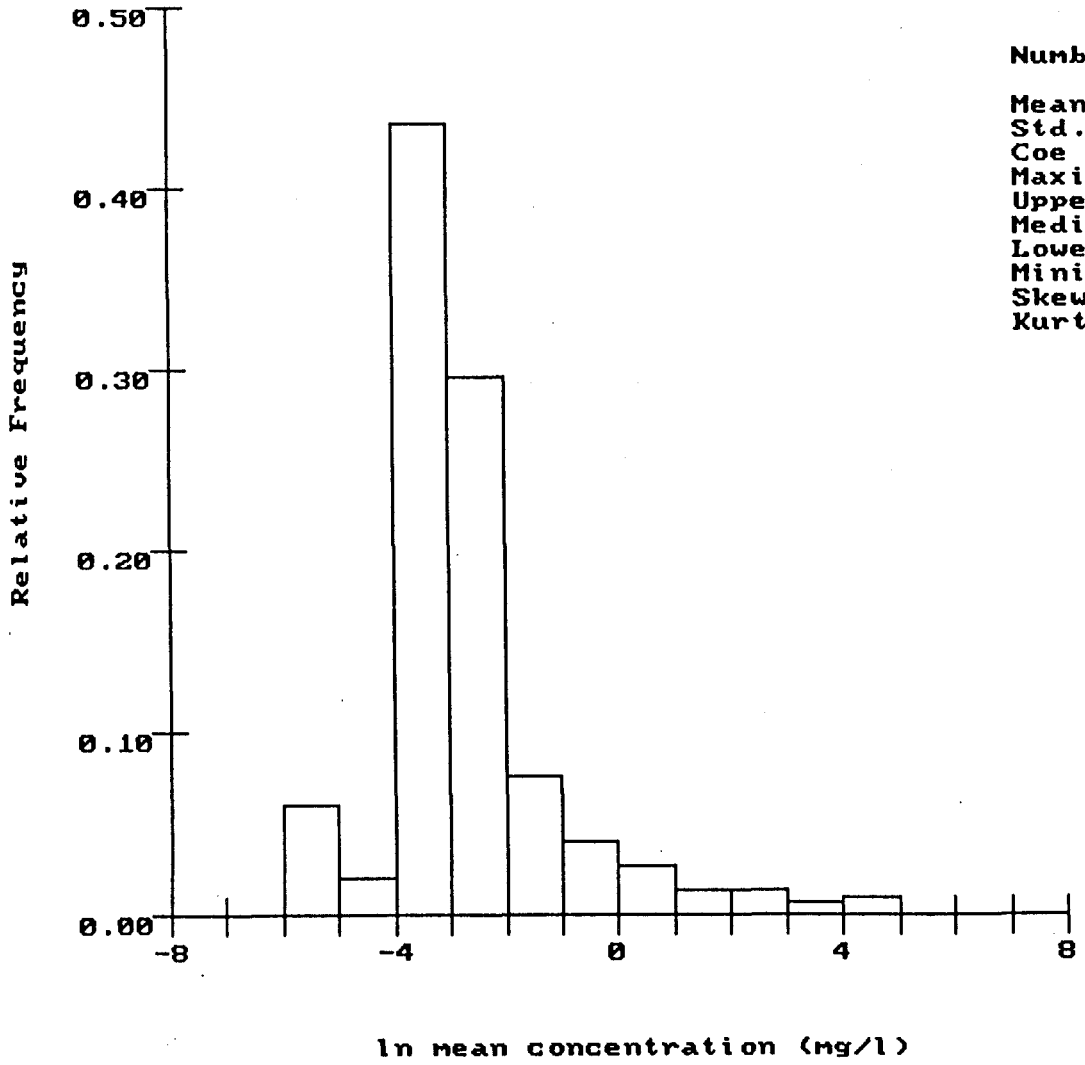
Number of Data	300
Mean	4.399
Std. Dev.	.787
Coe f. of Var	.179
Maximum	7.390
Upper Quartile	4.800
Median	4.490
Lower Quartile	3.980
Minimum	2.440
Skewness	1.285
Kurtosis	3.823

UHSU CHLORIDE ln MEAN CONCENTRATION



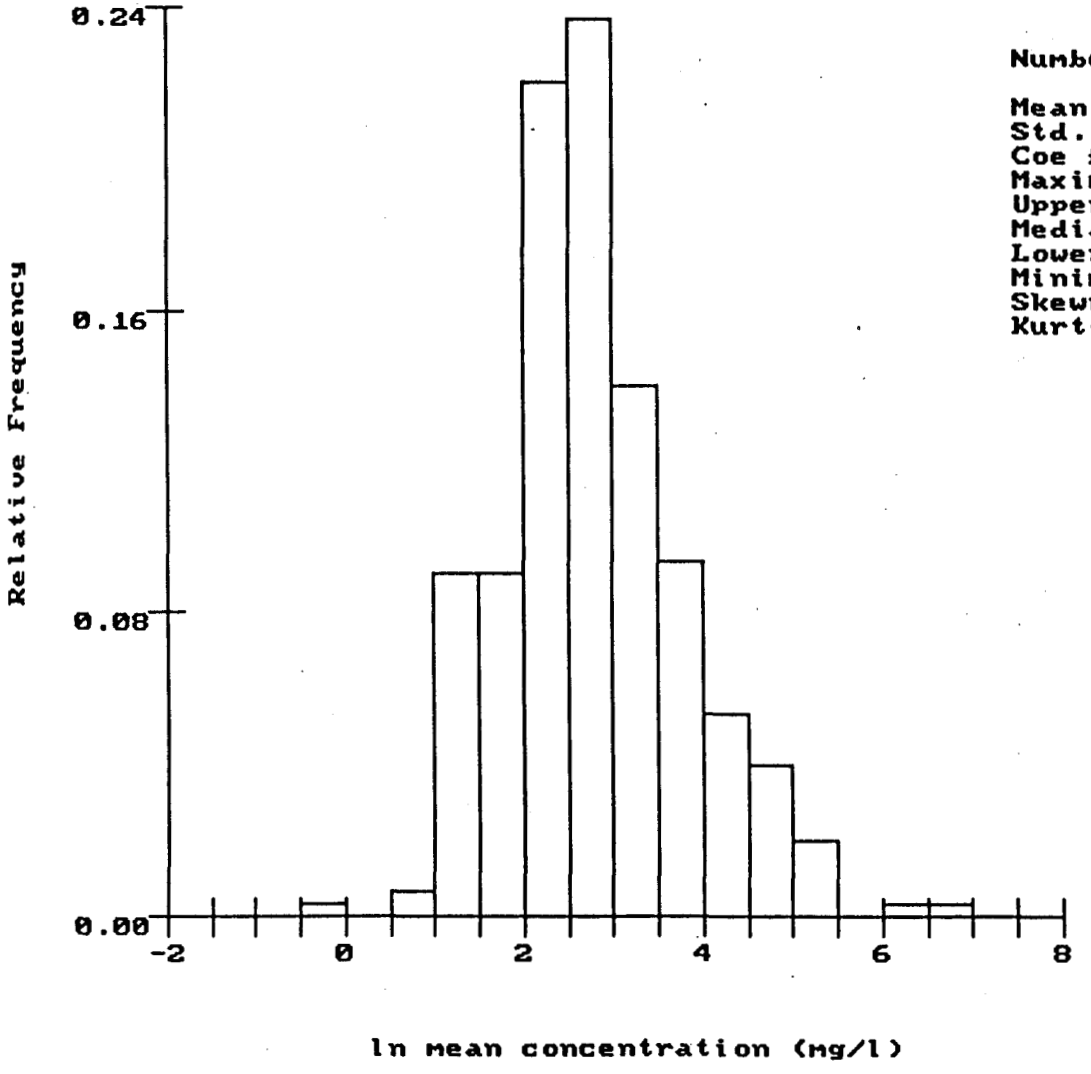
Number of Data	355
Mean	3.544
Std. Dev.	1.312
Coe f. of Var	.370
Maximum	7.440
Upper Quartile	4.305
Median	3.730
Lower Quartile	2.805
Minimum	.410
Skewness	.857
Kurtosis	2.581

UHSU IRON MEAN ln CONCENTRATION



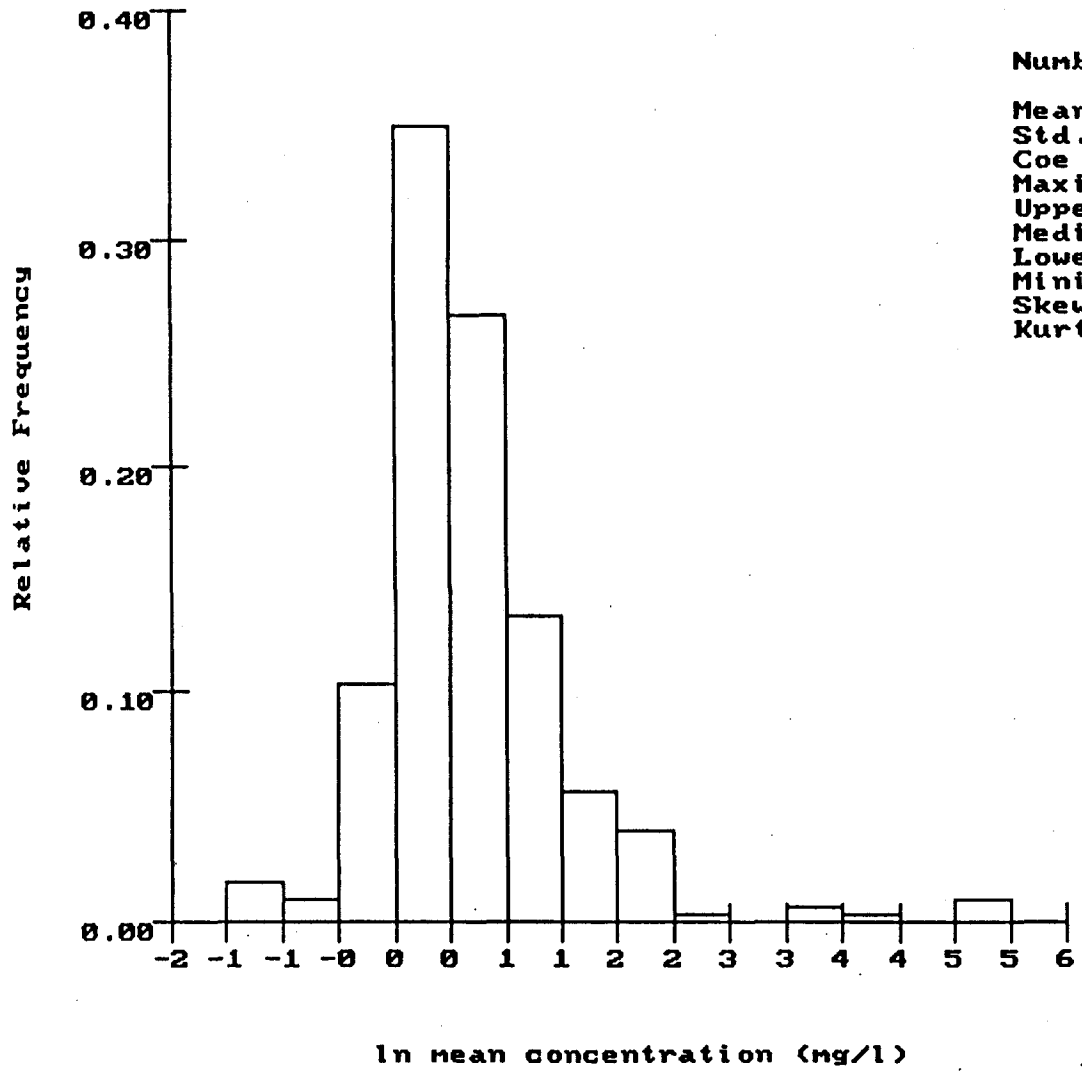
Number of Data	300
Mean	-2.691
Std. Dev.	1.617
Coe f. of Var	-.601
Maximum	4.300
Upper Quartile	-2.555
Median	-3.025
Lower Quartile	-3.370
Minimum	-5.990
Skewness	.346
Kurtosis	4.257

UHSU MAGNESIUM MEAN ln CONCENTRATION



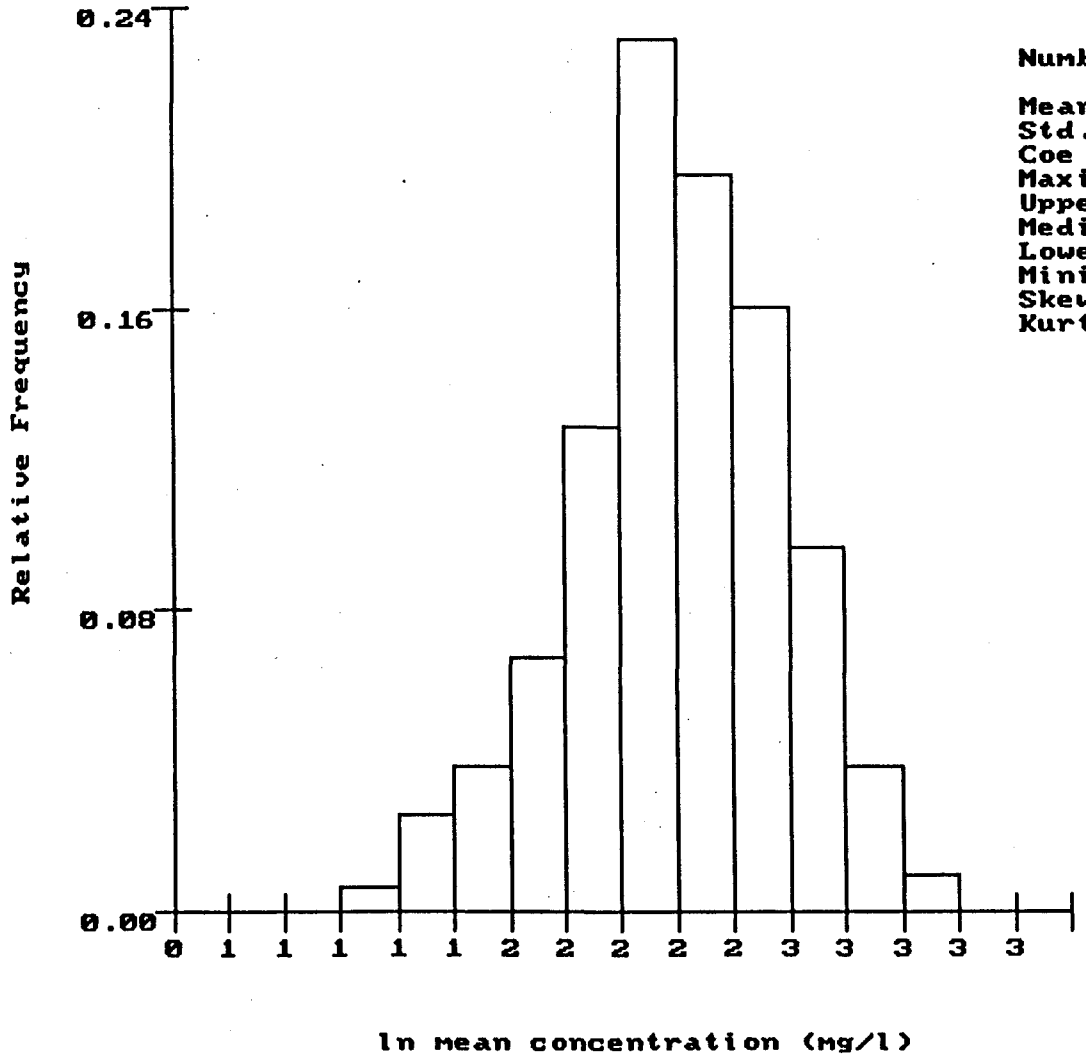
Number of Data	300
Mean	2.773
Std. Dev.	.995
Coe f. of Var	.359
Maximum	6.520
Upper Quartile	3.355
Median	2.640
Lower Quartile	2.200
Minimum	-.240
Skewness	1.644
Kurtosis	3.616

UHSU POTASSIUM MEAN ln CONCENTRATION



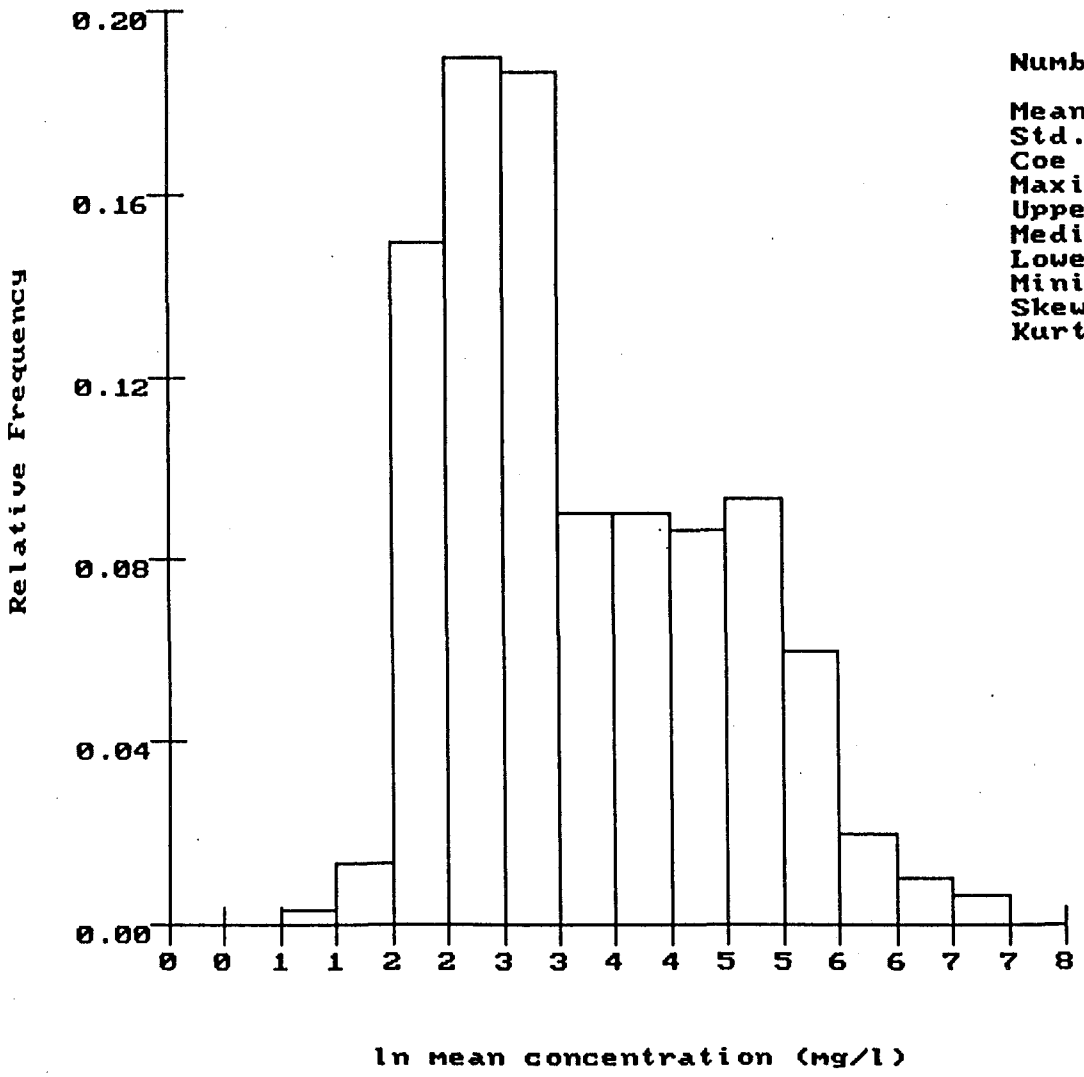
Number of Data	300
Mean	.690
Std. Dev.	.849
Coe f. of Var	1.230
Maximum	5.200
Upper Quartile	1.020
Median	.535
Lower Quartile	.195
Minimum	-1.090
Skewness	2.303
Kurtosis	7.654

UHSU: SILICA ln MEAN CONCENTRATION



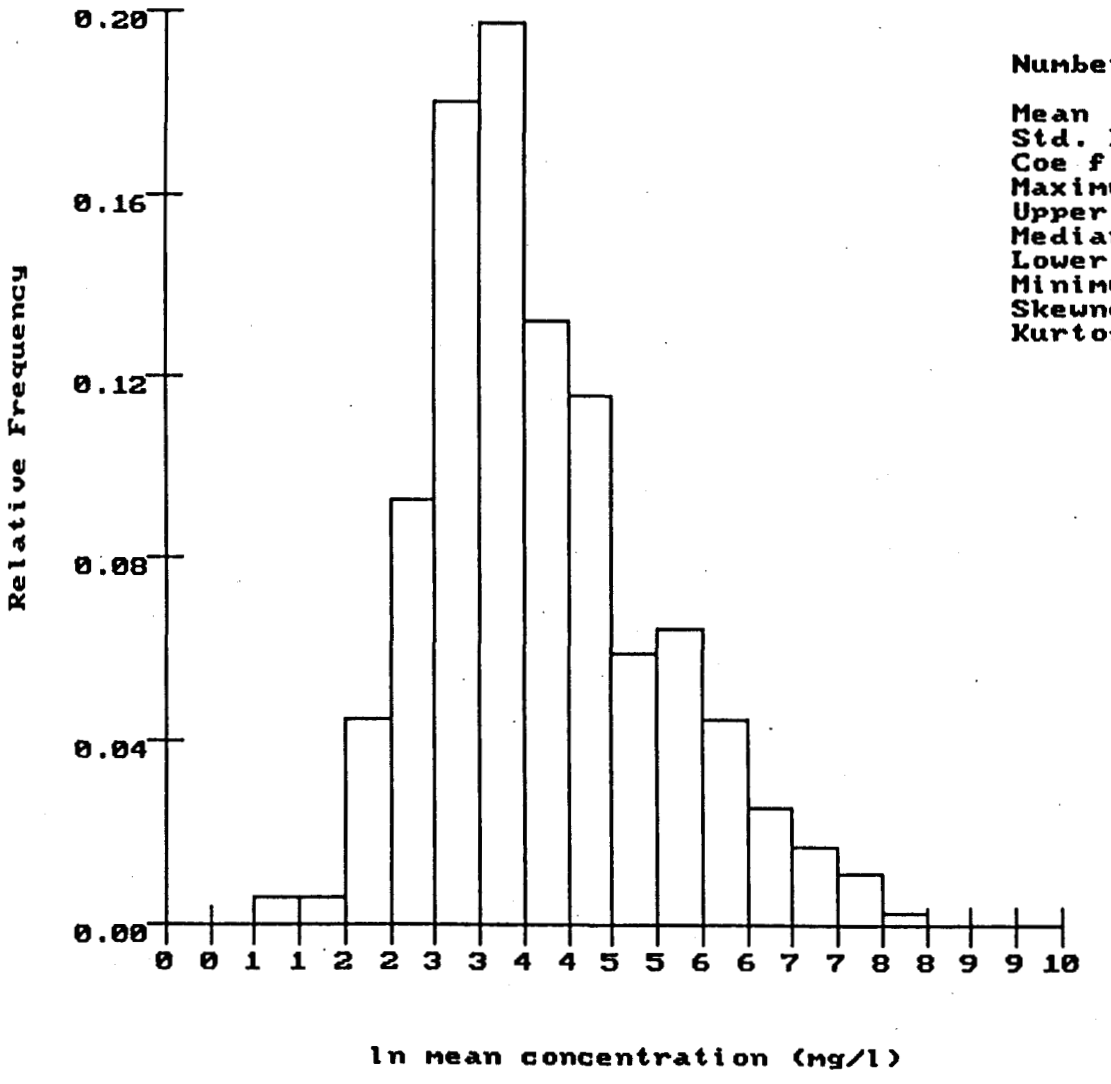
Number of Data	311
Mean	2.605
Std. Dev.	.377
Coe f. of Var	.145
Maximum	3.680
Upper Quartile	2.868
Median	2.610
Lower Quartile	2.370
Minimum	1.500
Skewness	1.283
Kurtosis	1.828

UHSU SODIUM MEAN ln CONCENTRATIONS



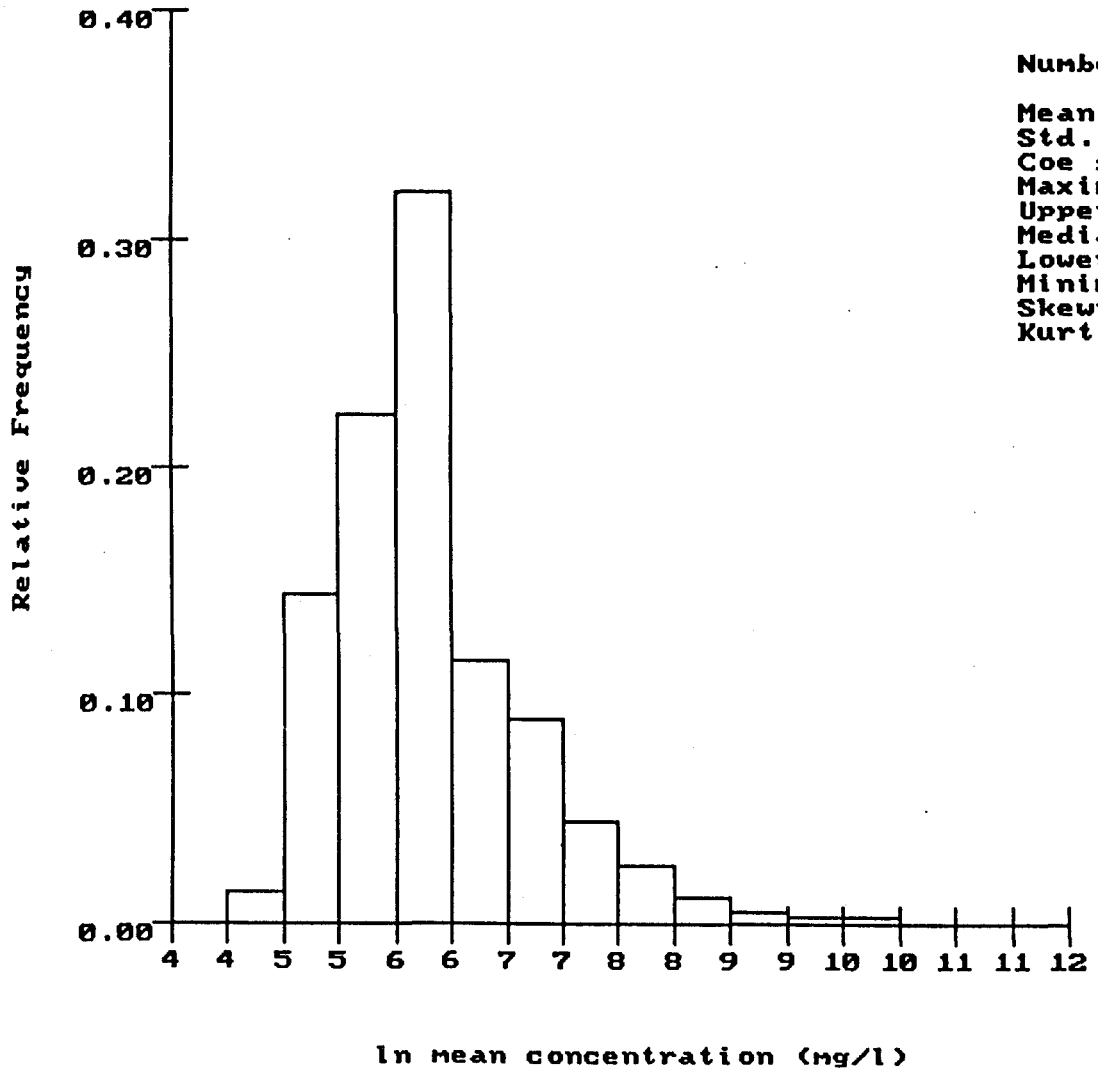
Number of Data	300
Mean	3.678
Std. Dev.	1.219
Coe f. of Var	.331
Maximum	7.540
Upper Quartile	4.670
Median	3.330
Lower Quartile	2.675
Minimum	1.350
Skewness	1.636
Kurtosis	3.405

UHSU SULFATE MEAN ln CONCENTRATION



Number of Data	355
Mean	4.170
Std. Dev.	1.250
Coe f. of Var	.300
Maximum	8.050
Upper Quartile	4.865
Median	3.920
Lower Quartile	3.250
Minimum	1.100
Skewness	1.053
Kurtosis	3.580

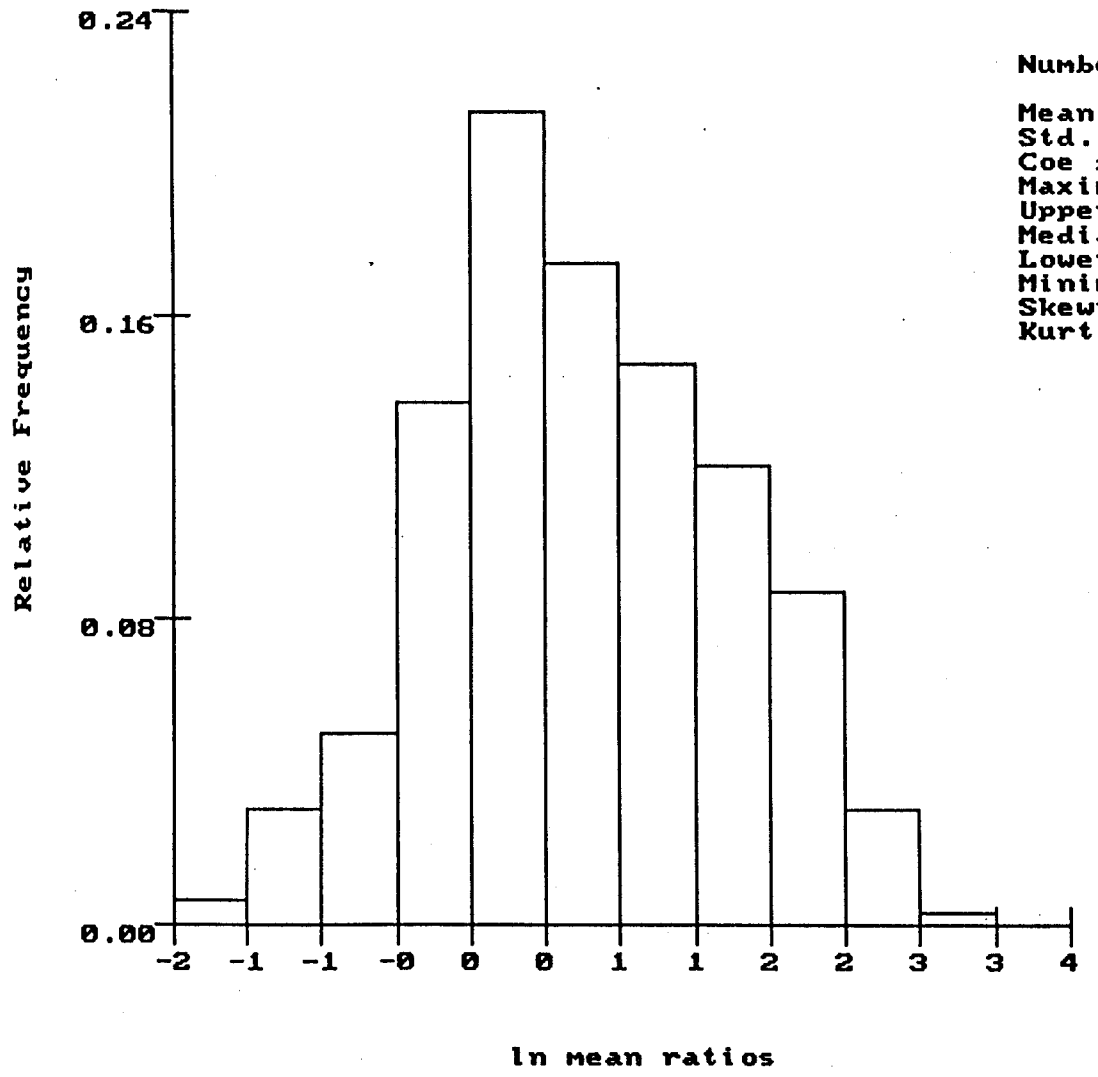
UHSU Total Dissolved Solids



Number of Data	355
Mean	6.291
Std. Dev.	.863
Coe f. of Var	.137
Maximum	10.380
Upper Quartile	6.637
Median	6.130
Lower Quartile	5.793
Minimum	4.650
Skewness	1.952
Kurtosis	6.224

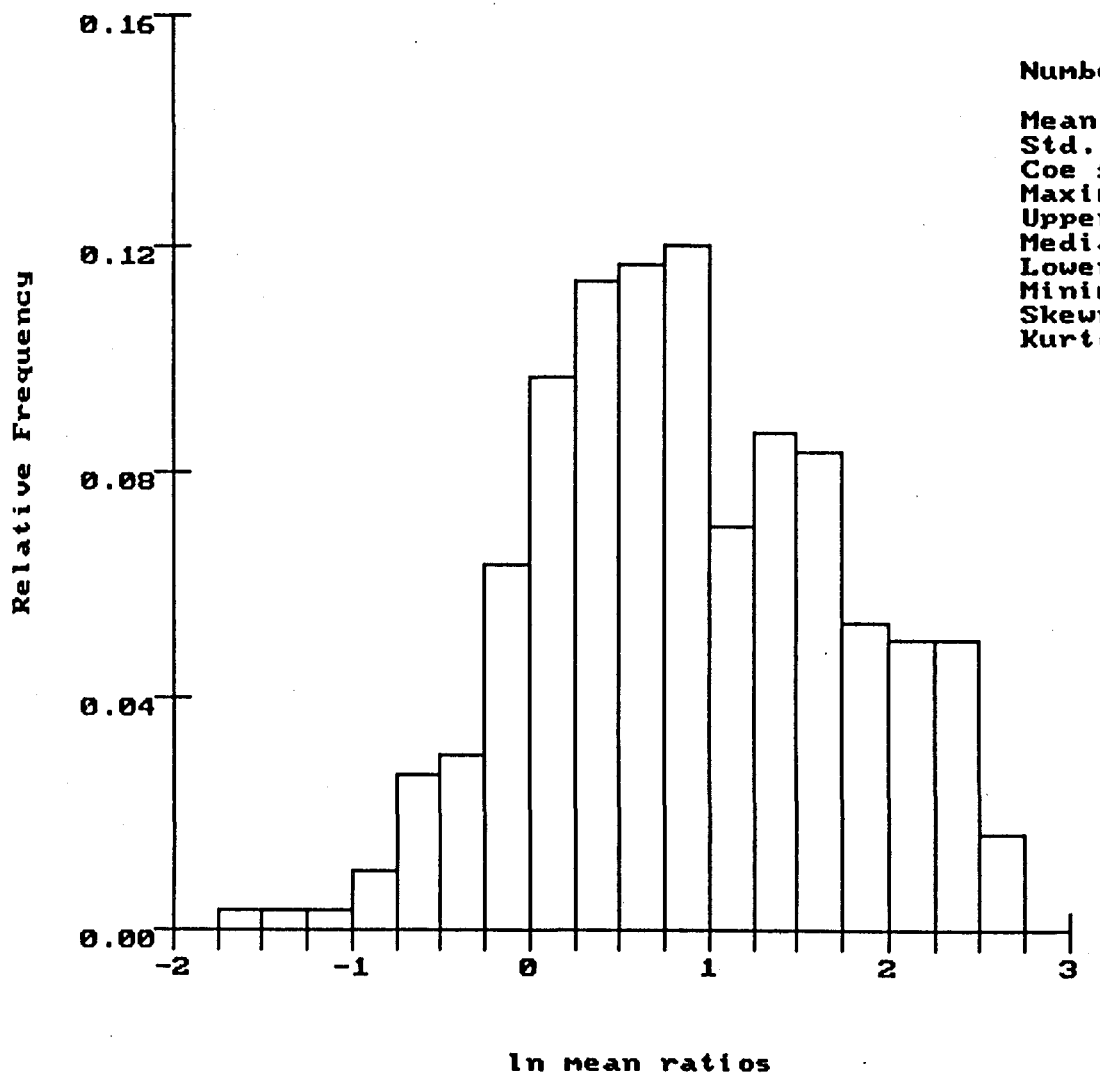
UHSU Ca/Na RATIOS

Values Based on Mean ln Concentrations



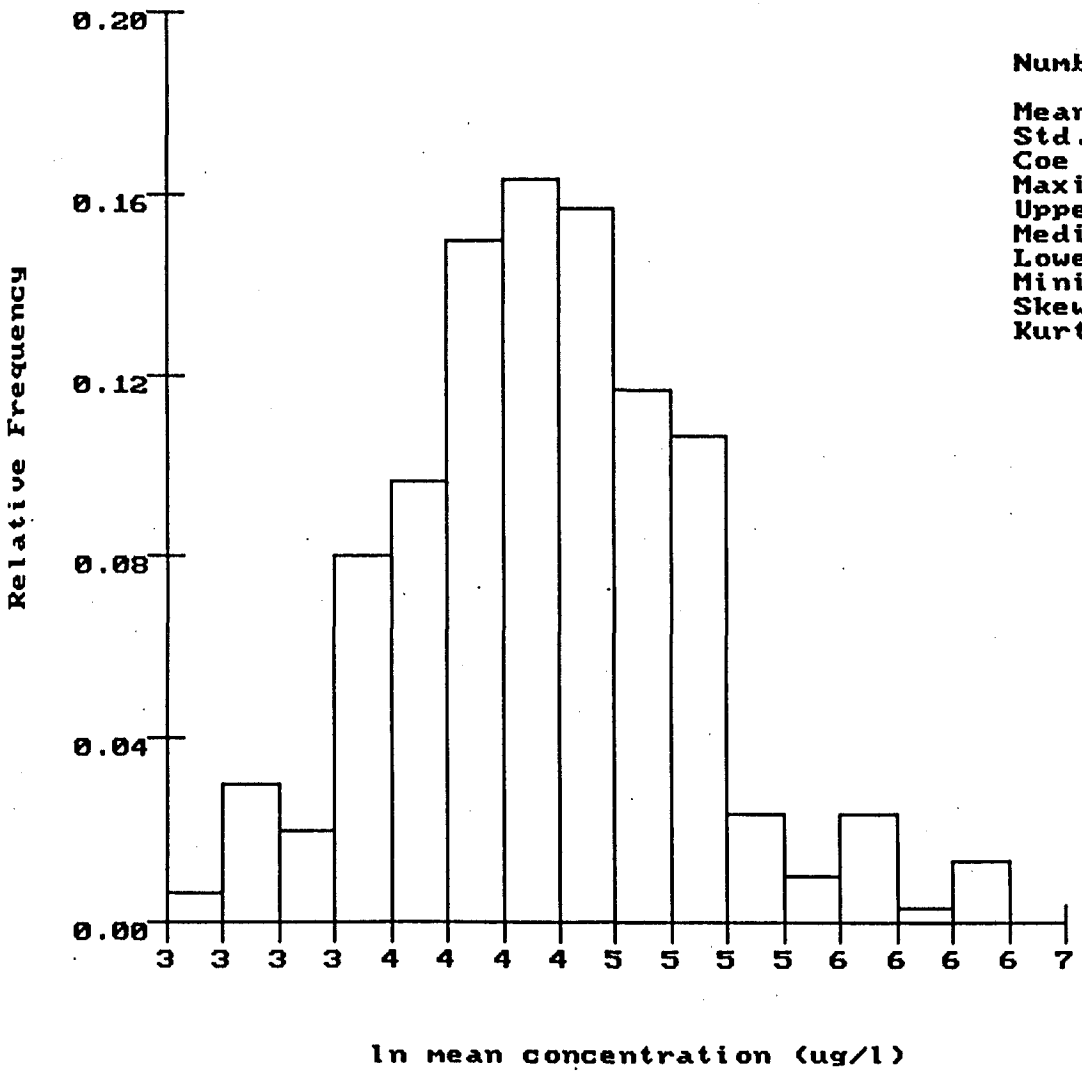
Number of Data	299
Mean	.751
Std. Dev.	.957
Coe f. of Var	1.273
Maximum	3.040
Upper Quartile	1.480
Median	.710
Lower Quartile	.090
Minimum	-1.850
Skewness	1.396
Kurtosis	2.564

UHSU Ca+Mg/Na+K



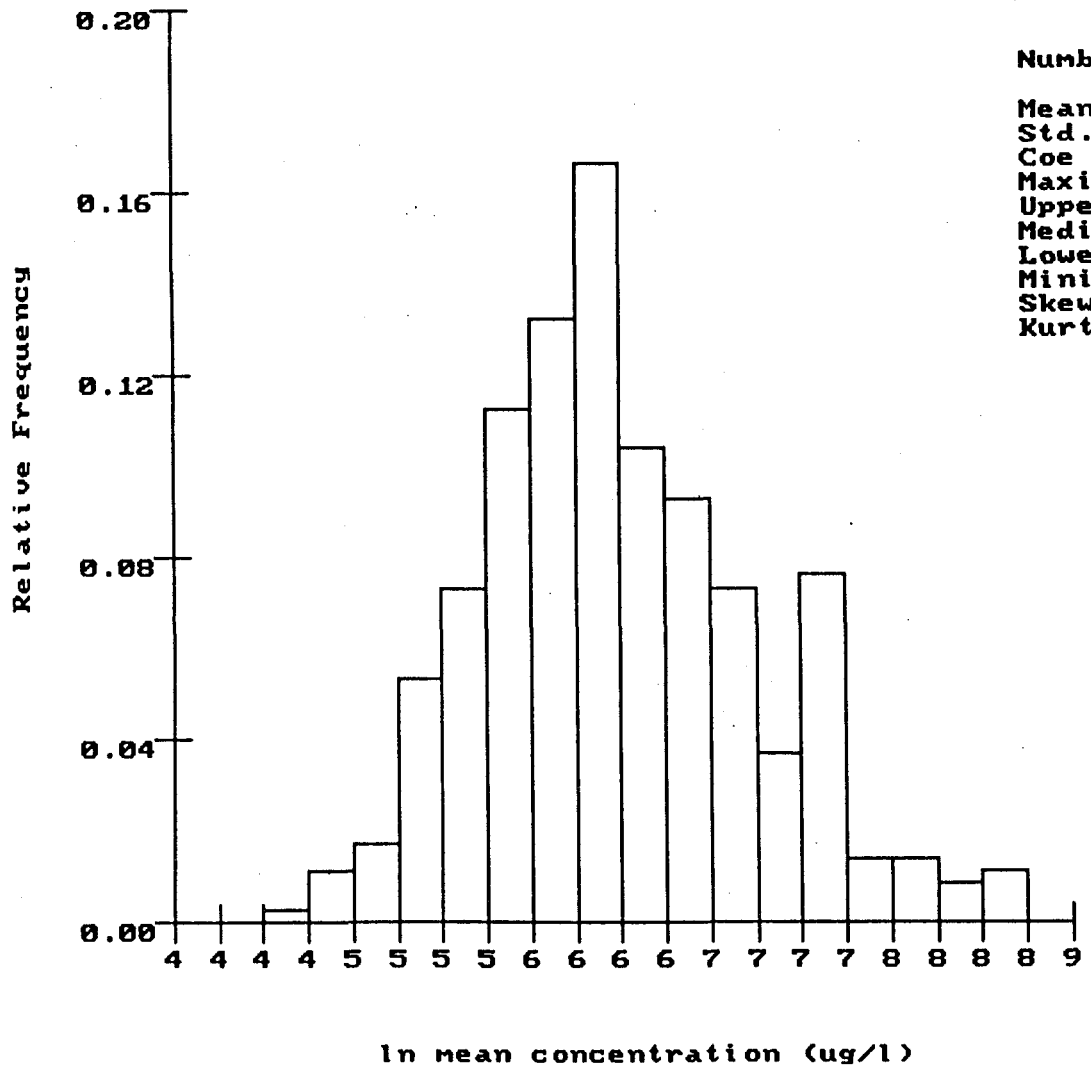
Number of Data	299
Mean	.877
Std. Dev.	.845
Coe f. of Var	.963
Maximum	2.750
Upper Quartile	1.518
Median	.810
Lower Quartile	.273
Minimum	-1.590
Skewness	1.429
Kurtosis	2.392

UHSU: BARIUM ln MEAN CONCENTRATIONS



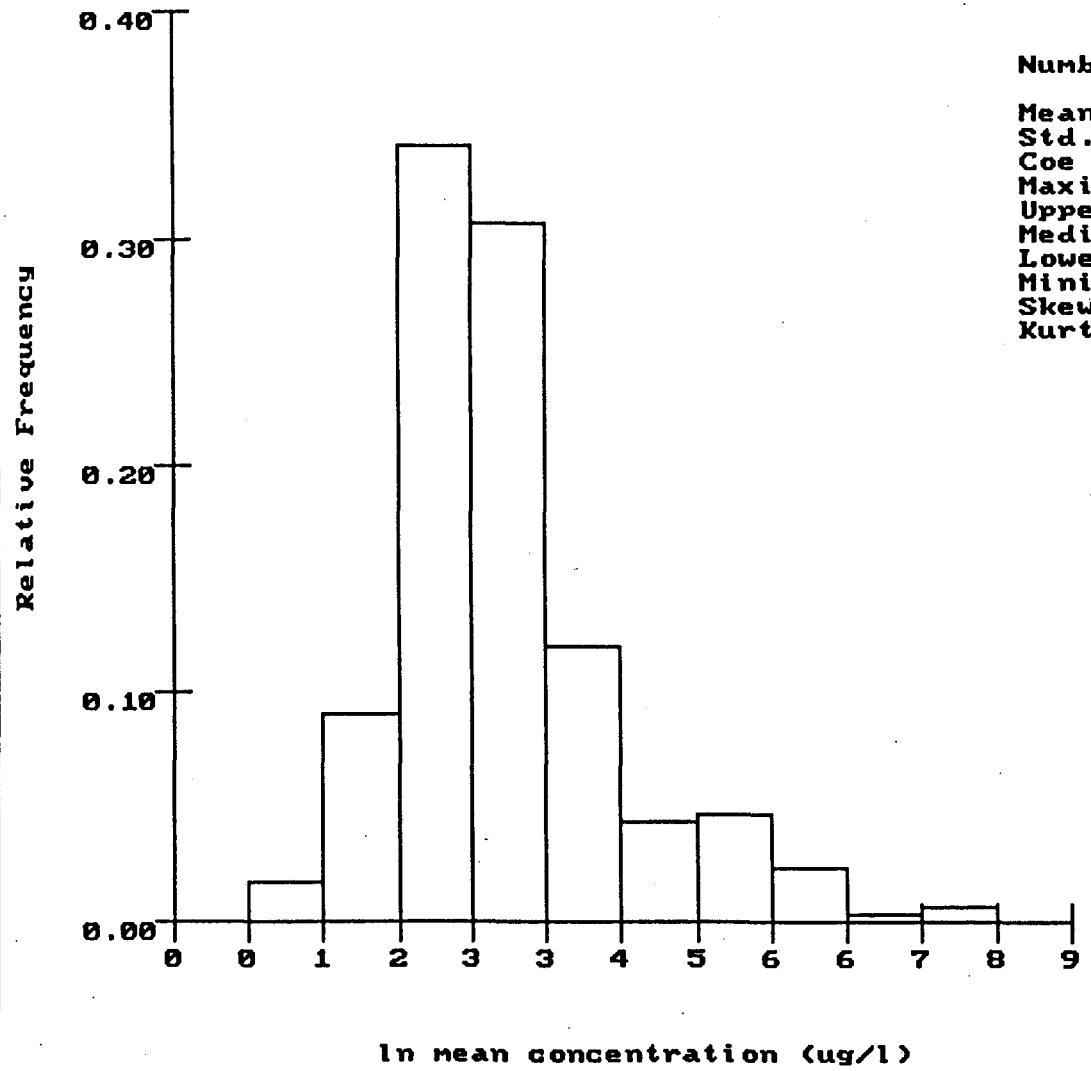
Number of Data	300
Mean	4.691
Std. Dev.	.635
Coe f. of Var	.135
Maximum	6.620
Upper Quartile	5.050
Median	4.670
Lower Quartile	4.265
Minimum	3.180
Skewness	1.503
Kurtosis	2.791

UHSU FLOURIDE ln MEAN CONCENTRATIONS



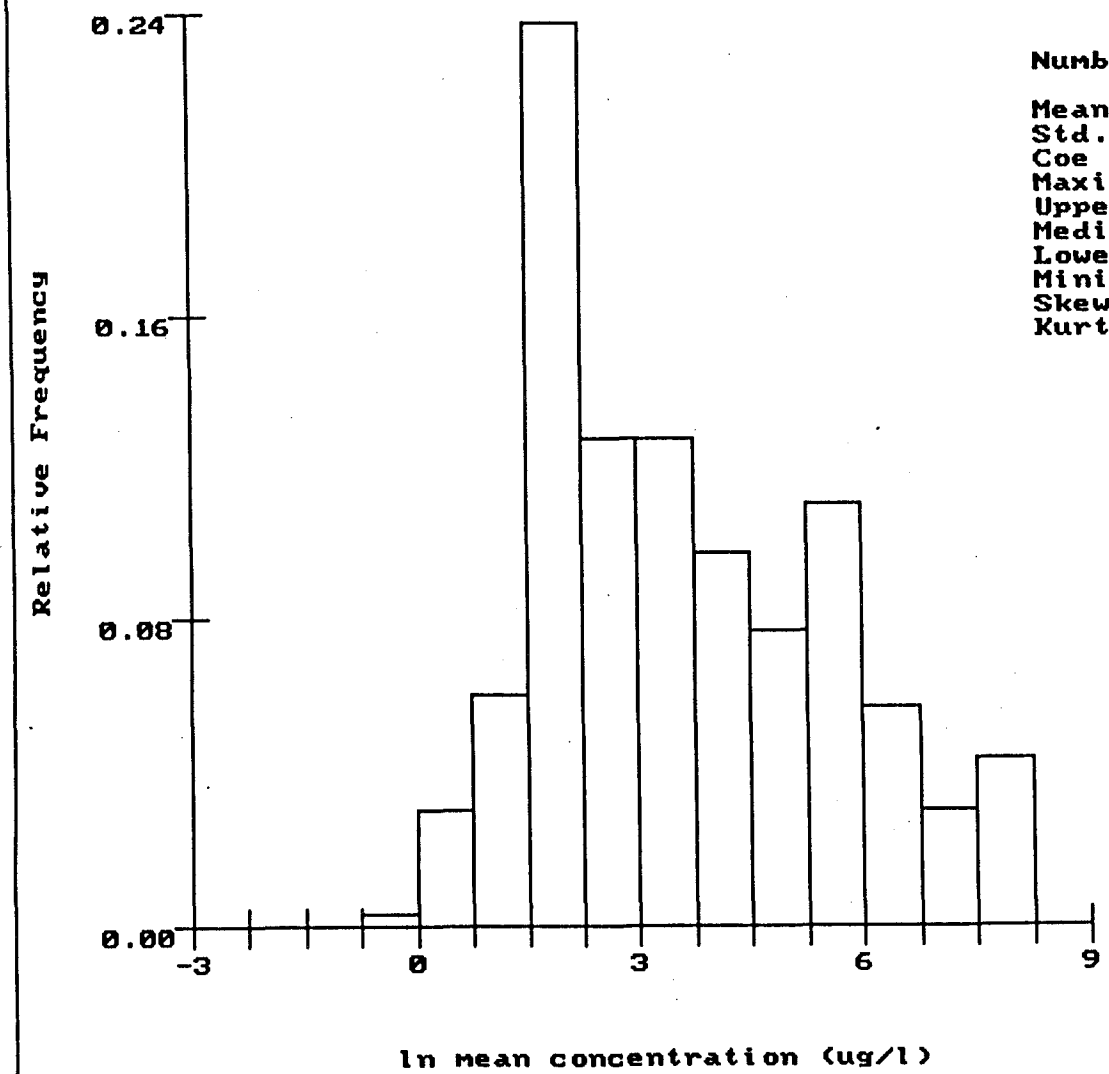
Number of Data	355
Mean	6.479
Std. Dev.	.749
Coe f. of Var	.116
Maximum	8.870
Upper Quartile	6.947
Median	6.390
Lower Quartile	5.970
Minimum	4.740
Skewness	1.571
Kurtosis	3.481

UHSU LITHIUM MEAN CONCENTRATIONS



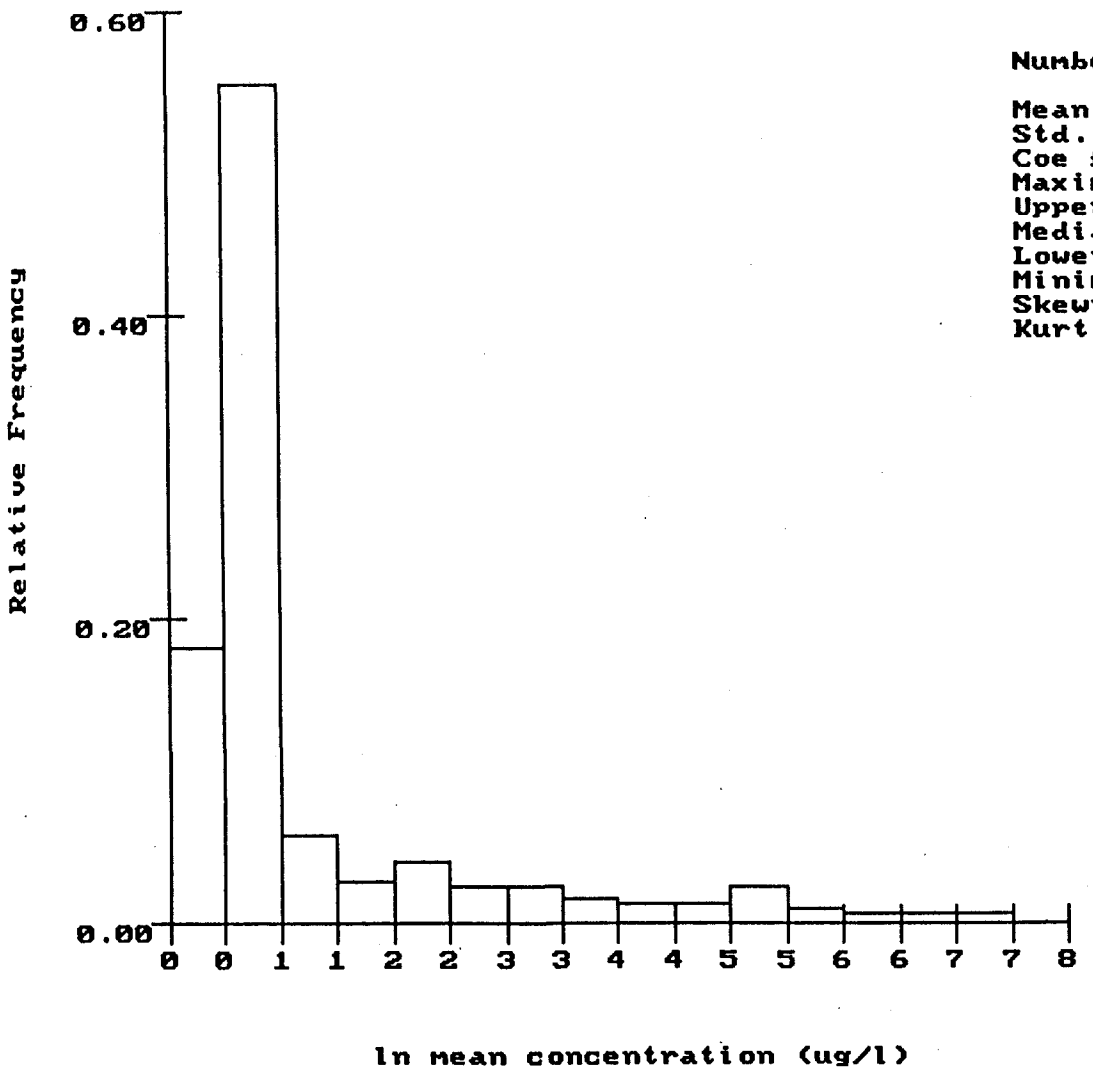
Number of Data	299
Mean	3.303
Std. Dev.	1.109
Coe f. of Var	.336
Maximum	8.680
Upper Quartile	3.690
Median	3.070
Lower Quartile	2.710
Minimum	.850
Skewness	1.944
Kurtosis	6.621

UHSU MANGANESE ln MEAN CONCENTRATIONS



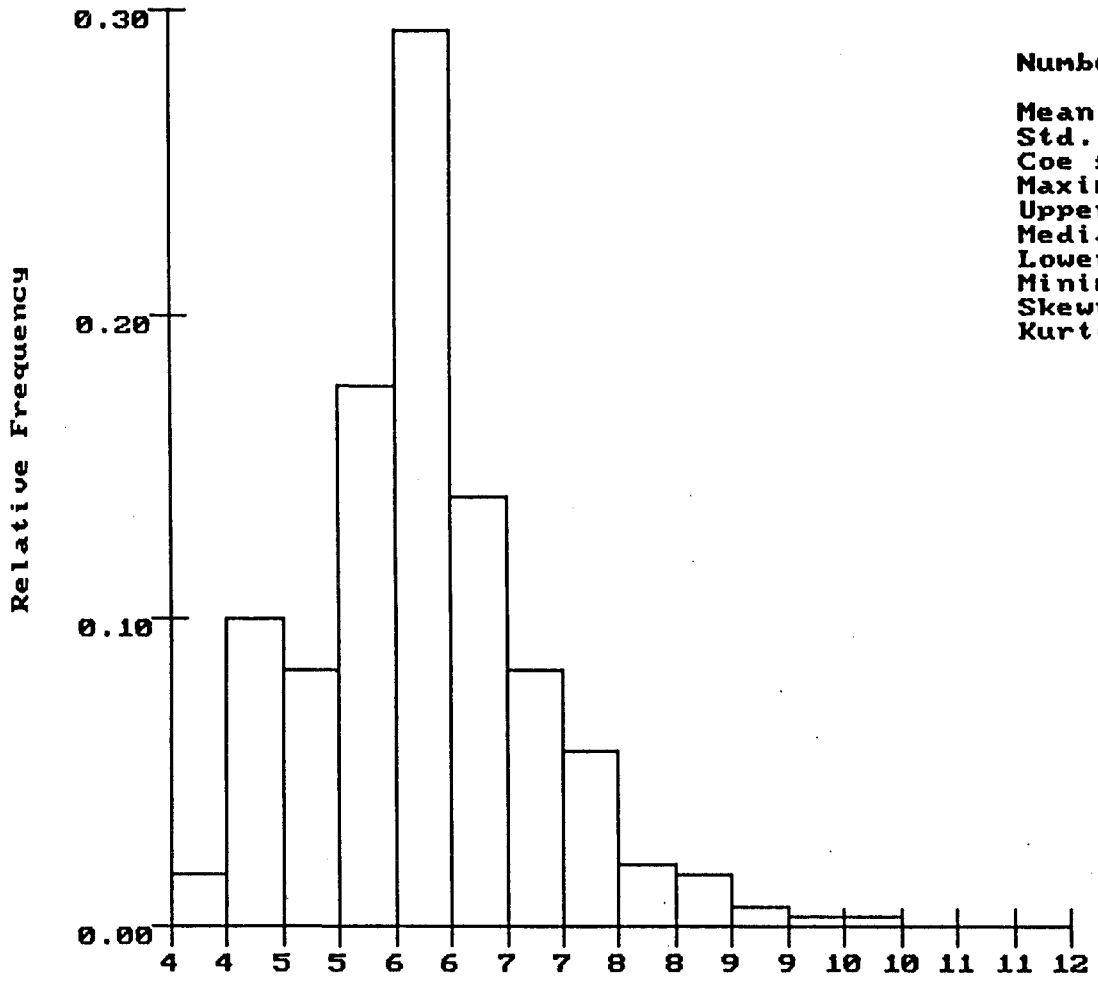
Number of Data	299
Mean	3.616
Std. Dev.	1.990
Coe f. of Var	.550
Maximum	8.720
Upper Quartile	5.185
Median	3.300
Lower Quartile	1.953
Minimum	-.690
Skewness	1.258
Kurtosis	3.035

UHSU Se ln MEAN CONCENTRATIONS



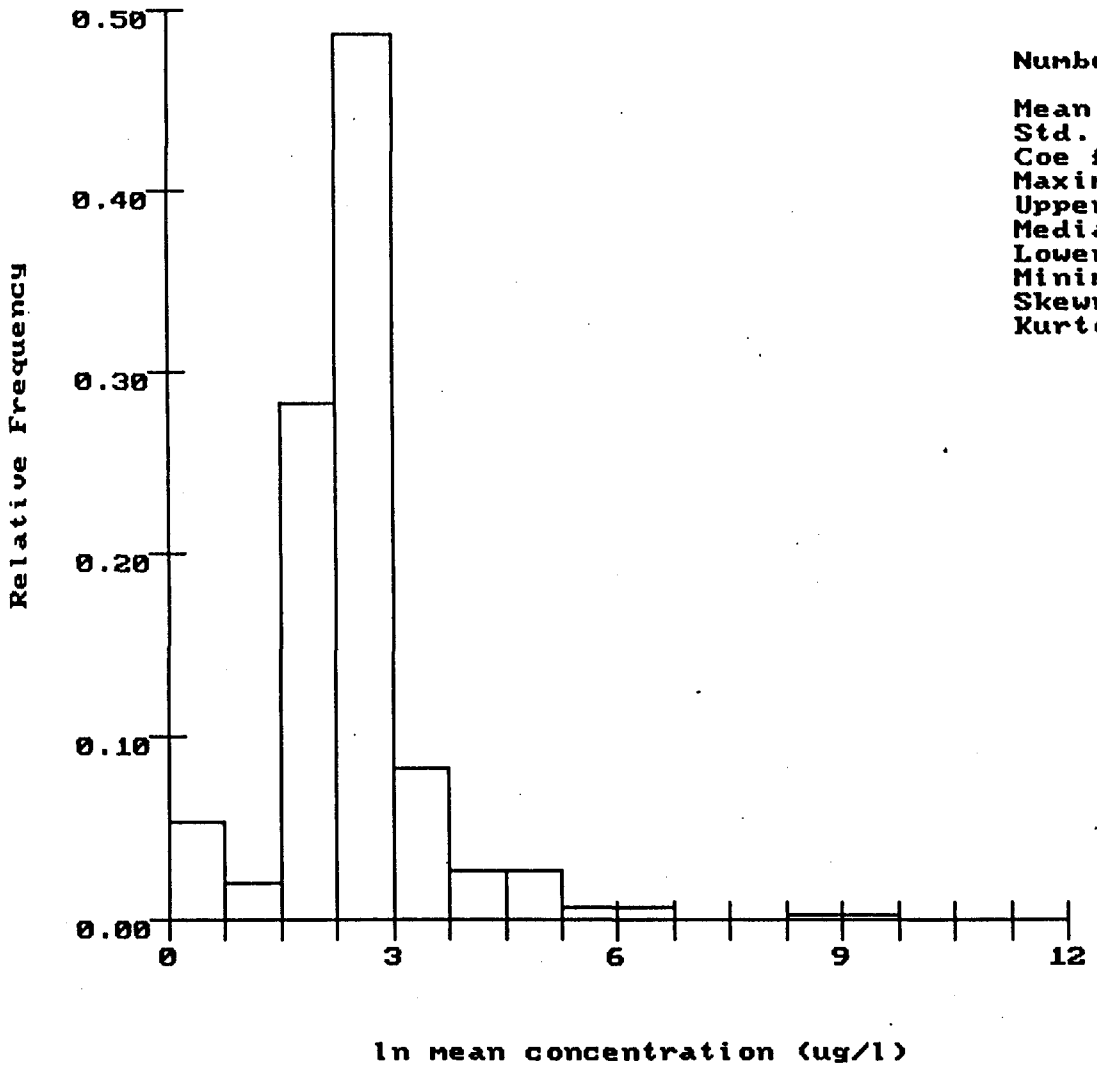
Number of Data	299
Mean	1.292
Std. Dev.	1.459
Coe f. of Var	1.129
Maximum	7.060
Upper Quartile	1.115
Median	.770
Lower Quartile	.565
Minimum	.000
Skewness	2.587
Kurtosis	8.223

UHSU Sr (ug/L)



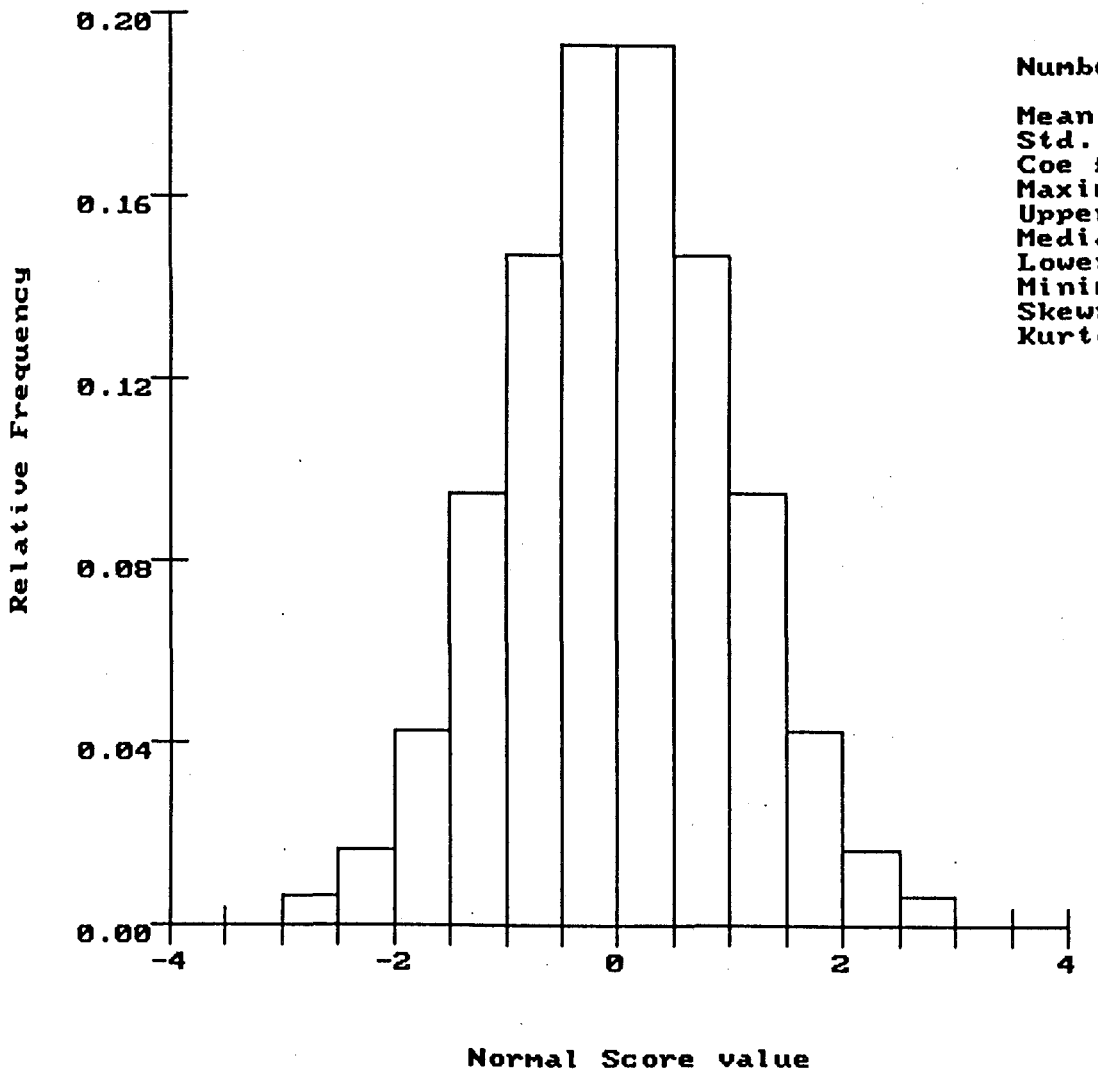
Number of Data	300
Mean	6.264
Std. Dev.	.983
Coe f. of Var	.157
Maximum	10.050
Upper Quartile	6.765
Median	6.210
Lower Quartile	5.765
Minimum	4.150
Skewness	1.249
Kurtosis	4.263

UHSU: ZINC ln MEAN CONCENTRATION



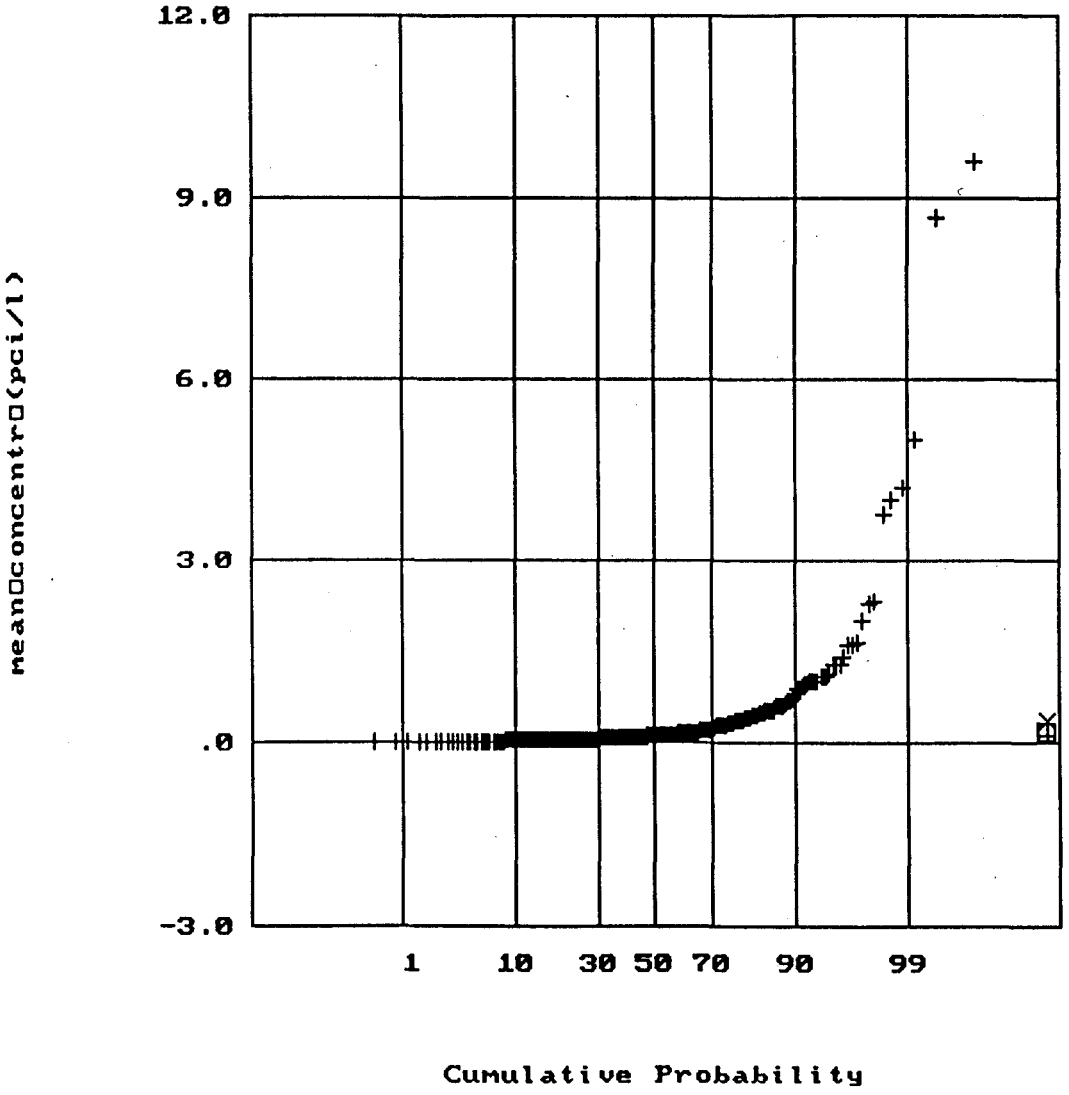
Number of Data	300
Mean	2.497
Std. Dev.	1.022
Coe f. of Var	.409
Maximum	9.200
Upper Quartile	2.770
Median	2.360
Lower Quartile	2.080
Minimum	.410
Skewness	2.618
Kurtosis	12.350

Normal Score Transform
UHSU: U-235



Number of Data	306
Mean	.000
Std. Dev.	.998
Coe f. of Var	82716.450
Maximum	2.942
Upper Quartile	.674
Median	.000
Lower Quartile	-.674
Minimum	-2.941
Skewness	.000
Kurtosis	2.929

UHSU: U- 235 MEAN CONCENTRATIONS



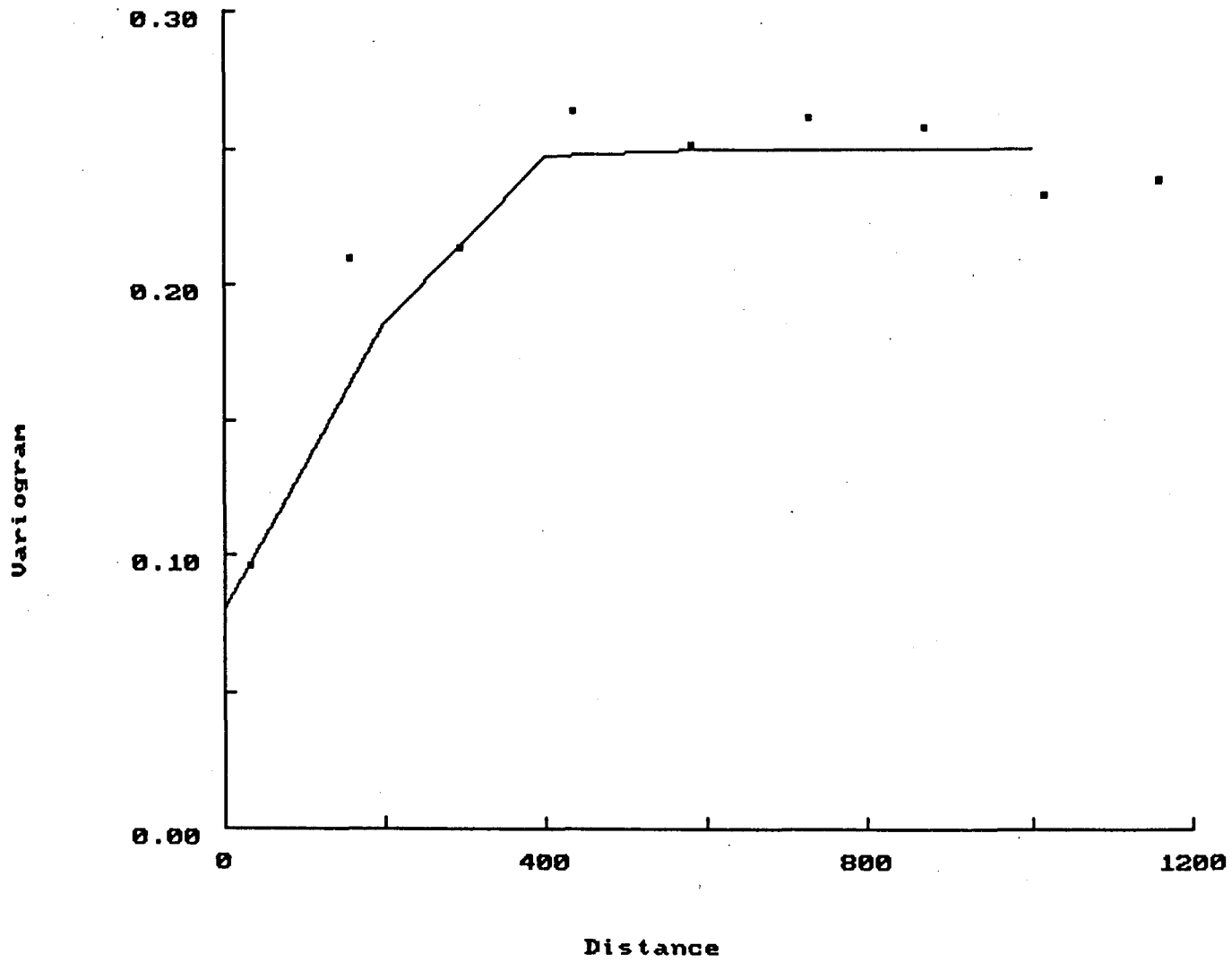
Number of Data	306
Mean	.362
Std. Dev.	.919
Coef. of Var	2.540
Maximum	9.600
Upper Quartile	.310
Median	.110
Lower Quartile	.050
Minimum	-.006
Skewness	6.557
Kurtosis	53.994

A= 450.00 C= .17
# of Lags: 10.000
Unit Sep.Dis: 145.000
Lag Tolerance: 72.500

Azimuth Tol: 90.000
Bandwidth: 8000.000

Semivariogram

UHSU HCO3: ln mean concentration (mg/l)

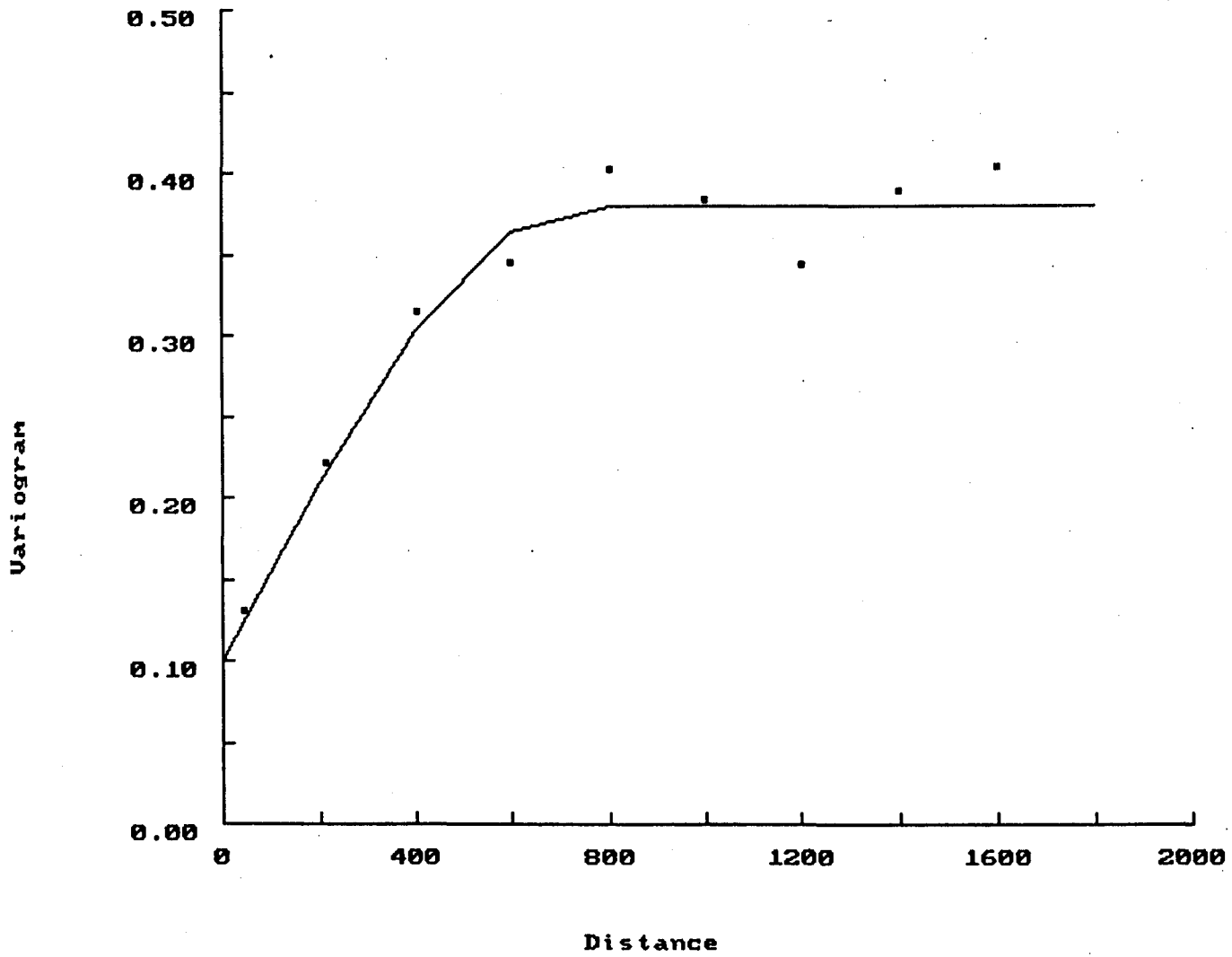


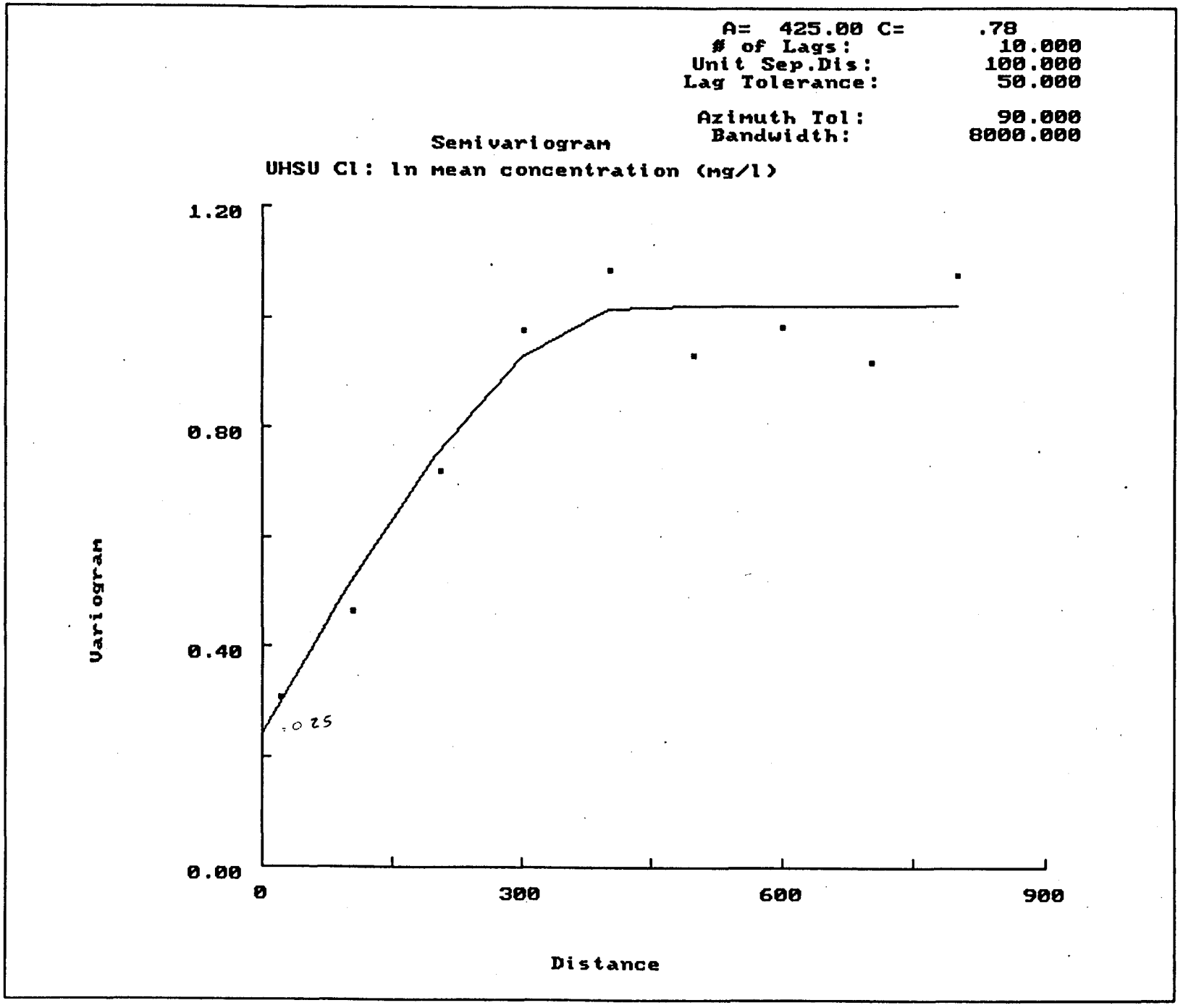
A= 750.00 C= .28
# of Lags: 10.000
Unit Sep.Dis: 200.000
Lag Tolerance: 100.000

Azimuth Tol: 90.000
Bandwidth: 8000.000

Semivariogram

UHSU Ca: ln mean concentration (mg/l)



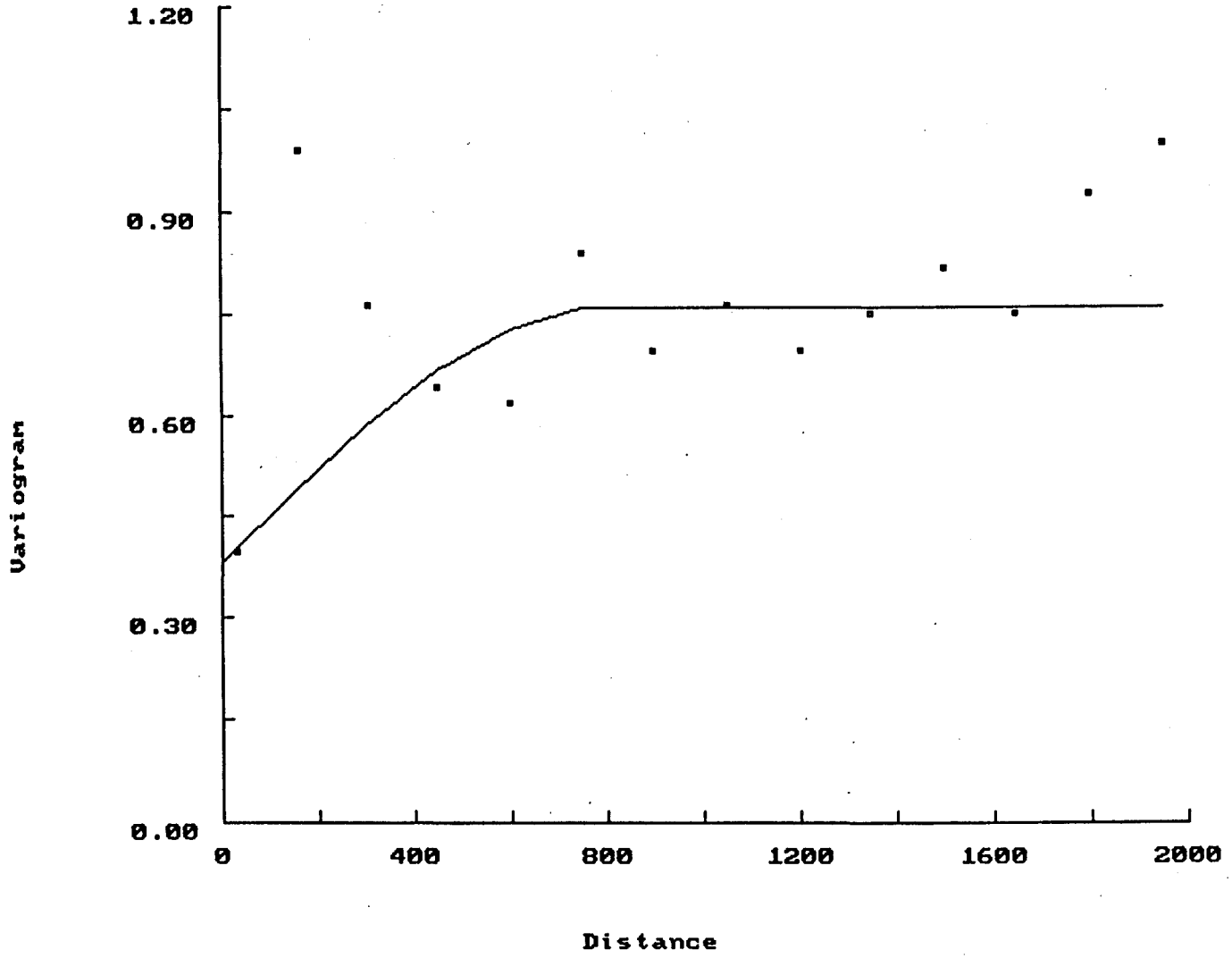

A= 425.00 C= .78
# of Lags: 10.000
Unit Sep.Dis: 100.000
Lag Tolerance: 50.000
Azimuth Tol: 90.000
Bandwidth: 8000.000
Semivariogram
UHSU Cl: ln mean concentration (mg/l)
1.20
0.80
0.40
0.00
Variogram
.025
0
300
600
900
Distance

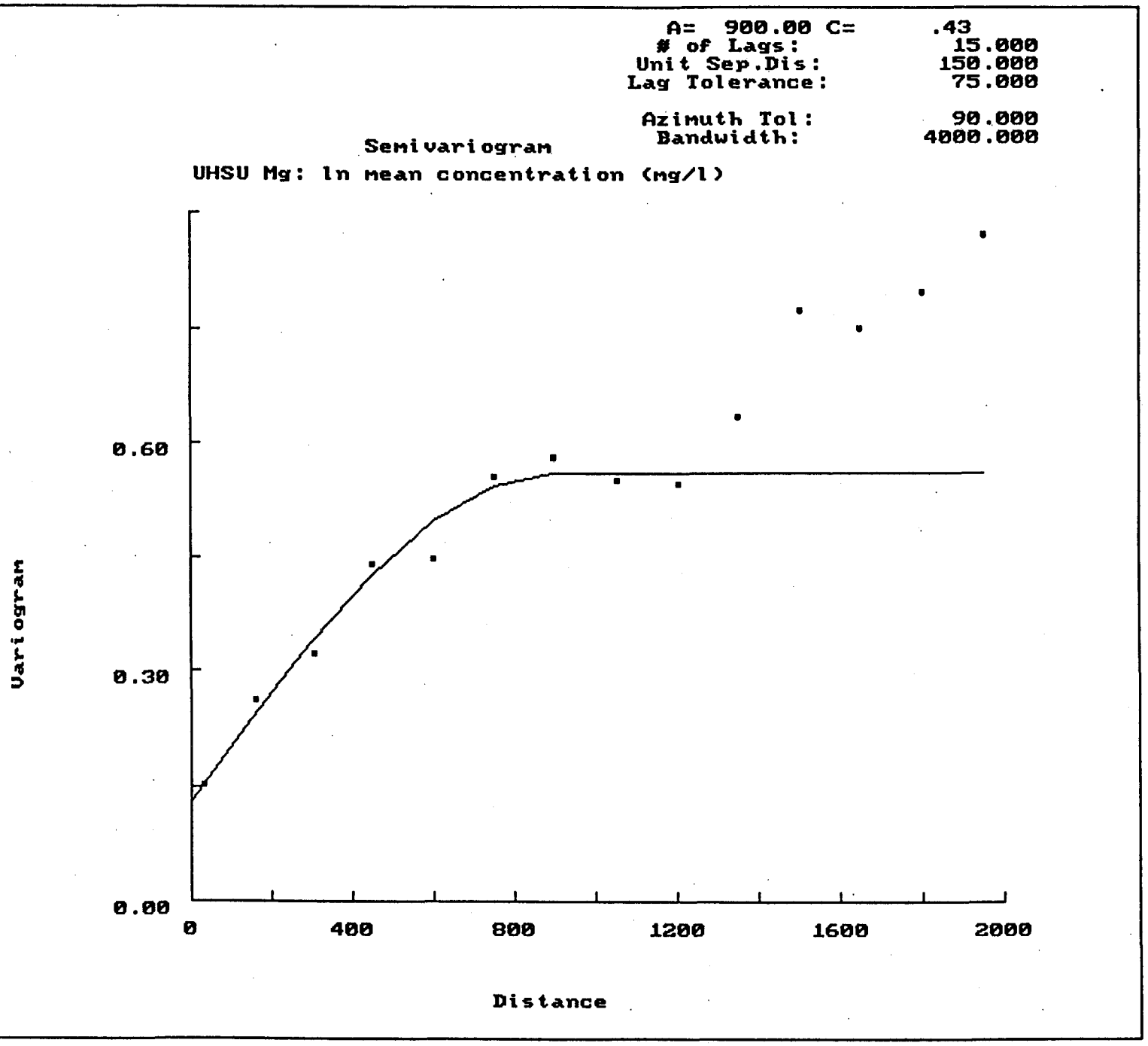
A= 800.00 C= .38
# of Lags: 15.000
Unit Sep.Dis: 150.000
Lag Tolerance: 75.000

Azimuth Tol: 90.000
Bandwidth: 5000.000

Semivariogram

UHSU K: ln mean concentration (mg/l)



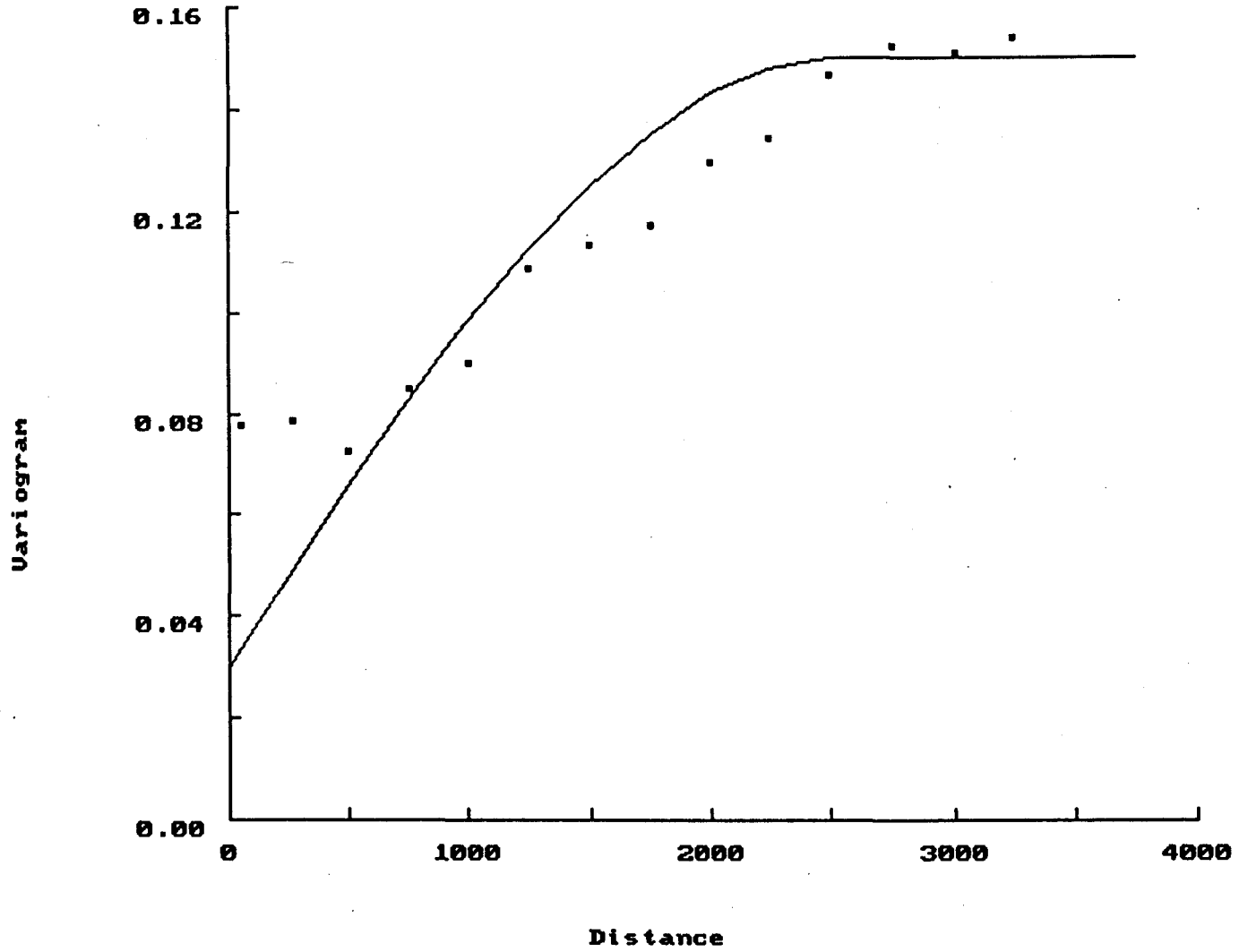

A= 900.00 C= .43
# of Lags: 15.000
Unit Sep.Dis: 150.000
Lag Tolerance: 75.000
Azimuth Tol: 90.000
Bandwidth: 4000.000
Semivariogram
UHSU Mg: ln mean concentration (mg/l)
Variogram
0.60
0.30
0.00
0
400
800
1200
1600
2000
Distance

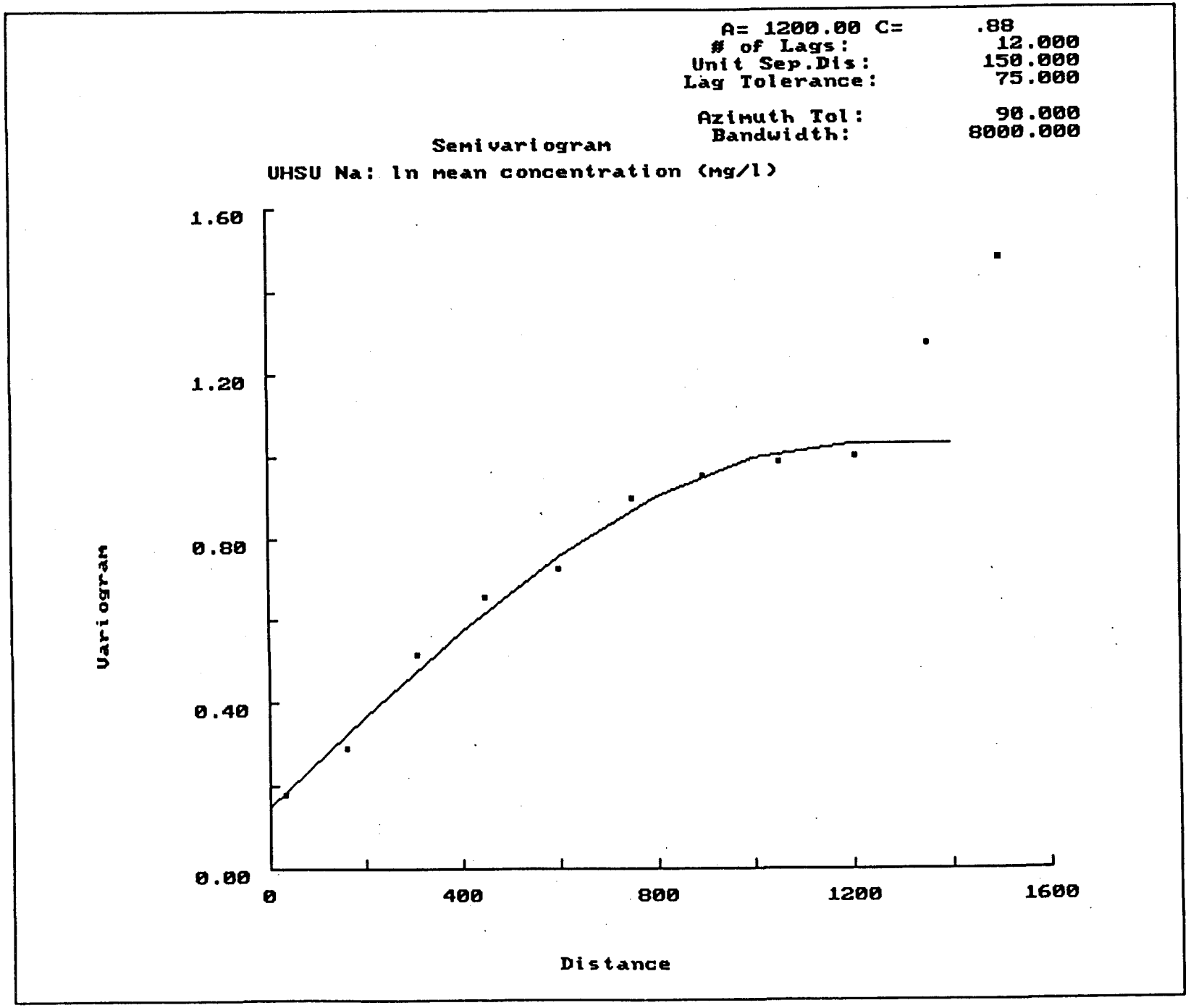
A= 2500.00 C= .12
# of Lags: 15.000
Unit Sep.Dis: 250.000
Lag Tolerance: 125.000

Azimuth Tol: 90.000
Bandwidth: 8000.000

Semivariogram

UHSU: SiO2 ln mean concentration (mg/l)



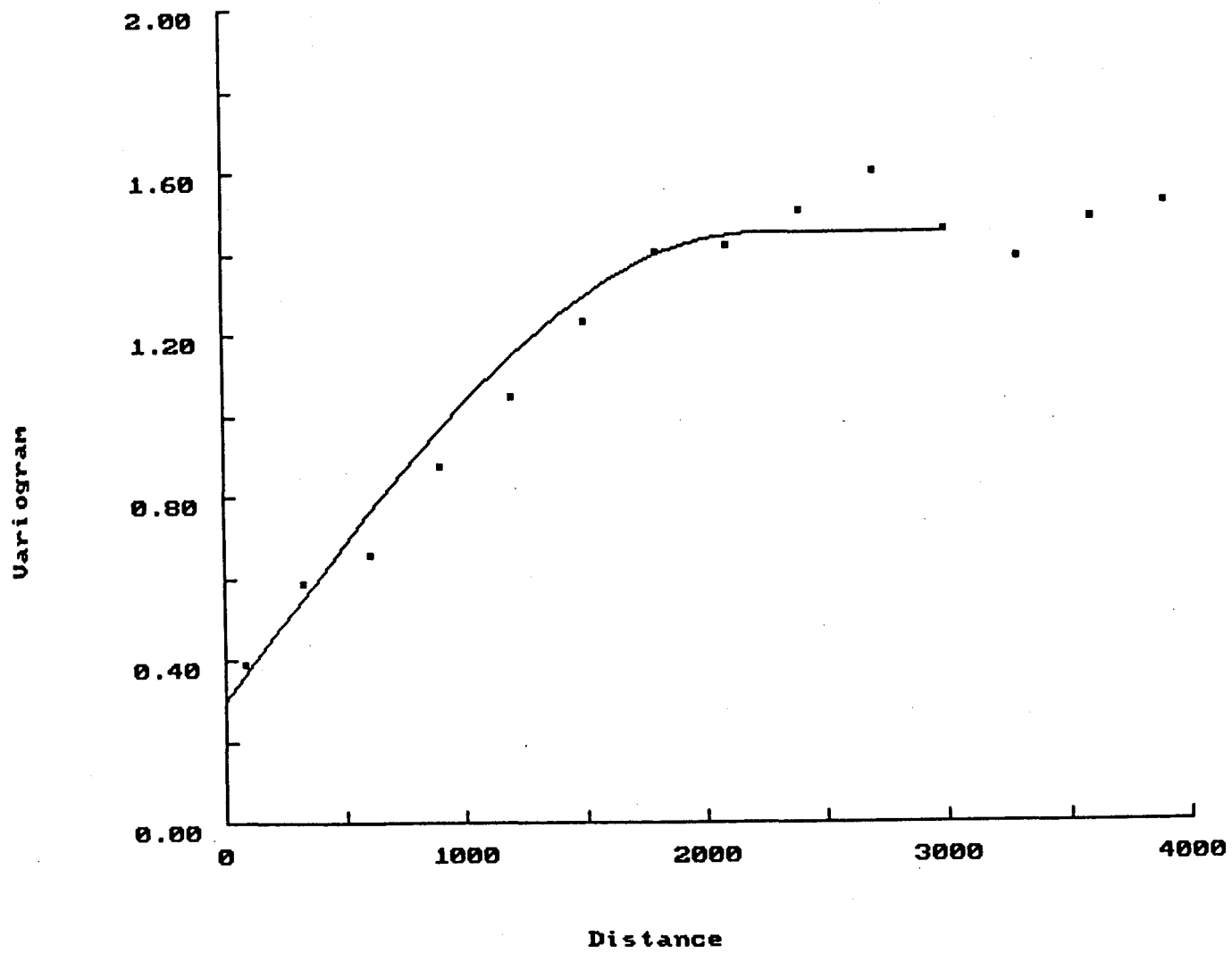

A= 1200.00 C= .88
# of Lags: 12.000
Unit Sep.Dis: 150.000
Lag Tolerance: 75.000
Azimuth Tol: 90.000
Bandwidth: 8000.000
Semivariogram
UHSU Na: ln mean concentration (mg/l)
Variogram
1.60
1.20
0.80
0.40
0.00
0
400
800
1200
1600
Distance

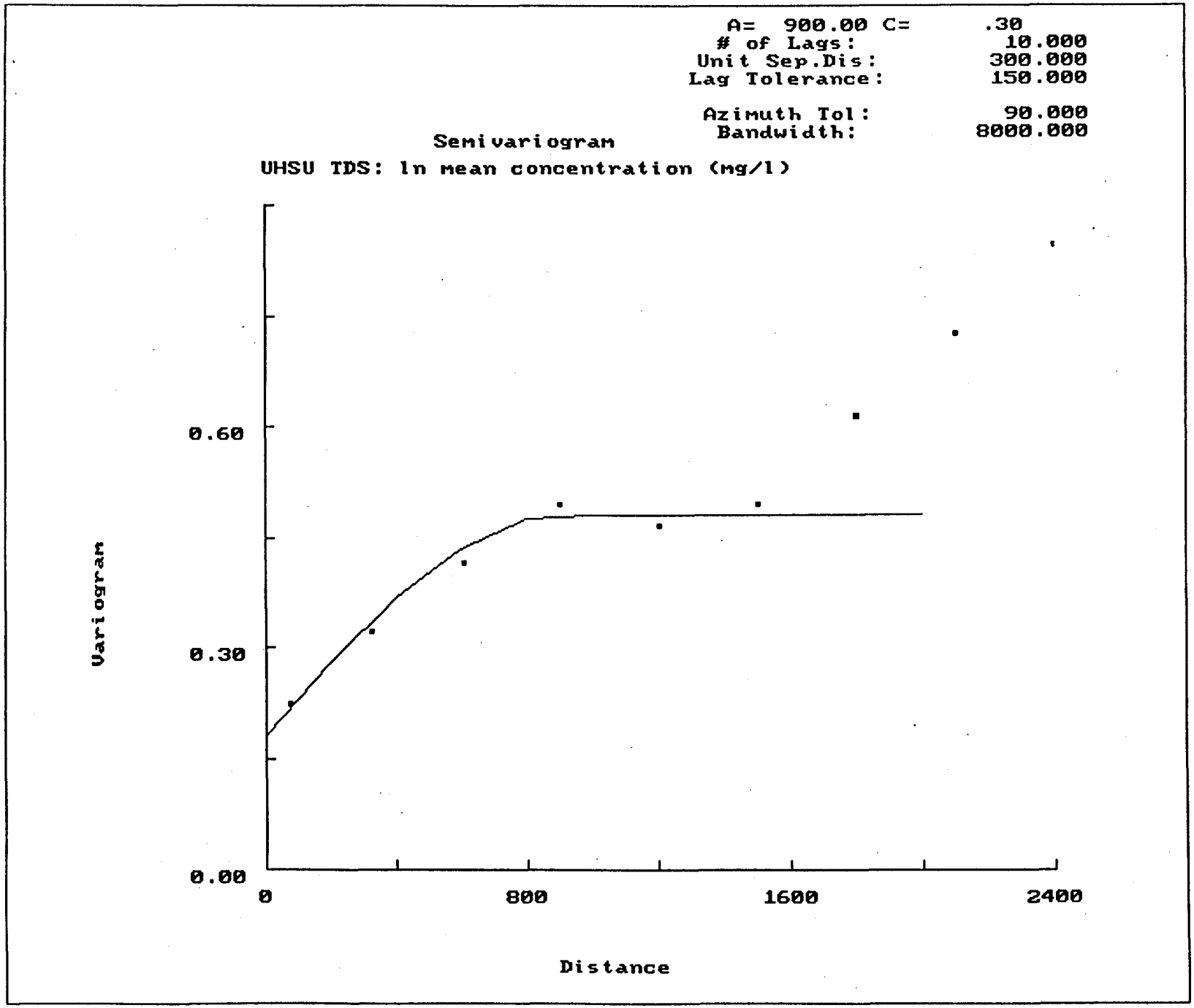
A= 2200.00 C= 1.15
# of Lags: 15.000
Unit Sep.Dis: 300.000
Lag Tolerance: 150.000

Azimuth Tol: 90.000
Bandwidth: 8000.000

Semivariogram

UHSU SO4: ln mean concentration (mg/l)

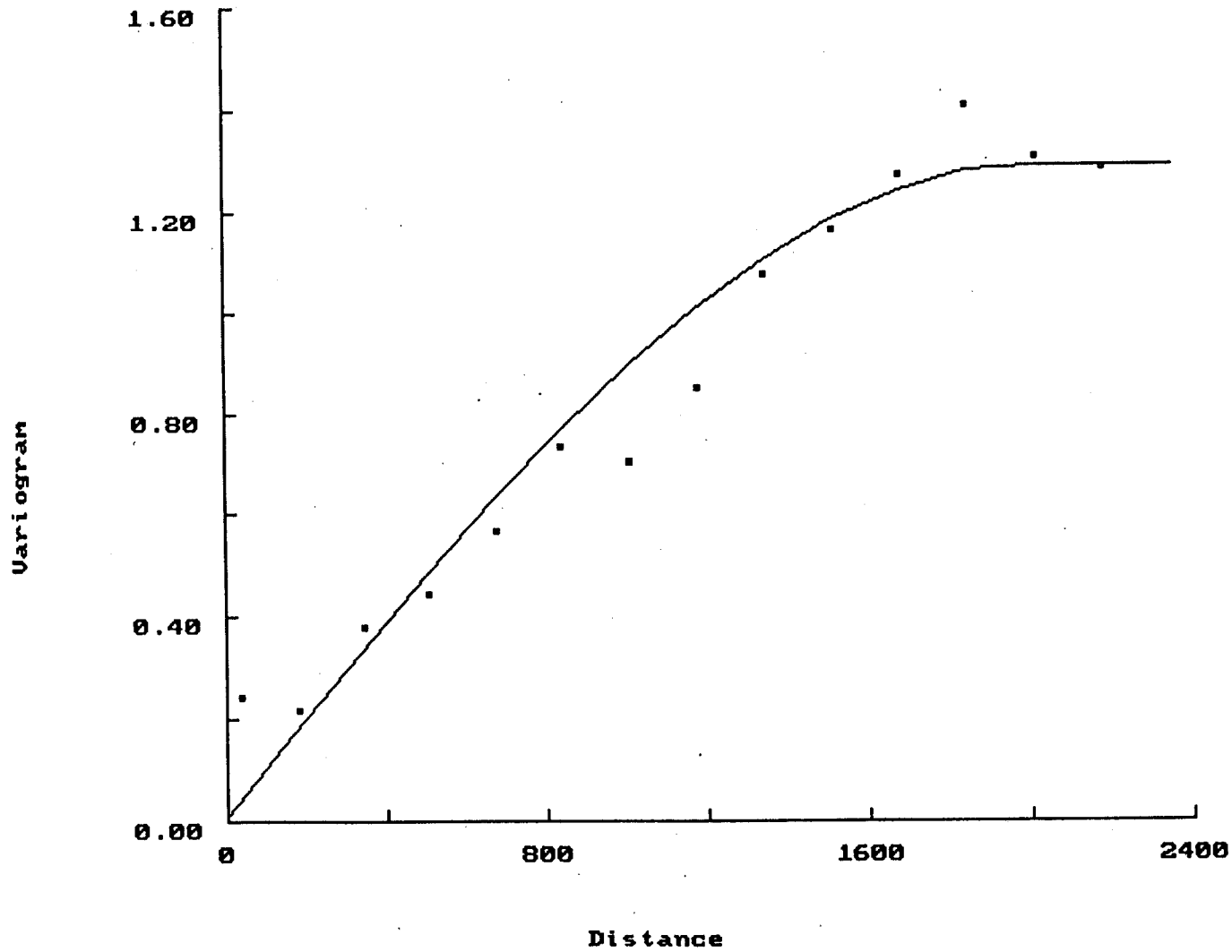


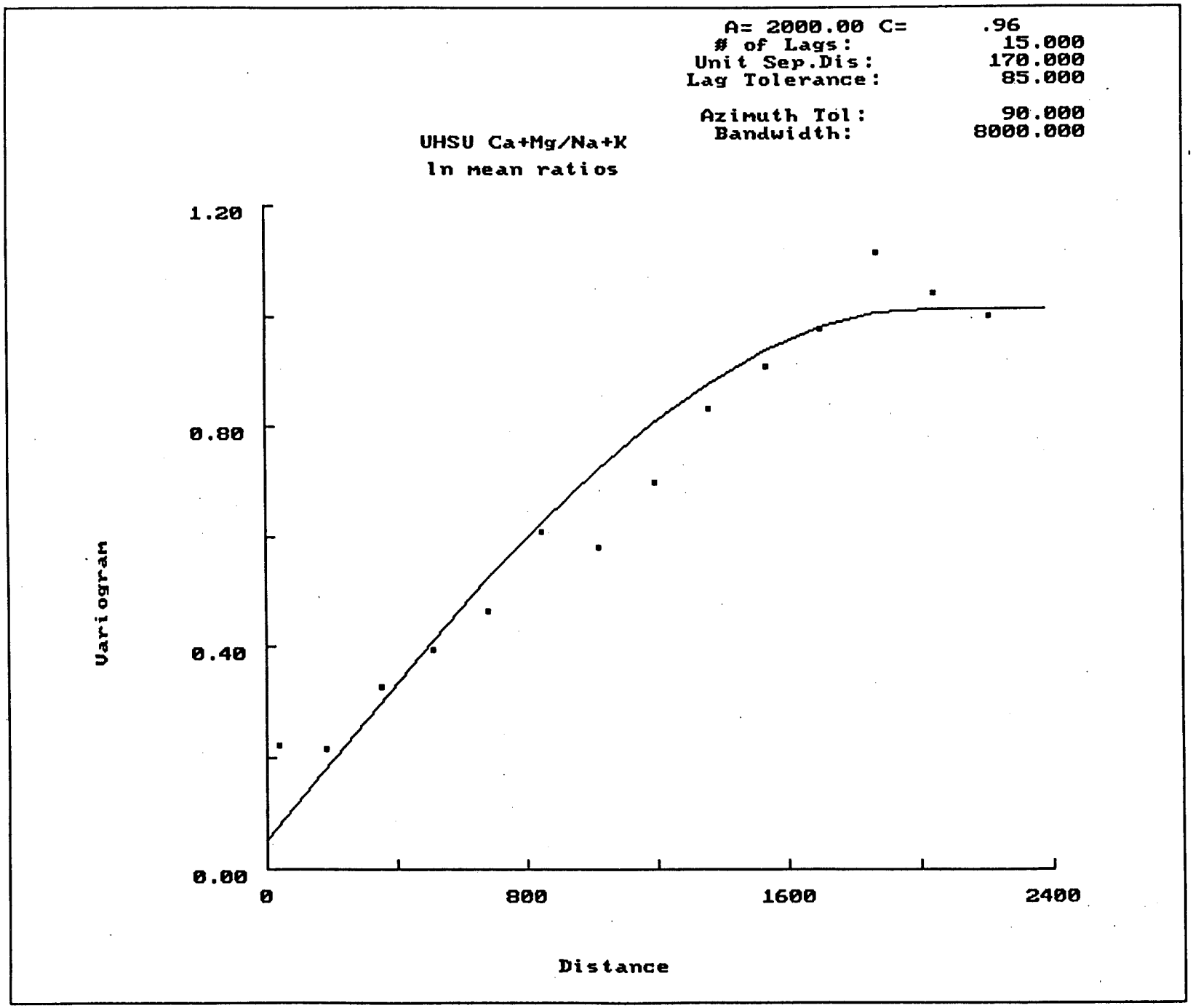

A= 900.00 C= .30
# of Lags: 10.000
Unit Sep.Dis: 300.000
Lag Tolerance: 150.000
Azimuth Tol: 90.000
Bandwidth: 8000.000
Semivariogram
UHSU TDS: ln mean concentration (mg/l)
Variogram
0.60
0.30
0.00
0
800
1600
2400
Distance

A= 2000.00 C= 1.28
# of Lags: 15.000
Unit Sep.Dis: 168.000
Lag Tolerance: 84.000

Azimuth Tol: 90.000
Bandwidth: 8000.000

UHSU Ca/Na RATIOS
ln mean ratios



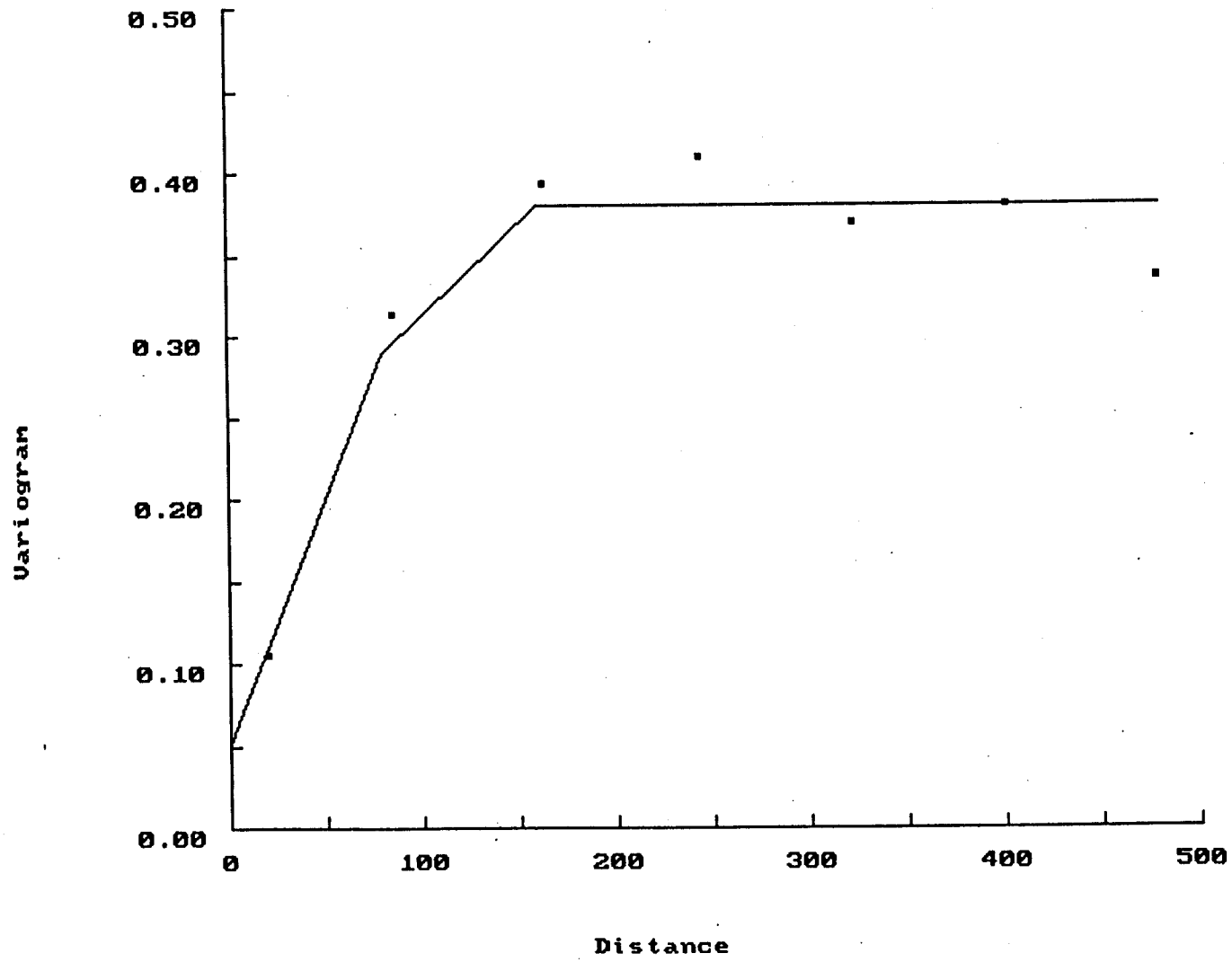

A= 2000.00 C= .96
# of Lags: 15.000
Unit Sep.Dis: 170.000
Lag Tolerance: 85.000
Azimuth Tol: 90.000
Bandwidth: 8000.000
UHSU Ca+Mg/Na+K
ln mean ratios
1.20
0.80
0.40
0.00
Variogram
0
800
1600
2400
Distance

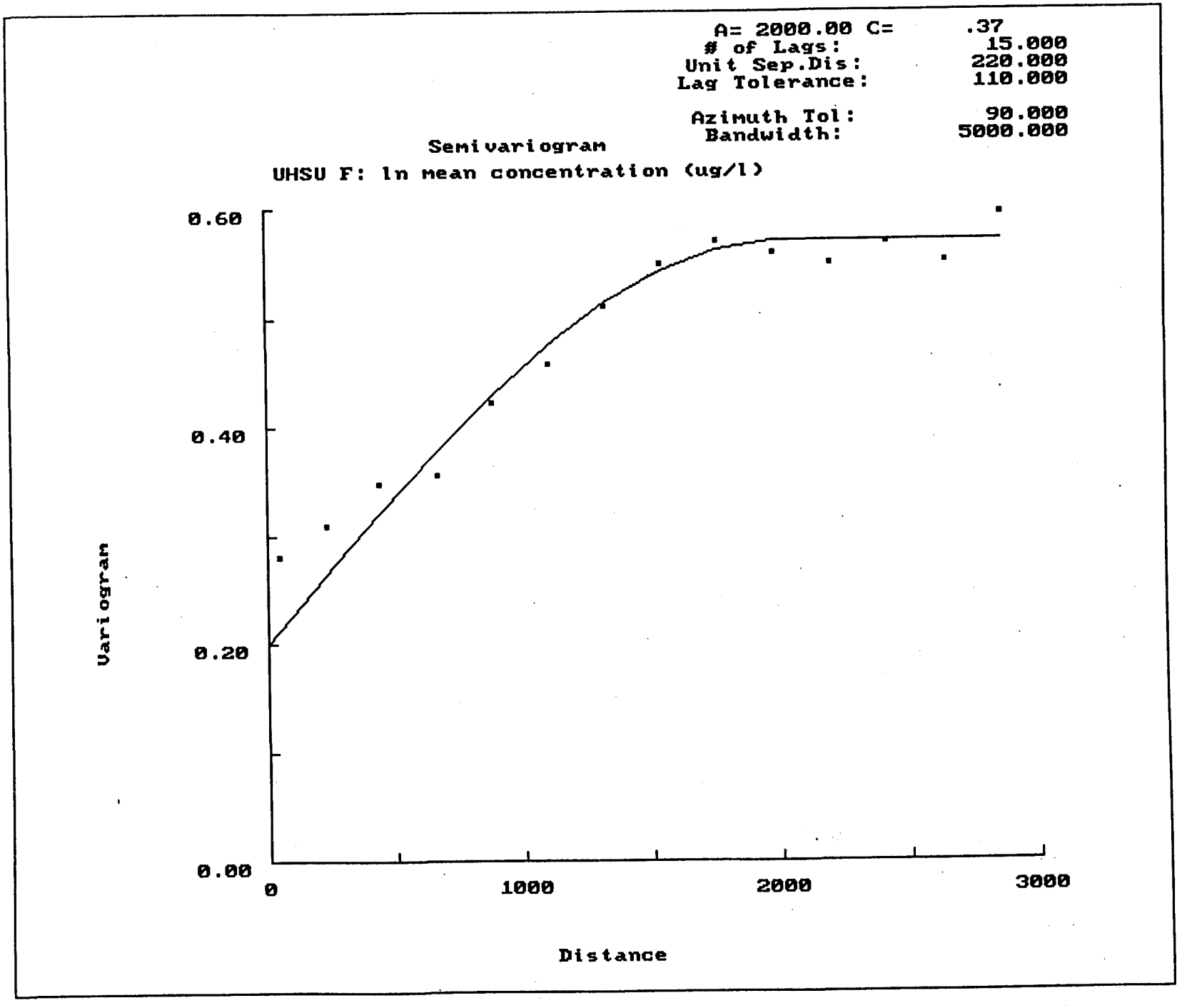
A= 150.00 C= .33
# of Lags: 8.000
Unit Sep.Dis: 80.000
Lag Tolerance: 40.000

Azimuth Tol: 90.000
Bandwidth: 5000.000

Semivariogram

UHSU Ba: ln mean concentration (ug/l)



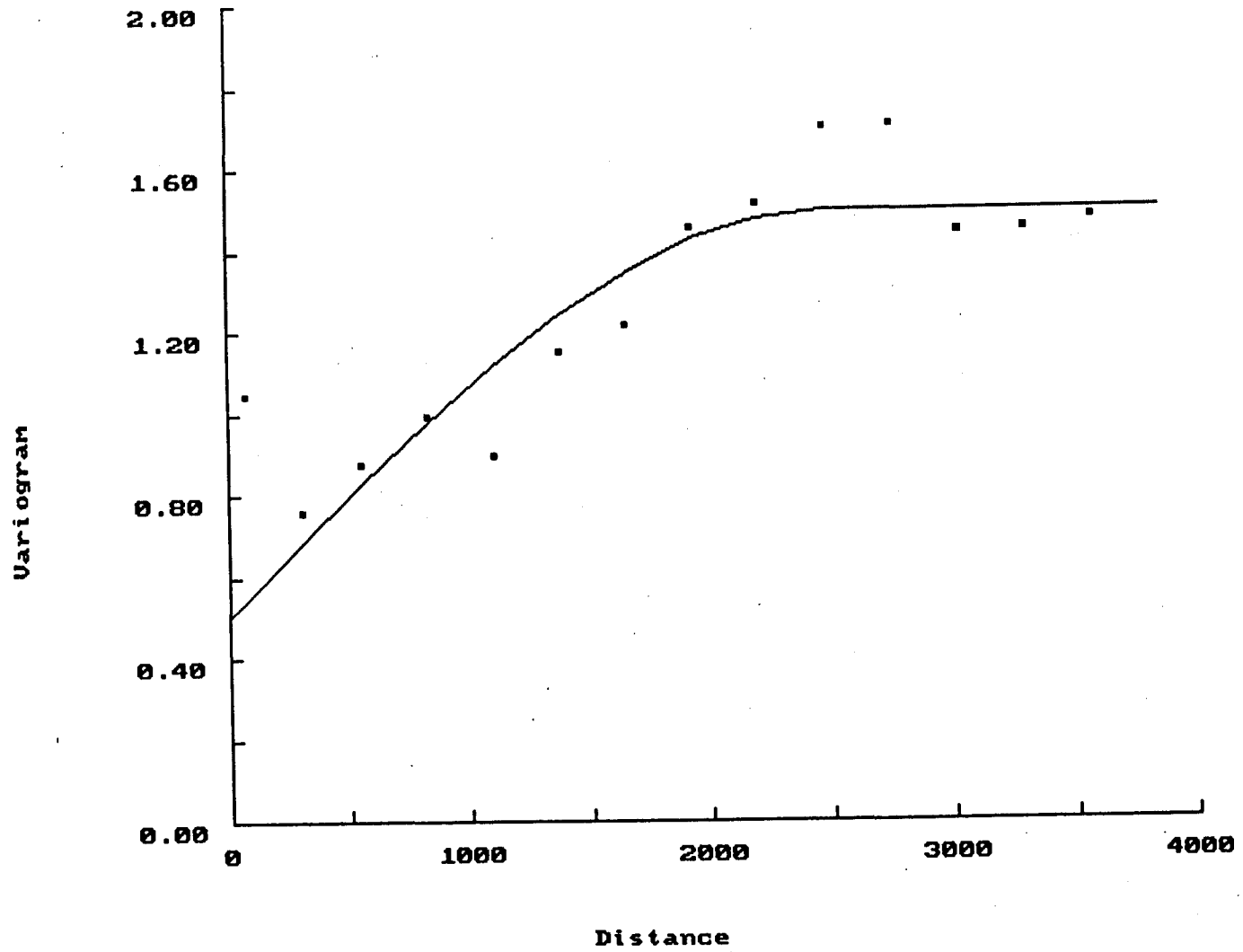

A= 2000.00 C= .37
# of Lags: 15.000
Unit Sep.Dis: 220.000
Lag Tolerance: 110.000
Azimuth Tol: 90.000
Bandwidth: 5000.000
Semivariogram
UHSU F: ln mean concentration (ug/l)
0.60
0.40
0.20
0.00
Variogram
0
1000
2000
3000
Distance

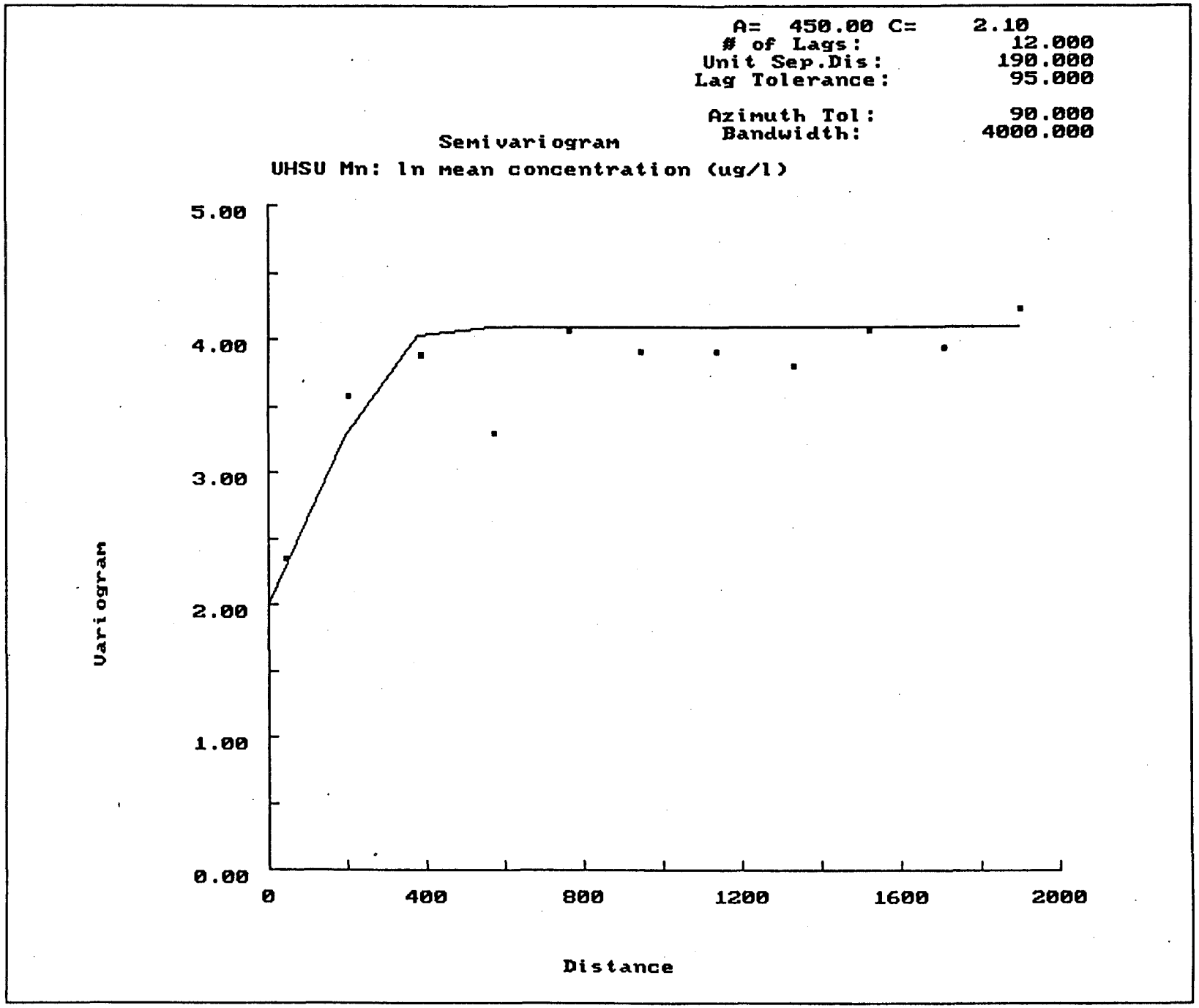
A= 2500.00 C= 1.00
# of Lags: 15.000
Unit Sep.Dis: 275.000
Lag Tolerance: 137.500

Azimuth Tol: 90.000
Bandwidth: 4000.000

Semivariogram

UHSU Li: ln mean concentration (ug/l)



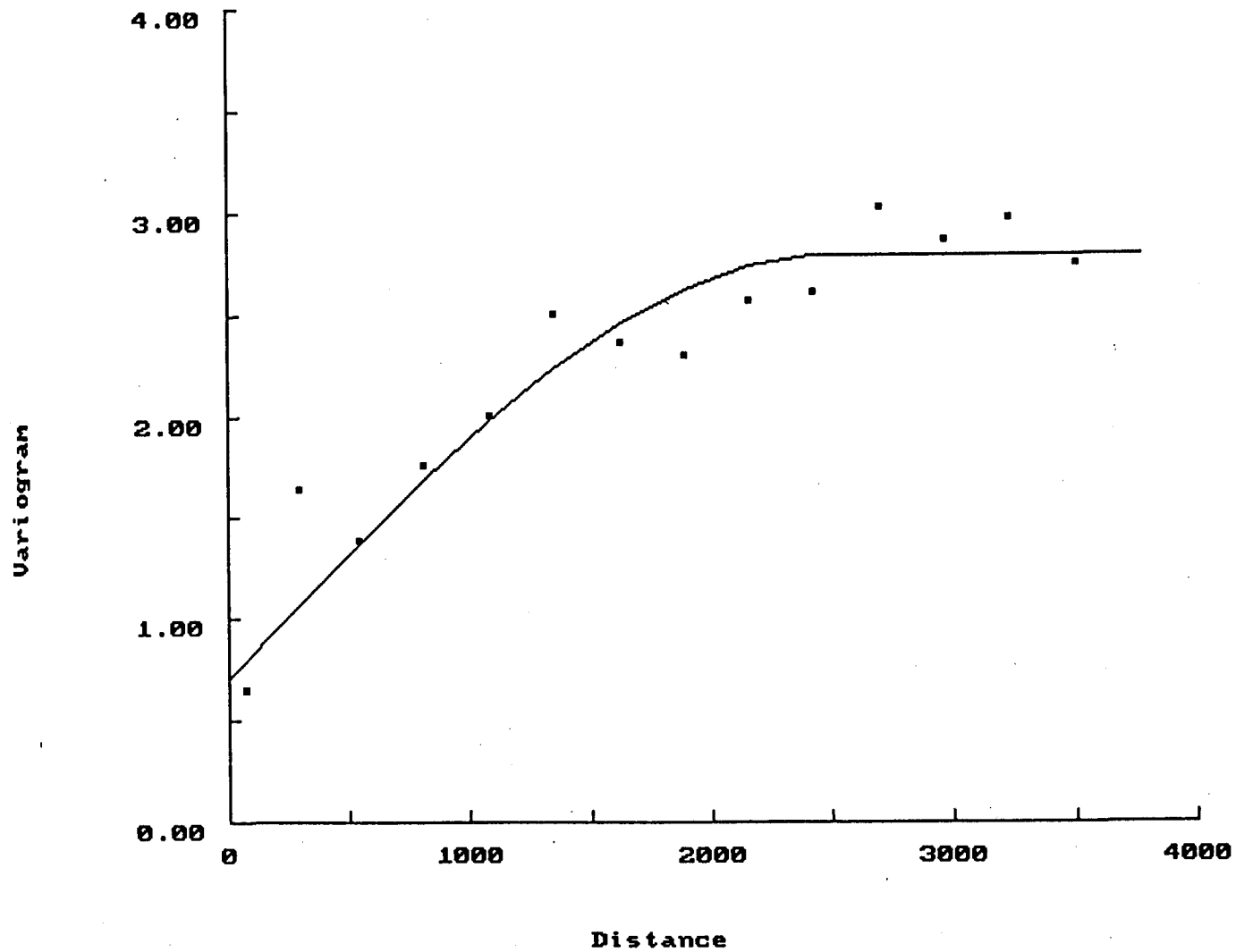

A= 450.00 C= 2.10
# of Lags: 12.000
Unit Sep.Dis: 190.000
Lag Tolerance: 95.000
Azimuth Tol: 90.000
Bandwidth: 4000.000
Semivariogram
UHSU Mn: ln mean concentration (ug/l)
5.00
4.00
3.00
2.00
1.00
0.00
Variogram
0
400
800
1200
1600
2000
Distance

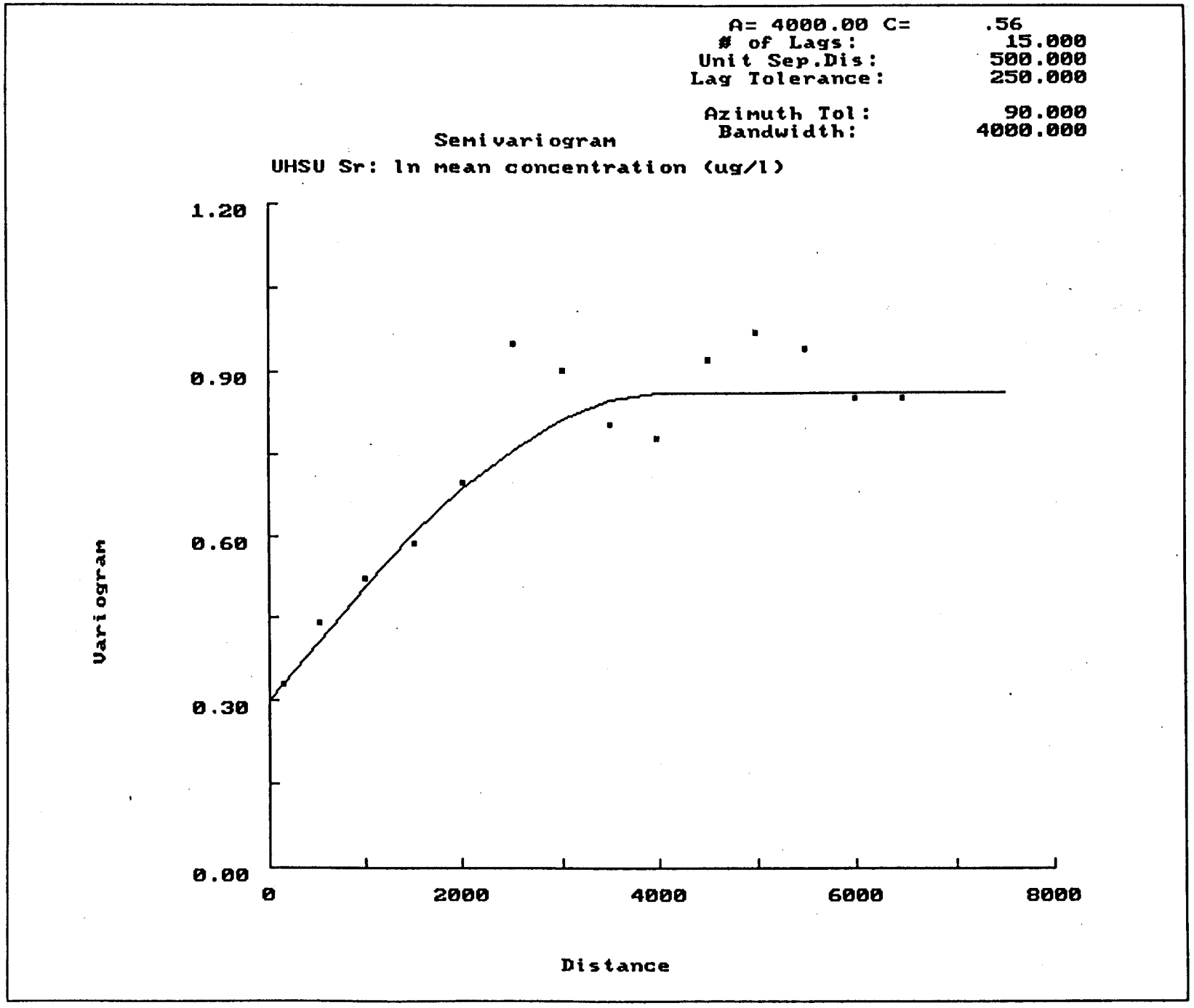
A= 2500.00 C= 2.10
# of Lags: 15.000
Unit Sep.Dis: 270.000
Lag Tolerance: 135.000

Azimuth Tol: 90.000
Bandwidth: 8000.000

Semivariogram

UHSU Se: ln mean concentration (ug/l)



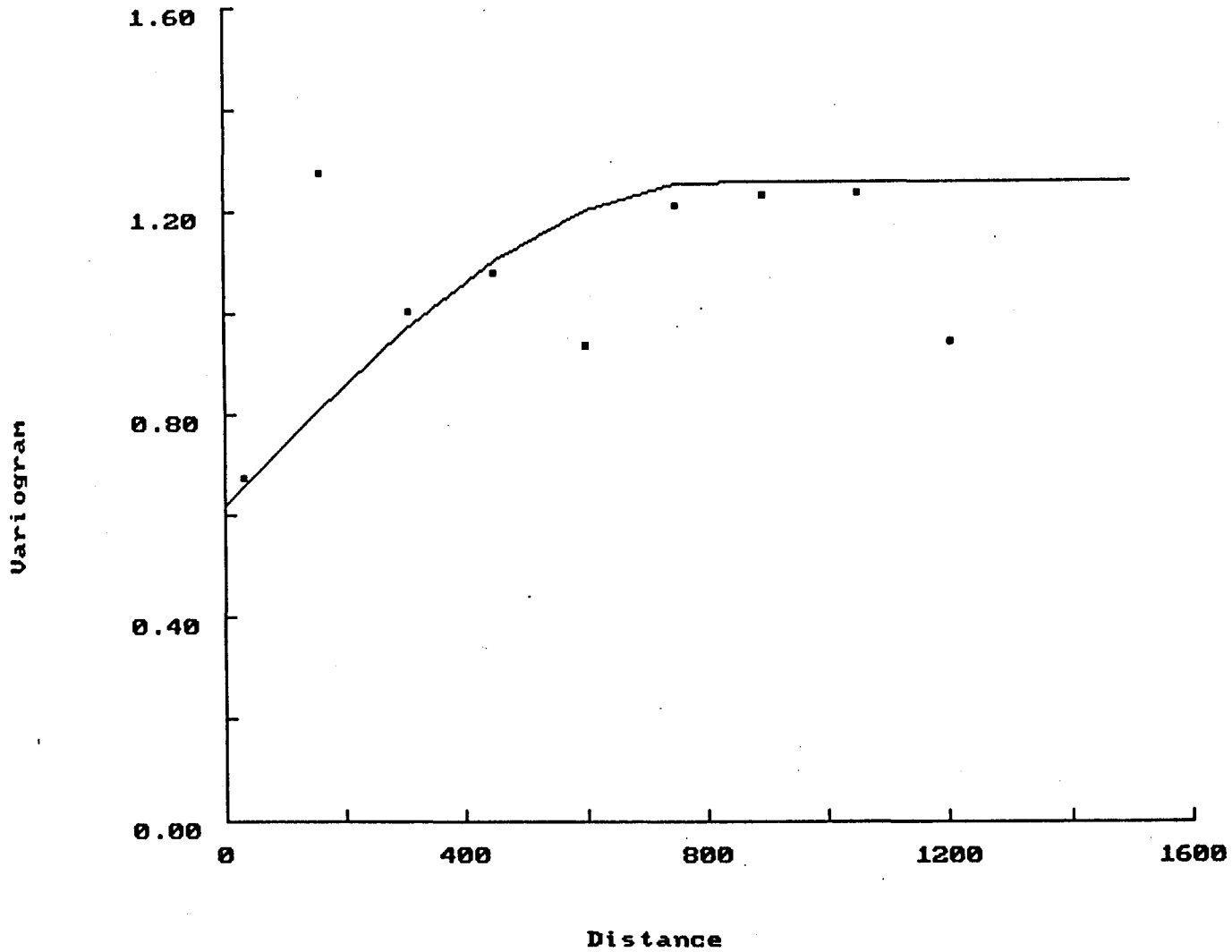

A= 4000.00 C= .56
# of Lags: 15.000
Unit Sep.Dis: 500.000
Lag Tolerance: 250.000
Azimuth Tol: 90.000
Bandwidth: 4000.000
Semivariogram
UHSU Sr: ln mean concentration (ug/l)
1.20
0.90
0.60
0.30
0.00
Variogram
0
2000
4000
6000
8000
Distance

A= 800.00 C= .64
# of Lags: 10.000
Unit Sep.Dis: 150.000
Lag Tolerance: 75.000

Azimuth Tol: 90.000
Bandwidth: 4000.000

Semivariogram

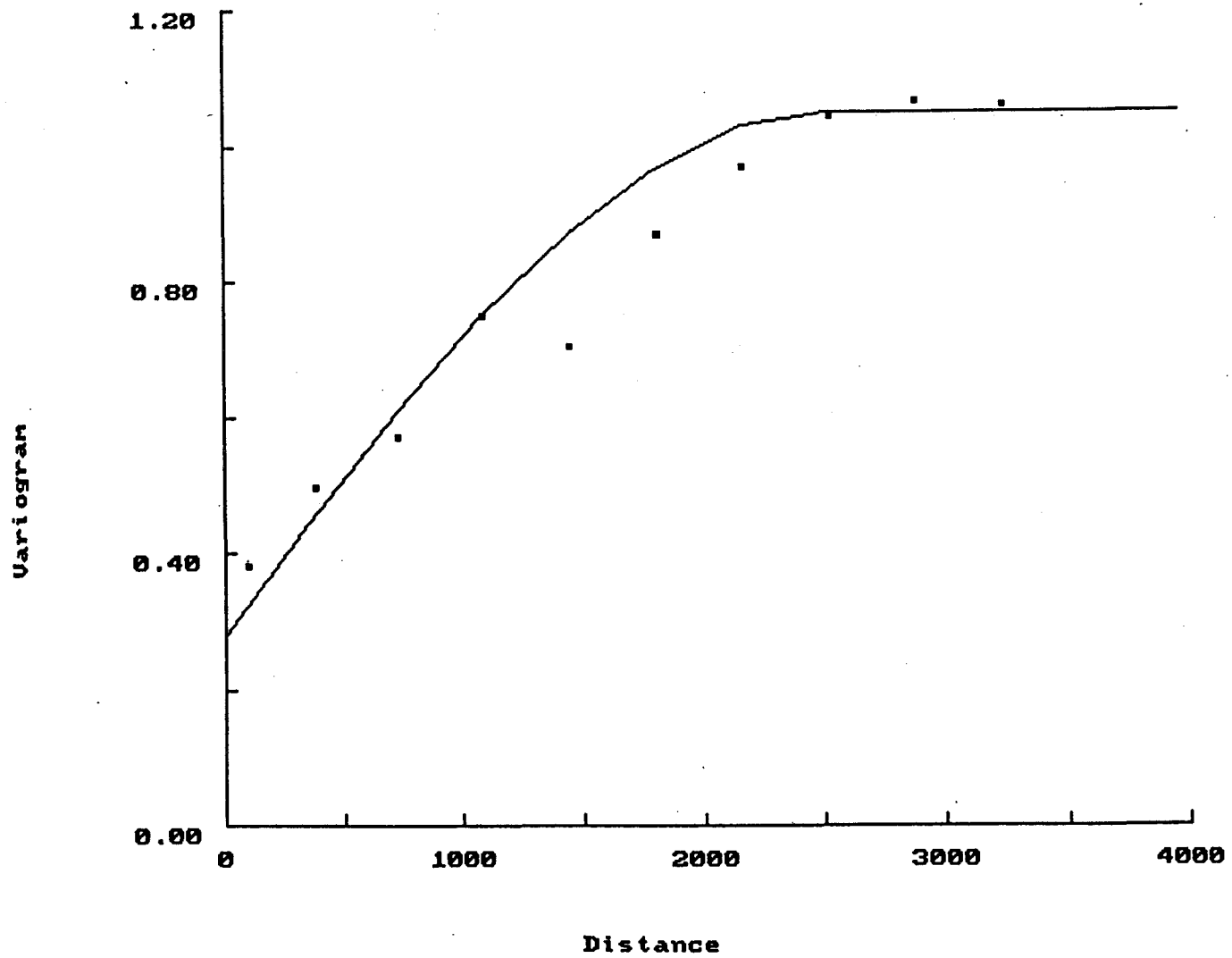
UHSU Zn: ln mean concentration (ug/l)



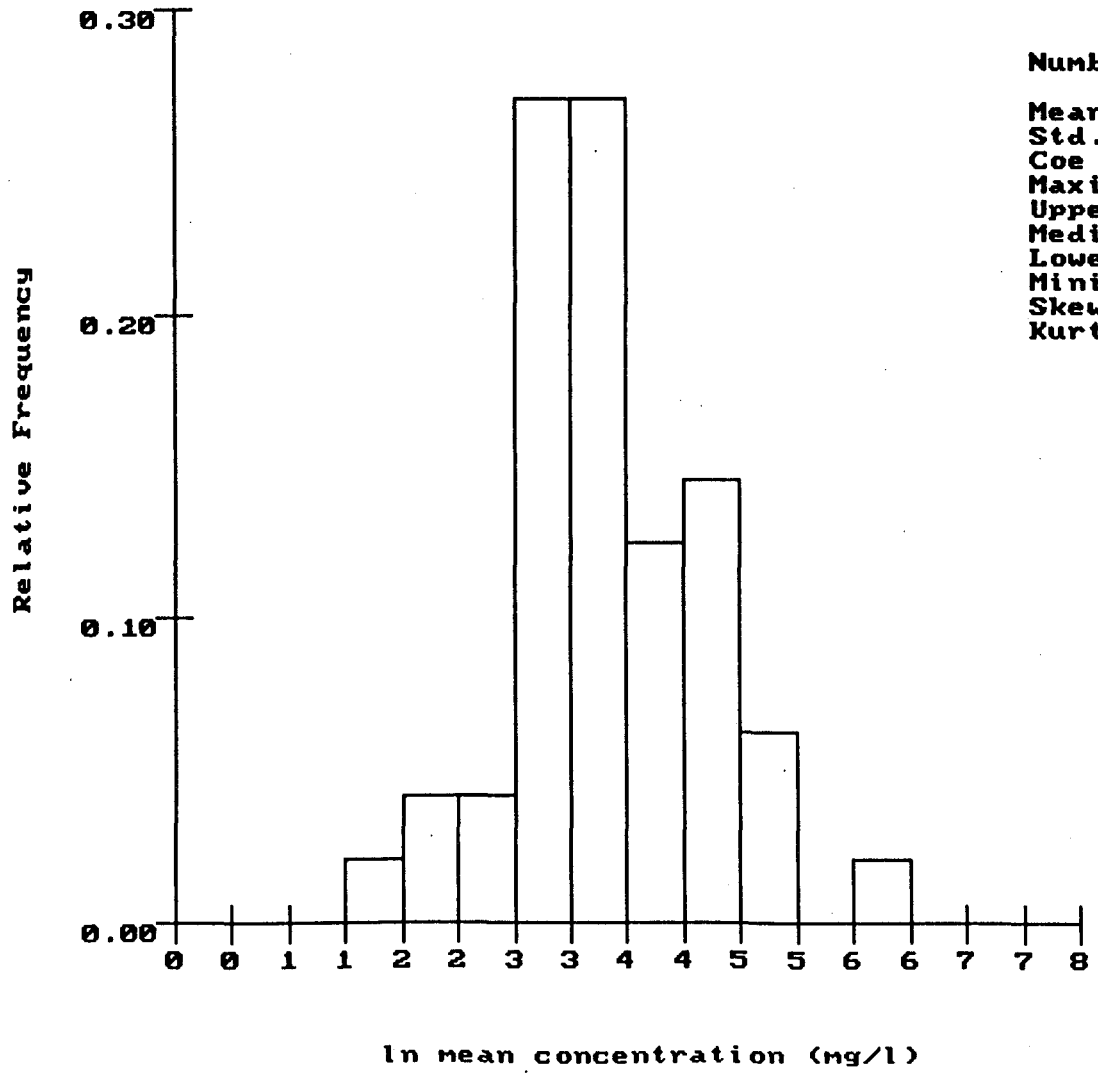
A= 2500.00 C= .77
# of Lags: 11.000
Unit Sep.Dis: 360.000
Lag Tolerance: 180.000

Azimuth Tol: 90.000
Bandwidth: 8000.000

Semivariogram: UHSU U-235
Normal Score value

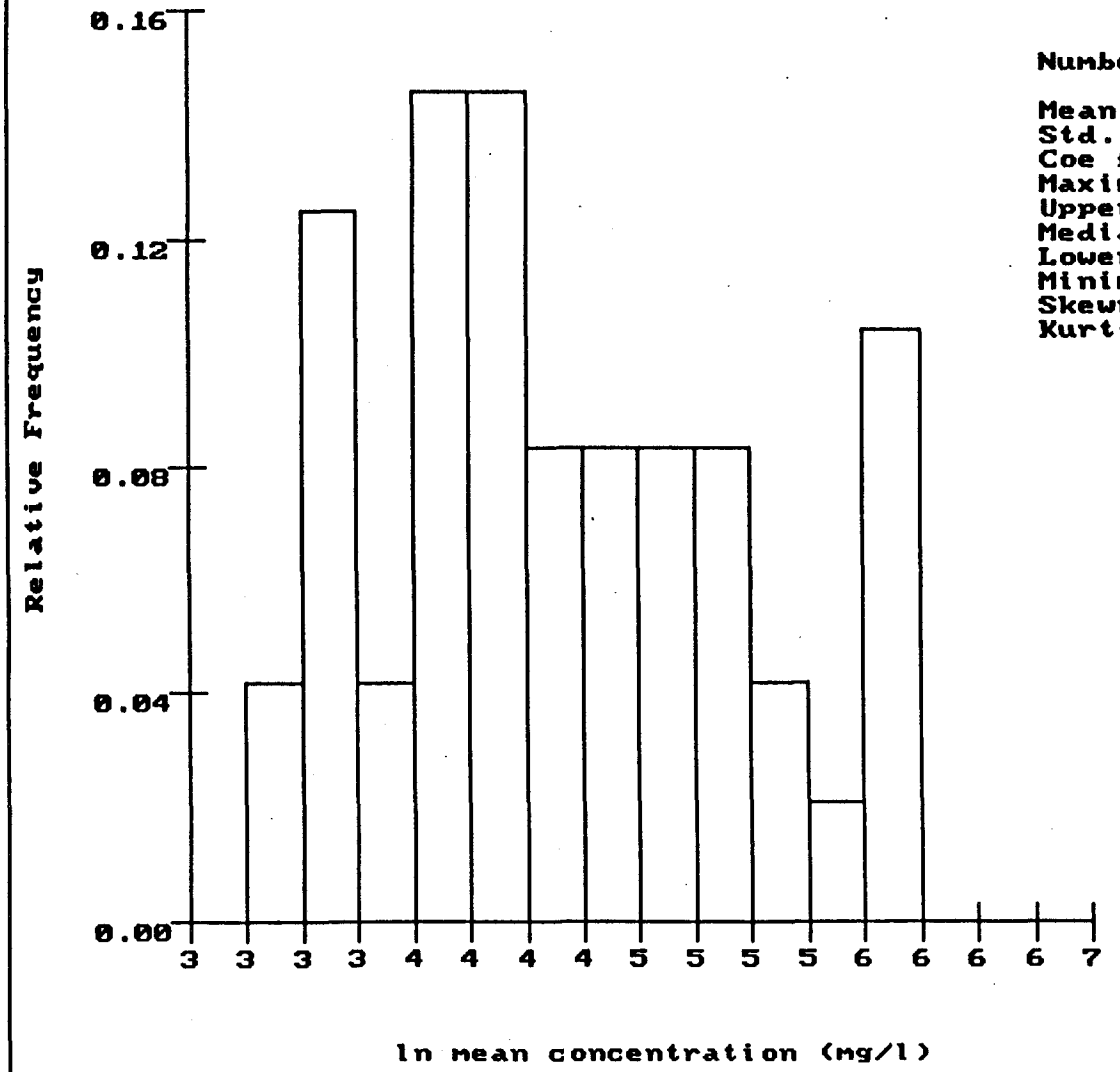


LHSU CALCIUM MEAN ln CONCENTRATIONS

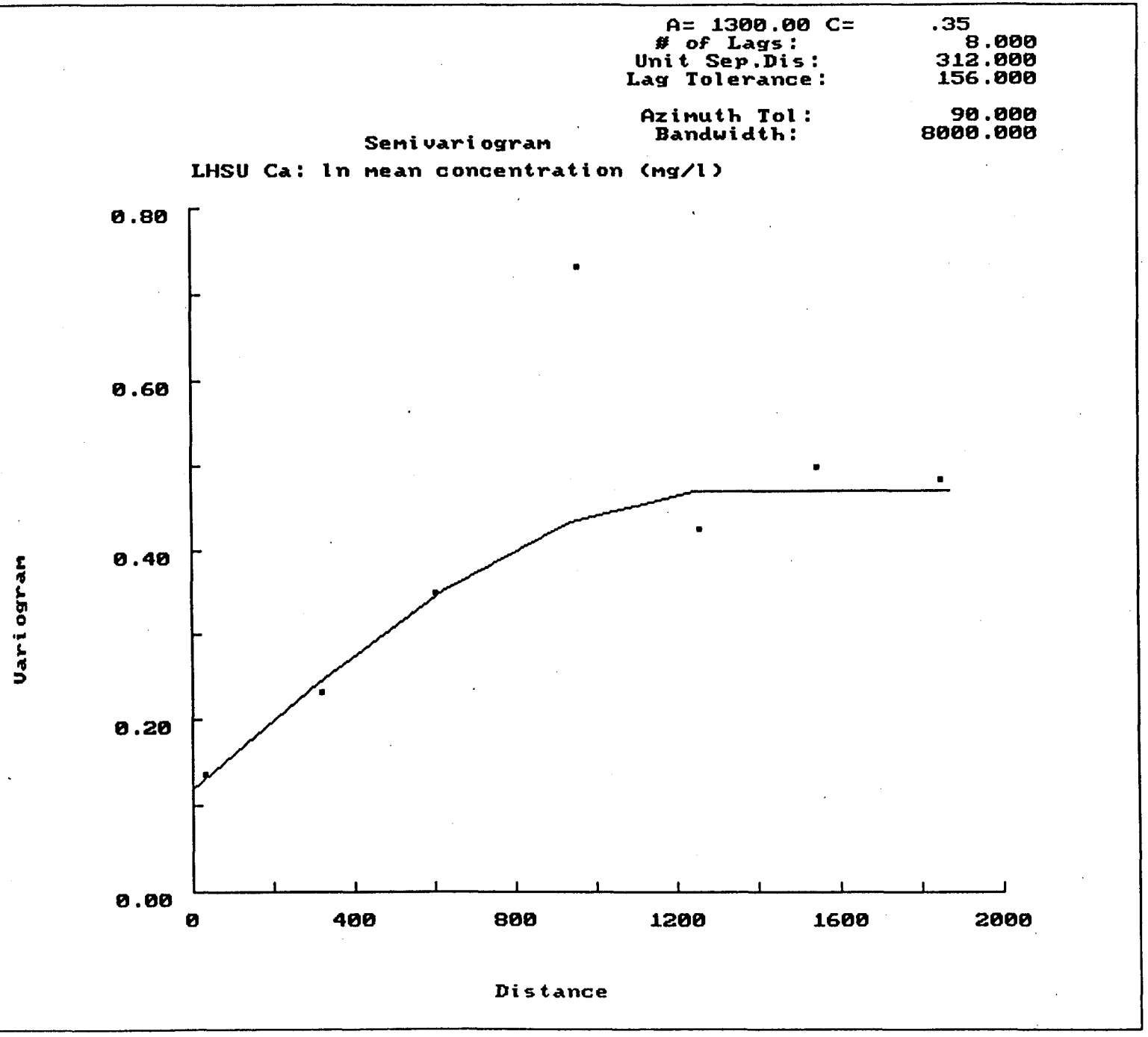


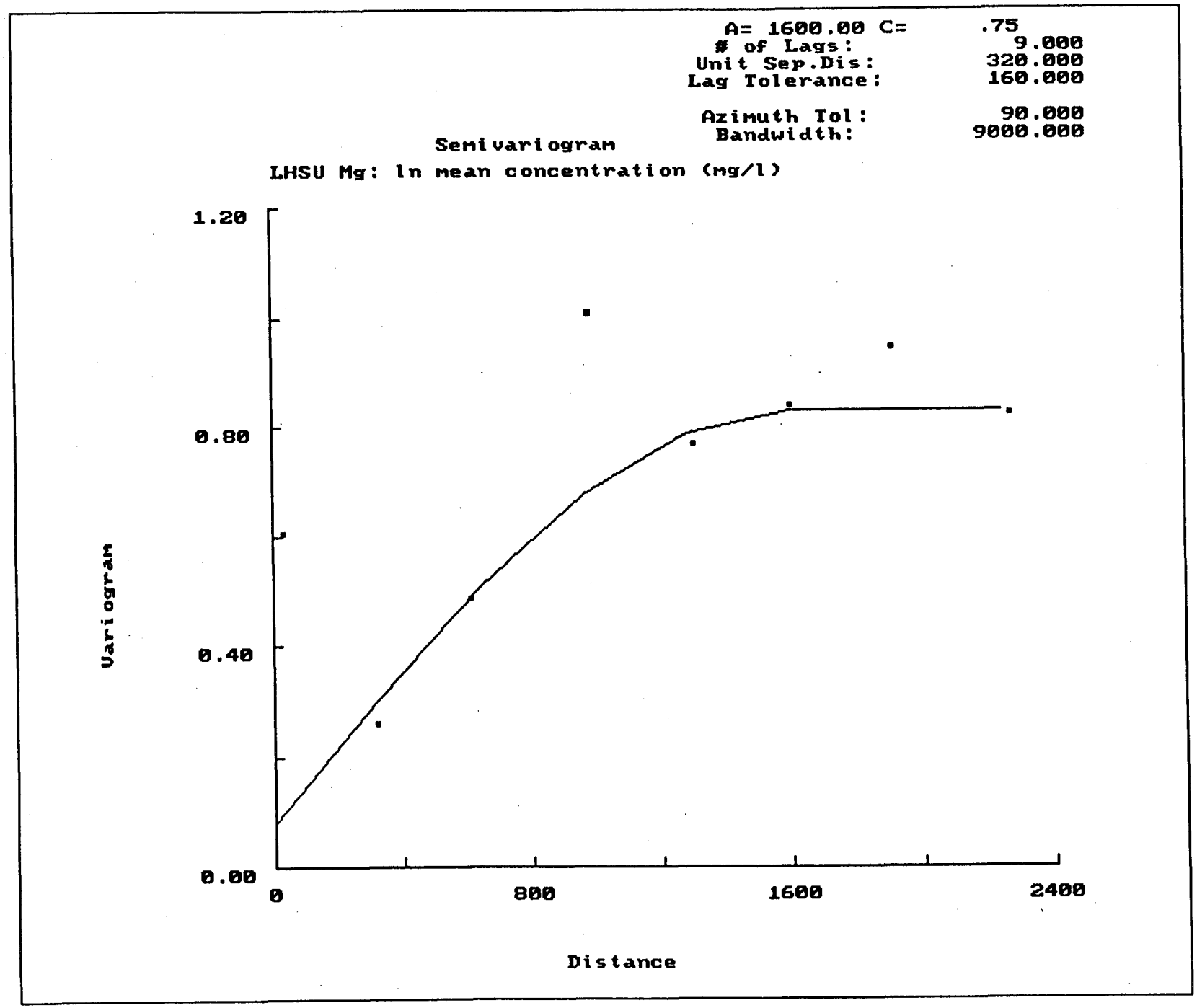
Number of Data	48
Mean	3.843
Std. Dev.	.890
Coe f. of Var	.232
Maximum	6.230
Upper Quartile	4.380
Median	3.740
Lower Quartile	3.200
Minimum	1.910
Skewness	1.548
Kurtosis	2.899

LHSU Mg: ln mean concentration (mg/L)



Number of Data	48
Mean	4.666
Std. Dev.	.796
Coe f. of Var	.171
Maximum	6.140
Upper Quartile	5.305
Median	4.480
Lower Quartile	4.090
Minimum	3.430
Skewness	1.539
Kurtosis	2.692


A= 1300.00 C= .35
# of Lags: 8.000
Unit Sep.Dis: 312.000
Lag Tolerance: 156.000
Azimuth Tol: 90.000
Bandwidth: 8000.000
Semivariogram
LHSU Ca: ln mean concentration (mg/l)
Variogram
0.80
0.60
0.40
0.20
0.00
0
400
800
1200
1600
2000
Distance


A= 1600.00 C= .75
# of Lags: 9.000
Unit Sep.Dis: 320.000
Lag Tolerance: 160.000
Azimuth Tol: 90.000
Bandwidth: 9000.000
Semivariogram
LHSU Mg: ln mean concentration (mg/l)
1.20
0.80
0.40
0.00
Variogram
0
800
1600
2400
Distance

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE STABLE-ISOTOPE STUDY:
COMPARISON OF LABORATORY RESULTS

RFP Well Number	Quarter Sampled	Relative Percent Difference Calculations for Split Samples (RPD)								
		University of Colorado results			University of Waterloo results			Relative Percent Difference		
		δ18O	δD	*d*	δ18O	δD	*d*	δ18O	δD	*d*
1186	1st 1991	-12.43	-99.5	-0.06	-12.49	-100.9	-0.98	-0.32	-0.93	-167.27
1486	1st 1991	-14.81			-13.97	-111.6	0.16	3.85		
1586	1st 1991	-13.54	-104.2	4.12	-13.57	-102.4	6.16	-0.15	1.16	-28.33
3586	1st 1991	-14.24	-108.7	5.22	-14.27	-104.6	9.56	-0.14	2.55	-43.40
4286	1st 1991	-13.83	-106.6	4.04	-14.25	-105.6	8.4	-2.00	0.63	-52.91
5086	1st 1991	-11.12	-98.5	-9.54	-11.34	-85.14	5.58	-1.31	9.47	224.00
6586	1st 1991	-13.12			-13.28	-103.7	2.54	-0.81		
2587	1st 1991	-13.57	-115.3	-6.74	-15.41	-116.8	6.48	-8.65	-0.86	377.71
4187	1st 1991	-13.59			-13.53	-98.84	9.4	0.29		
4587	1st 1991	-10.98	-101.2	-13.36	-13.29	-102	4.32	-13.11	-0.53	157.86
1186	2nd 1991	-14.24	-101	12.92	-12.66	-96.8	4.48	7.68	2.81	55.67
1486	2nd 1991	-14.33	-110.1	4.54	-14.23	-110.1	3.74	0.47	0.00	12.48
1586	2nd 1991	-13.57	-114.9	-6.34	-13.56	-97.54	10.94	0.05	10.61	1986.21
3386	2nd 1991	-10.28	-76.1	6.14	-10.33	-68.19	14.45	-0.32	7.18	-62.18
3586	2nd 1991	-12.28	-109.4	-11.16	-14.33	-112.2	2.44	-10.54	-1.69	136.82
4086	2nd 1991	-11.73	-90.3	3.54	-11.82	-86.56	8	-0.51	2.80	-59.15
2587	2nd 1991	-15.16	-114	7.28	-15.19	-115.1	6.42	-0.13	-0.64	8.20

RPD = (N1-N2)/[(N1+N2/2)] * 100

Appendix G

Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	Surface Elevation[2]	Top of Casing[2]	Well Stick-Up[3]	Total Depth of Casing[4]	Depth to Top of Screen[4]	Depth to Bottom of Screen[4]	Screen Length (ft)	Depth to Top of Bedrock[4]	Depth to Middle of Screen[4]	Depth below Top of Bedrock[4]
0186	Qa	s	5627.67	5629.32	1.65	10.2	3.2	10.2	7.0	9.3	6.7	NP
1186	Qa	s	5718.04	5720.09	2.05	10.3	3.9	10.3	6.3	9.5	7.1	NP
1586	Qc	s	5848.43	5850.63	2.20	14.4	4.1	14.4	10.4	12.5	9.3	NP
1786	Qc	s	5868.43	5869.57	1.14	14.0	3.7	14.0	10.3	12.5	8.9	NP
2286	Qrf	s	5978.77	5979.55	0.78	11.2	3.2	11.2	8.0	11.0	7.2	NP
2486	Qrf	s	5982.45	5983.56	1.11	7.5	3.0	7.5	4.5	7.2	5.2	NP
2686	Qrf	s	5975.42	5977.17	1.75	11.0	3.8	11.0	7.3	10.5	7.4	NP
3386	Qrf	s	5951.40	5952.42	1.02	7.3	3.0	7.3	4.4	6.8	5.2	NP
3586	Qc	s	5910.75	5912.76	2.01	11.6	4.9	11.6	6.7	10.5	8.2	NP
3686	Qc	s	5883.69	5885.22	1.53	6.5	3.5	6.5	3.0	5.5	5.0	NP
3886	Qa	s	5734.05	5736.08	2.03	8.5	2.9	8.5	5.6	6.0	5.7	NP
3986	Qrf	s	5908.23	5909.41	1.18	31.5	5.0	31.5	26.5	30.5	18.3	NP
4186	Qrf	s	5942.62	5944.36	1.74	44.7	3.9	44.7	40.8	44.6	24.3	NP
4286	Qrf	s	5956.27	5957.87	1.60	29.7	6.1	29.7	23.6	28.3	17.9	NP
4486	Qrf	s	6019.9	6021.96		26.3	3.2	26.3	23.1	25.5	14.8	NP
4586	Qrf	s	6049.99	6051.55	1.56	48.2	3.0	48.2	45.2	49.7	25.6	NP
4786	Qrf	s	6081.90	6083.67	1.77	94.5	6.2	94.5	88.3	93.0	50.4	NP
4986	Qrf	s	6097.37	6098.89	1.52	67.6	4.1	67.6	63.5	68.0	35.9	NP
5086	Qrf	s	6121.04	6122.94	1.90	96.2	2.9	96.2	93.3	98.0	49.5	NP
5186	Qrf	s	6142.37	6144.25	1.88	79.1	4.8	79.1	74.2	78.5	41.9	NP
5386	Qrf	s	6065.75	6066.63	0.88	7.8	2.5	7.8	5.3	7.0	5.2	NP
5586	Qrf	s	6116.64	6118.72	2.08	36.4	3.6	36.4	32.8	35.5	20.0	NP
5686	Qc	s	5987.46	5988.93	1.47	9.6	2.6	9.6	7.0	9.0	6.1	NP
5786	Qc	s	5951.46	5952.88	1.42	6.8	2.5	6.5	4.0	6.0	4.5	NP
6186	Qrf	s	5999.5	6000.60		12.3	5.0	12.0	7.0	11.5	8.5	NP
6586	Qa	s	5786.66	5788.27	1.61	8.0	2.5	8.0	5.5	7.1	5.3	NP
6886	Qc	s	5887.97	5890.49	2.52	3.5	1.5	3.5	2.0	2.8	2.5	NP
7086	Qc	s	5937.69	5939.39	1.70	7.9	2.4	7.9	5.5	7.0	5.1	NP
0487	Qc	s	5910.12	5911.58	1.46	19.7	3.5	19.5	16.0	19.7	11.5	NP
1787	Qrf	s	5968.01	5969.56	1.55	25.8	3.5	25.5	22.0	25.0	14.5	NP
2187	Qc	s	5928.43	5929.69	1.26	10.6	3.3	10.4	7.2	8.0	6.8	NP
2987	Qc	s	5812.61	5814.29	1.68	20.6	3.5	20.3	16.8	19.8	11.9	NP
3287	Qrf	s	5946.38	5947.97	1.59	46.8	36.0	46.6	10.6	46.0	41.3	NP
4387	Qc	s	5925.06	5926.41	1.35	12.5	3.5	12.3	8.8	12.0	7.9	NP
5487	Qc	s	5955.85	5957.62	1.77	4.7	1.3	4.5	3.2	4.0	2.9	NP
5687	Qrf	s	5978.39	5979.77	1.38	9.9	3.5	9.7	6.2	9.4	6.6	NP
B400189	Qrf	s	6122.20	6124.15	1.95	51.4	10.1	49.6	39.5	52.5	29.8	NP
B400289	Qrf	s	6106.00	6107.71	1.71	51.3	20.5	50.0	29.5	NP	35.3	NP
B400389	Qrf	s	6122.00	6124.00	2.00	50.3	9.5	49.0	39.5	48.5	29.3	NP
B400489	Qrf	s	6105.01	6107.07	2.06	55.7	9.9	54.5	44.6	54.0	32.2	NP
B200589	Qrf	s	5968.40	5970.17	1.77	33.3	11.9	31.6	19.7	30.5	21.7	NP

[1] s=surficial deposits, w=weathered bedrock, u=unweathered bedrock

[2] *units=feet* above mean sea level

[3] units=feet above ground surface

[4] units=feet below ground surface, NP=not penetrated, ND=not determined

Appendix G
Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	Surface Elevation[2]	Top of Casing[2]	Well Stick-Up[3]	Total Depth of Casing[4]	Depth to Top of Screen[4]	Depth to Bottom of Screen[4]	Screen Length (ft)	Depth to Top of Bedrock[4]	Depth to Middle of Screen[4]	Depth below Top of Bedrock[4]
B200689	Qrf	s	5960.10	5961.94	1.84	32.8	11.6	31.1	19.5	30.5	21.3	NP
B200789	Qrf	s	5946.10	5948.08	1.98	30.5	9.1	28.5	19.4	28.0	18.8	NP
B200889	Qrf	s	5936.10	5938.08	1.98	24.7	8.6	23.1	14.5	22.7	15.9	NP
B401989	Qc	s	6025.60	6027.67	2.07	22.7	6.6	21.0	14.5	20.5	13.8	NP
B302089	Qc	s	5907.60	5909.55	1.95	15.0	3.9	13.3	9.5	13.5	8.6	NP
B102289	Qc	s	5978.30	5980.06	1.76	14.2	3.0	12.5	9.5	12.5	7.7	NP
B202489	Qc	s	5770.90	5772.83	1.93	14.7	3.4	12.9	9.5	12.4	8.2	NP
B402689	Qc	s	6045.40	6047.07	1.67	5.9	2.6	3.3	0.7	2.8	2.9	NP
B205589	Qc	s	5806.4	5808.46		18.0	6.9	16.3	9.4	32.3	11.6	NP
B405689	Qrf	s	6105.30	6107.25	1.95	23.8	3.0	22.5	19.5	NP	12.8	NP
B405789	Qrf	s	6104.80	6106.70	1.90	53.7	43.0	52.5	9.5	52.0	47.8	NP
P207689	Qrf	s	5966.32	5967.88	1.56	14.4	3.6	13.1	9.5	12.6	8.4	NP
P207889	Qrf	s	5962.82	5964.90	2.08	9.0	3.3	7.7	4.4	8.5	5.5	NP
B208089	Qc	s	5935.40	5937.07	1.67	14.2	3.4	12.9	9.5	12.2	8.2	NP
B208789	Qc	s	5907.10	5909.03	1.93	12.3	2.9	10.9	8.1	8.4	6.9	NP
P209289	Qrf	s	5981.59	5983.42	1.83	13.4	8.2	12.7	4.5	12.2	10.4	NP
P209789	Qrf	s	5962.82	5964.94	2.12	13.8	3.0	12.5	9.5	12.0	7.8	NP
B210489	Qc	s	5856.40	5858.71	2.31	8.7	3.0	7.4	4.4	7.0	5.2	NP
P213689	Qrf	s	5994.3	5996.04		14.8	9.1	13.5	4.4	13.0	11.3	NP
P215789	Qrf	s	6002.0	6003.66		19.6	14.5	18.5	4.0	18.0	16.5	NP
P218289	Qrf	s	6016.9	6018.20		24.7	9.5	23.5	14.0	23.0	16.5	NP
P313589	Qrf	s	6008.5	6010.11		13.8	8.1	12.5	4.4	11.0	10.3	NP
P317989	Qrf	s	5990.9	5992.84		8.7	3.0	7.5	4.5	6.4	5.3	NP
B410589	Qrf	s	6111.80	6113.80	2.00	61.3	40.6	60.0	19.5	NP	50.3	NP
B410689	Qrf	s	6091.70	6093.71	2.01	51.3	30.5	50.1	19.6	NP	40.3	NP
B410789	Qrf	s	6082.10	6083.66	1.56	46.3	25.5	45.0	19.5	NP	35.3	NP
B110889	Qrf	s	6075.60	6077.77	2.17	65.8	45.3	64.8	19.5	65.0	55.0	NP
B110989	Qrf	s	6082.30	6084.36	2.06	66.9	46.1	65.6	19.5	71.0	55.9	NP
B111189	Qrf	s	6105.70	6107.52	1.82	73.8	53.1	72.6	19.5	NP	62.8	NP
B411289	Qrf	s	6125.40	6127.30	1.90	69.7	48.9	68.4	19.5	NP	58.6	NP
B411389	Qrf	s	6109.50	6111.06	1.56	64.8	44.0	63.5	19.5	NP	53.8	NP
P114489	Qrf	s	6033.4	6035.43	2.03	50.1	44.4	48.8	4.4	48.3	46.6	NP
P114589	Qrf	s	6024.1	6025.90	1.80	37.6	32.5	36.5	4.0	27.5	34.5	NP
P114689	Qrf	s	6004.00	6005.76	1.76	23.5	17.8	22.2	4.4	22.0	20.0	NP
P114789	Qrf	s	6010.7	6012.40	1.70	27.7	21.8	26.2	4.4	26.0	24.0	NP
P114989	Qrf	s	6029.8	6031.84	2.04	39.3	33.6	38.0	4.4	37.5	35.8	NP
P115089	Qrf	s	6038.1	6040.10	2.00	42.0	36.3	40.7	4.4	40.2	38.5	NP
P115489	Qrf	s	6023.4	6025.10	1.70	27.8	22.1	26.5	4.4	26.0	24.3	NP
P115589	Qrf	s	6014.1	6015.77	1.67	30.7	25.1	29.5	4.4	29.0	27.3	NP
P115689	Qrf	s	6006.9	6008.71	1.81	21.3	16.2	20.2	4.0	19.7	18.2	NP
P119389	Qrf	s	6011.7	6013.18	1.48	18.2	12.5	16.9	4.4	16.4	14.7	NP

[1] s=surficial deposits, w=weathered bedrock, u=unweathered bedrock
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Appendix G
Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	Surface Elevation[2]	Top of Casing[2]	Well Stick-Up[3]	Total Depth of Casing[4]	Depth to Top of Screen[4]	Depth to Bottom of Screen[4]	Screen Length (ft)	Depth to Top of Bedrock[4]	Depth to Middle of Screen[4]	Depth below Top of Bedrock[4]
P314089	Qrf	s	5996.70	5998.49	1.79	11.1	5.4	9.8	4.4	9.3	7.6	NP
P320089	Qrf	s	6009.90	6011.87	1.97	20.1	14.4	18.8	4.4	18.8	16.6	NP
P414189	Qrf	s	6010.6	6012.18	1.58	19.8	14.1	18.5	4.4	18.0	16.3	NP
P415889	Qrf	s	6050.4	6052.60	2.20	44.5	38.8	43.2	4.4	49.5	41.0	NP
P415989	Qrf	s	6044.9	6046.71	1.81	28.0	22.3	26.7	4.4	34.0	24.5	NP
P416089	Qrf	s	6051.7	6053.95	2.25	35.4	29.2	34.0	4.8	33.5	31.6	NP
P416189	Qrf	s	6045.6	6047.95	2.35	30.9	25.2	29.7	4.5	29.2	27.5	NP
P416289	Qrf	s	6038.6	6040.22	1.62	24.8	19.1	23.5	4.4	23.0	21.3	NP
P416389	Qrf	s	6055.40	6057.14	1.74	31.4	25.7	30.1	4.4	30.0	27.9	NP
P416489	Qrf	s	6048.50	6050.15	1.65	27.0	21.3	25.7	4.4	25.2	23.5	NP
P416589	Qrf	s	6041.20	6042.81	1.61	32.1	27.0	31.0	4.0	30.5	29.0	NP
P416689	Qrf	s	6035.00	6036.55	1.55	33.8	28.1	32.5	4.4	32.0	30.3	NP
P416789	Qrf	s	6027.80	6029.27	1.47	28.2	22.5	26.9	4.4	26.4	24.7	NP
P416889	Qrf	s	6017.4	6018.79	1.39	21.5	15.9	20.3	4.4	20.2	18.1	NP
P218089	Qrf	s	5985.80	5987.55	1.75	8.7	3.0	7.4	4.4	6.0	5.2	NP
P219189	Qc	s	5941.20	5943.15	1.95	12.8	7.1	11.5	4.4	11.0	9.3	NP
P419689	Qrf & Kss	s	6022.40	6023.42	1.02	24.8	19.1	23.5	4.4	22.0	21.3	NP
0390	Qrf	s	6075.4	6079.13	3.73	70.0	50.0	65.0	15.0	92.0	57.5	NP
0590	Qrf	s	6096.80	6099.77	2.97	31.5	11.0	26.0	15.0	50.0	18.5	NP
0690	Qrf	s	6083.70	6086.91	3.21	27.3	7.0	22.0	15.0	41.3	14.5	NP
0790	Qrf	s	6095.90	6098.79	2.89	53.3	33.0	48.0	15.0	48.8	40.5	NP
0990	Qrf	s	6080.50	6083.48	2.98	40.3	20.0	35.0	15.0	35.0	27.5	NP
00191	Qrf	s	5968.86	5970.44	1.58	27.0	15.0	25.0	10.0	24.2	20.0	NP
01391	Qrf	s	5973.70	5975.30	1.60	16.0	6.0	14.0	8.0	14.5	10.0	NP
03991	Qrf	s	5935.17	5936.87	1.70	39.4	27.4	37.4	10.0	36.0	32.4	NP
04191	Qrf	s	5955.58	5956.99	1.41	19.1	7.1	17.1	10.0	17.1	12.1	NP
04591	Qrf	s	5948.69	5950.25	1.56	46.1	34.1	44.1	10.0	44.2	39.1	NP
05091	Qrf	s	5937.63	5939.24	1.61	46.0	34.0	44.0	10.0	43.5	39.0	NP
05191	Qrf	s	5938.40	5939.85	1.45	48.0	36.0	46.0	10.0	44.8	41.0	NP
05391	Qrf	s	5940.19	5941.67	1.48	37.1	22.0	35.1	13.1	34.9	28.6	NP
5691	Qrf	s	5947.60	5948.99	1.39	37.1	25.1	35.1	10.0	35.2	30.1	NP
06091	Qrf	s	5930.08	5931.60	1.52	42.7	30.7	40.7	10.0	39.1	35.7	NP
06191	Qrf	s	5919.21	5920.72	1.51	34.1	22.1	32.1	10.0	32.0	27.1	NP
06791	Qrf	s	5978.87	5980.38	1.51	23.2	11.2	21.2	10.0	21.2	16.2	NP
06891	Qrf	s	5974.14	5975.62	1.48	16.0	6.0	14.0	8.0	14.0	10.0	NP
06991	Qrf	s	5972.91	5974.57	1.66	31.0	14.0	29.0	15.0	28.6	21.5	NP
07191	Qrf	s	5974.79	5976.34	1.55	23.1	11.1	21.1	10.0	20.0	16.1	NP
13091	Qrf	s	5973.68	5975.20	1.52	23.3	11.3	21.3	10.0	19.5	16.3	NP
13391	Qrf	s	5923.83	5925.35	1.52	41.0	29.0	39.0	10.0	38.6	34.0	NP
37591	Qrf	s	5991.42	5993.45	2.03	14.6	7.6	12.6	5.0	12.0	10.1	NP
41091	Qa	s	5719.56	5721.85	2.29	12.3	7.8	10.0	2.2	10.0	8.9	NP

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Appendix G

Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	Surface Elevation[2]	Top of Casing[2]	Well Stick-Up[3]	Total Depth of Casing[4]	Depth to Top of Screen[4]	Depth to Bottom of Screen[4]	Screen Length (ft)	Depth to Top of Bedrock[4]	Depth to Middle of Screen[4]	Depth below Top of Bedrock[4]
10692	Qc	s	5941.50	5943.60	2.10	21.3	5.0	19.4	14.4	18.9	12.2	NP
43392	Qrf	s	6041.9	6043.44	1.54	32.8	25.6	30.3	4.7	31.4	28.0	NP
46192	Qrf	s	6141.50	6143.37	1.87	80.0	57.2	77.2	20.0	77.0	67.2	NP
46292	Qrf	s	6095.30	6097.24	1.94	93.3	45.5	90.5	45.0	90.5	68.0	NP
46492	Qrf	s	6054.7	6056.81	2.11	46.0	28.2	43.2	15.0	43.0	35.7	NP
50092	Qa	s	5822.3	5824.30	2.00	13.1	5.3	10.3	5.0	10.2	7.8	NP
75292	Qa	s	5754.9	5756.90	2.00	9.6	5.6	7.6	2.0	7.6	6.6	NP
61593		s	5931.4			8.1	3.1	8.1	5.0	NP	5.6	NP
61693		s	5945.5			14.8	9.8	14.8	5.0	NP	12.3	NP
61793		s	5918.7			5.9	0.9	5.9	5.0	NP	3.4	NP
61893		s	5946.2			8.8	3.8	8.8	5.0	NP	6.3	NP
62093		s	6011.3			8.8	3.8	8.8	5.0	NP	6.3	NP
62193		s	6018.4			5.9	0.9	5.9	5.0	NP	3.4	NP
62293		s	6023.3			5.7	0.7	5.7	5.0	NP	3.2	NP
62393		s	6064.1			5.7	0.7	5.7	5.0	NP	3.2	NP
62493		s	6047.6			8.8	3.8	8.8	5.0	NP	6.3	NP
62593		s	6047.8			8.4	3.4	8.4	5.0	NP	5.9	NP
62693		s	6041.8			8.6	3.6	8.6	5.0	NP	6.1	NP
62793		s	5939.5			11.8	6.8	11.8	5.0	NP	9.3	NP
62893		s	5995.2			14.8	9.8	14.8	5.0	NP	12.3	NP
0886	Kssit	u	5925.60	5926.90	1.30	63.8	59.1	63.8	4.7	1.0	61.4	60.4
0986	Kss & Kssit	u	5996.39	5998.23	1.84	135.4	122.6	135.4	12.8	30.3	129.0	98.7
1486	Kss & Ksclst	u	5844.71	5846.71	2.00	55.4	39.4	55.4	15.9	11.0	47.4	36.4
1686	Ksltss	u	5867.92	5869.55	1.63	45.1	39.1	45.1	6.0	7.0	42.1	35.1
2186	Kss & Ksltclst	u	6004.8	6005.96	1.16	67.3	35.0	67.2	32.2	15.0	51.1	36.1
2386	Kslt & Ksltclst	u	5982.46	5982.46	0.00	117.3	113.0	117.3	4.3	8.2	115.1	106.9
2586	Ksltclst & Kclst	u	5975.24	5977.14	1.90	82.0	59.9	82.0	22.1	8.0	71.0	63.0
2786	Kssits & Ksclst	u	5962.89	5963.88	0.99	133.0	128.5	133.0	4.5	11.0	130.8	119.8
3286	Kss & Ksltss	u	5966.08	5967.92	1.84	125.5	114.9	125.5	10.6	1.0	120.2	119.2
3486	Kcss & Kcslt	u	5912.00	5913.95	1.95	56.3	44.2	56.3	12.0	16.0	50.2	34.2
4086	Kclst	u	5943.85	5944.89	1.04	111.5	88.0	111.5	23.5	45.0	99.7	54.7
4686	Kslt & Kcslt	u	6081.99	6083.99	2.00	160.8	140.3	160.8	20.5	90.0	150.6	60.6
4886	Kssit & Kcslt	u	6097.14	6099.10	1.96	207.1	192.0	207.1	15.1	70.0	199.5	129.5
5486	Kssit & Kslt	u	6116.48	6117.62	1.14	85.3	75.4	85.2	9.8	36.0	80.3	44.3
0387	Kssit & Kcslt	u	5930.58	5932.44	1.86	108.0	102.8	107.8	5.0	20.8	105.3	84.5
0887	Ksltclst & Kclst	u	5919.95	5921.55	1.60	89.3	84.0	89.0	5.0	8.7	86.5	77.8
1687	Kslt	u	5969.49	5970.79	1.30	125.2	100.0	125.0	25.0	22.2	112.5	90.3
1887	Kss & Kssit	u	5967.99	5969.49	1.50	133.7	127.0	133.5	6.4	25.2	130.2	105.0
2087	Ksltclst	u	5968.66	5970.14	1.48	116.4	107.3	116.1	8.8	11.8	111.7	99.9
2287	Kss & Kslt	u	5931.18	5932.80	1.62	88.7	81.4	88.5	7.1	12.8	84.9	72.1
2887	Kslt & Kclst	u	5947.56	5949.90	2.34	197.7	187.4	197.4	10.0	43.5	192.4	148.9

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Appendix G

Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	Surface Elevation[2]	Top of Casing[2]	Well Stick-Up[3]	Total Depth of Casing[4]	Depth to Top of Screen[4]	Depth to Bottom of Screen[4]	Screen Length (ft)	Depth to Top of Bedrock[4]	Depth to Middle of Screen[4]	Depth below Top of Bedrock[4]
3087	Kcslt	u	5810.12	5811.77	1.65	94.4	85.8	94.4	8.6	16.0	90.1	74.1
3187		u	5945.31	5947.46	2.15	129.6	110.7	129.4	18.8	45.0	120.0	75.0
3487	Ksltclst & Kslt	u	5945.60	5947.22	1.62	104.5	97.3	104.2	6.9	20.0	100.8	80.8
3987	Ksslt & Kclst	u	5946.95	5948.42	1.47	117.4	110.0	117.1	7.2	3.5	113.6	110.1
3987 DUP	Ksslt & Kclst	u	5946.95	5948.42	1.47	117.4	110.0	117.1	7.2	3.5	113.6	110.1
4187	Ksltss	u	5883.0	5884.49	1.49	94.0	81.2	93.8	12.6	3.5	87.5	84.0
4587	Kss & Kslt & Kclst	u	5949.32	5950.91	1.59	101.3	89.5	97.1	7.6	4.0	93.3	89.3
B203789	Kcslt & Kclst	u	5946.20	5948.28	2.08	140.8	134.2	138.6	4.4	28.7	136.4	107.7
B203889	Kclst	u	5935.80	5937.69	1.89	113.9	107.0	111.4	4.4	28.5	109.2	80.7
B203989	Ksltss & Kslt	u	5920.9	5922.78		132.7	126.0	130.4	4.4	22.7	128.2	105.5
B204089	Ksltss	u	5877.60	5879.29	1.69	115.2	106.5	112.9	6.4	1.2	109.7	108.5
B204189	Kcss, Ksltss & Ksclst	u	5826.90	5828.86	1.96	97.6	81.1	95.3	14.2	3.5	88.2	84.7
B304289	Kss & Kslt & Kclst	u	5833.00	5838.18	5.18	91.0	84.0	88.5	4.5	10.5	86.3	75.8
B207089	Ksclst & Ksltclst	u	5883.1	5884.95	1.85	54.0	31.3	53.0	21.7	6.0	42.2	36.2
P208889	Ksltclst	u	5947.30	5949.25	1.95	99.2	87.8	96.9	9.2	5.5	92.4	86.9
P416989	Ksslt & Kslt	u	6045.2	6047.55	2.35	158.0	151.2	155.6	4.4	30.0	153.4	123.4
B217289	Kss, Ksltss, Kcslt	u	5677.60	5679.10	1.50	136.4	109.8	134.1	24.3	5.1	122.0	116.9
B217489	Kss	u	5961.20	5963.23	2.03	148.7	142.0	146.4	4.4	25.2	144.2	119.0
B217589	Kss & Ksltclst	u	5952.90	5954.89	1.99	92.9	85.2	90.7	5.5	17.3	88.0	70.7
B217689	Kclss	u	5960.53	5961.82	1.29	105.1	98.5	102.9	4.4	22.0	100.7	78.7
B217789	Ksltclst	u	5954.9	5956.85	1.95	86.0	72.0	83.8	11.8	23.6	77.9	54.3
00291	Kclss & Ksclst	u	5966.17	5967.57	1.40	56.0	44.0	54.0	10.0	16.0	49.0	33.0
46692	Ksltss, Ksslt & Kclst	u	5956.20	5958.25	2.05	89.8	72.0	87.0	15.0	24.5	79.5	55.0
46792	Ksslt, Kcslt & Kslt	u	5956.30	5958.44	2.14	114.6	96.8	111.8	15.0	24.5	104.3	79.8
46892	Ksltss, Ksslt & Kclst	u	5956.70	5958.56	1.86	164.7	146.9	161.9	15.0	24.5	154.4	129.9
22093	Kclst, Kclst & Ksltss	u	5945.0	5947.43	2.43	66.3	48.0	63.0	15.0	8.8	55.5	46.7
22193	Ksclst, Kcss & Kcls	u	5960.9	5963.36	2.46	59.7	49.6	56.4	6.8	8.5	53.0	44.5
22293	Ksclst, Kslst & Kcss	u	5881.5	5884.12	2.62	85.0	67.0	82.0	15.0	21.0	74.5	53.5
22393	Kcslst & Kclst	u	5969.3	5972.14	2.84	121.3	108.2	118.0	9.8	12.7	113.1	100.4
23193	Kss, Ksltss & Kcss	u	5948.2	5950.46	2.26	77.0	66.8	73.8	7.0	8.0	70.3	62.3
22593		u	5947.6	5950.20	2.60	98.0	85.0	95.0	10.0	ND	90.0	90.0
B405489	Ksltclst & Kclst	u/w?	6115.90	6117.67	1.77	50.1	39.1	48.6	9.5	34.0	43.9	9.9
0386	Kss	w	5676.2	5677.86	1.66	23.7	10.4	23.7	13.3	8.0	17.1	9.1
1986	Kclst	w	5943.08	5943.86	0.78	12.3	3.0	12.3	9.3	11.5	7.6	-3.9
3086	Kclst	w	5957.42	5958.39	0.97	14.9	2.5	14.9	12.5	2.5	8.7	6.2
5286	Kss & Ksltclst	w	6142.14	6144.44	2.30	125.7	92.0	125.8	33.8	72.0	108.9	36.9
6286	Ksltss & Kcss	w	5902.01	5903.18	1.17	35.2	25.2	35.2	10.0	22.0	30.2	8.2
0587	Kss & Ksltss	w	5927.85	5929.99	2.14	51.5	42.0	51.3	9.3	11.0	46.6	35.6
0987	Kss	w	5980.22	5981.70	1.48	32.4	14.5	32.2	17.7	12.5	23.3	10.8
1187	Kcss	w	5913.60	5915.12	1.52	20.5	15.2	20.3	5.1	5.2	17.7	12.5
1287	Kcslt	w	5934.81	5936.30	1.49	10.3	4.9	10.0	5.1	3.5	7.5	4.0

[1] s=surficial deposits, w=weathered bedrock, u=unweathered bedrock

[2] units=feet above mean sea level

[3] units=feet above ground surface

[4] units=feet below ground surface, NP=not penetrated, ND=not determined

Appendix G

Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	Surface Elevation[2]	Top of Casing[2]	Well Stick-Up[3]	Total Depth of Casing[4]	Depth to Top of Screen[4]	Depth to Bottom of Screen[4]	Screen Length (ft)	Depth to Top of Bedrock[4]	Depth to Middle of Screen[4]	Depth below Top of Bedrock[4]
1487	Kss & Kslt	w	5854.98	5856.56	1.58	24.3	19.0	24.1	5.1	5.2	21.5	16.3
2587	Ksltss & Kss	w	5959.48	5960.98	1.50	43.7	17.5	43.5	26.0	16.5	30.5	14.0
3687	Kss & Kslt & Kclst	w	5949.67	5951.11	1.44	63.6	19.8	63.4	43.6	7.4	41.6	34.2
B402189	Kss	w	6024.50	6026.49	1.99	24.6	13.5	22.9	9.4	7.5	18.2	10.7
B203189	Kclst & Ksclst	w	5968.00	5970.12	2.12	46.5	35.3	44.7	9.4	29.7	40.0	10.3
B203289	Kclst & Ksclst	w	5959.70	5961.59	1.89	46.0	35.0	44.5	9.5	30.1	39.8	9.7
B203489	Kclst	w	5945.70	5947.71	2.01	41.3	31.0	40.5	9.5	28.6	35.8	7.2
B203589	Qrf & Ksclst & Kclst	w	5935.20	5937.07	1.87	40.9	29.7	39.2	9.5	31.1	34.5	3.4
B303089	Kclst	w	5601.2	5602.93		8.9	4.6	7.0	2.4	4.6	5.8	1.2
B304889	Kclst	w	5730.60	5732.56	1.96	25.9	14.7	24.1	9.2	9.2	19.4	10.2
B304989	Ksltss & Ksslt	w	5729.70	5731.85	2.15	86.3	75.5	83.9	8.4	8.4	79.7	71.3
B405289	Ksclst & Ksltclst	w	5965.70	5967.31	1.61	48.0	41.2	45.7	4.5	8.6	43.5	34.9
B305389	Ksltclst & Kclst	w	5831.90	5833.90	2.00	26.3	15.2	24.6	9.4	10.0	19.9	9.9
B405889	Kss	w	6024.90	6026.87	1.97	46.8	36.0	45.5	9.5	6.5	40.8	34.3
P207389	Kss & Kclst	w	5981.02	5982.77	1.75	16.3	10.5	15.2	4.7	7.0	12.9	5.9
P207589	Ksltclst	w	5974.06	5975.96	1.90	25.1	14.4	23.9	9.5	9.4	19.1	9.7
P207789	Ksltclst	w	5965.88	5967.75	1.87	28.6	17.9	27.3	9.4	12.9	22.6	9.7
P207989	Kclst	w	5963.09	5965.17	2.08	21.7	11.0	20.5	9.5	5.8	15.7	9.9
B208189	Kclst	w	5935.40	5937.46	2.06	27.6	16.9	26.3	9.4	11.0	21.6	10.6
B208389	Ksclst & Kclst	w	5876.80	5878.66	1.86	9.1	3.4	7.8	4.4	0.2	5.6	5.4
B208689	Ksltclst	w	5867.60	5869.60	2.00	23.1	12.3	21.8	9.5	7.3	17.1	9.8
P208989	Ksltss & Ksltclst	w	5962.53	5964.56	2.03	26.1	15.4	24.8	9.4	3.5	20.1	16.6
P209089	Ksltclst	w	5972.16	5974.25	2.09	27.2	16.5	26.0	9.5	11.5	21.2	9.7
P209189	Kss & Ksltclst	w	5980.66	5982.21	1.55	36.1	13.3	35.0	21.7	10.3	24.2	13.9
P209389	Kss & Ksltss & Kcss	w	5981.47	5983.39	1.92	30.1	16.8	28.8	12.0	13.8	22.8	9.0
P209489	Kss & Ksltss	w	5977.98	5980.10	2.12	36.3	15.5	35.0	19.5	9.0	25.2	16.2
P209589	Ksltclst & Ksclst	w	5948.17	5950.04	1.87	19.8	9.1	18.5	9.5	4.1	13.8	9.7
P209689	Ksltclst	w	5962.63	5964.43	1.80	27.9	17.2	26.7	9.5	12.2	21.9	9.7
P209889	Ksltclst	w	5940.28	5942.40	2.12	19.6	8.9	18.3	9.4	3.9	13.6	9.7
P210089	Ksltclst	w	5898.40	5900.40	2.00	22.9	12.2	21.5	9.3	7.2	16.9	9.7
P210189	Ksltss & Ksclst	w	5980.82	5982.48	1.66	37.1	20.4	36.1	15.7	14.6	28.3	13.7
00391	Ksclst & Kcss	w	5920.84	5922.40	1.56	23.8	16.8	21.8	5.0	16.9	19.3	2.4
01491	Kss & Kcs	w	5970.37	5972.03	1.66	26.0	14.0	24.0	10.0	1.6	19.0	17.4
02091	Ksclst, Ksslt, Ksltclst	w	5965.19	5966.65	1.46	32.6	15.6	30.6	15.0	16.1	23.1	7.0
02291	Ksclst & Kclss	w	5936.66	5938.26	1.60	18.5	11.5	16.5	5.0	8.8	14.0	5.2
02491	Ksltss, Ksslt	w	5944.54	5946.21	1.67	18.8	11.8	16.8	5.0	8.5	14.3	5.8
02591	Kclss & Ksclst	w	5923.57	5925.34	1.77	51.1	42.1	49.1	7.0	39.8	45.6	5.8
02991	Kclss & Ksclst	w	5956.30	5957.90	1.60	54.0	42.0	52.0	10.0	15.8	47.0	31.2
03391	Kss, Ksltss & Ksclst	w	5944.54	5946.22	1.68	41.9	29.9	39.9	10.0	10.8	34.9	24.1
03691	Kss & Kcss	w	5932.55	5934.43	1.88	42.0	30.0	40.0	10.0	7.5	35.0	27.5
03791	Kss, Ksclst & Ksltss	w	5936.80	5938.24	1.44	50.0	38.0	48.0	10.0	4.9	43.0	38.1

[1] s=surficial deposits, w=weathered bedrock, u=unweathered bedrock

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[4] units=feet below ground surface, NP=not penetrated, ND=not determined

Appendix G
Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	Surface Elevation[2]	Top of Casing[2]	Well Stick-Up[3]	Total Depth of Casing[4]	Depth to Top of Screen[4]	Depth to Bottom of Screen[4]	Screen Length (ft)	Depth to Top of Bedrock[4]	Depth to Middle of Screen[4]	Depth below Top of Bedrock[4]
06591	Ksclst & Ksltclst	w	5978.28	5979.78	1.50	50.0	33.0	48.0	15.0	15.4	40.5	25.1
09691	Ksltss & Kclst	w	5935.6	5937.05	1.45	16.0	6.0	14.0	8.0	3.1	10.0	6.9
10991	Ksltss	w	5940.01	5941.64	1.63	53.0	46.0	51.0	5.0	45.2	48.5	3.3
11691	Kclss & Kss	w	5938.63	5939.91	1.28	35.5	18.5	33.5	15.0	9.5	26.0	16.5
11791	Ksclst	w	5923.29	5925.03	1.74	15.7	8.7	13.7	5.0	6.9	11.2	4.3
11891	Kssltt & Ksltss	w	5945.51	5947.44	1.93	30.0	13.0	28.0	15.0	12.0	20.5	8.5
12091	Ksltss	w	5971.59	5973.27	1.68	24.0	14.0	22.0	8.0	13.2	18.0	4.8
12191	Ksltss & Kss	w	5956.49	5958.19	1.70	35.0	18.0	33.0	15.0	15.7	25.5	9.8
12391	Kss, Ksltss & Kclss	w	5940.07	5941.70	1.63	70.4	58.4	68.4	10.0	36.5	63.4	26.9
12491	Kss & Kclss	w	5946.84	5948.35	1.51	62.0	45.0	60.0	15.0	30.0	52.5	22.5
12491 DU	Kss & Kclss	w	5946.84	5948.35	1.51	62.0	45.0	60.0	15.0	30.0	52.5	22.5
12691	Kss	w	5949.68	5951.08	1.40	65.1	48.1	63.1	15.0	20.0	55.6	35.6
12991	Ksclst	w	5965.71	5967.22	1.51	36.5	19.5	34.5	15.0	16.1	27.0	10.9
13191	Ksclst	w	5978.25	5979.90	1.65	27.7	15.7	25.7	10.0	15.4	20.7	5.3
20791	Kclst & Ksclst	w	5967.90	5969.49	1.59	36.5	29.5	34.5	5.0	24.5	32.0	7.5
37891	Kcsltst & Ksltst	w	5925.22	5926.29	1.07	55.2	43.2	53.2	10.0	4.7	48.2	43.5
37991	Kcsltst & Kssltst	w	5931.45	5933.55	2.10	57.2	45.2	55.2	10.0	6.9	50.2	43.3
38991	Kclst, Ksltst, Kcsltst	w	5893.08	5895.45	2.37	38.8	26.8	36.8	10.0	19.5	31.8	12.3
39191	Ksltst, Kclsltst, Kclst	w	5918.16	5918.32	0.16	44.8	32.8	42.8	10.0	7.1	37.8	30.7
39291	Ksltclst, Kcsltst	w	5908.38	5910.24	1.86	46.0	34.0	44.0	10.0	10.8	39.0	28.2
46392	Kclst	w	6063.20	6065.03	1.83	82.3	64.5	79.5	15.0	56.0	72.0	16.0
75092	Ksltclst	w	5723.4	5725.40	2.00	16.7	7.2	14.7	7.5	6.3	11.0	4.7
06093		?										
0881		aban	6064.50	6065.92	1.42	20.0					0.0	
0981		aban	6063.50	6065.16	1.66	14.1					0.0	

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Appendix G

Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	1st Quarter 1991			2nd Quarter 1991			4th Quarter 1991			1st Quarter 1992		
			$\delta^{18}O$ (SMOW)	δD (SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD (SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD (SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)
0186	Qa	s										-11.44	-90.835	0.685
1186	Qa	s	-12.49	-100.9	-0.98	-12.66	-96.8	4.48				-12.67	-92.13	9.23
1586	Qc	s	-13.57	-102.4	6.16	-13.56	-97.71	10.77						
1786	Qc	s												
2286	Qrf	s												
2486	Qrf	s										-13.66	-106.4	2.88
2686	Qrf	s				-13.77	-108.5	1.66						
3386	Qrf	s				-10.33	-67.38	15.26						
3586	Qc	s	-14.27	-104.6	9.56	-14.33	-112.2	2.44						
3686	Qc	s												
3886	Qa	s												
3986	Qrf	s												
4186	Qrf	s							-13.65	-102.95	6.25	-13.8	-105.6	4.8
4286	Qrf	s	-14.25	-105.6	8.4									
4486	Qrf	s										-14.72	-111.7	6.06
4586	Qrf	s										-13.89	-103.5	7.62
4786	Qrf	s												
4986	Qrf	s												
5086	Qrf	s	-11.34	-85.14	5.58							-14.265	-112.3	1.82
5186	Qrf	s												
5386	Qrf	s												
5586	Qrf	s												
5686	Qc	s												
5786	Qc	s												
6186	Qrf	s												
6586	Qa	s	-13.28	-103.7	2.54	-13.62	-105.8	3.16	-11.73	-87.07	6.77	-12.83	-92.62	10.02
6886	Qc	s												
7086	Qc	s												
0487	Qc	s							-13.59	-99.9	8.82	-13.915	-103.3	8.02
1787	Qrf	s												
2187	Qc	s												
2987	Qc	s							-13.825	-105.3	5.3	-13.89	-106.9	4.22
3287	Qrf	s												
4387	Qc	s												
5487	Qc	s												
5687	Qrf	s												
B400189	Qrf	s							-13.57	-100.4	8.16	-13.89	-106.0	5.12
B400289	Qrf	s	-14.21	-108.6	5.08									
B400389	Qrf	s												
B400489	Qrf	s												
B200589	Qrf	s												

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Appendix G
Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	1st Quarter 1991			2nd Quarter 1991			4th Quarter 1991			1st Quarter 1992		
			$\delta^{18}O$ (SMOW)	δD (SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD (SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD (SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)
B200689	Qrf	s												
B200789	Qrf	s				-15.49	-117.4	6.52	-14.53	-107.5	8.74			
B200889	Qrf	s												
B401989	Qc	s												
B302089	Qc	s												
B102289	Qc	s	-14.27	-109.1	5.06				-13.81	-102.7	7.78	-13.7	-105.3	4.3
B202489	Qc	s				-14.275	-110.1	4.1	-14.02	-106.3	5.86			
B402689	Qc	s												
B205589	Qc	s												
B405689	Qrf	s				-15.39	-116.7	6.42	-14.55	-114.0	2.4	-14.48	-112.8	3.04
B405789	Qrf	s							-11.93	-97.54	-2.1	-11.74	-100.6	-6.68
P207689	Qrf	s												
P207889	Qrf	s												
B208089	Qc	s												
B208789	Qc	s												
P209289	Qrf	s												
P209789	Qrf	s												
B210489	Qc	s												
P213689	Qrf	s												
P215789	Qrf	s												
P218289	Qrf	s												
P313589	Qrf	s												
P317989	Qrf	s										-12.24	-93.27	4.65
B410589	Qrf	s										-13.35	-104.4	2.4
B410689	Qrf	s										-14.3	-105.4	9
B410789	Qrf	s										-13.15	-107.4	-2.2
B110889	Qrf	s										-12.99	-98.34	5.58
B110989	Qrf	s										-13.52	-106.6	1.56
B111189	Qrf	s	-14.16	-103.7	9.58							-13.44	-107.3	0.22
B411289	Qrf	s										-13.44	-104.2	3.32
B411389	Qrf	s												
P114489	Qrf	s												
P114589	Qrf	s												
P114689	Qrf	s												
P114789	Qrf	s												
P114989	Qrf	s												
P115089	Qrf	s												
P115489	Qrf	s												
P115589	Qrf	s												
P115689	Qrf	s												
P119389	Qrf	s												

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Appendix G
Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	1st Quarter 1991			2nd Quarter 1991			4th Quarter 1991			1st Quarter 1992		
			$\delta^{18}O$ (SMOW)	δD (SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD (SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD (SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)
P314089	Qrf	s												
P320089	Qrf	s												
P414189	Qrf	s												
P415889	Qrf	s												
P415989	Qrf	s												
P416089	Qrf	s												
P416189	Qrf	s												
P416289	Qrf	s												
P416389	Qrf	s												
P416489	Qrf	s												
P416589	Qrf	s												
P416689	Qrf	s												
P416789	Qrf	s												
P416889	Qrf	s												
P218089	Qrf	s												
P219189	Qc	s												
P419689	Qrf & Kss	s												
0390	Qrf	s												
0590	Qrf	s												
0690	Qrf	s												
0790	Qrf	s												
0990	Qrf	s												
00191	Qrf	s												
01391	Qrf	s												
03991	Qrf	s												
04191	Qrf	s												
04591	Qrf	s												
05091	Qrf	s							-13.895	-109.3	1.86			
05191	Qrf	s							-14.22	-109.9	3.86			
05391	Qrf	s							-14.09	-113.35	-0.63			
5691	Qrf	s												
06091	Qrf	s							-12.71	-103.5	-1.82			
06191	Qrf	s												
06791	Qrf	s												
06891	Qrf	s												
06991	Qrf	s												
07191	Qrf	s												
13091	Qrf	s												
13391	Qrf	s												
37591	Qrf	s												
41091	Qa	s												

[1]s=surficial deposits, w=weathered bedrock, u=unweathered bedrock
[2] units=feet above mean sea level
[3] units=feet above ground surface
[4] units=feet below ground surface, NP=not penetrated, ND=not determined

Appendix G

Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	1st Quarter 1991			2nd Quarter 1991			4th Quarter 1991			1st Quarter 1992		
			$\delta^{18}O$ (SMOW)	δD (SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD (SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD (SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)
10692	Qc	s												
43392	Qrf	s												
46192	Qrf	s												
46292	Qrf	s												
46492	Qrf	s												
50092	Qa	s												
75292	Qa	s												
61593		s												
61693		s												
61793		s												
61893		s												
62093		s												
62193		s												
62293		s												
62393		s												
62493		s												
62593		s												
62693		s												
62793		s												
62893		s												
0886	Kssit	u												
0986	Kss & Kssit	u										-13.95	-106.7	4.9
1486	Kss & Ksclst	u	-13.97	-111.6	0.16	-14.23	-110.1	3.74						
1686	Ksltss	u												
2186	Kss & Ksltclst	u										-11.55	-89.29	3.11
2386	Kslt & Ksltclst	u										-11.46	-93.67	-1.99
2586	Ksltclst & Kclst	u										-12.21	-96.23	1.45
2786	Kssits & Ksclst	u				-12.48	-98.39	1.45				-12.439	-92.63	6.882
3286	Kss & Ksltss	u										-12.435	-92.63	6.85
3486	Kcss & Kcslt	u												
4086	Kclst	u				-11.82	-86.56	8	-11.37	-89.76	1.2			
4686	Kslt & Kcslt	u										-12.31	-94.19	4.29
4886	Kssit & Kcslt	u												
5486	Kssit & Kslt	u				-12.08	-87.21	9.43						
0387	Kssit & Kcslt	u	-14.42	-104.4	10.96				-14.69	-109.8	7.72			
0887	Ksltclst & Kclst	u	-14.55	-111.5	4.9				-14.62	-113.8	3.16			
1687	Kslt	u												
1887	Kss & Kssit	u							-11.75	-90.06	3.94	-11.82	-91.31	3.25
2087	Ksltclst	u												
2287	Kss & Kslt	u												
2887	Kslt & Kclst	u												

[1] s=surficial deposits, w=weathered bedrock, u=unweathered bedrock

[2] units=feet above mean sea level

[3] units=feet above ground surface

[4] units=feet below ground surface, NP=not penetrated, ND=not determined

Appendix G

Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	1st Quarter 1991			2nd Quarter 1991			4th Quarter 1991			1st Quarter 1992		
			$\delta^{18}O$ (SMOW)	δD (SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD (SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD (SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)
3087	Kcslt	u												
3187		u				-12.04	-92.695	3.625	-11.65	-92.56	0.64			
3487	Ksltclst & Kslt	u												
3987	Ksslt & Kclst	u				-12.08	-93.37	3.27						
3987 DUP	Ksslt & Kclst	u												
4187	Ksltss	u	-13.53	-98.84	9.4									
4587	Kss & Kslt & Kclst	u	-13.29	-102	4.32									
B203789	Kcslt & Kclst	u							-13.02	-102.8	1.36			
B203889	Kclst	u												
B203989	Ksltss & Kslt	u												
B204089	Ksltss	u												
B204189	Kcss, Ksltss & Kscslst	u												
B304289	Kss & Kslt & Kclst	u												
B207089	Kscltst & Ksltclst	u												
P208889	Ksltclst	u												
P416989	Ksslt & Kslt	u												
B217289	Kss, Ksltss, Kcslt	u												
B217489	Kss	u												
B217589	Kss & Ksltclst	u												
B217689	Kclss	u												
B217789	Ksltclst	u												
00291	Kclss & Kscslst	u												
46692	Ksltss, Ksslt & Kclst	u												
46792	Ksslt, Kcslt & Kslt	u												
46892	Ksltss, Ksslt & Kclst	u												
22093	Kclst, Kclst & Ksltss	u												
22193	Kscslst, Kcss & Kcls	u												
22293	Kscslst, Kslst & Kcss	u												
22393	Kcslst & Kclst	u												
23193	Kss, Ksltss & Kcss	u												
22593		u												
B405489	Ksltclst & Kclst	u/w?										-13.67	-105.3	4.06
0386	Kss	w												
1986	Kclst	w												
3086	Kclst	w												
5286	Kss & Ksltclst	w										-13.22	-101.315	4.445
6286	Ksltss & Kcss	w												
0587	Kss & Ksltss	w												
0987	Kss	w							-13.76	-110.6	-0.52	-14.28	-107.2	7.04
1187	Kcss	w												
1287	Kcslt	w												

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[4] units=feet below ground surface, NP=not penetrated, ND=not determined

Appendix G

Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	1st Quarter 1991			2nd Quarter 1991			4th Quarter 1991			1st Quarter 1992		
			$\delta^{18}O$ (SMOW)	δD (SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD (SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD (SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)
1487	Kss & Kslt	w												
2587	Ksltss & Kss	w	-15.41	-116.8	6.48	-15.19	-112.65	8.87						
3687	Kss & Kslt & Kclst	w							-14.22	-111.8	1.96			
B402189	Kss	w												
B203189	Kclst & Ksclst	w												
B203289	Kclst & Ksclst	w							-13.75	-101.8	8.2	-13.405	-104.6	2.64
B203489	Kclst	w												
B203589	Qrf & Ksclst & Kclst	w												
B303089	Kclst	w												
B304889	Kclst	w												
B304989	Ksltss & Ksslt	w												
B405289	Ksclst & Ksltclst	w												
B305389	Ksltclst & Kclst	w												
B405889	Kss	w												
P207389	Kss & Kclst	w												
P207589	Ksltclst	w												
P207789	Ksltclst	w												
P207989	Kclst	w												
B208189	Kclst	w												
B208389	Ksclst & Kclst	w												
B208689	Ksltclst	w										-12.92	-107.1	-3.74
P208989	Ksltss & Ksltclst	w	-13.71	-109.6	0.08									
P209089	Ksltclst	w												
P209189	Kss & Ksltclst	w												
P209389	Kss & Ksltss & Kcss	w												
P209489	Kss & Ksltss	w												
P209589	Ksltclst & Ksclst	w												
P209689	Ksltclst	w										-12.92	-105.8	-2.44
P209889	Ksltclst	w	-13.31	-99.91	6.57									
P210089	Ksltclst	w												
P210189	Ksltss & Ksclst	w												
00391	Ksclst & Kcss	w												
01491	Kss & Kcs	w												
02091	Ksclst, Kssit, Ksltclst	w												
02291	Ksclst & Kclss	w												
02491	Ksltss, Kssit	w												
02591	Kclss & Ksclst	w												
02991	Kclss & Ksclst	w												
03391	Kss, Ksltss & Ksclst	w												
03691	Kss & Kcss	w							-14.49	-103.2	12.72	-14.685	-110.3	7.18
03791	Kss, Ksclst & Ksltss	w												

[1] s=surficial deposits, w=weathered bedrock, u=unweathered bedrock

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Appendix G
Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	1st Quarter 1991			2nd Quarter 1991			4th Quarter 1991			1st Quarter 1992		
			$\delta^{18}O$ (SMOW)	δD (SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD (SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD (SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)
06591	Ksclst & Ksltclst	w												
09691	Ksltss & Kclst	w												
10991	Ksltss	w												
11691	Kclss & Kss	w												
11791	Ksclst	w												
11891	Kssit & Ksltss	w												
12091	Ksltss	w												
12191	Ksltss & Kss	w												
12391	Kss, Ksltss & Kclss	w												
12491	Kss & Kclss	w												
12491 DU	Kss & Kclss	w												
12691	Kss	w												
12991	Ksclst	w												
13191	Ksclst	w												
20791	Kclst & Ksclst	w												
37891	Kcsltst & Ksltst	w												
37991	Kcsltst & Kssltst	w												
38991	Kclst, Ksltst, Kcsltst	w												
39191	Ksltst, Kclsltst, Kclst	w												
39291	Ksltclst, Kcsltst	w												
46392	Kclst	w												
75092	Ksltclst	w												
06093		?												
0881		aban										-13.15	-103.3	1.9
0981		aban										-11.4	-105.1	-13.9

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Appendix G

Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	2nd Quarter 1992					3rd Quarter 1992			4th Quarter 1992		
			$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	Tritium (TU)	Tritium Error (TU)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)
0186	Qa	s											
1186	Qa	s	-11.37	-83.99	6.97			-11.9	-97.84	-2.64			
1586	Qc	s	-12.39	-97.76	1.36			-12.33	-99.63	-0.99			
1786	Qc	s											
2286	Qrf	s											
2486	Qrf	s											
2686	Qrf	s	-12.86	-102.65	0.23								
3386	Qrf	s											
3586	Qc	s											
3686	Qc	s											
3886	Qa	s											
3986	Qrf	s											
4186	Qrf	s	-12.91	-102.8	0.48								
4286	Qrf	s	-13.17	-101	4.36			-14.23	-105.6	8.24	-14.03	-106.4	5.84
4486	Qrf	s											
4586	Qrf	s	-14.16	-106.8	6.48								
4786	Qrf	s	-12.35	-100.4	-1.6			-13.4	-105.25	1.95			
4986	Qrf	s											
5086	Qrf	s											
5186	Qrf	s											
5386	Qrf	s											
5586	Qrf	s											
5686	Qc	s											
5786	Qc	s											
6186	Qrf	s											
6586	Qa	s	-12.34	-97.22	1.5								
6886	Qc	s											
7086	Qc	s											
0487	Qc	s											
1787	Qrf	s	-13.36	-104.4	2.48								
2187	Qc	s											
2987	Qc	s											
3287	Qrf	s											
4387	Qc	s											
5487	Qc	s											
5687	Qrf	s											
B400189	Qrf	s											
B400289	Qrf	s	-13.14	-107.5	-2.38								
B400389	Qrf	s											
B400489	Qrf	s											
B200589	Qrf	s											

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Appendix G
Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	2nd Quarter 1992					3rd Quarter 1992			4th Quarter 1992		
			$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	Tritium (TU)	Tritium Error (TU)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)
B200689	Qrf	s											
B200789	Qrf	s	-13.35	-108.3	-1.5			-15.35	-114.9	7.9	-15.29	-113.2	9.12
B200889	Qrf	s											
B401989	Qc	s											
B302089	Qc	s											
B102289	Qc	s	-12.67	-97.3	4.06								
B202489	Qc	s	-11.7	-88.44	5.16								
B402689	Qc	s											
B205589	Qc	s											
B405689	Qrf	s	-12.7	-100.1	1.5								
B405789	Qrf	s	-11.2	-88.75	0.85								
P207689	Qrf	s											
P207889	Qrf	s											
B208089	Qc	s											
B208789	Qc	s											
P209289	Qrf	s											
P209789	Qrf	s											
B210489	Qc	s											
P213689	Qrf	s											
P215789	Qrf	s											
P218289	Qrf	s											
P313589	Qrf	s											
P317989	Qrf	s											
B410589	Qrf	s											
B410689	Qrf	s	-13.31	-104	2.48			-13.24	-106.4	-0.48			
B410789	Qrf	s											
B110889	Qrf	s											
B110989	Qrf	s	-12.53	-99.08	1.16			-13.1	-97.01	7.79			
B111189	Qrf	s	-12.75	-102.1	-0.1			-12.935	-97.27	6.21			
B411289	Qrf	s											
B411389	Qrf	s											
P114489	Qrf	s											
P114589	Qrf	s											
P114689	Qrf	s											
P114789	Qrf	s											
P114989	Qrf	s											
P115089	Qrf	s											
P115489	Qrf	s											
P115589	Qrf	s											
P115689	Qrf	s											
P119389	Qrf	s											

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Appendix G
Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	2nd Quarter 1992					3rd Quarter 1992			4th Quarter 1992		
			$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	Tritium (TU)	Tritium Error (TU)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)
P314089	Qrf	s											
P320089	Qrf	s											
P414189	Qrf	s											
P415889	Qrf	s											
P415989	Qrf	s											
P416089	Qrf	s											
P416189	Qrf	s											
P416289	Qrf	s											
P416389	Qrf	s											
P416489	Qrf	s											
P416589	Qrf	s											
P416689	Qrf	s											
P416789	Qrf	s											
P416889	Qrf	s											
P218089	Qrf	s											
P219189	Qc	s											
P419689	Qrf & Kss	s											
0390	Qrf	s											
0590	Qrf	s											
0690	Qrf	s											
0790	Qrf	s											
0990	Qrf	s											
00191	Qrf	s											
01391	Qrf	s											
03991	Qrf	s											
04191	Qrf	s											
04591	Qrf	s											
05091	Qrf	s											
05191	Qrf	s											
05391	Qrf	s											
5691	Qrf	s											
06091	Qrf	s											
06191	Qrf	s											
06791	Qrf	s											
06891	Qrf	s											
06991	Qrf	s											
07191	Qrf	s											
13091	Qrf	s											
13391	Qrf	s	-13.01	-108.7	-4.62								
37591	Qrf	s											
41091	Qa	s											

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Appendix G
Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	2nd Quarter 1992					3rd Quarter 1992			4th Quarter 1992		
			$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	Tritium (TU)	Tritium Error (TU)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)
10692	Qc	s											
43392	Qrf	s											
46192	Qrf	s											
46292	Qrf	s											
46492	Qrf	s											
50092	Qa	s											
75292	Qa	s											
61593		s											
61693		s											
61793		s											
61893		s											
62093		s											
62193		s											
62293		s											
62393		s											
62493		s											
62593		s											
62693		s											
62793		s											
62893		s											
0886	Kssit	u											
0986	Kss & Kssit	u											
1486	Kss & Ksclst	u	-13.72	-108	1.76			-13.66	-105.2	4.08			
1686	Ksltss	u											
2186	Kss & Ksltclst	u											
2386	Kslt & Ksltclst	u	-10.58	-88.52	-3.88								
2586	Ksltclst & Kclst	u	-10.5	-86.39	-2.39			-10.45	-86.97	-3.37	-12.11	-88.96	7.92
2786	Kssits & Ksclst	u	-12.48	-98.39	1.45								
3286	Kss & Ksltss	u	-12	-86.36	9.64			-11.55	-95.38	-2.98			
3486	Kcss & Kcslt	u											
4086	Kclst	u											
4686	Kslt & Kcslt	u	-12.31	-94.19	4.29			-11.14	-90.61	-1.49			
4886	Kssit & Kcslt	u											
5486	Kssit & Kslt	u											
0387	Kssit & Kcslt	u											
0887	Ksltclst & Kclst	u											
1687	Kslt	u											
1887	Kss & Kssit	u											
2087	Ksltclst	u	-11.46	-89.05	2.63								
2287	Kss & Kslt	u											
2887	Kslt & Kclst	u											

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Appendix G

Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	2nd Quarter 1992					3rd Quarter 1992			4th Quarter 1992		
			$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	Tritium (TU)	Tritium Error (TU)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)
3087	Kcslt	u											
3187		u						-11.99	-92.16	3.76	-12.02	-92.15	4.01
3487	Ksltclst & Kslt	u											
3987	Ksslt & Kclst	u	-11.77	-92.81	1.35								
3987 DUP	Ksslt & Kclst	u											
4187	Ksltss	u											
4587	Kss & Kslt & Kclst	u											
B203789	Kcslt & Kclst	u	-11.64	-82.685	10.435			-13.16	-95.91	9.37	-13.08	-99.65	4.99
B203889	Kclst	u											
B203989	Ksltss & Kslt	u											
B204089	Ksltss	u	-11.74	-96.5	-2.58								
B204189	Kcss, Ksltss & Ksclst	u	-11.06	-91.63	-3.15								
B304289	Kss & Kslt & Kclst	u											
B207089	Kscltst & Ksltclst	u											
P208889	Ksltclst	u											
P416989	Ksslt & Kslt	u											
B217289	Kss, Ksltss, Kcslt	u											
B217489	Kss	u											
B217589	Kss & Ksltclst	u											
B217689	Kclss	u											
B217789	Ksltclst	u											
00291	Kclss & Ksclst	u											
46692	Ksltss, Ksslt & Kclst	u											
46792	Ksslt, Kcslt & Kslt	u											
46892	Ksltss, Ksslt & Kclst	u											
22093	Kclst, Kclst & Ksltss	u											
22193	Kscist, Kcss & Kcls	u											
22293	Kscist, Kslst & Kcss	u											
22393	Kcslst & Kclst	u											
23193	Kss, Ksltss & Kcss	u											
22593		u											
B405489	Ksltclst & Kclst	u/w?	-13.00	-102.5	1.5								
0386	Kss	w											
1986	Kclst	w											
3086	Kclst	w											
5286	Kss & Ksltclst	w	-12.34	-100.6	-1.88			-13.21	-101.6	4.08			
6286	Ksltss & Kcss	w											
0587	Kss & Ksltss	w											
0987	Kss	w						-13.65	-103.6	5.6			
1187	Kcss	w	-10.74	-87.57	-1.65								
1287	Kcslt	w											

[1]s=surficial deposits, w=weathered bedrock, u=unweathered bedrock

[2] units=feet above mean sea level

[3] units=feet above ground surface

[4] units=feet below ground surface, NP=not penetrated, ND=not determined

Appendix G
Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	2nd Quarter 1992					3rd Quarter 1992			4th Quarter 1992		
			$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	Tritium (TU)	Tritium Error (TU)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)
1487	Kss & Kslt	w											
2587	Ksltss & Kss	w											
3687	Kss & Kslt & Kclst	w	-13.17	-106.1	-0.74			-14.52	-106.1	10.06	-14.71	-105.3	12.38
B402189	Kss	w											
B203189	Kclst & Ksclst	w											
B203289	Kclst & Ksclst	w											
B203489	Kclst	w	-12.54	-101.3	-0.98			-14.05	-103.5	8.9	-14.22	-101.9	11.86
B203589	Qrf & Ksclst & Kclst	w											
B303089	Kclst	w											
B304889	Kclst	w											
B304989	Ksltss & Kslt	w											
B405289	Ksclst & Ksltclst	w											
B305389	Ksltclst & Kclst	w											
B405889	Kss	w											
P207389	Kss & Kclst	w											
P207589	Ksltclst	w											
P207789	Ksltclst	w											
P207989	Kclst	w											
B208189	Kclst	w											
B208389	Ksclst & Kclst	w											
B208689	Ksltclst	w											
P208989	Ksltss & Ksltclst	w	-13.08	-105.6	-0.96			-12.96	-94.9	8.78			
P209089	Ksltclst	w											
P209189	Kss & Ksltclst	w											
P209389	Kss & Ksltss & Kcss	w											
P209489	Kss & Ksltss	w											
P209589	Ksltclst & Ksclst	w											
P209689	Ksltclst	w											
P209889	Ksltclst	w	-12.15	-104.8	-7.6			-12.21	-102.3	-4.62			
P210089	Ksltclst	w											
P210189	Ksltss & Ksclst	w											
00391	Ksclst & Kcss	w											
01491	Kss & Kcs	w											
02091	Ksclst, Kslt, Ksltclst	w											
02291	Ksclst & Kclss	w											
02491	Ksltss, Kslt	w											
02591	Kclss & Ksclst	w											
02991	Kclss & Ksclst	w											
03391	Kss, Ksltss & Ksclst	w											
03691	Kss & Kcss	w											
03791	Kss, Ksclst & Ksltss	w	-13.46	-108.4	-0.72			-14.01	-105.6	6.48			

[1]s=surficial deposits, w=weathered bedrock, u=unweathered bedrock
[2] units=feet above mean sea level
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Appendix G
Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	2nd Quarter 1992					3rd Quarter 1992			4th Quarter 1992		
			$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	Tritium (TU)	Tritium Error (TU)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)
06591	Ksclst & Ksltclst	w											
09691	Ksltss & Kclst	w											
10991	Ksltss	w											
11691	Kclss & Kss	w											
11791	Ksclst	w											
11891	Kssltss & Ksltss	w											
12091	Ksltss	w											
12191	Ksltss & Kss	w											
12391	Kss, Ksltss & Kclss	w											
12491	Kss & Kclss	w											
12491 DU	Kss & Kclss	w											
12691	Kss	w											
12991	Ksclst	w											
13191	Ksclst	w											
20791	Kclst & Ksclst	w											
37891	Kcsltst & Ksltst	w											
37991	Kcsltst & Kssltst	w											
38991	Kclst, Ksltst, Kcsltst	w											
39191	Ksltst, Kclsltst, Kclst	w											
39291	Ksltclst, Kcsltst	w											
46392	Kclst	w											
75092	Ksltclst	w											
06093		?											
0881		aban	-13	-98.66	5.34								
0981		aban	-13.57	-101.5	7.06								

[1]s=surficial deposits, w=weathered bedrock, u=unweathered bedrock
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[4] units=feet below ground surface, NP=not penetrated, ND=not determined

Appendix G
Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	1st Quarter 1993			2nd/3rd Quarters 1993					3rd Quarter 1993		
			$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	Tritium (TU)	Tritium Error (TU)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)
0186	Qa	s				-13.82	-102	8.56					
1186	Qa	s				-13.25	-107.8	-1.8					
1586	Qc	s				-13.3	-103.9	2.5					
1786	Qc	s				-14.07	-105.3	7.26					
2286	Qrf	s				-15.81	-115.8	10.68					
2486	Qrf	s				-15.16	-111.9	9.38					
2686	Qrf	s				-13.97	-105.2	6.56					
3386	Qrf	s				-12.26	-87.89	10.19					
3586	Qc	s				-14.25	-110	4					
3686	Qc	s				-15.13	-113.3	7.74					
3886	Qa	s				-16.51	-126.2	5.88					
3986	Qrf	s				-14.09	-100.5	12.22					
4186	Qrf	s											
4286	Qrf	s	-14.18	-104.7	8.74	-14.25	-105.9	8.1	21.3				
4486	Qrf	s											
4586	Qrf	s											
4786	Qrf	s				-14.04	-104.4	7.92					
4986	Qrf	s				-14.4	-107.2	8	22.9				
5086	Qrf	s				-12.01	-98.22	-2.14	30.8		-11.34	-85.14	5.58
5186	Qrf	s									-14.99	-113.5	6.42
5386	Qrf	s				-14.65	-109	8.2					
5586	Qrf	s				-13.11	-102	2.88	48.5				
5686	Qc	s				-13.42	-104.6	2.76					
5786	Qc	s				-13.28	-97.48	8.76					
6186	Qrf	s											
6586	Qa	s											
6886	Qc	s				-13.38	-103.4	3.64					
7086	Qc	s				-14.95	-114.6	5					
0487	Qc	s				-14.51	-111.3	4.78	16.8				
1787	Qrf	s				-13.87	-106.9	4.06	14.7				
2187	Qc	s				-14.28	-107.8	6.44					
2987	Qc	s				-13.84	-102.3	8.42					
3287	Qrf	s											
4387	Qc	s				-14.91	-114.2	5.08	8.6				
5487	Qc	s				-12.13	-83.46	13.58					
5687	Qrf	s				-13.88	-105.1	5.94					
B400189	Qrf	s				-14.62	-111.7	5.26					
B400289	Qrf	s				-14.38	-110.2	4.84	30.2				
B400389	Qrf	s				-14.63	-108.9	8.14					
B400489	Qrf	s				-12.18	-99.15	-1.71					
B200589	Qrf	s				-15	-113.3	6.7	25.4				

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Appendix G

Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	1st Quarter 1993			2nd/3rd Quarters 1993					3rd Quarter 1993		
			$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	Tritium (TU)	Tritium Error (TU)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)
B200689	Qrf	s				-15.08	-111.2	9.44					
B200789	Qrf	s	-15.28	-112.2	10.04	-15.22	-113.1	8.66	31.3				
B200889	Qrf	s				-15.25	-109.4	12.6	38.9				
B401989	Qc	s				-13.38	-105.3	1.74					
B302089	Qc	s				-14.35	-109.7	5.1					
B102289	Qc	s											
B202489	Qc	s											
B402689	Qc	s				-14.31	-108.6	5.88					
B205589	Qc	s											
B405689	Qrf	s				-14.58	-107.4	9.24					
B405789	Qrf	s				-11.93	-93.57	1.87					
P207689	Qrf	s				-14.8	-114.2	4.2	89.9				
P207889	Qrf	s				-14.46	-105.5	10.18					
B208089	Qc	s				-15	-111.3	8.7					
B208789	Qc	s				-13.04	-99.58	4.74					
P209289	Qrf	s				-10.99	-82.2	5.72	112.3				
P209789	Qrf	s				-14.06	-103.7	8.78					
B210489	Qc	s				-14.55	-114.1	2.3					
P213689	Qrf	s											
P215789	Qrf	s											
P218289	Qrf	s											
P313589	Qrf	s											
P317989	Qrf	s											
B410589	Qrf	s				-12.48	-101.1	-1.26					
B410689	Qrf	s											
B410789	Qrf	s											
B110889	Qrf	s											
B110989	Qrf	s											
B111189	Qrf	s											
B411289	Qrf	s											
B411389	Qrf	s											
P114489	Qrf	s											
P114589	Qrf	s											
P114689	Qrf	s											
P114789	Qrf	s											
P114989	Qrf	s											
P115089	Qrf	s											
P115489	Qrf	s											
P115589	Qrf	s											
P115689	Qrf	s											
P119389	Qrf	s											

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Appendix G

Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	1st Quarter 1993			2nd/3rd Quarters 1993					3rd Quarter 1993		
			$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	Tritium (TU)	Tritium Error (TU)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)
P314089	Qrf	s											
P320089	Qrf	s											
P414189	Qrf	s											
P415889	Qrf	s											
P415989	Qrf	s											
P416089	Qrf	s											
P416189	Qrf	s											
P416289	Qrf	s				-15.02	-112.7	7.46					
P416389	Qrf	s				-15.03	-112.2	8.04	19				
P416489	Qrf	s				-15.2	-113.8	7.8					
P416589	Qrf	s				-14.25	-110.2	3.8					
P416689	Qrf	s				-14.22	-107.4	6.36					
P416789	Qrf	s											
P416889	Qrf	s				-14.17	-105.8	7.56					
P218089	Qrf	s				-13.97	-103.3	8.46					
P219189	Qc	s				-14.15	-105.1	8.1	32.4				
P419689	Qrf & Kss	s											
0390	Qrf	s				-15.26	-113.4	8.68					
0590	Qrf	s				-15.38	-113.5	9.54					
0690	Qrf	s				-12.78	-103.3	-1.06					
0790	Qrf	s				-14.29	-112.9	1.42					
0990	Qrf	s				-13.84	-102.7	8.02					
00191	Qrf	s				-13.8	-104.6	5.8					
01391	Qrf	s				-14.37	-103.1	11.86	26				
03991	Qrf	s				-14.02	-108.3	3.86					
04191	Qrf	s				-14.28	-109.6	4.64					
04591	Qrf	s				-14.34	-108.6	6.12					
05091	Qrf	s				-14.48	-109.8	6.04					
05191	Qrf	s				-15.07	-112.8	7.76	29.5				
05391	Qrf	s				-14.3	-103.6	10.8	28.3				
5691	Qrf	s				-14.03	-103.9	8.34					
06091	Qrf	s				-14.43	-111.6	3.84					
06191	Qrf	s				-15.07	-110.8	9.76					
06791	Qrf	s				-15.95	-120.7	6.9					
06891	Qrf	s				-14.25	-106.9	7.1	14.8				
06991	Qrf	s				-15.13	-113	8.04	11				
07191	Qrf	s				-15.3	-112.3	10.1					
13091	Qrf	s				-14.2	-109.9	3.7	27.3				
13391	Qrf	s				-15.14	-114.7	6.42					
37591	Qrf	s				-13.26	-104.1	1.98	44.2				
41091	Qa	s											

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Appendix G

Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	1st Quarter 1993			2nd/3rd Quarters 1993					3rd Quarter 1993		
			$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	Tritium (TU)	Tritium Error (TU)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)
10692	Qc	s				-14.43	-111	4.44					
43392	Qrf	s									-15.5	-111.6	12.4
46192	Qrf	s				-13.69	-104.5	5.02					
46292	Qrf	s				-14.09	-105.6	7.12					
46492	Qrf	s											
50092	Qa	s											
75292	Qa	s											
61593		s									-14.39	-109.7	5.42
61693		s									-14.83	-112	6.64
61793		s									-14.41	-111.8	3.48
61893		s									-14.64	-110.1	7.02
62093		s									-14.51	-103.5	12.58
62193		s									-15.81	-119.65	6.83
62293		s									-14.39	-106.9	8.22
62393		s									-11.45	-87.36	4.24
62493		s									-12.71	-92.99	8.69
62593		s									-15.65	-103.8	21.4
62693		s									-15.29	-108.8	13.52
62793		s									-14.645	-110.6	6.56
62893		s									-14.85	-112	6.8
0886	Kssit	u				-12.9	-94.78	8.42	<0.8				
0986	Kss & Kssit	u				-13.14	-98.91	6.21	<0.8				
1486	Kss & Ksclst	u				-14.75	-110.1	7.9	0.8				
1686	Ksltss	u				-13.9	-104	7.2	<0.8				
2186	Kss & Ksltclst	u											
2386	Kslt & Ksltclst	u							0.9		-12.18	-94.36	3.08
2586	Ksltclst & Kclst	u	-11.82	-89.94	4.62	-11.78	-93.27	0.97	<0.8				
2786	Kssits & Ksclst	u				-12.46	-95.22	4.46					
3286	Kss & Ksltss	u	-12.66	-95.89	5.39	-12.81	-95.07	7.41					
3486	Kcss & Kcslt	u				-12.56	-99.26	1.22	<0.8				
4086	Kclst	u				-11.72	-88.68	5.08	<0.8				
4686	Kslt & Kcslt	u				-12.53	-92.15	8.09	<0.8				
4886	Kssit & Kcslt	u				-13.43	-102.7	4.74	<0.8				
5486	Kssit & Kslt	u				-12.1	-93.29	3.51	<0.8				
0387	Kssit & Kcslt	u											
0887	Ksltclst & Kclst	u											
1687	Kslt	u				-12.07	-90.95	5.61	<0.8				
1887	Kss & Kssit	u				-12.24	-95.4	2.52	<0.8				
2087	Ksltclst	u											
2287	Kss & Kslt	u				-12.99	-93.92	10	1.8				
2887	Kslt & Kclst	u				-12.79	-96.82	5.5	<0.8				

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Appendix G
Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	1st Quarter 1993			2nd/3rd Quarters 1993					3rd Quarter 1993		
			$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	Tritium (TU)	Tritium Error (TU)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)
3087	Kcslt	u				-14.29	-110.1	4.22	<0.8				
3187		u	-12.1	-90.28	6.52	-12.08	-93.01	3.63	<0.8				
3487	Ksltclst & Kslt	u				-12.04	-90.49	5.83	<0.8				
3987	Ksslt & Kclst	u									-12.465	-96.73	2.99
3987 DUP	Ksslt & Kclst	u									-12.47	-92.25	7.51
4187	Ksltss	u											
4587	Kss & Kslt & Kclst	u				-13.17	-100.9	4.46	2.1				
B203789	Kcslt & Kclst	u	-13.23	-97.86	7.98	-13.16	-98.77	6.51	<0.8				
B203889	Kclst	u				-12.49	-93.95	5.97	<0.8				
B203989	Ksltss & Kslt	u											
B204089	Ksltss	u											
B204189	Kcss, Ksltss & Kscist	u											
B304289	Kss & Kslt & Kclst	u				-14.48	-108.9	6.94	<0.8				
B207089	Kscltst & Ksltclst	u											
P208889	Ksltclst	u				-12.15	-91.36	5.84	1				
P416989	Ksslt & Kslt	u											
B217289	Kss, Ksltss, Kcslt	u									-13.01	-100.7	3.38
B217489	Kss	u				-12.3	-93.05	5.35	0.8				
B217589	Kss & Ksltclst	u				-12.24	-93.86	4.06	<0.8				
B217689	Kclss	u				-12.29	-93.72	4.6	<0.8				
B217789	Ksltclst	u											
00291	Kclss & Kscist	u				-13.74	-99.05	10.87	<0.8				
46692	Ksltss, Ksslt & Kclst	u				-12.53	-92.43	7.81	<0.8				
46792	Ksslt, Kcslt & Kslt	u				-11.79	-89.65	4.67	<0.8				
46892	Ksltss, Ksslt & Kclst	u				-12.48	-96.33	3.51	<0.8				
22093	Kclst, Kclst & Ksltss	u											
22193	Kscist, Kcss & Kcls	u									-13.67	-98.66	10.7
22293	Kscist, Kslst & Kcss	u									-14.77	-110.1	8.06
22393	Kcslst & Kclst	u											
23193	Kss, Ksltss & Kcss	u									-13.89	-104.9	6.22
22593		u									-12.73	-97.35	4.49
B405489	Ksltclst & Kclst	u/w?				-14.23	-101.7	12.14	<0.8				
0386	Kss	w									-16.49	-119.4	12.52
1986	Kclst	w				-13.81	-107	3.48					
3086	Kclst	w				-14.4	-112	3.2					
5286	Kss & Ksltclst	w											
6286	Ksltss & Kcss	w				-14.93	-115.8	3.64	1.6				
0587	Kss & Ksltss	w									-13.75	-104.5	5.5
0987	Kss	w	-14.75	-110.2	7.8	-15.01	-111.6	8.48	49.9				
1187	Kcss	w				-15.56	-111.1	13.38	36.1				
1287	Kcslt	w				-15.06	-114.6	5.88					

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Appendix G

Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	1st Quarter 1993			2nd/3rd Quarters 1993					3rd Quarter 1993		
			$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	Tritium (TU)	Tritium Error (TU)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)
1487	Kss & Kslt	w				-15.43	-116.7	6.74	15.1				
2587	Ksltss & Kss	w				-15.22	-113.4	8.36	26.4				
3687	Kss & Kslt & Kclst	w	-14.86	-110.7	8.18	-15.03	-111	9.24	38.8		-14.755	-111.3	6.74
B402189	Kss	w				-13.14	-100.3	4.82	22.5				
B203189	Kclst & Ksclst	w				-14.16	-104.2	9.08	<0.8				
B203289	Kclst & Ksclst	w				-13.93	-104.9	6.54	<0.8				
B203489	Kclst	w	-13.98	-106.1	5.74	-14.05	-106.1	6.3	5.5				
B203589	Qrf & Ksclst & Kclst	w				-13.67	-103.8	5.56	<0.8				
B303089	Kclst	w											
B304889	Kclst	w				-15.72	-122.1	3.66	<0.8				
B304989	Ksltss & Ksslt	w				-14.81	-112.1	6.38	<0.8				
B405289	Ksclst & Ksltclst	w				-13.44	-103.1	4.42	<0.8				
B305389	Ksltclst & Kclst	w				-13.64	-107.7	1.42	23.8				
B405889	Kss	w				-13.81	-103.5	6.98	19.4				
P207389	Kss & Kclst	w				-14.65	-105.6	11.6	126.6				
P207589	Ksltclst	w				-13.75	-99.84	10.16	<0.8				
P207789	Ksltclst	w				-13.48	-102.5	5.34	<0.8				
P207989	Kclst	w				-13.6	-102	6.8	2				
B208189	Kclst	w				-17.08	-130.8	5.84					
B208389	Ksclst & Kclst	w				-19.15	-140.9	12.3					
B208689	Ksltclst	w									-14.285	-110.9	3.38
P208989	Ksltss & Ksltclst	w				-13.7	-105.5	4.1					
P209089	Ksltclst	w				-13.53	-103.1	5.14					
P209189	Kss & Ksltclst	w				-13.29	-101.7	4.62					
P209389	Kss & Ksltss & Kcss	w				-10.1	-74.21	6.59	79.8				
P209489	Kss & Ksltss	w				-13.92	-101.5	9.86	204.2				
P209589	Ksltclst & Ksclst	w				-13.28	-109.1	-2.86					
P209689	Ksltclst	w				-11.27	-83.31	6.85	114				
P209889	Ksltclst	w				-13.45	-103.2	4.4					
P210089	Ksltclst	w				-12.06	-92.13	4.35					
P210189	Ksltss & Ksclst	w				-14.66	-108.6	8.68	295				
00391	Ksclst & Kcss	w				-14.65	-109	8.2	35.4				
01491	Kss & Kcs	w				-13.89	-106.5	4.62	26.1				
02091	Ksclst, Ksslt, Ksltclst	w				-14.61	-110.8	6.08	28.4				
02291	Ksclst & Kclss	w				-14.51	-112.6	3.48	66.3				
02491	Ksltss, Ksslt	w				-15.78	-119.8	6.44	22.8				
02591	Kclss & Ksclst	w				-14.05	-109.6	2.8	19.9				
02991	Kclss & Ksclst	w				-14.63	-107.4	9.64	23.2				
03391	Kss, Ksltss & Ksclst	w				-14.92	-113.1	6.26	35.4				
03691	Kss & Kcss	w				-14.62	-110.9	6.06	39.8				
03791	Kss, Ksclst & Ksltss	w				-14.81	-110.1	8.38	33.3				

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[4] units=feet below ground surface, NP=not penetrated, ND=not determined

Appendix G
Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	1st Quarter 1993			2nd/3rd Quarters 1993					3rd Quarter 1993		
			$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	Tritium (TU)	Tritium Error (TU)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)
06591	Ksclst & Ksltclst	w				-13.83	-101.2	9.44	1.4				
09691	Ksltss & Kclst	w									-14.82	-111.1	7.46
10991	Ksltss	w				-14.21	-103	10.68	16.6				
11691	Kclss & Kss	w				-15.28	-109.6	12.64					
11791	Ksclst	w				-14.61	-108.6	8.28					
11891	Kssit & Ksltss	w				-14.35	-102.3	12.5	30.2				
12091	Ksltss	w				-15.04	-114.2	6.12					
12191	Ksltss & Kss	w				-15.09	-113.2	7.52					
12391	Kss, Ksltss & Kclss	w				-14.91	-115.5	3.78	49.4				
12491	Kss & Kclss	w									-13.565	-104.35	4.17
12491 DU	Kss & Kclss	w									-13.605	-104.35	4.49
12691	Kss	w				-14.82	-109.1	9.46	29.8				
12991	Ksclst	w				-14.58	-108.4	8.24	32				
13191	Ksclst	w				-14.61	-109.8	7.08					
20791	Kclst & Ksclst	w				-13.37	-102.9	4.06					
37891	Kcsltst & Ksltst	w				-13.94	-108.6	2.92	2				
37991	Kcsltst & Kssltst	w				-13.7	-107.6	2	<0.8				
38991	Kclst, Ksltst, Kcsltst	w				-14.68	-112	5.44	6				
39191	Ksltst, Kclsltst, Kclst	w				-13.59	-107.9	0.82					
39291	Ksltclst, Kcsltst	w				-13.59	-105	3.72	0.9				
46392	Kclst	w				-13.67	-102.7	6.66					
75092	Ksltclst	w											
06093		?									-13.46	-103.8	3.88
0881		aban											
0981		aban											

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Appendix G
Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	3rd Quarter 1993		4th Quarter 1993					1st Quarter 1994				
			Tritium (TU)	Tritium Error (TU)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	Tritium (TU)	Tritium Error (TU)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	Tritium (TU)	Tritium Error (TU)
0186	Qa	s												
1186	Qa	s												
1586	Qc	s												
1786	Qc	s												
2286	Qrf	s												
2486	Qrf	s												
2686	Qrf	s												
3386	Qrf	s												
3586	Qc	s												
3686	Qc	s												
3886	Qa	s												
3986	Qrf	s												
4186	Qrf	s												
4286	Qrf	s								-14.17	-106.2	7.16	23.4	1.6
4486	Qrf	s								-15.80	-120.3	6.1	12.3	0.9
4586	Qrf	s												
4786	Qrf	s												
4986	Qrf	s												
5086	Qrf	s	30.8	2.1						-11.535	-92.48	-0.2	25.6	1.8
5186	Qrf	s	41											
5386	Qrf	s												
5586	Qrf	s												
5686	Qc	s												
5786	Qc	s												
6186	Qrf	s								-15.58	-109.7	14.94	17.3	1.2
6586	Qa	s												
6886	Qc	s												
7086	Qc	s												
0487	Qc	s												
1787	Qrf	s												
2187	Qc	s												
2987	Qc	s												
3287	Qrf	s												
4387	Qc	s												
5487	Qc	s												
5687	Qrf	s												
B400189	Qrf	s												
B400289	Qrf	s												
B400389	Qrf	s												
B400489	Qrf	s												
B200589	Qrf	s												

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Appendix G
Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	3rd Quarter 1993 Tritium (TU)	3rd Quarter 1993 Tritium Error (TU)	4th Quarter 1993 $\delta^{18}O$ (SMOW)	4th Quarter 1993 δD(SMOW)	4th Quarter 1993 D excess (*d*)	4th Quarter 1993 Tritium (TU)	4th Quarter 1993 Tritium Error (TU)	1st Quarter 1994 $\delta^{18}O$ (SMOW)	1st Quarter 1994 δD(SMOW)	1st Quarter 1994 D excess (*d*)	1st Quarter 1994 Tritium (TU)	1st Quarter 1994 Tritium Error (TU)
B200689	Qrf	s												
B200789	Qrf	s												
B200889	Qrf	s												
B401989	Qc	s												
B302089	Qc	s												
B102289	Qc	s												
B202489	Qc	s												
B402689	Qc	s												
B205589	Qc	s								-13.95	-110.0	1.6	0.9	0.4
B405689	Qrf	s												
B405789	Qrf	s												
P207689	Qrf	s												
P207889	Qrf	s												
B208089	Qc	s												
B208789	Qc	s												
P209289	Qrf	s												
P209789	Qrf	s												
B210489	Qc	s												
P213689	Qrf	s								-14.94	-116.9	2.62		
P215789	Qrf	s								-14.43	-111.2	4.24	42.9	2.9
P218289	Qrf	s								-14.20	-100.1	13.5	33.4	2.3
P313589	Qrf	s								-15.25	-116.0	6	38.3	2.6
P317989	Qrf	s								-15.09	-111.0	9.72	21.5	1.5
B410589	Qrf	s								-12.85	-100.915	1.885	43.2	2.8
B410689	Qrf	s								-13.55	-108.4	0	31.3	2.1
B410789	Qrf	s								-14.875	-111.2	7.8	28.3	2.0
B110889	Qrf	s								-13.785	-109.7	0.58	28.7	2.0
B110989	Qrf	s								-13.75	-107.9	2.1	23.2	1.6
B111189	Qrf	s								-14.30	-110.5	3.9	4.9	0.5
B411289	Qrf	s								-13.975	-104.1	7.7	1.4	0.6
B411389	Qrf	s								-14.40	-112.9	2.3	11.1	0.8
P114489	Qrf	s								-15.37	-113.7	9.26	32.6	2.2
P114589	Qrf	s								-14.06	-106.65	5.83		
P114689	Qrf	s								-13.57	-100.9	7.66		
P114789	Qrf	s								-14.475	-109.9	5.9	26.1	1.8
P114989	Qrf	s								-13.72	-102.6	7.16	<0.8	0.4
P115089	Qrf	s								-15.17	-113.65	7.71	41.2	2.8
P115489	Qrf	s								-14.96	-110.6	9.08	28.1	1.9
P115589	Qrf	s								-14.735	-109.3	8.58	42.2	2.9
P115689	Qrf	s								-14.68	-110.25	7.19	24.0	1.7
P119389	Qrf	s								-14.25	-100.93	13.07	14.6	1.1

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Appendix G
Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	3rd Quarter 1993 Tritium (TU)	3rd Quarter 1993 Tritium Error (TU)	4th Quarter 1993 $\delta^{18}O$ (SMOW)	4th Quarter 1993 δD(SMOW)	4th Quarter 1993 D excess (*d*)	4th Quarter 1993 Tritium (TU)	4th Quarter 1993 Tritium Error (TU)	1st Quarter 1994 $\delta^{18}O$ (SMOW)	1st Quarter 1994 δD(SMOW)	1st Quarter 1994 D excess (*d*)	1st Quarter 1994 Tritium (TU)	1st Quarter 1994 Tritium Error (TU)
P314089	Qrf	s								-14.8	-109.8	8.6		
P320089	Qrf	s								-14.98	-111.1	8.74	40.5	3
P414189	Qrf	s								-13.73	-108.4	1.44	50.7	3.4
P415889	Qrf	s								-15.19	-111.7	9.82	31.2	2.1
P415989	Qrf	s								-14.79	-112.75	5.57	41.6	2.8
P416089	Qrf	s								-15.01	-107.2	12.88	32.0	2.1
P416189	Qrf	s								-14.82	-113.1	5.46	19.9	1.4
P416289	Qrf	s								-15.78	-118.7	7.54	34.6	2.4
P416389	Qrf	s								-14.93	-106.8	12.64	35.6	2.4
P416489	Qrf	s								-15.39	-117.1	6.02	16.6	1.2
P416589	Qrf	s								-15.36	-117.5	5.38	41.4	2.8
P416689	Qrf	s								-14.47	-111.6	4.16	41.8	2.8
P416789	Qrf	s								-14.1	-108.4	4.4	34.9	2.4
P416889	Qrf	s								-13.9	-106.1	5.1	30.9	2.1
P218089	Qrf	s								-14.07	-106.8	5.76	33.5	2.3
P219189	Qc	s												
P419689	Qrf & Kss	s								-13.60	-100.505	8.295	24.7	1.7
0390	Qrf	s			-14.055	-104.6	7.84	6.8	0.6					
0590	Qrf	s												
0690	Qrf	s												
0790	Qrf	s												
0990	Qrf	s												
00191	Qrf	s												
01391	Qrf	s												
03991	Qrf	s												
04191	Qrf	s												
04591	Qrf	s												
05091	Qrf	s												
05191	Qrf	s												
05391	Qrf	s												
5691	Qrf	s												
06091	Qrf	s												
06191	Qrf	s												
06791	Qrf	s												
06891	Qrf	s												
06991	Qrf	s												
07191	Qrf	s												
13091	Qrf	s												
13391	Qrf	s												
37591	Qrf	s												
41091	Qa	s												

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Appendix G

Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	3rd Quarter 1993		4th Quarter 1993					1st Quarter 1994				
			Tritium (TU)	Tritium Error (TU)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	Tritium (TU)	Tritium Error (TU)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	Tritium (TU)	Tritium Error (TU)
10692	Qc	s												
43392	Qrf	s												
46192	Qrf	s								-13.82	-105.7	4.86	13.3	1.0
46292	Qrf	s								-14.72	-109.5	8.26	1.3	0.4
46492	Qrf	s								-12.41	-100.9	-1.62	19.9	1.4
50092	Qa	s								-14.28	-108.8	5.44	30.6	2.1
75292	Qa	s												
61593		s	25.2	1.8										
61693		s												
61793		s	26	1.8										
61893		s	23.1	1.6										
62093		s												
62193		s	20.5	1.5										
62293		s	30.45	1.95										
62393		s	38.7	2.6										
62493		s	NOT	DOING										
62593		s	32.8	2.3										
62693		s	26.7	1.9										
62793		s	37.2	2.5										
62893		s	47.1	3.2										
0886	Kssit	u												
0986	Kss & Kssit	u												
1486	Kss & Ksclst	u												
1686	Ksitss	u								-13.00	-94.215	9.785	<0.8	0.3
2186	Kss & Ksitclst	u											2.8	0.3
2386	Ksit & Ksitclst	u												
2586	Ksitclst & Kclst	u											<0.8	0.2
2786	Kssits & Ksclst	u											<0.8	0.3
3286	Kss & Ksitss	u												
3486	Kcss & Kcsit	u												
4086	Kclst	u												
4686	Ksit & Kcsit	u												
4886	Kssit & Kcsit	u												
5486	Kssit & Ksit	u												
0387	Kssit & Kcsit	u												
0887	Ksitclst & Kclst	u												
1687	Ksit	u												
1887	Kss & Kssit	u								-11.79	-91.765	2.555	<0.8	0.3
2087	Ksitclst	u											1.4	0.3
2287	Kss & Ksit	u												
2887	Ksit & Kclst	u												

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Appendix G
Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	3rd Quarter 1993 Tritium (TU)	3rd Quarter 1993 Tritium Error (TU)	4th Quarter 1993 $\delta^{18}O$ (SMOW)	4th Quarter 1993 δD(SMOW)	4th Quarter 1993 D excess (*d*)	4th Quarter 1993 Tritium (TU)	4th Quarter 1993 Tritium Error (TU)	1st Quarter 1994 $\delta^{18}O$ (SMOW)	1st Quarter 1994 δD(SMOW)	1st Quarter 1994 D excess (*d*)	1st Quarter 1994 Tritium (TU)	1st Quarter 1994 Tritium Error (TU)
3087	Kcslt	u												
3187		u												
3487	Ksltclst & Kslt	u												
3987	Ksslt & Kclst	u	<0.8	0.3				<0.8	0.3					
3987 DUP	Ksslt & Kclst	u												
4187	Ksltss	u												
4587	Kss & Kslt & Kclst	u						41.95	2.8				1.0	0.3
B203789	Kcslt & Kclst	u												
B203889	Kclst	u								-12.995	-100.7	3.26	<0.8	0.45
B203989	Ksltss & Kslt	u								-12.86	-101.3	1.58	<0.8	0.4
B204089	Ksltss	u								-12.67	-101.4	-0.04	<0.8	0.3
B204189	Kcss, Ksltss & Kscist	u												
B304289	Kss & Kslt & Kclst	u								-13.68	-107.6	1.84	<0.8	0.3
B207089	Kscltst & Ksltclst	u												
P208889	Ksltclst	u								-12.63	-94.03	7.01	0.9	0.3
P416989	Ksslt & Kslt	u								-13.01	-104.9	-0.82	<0.8	0.4
B217289	Kss, Ksltss, Kcslt	u	<0.8	0.3									<0.8	0.4
B217489	Kss	u												
B217589	Kss & Ksltclst	u												
B217689	Kclss	u								-11.94	-94.16	1.36	<0.8	0.3
B217789	Ksltclst	u												
00291	Kclss & Kscist	u												
46692	Ksltss, Ksslt & Kclst	u												
46792	Ksslt, Kcslt & Kslt	u												
46892	Ksltss, Ksslt & Kclst	u												
22093	Kclst, Kclst & Ksltss	u			-15.53	-115.0	9.24	<0.8	0.3					
22193	Kscist, Kcss & Kcls	u	<0.8	0.3										
22293	Kscist, Kslst & Kcss	u	<0.8	0.3										
22393	Kcslst & Kclst	u								-11.745	-87.495	6.465	<0.8	0.3
23193	Kss, Ksltss & Kcss	u	1.6	0.3										
22593		u	<0.8	0.3						-12.68	-94.96	6.48	<0.8	0.2
B405489	Ksltclst & Kclst	u/w?												
0386	Kss	w	44.5	3										
1986	Kclst	w								-14.23	-109.7	4.14	23.6	1.6
3086	Kclst	w												
5286	Kss & Ksltclst	w								-14.23	-108.55	5.29	5.3	0.6
6286	Ksltss & Kcss	w												
0587	Kss & Ksltss	w	0.8	0.3										
0987	Kss	w												
1187	Kcss	w												
1287	Kcslt	w												

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Appendix G
Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	3rd Quarter 1993		4th Quarter 1993					1st Quarter 1994				
			Tritium (TU)	Tritium Error (TU)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	Tritium (TU)	Tritium Error (TU)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	Tritium (TU)	Tritium Error (TU)
1487	Kss & Kslt	w												
2587	Ksltss & Kss	w												
3687	Kss & Kslt & Kclst	w	42.0	2.8										
B402189	Kss	w												
B203189	Kclst & Ksclst	w												
B203289	Kclst & Ksclst	w												
B203489	Kclst	w												
B203589	Qrf & Ksclst & Kclst	w								-13.54	-107.9	0.42	9.0	0.8
B303089	Kclst	w												
B304889	Kclst	w												
B304989	Ksltss & Kssit	w												
B405289	Ksclst & Ksltclst	w												
B305389	Ksltclst & Kclst	w												
B405889	Kss	w												
P207389	Kss & Kclst	w												
P207589	Ksltclst	w												
P207789	Ksltclst	w												
P207989	Kclst	w												
B208189	Kclst	w												
B208389	Ksclst & Kclst	w												
B208689	Ksltclst	w	<0.8	0.3										
P208989	Ksltss & Ksltclst	w												
P209089	Ksltclst	w												
P209189	Kss & Ksltclst	w												
P209389	Kss & Ksltss & Kcss	w												
P209489	Kss & Ksltss	w						3703	240					
P209589	Ksltclst & Ksclst	w												
P209689	Ksltclst	w												
P209889	Ksltclst	w												
P210089	Ksltclst	w												
P210189	Ksltss & Ksclst	w												
00391	Ksclst & Kcss	w												
01491	Kss & Kcs	w												
02091	Ksclst, Kssit, Ksltclst	w												
02291	Ksclst & Kclss	w												
02491	Ksltss, Kssit	w												
02591	Kclss & Ksclst	w												
02991	Kclss & Ksclst	w												
03391	Kss, Ksltss & Ksclst	w												
03691	Kss & Kcss	w												
03791	Kss, Ksclst & Ksltss	w												

[1] s=surficial deposits, w=weathered bedrock, u=unweathered bedrock
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Appendix G
Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	3rd Quarter 1993		4th Quarter 1993					1st Quarter 1994				
			Tritium (TU)	Tritium Error (TU)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	Tritium (TU)	Tritium Error (TU)	$\delta^{18}O$ (SMOW)	δD(SMOW)	D excess (*d*)	Tritium (TU)	Tritium Error (TU)
06591	Ksclst & Ksltclst	w												
09691	Ksltss & Kclst	w	20.1	1.4										
10991	Ksltss	w												
11691	Kclss & Kss	w												
11791	Ksclst	w												
11891	Ksslt & Ksltss	w												
12091	Ksltss	w												
12191	Ksltss & Kss	w												
12391	Kss, Ksltss & Kclss	w												
12491	Kss & Kclss	w	5.6	0.6										
12491 DU	Kss & Kclss	w												
12691	Kss	w												
12991	Ksclst	w												
13191	Ksclst	w	22.9	1.6										
20791	Kclst & Ksclst	w	4.5	0.4										
37891	Kcsltst & Ksltst	w												
37991	Kcsltst & Kssltst	w												
38991	Kclst, Ksltst, Kcsltst	w												
39191	Ksltst, Kclsltst, Kclst	w						1.5	0.4					
39291	Ksltclst, Kcsltst	w												
46392	Kclst	w	<0.8	0.5										
75092	Ksltclst	w								-15.23	-114.1	7.74	27.1	1.9
06093		?	<0.8	0.5										
0881		aban												
0981		aban												

[1] s=surficial deposits, w=weathered bedrock, u=unweathered bedrock
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[4] units=feet below ground surface, NP=not penetrated, ND=not determined

Appendix G
Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	Mean $\delta^{18}O$ (SMOW)	Number of Values	Mean δD(SMOW)	Number of Values	Mean Tritium (TU)	Number of Values
0186	Qa	s	-13.82	1	-102	1		0
1186	Qa	s	-12.19	6	-96.4	6		0
1586	Qc	s	-12.97	6	-98.9	6		0
1786	Qc	s	-14.07	1	-105.3	1		0
2286	Qrf	s	-15.81	1	-115.8	1		0
2486	Qrf	s	-15.16	1	-111.9	1		0
2686	Qrf	s	-13.57	4	-105.7	4		0
3386	Qrf	s	-11.30	2	-77.6	2		0
3586	Qc	s	-14.28	3	-108.9	3		0
3686	Qc	s	-15.13	1	-113.3	1		0
3886	Qa	s	-16.51	1	-126.2	1		0
3986	Qrf	s	-14.09	1	-100.5	1		0
4186	Qrf	s	-12.91	1	-102.8	1		0
4286	Qrf	s	-13.97	9	-104.9	9	22.4	2
4486	Qrf	s	-15.8	1	-120.3	1	12.3	1
4586	Qrf	s	-14.44	2	-109.3	2		0
4786	Qrf	s	-13.42	4	-103.4	4		0
4986	Qrf	s	-14.4	1	-107.2	1	22.9	1
5086	Qrf	s	-11.56	4	-90.2	4	29.1	3
5186	Qrf	s	-14.63	2	-112.9	2	41	1
5386	Qrf	s	-14.65	1	-109	1		0
5586	Qrf	s	-13.11	1	-102	1	48.5	1
5686	Qc	s	-13.42	1	-104.6	1		0
5786	Qc	s	-13.28	1	-97.5	1		0
6186	Qrf	s	-15.58	1	-109.7	1	17.3	1
6586	Qa	s	-12.76	5	-97.3	5		0
6886	Qc	s	-13.38	1	-103.4	1		0
7086	Qc	s	-14.95	1	-114.6	1		0
0487	Qc	s	-14.51	1	-111.3	1	16.8	1
1787	Qrf	s	-13.68	4	-103.6	4	14.7	1
2187	Qc	s	-14.28	1	-107.8	1		0
2987	Qc	s	-13.84	1	-102.3	1		0
3287	Qrf	s	-13.86	2	-106.1	2		0
4387	Qc	s	-14.91	1	-114.2	1	8.6	1
5487	Qc	s	-12.13	1	-83.5	1		0
5687	Qrf	s	-13.88	1	-105.1	1		0
B400189	Qrf	s	-7.31	2	-55.9	2		0
B400289	Qrf	s	-13.84	5	-106.5	5	30.2	1
B400389	Qrf	s	-14.63	1	-108.9	1		0
B400489	Qrf	s	-12.18	1	-99.2	1		0
B200589	Qrf	s	-15	1	-113.3	1	25.4	1

[1]s=surficial deposits, w=weathered bedrock, u=unweathered bedrock
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[4] units=feet below ground surface, NP=not penetrated, ND=not determined

Appendix G

Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	Mean $\delta^{18}O$ (SMOW)	Number of Values	Mean δD(SMOW)	Number of Values	Mean Tritium (TU)	Number of Values
B200689	Qrf	s	-15.08	1	-111.2	1		0
B200789	Qrf	s	-14.93	7	-112.4	7	31.3	1
B200889	Qrf	s	-15.25	1	-109.4	1	38.9	1
B401989	Qc	s	-13.38	1	-105.3	1		0
B302089	Qc	s	-14.35	1	-109.7	1		0
B102289	Qc	s	-13.61	4	-103.6	4		0
B202489	Qc	s	-13.33	3	-101.6	3		0
B402689	Qc	s	-14.31	1	-108.6	1		0
B205589	Qc	s	-13.95	1	-110	1	0.9	1
B405689	Qrf	s	-14.34	5	-110.2	5		0
B405789	Qrf	s	-11.70	4	-95.1	4		0
P207689	Qrf	s	-14.80	1	-114.2	1	89.9	1
P207889	Qrf	s	-14.46	1	-105.5	1		0
B208089	Qc	s	-15.00	1	-111.3	1		0
B208789	Qc	s	-13.04	1	-99.6	1		0
P209289	Qrf	s	-10.99	1	-82.2	1	112.3	1
P209789	Qrf	s	-14.06	1	-103.7	1		0
B210489	Qc	s	-14.55	1	-114.1	1		0
P213689	Qrf	s	-14.94	1	-116.9	1		0
P215789	Qrf	s	-14.43	1	-111.2	1	42.9	1
P218289	Qrf	s	-14.2	1	-100.1	1	33.4	1
P313589	Qrf	s	-15.25	1	-116	1	38.3	1
P317989	Qrf	s	-15.09	1	-111	1	21.5	1
B410589	Qrf	s	-12.52	3	-98.4	3	43.2	1
B410689	Qrf	s	-13.36	4	-105.8	4	31.3	1
B410789	Qrf	s	-14.59	2	-108.3	2	28.3	1
B110889	Qrf	s	-13.47	2	-108.6	2	28.7	1
B110989	Qrf	s	-13.09	4	-100.6	4	23.2	1
B111189	Qrf	s	-13.53	5	-104	5	4.9	1
B411289	Qrf	s	-13.71	2	-105.7	2	1.4	1
B411389	Qrf	s	-13.92	2	-108.6	2	11.1	1
P114489	Qrf	s	-15.37	1	-113.7	1	32.6	1
P114589	Qrf	s	-14.06	1	-106.7	1		0
P114689	Qrf	s	-13.57	1	-100.9	1		0
P114789	Qrf	s	-14.48	1	-109.9	1	26.1	1
P114989	Qrf	s	-13.72	1	-102.6	1	<0.8	1
P115089	Qrf	s	-15.17	1	-113.7	1	41.2	1
P115489	Qrf	s	-14.96	1	-110.6	1	28.1	1
P115589	Qrf	s	-14.74	1	-109.3	1	42.2	1
P115689	Qrf	s	-14.68	1	-110.3	1	24	1
P119389	Qrf	s	-14.25	1	-100.9	1	14.6	1

[1]s=surficial deposits, w=weathered bedrock, u=unweathered bedrock

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Appendix G
Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	Mean $\delta^{18}O$ (SMOW)	Number of Values	Mean δD(SMOW)	Number of Values	Mean Tritium (TU)	Number of Values
P314089	Qrf	s	-14.8	1	-109.8	1		0
P320089	Qrf	s	-14.98	1	-111.1	1	40.5	1
P414189	Qrf	s	-13.73	1	-108.4	1	50.7	1
P415889	Qrf	s	-15.19	1	-111.7	1	31.2	1
P415989	Qrf	s	-14.79	1	-112.8	1	41.6	1
P416089	Qrf	s	-15.01	1	-107.2	1	32	1
P416189	Qrf	s	-14.82	1	-113.1	1	19.9	1
P416289	Qrf	s	-15.78	1	-118.7	1	34.6	1
P416389	Qrf	s	-14.98	2	-109.8	2	35.6	1
P416489	Qrf	s	-15.21	2	-114.7	2	17.8	2
P416589	Qrf	s	-15.28	2	-115.7	2	41.4	1
P416689	Qrf	s	-14.36	2	-110.9	2	41.8	1
P416789	Qrf	s	-14.16	2	-107.9	2	34.9	1
P416889	Qrf	s	-13.9	1	-106.1	1	30.9	1
P218089	Qrf	s	-14.12	2	-106.3	2	33.5	1
P219189	Qc	s	-13.97	1	-103.3	1		0
P419689	Qrf & Kss	s	-13.88	2	-102.8	2	28.6	2
0390	Qrf	s	-14.06	1	-104.6	1	6.8	1
0590	Qrf	s	-15.26	1	-113.4	1		0
0690	Qrf	s	-15.38	1	-113.5	1		0
0790	Qrf	s	-12.78	1	-103.3	1		0
0990	Qrf	s	-14.29	1	-112.9	1		0
00191	Qrf	s	-13.84	1	-102.7	1		0
01391	Qrf	s	-13.8	1	-104.6	1		0
03991	Qrf	s	-14.37	1	-103.1	1	26	1
04191	Qrf	s	-14.02	1	-108.3	1		0
04591	Qrf	s	-14.28	1	-109.6	1		0
05091	Qrf	s	-14.12	2	-109	2		0
05191	Qrf	s	-14.35	2	-109.9	2		0
05391	Qrf	s	-14.58	2	-113.1	2	29.5	1
5691	Qrf	s	-14.3	1	-103.6	1	28.3	1
06091	Qrf	s	-13.37	2	-103.7	2		0
06191	Qrf	s	-14.43	1	-111.6	1		0
06791	Qrf	s	-15.07	1	-110.8	1		0
06891	Qrf	s	-15.95	1	-120.7	1		0
06991	Qrf	s	-14.25	1	-106.9	1	14.8	1
07191	Qrf	s	-15.13	1	-113	1	11	1
13091	Qrf	s	-15.3	1	-112.3	1		0
13391	Qrf	s	-13.61	2	-109.3	2	27.3	1
37591	Qrf	s	-15.14	1	-114.7	1		0
41091	Qa	s	-13.26	1	-104.1	1	44.2	1

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Appendix G
Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	Mean $\delta^{18}O$ (SMOW)	Number of Values	Mean δD(SMOW)	Number of Values	Mean Tritium (TU)	Number of Values
10692	Qc	s	-14.43	1	-111	1		0
43392	Qrf	s	-15.5	1	-111.6	1		0
46192	Qrf	s	-13.69	1	-104.5	1		0
46292	Qrf	s	-13.96	2	-105.7	2	13.3	1
46492	Qrf	s	-14.72	1	-109.5	1	1.3	1
50092	Qa	s	-12.41	1	-100.9	1	19.9	1
75292	Qa	s	-14.28	1	-108.8	1	30.6	1
61593		s	-14.39	1	-109.7	1	25.2	1
61693		s	-14.83	1	-112	1		0
61793		s	-14.41	1	-111.8	1	26	1
61893		s	-14.64	1	-110.1	1	23.1	1
62093		s	-14.51	1	-103.5	1		0
62193		s	-15.81	1	-119.7	1	20.5	1
62293		s	-14.39	1	-106.9	1	30.5	1
62393		s	-11.45	1	-87.4	1	38.7	1
62493		s	-12.71	1	-93	1	<0.8	1
62593		s	-15.65	1	-103.8	1	32.8	1
62693		s	-15.29	1	-108.8	1	26.7	1
62793		s	-14.65	1	-110.6	1	37.2	1
62893		s	-14.85	1	-112	1	47.1	1
0886	Kssit	u	-12.9	1	-94.8	1	<0.8	1
0986	Kss & Kssit	u	-13.14	1	-98.9	1	<0.8	1
1486	Kss & Ksclst	u	-14.05	6	-108.6	6	0.8	1
1686	Ksltss	u	-13.9	1	-104	1	<0.8	1
2186	Kss & Ksltclst	u	-13	1	-94.2	1	<0.8	1
2386	Kslt & Ksltclst	u	-11.44	3	-90.7	3	1.9	2
2586	Ksltclst & Kclst	u	-11.35	6	-89.9	6	<0.8	1
2786	Kssits & Ksclst	u	-12.41	4	-97.1	4	<0.8	1
3286	Kss & Ksltss	u	-12.29	5	-93.1	5	<0.8	1
3486	Kcss & Kcslt	u	-12.50	2	-95.9	2	<0.8	1
4086	Kclst	u	-11.64	3	-88.3	3	<0.8	1
4686	Kslt & Kcslt	u	-12.07	4	-92.8	4	<0.8	1
4886	Kssit & Kcslt	u	-13.43	1	-102.7	1	<0.8	1
5486	Kssit & Kslt	u	-12.09	2	-90.3	2	<0.8	1
0387	Kssit & Kcslt	u	-14.56	2	-107.1	2		0
0887	Ksltclst & Kclst	u	-14.59	2	-112.7	2		0
1687	Kslt	u	-12.07	1	-91	1	<0.8	1
1887	Kss & Kssit	u	-11.94	3	-92.3	3	<0.8	1
2087	Ksltclst	u	-11.63	2	-90.4	2	<0.8	1
2287	Kss & Kslt	u	-12.99	1	-93.9	1	1.6	2
2887	Kslt & Kclst	u	-12.79	1	-96.8	1	<0.8	1

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Appendix G
Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	Mean $\delta^{18}O$ (SMOW)	Number of Values	Mean δD(SMOW)	Number of Values	Mean Tritium (TU)	Number of Values
3087	Kcslt	u	-14.29	1	-110.1	1	<0.8	1
3187		u	-11.98	6	-92.1	6	<0.8	1
3487	Ksltclst & Kslt	u	-12.04	1	-90.5	1	<0.8	1
3987	Ksslt & Kclst	u	-12.11	3	-94.3	3	<0.8	2
3987 DUP	Ksslt & Kclst	u	-12.47	1	-92.3	1		0
4187	Ksltss	u	-13.53	1	-98.8	1		0
4587	Kss & Kslt & Kclst	u	-13.23	2	-101.5	2	15	3
B203789	Kcslt & Kclst	u	-12.88	6	-96.3	6	<0.8	1
B203889	Kclst	u	-12.49	1	-94	1	<0.8	1
B203989	Ksltss & Kslt	u	-13.00	1	-100.7	1	<0.8	1
B204089	Ksltss	u	-12.3	2	-98.9	2	<0.8	1
B204189	Kcss, Ksltss & Ksclst	u	-11.87	2	-96.5	2	<0.8	1
B304289	Kss & Kslt & Kclst	u	-14.48	1	-108.9	1	<0.8	1
B207089	Ksclst & Ksltclst	u	-13.68	1	-107.6	1	<0.8	1
P208889	Ksltclst	u	-12.15	1	-91.4	1	1	1
P416989	Ksslt & Kslt	u	-12.63	1	-94	1	0.9	1
B217289	Kss, Ksltss, Kcslt	u	-13.01	2	-102.8	2	<0.8	2
B217489	Kss	u	-12.3	1	-93.1	1	0.4	2
B217589	Kss & Ksltclst	u	-12.24	1	-93.9	1	<0.8	1
B217689	Kclss	u	-12.29	1	-93.7	1	<0.8	1
B217789	Ksltclst	u	-11.94	1	-94.2	1	<0.8	1
00291	Kclss & Ksclst	u	-13.74	1	-99.1	1	<0.8	1
46692	Ksltss, Ksslt & Kclst	u	-12.53	1	-92.4	1	<0.8	1
46792	Ksslt, Kcslt & Kslt	u	-11.79	1	-89.7	1	<0.8	1
46892	Ksltss, Ksslt & Kclst	u	-12.48	1	-96.3	1	<0.8	1
22093	Kclst, Kclst & Ksltss	u	-15.53	1	-115	1	<0.8	1
22193	Ksclst, Kcss & Kcls	u	-13.67	1	-98.7	1	<0.8	1
22293	Ksclst, Kslst & Kcss	u	-14.77	1	-110.1	1	<0.8	1
22393	Kcslst & Kclst	u	-11.75	1	-87.5	1	<0.8	1
23193	Kss, Ksltss & Kcss	u	-13.89	1	-104.9	1	1.6	1
22593		u	-12.71	2	-96.2	2	<0.8	2
B405489	Ksltclst & Kclst	u/w?	-13.63	3	-103.2	3	<0.8	1
0386	Kss	w	-16.49	1	-119.4	1	44.5	1
1986	Kclst	w	-14.02	2	-108.4	2	23.6	1
3086	Kclst	w	-14.4	1	-112	1		0
5286	Kss & Ksltclst	w	-13.25	4	-103	4	5.3	1
6286	Ksltss & Kcss	w	-14.93	1	-115.8	1	1.6	1
0587	Kss & Ksltss	w	-13.75	1	-104.5	1	0.8	1
0987	Kss	w	-14.29	5	-108.6	5	49.9	1
1187	Kcss	w	-13.15	2	-99.3	2	36.1	1
1287	Kcslt	w	-15.06	1	-114.6	1		0

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Appendix G
Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	Mean $\delta^{18}O$ (SMOW)	Number of Values	Mean δD(SMOW)	Number of Values	Mean Tritium (TU)	Number of Values
1487	Kss & Kslt	w	-15.43	1	-116.7	1	15.1	1
2587	Ksltss & Kss	w	-15.27	3	-114.3	3	26.4	1
3687	Kss & Kslt & Kclst	w	-14.47	7	-108.9	7	40.4	2
B402189	Kss	w	-13.14	1	-100.3	1	22.5	1
B203189	Kclst & Ksclst	w	-14.16	1	-104.2	1	<0.8	1
B203289	Kclst & Ksclst	w	-13.93	1	-104.9	1	<0.8	1
B203489	Kclst	w	-13.71	7	-103.6	7	5.5	1
B203589	Qrf & Ksclst & Kclst	w	-13.67	1	-103.8	1	<0.8	1
B303089	Kclst	w	-13.54	1	-107.9	1	9	1
B304889	Kclst	w	-15.72	1	-122.1	1	<0.8	1
B304989	Ksltss & Kssit	w	-14.81	1	-112.1	1	<0.8	1
B405289	Ksclst & Ksltclst	w	-13.44	1	-103.1	1	<0.8	1
B305389	Ksltclst & Kclst	w	-13.64	1	-107.7	1	23.8	1
B405889	Kss	w	-13.81	1	-103.5	1	19.4	1
P207389	Kss & Kclst	w	-14.65	1	-105.6	1	126.6	1
P207589	Ksltclst	w	-13.75	1	-99.8	1	<0.8	1
P207789	Ksltclst	w	-13.48	1	-102.5	1	<0.8	1
P207989	Kclst	w	-13.6	1	-102	1	2	1
B208189	Kclst	w	-17.08	1	-130.8	1		0
B208389	Ksclst & Kclst	w	-19.15	1	-140.9	1		0
B208689	Ksltclst	w	-14.29	1	-110.9	1	<0.8	1
P208989	Ksltss & Ksltclst	w	-13.27	5	-104.5	5		0
P209089	Ksltclst	w	-13.53	1	-103.1	1		0
P209189	Kss & Ksltclst	w	-13.29	1	-101.7	1		0
P209389	Kss & Ksltss & Kcss	w	-10.1	1	-74.2	1	79.8	1
P209489	Kss & Ksltss	w	-13.92	1	-101.5	1	204.2	1
P209589	Ksltclst & Ksclst	w	-13.28	1	-109.1	1	3703	1
P209689	Ksltclst	w	-11.27	1	-83.3	1	114	1
P209889	Ksltclst	w	-12.81	5	-103.2	5		0
P210089	Ksltclst	w	-12.06	1	-92.1	1		0
P210189	Ksltss & Ksclst	w	-14.66	1	-108.6	1	295	1
00391	Ksclst & Kcss	w	-14.65	1	-109	1	35.4	1
01491	Kss & Kcs	w	-13.89	1	-106.5	1	26.1	1
02091	Ksclst, Kssit, Ksltclst	w	-14.61	1	-110.8	1	28.4	1
02291	Ksclst & Kclss	w	-14.51	1	-112.6	1	66.3	1
02491	Ksltss, Kssit	w	-15.78	1	-119.8	1	22.8	1
02591	Kclss & Ksclst	w	-14.05	1	-109.6	1	19.9	1
02991	Kclss & Ksclst	w	-14.63	1	-107.4	1	23.2	1
03391	Kss, Ksltss & Ksclst	w	-14.92	1	-113.1	1	35.4	1
03691	Kss & Kcss	w	-14.62	1	-110.9	1	39.8	1
03791	Kss, Ksclst & Ksltss	w	-14.29	5	-107.5	5	33.3	1

[1]s=surficial deposits, w=weathered bedrock, u=unweathered bedrock
[2] units=feet above mean sea level
[3] units=feet above ground surface
[4] units=feet below ground surface, NP=not penetrated, ND=not determined

Appendix G
Isotopic Compositions of Groundwater

Well Name	Completion Unit	Lithologic Unit[1]	Mean $\delta^{18}O$ (SMOW)	Number of Values	Mean δD(SMOW)	Number of Values	Mean Tritium (TU)	Number of Values
06591	Kscist & Ksltcist	w	-13.83	1	-101.2	1	1.4	1
09691	Ksltss & Kcist	w	-14.82	1	-111.1	1	20.1	1
10991	Ksltss	w	-14.21	1	-103	1	16.6	1
11691	Kcisss & Kss	w	-15.28	1	-109.6	1		0
11791	Kscist	w	-14.61	1	-108.6	1		0
11891	Kssit & Ksltss	w	-14.35	1	-102.3	1	30.2	1
12091	Ksltss	w	-15.04	1	-114.2	1		0
12191	Ksltss & Kss	w	-15.09	1	-113.2	1		0
12391	Kss, Ksltss & Kcisss	w	-14.91	1	-115.5	1	49.4	1
12491	Kss & Kcisss	w	-13.57	1	-104.4	1	5.6	1
12491 DU	Kss & Kcisss	w	-13.61	1	-104.4	1		0
12691	Kss	w	-14.82	1	-109.1	1	29.8	1
12991	Kscist	w	-14.58	1	-108.4	1	32	1
13191	Kscist	w	-14.61	1	-109.8	1	22.9	1
20791	Kcist & Kscist	w	-13.37	1	-102.9	1	4.5	1
37891	Kcsltst & Ksltst	w	-13.94	1	-108.6	1	2	1
37991	Kcsltst & Kssltst	w	-13.7	1	-107.6	1	<0.8	1
38991	Kcist, Ksltst, Kcsltst	w	-14.68	1	-112	1	6	1
39191	Ksltst, Kcisltst, Kcist	w	-13.59	1	-107.9	1	1.5	1
39291	Ksltcist, Kcsltst	w	-13.59	1	-105	1	0.9	1
46392	Kcist	w	-13.67	1	-102.7	1	<0.8	1
75092	Ksltcist	w	-15.23	1	-114.1	1	27.1	1
06093		?	-13.46	1	-103.8	1	<0.8	1
0881		aban	-13.08	2	-101	2		0
0981		aban	-12.49	2	-103.3	2		0

[1]s=surficial deposits, w=weathered bedrock, u=unweathered bedrock
[2] units=feet above mean sea level
[3] units=feet above ground surface
[4] units=feet below ground surface, NP=not penetrated, ND=not determined

Appendix H
Examples of Output from WATEQF and NETPATH Models

WELL 2187 - INDUSTRIAL AREA FLOW PATH - USING EH=0.2 VOLTS
Eh=0.2 pH=6.98 temp=11.3 Davies Alk option=0 N*4.4=NO3
Run 7-15-94

SAMPLE ID 2187
SAMPLE COORDINATES X= 1.0000 Y= 1.0000 Z= 1.0000
TEMPERATURE = 11.30 DEGREES C PH = 6.980 DISSOLVED OXYGEN = 2.90 MG/L
SPECIFIC CONDUCTANCE = 2900.0000 LAB-MEASURED PH = 7.3000
MEASURED EH = .2000 VOLTS PE = 3.543

********** TOTAL CONCENTRATIONS OF INPUT SPECIES **********

SPECIES	TOTAL MOLALITY	LOG TOTAL MOLALITY	TOTAL MG/LITRE
AL 3+	3.715486E-06	-5.4300	1.000000E-01
ARSENIC	6.690287E-08	-7.1746	5.000000E-03
BA 2+	7.299359E-07	-6.1367	1.000000E-01
CA 2+	7.203549E-03	-2.1425	2.880000E+02
CHROMIUM	9.640107E-08	-7.0159	5.000000E-03
CL -	4.128399E-03	-2.3842	1.460000E+02
CS +	9.428643E-06	-5.0256	1.250000E+00
F -	5.540565E-05	-4.2564	1.050000E+00
HCO3 -	1.503315E-02	-1.8230	9.150000E+02
IRON	8.975361E-07	-6.0469	5.000000E-02
K +	6.409480E-05	-4.1932	2.500000E+00
LEAD	7.257437E-09	-8.1392	1.500000E-03
LI +	7.223620E-06	-5.1412	5.000000E-02
MG 2+	4.164688E-03	-2.3804	1.010000E+02
MN 2+	6.550936E-05	-4.1837	3.590000E+00
NA +	1.177363E-02	-1.9291	2.700000E+02
NO3 -	4.413858E-05	-4.3552	2.730000E+00
PO4 3-	3.377839E-07	-6.4714	3.200000E-02
RADIUM	1.518211E-06	-5.8187	3.423000E-01
SELENIUM	6.348113E-08	-7.1974	5.000000E-03
SILVER	4.646855E-08	-7.3328	5.000000E-03
SIO2 TOTAL	1.585042E-04	-3.8000	9.500000E+00
SO4 2-	7.722602E-03	-2.1122	7.400000E+02
SR 2+	2.505663E-05	-4.6011	2.190000E+00
URANIUM	3.640252E-07	-6.4389	8.643300E-02
VANADIUM	4.919839E-07	-6.3080	2.500000E-02
ZINC	6.363338E-05	-4.1963	4.150000E+00

********** CONVERGENCE ITERATIONS **********

ITERATION	S1-ANALCO3	S2-SO4TOT	S3-FTOT	S4-PTOT	S5-CLTOT
1	3.298642E-04	7.250931E-06	3.205478E-06	3.853848E-09	1.233763E-06
2	7.619960E-05	3.115339E-07	9.857170E-07	6.546436E-10	7.632904E-08
3	-2.785732E-06	-2.000165E-08	-3.090737E-08	-8.848650E-11	-7.281837E-09
4	2.185105E-07	-2.655301E-09	3.558859E-09	-8.658698E-12	-3.031546E-10
5	-6.638796E-09	-4.870990E-10	3.318523E-11	-1.678317E-12	-9.550369E-11
6	1.372162E-09	-6.613878E-11	3.453727E-11	-2.217843E-13	-1.089429E-11
7	7.101936E-11	-9.688435E-12	3.392110E-12	-3.348202E-14	-1.768321E-12
8	2.523962E-11	-1.549277E-12	7.308167E-13	-5.140366E-15	-2.773077E-13
9	-4.481067E-12	-4.577432E-13	2.240477E-15	-9.841064E-16	-3.245321E-14
10	4.148461E-12	3.707104E-15	5.581873E-14	1.735729E-18	2.191823E-15

THE REQUESTED CONVERGENCE TOLERANCES FOR THIS JOB WERE AS FOLLOWS

1.503176E-06	7.722602E-07	5.540565E-09	3.377839E-11	4.128399E-07	(REAL TOLERANCE)
.0001000000	.0001000000	.0001000000	.0001000000	.0001000000	(FRACTIONAL TOL.)

********** DESCRIPTION OF SOLUTION **********

		PH	ACTIVITY H2O = .9991
CATION MILLIEQUIVALENTS	30.040	6.980	PCO2 = 6.930017E-02
ANION MILLIEQUIVALENTS	29.840		PH2S = 0.000000E+00
RATIO CATIONS/ANIONS	1.007	TEMPERATURE	PO2 = 5.270628E-02
		11.30 DEG C	PCH4 = 4.807878E-61
			CO2 TOTAL = 1.851056E-02
		IONIC STRENGTH	DENSITY = 1.0000
		4.442651E-02	TDS = 2487.77MG/L

THE VALUES OF THE DEBYE-HUCKEL SOLVENT CONSTANTS ARE, A = .4998 AND B = .3265
THE ALKALINITY CORRECTION= 1.389473E-06 CORALK= 0 PECALC= 1 UNITS FLAG= 2 FEFLAG= 1

0

PE FROM EH MEAS. = 3.543 EH= .200 (MEASURED EH)

PE DOX = 14.686 EH= .829
PE SATO DOX = 3.395 EH= .192
THE DISTRIBUTION OF SPECIES WAS COMPUTED ASSUMING THAT PE = 3.543 EH= .200 VOLTS.

********** DISTRIBUTION OF SPECIES **********

ACTIVITY COEFFICIENTS WERE CALCULATED FROM THE DAVIES EQUATION.
THE SPECIES ARE SORTED BY PPM IN DESCENDING ORDER.

I	SPECIES	PPM	MOLALITY	LOG MOL.	ACTIVITY	LOG ACT.	ACT. COEFF.	LOG A. COF.
7	HCO3 -	8.72052E+02	1.43275E-02	-1.8438	1.20052E-02	-1.9206	.8379	-.0768
6	SO4 2-	5.32718E+02	5.55942E-03	-2.2550	2.69003E-03	-2.5702	.4839	-.3153
3	NA +	2.65061E+02	1.15583E-02	-1.9371	9.62987E-03	-2.0164	.8332	-.0793
1	CA 2+	2.23527E+02	5.59092E-03	-2.2525	2.76260E-03	-2.5587	.4941	-.3062
86	H2CO3	2.17584E+02	3.51674E-03	-2.4539	3.55799E-03	-2.4488	1.0117	.0051
32	CASO4	1.80131E+02	1.32642E-03	-2.8773	1.34006E-03	-2.8729	1.0103	.0044
5	CL -	1.45896E+02	4.12545E-03	-2.3845	3.39816E-03	-2.4688	.8237	-.0842
23	MGSO4	8.12338E+01	6.76530E-04	-3.1697	6.83486E-04	-3.1653	1.0103	.0044
2	MG 2+	7.82221E+01	3.22545E-03	-2.4914	1.62857E-03	-2.7882	.5049	-.2968
30	CAHCO3 +	2.74163E+01	2.71863E-04	-3.5656	2.25947E-04	-3.6460	.8311	-.0803
22	MGHCO3 +	2.16336E+01	2.54163E-04	-3.5949	2.11236E-04	-3.6752	.8311	-.0803
44	NASO4 -	1.77641E+01	1.49586E-04	-3.8251	1.24321E-04	-3.9055	.8311	-.0803
24	H4SIO4	1.51870E+01	1.58402E-04	-3.8002	1.60031E-04	-3.7958	1.0103	.0044
43	NAHCO3	5.39136E+00	6.43499E-05	-4.1915	6.50116E-05	-4.1870	1.0103	.0044
37	O2 AQUEOUS	2.89279E+00	9.06284E-05	-4.0427	9.15602E-05	-4.0383	1.0103	.0044
85	NO3 -	2.72992E+00	4.41373E-05	-4.3552	3.66827E-05	-4.4355	.8311	-.0803
381	ZNHCO3 +	2.69611E+00	2.13836E-05	-4.6699	1.77720E-05	-4.7503	.8311	-.0803
101	MN 2+	2.53799E+00	4.63126E-05	-4.3343	2.20965E-05	-4.6557	.4771	-.3214
4	K +	2.46389E+00	6.31690E-05	-4.1995	5.20327E-05	-4.2837	.8237	-.0842
88	SR 2+	2.19000E+00	2.50566E-05	-4.6011	1.19549E-05	-4.9225	.4771	-.3214
111	MNHCO3 +	1.91975E+00	1.65973E-05	-4.7800	1.37941E-05	-4.8603	.8311	-.0803
355	ZN 2+	1.60734E+00	2.46459E-05	-4.6083	1.17589E-05	-4.9296	.4771	-.3214
245	CS +	1.25000E+00	9.42864E-06	-5.0256	7.83619E-06	-5.1059	.8311	-.0803
31	CACO3	1.17679E+00	1.17868E-05	-4.9286	1.19080E-05	-4.9242	1.0103	.0044
382	ZNCO3	1.12206E+00	8.97089E-06	-5.0472	9.06313E-06	-5.0427	1.0103	.0044
372	ZNSO4	1.05829E+00	6.57160E-06	-5.1823	6.63917E-06	-5.1779	1.0103	.0044
62	F -	9.44110E-01	4.98181E-05	-4.3026	4.14041E-05	-4.3830	.8311	-.0803
18	CO3 2-	4.69085E-01	7.83636E-06	-5.1059	3.86287E-06	-5.4131	.4929	-.3072
21	MGCO3	4.05022E-01	4.81529E-06	-5.3174	4.86480E-06	-5.3129	1.0103	.0044
243	RA 2+	3.42300E-01	1.51821E-06	-5.8187	7.24362E-07	-6.1400	.4771	-.3214
109	MNSO4	3.34891E-01	2.22342E-06	-5.6530	2.24628E-06	-5.6485	1.0103	.0044
383	ZN(CO3)2 2-	2.90128E-01	1.56879E-06	-5.8044	7.48494E-07	-6.1258	.4771	-.3214
114	AL(OH)3	1.63205E-01	2.09748E-06	-5.6783	2.11905E-06	-5.6739	1.0103	.0044
20	MGF +	1.58381E-01	3.66601E-06	-5.4358	3.04684E-06	-5.5162	.8311	-.0803
46	KSO4 -	1.24211E-01	9.21259E-07	-6.0356	7.65663E-07	-6.1160	.8311	-.0803
66	CACL +	1.23016E-01	1.63270E-06	-5.7871	1.35694E-06	-5.8674	.8311	-.0803
121	UO2(CO3)3 4-	1.16144E-01	2.58710E-07	-6.5872	1.34062E-08	-7.8727	.0518	-1.2855
54	AL(OH)4 -	1.08261E-01	1.14230E-06	-5.9422	9.49374E-07	-6.0226	.8311	-.0803
90	BA 2+	9.99998E-02	7.29935E-07	-6.1367	3.48263E-07	-6.4581	.4771	-.3214
373	ZN(SO4)2 2-	8.72891E-02	3.39827E-07	-6.4687	1.62137E-07	-6.7901	.4771	-.3214
163	H2VO4 -	5.10907E-02	4.37931E-07	-6.3586	3.63966E-07	-6.4389	.8311	-.0803
49	CAF +	5.05370E-02	8.57556E-07	-6.0667	7.12719E-07	-6.1471	.8311	-.0803
81	LI +	4.94197E-02	7.13978E-06	-5.1463	5.93391E-06	-5.2267	.8311	-.0803
94	NACL	4.72140E-02	8.09881E-07	-6.0916	8.18208E-07	-6.0871	1.0103	.0044
8	FE 2+	4.17119E-02	7.48758E-07	-6.1257	3.57244E-07	-6.4470	.4771	-.3214
120	UO2(CO3)2 2-	3.97292E-02	1.02112E-07	-6.9909	4.87191E-08	-7.3123	.4771	-.3214
42	NACO3 -	3.32885E-02	4.02071E-07	-6.3957	3.34163E-07	-6.4760	.8311	-.0803
103	MNCL +	3.29575E-02	3.65519E-07	-6.4371	3.03785E-07	-6.5174	.8311	-.0803
34	FESO4	2.18278E-02	1.44049E-07	-6.8415	1.45530E-07	-6.8370	1.0103	.0044
56	ALF2 +	1.89915E-02	2.93004E-07	-6.5331	2.43517E-07	-6.6135	.8311	-.0803
48	H2PO4 -	1.07570E-02	1.11188E-07	-6.9539	9.24092E-08	-7.0343	.8311	-.0803
47	HPO4 2-	1.01447E-02	1.05960E-07	-6.9749	5.05554E-08	-7.2962	.4771	-.3214
25	H3SIO4 -	9.69806E-03	1.02224E-07	-6.9904	8.49587E-08	-7.0708	.8311	-.0803
97	NAF	9.58664E-03	2.28887E-07	-6.6404	2.31240E-07	-6.6359	1.0103	.0044
83	LISO4 -	8.61390E-03	8.38382E-08	-7.0766	6.96783E-08	-7.1569	.8311	-.0803
457	CR(OH)2 +	7.93316E-03	9.24648E-08	-7.0340	7.68479E-08	-7.1144	.8311	-.0803
74	CAHPO4	7.86673E-03	5.79626E-08	-7.2369	5.85585E-08	-7.2324	1.0103	.0044
345	HSEO3 -	7.56049E-03	5.92293E-08	-7.2275	4.92258E-08	-7.3078	.8311	-.0803
356	ZNCL +	6.90997E-03	6.86997E-08	-7.1630	5.70967E-08	-7.2434	.8311	-.0803
341	HASO4 2-	5.84625E-03	4.18849E-08	-7.3779	1.99839E-08	-7.6993	.4771	-.3214
73	MGHPO4	5.54355E-03	4.61993E-08	-7.3354	4.66743E-08	-7.3309	1.0103	.0044

167	HVO4 2-	5.47683E-03	4.73535E-08	-7.3246	2.25931E-08	-7.6460	.4771	-.3214
57	ALF3	4.49929E-03	5.37115E-08	-7.2699	5.42638E-08	-7.2655	1.0103	.0044
390	AGCL	4.09820E-03	2.86658E-08	-7.5426	2.89606E-08	-7.5382	1.0103	.0044
361	ZNOH +	4.09326E-03	4.98071E-08	-7.3027	4.13949E-08	-7.3831	.8311	-.0803
340	H2ASO4 -	3.51676E-03	2.50153E-08	-7.6018	2.07903E-08	-7.6821	.8311	-.0803
53	AL(OH)2 +	3.31273E-03	5.44459E-08	-7.2640	4.52503E-08	-7.3444	.8311	-.0803
[illegible]5	ALF 2+	3.07281E-03	6.69960E-08	-7.1740	3.19648E-08	-7.4953	.4771	-.3214
[illegible]1	AGCL2 -	2.33746E-03	1.31076E-08	-7.8825	1.08938E-08	-7.9628	.8311	-.0803
63	HSO4 -	2.19736E-03	2.26934E-08	-7.6441	1.88606E-08	-7.7244	.8311	-.0803
432	PBCO3	1.54368E-03	5.79146E-09	-8.2372	5.85101E-09	-8.2328	1.0103	.0044
360	ZNOHCL	1.46893E-03	1.24965E-08	-7.9032	1.26250E-08	-7.8988	1.0103	.0044
362	ZN(OH)2	1.32266E-03	1.33404E-08	-7.8748	1.34775E-08	-7.8704	1.0103	.0044
76	CAH2PO4 +	8.15088E-04	5.96145E-09	-8.2246	4.95459E-09	-8.3050	.8311	-.0803
27	OH -	6.61334E-04	3.89820E-08	-7.4091	3.23982E-08	-7.4895	.8311	-.0803
132	UO2CO3	6.23768E-04	1.89471E-09	-8.7225	1.91419E-09	-8.7180	1.0103	.0044
128	UO2(HPO4)2 2-	6.02304E-04	1.30698E-09	-8.8837	6.23580E-10	-9.2051	.4771	-.3214
173	H3V2O7 -	5.86176E-04	2.70923E-09	-8.5672	2.25165E-09	-8.6475	.8311	-.0803
368	ZNF +	5.81480E-04	6.90852E-09	-8.1606	5.74170E-09	-8.2410	.8311	-.0803
108	MNF +	5.74760E-04	7.79310E-09	-8.1083	6.47688E-09	-8.1886	.8311	-.0803
41	MGH2PO4 +	5.41523E-04	4.47548E-09	-8.3492	3.71960E-09	-8.4295	.8311	-.0803
344	SEO3 2-	5.38223E-04	4.24995E-09	-8.3716	2.02771E-09	-8.6930	.4771	-.3214
385	AG +	4.76552E-04	4.42894E-09	-8.3537	3.68091E-09	-8.4340	.8311	-.0803
19	MGOH +	3.63815E-04	8.82690E-09	-8.0542	7.33608E-09	-8.1345	.8311	-.0803
95	KCL	3.38432E-04	4.55068E-09	-8.3419	4.59747E-09	-8.3375	1.0103	.0044
78	FE(OH)3	3.07287E-04	2.88254E-09	-8.5402	2.91218E-09	-8.5358	1.0103	.0044
434	PBHCO3 +	2.67572E-04	1.00008E-09	-9.0000	8.31172E-10	-9.0803	.8311	-.0803
52	ALOH 2+	2.34003E-04	5.33285E-09	-8.2730	2.54438E-09	-8.5944	.4771	-.3214
106	MNOH +	1.73823E-04	2.42207E-09	-8.6158	2.01300E-09	-8.6962	.8311	-.0803
458	CR(OH)3	1.70860E-04	1.66269E-09	-8.7792	1.67978E-09	-8.7747	1.0103	.0044
367	ZNNO3 +	1.65657E-04	1.30369E-09	-8.8848	1.08350E-09	-8.9652	.8311	-.0803
75	CAPO4 -	1.63605E-04	1.21445E-09	-8.9156	1.00934E-09	-8.9960	.8311	-.0803
456	CROH 2+	1.54597E-04	2.24601E-09	-8.6486	1.07161E-09	-8.9700	.4771	-.3214
29	CAOH +	1.39840E-04	2.45569E-09	-8.6098	2.04094E-09	-8.6902	.8311	-.0803
50	NAHPO4 -	1.35545E-04	1.14217E-09	-8.9423	9.49266E-10	-9.0226	.8311	-.0803
64	H +	1.26684E-04	1.25992E-07	-6.8997	1.04713E-07	-6.9800	.8311	-.0803
[illegible]0	AL(OH)5 2-	1.26214E-04	1.13256E-09	-8.9459	5.40364E-10	-9.2673	.4771	-.3214
[illegible]0	MGPO4 -	1.14912E-04	9.65758E-10	-9.0151	8.02646E-10	-9.0955	.8311	-.0803
197	HF	1.00098E-04	5.01581E-09	-8.2997	5.06739E-09	-8.2952	1.0103	.0044
77	FE(OH)2 +	8.23060E-05	9.18204E-10	-9.0371	7.63124E-10	-9.1174	.8311	-.0803
168	H3VO4	6.10361E-05	5.18709E-10	-9.2851	5.24042E-10	-9.2806	1.0103	.0044
174	V3O9 3-	5.78938E-05	1.95534E-10	-9.7088	3.69935E-11	-10.4319	.1892	-.7231
11	FEOH +	4.88303E-05	6.71912E-10	-9.1727	5.58429E-10	-9.2530	.8311	-.0803
59	ALSO4 +	4.60436E-05	3.75140E-10	-9.4258	3.11781E-10	-9.5062	.8311	-.0803
401	AGSO4 -	4.18655E-05	2.05806E-10	-9.6865	1.71046E-10	-9.7669	.8311	-.0803
437	PBSO4	3.94794E-05	1.30507E-10	-9.8844	1.31849E-10	-9.8799	1.0103	.0044
423	PB(CO3)2 2-	3.88396E-05	1.18992E-10	-9.9245	5.67730E-11	-10.2459	.4771	-.3214
418	PB 2+	3.77577E-05	1.82683E-10	-9.7383	8.71606E-11	-10.0597	.4771	-.3214
104	MNCL2	3.48432E-05	2.77566E-10	-9.5566	2.80420E-10	-9.5522	1.0103	.0044
58	ALF4 -	3.15811E-05	3.07451E-10	-9.5122	2.55524E-10	-9.5926	.8311	-.0803
238	NAOH	2.68997E-05	6.74216E-10	-9.1712	6.81149E-10	-9.1668	1.0103	.0044
357	ZNCL2	2.58058E-05	1.89822E-10	-9.7217	1.91774E-10	-9.7172	1.0103	.0044
79	FE(OH)4 -	1.96376E-05	1.58921E-10	-9.7988	1.32080E-10	-9.8792	.8311	-.0803
172	H2V2O7 2-	1.53829E-05	7.14296E-11	-10.1461	3.40801E-11	-10.4675	.4771	-.3214
392	AGCL3 2-	1.26141E-05	5.90286E-11	-10.2289	2.81634E-11	-10.5503	.4771	-.3214
60	AL(SO4)2 -	1.21105E-05	5.54105E-11	-10.2564	4.60519E-11	-10.3368	.8311	-.0803
100	FEHPO4	1.07780E-05	7.11687E-11	-10.1477	7.19005E-11	-10.1433	1.0103	.0044
51	AL 3+	9.07115E-06	3.37037E-10	-9.4723	6.37647E-11	-10.1954	.1892	-.7231
428	PBOH +	4.36369E-06	1.95113E-11	-10.7097	1.62159E-11	-10.7901	.8311	-.0803
65	FEH2PO4 +	3.03503E-06	1.99078E-11	-10.7010	1.65455E-11	-10.7813	.8311	-.0803
176	HV6O17 3-	2.65122E-06	4.59319E-12	-11.3379	8.68994E-13	-12.0610	.1892	-.7231
419	PBCL +	2.40542E-06	9.93772E-12	-11.0027	8.25929E-12	-11.0831	.8311	-.0803
433	PB(SO4)2 2-	1.55401E-06	3.90131E-12	-11.4088	1.86138E-12	-11.7302	.4771	-.3214
365	ZN2OH 3+	1.52037E-06	1.03146E-11	-10.9865	1.95144E-12	-11.7096	.1892	-.7231
459	CR(OH)4 -	1.35960E-06	1.13558E-11	-10.9448	9.43789E-12	-11.0251	.8311	-.0803
[illegible]1	KHPO4 -	8.31574E-07	6.17145E-12	-11.2096	5.12912E-12	-11.2900	.8311	-.0803
[illegible]5	CR 3+	8.02371E-07	1.54699E-11	-10.8105	2.92678E-12	-11.5336	.1892	-.7231
171	HV2O7 3-	4.23376E-07	1.97514E-12	-11.7044	3.73681E-13	-12.4275	.1892	-.7231
342	ASO4 3-	3.03318E-07	2.18886E-12	-11.6598	4.14114E-13	-12.3829	.1892	-.7231
221	FEF 2+	3.00508E-07	4.02506E-12	-11.3952	1.92042E-12	-11.7166	.4771	-.3214

89 SROH +	2.92669E-07	2.80423E-12	-11.5522	2.33061E-12	-11.6325	.8311	-.0803
72 CANO3 +	2.79901E-07	2.74868E-12	-11.5609	2.28444E-12	-11.6412	.8311	-.0803
236 BANO3 +	2.74208E-07	1.37904E-12	-11.8604	1.14613E-12	-11.9408	.8311	-.0803
346 H2SEO3	2.38512E-07	1.85392E-12	-11.7319	1.87298E-12	-11.7275	1.0103	.0044
393 AGCL4 3-	2.09088E-07	8.39512E-13	-12.0760	1.58829E-13	-12.7991	.1892	-.7231
127 UO2HPO4	1.87102E-07	5.12472E-13	-12.2903	5.17741E-13	-12.2859	1.0103	.0044
358 ZNCL3 -	1.38275E-07	8.07157E-13	-12.0930	6.70832E-13	-12.1734	.8311	-.0803
137 UO2H3SIO4 +	1.22109E-07	3.35255E-13	-12.4746	2.78632E-13	-12.5550	.8311	-.0803
10 FEOH 2+	1.19023E-07	1.63779E-12	-11.7857	7.81415E-13	-12.1071	.4771	-.3214
69 H3PO4	1.12027E-07	1.14604E-12	-11.9408	1.15783E-12	-11.9364	1.0103	.0044
122 UO2OH +	1.01812E-07	3.55586E-13	-12.4491	2.95530E-13	-12.5294	.8311	-.0803
237 KOH	9.98574E-08	1.78425E-12	-11.7485	1.80259E-12	-11.7441	1.0103	.0044
133 UO2F +	8.62097E-08	2.99020E-13	-12.5243	2.48517E-13	-12.6046	.8311	-.0803
105 MNCL3 -	8.31652E-08	5.16889E-13	-12.2866	4.29589E-13	-12.3669	.8311	-.0803
45 PO4 3-	8.18015E-08	8.63476E-13	-12.0637	1.63363E-13	-12.7868	.1892	-.7231
363 ZN(OH)3 -	5.68139E-08	4.89301E-13	-12.3104	4.06660E-13	-12.3908	.8311	-.0803
224 FEH3SIO4 2+	5.61947E-08	3.73192E-13	-12.4281	1.78056E-13	-12.7494	.4771	-.3214
26 H2SIO4 2-	5.61009E-08	5.97673E-13	-12.2235	2.85159E-13	-12.5449	.4771	-.3214
394 AGF	5.50459E-08	4.34970E-13	-12.3615	4.39443E-13	-12.3571	1.0103	.0044
186 VO 2+	4.89560E-08	7.33157E-13	-12.1348	3.49801E-13	-12.4562	.4771	-.3214
339 H3ASO4	4.20810E-08	2.97203E-13	-12.5269	3.00259E-13	-12.5225	1.0103	.0044
222 FEF2 +	3.76796E-08	4.02516E-13	-12.3952	3.34533E-13	-12.4756	.8311	-.0803
441 PBHPO4	3.23790E-08	1.07064E-13	-12.9704	1.08165E-13	-12.9659	1.0103	.0044
461 CR3(OH)4 5+	3.05814E-08	1.36854E-13	-12.8637	1.34170E-15	-14.8723	.0098	-2.0086
216 ALF5 2-	2.95585E-08	2.42940E-13	-12.6145	1.15910E-13	-12.9359	.4771	-.3214
334 H3ASO3	2.71117E-08	2.15806E-13	-12.6659	2.18024E-13	-12.6615	1.0103	.0044
187 VOOH +	2.64061E-08	3.15337E-13	-12.5012	2.62078E-13	-12.5816	.8311	-.0803
119 UO2 2+	2.58542E-08	9.59852E-14	-13.0178	4.57960E-14	-13.3392	.4771	-.3214
134 UO2F2	2.32727E-08	7.57430E-14	-13.1207	7.65218E-14	-13.1162	1.0103	.0044
460 CR2(OH)2 4+	1.97855E-08	1.43724E-13	-12.8425	7.44769E-15	-14.1280	.0518	-1.2855
169 H4VO4 +	1.75660E-08	1.48018E-13	-12.8297	1.23018E-13	-12.9100	.8311	-.0803
424 PBF +	1.74227E-08	7.72161E-14	-13.1123	6.41746E-14	-13.1926	.8311	-.0803
123 UO2SO4	1.64931E-08	4.51651E-14	-13.3452	4.56295E-14	-13.3408	1.0103	.0044
420 PBCL2	1.59723E-08	5.75756E-14	-13.2398	5.81676E-14	-13.2353	1.0103	.0044
436 PBNO3 +	1.52801E-08	5.69018E-14	-13.2449	4.72914E-14	-13.3252	.8311	-.0803
429 PB(OH)2	1.43364E-08	5.95826E-14	-13.2249	6.01953E-14	-13.2204	1.0103	.0044
170 V2O7 4-	1.40311E-08	6.57669E-14	-13.1820	3.40801E-15	-14.4675	.0518	-1.2855
164 VO2 +	1.32845E-08	1.60568E-13	-12.7943	1.33449E-13	-12.8747	.8311	-.0803
402 AGNO3	1.16149E-08	6.85448E-14	-13.1640	6.92496E-14	-13.1596	1.0103	.0044
166 VO4 3-	9.40902E-09	8.20652E-14	-13.0858	1.55261E-14	-13.8089	.1892	-.7231
91 BAOH +	7.91428E-09	5.14036E-14	-13.2890	4.27218E-14	-13.3694	.8311	-.0803
462 CRCL 2+	7.07428E-09	8.10978E-14	-13.0910	3.86930E-14	-13.4124	.4771	-.3214
82 LIOH	7.03071E-09	2.94334E-13	-12.5312	2.97361E-13	-12.5267	1.0103	.0044
110 MN(NO3)2	6.21480E-09	3.48163E-14	-13.4582	3.51743E-14	-13.4538	1.0103	.0044
399 AGOH	4.33041E-09	3.47644E-14	-13.4589	3.51218E-14	-13.4544	1.0103	.0044
124 UO2(SO4)2 2-	3.47834E-09	7.54532E-15	-14.1223	3.59999E-15	-14.4437	.4771	-.3214
141 UO2 + (5 VALENT)	3.38771E-09	1.25771E-14	-13.9004	1.04529E-14	-13.9808	.8311	-.0803
218 AL2(OH)2 4+	1.90107E-09	2.16625E-14	-13.6643	1.12254E-15	-14.9498	.0518	-1.2855
442 PBH2PO4 +	1.81317E-09	5.97558E-15	-14.2236	4.96633E-15	-14.3040	.8311	-.0803
223 FEF3	1.33177E-09	1.18315E-14	-13.9270	1.19531E-14	-13.9225	1.0103	.0044
194 VOSO4	1.24516E-09	7.65816E-15	-14.1159	7.73690E-15	-14.1114	1.0103	.0044
235 HF2 -	1.11369E-09	5.31293E-14	-13.2747	4.41560E-14	-13.3550	.8311	-.0803
80 FE(OH)2	7.61843E-10	8.49910E-15	-14.0706	8.58649E-15	-14.0662	1.0103	.0044
359 ZNCL4 2-	4.41675E-10	2.13703E-15	-14.6702	1.01961E-15	-14.9916	.4771	-.3214
138 UO2F3 -	3.06058E-10	9.38227E-16	-15.0277	7.79765E-16	-15.1080	.8311	-.0803
15 FESO4 +	2.18249E-10	1.44030E-15	-14.8415	1.19704E-15	-14.9219	.8311	-.0803
335 H2ASO3 -	1.08362E-10	8.69503E-16	-15.0607	7.22648E-16	-15.1411	.8311	-.0803
125 UO2CL +	8.87341E-11	2.91198E-16	-15.5358	2.42016E-16	-15.6162	.8311	-.0803
277 FE(SO4)2 -	6.91082E-11	2.79390E-16	-15.5538	2.32202E-16	-15.6341	.8311	-.0803
421 PBCL3 -	5.40789E-11	1.72898E-16	-15.7622	1.43696E-16	-15.8426	.8311	-.0803
191 VOF +	5.23969E-11	6.11218E-16	-15.2138	5.07986E-16	-15.2941	.8311	-.0803
185 V(OH)3	1.98419E-11	1.95084E-16	-15.7098	1.97090E-16	-15.7053	1.0103	.0044
177 H2V6O17 2-	1.74776E-11	3.02269E-17	-16.5196	1.44217E-17	-16.8410	.4771	-.3214
9 FE 3+	1.62160E-11	2.91088E-16	-15.5360	5.50715E-17	-16.2591	.1892	-.7231
425 PBF2	1.31340E-11	5.36987E-17	-16.2700	5.42508E-17	-16.2656	1.0103	.0044
12 FE(OH)3 -	9.48779E-12	8.90010E-17	-16.0506	7.39692E-17	-16.1309	.8311	-.0803
217 ALF6 3-	6.07103E-12	4.31729E-17	-16.3648	8.16797E-18	-17.0879	.1892	-.7231
331 H2F2	4.35270E-12	1.09054E-16	-15.9624	1.10176E-16	-15.9579	1.0103	.0044
219 AL3(OH)4 5+	4.23113E-12	2.84727E-17	-16.5456	2.79142E-19	-18.5542	.0098	-2.0086

463	CRCL2 +	3.79102E-12	3.09228E-17	-16.5097	2.57001E-17	-16.5901	.8311	-.0803
140	U(OH)5 -	2.84420E-12	8.82577E-18	-17.0542	7.33514E-18	-17.1346	.8311	-.0803
93	HCL	2.23809E-12	6.15363E-17	-16.2109	6.21690E-17	-16.2064	1.0103	.0044
430	PB(OH)3 -	2.04381E-12	7.93468E-18	-17.1005	6.59455E-18	-17.1808	.8311	-.0803
129	UO2H2PO4 +	1.85670E-12	5.07154E-18	-17.2949	4.21498E-18	-17.3752	.8311	-.0803
347	SEO4 2-	1.64469E-12	1.15334E-17	-16.9380	5.50278E-18	-17.2594	.4771	-.3214
[illegible]9	FEH2PO4 2+	9.62903E-13	6.31603E-18	-17.1996	3.01348E-18	-17.5209	.4771	-.3214
[illegible]6	FECL 2+	4.65121E-13	5.10713E-18	-17.2918	2.43669E-18	-17.6132	.4771	-.3214
139	UO2F4 2-	3.86571E-13	1.11998E-18	-17.9508	5.34358E-19	-18.2722	.4771	-.3214
96	H2SO4	2.85629E-13	2.91954E-18	-17.5347	2.94956E-18	-17.5302	1.0103	.0044
13	FEHPO4 +	2.80369E-13	1.85125E-18	-17.7325	1.53858E-18	-17.8129	.8311	-.0803
184	V(OH)2 +	2.77650E-13	3.27632E-18	-17.4846	2.72296E-18	-17.5650	.8311	-.0803
135	(UO2)2(OH)2 2+	2.36658E-13	4.13275E-19	-18.3838	1.97180E-19	-18.7051	.4771	-.3214
364	ZN(OH)4 2-	1.71527E-13	1.28893E-18	-17.8898	6.14967E-19	-18.2111	.4771	-.3214
192	VOF2	1.65311E-13	1.57926E-18	-17.8015	1.59550E-18	-17.7971	1.0103	.0044
422	PBCL4 2-	1.52691E-13	4.38587E-19	-18.3579	2.09256E-19	-18.6793	.4771	-.3214
190	V4O9 2-	1.49595E-13	4.31241E-19	-18.3653	2.05752E-19	-18.6867	.4771	-.3214
115	HMNO2 -	7.36301E-14	8.39288E-19	-18.0761	6.97537E-19	-18.1564	.8311	-.0803
435	PB2OH 3+	7.19723E-14	1.67247E-19	-18.7766	3.16419E-20	-19.4997	.1892	-.7231
400	AG(OH)2 -	5.70676E-14	4.03220E-19	-18.3945	3.35119E-19	-18.4748	.8311	-.0803
175	V4O12 4-	4.54585E-14	1.15151E-19	-18.9387	5.96705E-21	-20.2242	.0518	-1.2855
28	FECL2 +	2.64278E-14	2.09018E-19	-18.6798	1.73716E-19	-18.7602	.8311	-.0803
161	U(OH)4	1.18479E-14	3.88078E-20	-19.4111	3.92068E-20	-19.4066	1.0103	.0044
107	MN(OH)3 -	5.78480E-15	5.47304E-20	-19.2618	4.54867E-20	-19.3421	.8311	-.0803
426	PBF3 -	5.15985E-15	1.95791E-20	-19.7082	1.62723E-20	-19.7886	.8311	-.0803
338	H4ASO3 +	1.72348E-15	1.36097E-20	-19.8661	1.13111E-20	-19.9465	.8311	-.0803
189	H2V2O4 2+	1.20836E-15	7.21505E-21	-20.1418	3.44241E-21	-20.4631	.4771	-.3214
336	HASO3 2-	7.59775E-16	6.14608E-21	-20.2114	2.93239E-21	-20.5328	.4771	-.3214
278	FE2(OH)2 4+	3.60891E-16	2.48298E-21	-20.6050	1.28667E-22	-21.8905	.0518	-1.2855
136	(UO2)3(OH)5 +	2.44538E-16	2.73871E-22	-21.5625	2.27616E-22	-21.6428	.8311	-.0803
193	VOF3 -	2.25112E-16	1.82088E-21	-20.7397	1.51334E-21	-20.8201	.8311	-.0803
182	VOH 2+	1.57724E-16	2.32701E-21	-20.6332	1.11025E-21	-20.9546	.4771	-.3214
84	MG4(OH)4 4+	1.43971E-16	8.73406E-22	-21.0588	4.52595E-23	-22.3443	.0518	-1.2855
130	UO2(H2PO4)2	9.65392E-17	2.08577E-22	-21.6807	2.10721E-22	-21.6763	1.0103	.0044
431	PB(OH)4 2-	8.29458E-17	3.02122E-22	-21.5198	1.44147E-22	-21.8412	.4771	-.3214
[illegible]3	FECL3	9.32449E-18	5.76288E-23	-22.2394	5.82214E-23	-22.2349	1.0103	.0044
[illegible]0	U(OH)3 +	7.65273E-18	2.65414E-23	-22.5761	2.20587E-23	-22.6564	.8311	-.0803
348	HSEO4 -	2.91035E-18	2.02660E-23	-22.6932	1.68432E-23	-22.7736	.8311	-.0803
352	HSE -	1.60217E-18	2.00851E-23	-22.6971	1.66928E-23	-22.7775	.8311	-.0803
181	V 3+	5.08446E-19	1.00059E-23	-22.9997	1.89303E-24	-23.7228	.1892	-.7231
279	FE3(OH)4 5+	1.93726E-19	8.24420E-25	-24.0839	8.08247E-27	-26.0925	.0098	-2.0086
427	PBF4 2-	1.90928E-19	6.75879E-25	-24.1701	3.22472E-25	-24.4915	.4771	-.3214
464	CRO4 2-	4.19889E-20	3.62896E-25	-24.4402	1.73143E-25	-24.7616	.4771	-.3214
366	ZN2(OH)6 2-	7.68684E-21	3.31009E-26	-25.4802	1.57929E-26	-25.8015	.4771	-.3214
465	HCRO4 -	7.60599E-21	6.51698E-26	-25.1860	5.41629E-26	-25.2663	.8311	-.0803
131	UO2(H2PO4)3 -	1.23887E-21	2.21388E-27	-26.6548	1.83997E-27	-26.7352	.8311	-.0803
440	PB3(OH)4 2+	1.21022E-21	1.75926E-27	-26.7547	8.39371E-28	-27.0760	.4771	-.3214
159	U(HPO4)4 4-	1.20372E-21	1.94024E-27	-26.7121	1.00542E-28	-27.9977	.0518	-1.2855
353	H2SE	8.45515E-22	1.04676E-26	-25.9802	1.05752E-26	-25.9757	1.0103	.0044
145	U(OH)2 2+	8.28941E-22	3.05468E-27	-26.5150	1.45744E-27	-26.8364	.4771	-.3214
337	ASO3 3-	4.27843E-22	3.48935E-27	-26.4573	6.60156E-28	-27.1804	.1892	-.7231
332	SIF6 2-	1.63982E-22	1.15707E-27	-26.9366	5.52054E-28	-27.2580	.4771	-.3214
349	H2SEO4	8.69295E-23	6.01119E-28	-27.2210	6.07300E-28	-27.2166	1.0103	.0044
102	MN 3+	8.57490E-23	1.56472E-27	-26.8056	2.96033E-28	-27.5287	.1892	-.7231
158	U(HPO4)3 2-	5.81176E-24	1.10772E-29	-28.9556	5.28511E-30	-29.2769	.4771	-.3214
157	U(HPO4)2	6.55344E-26	1.52790E-31	-30.8159	1.54361E-31	-30.8115	1.0103	.0044
144	UOH 3+	1.36490E-26	5.36514E-32	-31.2704	1.01504E-32	-31.9935	.1892	-.7231
351	SE 2-	1.13309E-26	1.43860E-31	-30.8421	6.86377E-32	-31.1634	.4771	-.3214
150	UF4	3.29203E-27	1.05096E-32	-31.9784	1.06176E-32	-31.9740	1.0103	.0044
149	UF3 +	2.22888E-27	7.57374E-33	-32.1207	6.29457E-33	-32.2010	.8311	-.0803
148	UF2 2+	1.91163E-27	6.94282E-33	-32.1585	3.31252E-33	-32.4798	.4771	-.3214
180	V 2+	1.34135E-27	2.63969E-32	-31.5784	1.25944E-32	-31.8998	.4771	-.3214
147	UF 3+	1.90990E-28	7.44925E-34	-33.1279	1.40934E-34	-33.8510	.1892	-.7231
156	UHPO4 2+	1.73255E-28	5.20010E-34	-33.2840	2.48105E-34	-33.6054	.4771	-.3214
[illegible]5	U(SO4)2	1.14698E-28	2.67315E-34	-33.5730	2.70063E-34	-33.5685	1.0103	.0044
[illegible]8	VOH +	7.47270E-29	1.10250E-33	-32.9576	9.16292E-34	-33.0380	.8311	-.0803
466	H2CRO4	3.97179E-29	3.37405E-34	-33.4718	3.40875E-34	-33.4674	1.0103	.0044
151	UF5 -	6.54610E-30	1.97057E-35	-34.7054	1.63775E-35	-34.7858	.8311	-.0803
350	SE2 2-	5.90392E-30	3.74788E-35	-34.4262	1.78817E-35	-34.7476	.4771	-.3214

178 V10O28 6-	4.98377E-30	5.21852E-36	-35.2825	6.68587E-39	-38.1748	.0013	-2.8924
154 USO4 2+	4.93788E-30	1.48171E-35	-34.8292	7.06946E-36	-35.1506	.4771	-.3214
152 UF6 2-	1.67060E-31	4.75759E-37	-36.3226	2.26992E-37	-36.6440	.4771	-.3214
179 HV10O28 5-	9.86800E-32	1.03219E-37	-36.9862	1.01195E-39	-38.9948	.0098	-2.0086
143 U 4+	5.64027E-32	2.37548E-37	-36.6242	1.23096E-38	-37.9098	.0518	-1.2855
153 UCL 3+	5.75291E-34	2.10882E-39	-38.6760	3.98972E-40	-39.3991	.1892	-.7231
183 V2(OH)2 4+	1.65379E-35	1.21998E-40	-39.9137	6.32185E-42	-41.1992	.0518	-1.2855
165 H2V10O28 4-	8.94515E-36	9.34682E-42	-41.0293	4.84348E-43	-42.3148	.0518	-1.2855
452 PB(OH)6 2-	2.60266E-36	8.43719E-42	-41.0738	4.02551E-42	-41.3952	.4771	-.3214
467 CR2O7 2-	7.05364E-44	3.27390E-49	-48.4849	1.56203E-49	-48.8063	.4771	-.3214
142 U 3+	9.64145E-46	4.06064E-51	-50.3914	7.68240E-52	-51.1145	.1892	-.7231
113 MNO4 2-	1.03756E-53	8.74545E-59	-58.0582	4.17259E-59	-58.3796	.4771	-.3214
451 PB 4+	2.27987E-54	1.10307E-59	-58.9574	5.71605E-61	-60.2429	.0518	-1.2855
112 MNO4 -	9.89343E-61	8.33905E-66	-65.0789	6.93063E-66	-65.1592	.8311	-.0803
453 PB(OH)8 4-	4.40669E-62	1.28698E-67	-66.8904	6.66908E-69	-68.1759	.0518	-1.2855

********** ELEMENT RATIOS **********

MOLE RATIOS FROM ANALYTICAL MOLALITY		MOLE RATIOS FROM COMPUTED MOLALITY		ACTIVITY RATIOS	
CL/CA =	5.7311E-01	CL/CA =	7.3788E-01	CA/H2 =	2.5195E+11
CL/MG =	9.9129E-01	CL/MG =	1.2790E+00	MG/H2 =	1.4853E+11
CL/NA =	3.5065E-01	CL/NA =	3.5693E-01	NA/H1 =	9.1965E+04
CL/K =	6.4411E+01	CL/K =	6.5308E+01	K/H1 =	4.9691E+02
CL/AL =	1.1111E+03	CL/AL =	1.2240E+07	AL/H3 =	5.5537E+10
CL/FE =	4.5997E+03	CL/FE2 =	5.5097E+03	FE2/H2 =	3.2581E+07
CL/SO4 =	5.3459E-01	CL/SO4 =	7.4206E-01	CA/MG =	1.6963E+00
CL/HCO3 =	2.7465E-01	CL/HCO3 =	2.8794E-01	NA/K =	1.8507E+02
CA/MG =	1.7297E+00	CA/MG =	1.7334E+00	FE2/FE3=	6.4869E+09
NA/K =	1.8369E+02	NA/K =	1.8297E+02	UO2/H2 =	4.1766E+00
PO4TOT/U=	9.2791E-01	U6/U =	1.0000E+00		
SO4TOT/U=	2.1214E+04	U5/U =	3.4550E-08		
CL/U =	1.1341E+04	U4/U =	2.4352E-11		
U/V =	7.3991E-01	U6/U4 =	4.1065E+10		
NO3/NH4TOT=	0.0000E+00	SO4TOT/CO2TOT=	4.1720E-01		
		U/CO2TOT =	1.9666E-05		
		FE2TOT/FE3TOT=	2.2530E+02		

********** MINERAL SATURATION DATA **********

THE PHASES ARE LISTED IN DESCENDING ORDER BY LOG IAP/KT.

PHASE	FORMULA	IAP	KT	LOG IAP	LOG KT	IAP/KT	LOG IAP/KT	DELGR
682 NAUMANNITE	AG2SE	2.1599E-33	1.1229E-46	-32.6656	-45.9497	1.9236E+13	13.2841	17.2905
148 LEONHARDITE	CA2AL4SI8O24,7H2O	2.7068E-60	1.7798E-73	-59.5676	-72.7496	1.5208E+13	13.1821	17.1577
109 HEMATITE	FE2O3	2.2947E+09	1.2075E-03	9.3607	-2.9181	1.9004E+12	12.2788	15.9821
108 MAGNETITE	FE3O4	3.2952E+03	7.4193E-09	3.5179	-8.1296	4.4413E+11	11.6475	15.1604
805 CHROMITE	FECR2O4	2.1097E+26	1.6462E+16	26.3242	16.2165	1.2816E+10	10.1077	13.1562
632 FRANKLINITE	ZN(FEO2)2	2.4587E+18	5.5393E+08	18.3907	8.7435	4.4386E+09	9.6472	12.5568
634 LEGRANDITE	ZN3(ASO4)2,2.5H2O	5.9090E-17	1.7378E-25	-16.2285	-24.7600	3.4003E+08	8.5315	11.1046
808 MARIPOSITE	CR MICA	2.8945E-27	9.3326E-34	-26.5384	-33.0300	3.1015E+06	6.4916	8.4494
367 ILLITE-B	K,FE,H,MG-AL SILICATE	2.1292E-43	8.7096E-50	-42.6718	-49.0600	2.4447E+06	6.3882	8.3149
116 SMECTITE-A	MG,NA,K,H,FE-AL SILICATE	1.0532E-29	1.0715E-35	-28.9775	-34.9700	9.8286E+05	5.9925	7.7998
97 FLUORAPATITE	CA5(PO4)3F	2.9352E-62	3.2714E-68	-61.5324	-67.4853	8.9722E+05	5.9529	7.7483
807 VOLKHONSKOITE	CR SMECTITE	1.1089E-16	7.5858E-22	-15.9551	-21.1200	1.4618E+05	5.1649	6.7226
47 KAOLINITE	AL2SI2O5(OH)4	2.5464E-34	2.2642E-39	-33.5941	-38.6451	1.1246E+05	5.0510	6.5744
117 SMECTITE-B	MG,NA,K,H,FE-AL SILICATE	1.4873E-25	1.6596E-30	-24.8276	-29.7800	8.9619E+04	4.9524	6.4460
372 PARAGONITE	NAAL3SI3O10(OH)2	3.7419E-46	5.2096E-51	-45.4269	-50.2832	7.1827E+04	4.8563	6.3209
64 SMECTITE-CA	CA.17AL2.33SI3.67O12H2	4.5092E-43	8.6964E-48	-42.3459	-47.0607	5.1851E+04	4.7148	6.1367
49 BEIDELLITE	NA,K,MG-AL SILICATE	1.7181E-43	4.0679E-48	-42.7650	-47.3906	4.2234E+04	4.6257	6.0207
340 SAPONITE	MG,FE,NA,CA-AL SILICATE	1.7148E-10	4.6774E-15	-9.7658	-14.3300	3.6663E+04	4.5642	5.9408
44 MUSCOVITE	KAL3SI3O10(OH)2	2.0218E-48	3.2691E-52	-47.6943	-51.4856	6.1846E+03	3.7913	4.9348
129 LAUMONTITE	CAAL2SI4O12,4H2O	1.6445E-30	4.3823E-34	-29.7840	-33.3583	3.7526E+03	3.5743	4.6523
46 ILLITE-A	K.6MG.25AL2.3SI3.5O12H2	1.6741E-39	5.7486E-43	-38.7762	-42.2404	2.9121E+03	3.4642	4.5090
111 GOETHITE	FEO(OH)	1.8744E-39	7.9043E-43	-38.7271	-42.1021	2.3714E+03	3.3750	4.3929
110 MAGHEMITE	FE2O3	2.2947E+09	2.3442E+06	9.3607	6.3700	9.7885E+02	2.9907	3.8927
341 EPIDOTE	CA2FEAL2SI3O12(OH)	1.2408E-10	1.6310E-13	-9.9063	-12.7875	7.6075E+02	2.8812	3.7502
324 LAWSONITE	CAAL2SI2O8,2H2O	6.4102E-23	1.1429E-25	-22.1931	-24.9420	5.6089E+02	2.7489	3.5779
696 SILVER NATIVE	AG	1.0533E-12	3.9737E-15	-11.9774	-14.4008	2.6508E+02	2.4234	3.1542
451 RASO4		1.9486E-09	1.8368E-11	-8.7103	-10.7359	1.0609E+02	2.0257	2.6366
155 DIASPORE	ALO(OH)	2.1703E-33	3.0466E-35	-32.6635	-34.5162	7.1236E+01	1.8527	2.4115
146 WITHERITE	BACO3	1.3453E-12	2.7205E-14	-11.8712	-13.5653	4.9450E+01	1.6942	2.2051

344	MICROCLINE	KALSI308	2.0387E-22	5.1028E-24	-21.6906	-23.2922	3.9952E+01	1.6015	2.0846
317	DAWSONITE	NAAL(OH)2CO3	1.1513E-17	3.4396E-19	-16.9388	-18.4635	3.3472E+01	1.5247	1.9845
742	PLUMBOGUMMITE	PBAL3(PO4)2(OH)5,H2O	4.7654E-32	1.6218E-33	-31.3219	-32.7900	2.9383E+01	1.4681	1.9109
51	ALUNITE	KAL3(SO4)2(OH)6	1.1289E-85	4.2394E-87	-84.9473	-86.3727	2.6629E+01	1.4254	1.8552
54	PYROPHYLLITE	AL2SI4O10(OH)2	6.5499E-42	3.7153E-43	-41.1838	-42.4300	1.7629E+01	1.2462	1.6221
53	BOEHMITE	ALO(OH)	2.1703E-33	1.4782E-34	-32.6635	-33.8303	1.4682E+01	1.1668	1.5187
143	STRONTIANITE	SRCO3	4.6180E-11	3.2111E-12	-10.3355	-11.4933	1.4381E+01	1.1578	1.5070
193	MNHPO4		1.1171E-12	1.1298E-13	-11.9519	-12.9470	9.8876E+00	.9951	1.2952
145	BARITE	BASO4	9.3684E-10	1.0647E-10	-9.0283	-9.9728	8.7994E+00	.9445	1.2293
48	HALLOYSITE	AL2SI2O5(OH)4	2.5464E-34	4.0061E-35	-33.5941	-34.3973	6.3564E+00	.8032	1.0455
370	ANDRADITE	CA3FE2SI3O12	1.5081E+32	3.4941E+31	32.1784	31.5433	4.3160E+00	.6351	.8266
52	GIBBSITE	AL(OH)3	2.1684E-33	5.2382E-34	-32.6639	-33.2808	4.1396E+00	.6170	.8030
113	FE(OH)3 AMORPH.		4.7840E+04	1.3109E+04	4.6798	4.1176	3.6495E+00	.5622	.7318
12	DOLOMITE	CAMG(CO3)2	6.7134E-17	1.8735E-17	-16.1731	-16.7274	3.5834E+00	.5543	.7215
114	ANNITE	KFE3ALSI3O10(OH)2	1.0768E-86	3.5839E-87	-85.9679	-86.4456	3.0045E+00	.4778	.6219
13	CALCITE	CACO3	1.0672E-08	3.8892E-09	-7.9718	-8.4101	2.7439E+00	.4384	.5706
102	QUARTZ	SIO2	1.6031E-04	5.9624E-05	-3.7950	-4.2246	2.6887E+00	.4295	.5591
181	RHODOCHROSITE	MNCO3	8.5356E-11	3.4229E-11	-10.0688	-10.4656	2.4937E+00	.3968	.5165
345	HIGH SANIDINE	KALSI308	2.0387E-22	1.0031E-22	-21.6906	-21.9986	2.0323E+00	.3080	.4009
22	ARAGONITE	CACO3	1.0672E-08	7.7528E-09	-7.9718	-8.1105	1.3765E+00	.1388	.1806
100	CRISTOBALITE	SIO2	1.6031E-04	1.6590E-04	-3.7950	-3.7802	9.6632E-01	-.0149	-.0194
40	ADULARIA	KALSI308	2.0387E-22	2.1979E-22	-21.6906	-21.6580	9.2758E-01	-.0327	-.0425
636	ZNCO3,H2O		4.5384E-11	5.4954E-11	-10.3431	-10.2600	8.2585E-01	-.0831	-.1082
98	CHALCEDONY	SIO2	1.6031E-04	2.0610E-04	-3.7950	-3.6859	7.7782E-01	-.1091	-.1420
11	MAGNESITE	MGCO3	6.2910E-09	9.5012E-09	-8.2013	-8.0222	6.6212E-01	-.1791	-.2331
19	GYPSUM	CASO4,2H2O	7.4185E-06	1.7052E-05	-5.1297	-4.7682	4.3504E-01	-.3615	-.4705
242	JAROSITE	KFE3(SO4)2(OH)6	4.7457E-17	1.0965E-16	-16.3237	-15.9600	4.3281E-01	-.3637	-.4734
276	SMECTITE-V	K,V,MG,FE-AL SILICATE	7.6988E-44	2.3442E-43	-43.1136	-42.6300	3.2841E-01	-.4836	-.6294
624	SMITHSONITE	ZNCO3	4.5423E-11	1.4253E-10	-10.3427	-9.8461	3.1869E-01	-.4966	-.6464
41	ALBITE	NAALSI308	3.7731E-20	1.2185E-19	-19.4233	-18.9142	3.0965E-01	-.5091	-.6627
141	AL(OH)3 AMORPH.		2.1684E-33	8.5395E-33	-32.6639	-32.0686	2.5393E-01	-.5953	-.7748
679	CHLORARGYRITE	AGCL	1.2508E-11	4.9826E-11	-10.9028	-10.3025	2.5104E-01	-.6003	-.7813
101	SILICA GEL	SIO2	1.6031E-04	6.7029E-04	-3.7950	-3.1737	2.3917E-01	-.6213	-.8087
319	VARISCITE	ALPO4,2H2O	9.6363E-28	4.4970E-27	-27.0161	-26.3471	2.1428E-01	-.6690	-.8708
55	PHILLIPSITE	NA.5K.5ALSI308,H2O	2.7711E-21	1.3804E-20	-20.5574	-19.8600	2.0075E-01	-.6974	-.9077
18	ANHYDRITE	CASO4	7.4315E-06	3.8464E-05	-5.1289	-4.4149	1.9321E-01	-.7140	-.9293
63	FLUORITE	CAF2	4.7359E-12	2.7925E-11	-11.3246	-10.5540	1.6960E-01	-.7706	-1.0030
591	SELENIUM NATIVE	SE	1.7972E-65	1.3840E-64	-64.7454	-63.8589	1.2985E-01	-.8865	-1.1539
170	WHITLOCKITE	CA3(PO4)2	4.9146E-09	5.9694E-08	-8.3085	-7.2241	8.2330E-02	-1.0844	-1.4115
354	BIOTITE	K(MG2FE)(ALSI3)O10(OH)2	1.4602E+08	1.8621E+09	8.1644	9.2700	7.8418E-02	-1.1056	-1.4390
236	SILLIMANITE	AL2SIO5	1.5912E-30	3.0834E-29	-29.7983	-28.5110	5.1606E-02	-1.2873	-1.6755
373	JADEITE	NAALSI2O6	2.3536E-16	6.3260E-15	-15.6283	-14.1989	3.7205E-02	-1.4294	-1.8605
10	SIDERITE	FECO3	1.3800E-12	4.3460E-11	-11.8601	-10.3619	3.1753E-02	-1.4982	-1.9501
355	HYDROBIOTITE	H(MG2FE)(ALSI3)O10(OH)2	2.9386E+05	9.7724E+06	5.4681	6.9900	3.0070E-02	-1.5219	-1.9808
144	CELESTITE	SRSO4	3.2159E-08	1.1567E-06	-7.4927	-5.9368	2.7803E-02	-1.5559	-2.0252
320	ALSTONITE	BACA(CO3)2	1.4356E-20	1.0280E-18	-19.8430	-17.9880	1.3965E-02	-1.8550	-2.4144
316	NATROJAROSITE	NAFE3(SO4)2(OH)6	8.7830E-15	8.2035E-13	-14.0564	-12.0860	1.0706E-02	-1.9704	-2.5646
211	CORUNDUM	AL2O3	9.9259E-27	1.4483E-24	-26.0032	-23.8391	6.8534E-03	-2.1641	-2.8168
731	CERRUSITE	PBCO3	3.3669E-16	4.9938E-14	-15.4728	-13.3016	6.7421E-03	-2.1712	-2.8260
749	PLUMBOJAROSITE	PB.5FE3(SO4)2(OH)6	8.5149E-18	1.4125E-15	-17.0698	-14.8500	6.0281E-03	-2.2198	-2.8893
156	WAIRAKITE	CAAL2SI4O12,2H2O	1.6474E-30	2.8656E-28	-29.7832	-27.5428	5.7488E-03	-2.2404	-2.9161
628	WILLEMITE	ZN2SIO4	1.8405E+14	3.2212E+16	14.2649	16.5080	5.7138E-03	-2.2431	-2.9196
42	ANORTHITE	CAAL2SI2O8	6.4214E-23	1.1250E-20	-22.1924	-19.9488	5.7078E-03	-2.2435	-2.9202
43	ANALCIME	NAALSI2O6,H2O	2.3516E-16	4.5425E-14	-15.6286	-13.3427	5.1768E-03	-2.2859	-2.9754
368	CHLORITE-B	MG5FEALSI3O10(OH)8	1.4101E+36	6.6069E+38	36.1492	38.8200	2.1343E-03	-2.6708	-3.4762
142	PREHNITE	CA2AL2SI3O10(OH)2	2.5891E-15	1.2978E-12	-14.5868	-11.8868	1.9950E-03	-2.7001	-3.5144
147	STRENGITE	FEPO4,2H2O	8.9810E-30	4.6953E-27	-29.0467	-26.3283	1.9128E-03	-2.7183	-3.5382
625	ZINCITE	ZNO	1.0715E+09	8.1601E+11	9.0300	11.9117	1.3131E-03	-2.8817	-3.7508
118	HUNTITE	CAMG3(CO3)4	2.6569E-33	2.5082E-30	-32.5756	-29.6006	1.0593E-03	-2.9750	-3.8722
272	ROSCOELITE	K,V,FE,MG-AL SILICATE	7.4947E-59	7.2444E-56	-58.1252	-55.1400	1.0345E-03	-2.9852	-3.8856
149	EPSOMITE	MGSO4,7H2O	4.3542E-06	5.7494E-03	-5.3611	-2.2404	7.5733E-04	-3.1207	-4.0619
150	NESQUEHONITE	MGCO3,3H2O	6.2745E-09	8.9055E-06	-8.2024	-5.0503	7.0457E-04	-3.1521	-4.1027
59	NAHCOLITE	NAHCO3	1.1561E-04	2.0926E-01	-3.9370	-.6793	5.5248E-04	-3.2577	-4.2402
321	BRUSHITE	CAHPO4,2H2O	1.3942E-10	2.7464E-07	-9.8557	-6.5612	5.0764E-04	-3.2944	-4.2880
374	NEPHELINE	NAALSIO4	1.4682E-12	3.6439E-09	-11.8332	-8.4384	4.0292E-04	-3.3948	-4.4186
806	CR(OH)3		2.5425E+09	6.4416E+12	9.4053	12.8090	3.9469E-04	-3.4037	-4.4303
639	ZN(OH)2		1.0706E+09	2.9586E+12	9.0296	12.4711	3.6184E-04	-3.4415	-4.4794
46	SPODUMENE	LIALSI2O6	1.4503E-19	4.9220E-16	-18.8385	-15.3079	2.9466E-04	-3.5307	-4.5955
746	CLAUSTHALITE	PBSE	1.3895E-26	5.9096E-23	-25.8572	-22.2284	2.3512E-04	-3.6287	-4.7231

292	TYUYAMUNITE	CA(UO2)2(VO4)2	6.3841E-15	1.0283E-10	-14.1949	-9.9879	6.2086E-05	-4.2070	-5.4758
238	TAURISCITE	FESO4,7H2O	9.5515E-10	1.6334E-05	-9.0199	-4.7869	5.8476E-05	-4.2330	-5.5097
338	BA3(PO4)2		1.1273E-45	2.3277E-41	-44.9480	-40.6331	4.8429E-05	-4.3149	-5.6163
217	RUTHERFORDINE	UO2CO3	1.7690E-19	3.8818E-15	-18.7523	-14.4110	4.5572E-05	-4.3413	-5.6506
328	WUSTITE	FE.95O	1.5462E+08	4.0678E+12	8.1893	12.6094	3.8011E-05	-4.4201	-5.7532
30	CLINOENSTATITE	MGSIO3	2.7427E-22	7.8408E-18	-21.5618	-17.1056	3.4980E-05	-4.4562	-5.8001
38	TALC	MG3SI4O10(OH)2	3.3048E-69	1.3156E-64	-68.4809	-63.8809	2.5119E-05	-4.6000	-5.9873
96	HYDROXYAPATITE	CA5(PO4)3(OH)	2.2967E-65	1.1014E-60	-64.6389	-59.9581	2.0854E-05	-4.6808	-6.0925
50	CHLORITE-A	MG5AL2SI3O10(OH)8	5.1816E-98	2.8634E-93	-97.2855	-92.5431	1.8096E-05	-4.7424	-6.1727
447	CASEO3,2H2O		5.5920E-12	3.0903E-07	-11.2524	-6.5100	1.8095E-05	-4.7424	-6.1727
760	PB(OH)2		7.9353E+03	4.4042E+08	3.8996	8.6439	1.8017E-05	-4.7443	-6.1752
330	FAYALITE	FE2SIO4	1.6988E+11	9.8498E+15	11.2301	15.9934	1.7247E-05	-4.7633	-6.1999
732	ANGLESITE	PBSO4	2.3446E-13	1.3618E-08	-12.6299	-7.8659	1.7218E-05	-4.7640	-6.2008
67	MIRABILITE	NA2SO4,10H2O	2.4729E-07	1.6471E-02	-6.6068	-1.7833	1.5014E-05	-4.8235	-6.2783
369	CHLORITE-C	MG5FE.6AL1.4SI3O10(OH)8	1.1925E+29	8.3176E+33	29.0765	33.9200	1.4337E-05	-4.8435	-6.3043
568	NAUO2ASO4,4H2O		8.3871E-17	7.0795E-12	-16.0764	-11.1500	1.1847E-05	-4.9264	-6.4122
449	VERMICULITE	HYDROUS MG,FE,AL-SILICAT	6.4458E+04	5.8884E+09	4.8093	9.7700	1.0947E-05	-4.9607	-6.4569
234	SCHOEPITE	UO2(OH)2,H2O	4.1657E+00	6.6177E+05	.6197	5.8207	6.2948E-06	-5.2010	-6.7696
364	SRHPO4		6.0438E-13	1.3708E-07	-12.2187	-6.8630	4.4090E-06	-5.3557	-6.9709
232	UO2(OH)2		4.1694E+00	1.0872E+06	.6201	6.0363	3.8351E-06	-5.4162	-7.0497
631	GOSLARITE	ZNSO4,7H2O	3.1439E-08	8.3850E-03	-7.5025	-2.0765	3.7495E-06	-5.4260	-7.0625
39	HYDROMAGNESITE	MG5(CO3)4(OH)2,4H2O	4.2448E-43	1.2048E-37	-42.3721	-36.9191	3.5234E-06	-5.4530	-7.0977
352	BOBERRITE	MG3(PO4)2,8H2O	3.0466E+05	9.0365E+10	5.4838	10.9560	3.3715E-06	-5.4722	-7.1226
684	ARGENTOJAROSITE	AGFE3(SO4)2(OH)6	3.3572E-21	1.0965E-15	-20.4740	-14.9600	3.0618E-06	-5.5140	-7.1770
757	PBHPO4		4.4064E-18	1.9565E-12	-17.3559	-11.7085	2.2522E-06	-5.6474	-7.3506
630	BIANCHITE	ZNSO4,6H2O	3.1467E-08	1.7404E-02	-7.5021	-1.7594	1.8080E-06	-5.7428	-7.4748
295	DUTTONITE	VO(OH)2	1.1430E-24	6.7608E-19	-23.9419	-18.1700	1.6906E-06	-5.7719	-7.5127
590	MNSEO3,2H2O		4.4727E-14	3.1103E-08	-13.3494	-7.5072	1.4380E-06	-5.8422	-7.6042
37	SEPIOLITE-A	MG2SI3O7.5(OH),3H2O	1.2023E-47	9.1913E-42	-46.9200	-41.0366	1.3081E-06	-5.8834	-7.6578
570	SCORODITE	FEASO4,2H2O	1.0492E-17	8.5114E-12	-16.9791	-11.0700	1.2327E-06	-5.9092	-7.6913
29	DIOPSIDE	CAMGSI2O6	1.2761E-43	1.0843E-37	-42.8941	-36.9649	1.1769E-06	-5.9292	-7.7175
218	URANINITE	UO2	3.7502E-21	3.8800E-15	-20.4259	-14.4112	9.6654E-07	-6.0148	-7.8288
65	HALITE	NACL	3.2724E-05	3.5448E+01	-4.4851	1.5496	9.2315E-07	-6.0347	-7.8548
745	LAURIONITE	PBOHCL	2.8261E-06	4.1976E+00	-5.5488	.6230	6.7326E-07	-6.1718	-8.0332
291	CARNOTITE-B	K2(UO2)2(VO4)2,3H2O	6.2401E-21	1.0725E-14	-20.2048	-13.9696	5.8185E-07	-6.2352	-8.1157
20	BRUCITE	MG(OH)2	1.7094E-18	3.6307E-12	-17.7672	-11.4400	4.7082E-07	-6.3271	-8.2354
180	MANGANITE	MNO(OH)	2.5738E-07	5.7810E-01	-6.5894	-.2380	4.4523E-07	-6.3514	-8.2670
361	SRF2		2.0494E-14	4.6107E-08	-13.6884	-7.3362	4.4449E-07	-6.3521	-8.2679
567	KUO2ASO4		4.5476E-19	1.0965E-12	-18.3422	-11.9600	4.1475E-07	-6.3822	-8.3071
273	CARNOTITE-A	K2(UO2)2(VO4)2	6.2565E-21	1.5643E-14	-20.2037	-13.8057	3.9996E-07	-6.3980	-8.3276
66	THENARDITE	NA2SO4	2.4946E-07	6.9373E-01	-6.6030	-.1588	3.5959E-07	-6.4442	-8.3877
294	PARAMONTROSEITE	V2O4	1.3088E-48	4.4797E-42	-47.8831	-41.3488	2.9216E-07	-6.5344	-8.5051
178	PYROCHROSITE	MN(OH)2	2.3193E-20	8.7753E-14	-19.6346	-13.0567	2.6430E-07	-6.5779	-8.5618
231	COFFINITE	USIO4	6.0119E-25	2.6318E-18	-24.2210	-17.5797	2.2843E-07	-6.6412	-8.6442
347	EUCRYPTITE	LIALSIO4	9.0468E-16	4.4383E-09	-15.0435	-8.3528	2.0383E-07	-6.6907	-8.7086
740	PYROMORPHITE(CL)	PB5(PO4)3CL	7.4525E-92	3.7153E-85	-91.1277	-84.4300	2.0059E-07	-6.6977	-8.7177
209	WOLLASTONITE	CASIO3	4.0355E+07	2.7735E+14	7.6059	14.4430	1.4550E-07	-6.8371	-8.8992
589	MGSEO3,6H2O		3.2850E-12	3.6365E-05	-11.4835	-4.4393	9.0335E-08	-7.0441	-9.1686
151	ARTINITE	MG2(OH)2CO3,3H2O	3.0864E-26	3.8231E-19	-25.5105	-18.4176	8.0729E-08	-7.0930	-9.2322
766	PB3(VO4)2		7.2960E-16	1.1237E-08	-15.1369	-7.9493	6.4925E-08	-7.1876	-9.3553
735	MATLOCKITE	PBCLF	1.2263E-17	1.9469E-10	-16.9114	-9.7106	6.2988E-08	-7.2007	-9.3725
342	SYLVITE	KCL	1.7682E-07	4.9992E+00	-6.7525	.6989	3.5369E-08	-7.4514	-9.6987
767	ALAMOSITE	PBSIO3	1.2732E+00	4.4350E+07	.1049	7.6469	2.8708E-08	-7.5420	-9.8166
61	NATRON	NA2CO3,10H2O	3.5511E-10	1.3589E-02	-9.4496	-1.8668	2.6133E-08	-7.5828	-9.8698
569	MANSFIELDITE	ALASO4,2H2O	2.1821E-35	1.1749E-27	-34.6611	-26.9300	1.8573E-08	-7.7311	-10.0628
21	CHRYSOTILE	MG3SI2O5(OH)4	1.2848E-61	1.6835E-53	-60.8912	-52.7738	7.6320E-09	-8.1174	-10.5655
638	HOPEITE	ZN3(PO4)2,4H2O	4.3241E-41	9.1201E-33	-40.3641	-32.0400	4.7413E-09	-8.3241	-10.8346
694	AG2SEO3		2.7474E-26	7.2955E-18	-25.5611	-17.1369	3.7658E-09	-8.4241	-10.9648
216	UO2HPO4		7.8339E-34	2.9017E-25	-33.1060	-24.5373	2.6998E-09	-8.5687	-11.1529
739	LARNAKITE	PBO.PBSO4	1.8622E-09	8.8581E-01	-8.7300	-.0527	2.1022E-09	-8.6773	-11.2944
112	GREENALITE	FE3SI2O5(OH)4	1.3562E-72	6.4566E-64	-71.8677	-63.1900	2.1005E-09	-8.6777	-11.2948
645	ZN4(OH)6SO4		3.8811E+19	2.5119E+28	19.5890	28.4000	1.5451E-09	-8.8110	-11.4684
466	CSCL		2.6629E-08	2.0942E+01	-7.5747	1.3210	1.2715E-09	-8.8957	-11.5786
107	VIVIANITE	FE3(PO4)2,8H2O	1.2083E-45	1.0000E-36	-44.9178	-36.0000	1.2083E-09	-8.9178	-11.6074
353	SPINEL	MGAL2O4	1.4730E-15	1.7247E-06	-14.8318	-5.7633	8.5403E-10	-9.0685	-11.8036
222	AUTUNITE-NA	NA2(UO2)2(PO4)2	5.1904E-57	6.2711E-48	-56.2848	-47.2027	8.2768E-10	-9.0821	-11.8213
315	ARCANITE	K2SO4	7.2830E-12	8.8001E-03	-11.1377	-2.0555	8.2760E-10	-9.0822	-11.8213
633	ZNSE		1.7305E-77	2.3465E-68	-76.7618	-67.6296	7.3751E-10	-9.1322	-11.8865
738	LITHARGE	PBO	7.9422E+03	1.9872E+13	3.8999	13.2982	3.9967E-10	-9.3983	-12.2328

188	RHODONITE	MNSIO3	7.1323E+00	1.9705E+10	.8532	10.2946	3.6195E-10	-9.4413	-12.2888
172	MANGANOSITE	MNO	2.0135E+09	6.1111E+18	9.3039	18.7861	3.2948E-10	-9.4822	-12.3420
334	BAF2		5.9703E-16	1.9615E-06	-15.2240	-5.7074	3.0437E-10	-9.5166	-12.3868
99	MAGADIITE	NASI7O13(OH)3,3H2O	1.3462E-24	5.0119E-15	-23.8709	-14.3000	2.6860E-10	-9.5709	-12.4574
734	HYDROCERRUSITE	2(PBCO3).PB(OH)2	8.9955E-28	3.4674E-18	-27.0460	-17.4600	2.5943E-10	-9.5860	-12.4771
737	MASSICOT	PBO	7.9422E+03	3.1795E+13	3.8999	13.5024	2.4979E-10	-9.6024	-12.4985
62	THERMONATRITE	NA2CO3,H2O	3.5791E-10	1.6746E+00	-9.4462	.2239	2.1373E-10	-9.6701	-12.5866
154	SEPIOLITE-B	MG2SI3O7.5(OH),3H2O	1.2023E-47	6.1376E-38	-46.9200	-37.2120	1.9589E-10	-9.7080	-12.6359
187	TEPHROITE	MN2SIO4	6.4990E+14	3.4370E+24	14.8128	24.5362	1.8909E-10	-9.7233	-12.6559
730	COTUNNITE	PBCL2	1.0065E-15	1.0772E-05	-14.9972	-4.9677	9.3432E-11	-10.0295	-13.0544
452	RACL2,2H2O		8.3500E-12	9.0943E-02	-11.0783	-1.0412	9.1816E-11	-10.0371	-13.0642
362	SRCL2,6H2O		1.3733E-10	2.6954E+00	-9.8622	.4306	5.0948E-11	-10.2929	-13.3972
293	MONTROSEITE	VOOH	3.4280E-35	7.9433E-25	-34.4650	-24.1000	4.3156E-11	-10.3650	-13.4910
190	MNSO4		5.9440E-08	1.6424E+03	-7.2259	3.2155	3.6192E-11	-10.4414	-13.5905
761	PB2(OH)3CL		2.2426E-02	6.2087E+08	-1.6493	8.7930	3.6120E-11	-10.4423	-13.5916
233	GUMMITE	UO3	4.1730E+00	1.6266E+11	.6204	11.2113	2.5656E-11	-10.5908	-13.7850
736	PHOSGENITE	PBCL2.PBCO3	3.3887E-31	1.5488E-20	-30.4700	-19.8100	2.1879E-11	-10.6600	-13.8750
32	TREMOLITE	CA2MG5SI8O22(OH)2	5.3816-155	3.2754-144	-154.2691	-143.4847	1.6430E-11	-10.7843	-14.0369
360	CRYOLITE	NA3ALF6	5.1531E-67	3.3343E-56	-66.2879	-55.4770	1.5455E-11	-10.8109	-14.0715
356	ANTIGORITE	MG4.8SI3.4O8.5(OH)6.2	5.2305E+40	3.5046E+51	40.7185	51.5446	1.4925E-11	-10.8261	-14.0912
685	AG2CO3		5.2339E-23	3.9226E-12	-22.2812	-11.4064	1.3343E-11	-10.8748	-14.1545
28	FORSTERITE	MG2SIO4	4.6926E-40	5.2249E-29	-39.3286	-28.2819	8.9811E-12	-11.0467	-14.3783
227	AUTUNITE-CA	CA(UO2)2(PO4)2	1.5462E-55	2.0287E-44	-54.8107	-43.6928	7.6218E-12	-11.1179	-14.4711
629	ZINCOSITE	ZNSO4	3.1632E-08	4.8729E+03	-7.4999	3.6878	6.4913E-12	-11.1877	-14.5618
758	PB3(PO4)2		1.5435E-31	2.4488E-20	-30.8115	-19.6110	6.3029E-12	-11.2005	-14.5785
755	PBF2		1.4942E-19	3.8434E-08	-18.8256	-7.4153	3.8877E-12	-11.4103	-14.8516
45	PHLOGOPITE	KMG3ALSI3O10(OH)2	1.0201E-75	2.9512E-64	-74.9913	-63.5300	3.4566E-12	-11.4614	-14.9180
335	BACL2,2H2O		4.0145E-12	1.1840E+00	-11.3964	.0734	3.3906E-12	-11.4697	-14.9289
756	PBO.PBCO3		2.6741E-12	8.0271E-01	-11.5728	-.0954	3.3313E-12	-11.4774	-14.9389
351	PERICLASE	MGO	1.4840E+11	5.6521E+22	11.1714	22.7522	2.6255E-12	-11.5808	-15.0735
743	HINSDALITE	PBAL3PO4SO4(OH)6	7.4938E-15	3.1623E-03	-14.1253	-2.5000	2.3697E-12	-11.6253	-15.1314
186	MNCL2,4H2O		2.5427E-10	1.2487E+02	-9.5947	2.0965	2.0363E-12	-11.6912	-15.2172
226	SALEEITE	MG(UO2)2(PO4)2	9.1152E-56	6.4060E-44	-55.0402	-43.1934	1.4229E-12	-11.8468	-15.4198
371	GROSSULAR	CA3AL2SI3O12	6.5233E-04	5.9704E+08	-3.1855	8.7760	1.0926E-12	-11.9615	-15.5691
592	FERROSELITE	FESE2	9.4487-144	9.1626-132	-143.0246	-131.0380	1.0312E-12	-11.9866	-15.6018
271	NINGYOITE	CAU(PO4)2,2H2O	2.9034E-52	2.9102E-40	-51.5371	-39.5361	9.9765E-13	-12.0010	-15.6205
219	UO2 AMORPHOUS		3.7502E-21	5.2156E-09	-20.4259	-8.2827	7.1904E-13	-12.1432	-15.8056
644	ZN5(OH)8CL2		1.7836E+26	3.1623E+38	26.2513	38.5000	5.6402E-13	-12.2487	-15.9429
350	BISCHOFITE	MGCL2,6H2O	1.8708E-08	3.9795E+04	-7.7280	4.5998	4.7010E-13	-12.3278	-16.0458
269	URANOPHANE	CA(UO2)2(HSIO4)2	1.1256E+05	3.0903E+17	5.0514	17.4900	3.6423E-13	-12.4386	-16.1901
224	AUTUNITE-K	K2(UO2)2(PO4)2	1.5154E-61	5.2970E-49	-60.8195	-48.2760	2.8608E-13	-12.5435	-16.3266
453	RA(NO3)2		9.7472E-16	3.4265E-03	-15.0111	-2.4651	2.8446E-13	-12.5460	-16.3298
637	ZNF2		2.0158E-14	8.7447E-02	-13.6955	-1.0583	2.3052E-13	-12.6373	-16.4487
692	AGNO3		1.3503E-13	9.5439E-01	-12.8696	-.0203	1.4148E-13	-12.8493	-16.7246
173	PYROLUSITE	MNO2	8.5896E+03	7.7822E+16	3.9340	16.8911	1.1037E-13	-12.9571	-16.8650
228	AUTUNITE-SR	SR(UO2)2(PO4)2	6.6912E-58	6.7497E-45	-57.1745	-44.1707	9.9134E-14	-13.0038	-16.9257
268	U3O8, ALPHA		6.5306E-20	8.1169E-07	-19.1851	-6.0906	8.0456E-14	-13.0944	-17.0437
176	BIXBYITE	MN2O3	6.6305E-14	8.4562E-01	-13.1785	-.0728	7.8410E-14	-13.1056	-17.0582
220	(UO2)3(PO4)2		2.5632E-66	4.1037E-53	-65.5912	-52.3868	6.2462E-14	-13.2044	-17.1868
686	AGF,4H2O		1.5187E-13	2.5076E+00	-12.8185	.3993	6.0565E-14	-13.2178	-17.2042
60	TRONA	NAHCO3,NA2CO3,2H2O	4.1341E-14	6.9252E-01	-13.3836	-.1596	5.9697E-14	-13.2240	-17.2124
349	LI2CO3		4.0369E-06	8.3709E+07	-5.3939	7.9228	4.8226E-14	-13.3167	-17.3330
314	ALUM	KAL(SO4)2,12H2O	4.2677E-44	8.8685E-31	-43.3698	-30.0521	4.8122E-14	-13.3177	-17.3342
185	MNCL2,2H2O		2.5471E-10	8.1966E+03	-9.5939	3.9136	3.1075E-14	-13.5076	-17.5814
175	NSUTITE	MNO2	8.5896E+03	3.1915E+17	3.9340	17.5040	2.6914E-14	-13.5700	-17.6627
179	MN(OH)3 AMORPH.		1.0067E-50	4.4339E-37	-49.9971	-36.3532	2.2705E-14	-13.6439	-17.7588
174	BIRNESSITE,DELTA	MNO2	8.5896E+03	1.2331E+18	3.9340	18.0910	6.9658E-15	-14.1570	-18.4267
689	AG2SO4		3.6448E-20	8.5108E-06	-19.4383	-5.0700	4.2825E-15	-14.3683	-18.7017
229	URANOCIRCITE	BA(UO2)2(PO4)2	1.9493E-59	8.9608E-45	-58.7101	-44.0477	2.1753E-15	-14.6625	-19.0846
588	SELENOLITE	SEO2	2.2253E-23	1.2973E-08	-22.6526	-7.8869	1.7153E-15	-14.7657	-19.2189
348	LIOH		5.6619E+01	3.6876E+16	1.7530	16.5667	1.5354E-15	-14.8138	-19.2816
230	BASSETITE	FE(UO2)2(PO4)2	1.9995E-59	1.4918E-44	-58.6991	-43.8263	1.3404E-15	-14.8728	-19.3583
593	ACHAVALITE	FESE	5.2575E-79	6.4215E-64	-78.2792	-63.1924	8.1874E-16	-15.0869	-19.6370
468	CSHCO3		9.4075E-08	1.4236E+08	-7.0265	8.1534	6.6081E-16	-15.1799	-19.7581
184	MNCL2,H2O		2.5494E-10	5.9606E+05	-9.5936	5.7753	4.2770E-16	-15.3689	-20.0040
177	HAUSMANITE	MN3O4	9.0830E+48	2.3392E+64	48.9582	64.3691	3.8829E-16	-15.4108	-20.0587
192	MN3(PO4)2		2.8792E-40	1.2536E-24	-39.5407	-23.9018	2.2967E-16	-15.6389	-20.3555
687	AG2O		1.2346E-03	8.8756E+12	-2.9085	12.9482	1.3910E-16	-15.8567	-20.6390
448	CA3(ASO4)2		7.6792E-10	1.0824E+07	-9.1147	7.0344	7.0946E-17	-16.1491	-21.0196

695	AG3ASO4		9.5181E-27	1.3490E-10	-26.0215	-9.8700	7.0558E-17	-16.1515	-21.0227
759	PB2SIO4		1.0112E+04	4.7626E+20	4.0048	20.6778	2.1232E-17	-16.6730	-21.7015
296	KARELIANITE	V2O3	1.1762E-69	7.5907E-53	-68.9295	-52.1197	1.5495E-17	-16.8098	-21.8796
594	CASEO4,2H2O		6.2225E+09	4.1856E+26	9.7940	26.6218	1.4866E-17	-16.8278	-21.9030
754	PYROMORPHITE(F)	PB5(PO4)3F	9.0803E-94	9.7723E-77	-93.0419	-76.0100	9.2919E-18	-17.0319	-22.1687
642	ZN(NO3)2,6H2O		1.5740E-14	1.7599E+03	-13.8030	3.2455	8.9440E-18	-17.0485	-22.1902
333	BA(OH)2,8H2O		3.1486E+07	7.1883E+24	7.4981	24.8566	4.3802E-18	-17.3585	-22.5938
635	ZNCL2		1.3579E-10	4.4368E+07	-9.8671	7.6471	3.0604E-18	-17.5142	-22.7964
467	CS2SO4		1.6518E-13	9.3201E+04	-12.7820	4.9694	1.7723E-18	-17.7515	-23.1052
752	PRZHEVALSKITE	PB(UO2)2(PO4)2	4.2610E-38	5.9917E-20	-37.3705	-19.2225	7.1115E-19	-18.1480	-23.6214
221	AUTUNITE-H	H2(UO2)2(PO4)2	6.1371E-67	1.1048E-48	-66.2120	-47.9567	5.5549E-19	-18.2553	-23.7611
741	PYROMORPHITE(OH)	PB5(PO4)3OH	2.0926E-82	1.6218E-63	-81.6793	-62.7900	1.2903E-19	-18.8893	-24.5863
183	MNCL2		2.5516E-10	2.4104E+09	-9.5932	9.3821	1.0586E-19	-18.9753	-24.6981
267	U4O9		2.2009E-61	2.8963E-42	-60.6574	-41.5382	7.5991E-20	-19.1192	-24.8855
765	PB3(ASO4)2		1.1355E-55	3.9537E-36	-54.9448	-35.4030	2.8721E-20	-19.5418	-25.4355
339	HYDROPHILITE	CACL2	3.1901E-08	4.0093E+12	-7.4962	12.6031	7.9569E-21	-20.0993	-26.1611
748	KERSTENITE	PBSEO4	4.7963E-28	1.0613E-07	-27.3191	-6.9741	4.5191E-21	-20.3450	-26.4809
688	AG3PO4		8.1474E-39	2.8184E-18	-38.0890	-17.5500	2.8908E-21	-20.5390	-26.7335
366	SR(OH)2		1.0884E+09	1.3480E+30	9.0368	30.1297	8.0741E-22	-21.0929	-27.4544
770	LEAD NATIVE	PB	7.1375E-18	1.8025E+04	-17.1465	4.2559	3.9597E-22	-21.4023	-27.8572
376	PYROPE	MG3AL2SI3O12	1.3364E-04	6.6713E+17	-3.8741	17.8242	2.0032E-22	-21.6983	-28.2424
322	LARNITE	CA2SIO4	1.0159E+19	8.1495E+40	19.0068	40.9111	1.2466E-22	-21.9043	-28.5105
762	PB4(OH)6SO4		1.1716E-01	1.2589E+21	-.9312	21.1000	9.3060E-23	-22.0312	-28.6758
470	CESIUM ALUM	CSAL(SO4)2,12H2O	6.4273E-45	1.7975E-21	-44.1920	-20.7453	3.5756E-24	-23.4467	-30.5181
576	ARSENOLITE	AS2O3	4.7659E-26	2.6052E-02	-25.3219	-1.5842	1.8294E-24	-23.7377	-30.8969
377	ANTHOPHYLLITE	MG7SI8O22(OH)2	6.9071E+47	3.6019E+72	47.8393	72.5565	1.9177E-25	-24.7172	-32.1719
343	TARANAKITE-K	H6K3AL5(PO4)8,18H2O	9.1727-170	6.0256-145	-169.0375	-144.2200	1.5223E-25	-24.8175	-32.3024
683	AG2SEO4		7.4558E-35	5.3000E-10	-34.1275	-9.2757	1.4068E-25	-24.8518	-32.3470
270	U(HPO4)2.4H2O		1.1503E-63	7.3831E-38	-62.9392	-37.1318	1.5581E-26	-25.8074	-33.5908
768	PLATTNERITE	PBO2	8.8377E+24	6.2644E+51	24.9463	51.7969	1.4108E-27	-26.8505	-34.9486
266	UF4,2.5H2O		1.3244E-66	1.0125E-38	-65.8780	-37.9946	1.3081E-28	-27.8834	-36.2929
365	SR2SIO4		1.9024E+14	2.1459E+43	14.2793	43.3316	8.8650E-30	-29.0523	-37.8144
375	PARGASITE	NACA2MG4AL3SI6O22(OH)2	4.7376E+10	1.1300E+40	10.6756	40.0531	4.1925E-30	-29.3775	-38.2377
578	ARSENIC NATIVE	AS	5.8814E-45	3.9847E-13	-44.2305	-12.3996	1.4760E-32	-31.8309	-41.4310
235	AL2(SO4)3,6H2O		2.5404E-76	3.2653E-44	-75.5951	-43.4861	7.7800E-33	-32.1090	-41.7930
469	CS2CO3		7.0401E-06	1.7155E+27	-5.1524	27.2344	4.1038E-33	-32.3868	-42.1546
337	BA2SIO4		1.6144E+11	4.4478E+46	11.2080	46.6481	3.6297E-36	-35.4401	-46.1287
265	UF4		1.3273E-66	5.3922E-29	-65.8770	-28.2682	2.4616E-38	-37.6088	-48.9515
623	ZINC NATIVE	ZN	9.6292E-13	1.1360E+27	-12.0164	27.0554	8.4761E-40	-39.0718	-50.8557
329	FE2(SO4)3		5.9037E-41	2.2982E+01	-40.2289	1.3614	2.5689E-42	-41.5903	-54.1337
769	MINIUM	PB3O4	5.5747E+32	2.0778E+77	32.7462	77.3176	2.6830E-45	-44.5714	-58.0139
418	CASE		4.4040E-19	9.9849E+26	-18.3562	26.9993	4.4107E-46	-45.3555	-59.0345
191	MN2(SO4)3		1.7059E-63	4.6546E-05	-62.7680	-4.3321	3.6650E-59	-58.4359	-76.0600
572	KANEITE	MNAS	1.0642E-56	1.7753E+19	-55.9730	19.2493	5.9944E-76	-75.2223	-97.9090
577	ARSINE GAS	ASH3	1.5824E-76	1.6620E+00	-75.8007	.2206	9.5210E-77	-76.0213	-98.9491
573	LOELLINGITE	FEAS2	1.0119-102	1.8877E-20	-101.9949	-19.7241	5.3607E-83	-82.2708	-107.0833

NETPATH MODELS FOR THE INDUSTRIAL AREA FLOW PATH - FILE: IA_MOD11.NET

Initial Well : Well B411289 - Industrial
Final Well : Well 41691 - Industrial

	Final	Initial
C	3.3520	1.8350
S	.8760	.0330
CA	1.6200	.3090
AL	.0020	.0020
MG	.6380	.0990
NA	1.8060	.6070
K	.1230	.0180
F	.0290	.0200
SI	.1960	.2650
BA	.0010	.0010
SR	.0050	.0010
FE	.0010	.0340
MN	.0110	.0230

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Microcln NA   .0520AL  1.0000SI  3.0000K    .6750CA   .0120MN   .0050FE   .0020        MG   .0090
ILLITE   K    .6000MG   .2500AL  2.3000SI  3.5000
KAOLINIT AL  2.0000SI  2.0000
SiO2     SI  1.0000
Albite   NA   .4160AL  1.0000SI  3.3970K    .1920CA   .0170FE   .0100
Biotite  AL  1.0000MG   .5170K    .5800SI  2.1450CA   .0320MN   .0370FE   .6630
CALCITE  CA  1.0000C   1.0000RS  4.0000I1   .0000I2   .0000
CHLORITE MG  5.0000AL  2.0000SI  3.0000
CO2 GAS  C   1.0000RS  4.0000I1-25.0000I2100.0000
Ca-MONT  CA   .1670AL  2.3300SI  3.6700
FeOOH    SI   .0340CA   .0800MN   .0160FE  1.0000MG   .0170
DOLOMITE CA  1.0000MG  1.0000C   2.0000RS  8.0000I1   .0000I2   .0000
EX-K-Na  K  -1.0000NA  1.0000
Ex-Ca-Na CA -1.0000NA  2.0000
Ex-Mg-Na NA  2.0000MG -1.0000
FLUORAP  CA  5.0000P   4.0000F   1.0000
GIBBSITE AL  1.0000
GOETHITE FE  1.0000RS  3.0000
K-MICA   K   1.0000AL  3.0000SI  3.0000
K-MONT   K    .3300AL  2.3300SI  3.6700
Montmor  CA   .1000MG   .2000NA   .1000AL  1.0000SI  2.4000
Mg-MONT  MG   .1670AL  2.3300SI  3.6700
MnO2     MN  1.0000RS  4.0000
MnOOH    MN  1.0000RS  2.0000
Na-MONT  NA   .3300AL  2.3300SI  3.6700
PYRITE   FE  1.0000S   2.0000RS   .0000I3-60.0000
Siderite FE  1.0000C   1.0000RS  6.0000CA   .1700MN   .0070MG   .1500SI   .0040
STRONITE SR  1.0000C   1.0000RS  4.0000
WITHERIT BA  1.0000C   1.0000RS  4.0000
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          MODEL   1
Microcln  + F        .48621
ILLITE      F      -1.27485
KAOLINIT  - F       -.18775
SiO2      - F      -6.46826
Albite    +         2.82143
FeOOH               5.69626
DOLOMITE  +          .75650
FLUORAP              .00900
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GOETHITE		-6.17995
MnO2		-.10557
PYRITE	+	.42150
STRONITE		.00400
WITHERIT		.00000

MODEL 2

Microcln	+ F	.48621
ILLITE	F	-1.27485
KAOLINIT	- F	-.18775
SiO2	- F	-6.46826
Albite	+	2.82143
FeOOH		5.69626
DOLOMITE	+	.75650
FLUORAP		.00900
GOETHITE		-6.17995
MnOOH		-.10557
PYRITE	+	.42150
STRONITE		.00400
WITHERIT		.00000

MODEL 3

Microcln	+ F	.87713
ILLITE	F	.00110
KAOLINIT	- F	-1.01368
SiO2	- F	-3.01364
Biotite	+	1.14769
CALCITE		1.51300
FeOOH		-3.67815
EX-K-Na	+	1.15339
FLUORAP		.00900
GOETHITE		2.46097
PYRITE	+	.42150
STRONITE		.00400
WITHERIT		.00000

MODEL 4

Microcln	+ F	.30143
ILLITE	F	1.80810
KAOLINIT	- F	-2.23003
SiO2	- F	-2.80536
CALCITE		1.23654
CO2 GAS		-.41526
FeOOH		-1.14683
EX-K-Na	+	1.18333
FLUORAP		.00900
PYRITE	+	.42150
Siderite	+	.69172
STRONITE		.00400
WITHERIT		.00000

MODEL 5

Microcln	+ F	.01474
ILLITE	F	2.15547
KAOLINIT	- F	-2.48616
SiO2	- F	-2.68505
CALCITE		1.26582
CO2 GAS		.24718
EX-K-Na	+	1.19823
FLUORAP		.00900

GOETHITE			-.45453
MnO2			-.01207
PYRITE	+		.42150
STRONITE			.00400
WITHERIT			.00000

MODEL 6

Microcln	+	F	.01474
ILLITE		F	2.15547
KAOLINIT	-	F	-2.48616
SiO2	-	F	-2.68505
CALCITE			1.26582
CO2 GAS			.24718
EX-K-Na	+		1.19823
FLUORAP			.00900
GOETHITE			-.45453
MnOOH			-.01207
PYRITE	+		.42150
STRONITE			.00400
WITHERIT			.00000

MODEL 7

Microcln	+	F	.01474
ILLITE		F	2.15547
KAOLINIT	-	F	-.76184
SiO2	-	F	-.70171
CALCITE			1.51300
Ca-MONT	-		-1.48010
EX-K-Na	+		1.19823
FLUORAP			.00900
GOETHITE			-.45453
MnO2			-.01207
PYRITE	+		.42150
STRONITE			.00400
WITHERIT			.00000

MODEL 8

Microcln	+	F	.01474
ILLITE		F	2.15547
KAOLINIT	-	F	-.76184
SiO2	-	F	-.70171
CALCITE			1.51300
Ca-MONT	-		-1.48010
EX-K-Na	+		1.19823
FLUORAP			.00900
GOETHITE			-.45453
MnOOH			-.01207
PYRITE	+		.42150
STRONITE			.00400
WITHERIT			.00000

MODEL 9

Microcln	+	F	.57196
ILLITE		F	1.48031
KAOLINIT	-	F	-1.98833
SiO2	-	F	-2.95771
CALCITE			1.15387
FeOOH			-.92874
DOLOMITE	+		.17956
EX-K-Na	+		1.16926

FLUORAP		.00900
GOETHITE		.47309
PYRITE	+	.42150
STRONITE		.00400
WITHERIT		.00000

MODEL 10

Microcln	+ F	.73463
ILLITE	F	1.28321
KAOLINIT	- F	-1.84300
SiO2	- F	-3.06260
CALCITE		1.07432
FeOOH		-.45597
DOLOMITE	+	.21934
EX-K-Na	+	1.16080
FLUORAP		.00900
MnO2		-.00838
PYRITE	+	.42150
STRONITE		.00400
WITHERIT		.00000

MODEL 11

Microcln	+ F	.73463
ILLITE	F	1.28321
KAOLINIT	- F	-1.84300
SiO2	- F	-3.06260
CALCITE		1.07432
FeOOH		-.45597
DOLOMITE	+	.21934
EX-K-Na	+	1.16080
FLUORAP		.00900
MnOOH		-.00838
PYRITE	+	.42150
STRONITE		.00400
WITHERIT		.00000

MODEL 12

Microcln	+ F	.07434
ILLITE	F	2.08326
KAOLINIT	- F	-2.43292
SiO2	- F	-2.68896
CALCITE		1.29793
FeOOH		-.86732
EX-K-Na	+	1.19513
FLUORAP		.00900
GOETHITE		.19761
PYRITE	+	.42150
Siderite	+	.21507
STRONITE		.00400
WITHERIT		.00000

MODEL 13

Microcln	+ F	.09374
ILLITE	F	2.05975
KAOLINIT	- F	-2.41558
SiO2	- F	-2.70574
CALCITE		1.28031
FeOOH		-.68738
EX-K-Na	+	1.19413
FLUORAP		.00900

MnO2			-.00310
PYRITE	+		.42150
Siderite	+		.23269
STRONITE			.00400
WITHERIT			.00000

MODEL 14

Microcln	+	F	.09374
ILLITE		F	2.05975
KAOLINIT	-	F	-2.41558
SiO2	-	F	-2.70574
CALCITE			1.28031
FeOOH			-.68738
EX-K-Na	+		1.19413
FLUORAP			.00900
MnOOH			-.00310
PYRITE	+		.42150
Siderite	+		.23269
STRONITE			.00400
WITHERIT			.00000

MODEL 15

Microcln	+	F	.89152
ILLITE		F	1.09311
KAOLINIT	-	F	-1.70284
SiO2	-	F	-3.16377
CALCITE			.99760
DOLOMITE	+		.25770
EX-K-Na	+		1.15264
FLUORAP			.00900
GOETHITE			-.45628
MnO2			-.01646
PYRITE	+		.42150
STRONITE			.00400
WITHERIT			.00000

MODEL 16

Microcln	+	F	.89152
ILLITE		F	1.09311
KAOLINIT	-	F	-1.70284
SiO2	-	F	-3.16377
CALCITE			.99760
DOLOMITE	+		.25770
EX-K-Na	+		1.15264
FLUORAP			.00900
GOETHITE			-.45628
MnOOH			-.01646
PYRITE	+		.42150
STRONITE			.00400
WITHERIT			.00000

MODEL 17

Microcln	+	F	.16786
ILLITE		F	1.96995
KAOLINIT	-	F	-2.34937
SiO2	-	F	-2.76985
CALCITE			1.21298
EX-K-Na	+		1.19027
FLUORAP			.00900
GOETHITE			-.75485

MnO2		-.01494
PYRITE	+	.42150
Siderite	+	.30002
STRONITE		.00400
WITHERIT		.00000

MODEL 18

Microcln	+ F	.16786
ILLITE	F	1.96995
KAOLINIT	- F	-2.34937
SiO2	- F	-2.76985
CALCITE		1.21298
EX-K-Na	+	1.19027
FLUORAP		.00900
GOETHITE		-.75485
MnOOH		-.01494
PYRITE	+	.42150
Siderite	+	.30002
STRONITE		.00400
WITHERIT		.00000

MODEL 21

Microcln	+ F	.08686
ILLITE	F	.07728
KAOLINIT	- F	-.13231
SiO2	- F	-.36522
CO2 GAS		-5.92793
Ex-Mg-Na	+	.59724
FLUORAP		.00900
GOETHITE		-7.89560
MnO2		-.06452
PYRITE	+	.42150
Siderite	+	7.44093
STRONITE		.00400
WITHERIT		.00000

MODEL 22

Microcln	+ F	.08686
ILLITE	F	.07728
KAOLINIT	- F	-.13231
SiO2	- F	-.36522
CO2 GAS		-5.92793
Ex-Mg-Na	+	.59724
FLUORAP		.00900
GOETHITE		-7.89560
MnOOH		-.06452
PYRITE	+	.42150
Siderite	+	7.44093
STRONITE		.00400
WITHERIT		.00000

2042975 models were tested.
24 models were found which satisfied the constraints.

Models requiring more than 10 mmoles dissolution or precipitation were eliminated from consideration as viable models.

NETPATH MODELS FOR THE ROCK CREEK FLOW PATH - FILE: ROCKMOD7.NET

Initial Well : Well B111189, Rock Creek flow pa
Final Well : Well B202589 - Rock Creek

	Final	Initial
C	3.2060	1.1890
S	.4560	.1100
CA	1.1810	.3040
AL	.0040	.0020
MG	.4400	.1030
NA	1.3180	.6740
K	.0540	.0350
F	.0220	.0210
SI	.2560	.3450
BA	.0010	.0000
SR	.0030	.0010
FE	.0020	.0010
MN	.0020	.0000

Microcln	NA	.0520AL	1.0000SI	3.0000K	.6750CA	.0120MN	.0050FE	.0020	MG	.0090
ILLITE	K	.6000MG	.2500AL	2.3000SI	3.5000					
KAOLINIT	AL	2.0000SI	2.0000							
SiO2	SI	1.0000								
Albite	NA	.4160AL	1.0000SI	3.3970K	.1920CA	.0170FE	.0100			
Biotite	AL	1.0000MG	.5170K	.5800SI	2.1450CA	.0320MN	.0370FE	.6630		
CALCITE	CA	1.0000C	1.0000RS	4.0000I1	.0000I2	.0000				
CHLORITE	MG	5.0000AL	2.0000SI	3.0000						
CO2 GAS	C	1.0000RS	4.0000I1-25.0000I2100.0000							
Ca-MONT	CA	.1670AL	2.3300SI	3.6700						
FeOOH	SI	.0340CA	.0800MN	.0160FE	1.0000MG	.0170				
DOLOMITE	CA	1.0000MG	1.0000C	2.0000RS	8.0000I1	.0000I2	.0000			
EX-K-Na	K	-1.0000NA	1.0000							
Ex-Ca-Na	CA	-1.0000NA	2.0000							
Ex-Mg-Na	NA	2.0000MG	-1.0000							
FLUORAP	CA	5.0000P	4.0000F	1.0000						
GIBBSITE	AL	1.0000								
GOETHITE	FE	1.0000RS	3.0000							
K-MICA	K	1.0000AL	3.0000SI	3.0000						
K-MONT	K	.3300AL	2.3300SI	3.6700						
Montmor	CA	.1000MG	.2000NA	.1000AL	1.0000SI	2.4000				
Mg-MONT	MG	.1670AL	2.3300SI	3.6700						
MnO2	MN	1.0000RS	4.0000							
MnOOH	MN	1.0000RS	2.0000							
Na-MONT	NA	.3300AL	2.3300SI	3.6700						
PYRITE	FE	1.0000S	2.0000RS	.0000I3-60.0000						
Siderite	FE	1.0000C	1.0000RS	6.0000CA	.1700MN	.0070MG	.1500SI	.0040		
STRONITE	SR	1.0000C	1.0000RS	4.0000						
WITHERIT	BA	1.0000C	1.0000RS	4.0000						

MODEL 1

Microcln	+	F	.13815
ILLITE		F	-1.43540
KAOLINIT	-	F	-4.46282
SiO2	-	F	-8.78589
Albite	+		1.53081
Biotite	+		.85013
Ca-MONT			4.16738
FeOOH			-2.76522

FLUORAP			.00100
PYRITE	+		.17300
Siderite	+		2.01400
STRONITE			.00200
WITHERIT			.00100

MODEL 2

Microcln	+	F	.40000
ILLITE		F	-.89772
KAOLINIT	-	F	-.02723
SiO2	-	F	-3.51619
Albite	+		1.49808
CALCITE			.84173
CHLORITE			.11157
CO2 GAS			1.17227
FLUORAP			.00100
GOETHITE			-.18778
PYRITE	+		.17300
STRONITE			.00200
WITHERIT			.00100

MODEL 6

Microcln	+	F	1.00234
ILLITE		F	-1.55126
KAOLINIT	-	F	-.34740
SiO2	-	F	-4.69614
Albite	+		1.42278
CO2 GAS			.57601
Ca-MONT			.78951
FeOOH			-.18823
DOLOMITE	+		.71899
FLUORAP			.00100
PYRITE	+		.17300
STRONITE			.00200
WITHERIT			.00100

MODEL 7

Microcln	+	F	1.00234
ILLITE		F	1.32472
KAOLINIT	-	F	-2.57867
SiO2	-	F	-6.90956
Albite	+		1.42278
CO2 GAS			2.01400
Ca-MONT			5.09487
FeOOH			-.18823
FLUORAP			.00100
K-MONT	-		-5.22905
PYRITE	+		.17300
STRONITE			.00200
WITHERIT			.00100

MODEL 8

Microcln	+	F	.40000
ILLITE		F	-.89772
KAOLINIT	-	F	-1.89619
SiO2	-	F	-5.68265
Albite	+		1.49808
CO2 GAS			.89834
Ca-MONT			1.70002
DOLOMITE	+		.55783

FLUORAP			.00100
GOETHITE			-.18778
PYRITE	+		.17300
STRONITE			.00200
WITHERIT			.00100

MODEL 9

Microcln	+	F	.40000
ILLITE		F	1.33360
KAOLINIT	-	F	-3.62731
SiO2	-	F	-7.39993
Albite	+		1.49808
CO2 GAS			2.01400
Ca-MONT			5.04032
FLUORAP			.00100
GOETHITE			-.18778
K-MONT	-		-4.05694
PYRITE	+		.17300
STRONITE			.00200
WITHERIT			.00100

MODEL 11

Microcln	+	F	.75726
ILLITE		F	-.25725
KAOLINIT	-	F	-.31181
SiO2	-	F	-1.77012
Biotite	+		.46004
CALCITE			.77496
FeOOH			-1.71756
EX-K-Na	+		.60462
FLUORAP			.00100
PYRITE	+		.17300
Siderite	+		1.23904
STRONITE			.00200
WITHERIT			.00100

MODEL 13

Microcln	+	F	1.26024
ILLITE		F	-1.03063
KAOLINIT	-	F	-4.66166
SiO2	-	F	-7.65454
Biotite	+		.62963
Ca-MONT			4.20854
FeOOH			-2.60596
EX-K-Na	+		.57847
FLUORAP			.00100
PYRITE	+		.17300
Siderite	+		2.01400
STRONITE			.00200
WITHERIT			.00100

MODEL 14

Microcln	+	F	.51169
ILLITE		F	-1.28883
KAOLINIT	-	F	-6.29689
SiO2	-	F	-8.57768
Biotite	+		.77053
Ca-MONT			6.12784
FeOOH			-2.69789
Ex-Ca-Na	+		.30870

FLUORAP		.00100
PYRITE	+	.17300
Siderite	+	2.01400
STRONITE		.00200
WITHERIT		.00100

MODEL 16

Microcln	+ F	.95652
ILLITE	F	-.05399
KAOLINIT	- F	-.48415
SiO2	- F	-2.00232
CALCITE		.87443
CHLORITE		.06897
CO2 GAS		1.13957
FeOOH		-.17391
EX-K-Na	+	.59426
FLUORAP		.00100
PYRITE	+	.17300
STRONITE		.00200
WITHERIT		.00100

MODEL 17

Microcln	+ F	.40000
ILLITE	F	.62033
KAOLINIT	- F	-.94805
SiO2	- F	-1.67106
CALCITE		.86720
CHLORITE		.03566
CO2 GAS		1.14680
EX-K-Na	+	.62320
FLUORAP		.00100
GOETHITE		-.17280
PYRITE	+	.17300
STRONITE		.00200
WITHERIT		.00100

MODEL 19

Microcln	+ F	.95652
ILLITE	F	-.05399
KAOLINIT	- F	-.25623
SiO2	- F	-1.77440
CALCITE		-.26513
CHLORITE		-.15894
FeOOH		-.17391
DOLOMITE	+	1.13957
EX-K-Na	+	.59426
FLUORAP		.00100
PYRITE	+	.17300
STRONITE		.00200
WITHERIT		.00100

MODEL 20

Microcln	+ F	.40000
ILLITE	F	.62033
KAOLINIT	- F	-.71869
SiO2	- F	-1.44170
CALCITE		-.27960
CHLORITE		-.19370
DOLOMITE	+	1.14680
EX-K-Na	+	.62320

FLUORAP		.00100
GOETHITE		-.17280
PYRITE	+	.17300
STRONITE		.00200
WITHERIT		.00100

MODEL 21

Microcln	+ F	.95652
ILLITE	F	-.05399
KAOLINIT	- F	-.41518
SiO2	- F	-1.93335
CALCITE		.52959
CO2 GAS		.79472
FeOOH		-.17391
DOLOMITE	+	.34484
EX-K-Na	+	.59426
FLUORAP		.00100
PYRITE	+	.17300
STRONITE		.00200
WITHERIT		.00100

MODEL 22

Microcln	+ F	.40000
ILLITE	F	.62033
KAOLINIT	- F	-.91238
SiO2	- F	-1.63540
CALCITE		.68888
CO2 GAS		.96848
DOLOMITE	+	.17832
EX-K-Na	+	.62320
FLUORAP		.00100
GOETHITE		-.17280
PYRITE	+	.17300
STRONITE		.00200
WITHERIT		.00100

MODEL 23

Microcln	+ F	.40000
ILLITE	F	1.33360
KAOLINIT	- F	-.22181
SiO2	- F	-.75354
CALCITE		.86720
CO2 GAS		1.14680
EX-K-Na	+	.62320
FLUORAP		.00100
GOETHITE		-.17280
K-MONT	-	-1.29685
PYRITE	+	.17300
STRONITE		.00200
WITHERIT		.00100

MODEL 24

Microcln	+ F	.40000
ILLITE	F	1.33360
KAOLINIT	- F	-.22181
SiO2	- F	-.75354
CALCITE		.86720
CO2 GAS		1.14680
EX-K-Na	+	1.05116
FLUORAP		.00100

GOETHITE			-.17280
Na-MONT	-		-1.29685
PYRITE	+		.17300
STRONITE			.00200
WITHERIT			.00100

MODEL 37

Microcln	+	F	.43547
ILLITE		F	.57735
KAOLINIT	-	F	-.88069
SiO2	-	F	-1.63998
CALCITE			.68875
FeOOH			-.59088
EX-K-Na	+		.62136
FLUORAP			.00100
GOETHITE			-.90724
PYRITE	+		.17300
Siderite	+		1.32525
STRONITE			.00200
WITHERIT			.00100

MODEL 38

Microcln	+	F	.34639
ILLITE		F	.68529
KAOLINIT	-	F	-.96028
SiO2	-	F	-1.56293
CALCITE			.76967
FeOOH			-1.41702
EX-K-Na	+		.62599
FLUORAP			.00100
MnO2			.01423
PYRITE	+		.17300
Siderite	+		1.24433
STRONITE			.00200
WITHERIT			.00100

MODEL 39

Microcln	+	F	.34639
ILLITE		F	.68529
KAOLINIT	-	F	-.96028
SiO2	-	F	-1.56293
CALCITE			.76967
FeOOH			-1.41702
EX-K-Na	+		.62599
FLUORAP			.00100
MnOOH			.01423
PYRITE	+		.17300
Siderite	+		1.24433
STRONITE			.00200
WITHERIT			.00100

MODEL 40

Microcln	+	F	.49918
ILLITE		F	.50016
KAOLINIT	-	F	-.82377
SiO2	-	F	-1.69509
CALCITE			.63088
EX-K-Na	+		.61804
FLUORAP			.00100
GOETHITE			-1.55612

MnO2		-.01018
PYRITE	+	.17300
Siderite	+	1.38312
STRONITE		.00200
WITHERIT		.00100

MODEL 41

Microcln	+ F	.49918
ILLITE	F	.50016
KAOLINIT	- F	-.82377
SiO2	- F	-1.69509
CALCITE		.63088
EX-K-Na	+	.61804
FLUORAP		.00100
GOETHITE		-1.55612
MnOOH		-.01018
PYRITE	+	.17300
Siderite	+	1.38312
STRONITE		.00200
WITHERIT		.00100

MODEL 42

Microcln	+ F	.95652
ILLITE	F	-.05399
KAOLINIT	- F	-6.58425
SiO2	- F	-9.01874
CHLORITE		.06897
CO2 GAS		2.01400
Ca-MONT		5.23614
FeOOH		-.17391
EX-K-Na	+	.59426
FLUORAP		.00100
PYRITE	+	.17300
STRONITE		.00200
WITHERIT		.00100

MODEL 44

Microcln	+ F	.95652
ILLITE	F	-1.04442
KAOLINIT	- F	-5.55419
SiO2	- F	-7.93917
CHLORITE		.17792
CO2 GAS		2.01400
Ca-MONT		5.23614
FeOOH		-.17391
Ex-Mg-Na	+	.29713
FLUORAP		.00100
PYRITE	+	.17300
STRONITE		.00200
WITHERIT		.00100

MODEL 45

Microcln	+ F	.40000
ILLITE	F	.62033
KAOLINIT	- F	-6.99768
SiO2	- F	-8.62943
CHLORITE		.03566
CO2 GAS		2.01400
Ca-MONT		5.19281
EX-K-Na	+	.62320

FLUORAP		.00100
GOETHITE		-.17280
PYRITE	+	.17300
STRONITE		.00200
WITHERIT		.00100

MODEL 46

Microcln	+ F	.40000
ILLITE	F	-.41833
KAOLINIT	- F	-8.02888
SiO2	- F	-9.93523
CHLORITE		.08760
CO2 GAS		2.01400
Ca-MONT		7.05868
Ex-Ca-Na	+	.31160
FLUORAP		.00100
GOETHITE		-.17280
PYRITE	+	.17300
STRONITE		.00200
WITHERIT		.00100

MODEL 47

Microcln	+ F	.40000
ILLITE	F	-.41833
KAOLINIT	- F	-5.91746
SiO2	- F	-7.49729
CHLORITE		.14992
CO2 GAS		2.01400
Ca-MONT		5.19281
Ex-Mg-Na	+	.31160
FLUORAP		.00100
GOETHITE		-.17280
PYRITE	+	.17300
STRONITE		.00200
WITHERIT		.00100

MODEL 48

Microcln	+ F	.95652
ILLITE	F	-.05399
KAOLINIT	- F	-.30926
SiO2	- F	-1.82743
CHLORITE		-.10592
CO2 GAS		.26513
FeOOH		-.17391
DOLOMITE	+	.87443
EX-K-Na	+	.59426
FLUORAP		.00100
PYRITE	+	.17300
STRONITE		.00200
WITHERIT		.00100

MODEL 49

Microcln	+ F	.40000
ILLITE	F	.62033
KAOLINIT	- F	-.77461
SiO2	- F	-1.49762
CHLORITE		-.13778
CO2 GAS		.27960
DOLOMITE	+	.86720
EX-K-Na	+	.62320

FLUORAP		.00100
GOETHITE		-.17280
PYRITE	+	.17300
STRONITE		.00200
WITHERIT		.00100

MODEL 50

Microcln	+ F	.95652
ILLITE	F	-1.04442
KAOLINIT	- F	-.34128
SiO2	- F	-1.98238
CHLORITE		-.08291
Ca-MONT		.98542
FeOOH		-.17391
DOLOMITE	+	1.00700
Ex-Ca-Na	+	.29713
FLUORAP		.00100
PYRITE	+	.17300
STRONITE		.00200
WITHERIT		.00100

MODEL 51

Microcln	+ F	4.60507
ILLITE	F	-4.47481
KAOLINIT	- F	-1.91966
SiO2	- F	-9.31006
CHLORITE		.22990
Ca-MONT		3.89207
FeOOH		-2.19521
EX-K-Na	+	.40454
FLUORAP		.00100
PYRITE	+	.17300
Siderite	+	2.01400
STRONITE		.00200
WITHERIT		.00100

MODEL 53

Microcln	+ F	4.60507
ILLITE	F	-5.14904
KAOLINIT	- F	-1.21846
SiO2	- F	-8.57515
CHLORITE		.30406
Ca-MONT		3.89207
FeOOH		-2.19521
Ex-Mg-Na	+	.20227
FLUORAP		.00100
PYRITE	+	.17300
Siderite	+	2.01400
STRONITE		.00200
WITHERIT		.00100

MODEL 54

Microcln	+ F	.40000
ILLITE	F	-.41833
KAOLINIT	- F	-.80260
SiO2	- F	-1.65371
CHLORITE		-.11380
Ca-MONT		1.02874
DOLOMITE	+	1.00700
Ex-Ca-Na	+	.31160

FLUORAP			.00100
GOETHITE			-.17280
PYRITE	+		.17300
STRONITE			.00200
WITHERIT			.00100

MODEL 55

Microcln	+	F	.40000
ILLITE		F	.15433
KAOLINIT	-	F	-.23405
SiO2	-	F	-.93376
CHLORITE			-.14244
DOLOMITE	+		1.00700
EX-K-Na	+		.34360
Ex-Ca-Na	+		.13980
FLUORAP			.00100
GOETHITE			-.17280
PYRITE	+		.17300
STRONITE			.00200
WITHERIT			.00100

MODEL 56

Microcln	+	F	.95652
ILLITE		F	-.05399
KAOLINIT	-	F	-4.10963
SiO2	-	F	-6.18276
CO2 GAS			1.32431
Ca-MONT			3.17120
FeOOH			-.17391
DOLOMITE	+		.34484
EX-K-Na	+		.59426
FLUORAP			.00100
PYRITE	+		.17300
STRONITE			.00200
WITHERIT			.00100

MODEL 57

Microcln	+	F	.95652
ILLITE		F	-1.04442
KAOLINIT	-	F	-3.31609
SiO2	-	F	-5.39160
CO2 GAS			.82909
Ca-MONT			3.46774
FeOOH			-.17391
DOLOMITE	+		.59245
Ex-Ca-Na	+		.29713
FLUORAP			.00100
PYRITE	+		.17300
STRONITE			.00200
WITHERIT			.00100

MODEL 58

Microcln	+	F	.95652
ILLITE		F	1.32539
KAOLINIT	-	F	-5.17979
SiO2	-	F	-7.24436
CO2 GAS			2.01400
Ca-MONT			5.23614
FeOOH			-.17391
EX-K-Na	+		.59426

FLUORAP			.00100
K-MONT	-		-2.50796
PYRITE	+		.17300
STRONITE			.00200
WITHERIT			.00100

MODEL 59

Microcln	+	F	.95652
ILLITE		F	1.32539
KAOLINIT	-	F	-5.17979
SiO2	-	F	-7.24436
CO2 GAS			2.01400
Ca-MONT			5.23614
FeOOH			-.17391
EX-K-Na	+		1.42189
FLUORAP			.00100
Na-MONT	-		-2.50796
PYRITE	+		.17300
STRONITE			.00200
WITHERIT			.00100

MODEL 60

Microcln	+	F	.95652
ILLITE		F	1.32539
KAOLINIT	-	F	-5.15466
SiO2	-	F	-7.21546
CO2 GAS			2.01400
Ca-MONT			7.01536
FeOOH			-.17391
Ex-Ca-Na	+		.29713
FLUORAP			.00100
K-MONT	-		-4.30875
PYRITE	+		.17300
STRONITE			.00200
WITHERIT			.00100

MODEL 61

Microcln	+	F	.95652
ILLITE		F	2.51391
KAOLINIT	-	F	-1.93116
SiO2	-	F	-3.36185
CO2 GAS			2.01400
Ca-MONT			5.23614
FeOOH			-.17391
Ex-Mg-Na	+		.29713
FLUORAP			.00100
K-MONT	-		-6.46970
PYRITE	+		.17300
STRONITE			.00200
WITHERIT			.00100

MODEL 62

Microcln	+	F	.40000
ILLITE		F	.62033
KAOLINIT	-	F	-5.71807
SiO2	-	F	-7.16297
CO2 GAS			1.65737
Ca-MONT			4.12505
DOLOMITE	+		.17832
EX-K-Na	+		.62320

FLUORAP			.00100
GOETHITE			-.17280
PYRITE	+		.17300
STRONITE			.00200
WITHERIT			.00100

MODEL 63

Microcln	+	F	.40000
ILLITE		F	-.41833
KAOLINIT	-	F	-4.88589
SiO2	-	F	-6.33328
CO2 GAS			1.13803
Ca-MONT			4.43603
DOLOMITE	+		.43798
Ex-Ca-Na	+		.31160
FLUORAP			.00100
GOETHITE			-.17280
PYRITE	+		.17300
STRONITE			.00200
WITHERIT			.00100

MODEL 64

Microcln	+	F	.40000
ILLITE		F	-.41833
KAOLINIT	-	F	-.53842
SiO2	-	F	-1.33275
CO2 GAS			.51483
Ca-MONT			.70429
DOLOMITE	+		.74958
Ex-Mg-Na	+		.31160
FLUORAP			.00100
GOETHITE			-.17280
PYRITE	+		.17300
STRONITE			.00200
WITHERIT			.00100

MODEL 65

Microcln	+	F	.40000
ILLITE		F	1.33360
KAOLINIT	-	F	-6.27144
SiO2	-	F	-7.71191
CO2 GAS			2.01400
Ca-MONT			5.19281
EX-K-Na	+		.62320
FLUORAP			.00100
GOETHITE			-.17280
K-MONT	-		-1.29685
PYRITE	+		.17300
STRONITE			.00200
WITHERIT			.00100

MODEL 66

Microcln	+	F	.40000
ILLITE		F	1.33360
KAOLINIT	-	F	-6.27144
SiO2	-	F	-7.71191
CO2 GAS			2.01400
Ca-MONT			5.19281
EX-K-Na	+		1.05116
FLUORAP			.00100

GOETHITE			-.17280
Na-MONT	-		-1.29685
PYRITE	+		.17300
STRONITE			.00200
WITHERIT			.00100

MODEL 67

Microcln	+	F	.40000
ILLITE		F	1.33360
KAOLINIT	-	F	-6.24509
SiO2	-	F	-7.68161
CO2 GAS			2.01400
Ca-MONT			7.05868
Ex-Ca-Na	+		.31160
FLUORAP			.00100
GOETHITE			-.17280
K-MONT	-		-3.18533
PYRITE	+		.17300
STRONITE			.00200
WITHERIT			.00100

MODEL 68

Microcln	+	F	.40000
ILLITE		F	2.58000
KAOLINIT	-	F	-2.86461
SiO2	-	F	-3.64034
CO2 GAS			2.01400
Ca-MONT			5.19281
Ex-Mg-Na	+		.31160
FLUORAP			.00100
GOETHITE			-.17280
K-MONT	-		-5.45152
PYRITE	+		.17300
STRONITE			.00200
WITHERIT			.00100

MODEL 71

Microcln	+	F	2.29008
ILLITE		F	-1.66981
KAOLINIT	-	F	-.29427
SiO2	-	F	-3.87061
Ca-MONT			.91889
FeOOH			-.91270
DOLOMITE	+		.63894
EX-K-Na	+		.52492
FLUORAP			.00100
PYRITE	+		.17300
Siderite	+		.73612
STRONITE			.00200
WITHERIT			.00100

MODEL 72

Microcln	+	F	.95652
ILLITE		F	-2.70261
KAOLINIT	-	F	-.00965
SiO2	-	F	-.07546
Ca-MONT			.98542
FeOOH			-.17391
DOLOMITE	+		1.00700
Ex-Ca-Na	+		.29713

FLUORAP			.00100
K-MICA	+		.99491
PYRITE	+		.17300
STRONITE			.00200
WITHERIT			.00100

MODEL 73

Microcln	+	F	.95652
ILLITE		F	-1.04442
KAOLINIT	-	F	-1.55675
SiO2	-	F	-1.65819
Ca-MONT			2.84716
FeOOH			-.17391
DOLOMITE	+		1.00700
Ex-Ca-Na	+		.40077
FLUORAP			.00100
Montmor	-		-2.07274
PYRITE	+		.17300
STRONITE			.00200
WITHERIT			.00100

MODEL 74

Microcln	+	F	1.82950
ILLITE		F	-2.02652
KAOLINIT	-	F	-.87909
SiO2	-	F	-3.93845
Ca-MONT			1.97068
FeOOH			-.65754
DOLOMITE	+		.76606
Ex-Ca-Na	+		.27443
FLUORAP			.00100
PYRITE	+		.17300
Siderite	+		.48188
STRONITE			.00200
WITHERIT			.00100

MODEL 75

Microcln	+	F	.76361
ILLITE		F	.17975
KAOLINIT	-	F	-4.77341
SiO2	-	F	-6.62284
Ca-MONT			3.59304
FeOOH			-.99475
EX-K-Na	+		.60429
FLUORAP			.00100
GOETHITE			-1.19277
PYRITE	+		.17300
Siderite	+		2.01400
STRONITE			.00200
WITHERIT			.00100

MODEL 76

Microcln	+	F	.69463
ILLITE		F	.26334
KAOLINIT	-	F	-5.50640
SiO2	-	F	-7.31684
Ca-MONT			4.16931
FeOOH			-2.18739
EX-K-Na	+		.60788
FLUORAP			.00100

MnO2			.01943
PYRITE	+		.17300
Siderite	+		2.01400
STRONITE			.00200
WITHERIT			.00100

MODEL 77

Microcln	+	F	.69463
ILLITE		F	.26334
KAOLINIT	-	F	-5.50640
SiO2	-	F	-7.31684
Ca-MONT			4.16931
FeOOH			-2.18739
EX-K-Na	+		.60788
FLUORAP			.00100
MnOOH			.01943
PYRITE	+		.17300
Siderite	+		2.01400
STRONITE			.00200
WITHERIT			.00100

MODEL 78

Microcln	+	F	.40000
ILLITE		F	-.41833
KAOLINIT	-	F	-2.47098
SiO2	-	F	-1.20872
Ca-MONT			3.58421
DOLOMITE	+		1.00700
Ex-Ca-Na	+		.45385
FLUORAP			.00100
GOETHITE			-.17280
Montmor	-		-2.84508
PYRITE	+		.17300
STRONITE			.00200
WITHERIT			.00100

MODEL 79

Microcln	+	F	.82115
ILLITE		F	.11004
KAOLINIT	-	F	-4.16203
SiO2	-	F	-6.04398
Ca-MONT			3.11237
EX-K-Na	+		.60130
FLUORAP			.00100
GOETHITE			-2.18764
MnO2			-.01620
PYRITE	+		.17300
Siderite	+		2.01400
STRONITE			.00200
WITHERIT			.00100

MODEL 80

Microcln	+	F	.82115
ILLITE		F	.11004
KAOLINIT	-	F	-4.16203
SiO2	-	F	-6.04398
Ca-MONT			3.11237
EX-K-Na	+		.60130
FLUORAP			.00100
GOETHITE			-2.18764

MnOOH			-.01620
PYRITE	+		.17300
Siderite	+		2.01400
STRONITE			.00200
WITHERIT			.00100

MODEL 81

Microcln	+	F	1.19371
ILLITE		F	-.34137
KAOLINIT	-	F	-.20327
SiO2	-	F	-2.29582
FeOOH			6.44119
EX-K-Na	+		.58193
FLUORAP			.00100
GOETHITE			-8.62958
MnO2			-.12113
PYRITE	+		.17300
Siderite	+		2.01400
STRONITE			.00200
WITHERIT			.00100

MODEL 82

Microcln	+	F	1.19371
ILLITE		F	-.34137
KAOLINIT	-	F	-.20327
SiO2	-	F	-2.29582
FeOOH			6.44119
EX-K-Na	+		.58193
FLUORAP			.00100
GOETHITE			-8.62958
MnOOH			-.12113
PYRITE	+		.17300
Siderite	+		2.01400
STRONITE			.00200
WITHERIT			.00100

2042975 models were tested.
82 models were found which satisfied the constraints.

Models requiring more than 10 mmol dissolution or precipitation were eliminated from consideration as viable models.

Sitewide Geoscience Characterization Study

Groundwater Geochemistry Report

Groundwater Contamination at Superfund Sites

June 23, 1994

EG&G Rocky Flats, Inc.
Rocky Flats Site
P.O. Box 464
Golden, Colorado 80402

EG&G ROCKY FLATS

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1. GROUNDWATER CONTAMINATION AT SUPERFUND SITES ALONG THE COLORADO FRONT RANGE

A number of uncontrolled hazardous waste sites subject to the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) as amended by the Superfund Amendments and Re-authorization Act (SARA) are located in the State of Colorado. The U.S. Environmental Protection Agency (EPA) has the responsibility to weigh the need to protect human health and the environment at these sites. The EPA's hazard ranking system identifies those sites that pose the most serious threat to health, welfare, or the environment. These sites are placed on the National Priority List (NPL) by EPA.

Eighteen NPL sites are found in Colorado (Table 1); eleven of these, including the Rocky Flats site, are located along the Colorado Front Range (Figure 1). These sites have been, or are currently, under investigation to determine the nature and extent of contamination, describe the fate and transport of contaminants originating from the sites, and determine appropriate remedial actions necessary to protect human health and the environment.

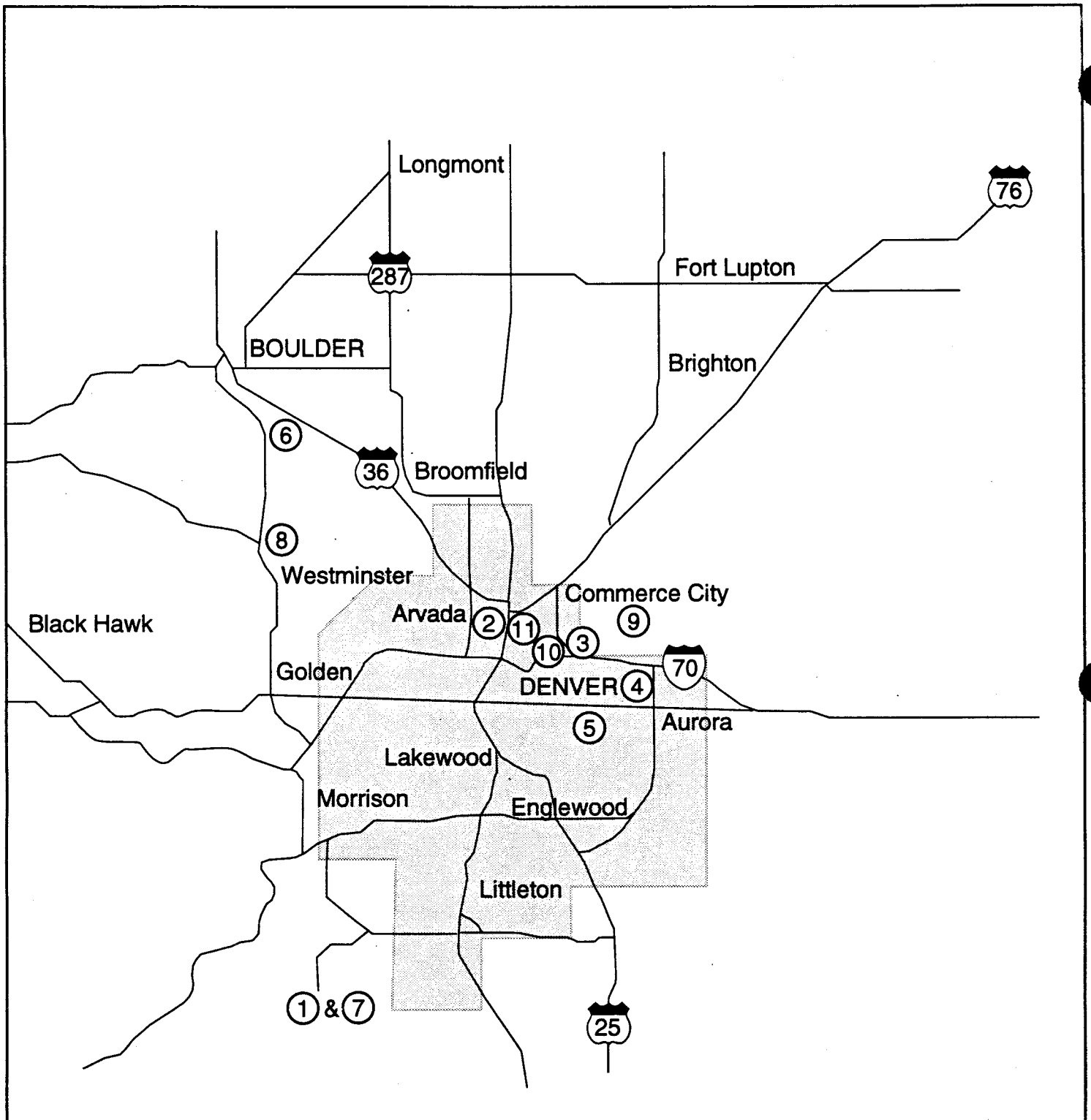
Ten NPL sites, not including Rocky Flats, are described below. Specifically addressed are the impacts to groundwater on and off the sites, the types of contaminants identified in groundwater, the monitoring programs currently in place, and selected remedies for groundwater contamination. Each description includes summaries of the site's history, past and current use, and geographic and physical setting and descriptions of contaminant sources, nature and extent of contamination, contaminant concentrations in groundwater, and existing or planned monitoring programs and remedial actions.

The following summaries of site information were obtained primarily from records of decisions (Rods) prepared by the EPA. At some of the sites, the ROD has not yet been prepared and the summary was compiled from other sources of information such as remedial investigation (RI) reports. A comprehensive reference list is provided at the end of this chapter.

References used to compile this summary are located at the EPA Superfund Records Center, except those listed for the Rocky Mountain Arsenal and the Air Force Plant PJKS sites. Rocky Mountain Arsenal references are housed at the Joint Administrative

Table 1
EPA National Priority List Sites: Colorado

Site Name	County	Front Range Sites Included in Report
Air Force Plant PJKS	Jefferson	X
Broderick Wood	Adams	X
California Gulch	Lake	
Central City-Clear Creek	Clear Creek/Gilpin	
Chemical Sales	Adams/Denver	X
Denver Radium	Denver	X
Eagle Mine	Eagle	
Lincoln Park	Fremont	
Lowry Landfill	Arapahoe	X
Marshall Landfill	Boulder	X
Martin Marietta	Jefferson	X
Rocky Flats Plant	Jefferson	
Rocky Mountain Arsenal	Adams	X
Sand Creek Industrial	Adams	X
Smeltertown	Chaffee	
Smuggler Mountain	Pitkin	
Uravan Uranium	Montrose	
Woodbury Chemical	Adams	X



Scale 1:500,000

10 Miles

10 KM

N

Shaded area: densely populated areas

Key

1. Air Force Plant PJKS
2. Broderick Wood
3. Chemical Sales
4. Denver Radium
5. Lowry Landfill
6. Marshall Landfill
7. Martin Marietta
8. Rocky Flats Plant
9. Rocky Mountain Arsenal
10. Sand Creek Industrial
11. Woodbury Chemical

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Superfund Site Location Map

June 1994 Draft

Figure 1

M\ES\DENVER MAP.ill\5-12-94

Record and Document Facility located at the west gate of Rocky Mountain Arsenal. U.S. Air Force PJKS Property reports are located at the Columbine Library in Jefferson County.

1.1 Lowry Landfill

The Lowry Landfill Superfund Site (the Lowry Site) is located in unincorporated Arapahoe County, Colorado, approximately 15 miles southeast of the City and County of Denver and 2 miles east of the City of Aurora. The Lowry Site covers 480 acres and is a portion of the Denver Arapahoe Disposal Site owned by the City and County of Denver (Denver) and operated by Waste Management of Colorado, Inc.

1.1.1 Site History and Land Use

From 1966 until 1990, Denver operated a municipal solid-waste landfill. The materials accepted prior to 1980 included solid municipal refuse and industrial wastes containing hazardous substances, such as volatile organic compounds and heavy metals, listed pursuant to 40 CFR Section 302.4. At the same time, approximately 138 million gallons of liquid waste were disposed of at the Lowry Site by co-disposal with solid wastes. These wastes were disposed of in unlined waste pits or trenches topped with municipal refuse. In addition, land application of wastewater sludge began at the site in 1969 and continued into 1986. The sludge and leachate collected from the landfill were applied to the ground surface and incorporated in native soils over a 160-acre area. Municipal solid-waste disposal activities continued from 1980 through August 1990. In 1990, a 4-foot-thick soil cover was completed over the closed landfill. The primary sources of groundwater contamination at the Lowry Site have been identified as the waste pits and landfill solids within and underneath the landfill mass.

Current zoning and land uses by Arapahoe County in the vicinity of the Lowry Site are primarily agricultural and mixed use (industrial, commercial, and residential). Much of the area surrounding the Lowry Site is undeveloped and used primarily for cattle ranching and grazing. Residential areas are located approximately 1 mile south, and two miles north and west of the site. No residences are located onsite. The City of Aurora anticipates future mixed land use for the area surrounding the Lowry Site.

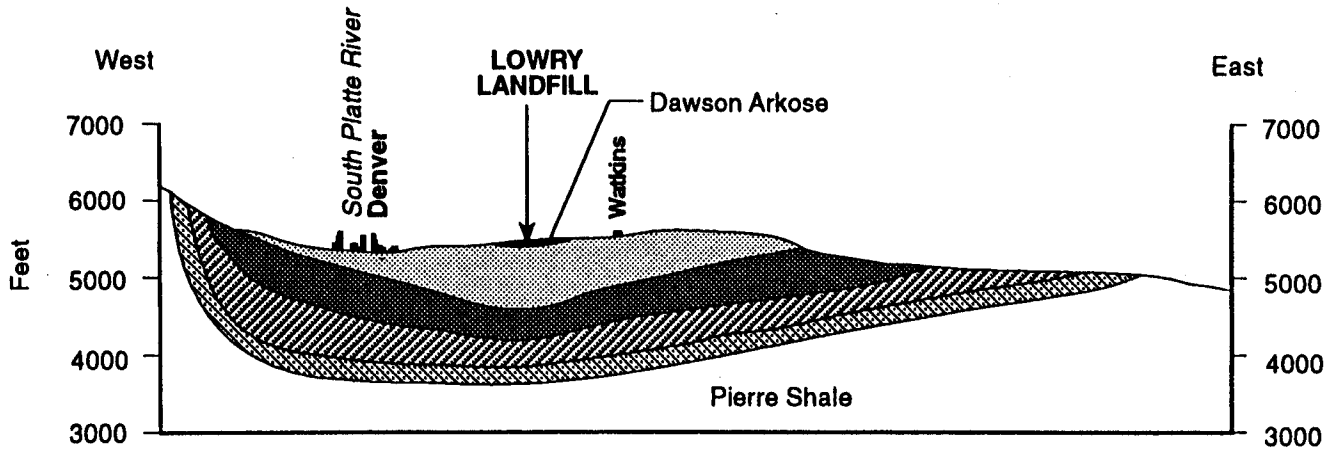
1.1.2 Physical Setting

The Lowry Site is located within the Murphy Creek drainage system, which covers approximately 7,800 acres. An unnamed creek and its tributaries and Murphy Creek and its tributaries to the east and north are included in this system. These streams generally flow north, although flow is ephemeral, usually in response to storm events or snowmelt.

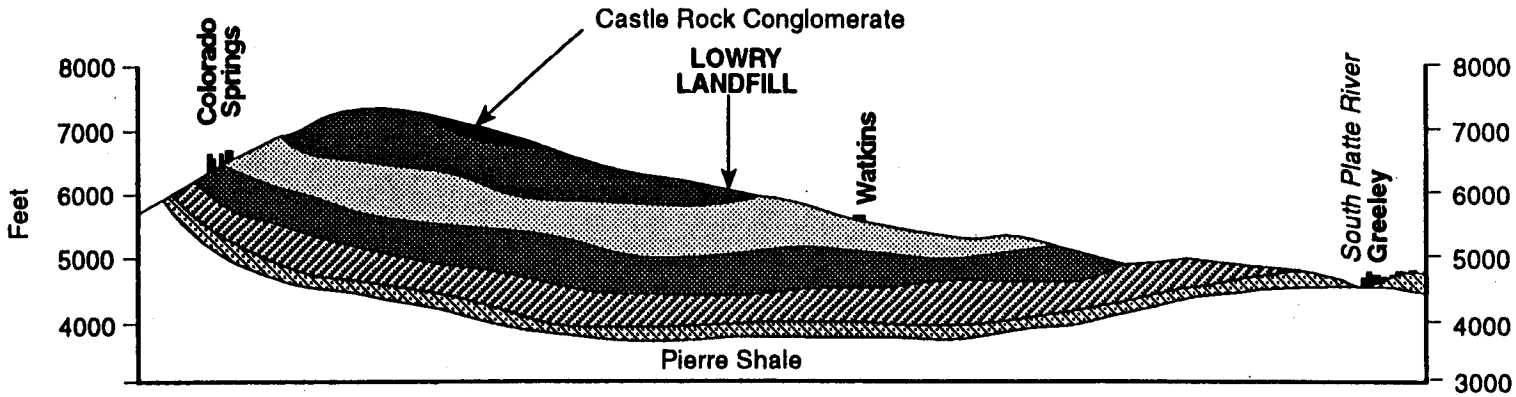
The site is underlain by surficial deposits of soil, colluvium, and alluvium that overlie the Dawson Formation (Figure 2). Approximately 200 to 300 feet of the Lower Dawson Formation are present at the site. The Dawson Formation generally consists of arkosic conglomerates and sandstones interbedded with lesser amounts of siltstones, shales, and local lignitic coal beds. The late Cretaceous and Paleocene Denver Formation unconformably underlies the Dawson Formation and consists of approximately 600 to 1,500 feet of interbedded claystones, siltstones, fine-grained sandstones, minor conglomerates, and lignites.

There are two major groundwater systems at the Lowry site: shallow groundwater (Operable Unit [OU] 1) and deep groundwater (OU 6). The division of the two systems is based on the presence of a low-permeability separation layer within the lower part of the Lower Dawson Formation. The shallow groundwater system includes all groundwater contained within alluvial deposits and groundwater in the Dawson Aquifer (i.e., the weathered portions of the Dawson Formation above and including the separation layer). Groundwater flow in the shallow groundwater system occurs within the weathered and unweathered Dawson Formation, the overlying alluvial deposits, the refuse, and waste-pit solids. The predominant groundwater flow direction in the shallow groundwater system is toward the north.

The deep groundwater system consists of all groundwater in the unweathered bedrock below the separation layer. Deep groundwater is defined as the water-bearing zones below the Dawson Aquifer. These strata include the lower portion of the Dawson Formation beneath the Lowry Site and the underlying formations extending vertically through the Arapahoe Aquifer to the base of the Laramie-Fox Hills Aquifer. Groundwater flow within the deep groundwater system is predominantly horizontal and to the north. A less significant vertical hydraulic gradient is present within and between aquifers; the vertical flow is predominantly downward.



West-East Geologic Section



South-North Geologic Section

0 5 10 15 20 Miles

The locations shown are approximate.

LEGEND:

- Dawson Formation
- Denver Formation
- Arapahoe Formation
- Laramie Formation
- Fox Hills Sandstone

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Figure 2
CROSS-SECTION THROUGH THE DENVER BASIN
from Lowry Landfill Record of Decision (EPA, 1994)

June 1994 Draft | Figure 2

1.1.3 Nature and Extent of Contamination

Preliminary site investigations at the Lowry Site began in the mid-1970s. Various parties (U.S. Geological Survey, EPA, Colorado Department of Health [CDH], the City of Denver, and Waste Management of Colorado, Inc.) performed site studies prior to EPA's listing the Lowry Site on the NPL in 1984. These investigations included installation of groundwater monitoring wells, surface water and sediment sampling, air studies, soil gas monitoring, and surface geophysical surveys.

The first phase of the CERCLA RI was conducted by EPA. The findings of the Phase I investigations are described in the RI report dated September 1986 (CH2M Hill, 1986a). The second phase of the RI also was conducted by EPA, and involved remedial planning, preliminary assessment of data and risks, and an extensive sampling program. EPA issued a series of technical memoranda that documented Phase II of the RI (CH2M Hill, 1988).

In 1988, EPA divided the Lowry Site into six OUs or study areas. These were grouped according to the contaminated media they address: OU 1, Shallow Groundwater and Subsurface Liquids; OU 2, Landfill Solids; OU 3, Landfill Gas; OU 4, Soils; OU 5, Surface Water and Sediments; and OU 6, Deep Groundwater. In accordance with the requirements of CERCLA, as amended by SARA, EPA provided the potentially responsible parties with the opportunity to perform the OU RI/FSs at the site. OUs 1 and 6 were studied together to facilitate effective implementation of the RI/feasibility study (FS) activities for groundwater.

A variety of contaminants—including organic chemicals, trace metals, and radionuclides—have been detected in the shallow groundwater directly beneath the Lowry Site. Groundwater contamination was identified on the basis of comparisons with upgradient groundwater quality. The concentrations of naturally occurring chemicals, or anthropogentic chemicals not related to waste disposal activities at the Lowry Site, were determined through evaluation of upgradient water quality and review and evaluation of regional water-quality data. Review of the regional water-quality data included an evaluation of descriptions of water quality in regional aquifers, groundwater data from the U.S. Geological Survey, water-quality data from the East Cherry Creek Valley Water and Sanitation District, data from residential wells, EPA data on ambient radionuclide concentrations in groundwater, U.S. Department of Energy (DOE) data describing background concentrations of radionuclides at the

Rocky Flats site, and background radionuclide concentrations measured at the Fort St. Vrain Nuclear Generating Facility in northern Colorado. Using data from these sources, an upper tolerance limit was calculated for inorganic parameters in shallow groundwater at the Lowry site. The ranges of inorganic concentrations in deeper groundwater from the Denver Formation and ranges of radionuclide activities in groundwater from the Front Range region were described. However, the use of regional data to represent upgradient water quality for Lowry Landfill was not recommended, and the data from Lowry upgradient wells were used to represent upgradient water quality (EPA, 1992a and 1994a).

The waste pits and associated liquids contain the highest average concentrations of nonhalogenated volatile organic compounds (VOCs) and semivolatile organic compounds (SVOCs), metals, and radionuclides compared to other groundwaters at the Lowry Site. Based on Resource Conservation and Recovery Act (RCRA) toxicity characteristic testing (toxicity characteristic leaching procedure), the waste-pit solids and liquids are hazardous materials. Immiscible phase liquids, including light nonaqueous phase liquids (LNAPLs) and dense nonaqueous phase liquids (DNAPLs), have been identified in 10 of approximately 70 waste pits. The presence of NAPL is based, in part, on the theoretical aqueous solubilities of compounds present in the liquid (HLA 1992a). NAPL samples collected from three locations were oversaturated with SVOCs and/or VOCs. Many VOCs and some SVOCs were also found present at 10 to 100 percent of the theoretical aqueous solubility limit in samples from these three locations. The extent of mobile-phase NAPL contamination coincides with the horizontal extent of the waste pits and the vertical extent of the weathered system.

VOCs, SVOCs, metals, and radionuclides were also found in liquid from saturated refuse and in shallow groundwater but at lower concentrations than in the waste-pit liquids. VOCs were the most prevalent organic compounds present in the groundwater from the weathered system. The SVOCs, pesticides/polychlorinated biphenyls (PCBs), and additional organic compounds were also present in the weathered system inside the boundaries of the source area. The horizontal extent of contamination coincides with the boundaries of the weathered Dawson Formation within the source area. The vertical extent of contamination extends to the base of the weathered system throughout the source area. The base of the weathered Dawson Formation is estimated to be 30 to 50 feet below the ground surface.

Groundwater in the Dawson Aquifer (weathered system and unweathered Dawson Formation) outside of the source area also contains VOCs, SVOCs, radionuclides, and trace metals. Maximum concentrations of contaminants outside of the source areas were detected in groundwater collected near the toe of the landfill mass and near the existing barrier wall.

The deep groundwater system consists of the water-bearing zones beneath the Dawson Aquifer, including the upper and lower Denver aquifers. To elevate possible impacts to this deep system, several deep monitoring wells were installed at the Lowry Site. Contaminants identified within the deep groundwater monitoring wells include organics, dissolved NAPL compounds, radionuclides, and trace metals. However, the extent of contamination in the deep groundwater is limited; the average concentration of organics in deep groundwater is substantially lower than the average concentrations of organics in shallow groundwater.

The estimated total areal extent of contamination is based on data from existing monitoring wells; certain portions of the Lowry Site lack sufficient numbers of wells for an exact determination of the horizontal and vertical extent of contamination. The extent of contamination in the poorly characterized areas of the site will be further refined during the remedial design phase. The total volume of potentially contaminated groundwater at the Lowry Site was estimated as follows: 900 million to 2 billion gallons of shallow groundwater, 93 million to 1.2 billion gallons of deep groundwater, 14 million gallons of liquid in saturated refuse, and 95 million gallons of liquid in saturated waste pits (EPA, 1994a).

The baseline risk assessment (EPA, 1992a) identified 46 contaminants of concern (COCs) in groundwater at the Lowry Site. The COCs include VOCs, SVOCs, pesticides/PCBs, and metals (Table 2). There are several residential wells approximately 2 miles downgradient of the Lowry Site that have been investigated for possible contamination from the groundwater. To date, there has been no evidence of contamination in these wells.

1.1.4 Groundwater Monitoring and Remedial Actions

In 1984, an interim remedial measure (consisting of a groundwater control and treatment system, referred to as the barrier wall, and a groundwater treatment plant) was planned to minimize offsite migration of contaminated shallow groundwater.

Table 2
Lowry Landfill
Minimum/Maximum Concentrations of Contaminants of Concern

Chemical	OUs 1 & 6 Subsurface Liquids (µg/L)	
	Minimum	Maximum
Organics		
1,1-Dichloroethane	2	1,100,000
1,1-Dichloroethene	0.8	14,000
1,2-Dichloroethane	3	1,800,000
1,2-Dichloroethene	1	160,000
1,1,2-Trichloroethane	3	100
1,2,4-Trichlorobenzene	8.5	1,700
1,1,2,2-Tetrachloroethane	66	66
2,4-Dichlorophenol	22	160
2,4-Dinitrophenol	500	500
2,3,7,8-TCDD	$5x10^{-6}$	$1.1x10^{-3}$
2-Butanone (MEK)	17	230,000
2-Chlorophenol	8	8
2-Hexanone	49	270
2-Methylnaphthalene	3	44,000
4-Chloroaniline		
4-Methyl-2-pentanone	4	960,000
Acetone	4	3,000,000
Benzene	1	970,000
Benzo(a)anthracene	84	84
Benzyl alcohol	7.2	1,900
bis(2-Chloroethyl)ether	3	3
bis(2-Ethylhexyl)phthalate	1	22,000
Carbazole	7	12
Carbon tetrachloride	15	26,000
Chloroethane	2	260
Chloroform	0.6	56,000
Di-n-octylphthalate	5.7	1,200

Chemical	OUs 1 & 6 Subsurface Liquids (µg/L)	
	Minimum	Maximum
Organics (continued)		
Dibenzofuran	2.0×10^{-6}	1.4×10^{-3}
Ethylene dibromide	0.12	0.28
Fluoranthene	26	200
Methylene chloride	3	440,000
Napththalene	2.0	110,000
Pentachlorophenol	4	4,100
Phenanthrene	4.2	1,700
Tetrachloroethylene	0.9	340,000
Toluene	0.9	11,000,000
trans-1,3-Dichloropropane	2.2	3.0
Trichloroethylene	4	7,700,000
Vinyl chloride	2.6	1,800
Inorganics (Total Metals)		
Arsenic	2.2	1,600
Chromium (total)	0.71	1,700
Cobalt	5.4	330
Lead	1	510
Manganese	180	70,000
Nickel	13	2,000
Thallium	0.34	760

Notes: MEK = Methyl Ethyl Ketone

Reference: EPA Record of Decision (EPA, 1994a)

Construction of the IRM was completed in 1992, and the facilities are currently operating. The groundwater barrier-wall system consists of a 30-foot-deep, 1,000-foot-long, compacted clay wall with a central collection sump. The base of the barrier wall is anchored to the top of the unweathered bedrock (Dawson Formation). Contaminated groundwater is collected at the barrier and pumped to a groundwater treatment plant.

Six remedial alternatives for groundwater were evaluated during the FS (HLA, 1992b). One of the features common to all of the remedial alternatives is performance and compliance monitoring. The purpose of the monitoring program will be to assess compliance with the remediation levels established for the groundwater system, monitor chemical concentrations in the treated effluent, evaluate horizontal and vertical migration of contamination, monitor soil and sediment erosion, and monitor migration of landfill gases. The FS estimated that approximately 60 to 100 monitoring wells will need to be sampled semi-annually. The groundwater monitoring component of the selected sitewide remedy includes an early-warning component; this will allow for timely remedial response if additional remedial actions are necessary.

The EPA's preferred alternative (EPA, 1994a) includes provisions addressing the containment, collection, and diversion of groundwater. Shallow groundwater would be contained and treated onsite. Approximately 6.3 million gallons of groundwater would be intercepted on an annual basis. The restoration time frame would be greater than 30 years, and because waste would be left in place, treatment would continue in perpetuity.

1.2 Rocky Mountain Arsenal

The Rocky Mountain Arsenal (RMA) site covers approximately 27 square miles in southern Adams County, Colorado. The arsenal was established in 1942 and was used by both government and industry to manufacture, test, package, and dispose of various chemical products, chemical warfare agents, and munitions including rocket fuels, herbicides, pesticides, mustard and nerve gases, and incendiary munitions.

1.2.2 Site History and Land Use

Industrial effluents generated at the RMA were routinely discharged to asphalt-lined and unlined evaporation basins. Solid wastes were buried at various locations. Spills of raw materials and final products occurred within the manufacturing complexes. All production operations at the site ceased in 1982, and investigations by the U.S. Army

have identified at least 178 on-post areas as being potentially contaminated with hazardous wastes.

The RMA was added to the NPL in 1987 and is subject to compliance with CERCLA. The U.S. Army and Shell Oil Company were identified as potentially responsible parties (PRPs) and are funding the cleanup. The site comprises two OUs: On-Post and Off-Post. The On-Post OU addresses media requiring remediation within the RMA boundaries, whereas the Off-Post OU addresses media requiring remediation outside the RMA boundaries. Three boundary containment systems currently intercept, treat, and recharge groundwater at the north, northwest, and west boundaries of the RMA. The containment systems are located along the physical boundary of the RMA and provide the delineation between OUs.

The Off-Post OU encompasses rural residential, agricultural, commercial, and industrial areas located north and northwest of RMA where contaminants from RMA are present in environmental media. The South Adams County Water and Sanitation District (SACWSD) has historically maintained and operated municipal wells within the area of the Off-Post OU that supplied water for businesses and residents in the district. A ROD was signed in 1987, implementing the construction of the Klein Water Treatment Plant, which began operating in 1989 as a permanent water-treatment system of the SACWSD.

1.2.2 Physical Setting

The RMA lies within the Denver Basin and is underlain by approximately 10 to 100 feet of eolian deposits and unconsolidated alluvium which overlie interbedded sedimentary rocks of the Denver Formation. The thickest deposits of unconsolidated materials occur in paleochannels eroded into the underlying Denver Formation. The Denver Formation consists of 250 to 300 feet of shale, claystone, siltstone, and sandstone. At the north end of the RMA, the Arapahoe Formation lies beneath the Denver Formation at a depth of 250 to 300 feet below ground surface.

The two main water-bearing units are the unconsolidated alluvial deposits and the underlying Denver Formation (refer to Figure 2). The hydraulic properties of these two units—including the hydraulic conductivity—are distinctly different, and the two units behave as two distinct hydrostratigraphic units; the unconfined flow system (alluvial

deposits and weathered portions of the Denver and Arapahoe Formations) and the confined flow system (deeper Denver and Arapahoe Formations).

The unconfined flow system is considered the principal route for migration of groundwater contaminants from the RMA to off-post areas. Paleochannels on the top surface of the bedrock direct groundwater flow in the unconsolidated sediments, because coarse, unconsolidated alluvial deposits fill these paleochannels and provide preferential pathways for groundwater flow. Groundwater contaminant plumes that have migrated from the RMA to the Off-Post OU are generally confined to these paleochannels. Three such paleochannels—the First Creek, the northern, and the northwestern paleochannels—are present in the off-post study area.

1.2.3 Nature and Extent of Contamination

In 1974, diisopropylmethyl phosphate (DIMP) and dicyclopentadiene (DCPD) were detected in surface water at the northern boundary of RMA. As a result, the Army initiated a program to investigate contamination and perform source-control actions. The primary result of this program was the installation of the three separate groundwater containment and treatment systems to intercept contaminated groundwater plumes flowing off post. These three systems—the Irondale Containment System, Northwest Boundary Containment System, and North Boundary Containment System—are still operating. Other interim response actions (IRAs) were implemented as source-control measures. An On-Post RI was initiated in 1984 to determine the nature and extent of water contamination. The RI identified contamination plumes emanating from suspected source areas and migrating predominantly north and northwest (Ebasco, 1989a).

Sources of groundwater contamination included lined and unlined basins, pits, burn sites, sewers, and structures (buildings, pipes, and tanks). A total of 15 contaminant plumes were identified in groundwater and evaluated as the result of an extensive review of chemical data collected from 1989 to 1991 (Ebasco, 1992). These plumes were assembled into five plume groups based on similar chemical compositions and downgradient coalescence (North Boundary Plume Group, Northwest Boundary Plume Group, Western Plume Group, South Plants Plume Group, and Basin A Plume Group).

On-post groundwater contamination exists primarily within the unconfined flow system. Contamination of groundwater in the confined portions of the Denver

Formation has not been confirmed, except near the source of the South Plants North Plume. Overall the South Plants Plume Group has the highest concentrations of organic analytes of any plume at RMA, and a portion of the plume contains LNAPL. On-Post plume contaminants are listed in Table 3.

Contaminants originating at the RMA migrated to the Off-Post study area primarily by transport in shallow groundwater. The Off-Post OU RI was completed in 1986. The RI results consistently indicated widespread contamination of groundwater by chlorinated volatile organic compounds. The most widespread RMA-related contaminant in the Off-Post study area is DIMP. The other primary contaminants present in the off-post unconfined flow system are chloroform, chlorobenzene, trichloroethene, tetrachloroethene, dibromochloropropane, dieldrin, dicyclopentadiene, arsenic, chloride, and fluoride. The highest concentrations of DIMP are in the First Creek paleochannel. The maximum concentrations of DIMP in the off-post study area have decreased by approximately 50 percent over the past 10 years as a result of treatment and recharge operations at the North Boundary Containment System. The contaminants found in groundwater downgradient of the North Boundary Containment System include chlorobenzene, chloroform, trichloroethene, and dicyclopentadiene. Chlorobenzene, chloroform, DIMP, and dieldrin are also present downgradient of the Northwest Boundary Containment System. Recent modifications to these two boundary containment systems, including planned remedial actions, will have a significant impact on reducing the contaminant levels downgradient of the RMA.

The off-post study area is a large, heterogeneous area with a variety of characteristics that can affect exposure levels. Therefore, the off-post study area was subdivided into six zones with different exposure conditions (EPA, 1993b). The primary factor used to define the exposure zones was the pattern of COC concentrations in groundwater. Mean exposure point concentrations for off-post groundwater COCs are presented in Table 4.

1.2.4 Groundwater Monitoring and Remedial Actions

Because chemicals were detected in the off-post study area, the Army initiated a regional hydrogeologic surveillance program requiring the quarterly collection and analysis of samples from more than 100 on-post and off-post wells and surface water stations. In the mid-1980s the Army developed the Comprehensive Monitoring Program (CMP), a long-term multimedia monitoring program to provide data to

Table 3
Rocky Mountain Arsenal On-Post Plume Contaminants

Plume Group	Analyte[1]	Concentration[2] (µg/L)
Northwest Boundary	Atrazine	7.1
	Chlordane	0.12
	Dieldrin	0.14
Western	Dibromochloropropane	1.5
	Nitrate/Nitrite	11,000
	Trichloroethylene	13
North Boundary	Atrazine	6.5
	Chlordane	0.16
	Dieldrin	0.14
	Fluoride	4,700
Basin A	1,1-Dichloroethylene	48
	1,2-Dichloroethane	9.5
	Carbon tetrachloride	15
	Chloroform	170
	Methylene chloride	39
	Tetrachloroethylene	300
	Trichloroethylene	23
	Benzene	34
	Atrazine	8.2
	Dibromochloropropane	8.5
	Dieldrin	.23
South Plants	Carbon tetrachloride	5.9
	Chlorobenzene	100
	Methylene chloride	30
	Tetrachloroethylene	17
	Trichloroethylene	15
	Benzene	140
	Aldrin	0.37
	Atrazine	4.8
	Chlordane	0.29
	Chloroform	880
	Dibromochloropropane	3.1
	Dieldrin	0.28
	Endrin	0.23

Notes:

[1] Analytes detected at TSGM (two-step geometric mean) concentrations above their respective target effluent concentrations.
[2] Maximum TSGM analyte concentrations in µg/L.

Reference: Ebasco, 1992

Table 4
Rocky Mountain Arsenal
Off-Post Contaminants of Concern

Contaminants of Concern	Exposure Point Concentration (µg/L)[1]					
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Aldrin	0.029	0.045	0.050	0.12	0.039	0.030
Arsenic	2.15	1.63	—	2.78	2.68	—
Atrazine	2.87	5.31	12.9	7.36	—	4.48
Benzene	0.61	0.64	0.75	0.93	—	—
Carbon tetrachloride	—	0.76	—	—	—	—
Chlordane	—	0.18	0.19	0.54	—	—
Chloride	120,000	205,000	487,000	660,000	262,000	191,000
Chlorobenzene	1.02	1.78	1.77	4.51	1.09	1.27
Chloroform	0.68	67.5	5.01	1.51	12.0	3.33
CPMSO	—	14.5	10.4	7.68	—	—
$CPMSO_2$	—	4.34	6.63	5.09	—	—
Dibromochloropropane	—	0.44	0.14	0.15	0.10	—
1,2-Dichloroethane	—	0.77	0.92	7.32	—	—
Dicyclopentadiene	—	3.64	163	66.6	—	—
DDE	0.029	0.029	0.22	0.085	—	—
DDT	0.037	0.033	0.11	0.10	—	—
Dichlorobenzene	—	5.1	—	2.9	—	—
DIMP	63.3	713	590	4,950	7.68	4.67
Dieldrin	0.034	0.035	0.21	0.055	0.071	0.039
Dithiane	—	—	1.97	4.22	—	—
Endrin	0.033	0.037	0.73	0.058	—	—
Ethylbenzene	—	—	—	0.57	—	—
Fluoride	1,830	2,210	3,510	3,290	1,810	2,230
Hexachlorocyclopentadiene	0.029	0.033	0.044	0.043	0.035	—
Isodrin	0.028	0.035	0.047	0.057	—	0.040
Malathion	—	0.26	0.38	0.32	—	—
Manganese	—	1,580	—	1,250	670	—
Oxathiane	—	—	1.32	2.21	—	—
Sulfate	340,000	636,000	909,000	1,118,000	148,000	213,000
Tetrachloroethene	0.70	10.1	20.7	6.09	0.75	1.67
Toluene	—	—	1.28	1.18	—	—
Trichloroethene	—	0.64	0.51	2.70	—	4.04
Xylene	0.75	—	—	1.11	—	—

Notes:

[1] All exposure point concentrations represent the upper 95 percent confidence limit on the arithmetic mean of measured concentrations in monitoring and private wells.

CPMSO = 4-chlorophenylmethyl sulfone
$CPMSO_2$ = 4-chlorophenylmethyl sulfoxide
DDE = 2,2-bis(p-chlorophenyl)-1,1-dichloroethene
DDT = 2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane
DIMP = diisopropylmethyl phosphonate

Reference: EPA Record of Decision (EPA, 1993b)

facilitate evaluation of response actions. Sample collection under the CMP began in 1987 and continues today as the Groundwater Monitoring Program (GMP) (Stoller, 1990).

On-post groundwater-extraction systems were designed to intercept contaminants in the unconfined aquifer, thereby preventing additional contamination of deeper aquifer zones (HLA, 1989; Morrison-Knudson, 1989; Woodward-Clyde, 1991). No remedial alternatives address the confined portions of the Denver Formation directly. Potable use of on-post groundwater is prohibited. A major component of the off-post remedial action includes a groundwater intercept and treatment system (EPA, 1993b). The system will involve withdrawing contaminated groundwater from the paleochannel areas north of the RMA boundary via extraction wells, treating the groundwater by carbon adsorption, and recharging the treated water using wells and trenches. Other components of the selected off-post remedy include continued operation of the boundary containment systems, long-term groundwater monitoring, five-year site reviews, and alternate water supplies to future users of groundwater in the vicinity of the off-post OU, if such groundwater contains contaminants at concentrations exceeding cleanup standards.

1.3 Chemical Sales Company

The Chemical Sales Company site is located in an area dominated by light industry in northeastern Denver. The site covers approximately 5 square miles adjacent to the west side of the RMA. The company is a wholesale distributor of commercial/industrial chemicals, detergents, and water treatment products.

1.3.1 Site History and Land Use

Operations at the Chemical Sales Company site include the storage and repackaging of bulk chemicals from rail cars and drums. A warehouse located onsite has been owned and operated by the company since 1976. Surface and underground storage tanks, ranging in size from 5,000 to 15,000 gallons, were installed between 1976 and 1977.

In 1981, as a result of EPA-sponsored national random sampling of drinking water, the groundwater in the South Adams County Water and Sanitation District (SACWSD) was found to be contaminated with organic chemicals, including bromoform at concentrations up to 50 μg/L. As a result of these findings, EPA began a RI/FS for the

Off-Post Rocky Mountain Arsenal OU 1 (EPA, 1986a). As discussed above, the RI results indicated widespread contamination by chlorinated VOCs in groundwater along the eastern portion of the Off-Post study area, and the adjacent RMA was suspected as one source of groundwater contaminants because of the history of waste disposal on that site. The Klein Water Treatment Plant was constructed in 1989 to treat the SACWSD municipal water supply, which is primarily drawn from the shallow alluvial aquifer described below. In addition, some 400 residences using private wells were connected to the SACWSD municipal water supply between the summer of 1986 and the fall of 1987.

Further investigation by EPA indicated that additional source areas must be present. The Chemical Sales Company site was identified by the EPA as a source of groundwater contamination in 1987.

There have been three reported spills at the Chemical Sales Company site, one of which occurred in 1985, when approximately 200 gallons of methylene chloride were spilled. In 1986, the discharge of contaminated water from the company property was discovered by the Denver Fire Department. The transfer pipe gallery between the storage tanks and the loading dock had filled with runoff water. The pipe gallery was pumped into a nearby drainage ditch along the railroad tracks. The third release was a methanol spill, which occurred in 1990, when approximately 3,700 gallons of methanol were released.

The Chemical Sales Company site is divided into four OUs. OU 1 addresses soil and groundwater contamination south of Sand Creek. The contaminant source area (Chemical Sales Company property) is within OU 1. OU 1 investigations address source control/source removal of contamination identified on, adjacent to, and downgradient of the Chemical Sales Company facility. OU 2 addresses groundwater contamination located primarily north of Sand Creek and downgradient of OU 1. OU 3 covers the same area as OU 2 but addresses residential exposure to contaminants through the domestic use of alluvial groundwater. OU 4 was established more recently to address contamination in SACWSD municipal wells located just beyond the northern boundary of OU 2 (SACWSD Wells 18, 21, and 47).

Land use within OU 1 is largely industrial, with a few residences present in the northern portion of the OU. The boundaries of OU 2 are approximately defined by the extent of groundwater contamination north of Sand Creek. OU 2 covers 4 square miles

of predominantly residential areas with some light industry. Wells in OU 4 lie within a dominantly residential area.

1.3.2 Physical Setting

The Chemical Sales site is characterized by topography of low relief that generally slopes northward. Natural topographic features have been extensively modified by construction and earthwork. The northern portion of OU 1 lies within the Sand Creek flood plain. Approximately three miles downstream (northwest), Sand Creek enters the South Platte River.

The general hydrogeology of OU 1 consists of an unconfined aquifer in unconsolidated alluvial sediments. The alluvium is underlain by bedrock shales, siltstones and sandstones of the Denver Formation. Paleochannel features exist in the surface of the bedrock and appear to direct flow in the alluvial aquifer. The depth to groundwater beneath OU 1 generally decreases to the north toward Sand Creek. The depth to the water table ranges from approximately 1 foot near Sand Creek to approximately 45 feet near the Chemical Sales Company warehouse. Alluvial groundwater flows toward the north-northwest beneath Sand Creek and continues northward into OU 2. The water table in the vicinity of OU 2 varies from several feet below ground surface, adjacent to the South Platte River, to about 50 feet below ground surface at the eastern boundary of the site. Groundwater within OU 2 flows generally north to northwest.

The unconsolidated alluvial material is highly transmissive, with aquifer transmissivity calculated at one location to be 25,000 ft^2/day. Water-level data from nested wells completed in alluvial and bedrock aquifers in OU 1 and the nearby RMA indicate variable hydraulic gradients between the alluvium and underlying bedrock. Within OU 2 the entire thickness of the unconsolidated alluvium is considered to be a single water-bearing unit throughout the site. However, in other areas the alluvial material may be hydraulically connected with the underlying Denver Formation.

1.3.3 Nature and Extent of Contamination

Two distinct groundwater plumes have been identified within the Chemical Sales site. The first plume, known as the Chemical Sales Company plume, or the trichloroethene (TCE) plume, originates on Chemical Sales property south of Sand Creek and is characterized by high TCE concentrations (typically greater than 300 µg/L; as much as

9,500 µg/L). The second plume, known as the tetrachloroethene (PCE) plume, originates north of Sand Creek and is characterized by high PCE concentrations. Both plumes are located in the shallow alluvial aquifer, with the direction of migration generally following the direction of groundwater flow (north to northwest). Both plumes also contain other contaminants.

The TCE plume follows the flow of groundwater north from OU 1 into OU 2. PCE, trichloroethane (TCA), and 1,2-dichloroethene (DCE) are also present within the plume bounds, the areal extent of which ranges from the Chemical Sales property to SACWSD wells within OU 4. Concentrations decrease steadily downgradient from the Chemical Sales property as a result of dilution, dispersion, adsorption, and biodegradation of contaminants along groundwater flow paths.

The PCE plume is migrating northward. The exact source of the plume has not been determined. It has been assumed that the PCE plume source is degrading because field investigations to date have not located a source and because recent sampling indicates that the plume is dispersing.

In addition to these two plumes, a plume consisting of dibromochloropropane (DBCP) and other VOCs is present east of OU 2 on RMA property. A more detailed discussion of the contaminants found in groundwater from OUs 1, 2 (includes 3), and 4 is provided below.

Operable Unit 1

During the RI for OU 1 (Engineering Science, 1991) 36 groundwater monitoring wells were sampled, and water was analyzed for VOCs, SVOCs, total and dissolved metals, and anions. As a result of this sampling, groundwater contamination was identified within the alluvial aquifer. Plume migration was to the north-northwest. The concentrations of groundwater contaminants decrease significantly, and the width of the groundwater plume increases, toward the northern portion of OU 1.

The concentration of groundwater contaminants decreases by an order of magnitude immediately north of Sand Creek, as a result of dilution from groundwater recharge from Sand Creek (Engineering Science, 1991). PCE has been detected at concentrations approaching 20 percent of its solubility limit in the suspected source areas of OU 1, indicating that free-phase tetrachloroethene (PCE) may exist in the

subsurface as a long-term source of contamination. The RI did not locate this source. Table 5 lists the COCs for groundwater at OU 1.

Table 5
Chemical Sales Company Site
Contaminants of Concern for Groundwater at OU 1

Analyte	Maximum Concentration (µg/L)
Tetrachloroethene	30,000
Trichloroethene	9,500
1,1,1-Trichloroethane	13,709
1,1,-Dichloroethene	17,000
1,1-Dichloroethane	485
cis-1,2-Dichloroethene	320
Vinyl Chloride	30
Methylene Chloride	39,000
Carbon Tetrachloride	61

Reference: EPA Record of Decision (EPA, 1991b)

Operable Units 2 and 3

RI activities for OU 2 were initiated in March 1989. Twelve monitoring wells were installed as part of the RI. Monitoring wells and private domestic wells were sampled to further define the nature and extent of groundwater contamination in the alluvial aquifer. Geophysics and borehole logs were used to determine the locations of thicker sequences of alluvial sediments that overlie the bedrock paleochannels controlling groundwater flow.

The results of the OU 2 RI show extensive groundwater contamination by volatile organic compounds in the study area (EPA, 1991a). The COCs in groundwater at OU 2 are listed in Table 6.

Table 6
Chemical Sales Company Site
Contaminants of Concern for Groundwater at OU 2

	Concentration Range (µg/L)		
Analyte	**1987**	**1988**	**1989**
1,1-Dichloroethane	0.33 - 12.0	0.16 - 21.3	0.38 - 830
1,1-Dichloroethylene	0.36 - 8.0	0.49 - 9.0	0.01 - 1,200
1,2-Dichloroethylene	1.0 - 85	1.0 - 33	0.25 - 150
1,1,1-Trichloromethane	0.5 - 130	0.18 - 22	0.1 - 14,000
Trichloroethene	0.17 - 100	0.12 - 143	0.37 - 9,300
Tetrachloroethene	0.38 - 120	0.19 - 120	0.13 - 14,000
Benzene	1	0.2 - 1.1	1.0 - 78
Vinyl Chloride	0.86	1.0 - 9.88	0.21 - 12

Reference: CDM, 1990

Maximum contaminant levels (MCLs) were exceeded for five of the eight COCs in OU 2 wells during sampling conducted in October 1989. These COCs included tetrachloroethene, trichloroethene, dichloroethene, and vinyl chloride.

Groundwater contamination at OU 2 is derived from two sources, OU 1 and suspected areas within the western portion of the Rocky Mountain Arsenal. Potential OU 2 contaminant source areas within the RMA are the motor pool and the railyard. Groundwater in the motor pool area contains high TCE concentrations while the railyard is a suspected source of DBCP. The Irondale Containment System, which consists of a series of withdrawal wells, a GAC treatment facility, and downgradient reinjection, was designed to treat and contain DBCP-contaminated groundwater derived from the railyard area. DBCP has not been detected in OU 2 in the vicinity of the Irondale system.

Operable Unit 4

Since at least 1981, trichloroethene has been present in Well 18 at concentrations above the MCL. Wells 47 and 21 are situated north and hydraulically downgradient from Well 18. Trichloroethene was first detected in Well 47 in 1991 and has remained

present at concentrations below the MCL since that time. No contamination of Well 21 has been observed.

1.3.4 Groundwater Monitoring and Remedial Actions

Groundwater remedial activities were undertaken separately at each of the OUs.

Operable Unit 1

Remedial activities within OU 1 addressed control and removal of contaminant source. Soils at the site were found to be the main source of contaminants. The remedial action selected by the EPA (EPA, 1991b) for OU 1 included thermally enhanced vapor extraction, high-volume groundwater extraction in the source and plume areas, air stripping, catalytic oxidation in the source area, and aquifer re-injection of treated water. A grid of approximately 65 extraction wells was expected to be required to remediate groundwater near the source area (south of East 48th Avenue). Extraction of groundwater in the plume area (between East 48th Avenue and East 52nd Avenue) was designed to prevent northward contaminant migration and reduce contamination of SACWSD wells by this groundwater plume. Groundwater collection within the plume area will be accomplished using four high-volume extraction wells. The remedial action also includes the monitoring of groundwater, discharged treated water, and air.

Operable Unit 2

The EPA-selected remedial action for OU 2 was PCE plume treatment by air stripping with hydraulic containment and standard pumping of SACWSD wells (EPA, 1991a). The remedy assumes continued operation of the Klein Water Treatment Plant.

The remedy for OU 2 includes extraction of contaminated groundwater by extraction wells, treatment of contaminated groundwater by air stripping, and reinjection of treated water to the aquifer by injection wells. This remedy also includes monitoring of approximately 15 wells for which water-quality criteria will be established, and voluntary abandonment of bedrock wells for which criteria will be established. The system will operate until contaminant concentrations are reduced to site remediation levels. This alternative assumes that the remedial action objectives for OU 1 and OU 3 will be met. Thus, contaminated groundwater will be prevented from entering OU 2 from OU 1, and users of shallow alluvial wells in OU 2 will be protected.

Operable Unit 3

The EPA-selected remedial action for OU 3 is intended to eliminate residential exposure to contaminants through domestic use of alluvial groundwater (EPA 1991a). The remedy for OU 3 includes the connection of residences currently using alluvial wells for domestic water to the SACWSD, installation of home activated carbon units for homes not readily accessible to SACWSD, and monitoring for vinyl chloride to ensure protection.

Operable Unit 4

The EPA selected remedy for OU 4 involves the connection of SACWSD wells 18, 21 and 47 to the Klein Water Treatment Facility (EPA, 1992b).

1.4 Sand Creek Industrial

The 550-acre Sand Creek Industrial site has an extensive history of industrial use including pesticide manufacturing, acidic waste disposal, municipal landfilling, and chemical storage and distribution. The site is located in Commerce City, Colorado, west of the Chemical Sales Company and RMA sites.

1.4.1 Site History and Land Use

The Sand Creek Industrial site includes four known sources of contamination: the Oriental Refinery, the Colorado Organic Chemical property, the L.C. Corporation acid pits, and the 48th Street and Holly Landfill. All of these facilities are currently inactive. The Oriental Refinery is a former oil refinery destroyed by fire. The site is now occupied by a propane distributing firm and a gas station. The Colorado Organic Chemical plant originally manufactured pesticides during the 1960s. The L.C. Corporation hauled and disposed of approximately 8,000 tons of acid waste in pits. The acid contamination in the pits and the surrounding area have been mitigated through the use of lime to neutralize the area. The 48th Street Landfill was used to dispose of municipal wastes. The site comprises six OUs; OU 4 addresses contaminated groundwater underlying the site.

1.4.2 Physical Setting

The intricate hydrogeologic setting within the unconsolidated Quaternary deposits at Sand Creek has led to a number of different aquifer interpretations. However, for consistency a three-aquifer model has been utilized to describe the hydrologic properties and the nature and extent of contamination at Sand Creek. Camp, Dresser, and McKee (CDM, 1988) originated the concept of a multi-aquifer system in the site area based on the presence of several discontinuous clay layers and hydraulic head differences in nested wells. CDM concluded that three groundwater systems separated by two discontinuous clayey strata are present on the site. The three groundwater systems were labeled Aquifer 0, Aquifer 1, and Aquifer 2. The interconnected aquifers are each within unconsolidated deposits overlying bedrock and exhibit very similar hydrologic characteristics (URS, 1993). Groundwater flow in each of the aquifers is generally to the north.

The unconsolidated Quaternary deposits in the site area are underlain by bedrock formations of the Denver Basin (refer to Figure 2). The Denver Formation, ranging in thickness from 100 to 200 feet, lies at depths ranging from 7 to over 100 feet below ground surface in the vicinity of the site. The bedrock aquifers, with the exception of the weathered upper portions of the Denver Formation, do not appear to be adversely affected by subsurface contamination. The low-permeability nature of the claystone at the top of the Denver Formation (below the weathered surface) provides further protection for the underlying units from dissolved subsurface contaminants (CDM, 1988).

1.4.3 Nature and Extent of Groundwater Contamination

Contaminants have been detected in groundwater, surface water, and soil at the Sand Creek site. Approximately 250 groundwater samples from 99 wells and soil borings were collected between 1986 and 1992. Numerous organic compounds, including VOCs, SVOCs, PCBs, pesticides, and herbicides, were detected in the groundwater at Sand Creek (EPA, 1994b).

Except for the eastern portion of OU 4 near the Chemical Sales Company site, low levels of organic contaminants have also been detected in upgradient wells used to define background water quality. These include chlorinated VOCs and benzene in Aquifer 0; benzene, toluene, xylene, acetone, and chlorobenzene in Aquifer 1; and

benzene, toluene, ketones, and chlorinated VOCs in Aquifer 2. The Chemical Sales site (refer to Section 1.3) is the most likely source of upgradient contamination. Although upgradient wells do show contamination, selected upgradient wells were used as background wells for comparisons with onsite and downgradient wells.

Groundwater in Aquifer 0 contains VOCs, phenols, napthalene, 1,4-dichlorobenzene, herbicides, and elevated concentrations of some metals compared to background. Contaminants detected in Aquifer 1 include chlorinated VOCs, ketones, BTEX, styrene, phenols, polyaromatic hydrocarbons (PAHs), chlorinated benzene, pesticides, herbicides, and sulfate. Aquifer 2 groundwater contains chlorinated VOCs, ketones, BTEX compounds, phenols, PAHs, sulfate, and some metals (including lead). An LNAPL plume is also present in Aquifer 2.

A free-phase plume investigation identified two free-phase LNAPL plumes at the Sand Creek site. One was located on Colorado Organic Chemical (Colorado Organic Chemical plume) and the other was located near E. 52nd Avenue (southern plume). URS estimated that the Colorado Organic Chemical plume contained 190,000 gallons of mobile LNAPL and 171,000 gallons of immobile (residual) LNAPL. The LNAPL plume is located in Aquifer 2 and overlying clay layers, and the thickness of the plume ranges from 1.7 to 4.7 feet. The LNAPL consists of two hydrocarbon products: a light naptha solvent and a diesel-like fuel oil. Dissolved-phase contamination associated with the LNAPL includes benzene, toluene, ethyl benzene, and xylene (BTEX), and a plume of tetraethyl lead (TEL).

Although contaminant plumes are migrating in a general northern direction, the movement appears to be slight, based on a comparison of contaminant concentrations over time from 1986 to 1992 (URS, 1993b). Paleochannels in the bedrock surface may act as a preferential flow paths governing the configuration and migration of contaminant plumes (Eneco Tech, 1986a, 1986b). The bedrock aquifers underlying the site, with the exception of the weathered surface of the Denver Formation, do not appear to have been affected by groundwater contaminants. The weathered surface at the top of the Denver Formation is characterized by extensive fracturing along bedding planes and behaves hydrologically as part of the overlying alluvial aquifer system.

Groundwater monitoring through 1993 has provided no evidence of the migration of contaminants from a source in OU 4 underneath Sand Creek to SACWSD municipal

wells. Groundwater monitoring will be continued to determine whether or not OU 4 contaminants are migrating under Sand Creek.

COCs were identified during the risk assessment (URS 1993b). Table 7 summarizes detected concentrations of COCs using data from 1991 and 1992 sampling events.

1.4.4 Groundwater Monitoring and Remedial Actions

The remedy selected for OU 4 will minimize direct contact with and ingestion of groundwater underlying the site and prevents further offsite migration of contaminants in excess of federal and state groundwater standards. The selected remedy includes (1) implementation of institutional controls that will minimize exposure to contaminated groundwater at OU 4 by limiting groundwater usage to non-domestic purposes and preventing any usage of highly contaminated groundwater, (2) quarterly sampling and analysis of groundwater and surface water to evaluate contaminant migration and changes in site conditions, and (3) removal of the recoverable portion of the LNAPL plume located in the northwest portion of the site with a dual vapor extraction (DVE) system. Recovered LNAPL will be transported offsite to a recycling facility. Five-year site reviews will be conducted at OU 4, and additional remedial action will be taken if warranted by a change in site conditions.

Existing and future groundwater monitoring wells (a total of approximately 16) will be sampled periodically to assess the effectiveness of ongoing remedial activities or changes in natural conditions. Samples will be analyzed for the presence of VOCs, SVOCs, pesticides, and metals. Monitoring points will be located upgradient of the site, downgradient of the LNAPL plume, downgradient of OU 4, within Sand Creek, and immediately north of Sand Creek. Samples will be collected quarterly for at least one year but may be collected less frequently if data indicate that site conditions are not changing significantly on a quarterly basis. Monitoring will continue for as long as contaminant concentrations in groundwater at the site boundary exceed Safe Drinking Water Act MCLs or state groundwater standards.

Table 7
Sand Creek Industrial Site Contaminants of Concern

Analyte	Minimum Value (µg/L)	Maximum Value (µg/L)	State Groundwater Standard (µg/L)	Total Samples > State Groundwater Standard
Volatile Organic Compounds				
1,1,1-Trichloroethane	0.50	410.00	200.000	3
1,1-Dichloroethene	0.10	150.00	7.000	6
1,2-Dichlorobenzene	0.00	0.00	620.000	0
1,2-Dichloroethene (total)	2.00	230.00	NV	0
1,4-Dichlorobenzene	0.00	0.00	75.000	0
Acetone	3.00	6.60	NV	0
Benzene	0.20	18,900.00	1.000	12
Chlorobenzene	0.40	66.00	100.000	0
Chloroform	1.10	48.50	6.000	2
Ethyl benzene	0.60	177.00	680.000	0
Methylene Chloride	0.00	0.00	NV	0
Napthalene	94.60	94.60	NV	0
Styrene	0.00	0.00	NV	0
Tetrachloroethene	0.10	330.00	5.000	23
Tetraethyl lead	0.20	120.90	NV	0
Toluene	0.08	1,030.00	1,000.00	1
Trichloroethene	0.40	490.00	5.000	23
Vinyl Chloride	2.10	47.50	2.000	6
Semivolatile Organic Compounds				
1,2-Dichlorobenzene	0.00	0.00	620.000	0
1,4-Dichlorobenzene	2.00	2.00	75.000	0
2-Methylnaphthalene	0.10	550.00	NV	0
Acenaphthene	0.20	1.00	NV	0
bis(2-Ethylhexyl) phthalate	0.30	290.00	NV	0
Dibenzofuran	0.10	0.90	NV	0
Fluoranthene	0.00	0.00	NV	0
Fluorene	0.20	50.00	NV	0

Analyte	Minimum Value (µg/L)	Maximum Value (µg/L)	State Groundwater Standard (µg/L)	Total Samples > State Groundwater Standard
Semivolatile Organic Compounds (continued)				
Naphthalene	0.50	300.00	NV	0
Phenanthrene	0.10	90.00	NV	0
Pyrene	0.10	0.10	NV	0
Pesticides/PCBs				
4,4'-DDD	0.00	0.00	NV	0
4,4'-DDT	0.00	0.00	0.100	0
alpha-BHC	0.00	0.00	0.006	0
Dieldrin	0.00	0.00	0.002	0
gamma-BHC (lindane)	0.00	0.00	0.200	0
Total Metals				
Antimony	24.50	87.10	NV	0
Arsenic	1.30	81.70	50.000	1
Cadmium	5.60	13.10	10.000	1
Manganese	1.10	9,820.00	NV	0
Selenium	1.50	22.10	10.000	5
Zinc	4.00	NV	0	

Notes:

NV = no value established

Reference: URS Consultants, 1993b

1.5 Woodbury Chemical

The 11-acre Woodbury Chemical site is located in Commerce City, Colorado. From the 1950s to 1971 the Woodbury Chemical Company operated a pesticide formulation facility at the site.

1.5.1 Site History and Land Use

The Woodbury Chemical facility was destroyed by fire in 1965 but was subsequently rebuilt. Contaminated rubble and debris from the fire, including water-soaked bags of pesticide and contaminated soils, were disposed of on a 2.2-acre vacant lot east of the Woodbury facility. During a 1985 RI of the 2.2-acre lot (the CERCLA site), EPA identified high levels of pesticides and metals in surface and subsurface soils (EPA, 1985). Significant additional soil contamination was later discovered at the Woodbury facility and adjacent properties to the west and north of the facility. As a result, a second RI was conducted (HLA, 1989) and a new remedy was selected for the site (EPA, 1989).

Present land use near the site is industrial with approximately 3,000 people living within one-half mile of the site. The present industrial use includes a substantial number of industries that use solvents.

1.5.2 Physical Setting

Woodbury Chemical site hydrogeology is characterized by unconfined aquifer conditions in the Quaternary Piney Creek alluvium and confined or semi-confined aquifer conditions in the underlying Denver and Arapahoe Formations. The confining layers of shale and claystone are locally discontinuous in both the Denver and Arapahoe Formations. Field investigations indicate that the depth to groundwater in the alluvial aquifer varies from 24 to 27 feet across the site. The saturated zone of alluvium is approximately 10 feet thick; a confining layer is indicated at 30 to 35 feet. Groundwater flow is northwest from the site toward the South Platte River.

Thirty industrial or residential wells are present downgradient (west to northwest) of the Woodbury site. Nineteen of these wells receive groundwater from the alluvial aquifer, and eleven receive water from the bedrock aquifers. The South Platte River provides recharge to alluvial wells that supply municipal water to the Denver metropolitan area. The South Platte River is also used for irrigation.

1.5.3 Nature and Extent of Contamination

Contamination by pesticides has occurred, at least to some extent, in four environmental media: soils, sediments, groundwater, and surface water. Of these, contamination of soils and sediments is considered the most significant.

The major source of contamination from the Woodbury site was rubble and debris disposed of on the adjacent vacant lot following destruction of the original facility by the 1965 fire. These materials were contaminated with approximately 1,565 pounds of organochloride pesticides. Three general types of contaminants are attributed to Woodbury Chemical wastes: VOCs, including PCE and TCE; other organics, including pesticides; and metals, including arsenic. The maximum concentrations of contaminants found in groundwater are presented in Table 8.

The EPA installed five monitoring wells along the perimeter of the site in 1984. Groundwater sampling results indicated that VOC concentrations in upgradient wells were the same as or higher than those detected in onsite wells. The nearest downgradient well completed in the alluvial aquifer is located one-half mile to the northwest. Several organic solvents (TCE and others) were observed in the majority of groundwater samples from this well, reflecting the general low-level contamination of groundwater in the Commerce City area. In downgradient offsite wells, the VOC concentrations were essentially the same as the concentrations detected in the onsite wells, indicating that VOC contamination of the groundwater may result from upgradient offsite sources. Solvent handling and disposal practices during previous operations at the Woodbury site may have also contributed to groundwater contamination.

Soil borings indicated that some downward migration of pesticide has occurred. However, even though pesticides may have migrated vertically downward through the soil, they have not been detected at high concentrations in groundwater. Pesticides were detected in groundwater from onsite wells in July 1984, but they were not found in the groundwater from the same wells in November 1984 (EPA, 1985). Therefore, pesticide contamination of the groundwater may be of limited extent, affected by a discontinuous source, or not confirmable due to possible sample contamination.

Table 8
Woodbury Chemical Site
Maximum Contaminant Concentrations in Groundwater

Contaminant	µg/L (ppb)
Pesticides	
Dieldrin	2.2
4,4'-DDT	0.2
alpha-BHC	0.2
beta-BHC	0.2
delta-BHC	0.2
Metals	
Cadmium	7.9
Zinc	43
Barium	107
Manganese	3,240
Volatile Organic Compounds	
1,1-Dichloroethane	243
1,1,2-Trichloroethane	1,300
Chloroform	1,300
Methylene Chloride	7
Tetrachloroethylene	50
Toluene	88
Trichloroethylene	280
Base-Neutral Extractable Organic Compounds	
Acetone	150

Notes:

ppb=parts per billion

Reference: EPA Record of Decision (EPA, 1985)

Sampling results indicate that elevated levels of arsenic, lead, and zinc were present in onsite soils in 1979. However, these inorganic contaminants do not appear to be migrating from the site via groundwater flow (EPA, 1985).

1.5.4 Groundwater Monitoring and Remedial Actions

The selected remedial action for this site included excavation and offsite incineration of 2,000 cubic yards of highly contaminated soil followed by offsite disposal; excavation and offsite disposal of 10,600 cubic yards of less-contaminated soil at a RCRA-permitted landfill; and backfilling and revegetation of the excavated area (EPA, 1989). Cleanup of the site began June 25, 1991, and was completed in March 1992.

Monitoring of the groundwater wells would not be required following the source removal. However, to ensure public health protection, a limited pesticide monitoring program is recommended. Two of the existing monitoring wells, one upgradient and one downgradient, will be sampled twice annually for a three-year period (EPA, 1985).

The selected remedy will protect groundwater resources and eliminate direct contact risks through the removal and subsequent destruction or disposal of contaminated soils (EPA,1989). The existing groundwater contamination affects an area much larger than the Woodbury site and will need to be addressed in a future action. Because the problem is widespread, it will be addressed during RI/FS work associated with other Superfund sites in the area, possibly under a new NPL listing.

1.6 Broderick Wood Products

The 64-acre BWP Wood Products (BWP) site is a former wood-treatment plant located in Commerce City, Colorado.

1.6.1 Site History and Land Use

Two distinct activities at the BWP site have contributed to contamination: railroad maintenance activities prior to 1947 and wood-treatment operations between 1947 and 1981. The wood-preserving process used creosote and pentachlorophenol (PCP) mixed with carrier oil (fuel oil) to treat wood products. Wastes were disposed of onsite, and the most were piped to two unlined impoundments in the northwestern corner of the property. Release of contaminants from the impoundments has occurred from leaching through the underlying soils to groundwater, as well as from volatilization and fugitive

dust emissions from the impoundment surface. These impoundments were the main sources of contamination on the site. No industrial activities currently take place on the site.

The BWP property encompasses approximately 64 acres and is situated in a primarily industrial area. Approximately 80,000 people live within 3 miles of the site; 2,900 people live within 1 mile of the site (EPA, 1992e).

1.6.2 Physical Setting

The BWP site is situated on an elevated Quaternary alluvial terrace approximately one-half mile south of Clear Creek. The site is located above the Clear Creek 100-year flood plain. The surface of the site is relatively flat but dips gently to the northeast. Fisher Ditch runs west to east along the northern boundary of the BWP site.

Groundwater is present in a series of three water-bearing geologic units beneath the site. The three partially saturated or saturated geologic units are referred to as the surficial aquifer, the Denver aquifer, and the Arapahoe aquifer. The uppermost surficial aquifer is an unconfined system composed of the Slocum alluvium and the weathered portion of the Denver Formation claystone. Depth to the weathered/unweathered bedrock contact ranges from 15 to 30 feet across the site. The aquifer receives recharge from surface infiltration, upgradient groundwater, and surface ditches. Flow in the surficial aquifer is to the north-northeast.

Unweathered bedrock of the Denver Formation constitutes the confined Denver aquifer and is made up of claystone, shale, and sandstone lenses. At the BWP site, the Denver aquifer contains lenses of permeable sandstone interbedded in less permeable claystone. These sandstone lenses are generally limited in their areal extent and provide only limited water supplies to relatively small areas.

The upper Arapahoe aquifer lies beneath the Denver aquifer and is a confined system that is composed predominantly of loosely consolidated sands with some interbedded claystone and shale. The Arapahoe Formation forms the major bedrock aquifer in the Denver Basin and lies at a depth of approximately 200 feet below the BWP site.

1.6.3 Nature and Extent of Groundwater Contamination

Contaminants derived from the BWP activities have affected soils, sediments in Fisher Ditch, and groundwater. The primary COCs affecting the soil, sediment, and groundwater are VOCs, including benzene, toluene, and xylenes; organics, including PAHs, dioxins, furans, PCP, and other phenolic compounds; and metals, including arsenic and lead.

Groundwater in the surficial and Denver aquifers beneath the BWP site is contaminated with wood-treating chemicals (pentachlorophenol, creosote, isopropyl ether) and volatile organic compounds (primarily fuel oil). Naphthalene is the most prevalent contaminant in groundwater. LNAPLs are present as a sheen in most of the wells in the process and impoundment areas but are not believed to have migrated off the BWP property. DNAPLs were detected in three wells on the BWP property.

Horizontal and vertical transport of contamination have been inhibited by the presence of Fisher Ditch and low hydraulic conductivities in the claystone/shale bedrock (Denver Formation). Downgradient of the impoundments, the groundwater flows north until it reaches Fisher Ditch; at that point, the ditch discharges surface water into the ground and intercepts a portion of the groundwater flow. When wood-treating chemicals in groundwater reach Fisher Ditch, they are unable to enter the ditch because of the water discharging from the ditch to groundwater. They are diluted by surface water that has leaked into the surficial aquifer and are carried with subsurface water to the discharge points at the terrace, seeps, and pond area. The vertical migration of wood-treating chemicals is controlled by the random location of broken or fragmented claystones and shales and the presence of sandstone interbeds within the bedrock (Phase III RI reference).

Contaminants in groundwater migrate downgradient of the source areas within the more permeable sands and gravels of the Denver Formation in the surficial aquifer. Vertical migration of wood-treating chemicals is controlled by the random location of fragmented claystones and shales and the presence of sandstone interbeds in the bedrock. Because of the nature of the contaminant migration, typical transport models and estimates cannot be applied to this setting.

The estimated volume of contaminated groundwater is 528 million gallons. Contaminated surficial groundwater has migrated at least 500 feet north of Fisher

Ditch. Groundwater contamination in the Denver aquifer is limited to the process and impoundment areas of the BWP property and is unlikely to migrate off the property. RI investigations detected only very small amounts of PAH and PCP in one of the four wells in the Arapahoe aquifer.

The concentrations of contaminants in groundwater at the BWP site are listed in Table 9.

1.6.4 Groundwater Monitoring and Remedial Actions

In 1988, the EPA issued a ROD for the site based on the Phase I and II RI/FS efforts. The ROD identified IRAs to control the major source of contamination at the site and to address risks from direct-contact exposure to site contaminants. The major components of the 1988 ROD were restriction of site access, treatment of water in the impoundments and buildings, excavation and incineration of sludges, and stockpiling or incineration of visibly contaminated soils in the impoundments.

The Phase III RI was completed in December 1990 (Retce, 1990). This RI identified contaminated groundwater, contaminated surface soils and hot spots of contamination at the site. The FS was completed in June 1991. The selected remedial action for groundwater at the site involves the following methods: groundwater and LNAPLs will be recovered from the surficial aquifer using subsurface drain trenches and recovery wells; a two-phase biological water-treatment process will remove the LNAPLs in an oil/water separator; the LNAPLs will be reclaimed at an offsite recycling facility, with the remaining water being treated, mixed with nutrients and an oxygenated chemical, then reinjected into the aquifer to stimulate bacterial growth to promote further breakdown of contamination within the shallow aquifer. DNAPLs and groundwater will be collected from existing monitoring wells in the Denver aquifer, treated in the oil/water separator, and sent offsite for recycling. Institutional controls will be placed on the property to control access to water in the surficial and Denver aquifers.

Groundwater in all aquifers will be monitored for 30 years using approximately 10 to 15 wells (EPA, 1992e). Additional monitoring wells will be installed in the Arapahoe aquifer to further assess groundwater quality in that unit. The ability to achieve chemical-specific groundwater clean-up goals (based on the Safe Drinking Water Act

Table 9
Broderick Wood Products Site
Chemicals of Interest in Groundwater

Chemical of Interest	Minimum (µg/L)	Maximum (µg/L)	Mean (µg/L)	Water Quality Standard (mg/L)
Surficial Aquifer				
Carbozole	1.00	951.00	92.0113	—
Naphthalene	1.00	24,900.00	1,653.7483	—
Acenaphthylene	1.00	3,930.00	280.7690	—
Acenaphthene	1.00	7,600.00	372.7000	—
Fluorene	0.10	8,180.00	544.7378	—
Phenanthrene	0.25	17,500.00	1,229.9015	—
Anthracene	0.25	4,160.00	248.8940	—
Fluoranthne	0.10	7,580.00	460.4488	—
Pyrene	0.10	10,800.00	643.6596	—
Benzo (g,h,i) perlyene	0.03	917.00	64.3343	—
Methylene chloride	2.50	25.00	7.0862	—
Trichloroethylene	0.50	66.00	6.6207	0.005[1,2]
Tetrachloroethylene	0.50	5.00	1.7586	0.005[2]
Phenol	2.50	2,500.00	219.0862	—
2-Chlorophenol	2.50	2,500.00	162.1552	—
2-Methylphenol	2.50	2,500.00	307.2321	—
4-Methyphenol	1.00	2,600.00	286.6897	—
2,4-Dimethylphenol	2.00	4,300.00	527.7069	—
2,4-Dichlorophenol	2.00	2,500.00	162.9138	0.21[1]
2,4,5-Trichlorophenol	2.00	2,500.00	171.2069	—
Pentachlorophenol	8.00	48,000.00	7,862.0000	0.001[3]
2,3,7,8 TCDD	—	—	—	1.0×10^{-8} µg/L[3]
Pentachlorodibenzo-p-dioxin	0.00	0.51	0.2551	—
Hexachlorodibenzo-p-dioxin	0.00	0.17	0.0840	—
Heptachlorodibenzo-p-dioxin	0.11	0.19	0.1460	—
Octachlorodibenzo-p-dioxin	0.65	0.86	0.7550	—
Tetrachlorodibenzofuran	0.52	0.52	0.5200	—
Pentachlorodibenzofuran	0.00	0.29	0.1451	—
Hexachlorodibenzofuran	0.01	0.29	0.1460	—
Heptachlorodibenzofuran	0.57	0.57	0.5650	—
Octachlorodibenzofuran	0.31	0.31	0.3050	—

Chemical of Interest	Minimum (µg/L)	Maximum (µg/L)	Mean (µg/L)	Water Quality Standard (mg/L)
Denver Aquifer				
Carbozole	1.00	19,700.00	1,915.7727	—
Naphthalene	1.00	233,000.00	9,500.2679	—
Acenaphthylene	1.00	41,800.00	1,639.1843	—
Acenaphthene	1.00	102,000.00	3,713.4464	—
Fluorene	0.10	54,100.00	2,042.7250	—
Phenanthrene	0.25	125,000.00	4,759.5446	—
Anthracene	0.25	24,000.00	923.2304	—
Fluoranthne	0.10	34,500.00	1,312.4536	—
Pyrene	0.10	99,600.00	3,726.6250	—
Benzo (g,h,i) perlyene	0.03	4,310.00	177.4555	—
Methylene chloride	1.00	25.00	5.2679	—
Phenol	2.50	20,000.00	1,051.9613	—
2-Chlorophenol	2.00	500.00	24.2679	—
2-Methylphenol	2.50	9,700.00	784.5370	—
4-Methyphenol	2.50	19,000.00	1,470.0000	—
2,4-Dimethylphenol	2.00	4,400.00	378.1607	—
2,4-Dichlorophenol	2.50	500.00	31.3393	0.21[1]
2,4,5-Trichlorophenol	2.50	2,500.00	122.9464	—
Pentachlorophenol	25.00	13,000.00	1,125.5900	0.001[3]
2,3,7,8 TCDD	—	—	—	1.0×10^{-8} µg/L[3]
Pentachlorodibenzo-p-dioxin	0.00	0.00	0.0000	—
Hexachlorodibenzo-p-dioxin	0.00	0.00	0.0000	—
Heptachlorodibenzo-p-dioxin	0.00	0.00	0.0000	—
Octachlorodibenzo-p-dioxin	0.00	0.00	0.0000	—
Tetrachlorodibenzofuran	0.00	0.00	0.0000	—
Pentachlorodibenzofuran	0.00	0.00	0.0000	—
Hexachlorodibenzofuran	0.00	0.00	0.0000	—
Heptachlorodibenzofuran	0.00	0.00	0.0000	—
Octachlorodibenzofuran	0.00	0.00	0.0000	—

Notes:

[1] Colorado Basic Standards for Groundwater
[2] Safe Drinking Water Act Maximum Contaminant Level (MCL)
[3] Proposed MCL
ARAR = Applicable or relevant and appropriate requirement

Reference: EPA Record of Decision (EPA, 1992e)

MCLs and Colorado Basic Standards) cannot be determined until the extraction system has been implemented. Therefore, EPA may need to modify the remedy if necessary.

1.7 Denver Radium

Denver Radium refers to a group of contaminated sites resulting from the World War I-era radium processing, refining, and fabrication industry. Forty-eight of 49 sites are located within the City of Denver.

1.7.1 Site History and Land Use

Radium-processing activities on the sites resulted in the radioactive contamination of soil and of debris left on the site. The 48 Denver Radium sites were combined into nine groups for cleanup. These groups include (1) 12th and Quivas Properties, (2) 11th and Umatilla Properties, (3) 1000 W. Louisiana Properties, (4) Robinson Brick Company (ROBCO) and Denver and Rio Grande Western (D&RGW) Properties, (5) Card Property, (6) Open Lands, (7) Denver Streets, (8) Shattuck Chemical Property, and (9) ROBCO Nonradioactive Contamination.

1.7.2 Physical Setting

The Denver Radium properties are located in light-industrial or commercial areas or on undeveloped properties within the South Platte River Basin. The groundwater flow system is a shallow alluvial aquifer overlying a paleotopographic bedrock surface in the South Platte River valley. Paleovalleys, now filled with alluvial sand and gravel, serve as the main migration pathways for groundwater. Groundwater flow in the alluvial aquifer is generally toward the South Platte River.

On most of the Denver Radium properties, the predominant radiological contamination is within the soils. The maximum depth of soil radiological contamination found was 120 inches (1979 through 1985 studies). The typical values for the Denver Radium materials were about half that for typical uranium mill tailings. The principal threat was from the buildup of radon gas in structures built over the contaminated soils. Approximately 342,000 cubic yards of contaminated soil were found on Denver Radium properties. Remedial action and cleanup on most of the properties involved excavation and removal or treatment and onsite disposal (combined with institutional controls) of the contaminated soils.

1.7.3 Nature and Extent of Contamination

Investigations of groundwater contamination were conducted at two of the Denver Radium sites, the ROBCO Properties (OU 9) and the Shattuck Property (OU 8).

ROBCO Properties

In the course of the cleanuup of radium-contaminated soils at the ROBCO Properties (then OU 4), metals-contaminated (arsenic, lead, zinc) soil was discovered onsite. Mining wastes used as fill were the source of the metals contamination. Excavation of the radiologically contaminated materials was completed, and the metals-contaminated soils were addressed under a new operable unit (OU 9). The site slopes gently to the west toward the South Platte River, which is approximately 1,000 feet from the ROBCO property boundary. During site characterization, groundwater was encountered at 10 to 20 feet below ground surface.

No contamination by arsenic, lead, or zinc extends into the soils or bedrock below the water table, and metals contamination is not migrating significantly from contaminated fill material into the alluvium or bedrock. Two downgradient groundwater monitoring wells contained concentrations of dissolved cadmium and selenium in excess of the State of Colorado primary drinking water standards. The detected cadmium concentrations were 181 µg/L and 178 µg/L. The detected selenium concentrations were 11.2 µg/L and 10.4 µg/L. Cadmium, lead, and zinc were also present at concentrations exceeding drinking water standards in pockets of low-pH groundwater on the site. The distribution of metals lead Sverdrup (1992) to conclude that the metals were not mobile in groundwater and that increases in the pH of groundwater cause the metals to precipitate out of solution.

Shattuck Property

The 10-acre Shattuck Property (OU 8) was used to treat and process molybdenum ores, radium slimes, and uranium compounds and ores. A 4.3-acre railroad right-of-way also is located on the property. Groundwater monitoring at the Shattuck Property was initiated in 1981 to characterize impacts to groundwater quality associated with a lined surface impoundment used to store process liquids. The onsite alluvial groundwater has gross alpha and gross beta activities in excess of Safe Drinking Water Act MCLs, and uranium concentrations in excess of the range of proposed standards.

In addition, arsenic, cadmium, and selenium were detected at concentrations exceeding MCLs, and high concentrations of molybdenum were observed in both onsite and downgradient offsite wells. VOCs (chloroform, trichloroethene, and 1,1,1-trichloroethane) were detected at concentrations above MCLs in an upgradient well, onsite wells, and downgradient offsite wells (Table 10). Data from the upgradient well provides evidence of an upgradient source for VOCs (specifically 1,1,1-trichloroethane). However, soil-boring data indicated onsite sources of tetrachloroethene and associated degradation products. The semivolatile compounds phenol, benzoic acid, and phthalates were also detected in onsite wells (EPA, 1992f). Concentrations of the nonradiological contaminants in groundwater downgradient of the site have decreased with time, indicating that natural processes are working to improve groundwater quality (Dames and Moore, 1990).

Groundwater flows to the west and northwest from the Shattuck Property, towards the South Platte River. Groundwater from the site is also infiltrating a storm sewer, which discharges to the South Platte River. Water samples from a downgradient well and the storm sewer outfall show elevated concentrations of ammonia, molybdenum, copper, and uranium. The alluvial aquifer downgradient from the site continues to exhibit significant concentrations of contaminants which decrease to background levels as the groundwater is diluted by mixing with South Platte alluvial groundwater and recharge from the South Platte River. Groundwater contamination beneath the site would be diluted by approximately five orders of magnitude upon discharge to the South Platte River. The dilution effect would reduce the reported concentrations of organic, inorganic, and radiological contaminants below the analytical detection limits. No potential receptors have been identified between the site and the South Platte River (Dames and Moore, 1990).

1.7.4 Groundwater Monitoring and Remedial Actions

At the ROBCO Properties site, recommendations were made for further sampling and hydrogeologic investigation to provide the additional data needed to better evaluate potential source(s) and the extent of the observed groundwater contamination (Sverdrup, 1992). The selected remediation included continued groundwater

Table 10
Denver Radium—Shattuck Site

Analyte	Aquifer Zone	Concentration (µg/L)	
		Minimum	Maximum
Chloroform	Shallow Deep	non-detect non-detect	1,800 600
Trichloroethene	Shallow Deep	non-detect non-detect	27 23
1,1,1-Trichloroethane	Shallow Deep	non-detect non-detect	1,100 760

Reference: Dames and Moore, 1990

monitoring and institutional controls to limit the use of groundwater at the site (EPA 1991c).

The selected remedy for the Shattuck Property addresses groundwater contamination only through source control, that is, through stabilization and disposal of contaminated soil. Additional active measures for groundwater restoration are not presently contemplated. Groundwater monitoring will be used to monitor the onsite soil-disposal unit, as well as to track the improvement in groundwater quality downgradient of the site. Evaluation of the monitoring data will determine whether groundwater quality is improving adequately or whether active restoration measures are warranted (EPA, 1992f).

1.8 Martin Marietta Astronautics Group and U.S. Air Force Property

The Martin Marietta site occupies approximately 5,200 acres in southern Jefferson County near the mouth of Waterton Canyon. The western portion of the site is located in the foothills of the Rocky Mountains. The eastern part of the site consists of a central valley that is separated from the plains by a hogback ridge.

1.8.1 Site History and Land Use

The site is the location of the Martin Marietta Astronautics Group (MMAG) high-technology engineering, design, development, and manufacturing operations. The western portion of the site is located in the foothills of the Rocky Mountains; the eastern part of the site consists of a central valley that is separated from the plains by a

hogback ridge. Most of the development on the site is confined to the southern end of the central valley. The developed area is divided into nine separate areas: Kassler, Filter Gulch, Lower Brush Creek, M3, Space Support Building (SSB), General Purpose Laboratory (GLP), Chemical Technology Laboratory (CTL), Inactive Site, and Rifle Range.

Wastes resulting from manufacturing operations have been managed in a number of areas at the site, including the Industrial Wastewater Treatment Plant in the M3 area, five disposal ponds located in the Inactive Site area, the Rifle Range Landfill, and the Evaporation Pond in the M3 area. The main waste types generated by onsite activities are various oils, fluoride, aluminum, chromium, titanium, nitrate, cyanide, organic solvents, acid etching sludges, chemical treatment sludges, and propellants. From 1959 to September 1980, all the waste that could not be treated on the site was disposed of in the five ponds in the Inactive Site.

The Denver Water Department operated the Kassler Water Treatment Plant located along the south side of the MMAG site. The Kassler plant, which has not operated since 1985, collected surface water from the South Platte River and groundwater from the South Platte alluvium. Groundwater was collected using infiltration galleries in saturated alluvium, treated, and mixed with surface water. Collection of groundwater was discontinued in December 1984.

1.8.2 Physical Setting

The general geology of the site consists of a series of Pennsylvanian to Cretaceous sedimentary rocks unconformably overlying Precambrian granite and metamorphic rocks. The sedimentary rocks dip to the northeast, with resistant sandstone units (Fountain Formation, Lyons Sandstone, and Dakota Group) forming north-south trending hogback ridges. The Pennsylvanian Fountain Formation is 2,200 feet thick and crops out below most of the Inactive Site area, M3 area, GPL area, and Filter Gulch area. The Fountain Formation consists primarily of laterally discontinuous layers of poorly sorted conglomeratic sandstone, sandstone, and sandy and silty claystone. The Dakota hogback marks the approximate eastern extent of operating facilities at the MMAG site. Unconsolidated alluvium exists within the drainages on the site, and in the central valley it reaches a maximum thickness of 35 feet.

There are two major components to the MMAG site hydrologic system: alluvial groundwater and bedrock groundwater (Geraghty and Miller, 1990). The alluvial groundwater occurs in narrow bands of alluvium along the major stream drainages and the South Platte River. The alluvial groundwater generally flows to the south-southeast and eventually discharges into the South Platte alluvium. Bedrock groundwater exists under unconfined, semi-confined, and confined conditions—depending on its location and depth. Overall, the groundwater flow gradient in the Fountain Formation is southeast toward the South Platte River.

1.8.3 Nature and Extent of Contamination

In 1961, MMAG began groundwater monitoring. In 1981, in compliance with RCRA regulations, groundwater monitoring of all RCRA facilities began (Woodward-Clyde, 1983). Large-scale site investigations began in 1986, and the RI was finalized in 1990 (Geraghty and Miller, 1990).

Martin Marietta Astronautics Group

On the MMAG site, significant contamination occurs in soil, surface water and groundwater. COCs were selected by a process of elimination (EPA, 1990). The following criteria were used to eliminate a detected contaminant:

- no toxicity evaluation criteria available
- chemical concentration does not exceed local or regional background concentrations
- chemical detected with a frequency of less than 5 percent or only once
- analytical results did not meet EPA Level 4 criteria for data quality and chemical was not detected above background in related media

Only dissolved, not total, metals were considered in groundwater, with the exception of hexavalent chromium.

Groundwater contamination was identified in each of 11 different geographic areas. Trichloroethene was detected in nine of the study areas and found in ppm concentrations in five study areas. Related chlorinated compounds and transformation products were also widespread. Other contaminants found in groundwater at

concentrations in the parts per million (ppm) range included acetone, 2-butanone, chlorinated aliphatic compounds, toluene and total xylenes, monomethyl hydrazine, dissolved metals (arsenic, chromium, iron, manganese, mercury, silver, copper), nitrate, nitrite, and ammonia. Hexavalent chromium was detected in six study areas and at ppm concentrations in the M3 and Inactive Site areas. Radionuclides were not considered potential contaminants because of the proximity of uranium-bearing geologic zones and minimal historic use of radioactive compounds on the site. The concentration of groundwater contaminants in the M3 and the Inactive Site area groundwater are presented in Tables 11a and 11b, respectively.

Groundwater contaminants—including trichloroethene (TCE)—have migrated offsite to the South Platte alluvial groundwater. As a result of the TCE migration, operation of the Denver Water Department's Kassler plant, which drew water from the South Platte alluvial aquifer, was discontinued.

U.S. Air Force (PJKS) Property

The U.S. Air Force owns approximately 464 acres within the Martin Marietta property. The PJKS property is an NPL site and is being addressed separately from the MMAG site. Trichloroethene; trichloroethane; freon; thorium; and gross alpha, beta, and gamma radiation were detected in the PJKS property groundwater. Groundwater contamination plumes were found in both alluvial and bedrock aquifers. Some of this contamination has moved onto the MMAG property. Cleanup strategies are being developed for the site.

1.8.4 Groundwater Monitoring and Remedial Actions

Groundwater monitoring will be conducted semiannually, at a minimum, with a sufficient number of wells to track contaminant migration from the site. Both alluvial and bedrock aquifers will be monitored (EPA, 1990).

The remedy selected for the groundwater is designed to address contaminated groundwater emanating from source areas identified during the RIs and units regulated under RCRA. The remedy will be a sitewide program to address the most significant groundwater contamination in the alluvium and a portion of the bedrock in the M3 area. The selected remedy is intended to restore groundwater to its beneficial uses, which include drinking water and agricultural supply. Groundwater remediation at the

Table 11a
Martin Marietta Astronautics Group
Contaminants in M3-Area Groundwater

Chemical	Water-Bearing Unit	Frequency of Detection[1] (1985-1989)	Minimum Value[2]	Maximum Value[2]	Units
Acetone	alluvial	2/7	18	18	µg/L
	bedrock	3/13	31	2,200	µg/L
Benzene	alluvial	4/54	5.3	11	µg/L
	bedrock	2/161	36	50.91	µg/L
2-Butanone	alluvial	1/11	—	56	µg/L
	bedrock	3/38	43	54	µg/L
1,1-Dichloroethane	alluvial	20/75	0.5	400	µg/L
	bedrock	15/208	0.79	240	µg/L
1,1-Dichloroethylene	alluvial	83/106	0.79	6,400	µg/L
	bedrock	87/235	1.4	930	µg/L
cis-1,2-Dichloroethylene	alluvial	16/23	5.9	820	µg/L
	bedrock	2/34	8.1	540	µg/L
trans-1,2-Dichloroethylene	alluvial	7/61	11.5	4.5	µg/L
	bedrock	14/183	7.7	3.7	µg/L
Methylene Chloride	alluvial	3/39	5.8	28	µg/L
	bedrock	10/94	5.4	1,100	µg/L
Tetrachloroethylene	alluvial	3/72	6.3	41	µg/L
Toluene	bedrock	3/158	9.3	120	µg/L
1,1,1-Trichloroethene	alluvial	95/111	13	110,000	µg/L
	bedrock	104/229	1.4	5,000	µg/L
Trichloroethylene	alluvial	59/96	6	150,000	µg/L
	bedrock	101/227	1.1	58,000	µg/L
Vinyl chloride	alluvial	6/68	4.8	240	µg/L
Phenols, total	alluvial	4/28	0.01	0.03	mg/L
	bedrock	11/72	0.01	0.08	mg/L
Aluminum, dissolved	alluvial	4/4	0.10	25	mg/L
	bedrock	6/13	2.3	59	mg/L

Chemical	Water-Bearing Unit	Frequency of Detection[1] (1985-1989)	Minimum Value[2]	Maximum Value[2]	Units
Arsenic, dissolved	bedrock	2/70	8	13	µg/L
Cadmium, dissolved	alluvial	18/39	0.10	5.0	mg/L
	bedrock	14/114	0.02	16	mg/L
Chromium, dissolved	alluvial	46/94	0.01	18	mg/L
	bedrock	86/159	0.02	5.2	mg/L
Copper, dissolved	alluvial	4/5	0.03	0.04	mg/L
	bedrock	8/11	0.03	0.26	mg/L
Lead, dissolved	alluvial	3/40	0.01	0.01	mg/L
	bedrock	17/18	0.01	0.08	mg/L
Mercury, dissolved	alluvial	3/16	0.40	0.95	µg/L
	bedrock	1/72	—	1.15	µg/L
Cyanide, total	alluvial	9/30	0.01	0.19	mg/L
	bedrock	25/74	0.01	0.18	mg/L
Gross alpha	alluvial	2/2	33	250	pCi/L
	bedrock	20/20	8.5	210	pCi/L
Gross beta	alluvial	2/2	37	230	pCi/L
	bedrock	20/20	10	150	pCi/L
Radium-226	alluvial	2/2	0.60	1.0	pCi/L
	bedrock	20/20	0.20	3.8	pCi/L
Radium-228	alluvial	1/1	—	6.0	pCi/L
	bedrock	5/5	0.4	2.2	pCi/L
Unsymetrical dimethyl hydrazine	bedrock	1/50	—	37	µg/L
Monomethyl hydrazine	alluvial	2/37	3,500	4,000	µg/L
	bedrock	6/90	2,000	7,300	µg/L

Notes:

[1] Number of "A" and "B" validated detected values divided by the total number of "A" and "B" validated (detected and non-detected) values.
[2] Minimum and maximum values shown may be the geometric mean of a "sample set."

Reference: Geraghty & Miller, 1990

Table 11b
Martin Marietta Astronautics Group
Contaminants in Inactive-Site Groundwater

Chemical	Water-Bearing Unit	Frequency of Detection[1] (1985-1989)	Minimum Value[2]	Maximum Value[2]	Units
Acetone	alluvial	3/12	28	500	µg/L
Benzene	alluvial	1/21	—	5.3	µg/L
2-Butanone	alluvial	1/16	—	16,000	µg/L
1,1-Dichloroethane	alluvial	9/24	68	1,500	µg/L
1,1-Dichloroethylene	alluvial	7/22	7.0	48	µg/L
	bedrock	3/38	5.0	52	µg/L
cis-1,2-Dichloroethylene	alluvial	18/23	8.5	13,000	µg/L
	bedrock	10/43	10	7,000	µg/L
trans-1.2-Dichloroethylene	alluvial	15/22	6.8	12,000	µg/L
	bedrock	4/40	3.8	5,500	µg/L
Methylene chloride	alluvial	4/18	42	2,500	µg/L
	bedrock	11/33	5.5	1,500	µg/L
Tetrachloroethylene	alluvial	13/24	5.4	8,100	µg/L
	bedrock	4/40	5.9	120	µg/L
Toluene	alluvial	6/23	7.8	1,200	µg/L
	bedrock	2/40	2.0	2,400	µg/L
1,1,1-Trichloroethane	alluvial	15/25	4.1	1,200	µg/L
	bedrock	4/39	9.0	190	µg/L
Trichloroethylene	alluvial	15/25	20	600,000	µg/L
	bedrock	4/39	6.0	32,000	µg/L
Xylenes, total	bedrock	1/5	—	4,900	µg/L
Phenol	alluvial	4/19	12	150	µg/L
Phenols, total	alluvial	4/15	0.02	0.21	mg/L
	bedrock	2/6	0.01	0.07	mg/L
PCB-1254	alluvial	1/15	—	1.0	µg/L
Aluminum, total	alluvial	3/3	2.0	44	mg/L

Chemical	Water-Bearing Unit	Frequency of Detection[1] (1985-1989)	Minimum Value[2]	Maximum Value[2]	Units
Chromium, total	alluvial	8/95/8	0.05	11	mg/L
	bedrock		0.07	0.62	mg/L
Chromium, hexavalent, total	alluvial	16/37	0.01	2.4	mg/L
	bedrock	17/40	0.01	0.59	mg/L
Copper, total	alluvial	2/2	0.01	0.16	mg/L
Lead, total	alluvial	1/2	—	0.02	mg/L
Aluminum, dissolved	alluvial	8/26	0.06	3.0	mg/L
Arsenic, dissolved	alluvial	11/27	4.5	21	µg/L
	bedrock	6/29	3.7	24	µg/L
Copper, dissolved	alluvial	11/28	0.01	0.086	mg/L
	bedrock	4/29	0.07	0.074	mg/L
Gross alpha	alluvial	2/2	25	48	pCi/L
Gross beta	alluvial	2/2	7.6	11	pCi/L
Radium-226	alluvial	2/2	0.20	0.40	pCi/L
Radium-228	alluvial	2/2	0.30	1.2	pCi/L
Uranium, dissolved	alluvial	2/2	0.03	0.04	mg/L
Uranium, total	alluvial	2/2	0.03	0.05	mg/L

Notes:

[1] Number of "A" and "B" validated detected values divided by the total number of "A" and "B" validated (detected and non-detected) values.

[2] Minimum and maximum values shown may be the geometric mean of a "sample set."

Reference: Geraghty and Miller, 1990

site includes a series of groundwater-recovery systems in both the alluvial and bedrock aquifers. The intercepted groundwater will be treated and reintroduced to the aquifers.

1.9 Marshall Landfill

The Marshall Landfill site is located three miles southeast of Boulder, Colorado. The site consists of two 80-acre parcels that were used as county landfills. The first parcel, the Marshall Landfill, is referred to as the "inactive site." The second parcel, the Boulder Landfill, was referred to as the "active site" until 1991 when it also stopped accepting wastes.

1.9.1 Site History and Land Use

The first parcel of Marshall Landfill received wastes from 1965 through 1974. This parcel accepted unstabilized sewage sludge and many unidentified and potentially hazardous wastes. Prior to 1970, these wastes also were disposed northwest of the landfill in Cowdrey Drainage. Septic wastes and possibly liquid industrial wastes also were disposed in septic ponds. From 1974 to 1991, the second parcel of the landfill accepted sewage sludge and municipal waste. Industrial waste may have been accepted during its early years of operation. Waste-disposal activities were suspended at the active parcel in 1991. Both parcels were designated county landfills under private operation. The area surrounding the landfills is used primarily for livestock grazing but also includes a storage facility for the National Center for Atmospheric Research adjacent to the site; Marshall Lake, an irrigation and municipal drinking water reservoir; and a small, non-food warehouse building to the northeast that has been leased for a variety of storage uses. The area within a one-mile radius of the site is sparsely populated.

1.9.2 Physical Setting

The Marshall Landfill is in Cowdrey Drainage, which conveys surface water from Cowdrey Reservoir No. 2 to South Boulder Creek. Community Ditch is also within the drainage and conveys potable water at various times of the year from Marshall Lake to the City of Louisville and irrigation water for the Farmers Reservoir and Irrigation Company. Additionally, two small lagoons, dug by Boulder County in an attempt to collect and contain landfill leachate, are on the inactive 80-acre Marshall Landfill.

The recently active Boulder Landfill is between the crest of Lake Mesa and a small bedrock ridge along the north side of Marshall Lake. Lake Mesa is a broad, upland pediment surface, consisting of a gravel-capped bedrock erosional surface along the crest, a series of colluvial and terrace deposits along the flanks, and colluvial and weathered soil along Cowdrey Drainage. Refuse within the inactive landfill was placed along the bedrock slope on the north side of Cowdrey Drainage.

The bedrock geology of the area consists of a faulted sequence of Laramie Formation and Fox Hills Sandstone. The continuity of the bedrock formations in this area has been severely disrupted by a series of northeast-trending, high-angle normal and reverse faults. The most prominent of these is the Crown Davidson Mesa fault, which bisects the inactive landfill. North of the fault, the landfill is underlain by a thick sequence of Laramie Formation shale. South of the fault, the landfill area is underlain by a thin sequence of Laramie Formation shales and coal, the A and B sandstones of the Laramie Formation, and the upper portion of the Fox Hills Sandstone.

The uppermost hydrogeologic unit at the site is an alluvial aquifer consisting of sands, gravels, and clays mantling the top and flank of Lake Mesa; colluvial material along the base of Lake Mesa; weathered bedrock in the low areas around Cowdrey Reservoir; alluvium along Cowdrey Drainage; and refuse that has been placed within the landfill. Flow in the aquifer is generally north and northwest. At greater depth, the Laramie-Fox Hills Aquifer underlies the site.

1.9.3 Nature and Extent of Contamination

Investigations by EPA, the State of Colorado, and Boulder County have shown extensive contamination in groundwater both on and off the Marshall Landfill site. Surface water on the site is also contaminated. Contaminated surface water and groundwater are characterized by elevated concentrations of major ions and heavy metals—including cadmium and lead—and the presence of VOCs—including trichloroethene, tetrachloroethene, dichloroethene, and benzene (EPA, 1986). Alluvial groundwater from the southern portion of the inactive Marshall Landfill has the most degraded water quality on the site. Contamination occurs offsite to the east despite north-northwest directed hydraulic gradients, suggesting that offsite sources may be present east of the landfill.

Piezometric-head data indicate a potential for recharge of sandstone aquifers with contaminated groundwater from the east-southeast portions of the Boulder landfill. Monitoring data for the shallow bedrock and deep bedrock wells in this sector of the landfill indicate low concentrations of 1,1-dichloroethane (refer to Table 12).

1.9.4 Groundwater Monitoring and Remedial Actions

The selected remedial action (EPA, 1986) includes installation of a subsurface collection system using natural hydraulic gradients to collect groundwater leaving the site, treatment of groundwater, landfill improvements, and groundwater and surface water monitoring.

A groundwater monitoring program has been implemented to verify the effectiveness of the remedial action and to further characterize contaminant transport. The plan for the monitoring network included seven wells to monitor drawdown and water quality adjacent to the east drain; one well along Community Ditch; six wells in Cowdrey Drainage; four wells east of the landfills; three wells, one each in alluvium, shallow bedrock, and deep bedrock; and two background wells to monitor water quality. The monitoring was initiated on a monthly frequency, followed by one year of quarterly monitoring, and semiannual monitoring thereafter.

Table 12
Boulder/Marshall Landfill Site
Maximum Contaminant Concentrations in Groundwater

Analyte	Background Alluvial	Onsite Alluvial	Offsite Alluvial	Onsite Shallow Bedrock	Onsite Deep Bedrock
Total dissolved solids	665	13,200	420	2,637	1,770
Chlorine	15	900	26	6	7
Sulfate	107	7,900	100	6	23
Ammonium	—	120	0.1	0.3	0.3
Iron	110	58,700	—	190	1,100
Manganese	39	6,500	310	160	220
Barium	130	2,000	600	120	160
Zinc	80	250	97	25	6
Arsenic	—	50	—	—	—
Cadmium	—	33	—	18	—
Lead	—	60	—	15	—
Selenium	—	90	—	—	—
Mercury	—	1.3	0.4	—	—
Chromium	—	8	9	—	—
Phenols	—	2,650	5	—	—
1,1-Dichloroethane	—	250	15 (77)	15	5
trans-1,2-Dichloroethane	—	530	66	9	—
Trichloroethylene	—	49	— (550)	—	—
1,1,1-Trichloroethylene	—	93	6 (79)	—	—
Tetrachloroethylene	—	340	73 (98)	—	—
Dichloroethylene	—	—	— (79)	—	—
Ethyl benzene	—	73	—	—	—
Toluene	—	1,250	—	—	—
Benzene	—	43	—	—	—

Notes:

Values in parantheses from well located east of (upgradient of) landfill.
Concentrations in mg/L .

Reference: EPA Record of Decision (EPA, 1986)

2. COMPARISON TO GROUNDWATER CONTAMINATION AT THE ROCKY FLATS SITE

The majority of the NPL sites discussed in the preceding section are located within the Denver metropolitan area and the South Platte River drainage basin. These sites share common geographic, geologic, and hydrologic characteristics. The fate of chemicals in the environment and their transport via groundwater flow are controlled at each site by similar physical, chemical, and biological characteristics.

2.1 Comparison of Conceptual Models for Groundwater Flow

Groundwater flow at the Rocky Flats site is described in terms of hydrostratigraphic units (EG&G, 1993). The upper hydrostratigraphic unit is composed of several lithostratigraphic units having a range of hydrologic characteristics but in hydraulic connection with each other and showing a similar major-ion chemistry. The upper hydrostratigraphic unit includes alluvial, colluvial, and valley-fill deposits, other unconsolidated surficial deposits, and the weathered portions of the underlying Arapahoe and Laramie Formations. Groundwater flow and contaminant transport are most rapid in the unconsolidated deposits.

Remedial investigations of most of the NPL sites described above have adopted the hydrostratigraphic-unit or flow-system concept to describe units of groundwater flow and contaminant transport. In contrast, groundwaters from distinct lithostratigraphic units have been described separately at a few sites (Lowry, Sand Creek Industrial, Denver Radium), even though the lithostratigraphic units may be interconnected. The uppermost hydrostratigraphic unit at sites located within the central Denver Basin is usually composed of unconsolidated alluvial deposits; other surficial deposits, if present; and the weathered portion of the bedrock. At the Lowry Site, where the relatively coarse-grained Dawson Formation is present under surficial deposits, the uppermost unit also includes unweathered bedrock above the first confining layer.

At the sites where the uppermost water-bearing unit is an unconsolidated deposit that overlies a paleotopographic surface on the bedrock, the conceptual models for groundwater flow are similar. At these sites, paleochannels in the bedrock surface are filled with younger sediments and provide preferential pathways for groundwater flow

and contaminant transport. Such preferential flow paths are currently under investigation in the OU 2 area of the Rocky Flats site.

2.2 Comparison of Contaminants in Groundwater

The upper hydrostratigraphic unit at Rocky Flats contains water in several lithologically distinct water-bearing units. Groundwaters in the different units are not distinguishable from each other on the basis of their major-ion compositions, and the groundwaters in the different lithologic units also contain similar concentrations of contaminants, although the contaminant distribution in the groundwaters may be slightly different as a result of the contrasting hydrologic characteristics of the different lithologic units (EG&G, 1994).

Contamination of groundwater in the upper hydrostratigraphic unit has been identified at the Rocky Flats site through comparison of chemical concentrations in onsite groundwater to concentrations in background groundwater. In general, detectable concentrations of VOCs in groundwater are interpreted as evidence for contamination. At the three RCRA-regulated units, contamination associated with RCRA waste-storage and disposal activities has been identified at each unit through comparison of downgradient water quality to upgradient water quality (DOE, 1994).

The principal groundwater contaminants on the Rocky Flats site include chlorinated VOCs, radionuclides, metals, and some inorganic parameters such as nitrate and sulfate (EG&G, 1994). The most pervasive groundwater contaminants present at the other sites reviewed are the organic compounds, especially chlorinated VOCs. Contamination by other VOCs, SVOCs, and metals was also common to most of the sites. Pesticides, herbicides, and radionuclides were found in groundwater from only a few of the sites. The types of groundwater contaminants present at each of the sites reviewed are summarized in Table 13.

Volatile Organic Compounds

The types of VOCs in groundwater were variable among the sites reviewed; DIMP and DBCP, which are the most pervasive contaminants present at the Chemical Sales and RMA study areas, are not detected in groundwater at the Rocky Flats site. The chlorinated solvents tetrachloroethene, trichloroethene, dichloroethene, and their transformation products are the groundwater contaminants common to most of the

sites. Aromatic hydrocarbons and BTEX constituents are also common groundwater contaminants at most of the sites.

At the Rocky Flats site, DNAPL concentrations exceeding 10 percent of the solubility limit were found only in four wells (EG&G, 1994). These wells were not located in close proximity to each other, thus, the presence or absence of DNAPLS in groundwater has not been definitively determined. At several of the NPL sites with significant contamination of groundwater by VOCs, NAPLs are present in the subsurface. Both LNAPL and DNAPL are present in source areas at the Lowry Site; DNAPL sources may also be present at the RMA, Chemical Sales Company, and Sand Creek Industrial sites.

Distinct plumes of contaminated groundwater have been delineated at some of the sites, including the Lowry Site, RMA, Chemical Sales Company, Sand Creek Industrial, and Martin Marietta. At all of these sites, the plumes are characterized by high concentrations of VOCs. Contaminant plumes have also been identified at Rocky Flats (EG&G, 1994), but they are usually not related to an identified source in the subsurface. Instead, the plumes emanate from several inactive waste-storage and disposal facilities around the plant. Plumes of contaminated groundwater characterized by high concentrations of inorganic parameters, dissolved metals, and VOCs are present at the Rocky Flats site. The spatial distribution of contaminant plumes at Rocky Flats has not significantly changed from 1990 to 1992 (EG&G, 1994).

SVOCs are not commonly detected in groundwater from the Rocky Flats site. Several of the other NPL sites do show significant groundwater contamination by SVOCs. SVOCs are the principal contaminants present at the BWP site and are also present at the Lowry, Sand Creek Industrial, Denver Radium (Shattuck), and Martin Marietta sites.

Radionuclides

Radiological contaminants are present in groundwater at the Rocky Flats, Lowry, and U.S. Air Force Property sites. The radionuclides present are different at the three sites, although some of the radionuclides found in groundwater from the Lowry Site are also locally present in groundwater from the Rocky Flats site (americium, plutonium, and uranium).

Metals

Metals contamination of groundwater is prevalent at municipal waste-disposal sites such as the Lowry Site, the Marshall Landfill, and the Present Landfill at Rocky Flats. Sand Creek Industrial and Denver Radium sites are also sources of metals contamination. At the Denver Radium sites, metals were described as relatively immobile in soils and their offsite transport via neutral-pH groundwater was described as insignificant.

Pesticides/PCBs/Herbicides

Pesticides have been detected infrequently and at concentrations near their detection limits in groundwater from the Rocky Flats site (EG&G, 1994). These results suggest that there has been no significant pesticide contamination of groundwater. PCBs and herbicides have not been detected in groundwater from the Rocky Flats site.

Pesticides are the principal contaminants present in groundwater at the RMA, Sand Creek Industrial, and Woodbury Chemical sites. Pesticides were also found in groundwater at Lowry Landfill. PCBs were not consistently detected in groundwater at any of the sites reviewed. Herbicides were only detected in groundwater from the Sand Creek Industrial site.

Table 13
Comparison of the Rocky Flats Site to Other NPL Sites:
Groundwater Contamination

Site	Uppermost Hydrostratigraphic Unit Description	Contaminant Types	Frequently Detected Contaminants or Contaminant of Concern		Offsite Transport via Groundwater
Rocky Flats Site	Alluvial and colluvial deposits, other unconsolidated surficial deposits, weathered Arapahoe and Laramie Formations	Radionuclides	√	Am, Pu, Ra, U, Tritium, Gross Alpha and Beta	None demonstrated
		Metals	√	Li, Sr	
		VOCs			
		halogenated	√		
		BTEX	√	toluene	
		other	√	(acetone)	
		SVOCs	√	PAHs, phenols	
		NAPL			
		Pesicides/PCBs			
		Inorganics	√	nitrate, sulfate, chloride, fluoride	
Lowry Landfill	Alluvial and colluvial deposits, refuse, waste pit fill, weathered and unweathered Dawson Formation above confining layer	Radionuclides	√	Am, Bi, Pb, Pu, Sb, Th, U	To barrier wall and treatment system only
		Metals	√	Sb, As, Cr, Co,Pb, Ni, Se, Tl, Zn	
		VOCs			
		halogenated	√		
		BTEX	√		
		other	√		
		SVOCs	√		
		NAPL	√	LNAPL and DNAPL	
		Pesicides/PCBs	√	pesticides	

Site	Uppermost Hydrostratigraphic Unit Description	Contaminant Types	Frequently Detected Contaminants or Contaminant of Concern		Offsite Transport via Groundwater
		Inorganics		fluoride	
Rocky Mountain Arsenal	Alluvial deposits, other unconsolidated surficial deposits, weathered Denver and Arapahoe Formation	Radionuclides			
		Metals	√	As, Mn	
		VOCs			
		halogenated	√		VOC plumes extend offsite
		BTEX	√		
		other	√	DIMP	
		SVOCs			
		NAPL			
		Pesicides/PCBs	√	pesticides	
		Inorganics	√	chloride, fluoride, sulfate	
Chemical Sales Company	Alluvial and other unconsolidated surficial deposits	Radionuclides			
		Metals			
		VOCs			
		halogenated	√	PCE and TCE plumes	VOC plumes extend offsite
		BTEX			
		other			
		SVOCs			
		NAPL	√	DNAPL possible	
		Pesicides/PCBs			
		Inorganics		none identified	

Site	Uppermost Hydrostratigraphic Unit Description	Contaminant Types	Frequently Detected Contaminants or Contaminant of Concern		Offsite Transport via Groundwater
Sand Creek Industrial Site	Three shallow aquifers identified in alluvial deposits overlying Denver Formation	Radionuclides			VOCs and pesticides present offsite
		Metals	√	Sb, As, Cd, Mn, Se, Zn	
		VOCs			
		halogenated	√		
		BTEX	√		
		other	√	PAHs	
		SVOCs	√		
		NAPL	√	LNAPL plumes	
		Pesicides/PCBs	√	pesticides and herbicides	
		Inorganics		none identified	
Woodbury Chemical	Piney Creek Alluvium	Radionuclides			Widspread offsite VOC contamination may not originate at Woodbury Chemical
		Metals	√	Ba, Cd, Mn, Zn	
		VOCs			
		halogenated	√		
		BTEX			
		other	√	acetone	
		SVOCs			
		NAPL			
		Pesicides/PCBs	√	pesticides	
		Inorganics		none identified	

Site	Uppermost Hydrostratigraphic Unit Description	Contaminant Types	Frequently Detected Contaminants or Contaminant of Concern		Offsite Transport via Groundwater
Broderick Wood Products	Surficial aquifer comprised of Slocum Alluvium and weathered Denver Formation	Radionuclides			Not demonstrated
		Metals	√	As, Pb	
		VOCs			
		halogenated			
		BTEX	√		
		other	√	fuel oil	
		SVOCs	√	napthalene, phenols, creosote	
		NAPL	√	LNAPLs present	
		Pesicides/PCBs			
		Inorganics		none identified	
Denver Radium	Alluvial deposits	Radionuclides			High metals concentrations in storm sewer water
		Metals	√	Cd, Cu, Pb, Mo, Se, Zn	
		VOCs			
		halogenated	√	Shattuck Properties only	
		BTEX			
		other			
		SVOCs	√	phenols, phthlates - Shattuck Properties only	
		NAPL			
		Pesicides/PCBs			
		Inorganics	√	ammonia	

Site	Uppermost Hydrostratigraphic Unit Description	Contaminant Types	Frequently Detected Contaminants or Contaminant of Concern		Offsite Transport via Groundwater
Martin Marietta and U.S. Air Force Property	Alluvial sediments including South Platte alluvium	Radionuclides	√	Th, gross alpha, beta, and gamma - Air Force property only	TCE contamination of South Platte alluvium
		Metals	√	As, Cr, Fe, Mn, Hg, Ag, Cu, Cr	
		VOCs			
		chlorinated	√	especially TCE	
		BTEX	√		
		other	√		
		SVOCs	√		
		NAPL			
		Pesicides/PCBs			
		Inorganics	√	nitrate, nitrite, ammonia	
Marshall Landfill	Alluvial and colluvial deposits, valley-fill alluvium, refuse, and weathered Laramie Formation	Radionuclides			Downgradient transport of VOCs, inorganics, metals
		Metals	√	Fe, Mn, Ba, Zn, As, Cd, Pb, Se, Ag, Cr	
		VOCs			
		chlorinated	√		
		BTEX	√		
		other			
		SVOCs	√	phenols	
		NAPL			
		Pesicides/PCBs			
		Inorganics	√	chloride, sulfate, ammonium	

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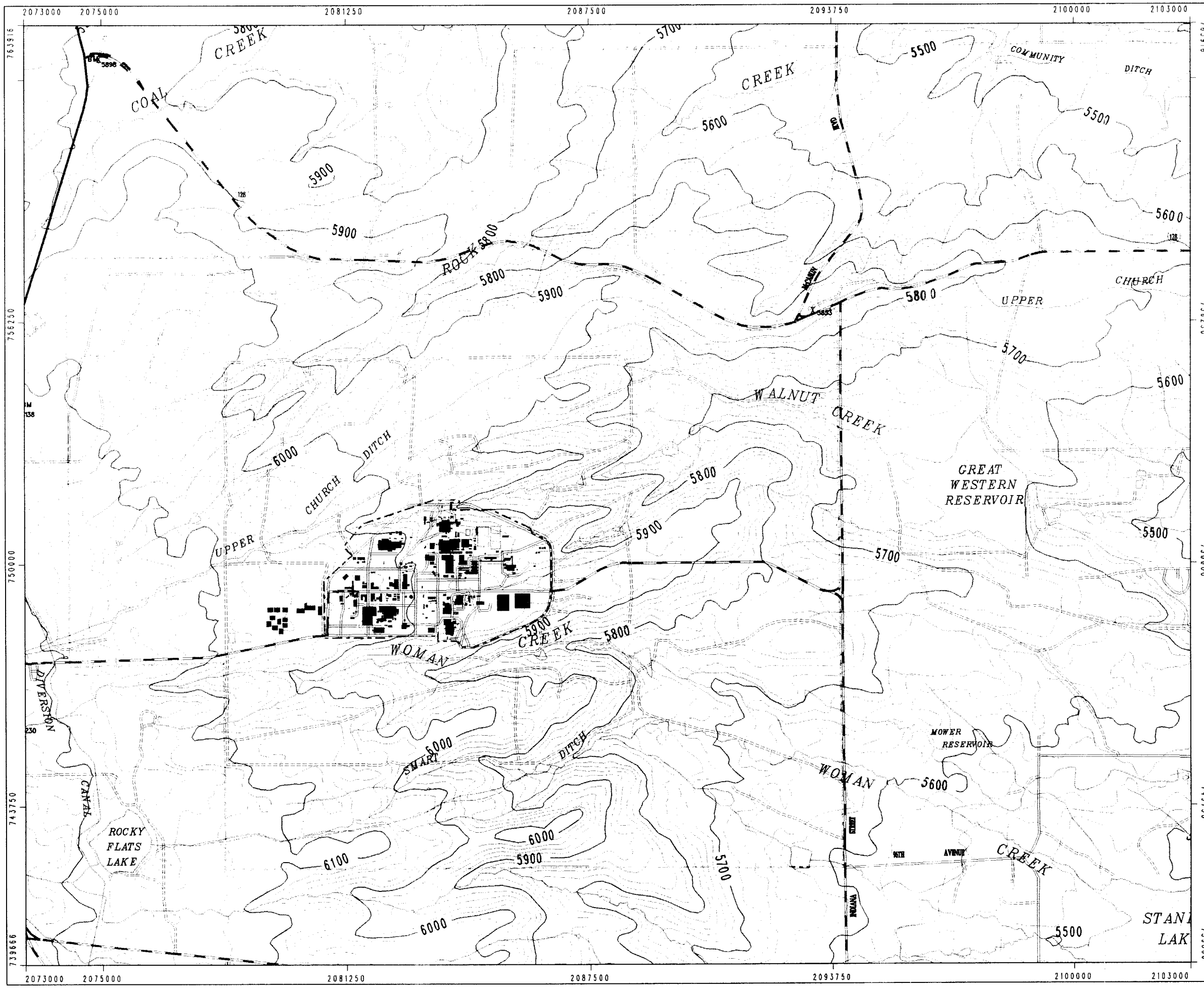


EXPLANATION

- Primary Roads
- Secondary Roads
- Lightduty Roads
- Unimproved Roads
- Trails
- Buffer Zone Boundary
- Industrial Area Boundary
- Buildings
- Surface Water Impoundments

Scale = 1 : 30000
1 inch = 2500 feet

1250 0 2500ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

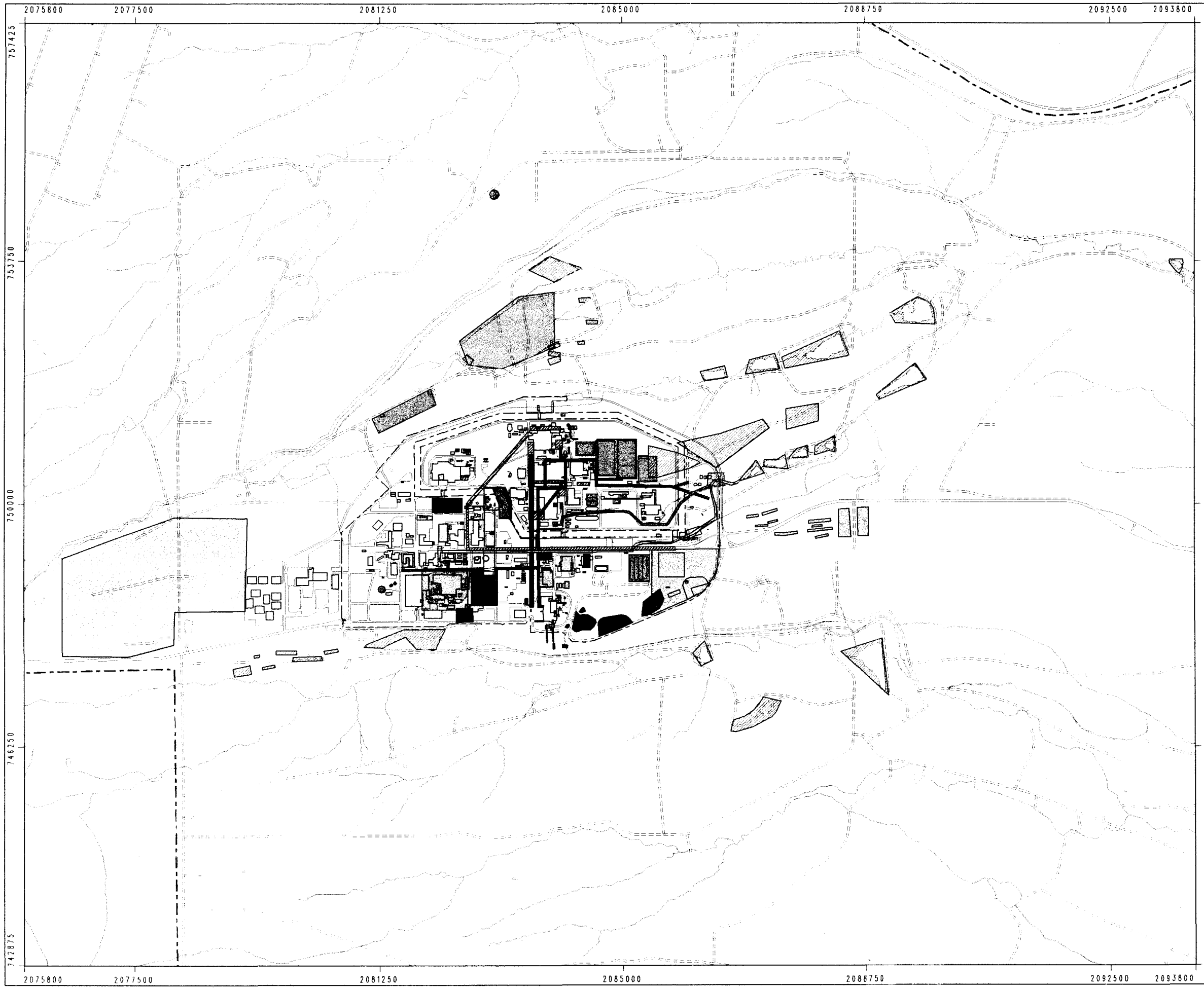
Rocky Flats Site, Golden, Colorado

Map of the
Rocky Flats Site

Groundwater Geochemistry Report

January 1995

Figure 2-1



EXPLANATION

- Operable Unit 1
- Operable Unit 2
- Operable Unit 4
- Operable Unit 5
- Operable Unit 6
- Operable Unit 7
- Operable Unit 8
- Operable Unit 9
- Operable Unit 10
- Operable Unit 11
- Operable Unit 12
- Operable Unit 13
- Operable Unit 14
- Operable Unit 15
- Operable Unit 16
- Streams, Ditches, and Drainages
- Paved Roads
- Dirt Roads
- Industrial Area and Security Zone Boundaries
- Buffer Zone Boundary
- Surface Water Impoundments
- Buildings

Scale = 1 : 18000
1 inch = 1500 feet

750 0 1500ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

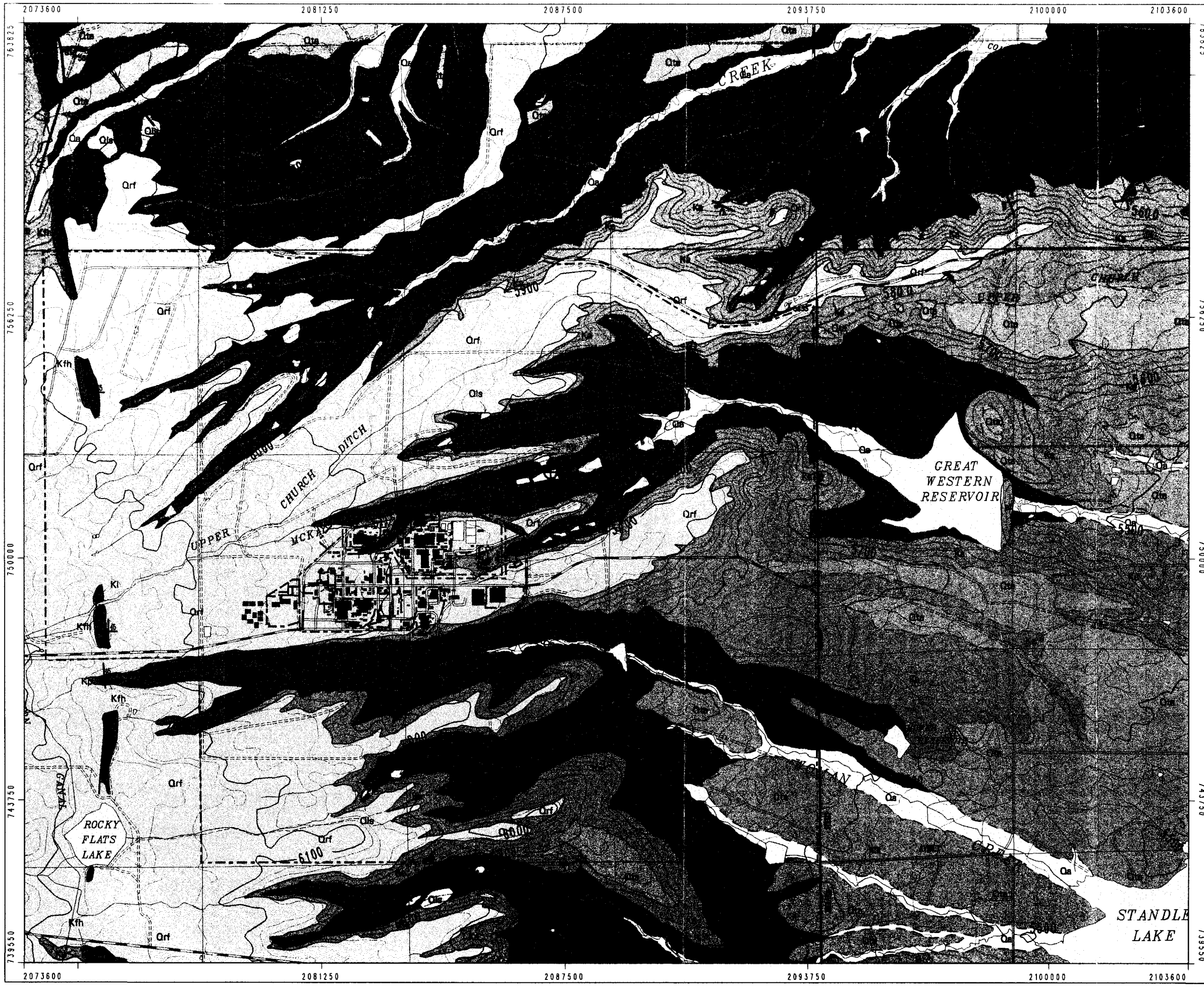
Rocky Flats Site, Golden, Colorado

Individual Hazardous Substance Sites and Operable Units at the Rocky Flats Site

Groundwater Geochemistry Report

January 1995

Figure 2-2



EXPLANATION

af	Artificial Fill (RECENT)
Qa	Valley Fill Alluvium (RECENT)
Qls	Landslide Slump (RECENT)
Qts	Undifferentiated Alluvium (PLEISTOCENE)
Qrf	Rocky Flats Alluvium (PLEISTOCENE)
Ka	Arapahoe Formation (CRETACEOUS)
	Laramie Formation (CRETACEOUS)
	Fox Hills Sandstone (CRETACEOUS)
Kp	Pierre Shale (CRETACEOUS)

Contact
(dashed where inferred)

Strike and Dip of Bedding Planes in Bedrock

50 Inclined

Vertical

20 Overturned

Horizontal

Area of Bedrock Exposure

Scale = 1 : 30000
1 inch = 2500 feet

1250 0 2500ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Geologic Map
of
Rocky Flats Site

Groundwater Geochemistry Report

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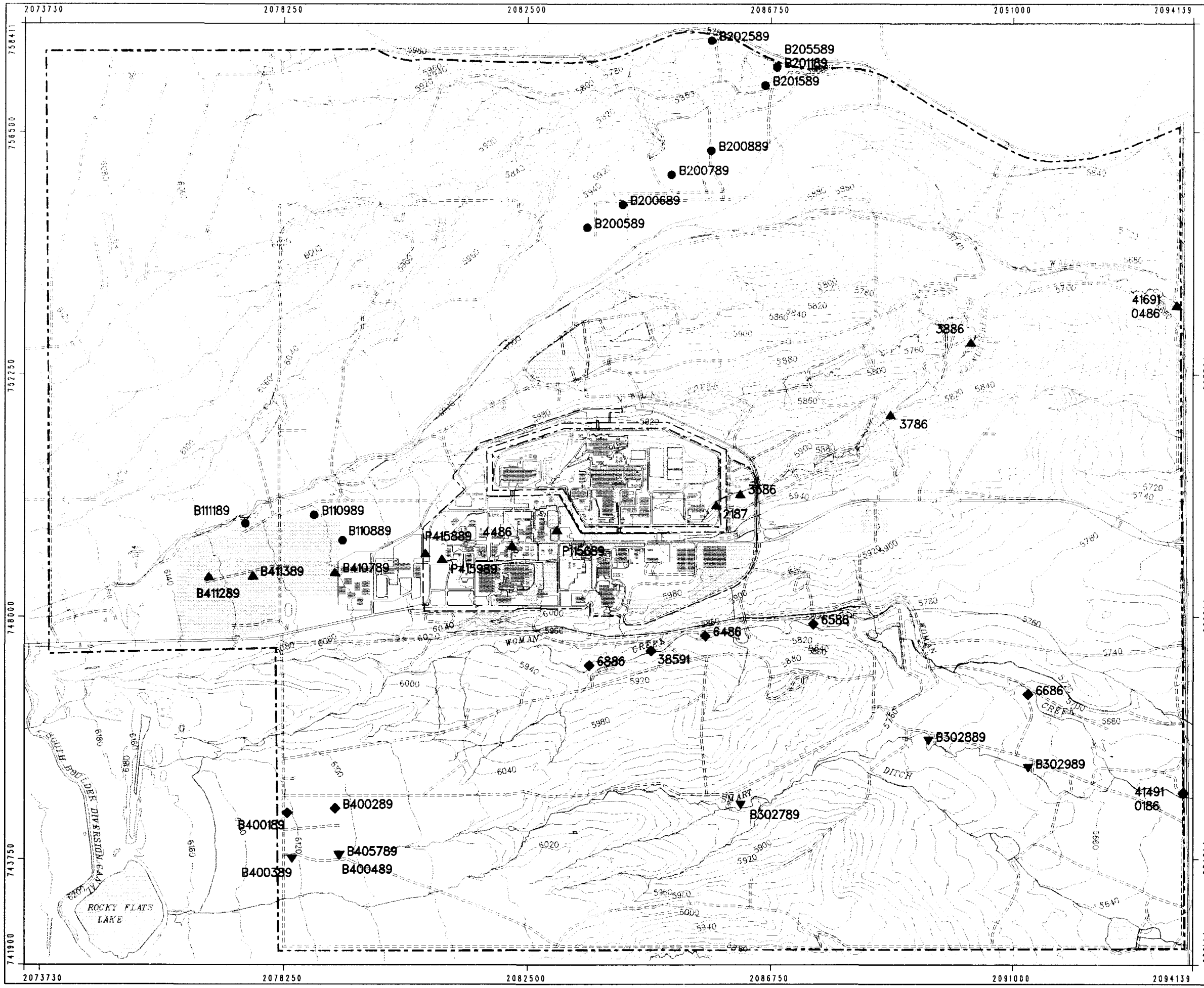

EXPLANATION

- Rock Creek Flow Path
- Industrial Area Flow Path
- Woman Creek Flow Path
- Southern Flow Path
- Streams, Ditches, and Drainages
- Paved Roads
- Dirt Roads
- Industrial Area and Security Zone Boundaries
- Buffer Zone Boundary
- Surface Water Impoundments
- Buildings
- Individual Hazardous Substance Sites

Scale = 1 : 20400
1 inch = 1700 feet

850 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Monitoring Wells Along Four UHSU Flow Paths

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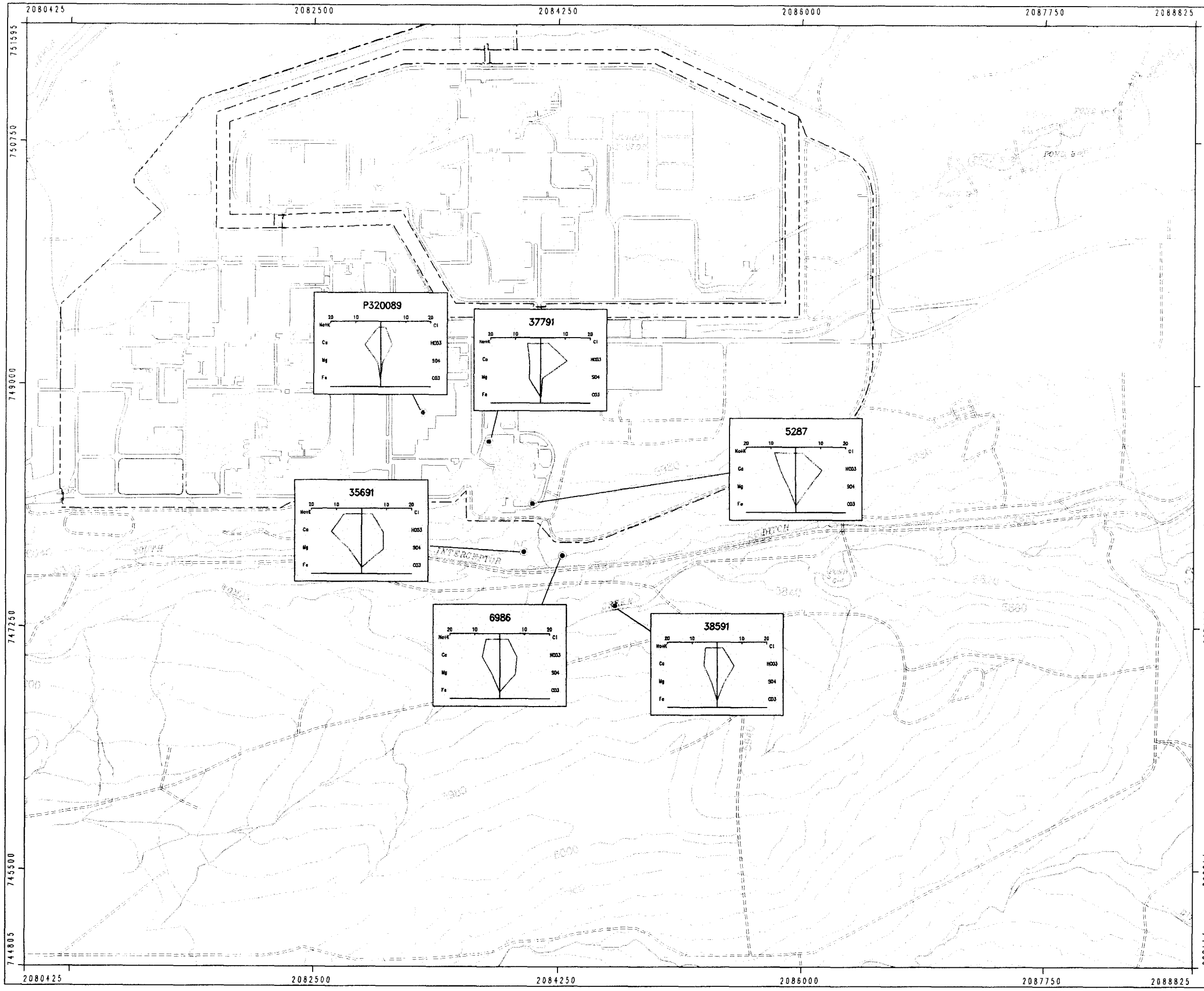
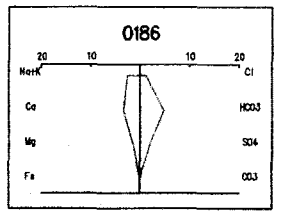
Figure 5-7



EXPLANATION

- Streams and Drainages
- Paved Roads
- Dirt Roads
- Industrial Area and Security Zone Boundaries
- Surface Water Impoundments
- Buildings
- Upper Hydrostratigraphic Unit Monitoring Well

Diagram of dissolved major-ion concentrations ("Stiff plot") for selected wells. Concentrations are in milliequivalents per liter.



N

Scale = 1 : 8400
1 inch = 700 feet

350 0 700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

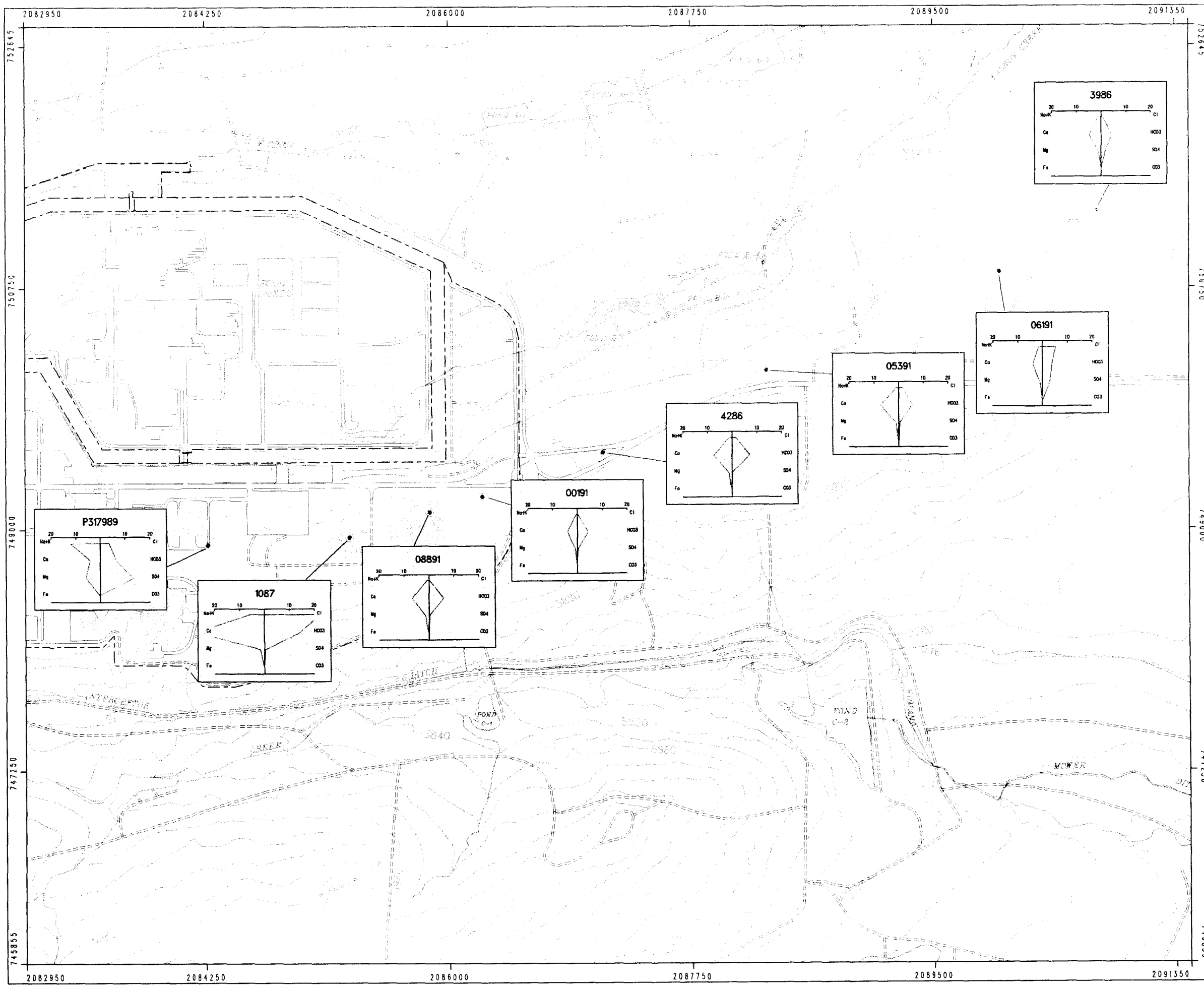
Major-Ion Concentrations

UHSU Groundwater
in Surficial Deposits
Across OU1

Groundwater Geochemistry Report

January 1995

Figure 5-19



EXPLANATION

Streams and Drainages

Paved Roads

Dirt Roads

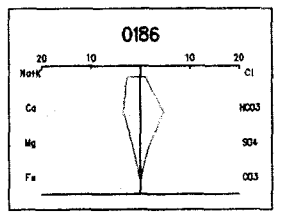
Industrial Area and Security Zone Boundaries

Surface Water Impoundments

Buildings

Upper Hydrostratigraphic Unit Monitoring Well

Diagram of dissolved major-ion concentrations ("Stiff plot") for selected wells. Concentrations are in milliequivalents per liter.



N

Scale = 1 : 8400
1 inch = 700 feet

350 0 700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Major-Ion Concentrations

UHSU Groundwater in Surficial Deposits Across OU2

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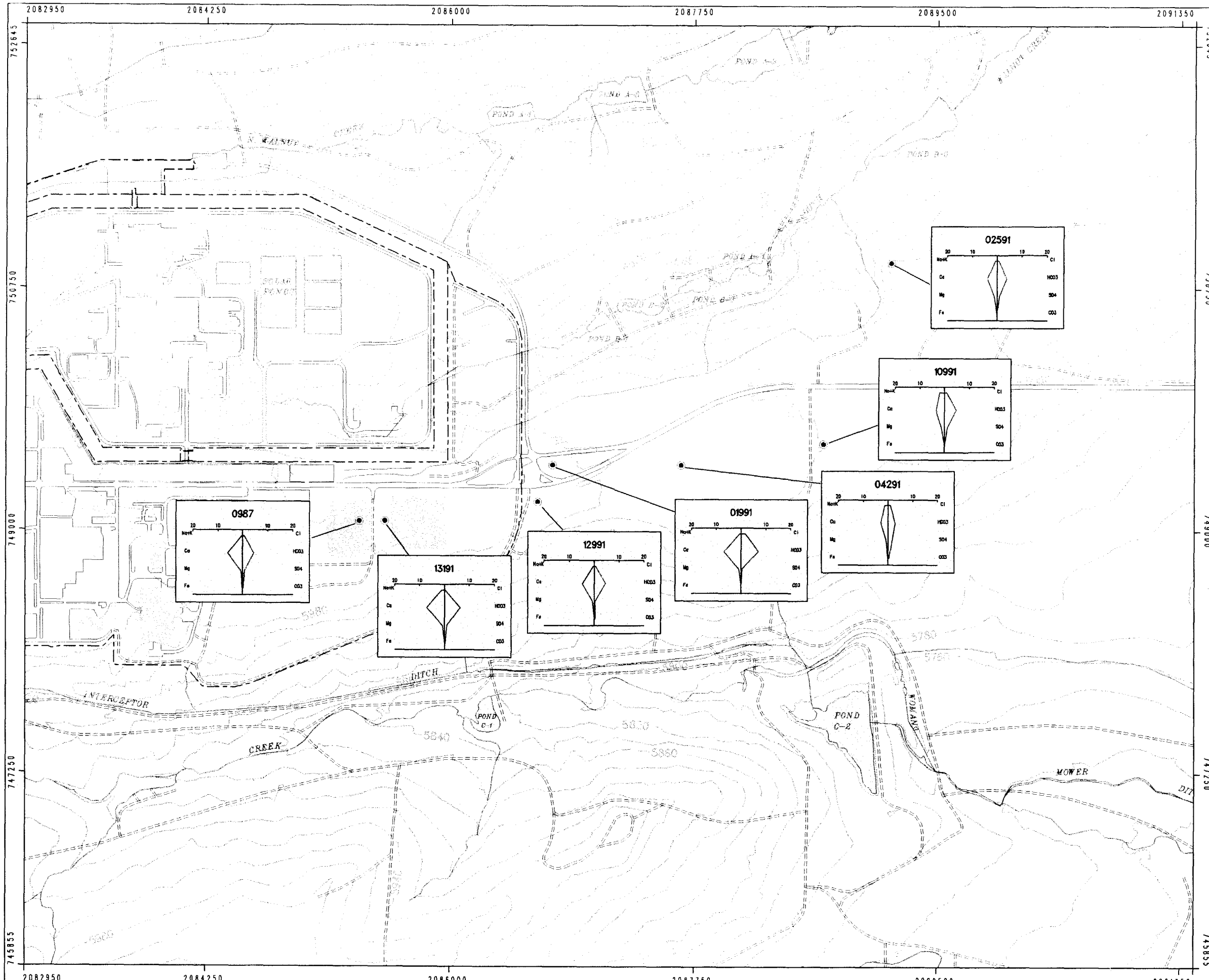
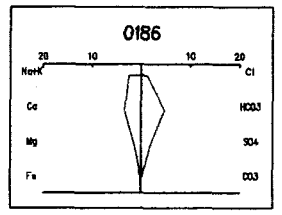
Figure 5-20



EXPLANATION

- Streams and Drainages
- Paved Roads
- Dirt Roads
- Industrial Area and Security Zone Boundaries
- Surface Water Impoundments
- Buildings
- Upper Hydrostratigraphic Unit Monitoring Well

Diagram of dissolved major-ion concentrations ("Stiff plot") for selected wells. Concentrations are in milliequivalents per liter.



Scale = 1 : 8400
1 inch = 700 feet

350 0 700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

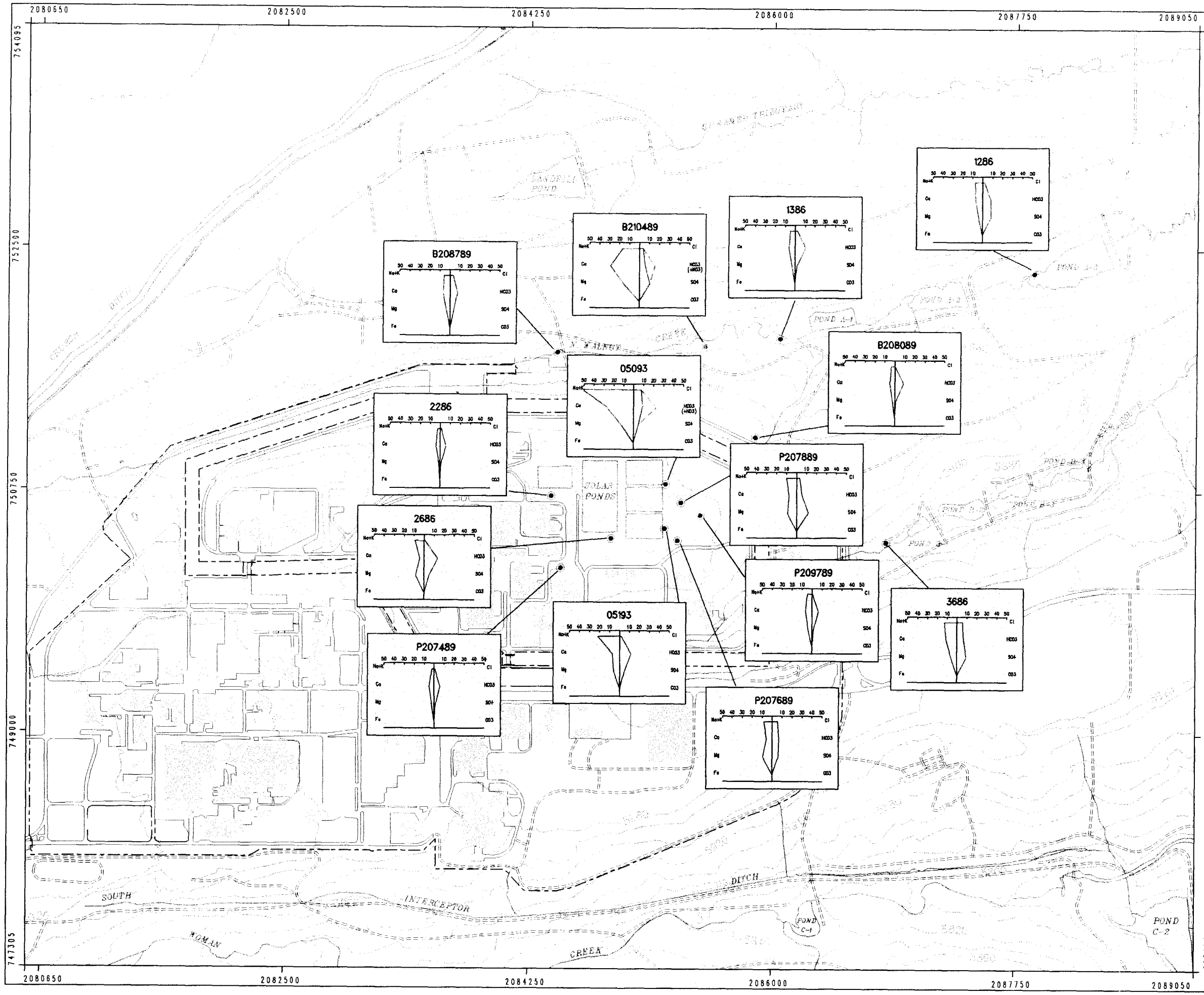
Major-Ion Concentrations

UHSU Groundwater in Weathered Bedrock Across OU2

Groundwater Geochemistry Report

January 1995

Figure 5-21



EXPLANATION

Streams and Drainages

Paved Roads

Dirt Roads

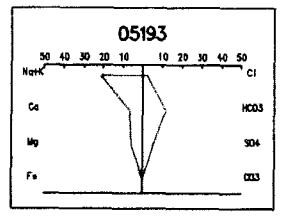
Industrial Area and Security Zone Boundaries

Surface Water Impoundments

Buildings

Upper Hydrostratigraphic Unit Monitoring Well

Diagram of dissolved major-ion concentrations ("Stiff plot") for selected wells. *Concentrations are in* milliequivalents per liter.



NOTE: Wells showing a strong charge imbalance contain significant quantities of NO3, as indicated by dashed lines representing combined HCO3 + NO3.

Scale = 1 : 8400
1 inch = 700 feet

350 0 700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Major-Ion Concentrations

UHSU Groundwater in Surficial Deposits Across OU4

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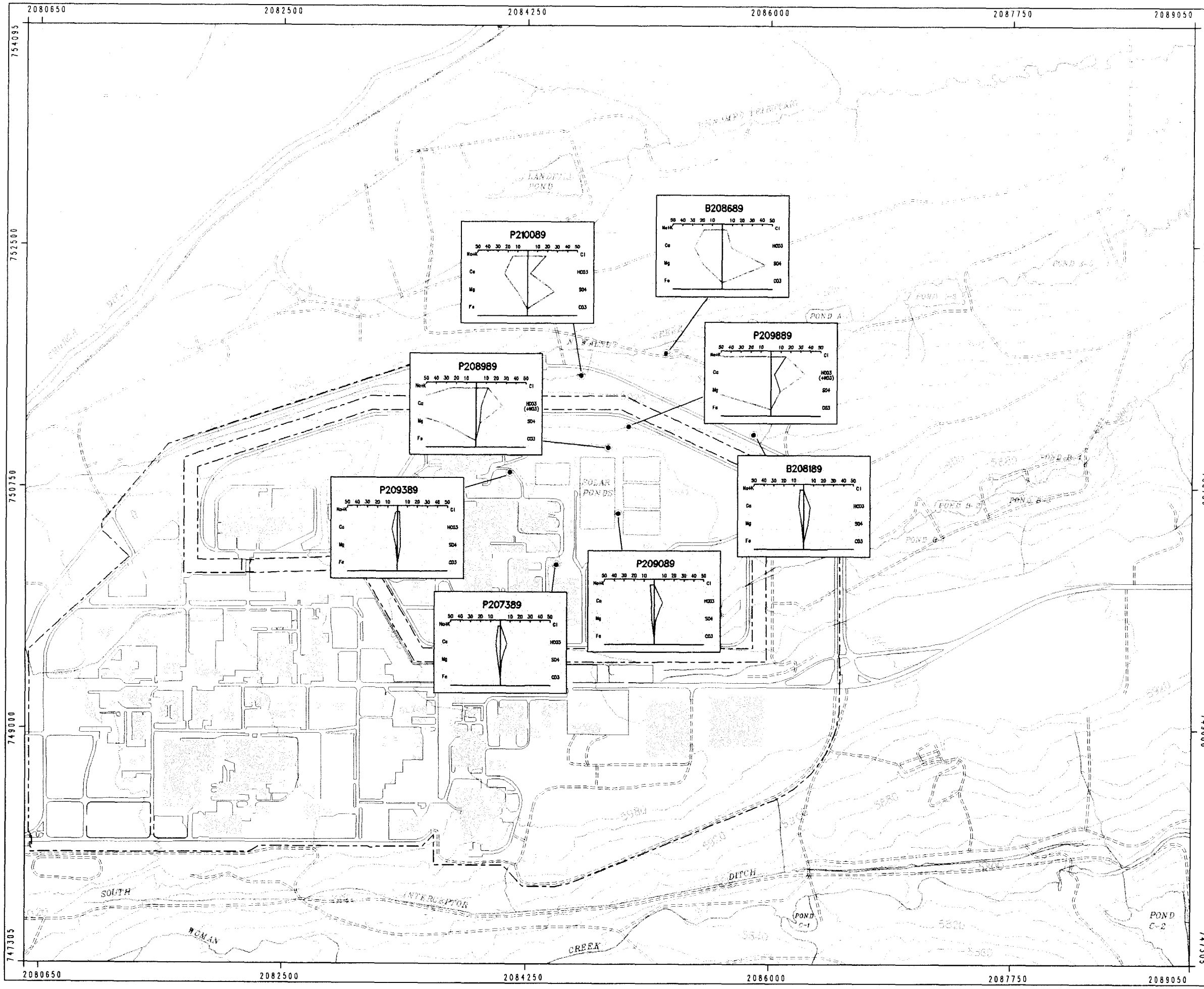
Figure 5-22



EXPLANATION

Streams and Drainages

Paved Roads

Dirt Roads

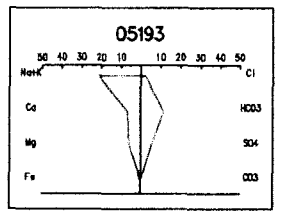
Industrial Area and Security Zone Boundaries

Surface Water Impoundments

Buildings

Upper Hydrostratigraphic Unit Monitoring Well

Diagram of dissolved major-ion concentrations ("Stiff plot") for selected wells. Concentrations are in milliequivalents per liter.



NOTE: Wells showing a strong charge imbalance contain significant quantities of NO3, as indicated by dashed lines representing combined HCO3 + NO3.

Scale = 1 : 8400
1 inch = 700 feet

350 0 700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Major-Ion Concentrations

UHSU Groundwater in Weathered Bedrock Across OU4

Groundwater Geochemistry Report

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Figure 5-23

EXPLANATION

Streams and Drainages

Paved Roads

Dirt Roads

Industrial Area and Security Zone Boundaries

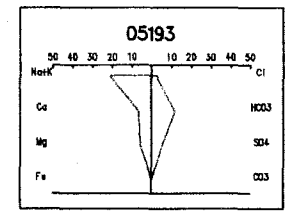
Surface Water Impoundments

Buildings

Upper Hydrostratigraphic Unit Monitoring Well

Upper Hydrostratigraphic Unit Bedrock Monitoring Well

Diagram of dissolved major-ion concentrations ("Stiff plot") for selected wells. Concentrations are in milliequivalents per liter.



N

Scale = 1 : 8400
1 inch = 700 feet

350 0 700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Major-Ion Concentrations

UHSU Groundwater
Across OU7

Groundwater Geochemistry Report

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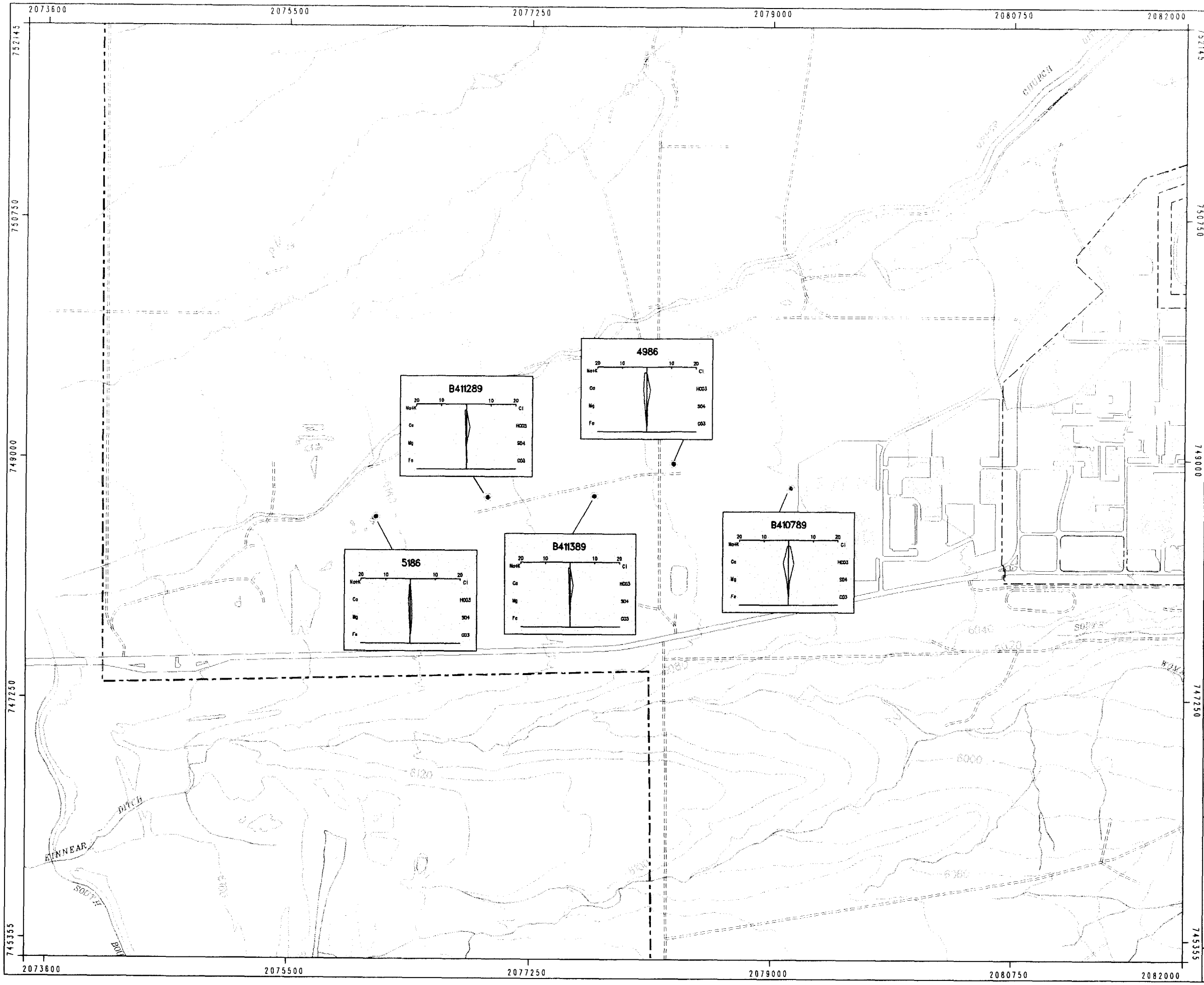
Figure 5-24



EXPLANATION

Streams and Drainages

Paved Roads

Dirt Roads

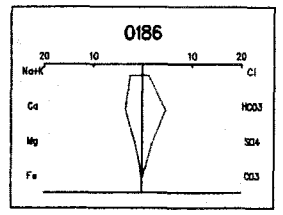
Industrial Area and Security Zone Boundaries

Surface Water Impoundments

Buildings

Upper Hydrostratigraphic Unit Monitoring Well

Diagram of dissolved major-ion concentrations ("Stiff plot") for selected wells. Concentrations are in milliequivalents per liter.



Scale = 1 : 8400
1 inch = 700 feet

350 0 700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Major-Ion Concentrations

UHSU Groundwater in Surficial Deposits Across OU11

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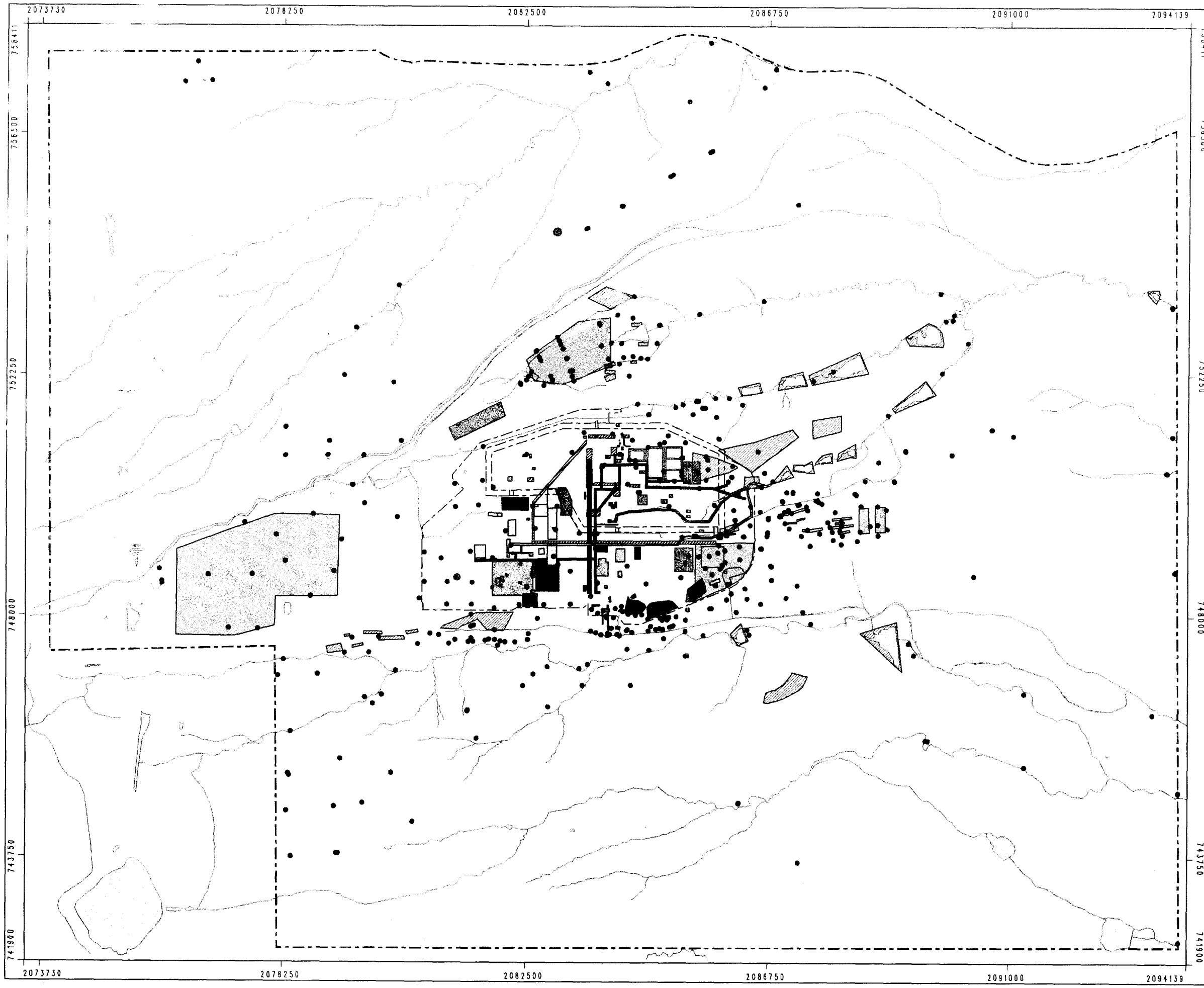
Figure 5-25



EXPLANATION

- Operable Unit 1
- Operable Unit 2
- Operable Unit 4
- Operable Unit 5
- Operable Unit 6
- Operable Unit 7
- Operable Unit 8
- Operable Unit 9
- Operable Unit 10
- Operable Unit 11
- Operable Unit 12
- Operable Unit 13
- Operable Unit 14
- Operable Unit 15
- Operable Unit 16
- UHSU Monitoring Wells
- Streams, Ditches, and Drainages
- Rocky Flats Plant Site and Security Zone Boundaries
- Rocky Flats Buffer Zone Boundary
- Surface Water Impoundments

Scale = 1 : 20400
1 inch = 1700 feet

860 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Locations
of
UHSU
Monitoring Wells

Groundwater Geochemistry Report

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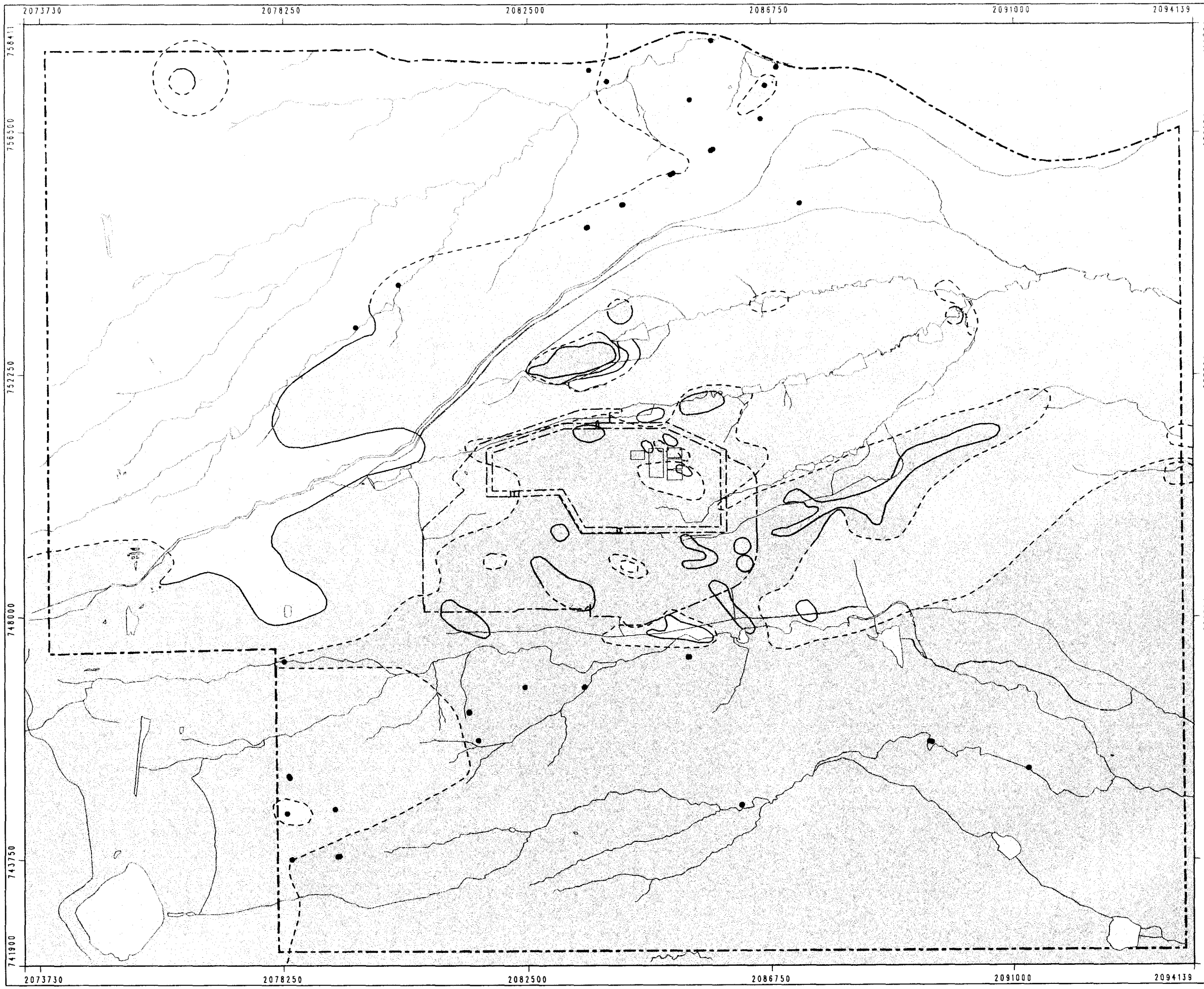
Figure 6-20



EXPLANATION

- > 200 ug/L
- 100 - 200 ug/L
- 50 - 100 ug/L
- < 50 ug/L

- Isoconcentration Lines (dashed where inferred)
- Background Wells
- Streams, Ditches, and Drainages
- Rocky Flats Plant Site and Security Zone Boundaries
- Rocky Flats Buffer Zone Boundary
- Surface Water Impoundments

N

Scale = 1 : 20400
1 inch = 1700 feet

880 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

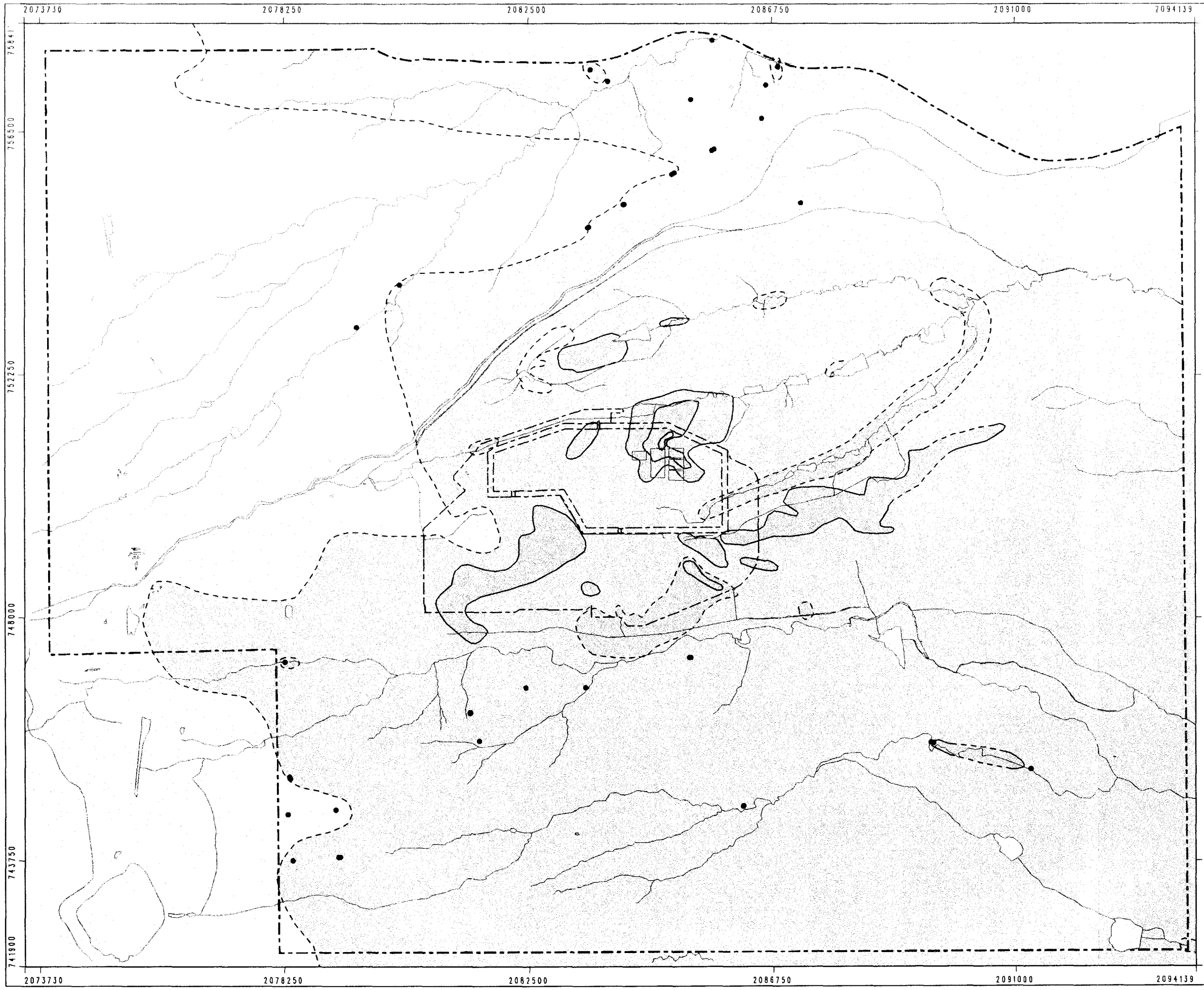
EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Dissolved Barium
in Upper Hydrostratigraphic Unit
Groundwater

Groundwater Geochemistry Report

January 1995 | Figure 6-21



EXPLANATION

- > 1,000 mg/L
- 500 - 1,000 mg/L
- 100 - 500 mg/L
- 25 - 100 mg/L
- < 25 mg/L

Isoconcentration Lines (dashed where inferred)

Background Wells

Streams, Ditches, and Drainages

Rocky Flats Plant Site and Security Zone Boundaries

Rocky Flats Buffer Zone Boundary

Surface Water Impoundments

Scale = 1 : 20400
1 inch = 1700 feet

850 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Dissolved Calcium
in Upper Hydrostratigraphic Unit
Groundwater

Groundwater Geochemistry Report

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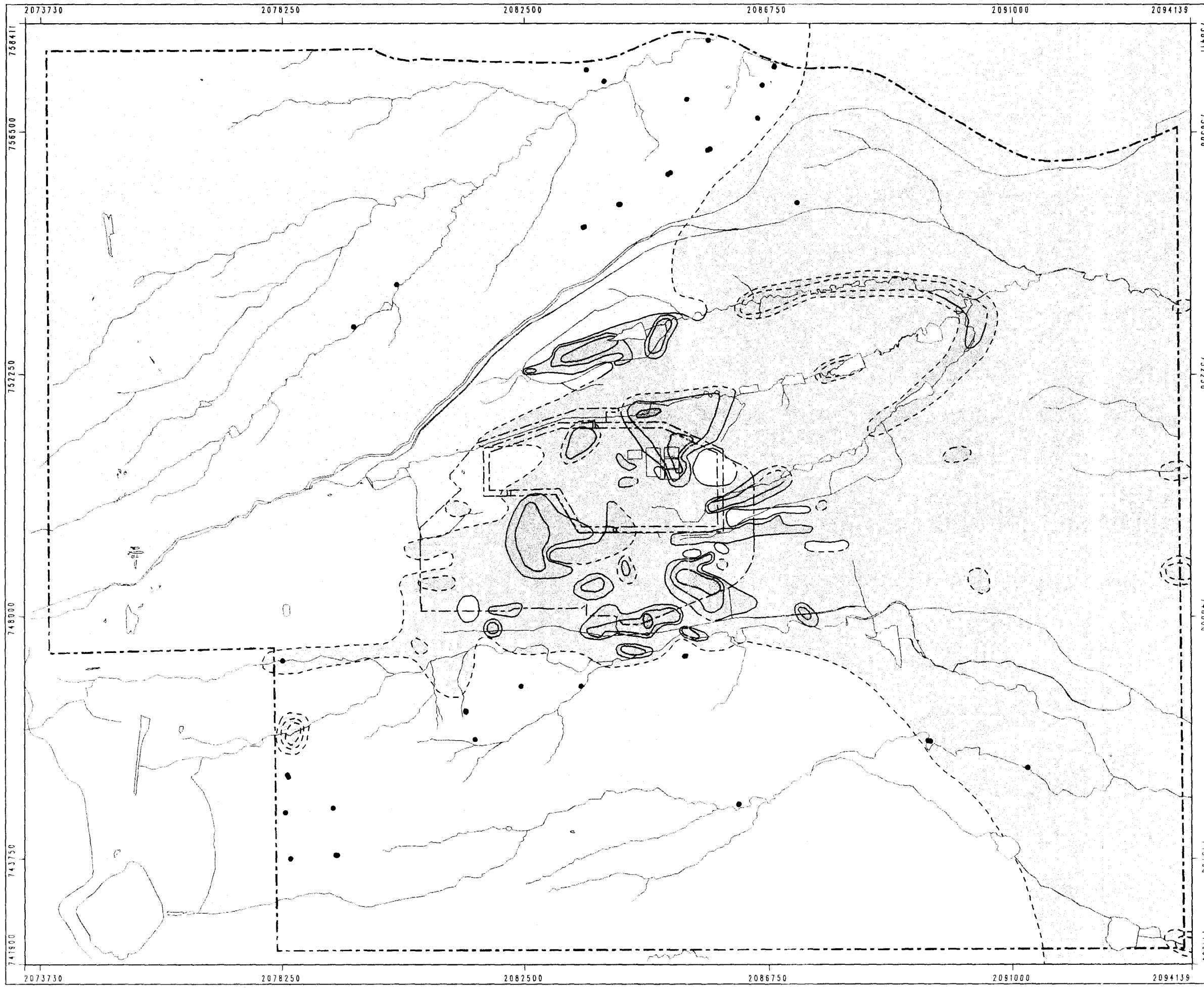

EXPLANATION

- > 500 mg/L
- 100 - 500 mg/L
- 50 - 100 mg/L
- 25 - 50 mg/L
- < 25 mg/L

Isoconcentration Lines
(dashed where inferred)

Background Wells

Streams, Ditches, and Drainages

Rocky Flats Plant Site and Security Zone Boundaries

Rocky Flats Buffer Zone Boundary

Surface Water Impoundments

N

Scale = 1 : 20400
1 inch = 1700 feet

850 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Chloride
in Upper Hydrostratigraphic Unit
Groundwater

Groundwater Geochemistry Report

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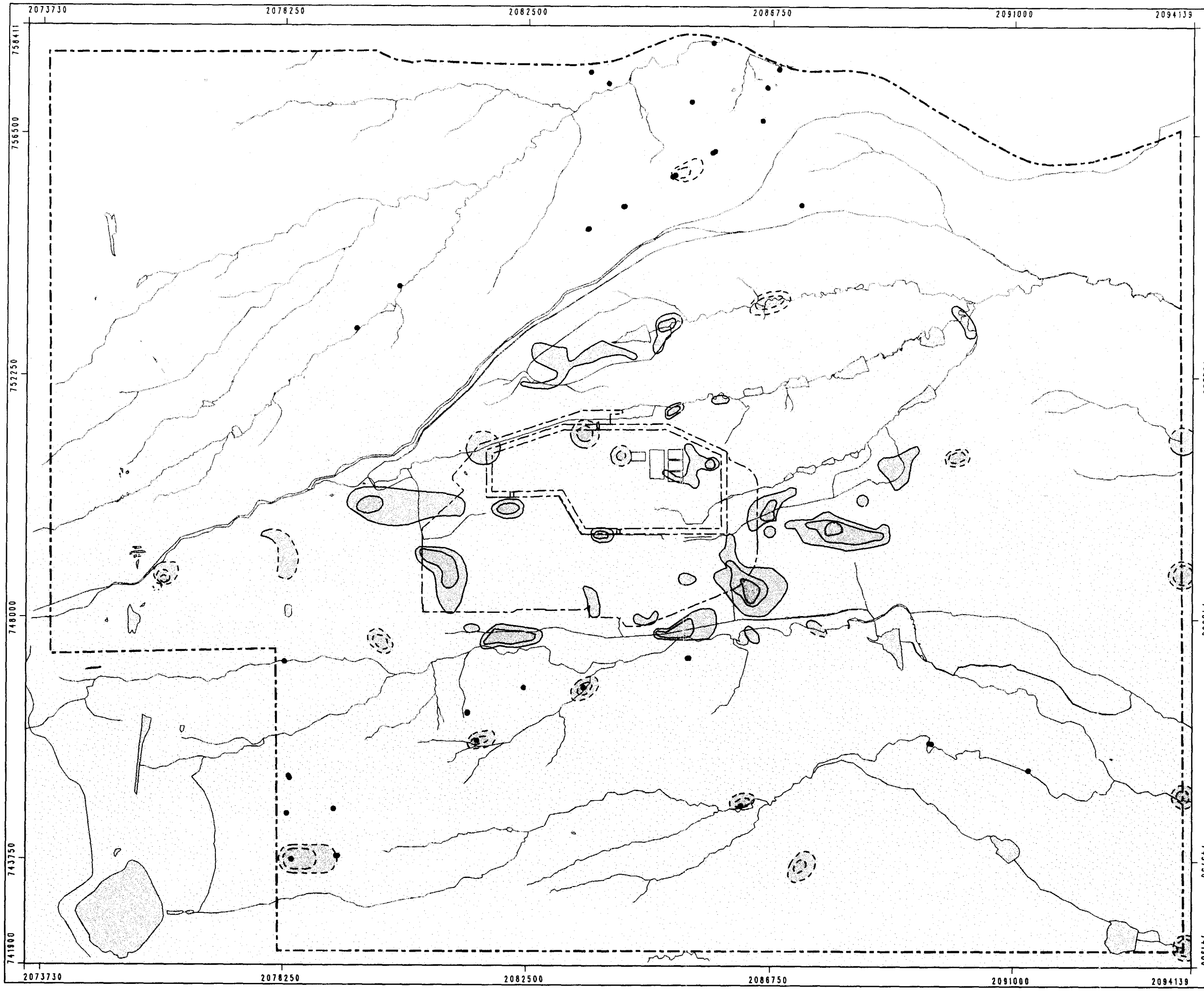
Figure 6-23



EXPLANATION

- > 10 mg/L
- 5 - 10 mg/L
- 2.5 - 5 mg/L
- < 2.5 mg/L

- Isoconcentration Lines (dashed where inferred)
- Background Wells
- Streams, Ditches, and Drainages
- Rocky Flats Plant Site and Security Zone Boundaries
- Rocky Flats Buffer Zone Boundary
- Surface Water Impoundments

N

Scale = 1 : 20400
1 inch = 1700 feet

880 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Carbonate
in Upper Hydrostratigraphic Unit
Groundwater

Groundwater Geochemistry Report

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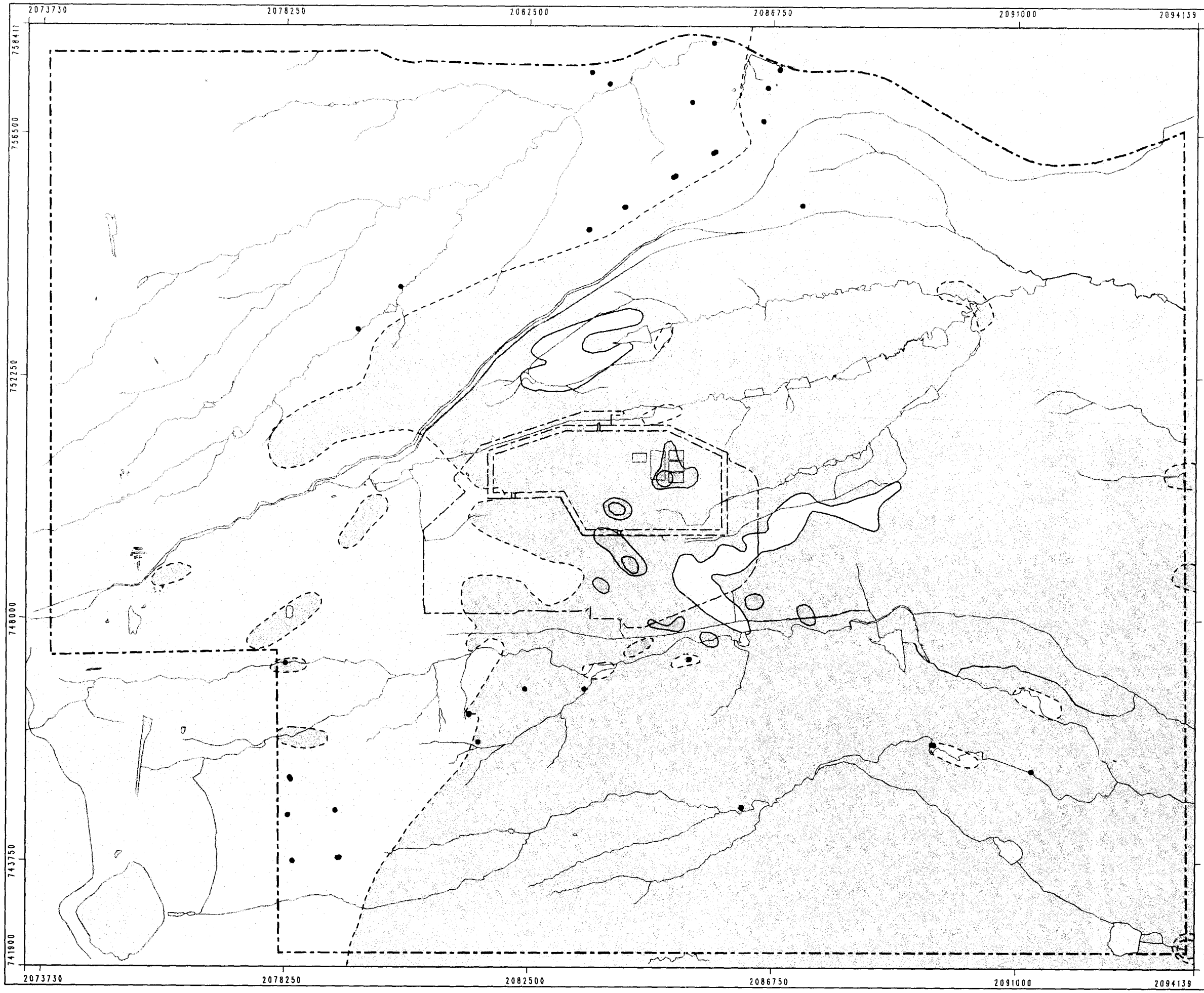

EXPLANATION

- > 5,000 ug/L
- 2,000 - 5,000 ug/L
- 500 - 2,000 ug/L
- < 500 ug/L

- Isoconcentration Lines (dashed where inferred)
- Background Wells
- Streams, Ditches, and Drainages
- Rocky Flats Plant Site and Security Zone Boundaries
- Rocky Flats Buffer Zone Boundary
- Surface Water Impoundments

Scale = 1 : 20400
1 inch = 1700 feet

850 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Fluoride
in Upper Hydrostratigraphic Unit
Groundwater

Groundwater Geochemistry Report

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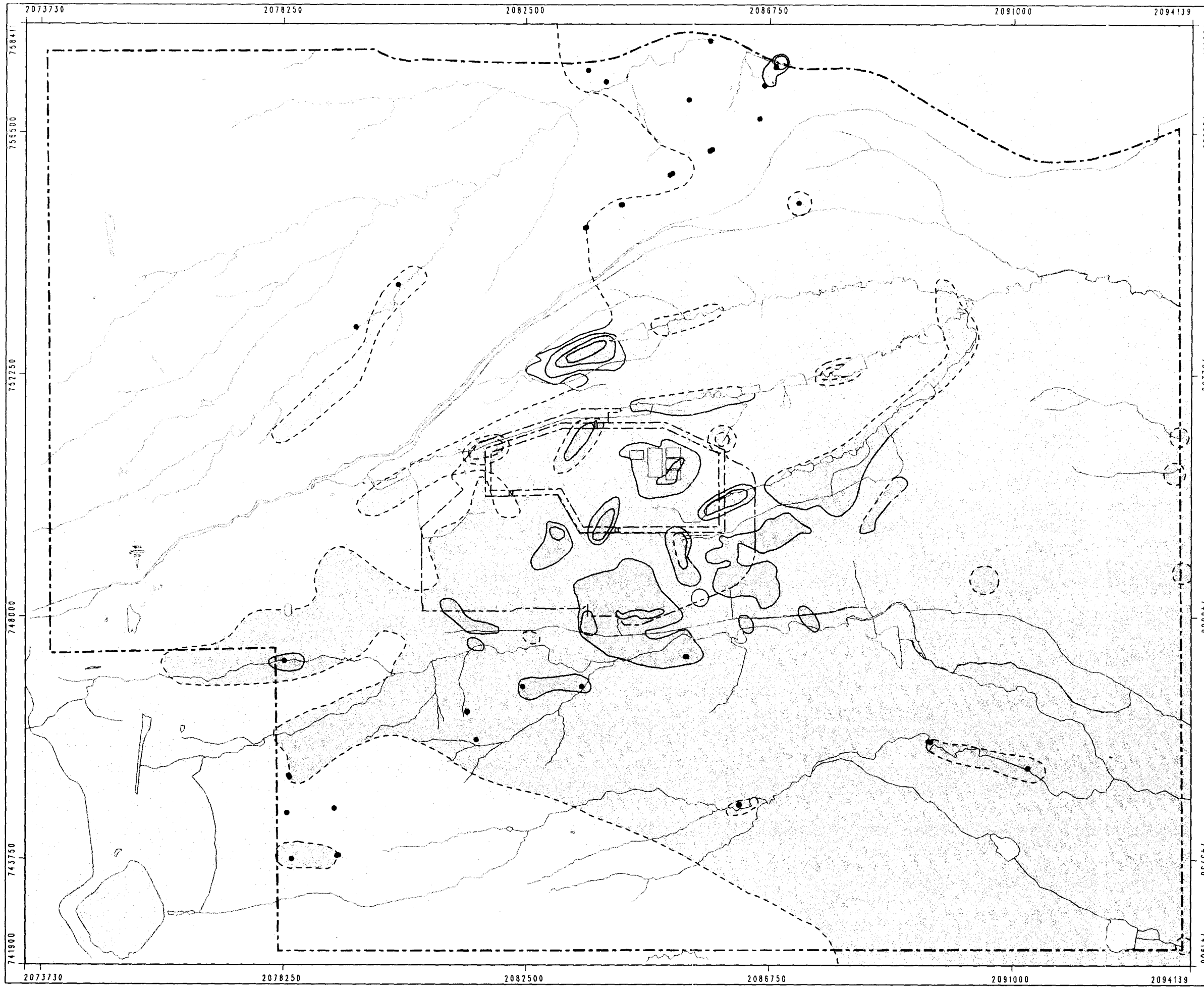

EXPLANATION

- > 1,000 mg/L
- 500 - 1,000 mg/L
- 250 - 500 mg/L
- 100 - 250 mg/L
- < 100 mg/L

Isoconcentration Lines
(dashed where inferred)

Background Wells

Streams,Ditches, and Drainages

Rocky Flats Plant Site and Security Zone Boundaries

Rocky Flats Buffer Zone Boundary

Surface Water Impoundments

Scale = 1 : 20400
1 inch = 1700 feet

850 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Bicarbonate
in Upper Hydrostratigraphic Unit
Groundwater

Groundwater Geochemistry Report

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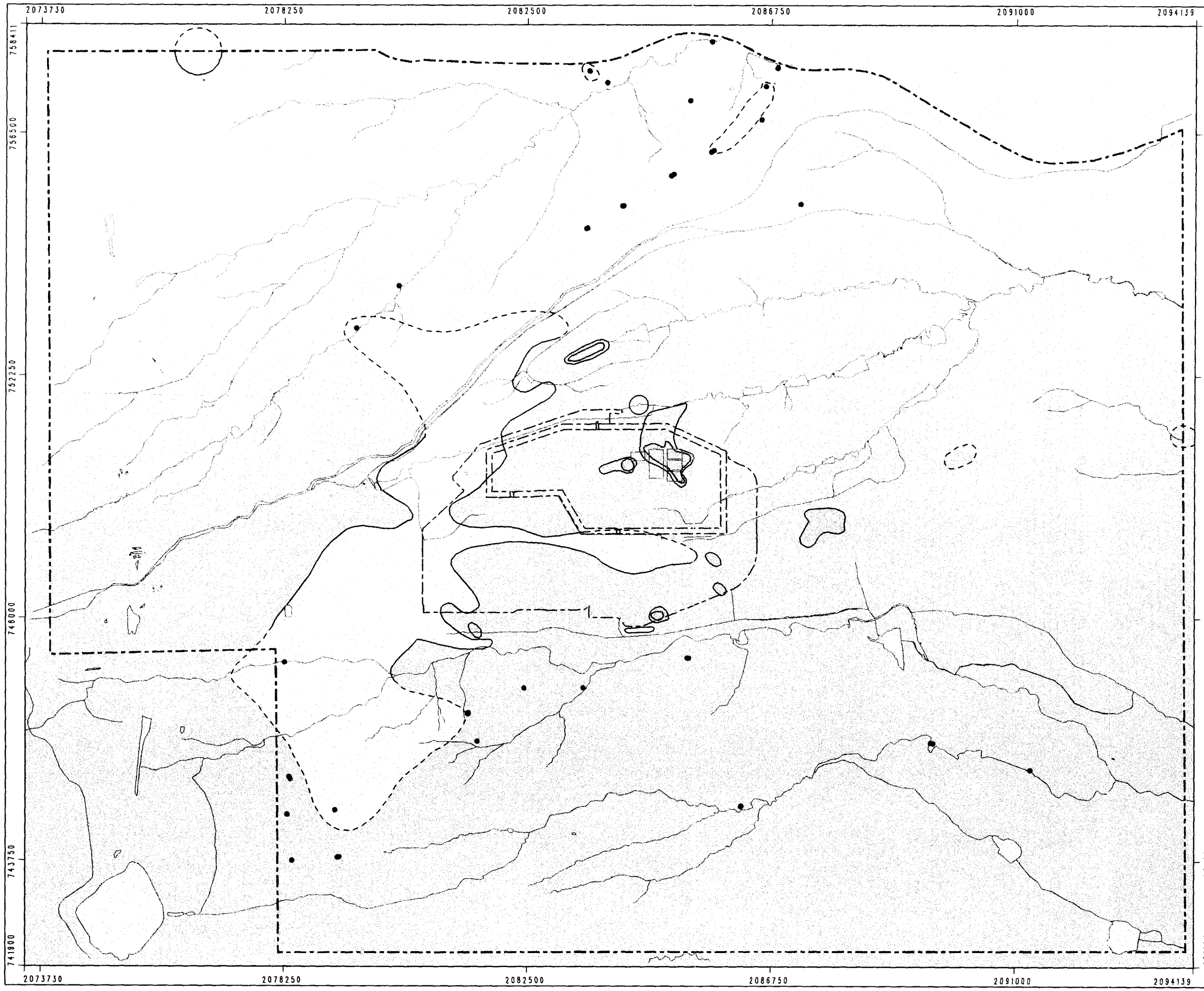

EXPLANATION

- > 10 mg/L
- 5 - 10 mg/L
- 1 - 5 mg/L
- < 1 mg/L

Isoconcentration Lines
(dashed where inferred)

Background Wells

Streams,Ditches, and Drainages

Rocky Flats Plant Site and Security Zone Boundaries

Rocky Flats Buffer Zone Boundary

Surface Water Impoundments

Scale = 1 : 20400
1 inch = 1700 feet

850 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Dissolved Potassium
in Upper Hydrostratigraphic Unit
Groundwater

Groundwater Geochemistry Report

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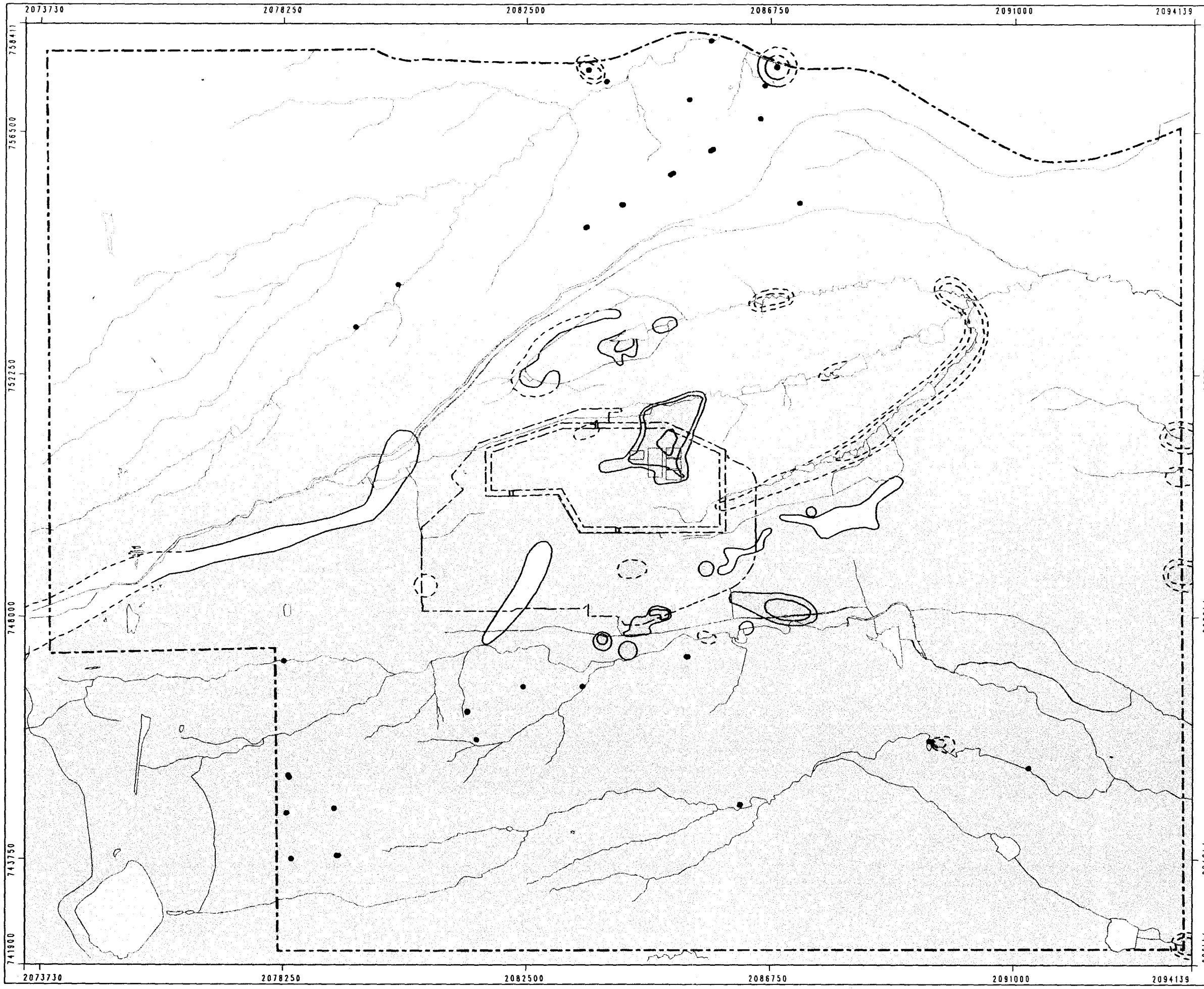
Figure 6-27



EXPLANATION

- > 500 ug/L
- 100 - 500 ug/L
- 50 - 100 ug/L
- 10 - 50 ug/L
- < 10 ug/L

Isoconcentration Lines (dashed where inferred)

Background Wells

Streams, Ditches, and Drainages

Rocky Flats Plant Site and Security Zone Boundaries

Rocky Flats Buffer Zone Boundary

Surface Water Impoundments

Scale = 1 : 20400
1 inch = 1700 feet

880 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

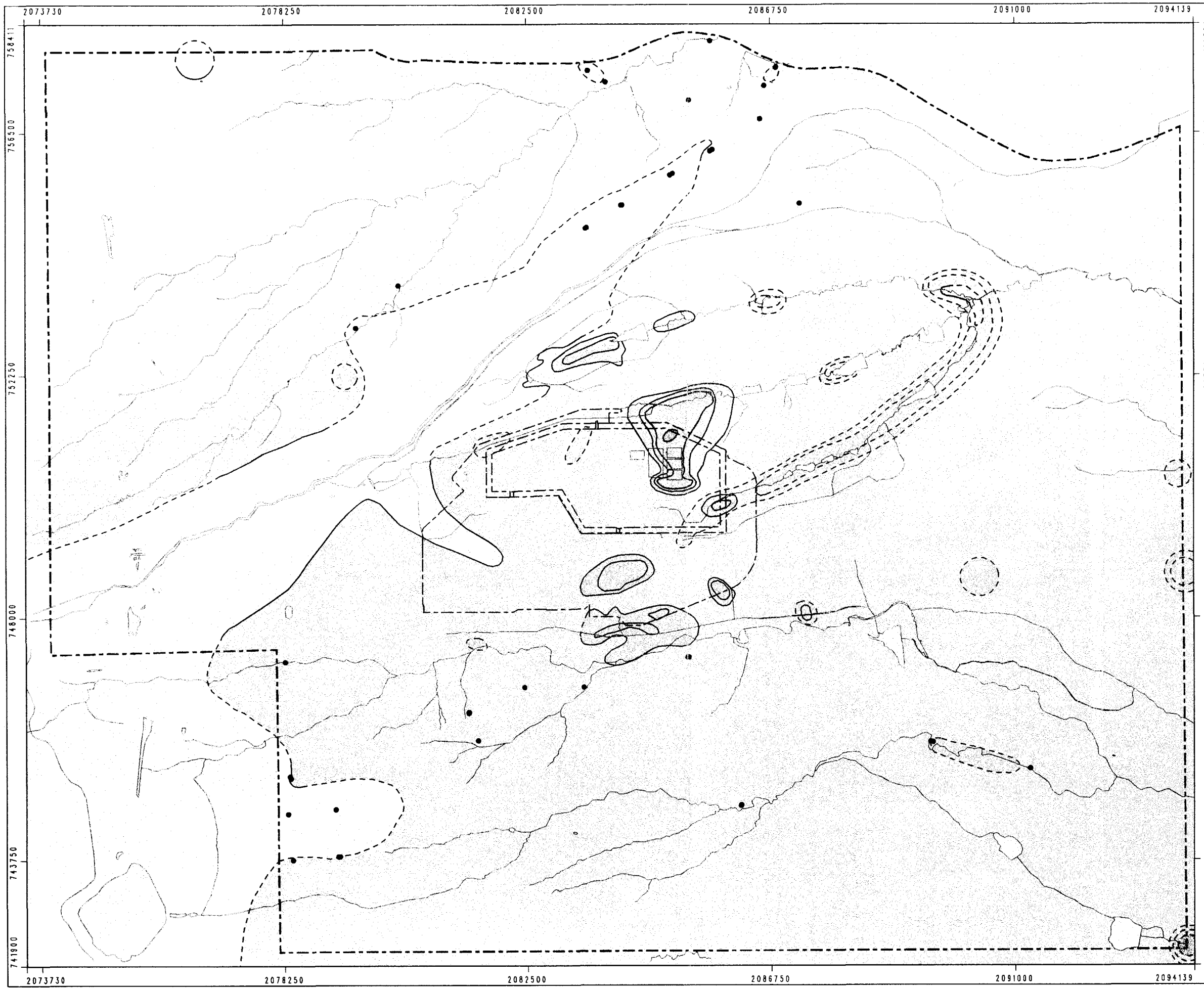
EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Dissolved Lithium in Upper Hydrostratigraphic Unit Groundwater

Groundwater Geochemistry Report

January 1995 | Figure 6-28



EXPLANATION

- > 500 mg/L
- 100 - 500 mg/L
- 50 - 100 mg/L
- 25 - 50 mg/L
- 5 - 25 mg/L
- < 5 mg/L
- Isoconcentration Lines (dashed where inferred)
- Background Wells
- Streams, Ditches, and Drainages
- Rocky Flats Plant Site and Security Zone Boundaries
- Rocky Flats Buffer Zone Boundary
- Surface Water Impoundments

N

Scale = 1 : 20400
1 inch = 1700 feet

850 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

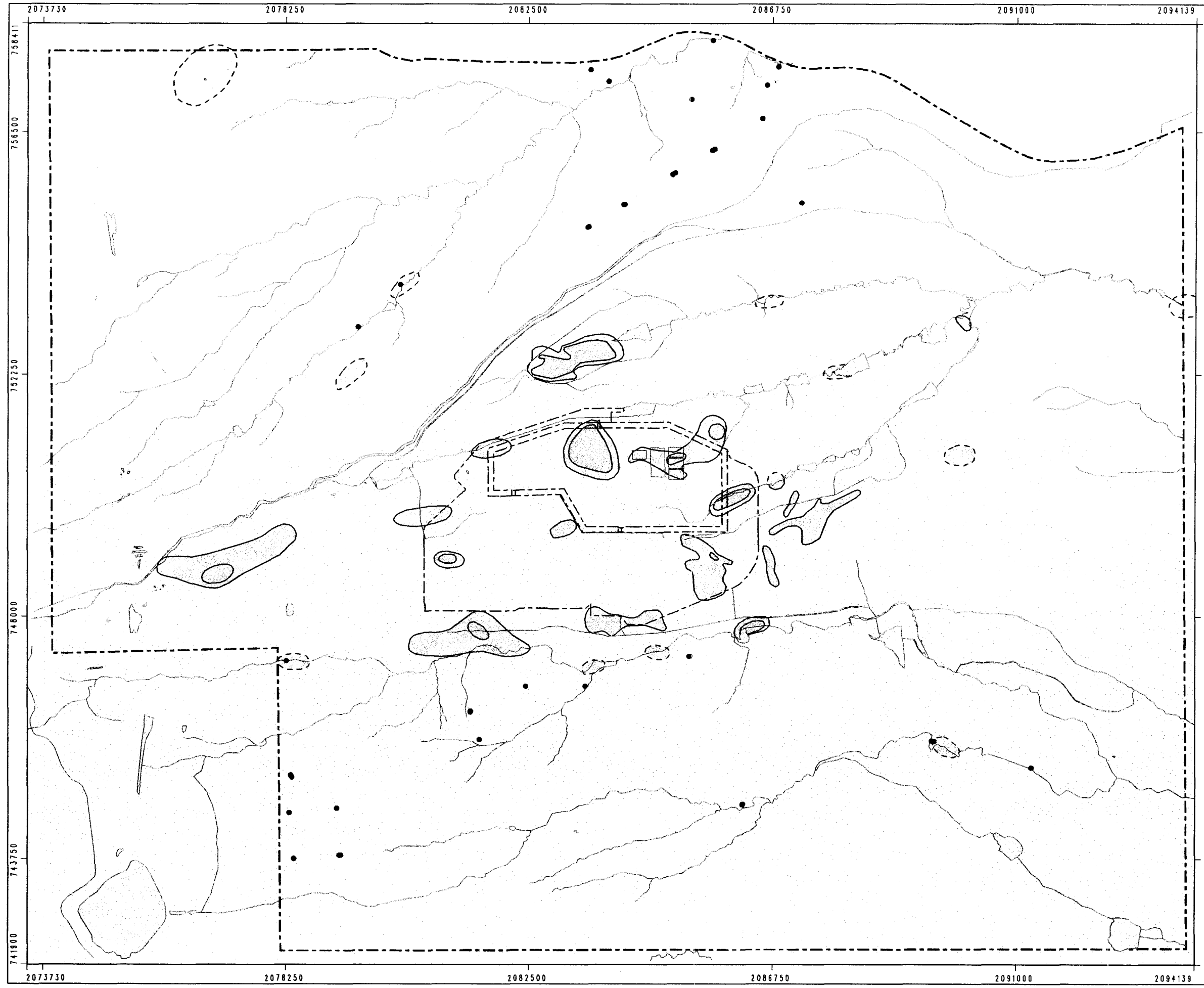
EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Dissolved Magnesium
in Upper Hydrostratigraphic Unit
Groundwater

Groundwater Geochemistry Report

January 1995 | Figure 6-29



EXPLANATION

> 1,000 ug/L

100 - 1,000 ug/L

< 100 ug/L

Isoconcentration Lines (dashed where inferred)

Background Wells

Streams, Ditches, and Drainages

Rocky Flats Plant Site and Security Zone Boundaries

Rocky Flats Buffer Zone Boundary

Surface Water Impoundments

Scale = 1 : 20400
1 inch = 1700 feet

850 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

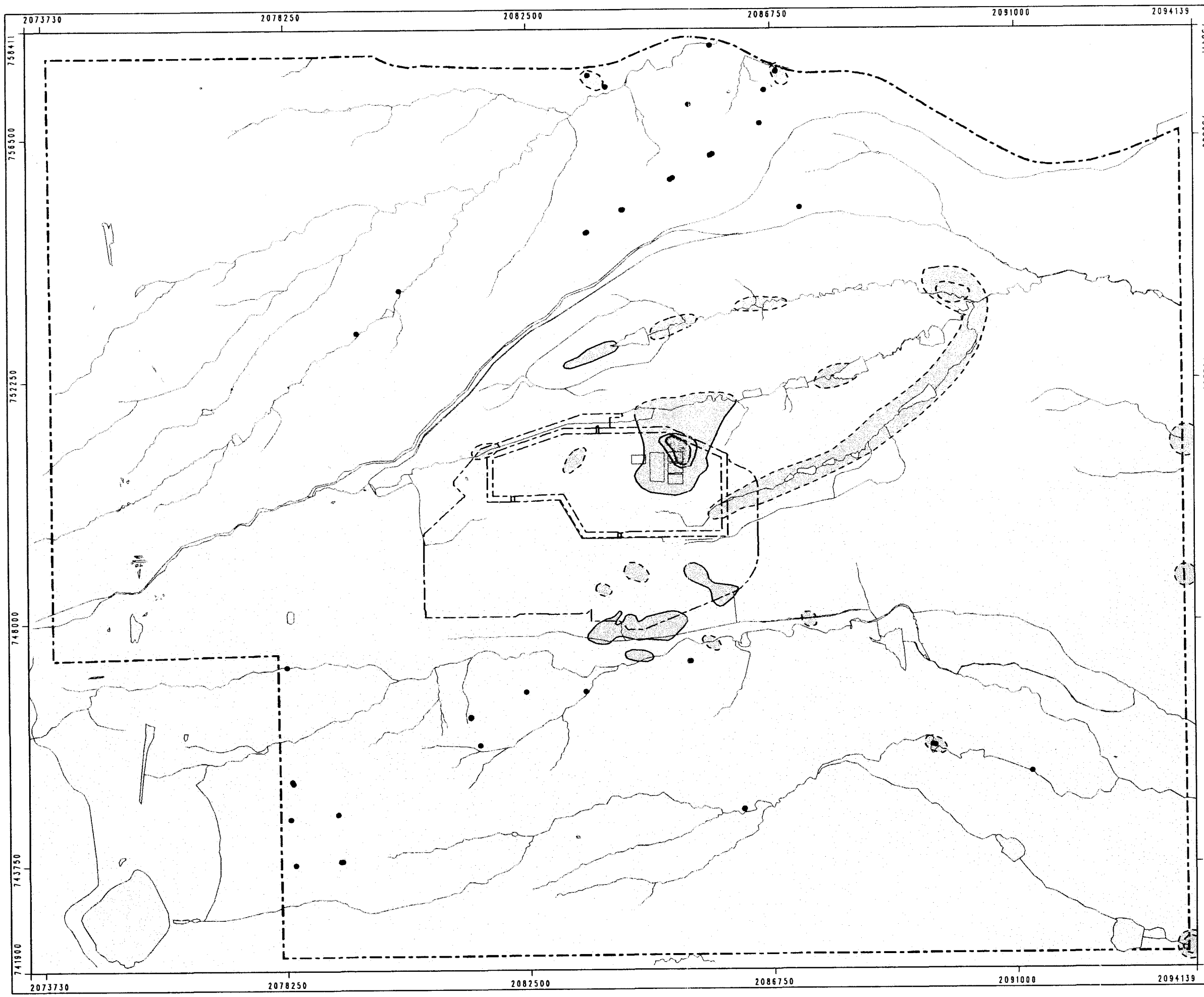
Rocky Flats Site, Golden, Colorado

Dissolved Manganese in Upper Hydrostratigraphic Unit Groundwater

Groundwater Geochemistry Report

January 1995

Figure 6-30



EXPLANATION

- > 1,000 mg/L
- 500 - 1,000 mg/L
- 100 - 500 mg/L
- < 100 mg/L

- Isoconcentration Lines (dashed where inferred)
- Background Wells
- Streams, Ditches, and Drainages
- Rocky Flats Plant Site and Security Zone Boundaries
- Rocky Flats Buffer Zone Boundary
- Surface Water Impoundments

N

Scale = 1 : 20400
1 inch = 1700 feet

880 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

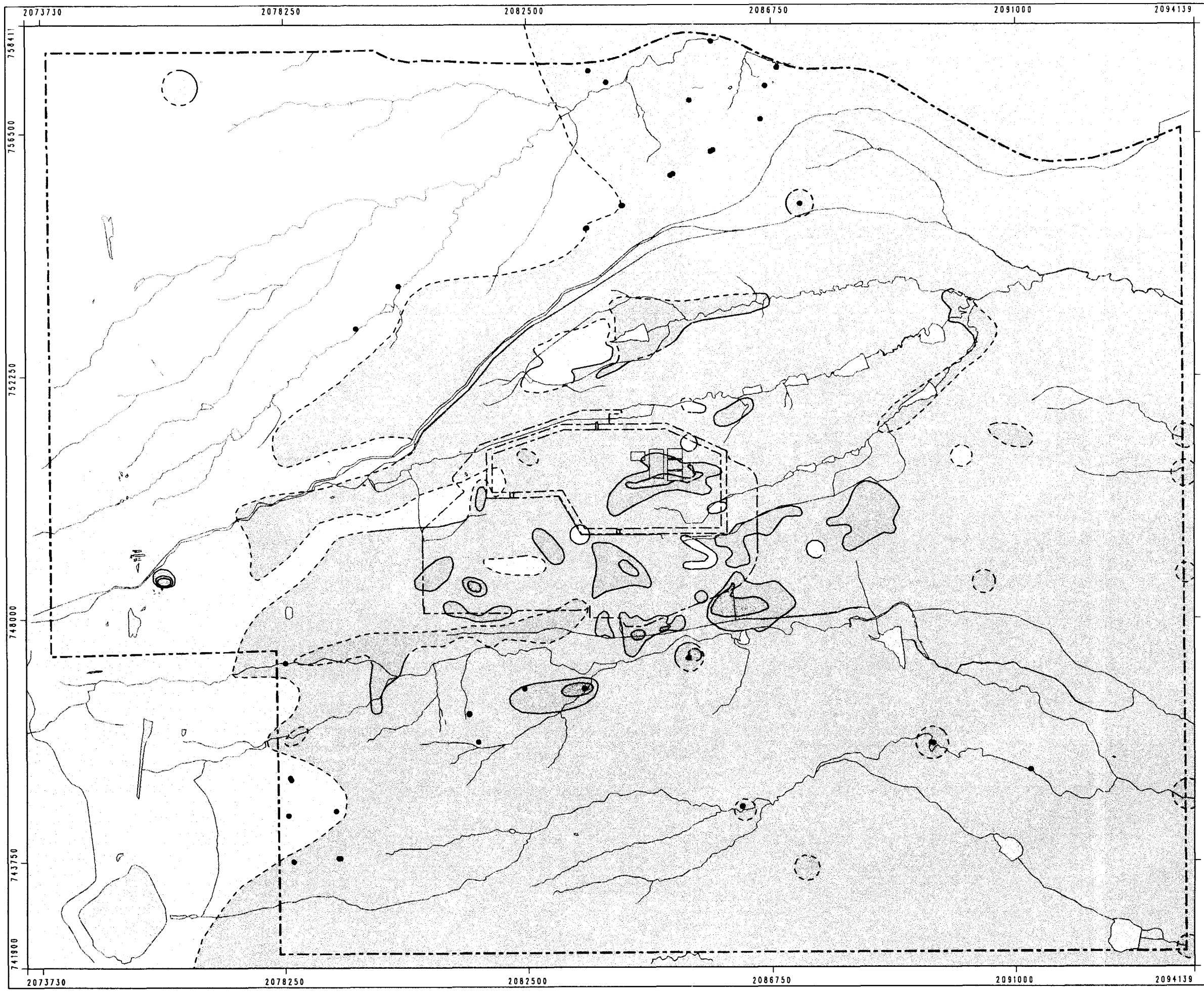
Rocky Flats Site, Golden, Colorado

Dissolved Sodium in Upper Hydrostratigraphic Unit Groundwater

Groundwater Geochemistry Report

January 1995

Figure 6-31



EXPLANATION

- > 8 pH
- 7.5 - 8 pH
- 7 - 7.5 pH
- < 7 pH

- Isoconcentration Lines (dashed where inferred)
- Background Wells
- Streams, Ditches, and Drainages
- Rocky Flats Plant Site and Security Zone Boundaries
- Rocky Flats Buffer Zone Boundary
- Surface Water Impoundments

N

Scale = 1 : 20400
1 inch = 1700 feet

880 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

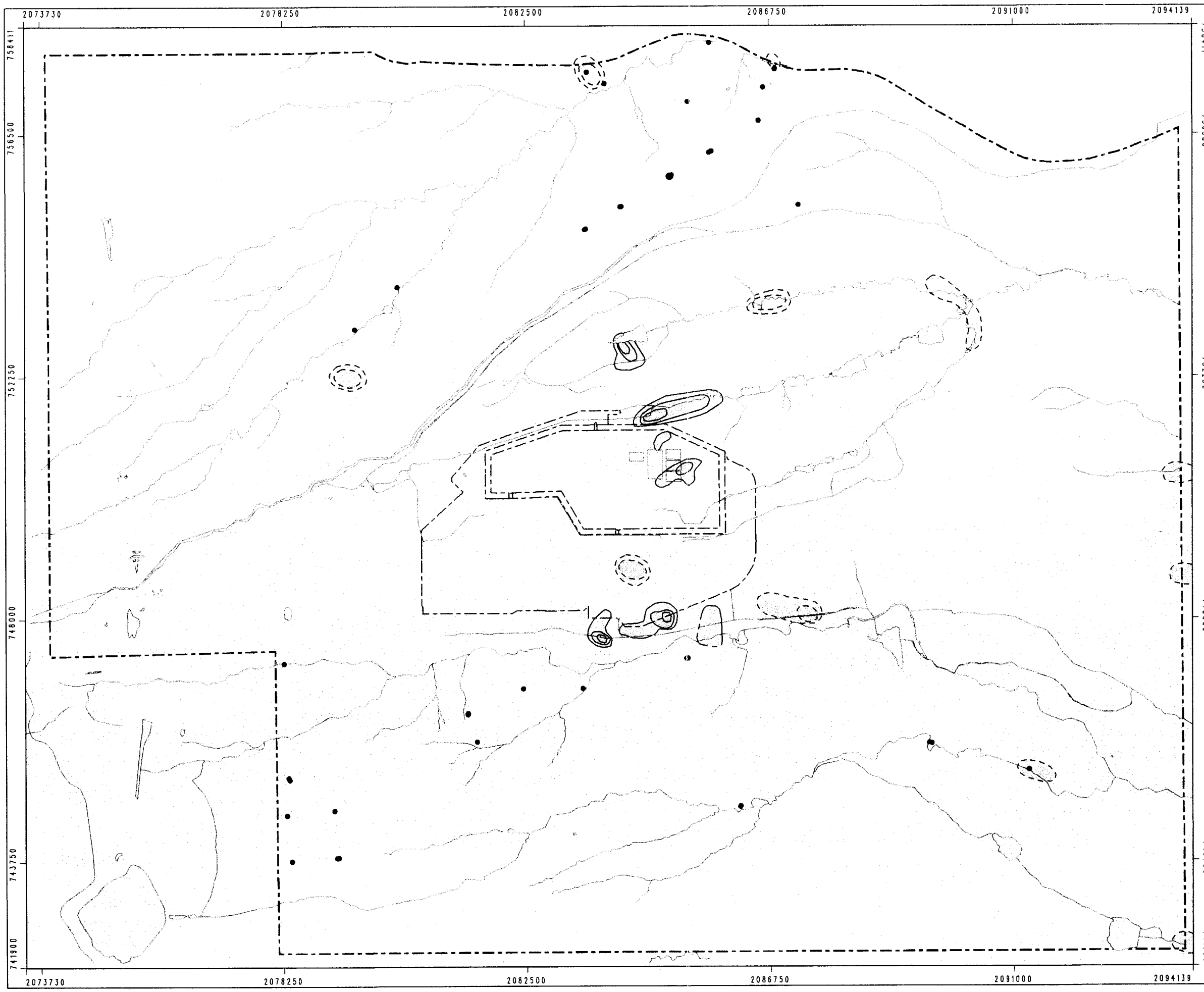
EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

pH
in Upper Hydrostratigraphic Unit
Groundwater

Groundwater Geochemistry Report

January 1995 | Figure 6-32



EXPLANATION

- > 500 ug/L
- 100 - 500 ug/L
- 10 - 100 ug/L
- < 10 ug/L

- Isoconcentration Lines
- (dashed where inferred)
- Background Wells
- Streams,Ditches, and Drainages
- Rocky Flats Plant Site and Security Zone Boundaries
- Rocky Flats Buffer Zone Boundary
- Surface Water Impoundments

Scale = 1 : 20400
1 inch = 1700 feet

880 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

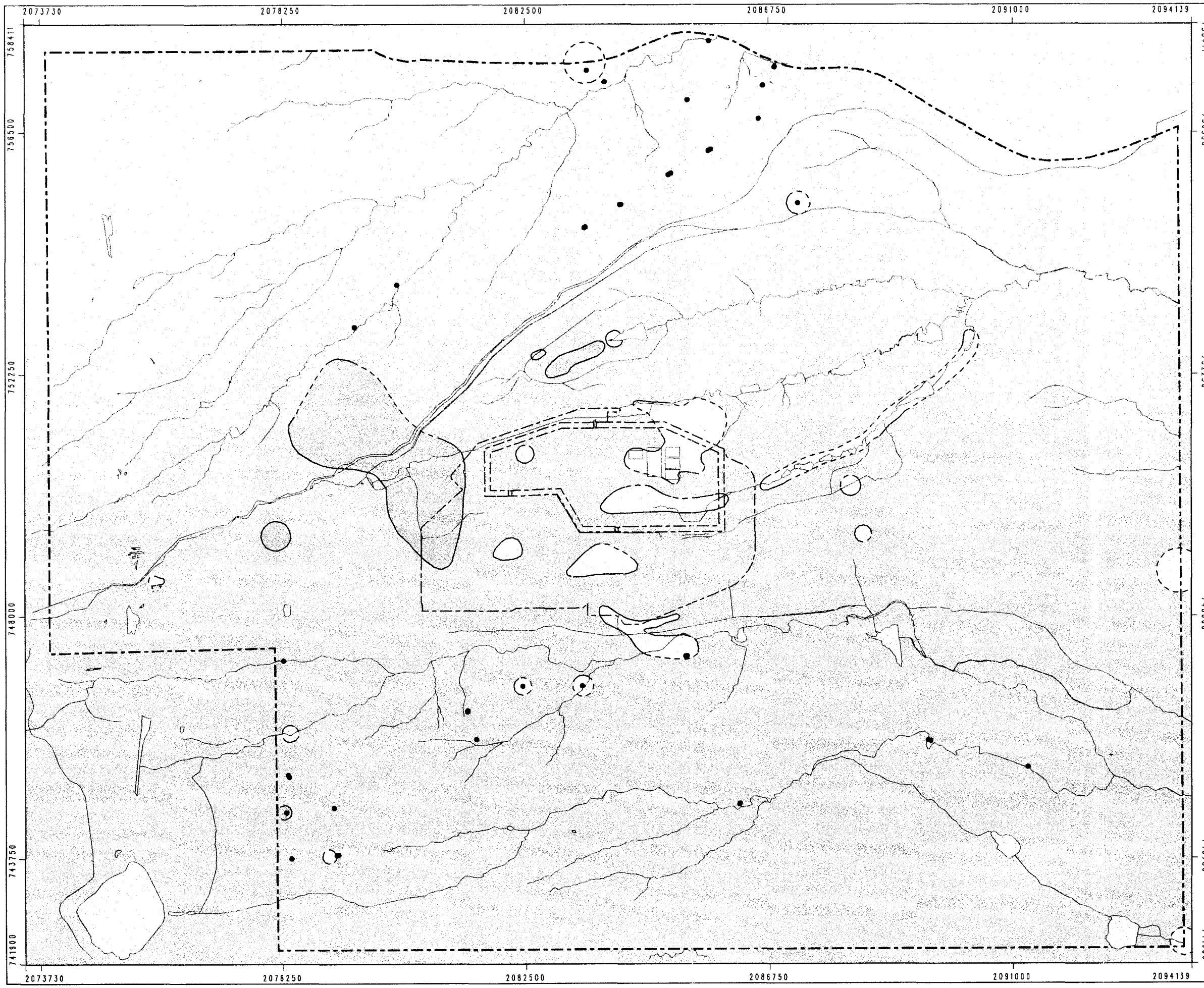
EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Dissolved Selenium
in Upper Hydrostratigraphic Unit
Groundwater

Groundwater Geochemistry Report

January 1995 | Figure 6-33



EXPLANATION

> 25 mg/L

10 - 25 mg/L

< 10 mg/L

Isoconcentration Lines
(dashed where inferred)

Background Wells

Streams, Ditches, and Drainages

Rocky Flats Plant Site and Security Zone Boundaries

Rocky Flats Buffer Zone Boundary

Surface Water Impoundments

Scale = 1 : 20400
1 inch = 1700 feet

850 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

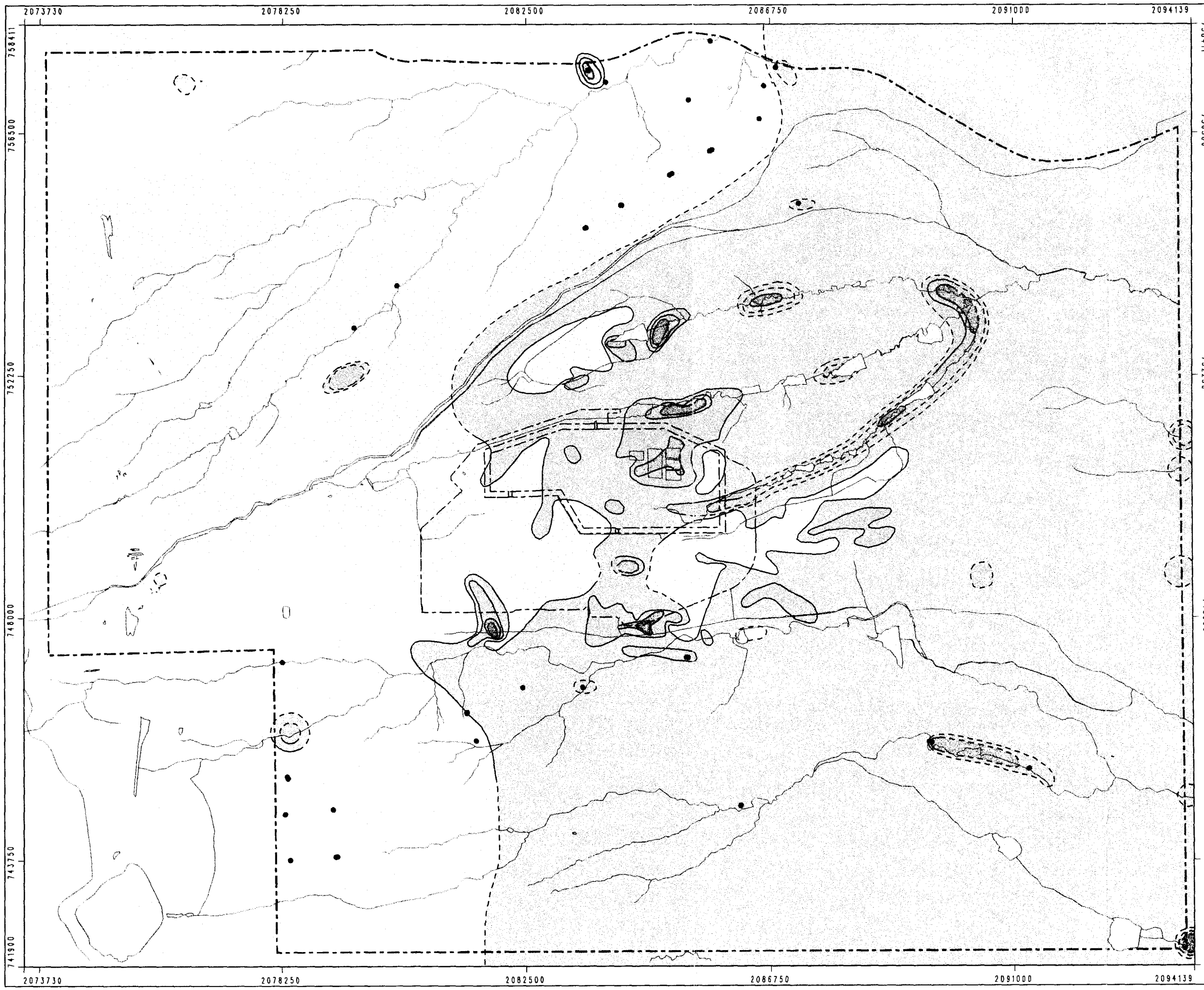
Silica

in Upper Hydrostratigraphic Unit Groundwater

Groundwater Geochemistry Report

January 1995

Figure 6-34



EXPLANATION

- > 1,000 mg/L
- 500 - 1,000 mg/L
- 100 - 500 mg/L
- 50 - 100 mg/L
- < 50 mg/L

Isoconcentration Lines (dashed where inferred)

Background Wells

Streams, Ditches, and Drainages

Rocky Flats Plant Site and Security Zone Boundaries

Rocky Flats Buffer Zone Boundary

Surface Water Impoundments

Scale = 1 : 20400
1 inch = 1700 feet

880 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

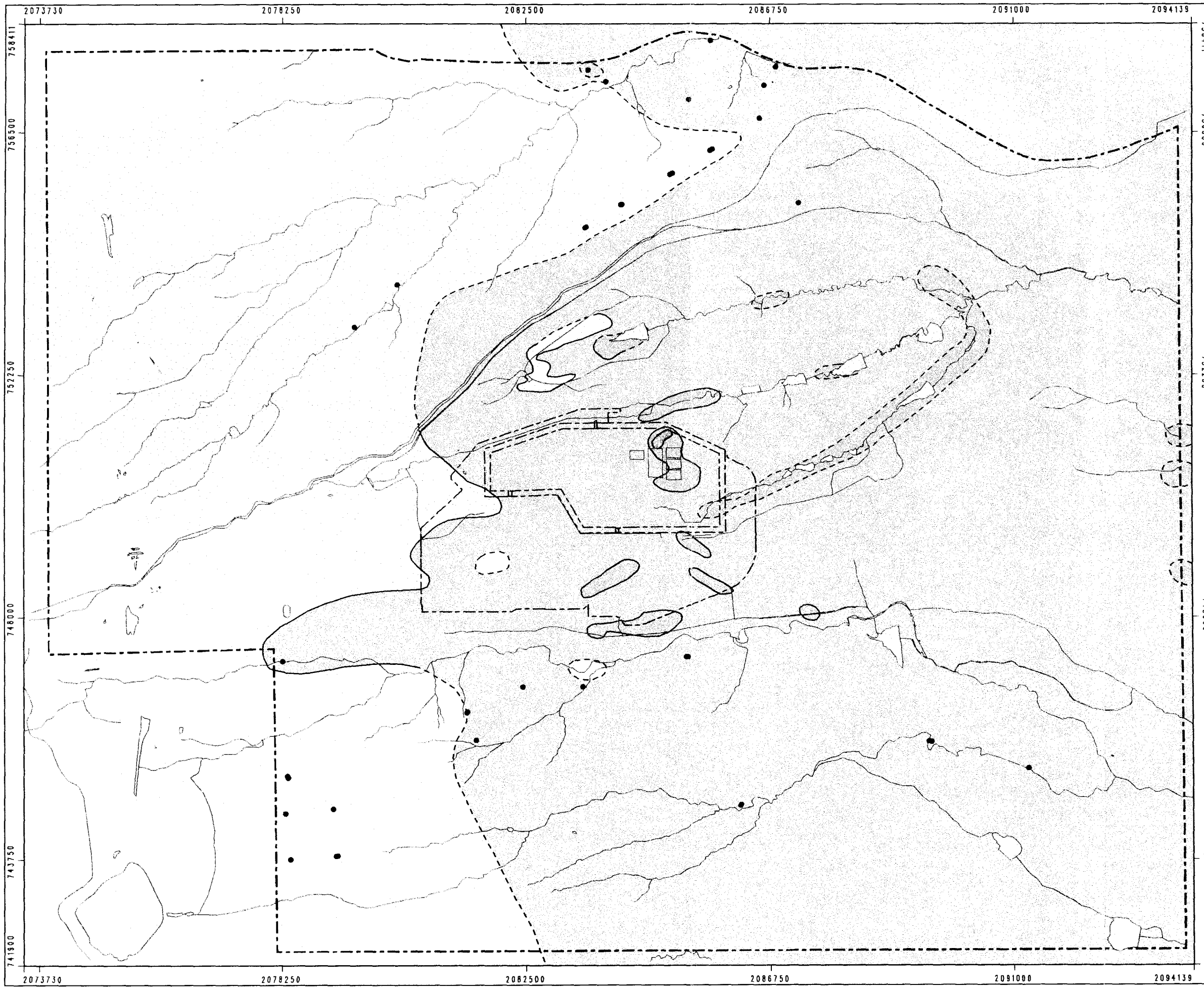
EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Sulfate in Upper Hydrostratigraphic Unit Groundwater

Groundwater Geochemistry Report

January 1995 | Figure 6-35



EXPLANATION

- > 10,000 ug/L
- 1,000 - 10,000 ug/L
- 250 - 1,000 ug/L
- < 250 ug/L

- Isoconcentration Lines (dashed where inferred)
- Background Wells
- Streams, Ditches, and Drainages
- Rocky Flats Plant Site and Security Zone Boundaries
- Rocky Flats Buffer Zone Boundary
- Surface Water Impoundments

N

Scale = 1 : 20400
1 inch = 1700 feet

850 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

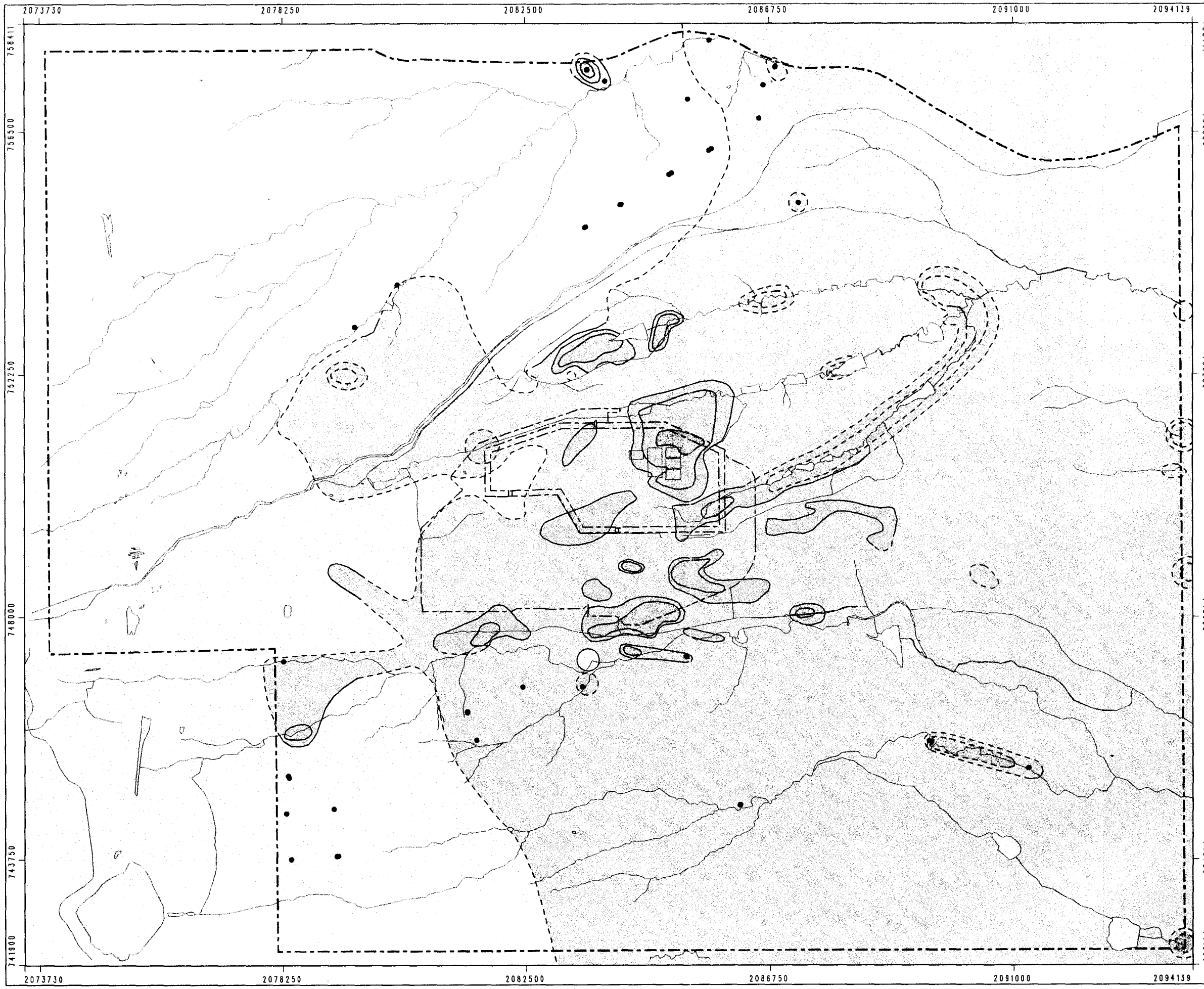
EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Dissolved Strontium in Upper Hydrostratigraphic Unit Groundwater

Groundwater Geochemistry Report

January 1995 | Figure 6-36



EXPLANATION

- > 10,000 mg/L
- 1,000 - 10,000 mg/L
- 500 - 1,000 mg/L
- 250 - 500 mg/L
- < 250 mg/L

Isoconcentration Lines (dashed where inferred)

Background Wells

Streams, Ditches, and Drainages

Rocky Flats Plant Site and Security Zone Boundaries

Rocky Flats Buffer Zone Boundary

Surface Water Impoundments

N

Scale = 1 : 20400
1 inch = 1700 feet

850 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

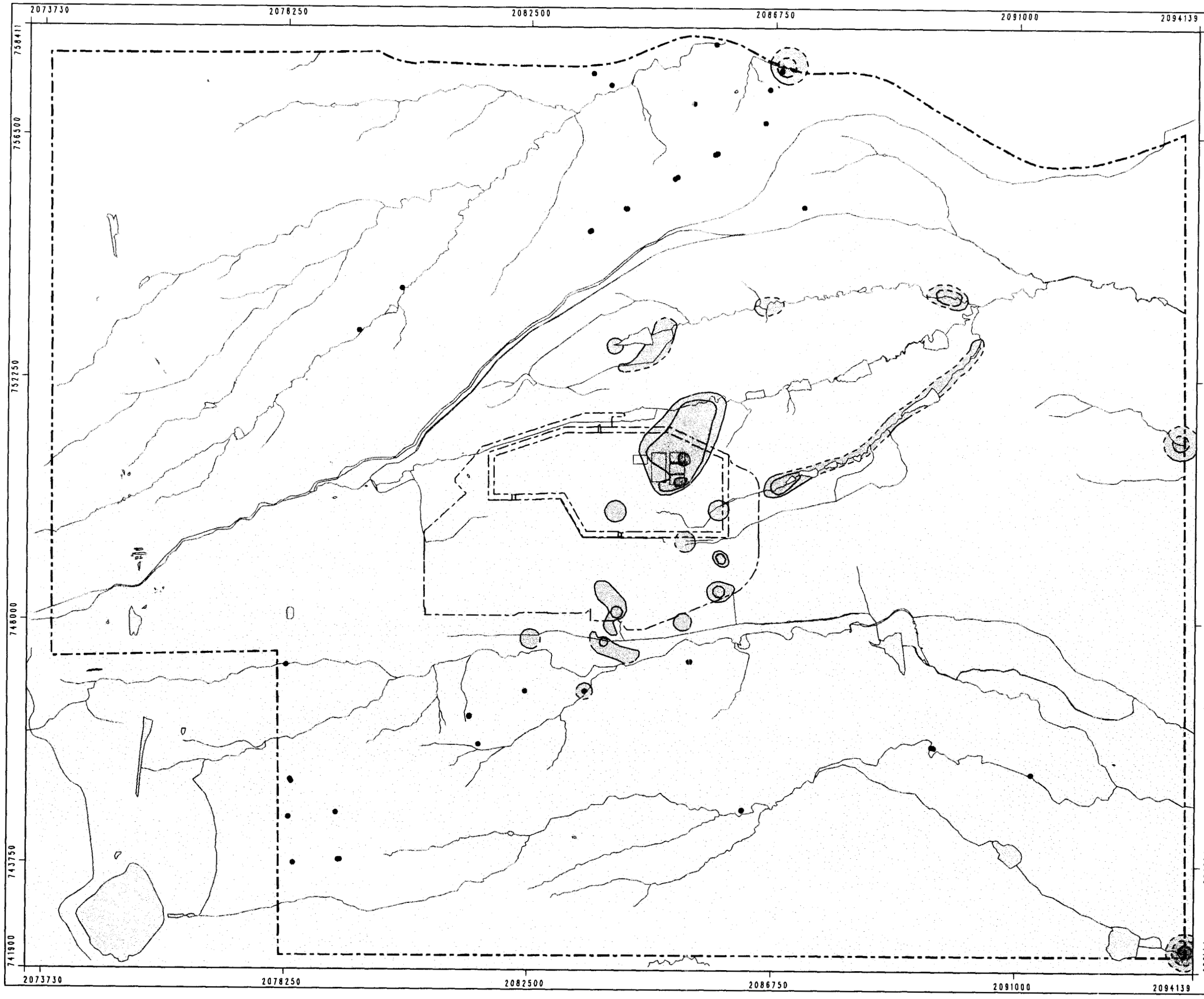
Rocky Flats Site, Golden, Colorado

Total Dissolved Solids in Upper Hydrostratigraphic Unit Groundwater

Groundwater Geochemistry Report

January 1995

Figure 6-37



EXPLANATION

- > 5 pCi/L
- 1 - 5 pCi/L
- 0.5 - 1 pCi/L
- < 0.5 pCi/L

- Isoconcentration Lines (dashed where inferred)
- Background Wells
- Streams, Ditches, and Drainages
- Rocky Flats Plant Site and Security Zone Boundaries
- Rocky Flats Buffer Zone Boundary
- Surface Water Impoundments

N

Scale = 1 : 20400
1 inch = 1700 feet

850 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Dissolved Uranium-235
in Upper Hydrostratigraphic Unit
Groundwater

Groundwater Geochemistry Report

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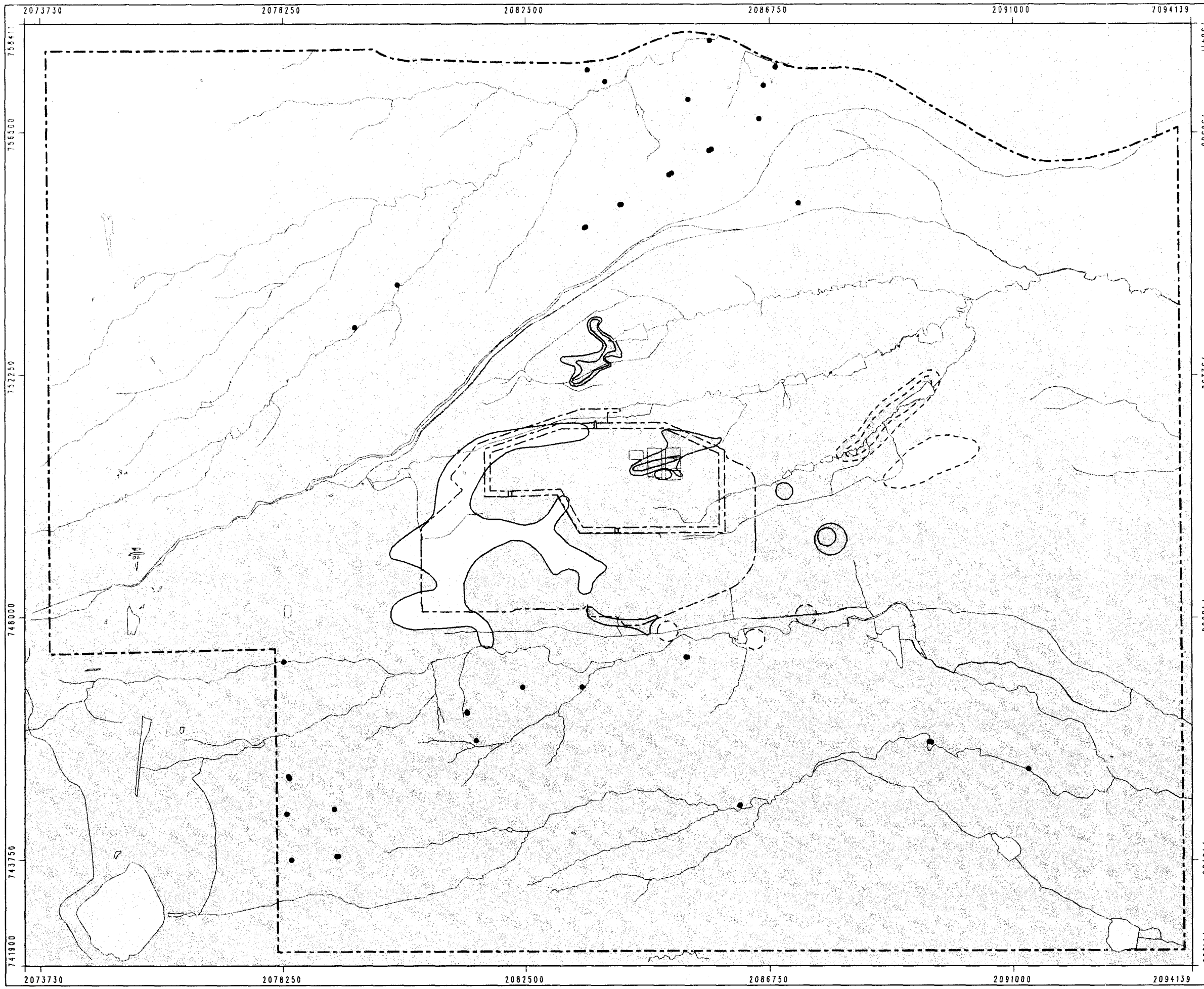
Figure 6-38



EXPLANATION

- > 100 ug/L
- 50 - 100 ug/L
- 5 - 50 ug/L
- < 5 ug/L

- Isoconcentration Lines (dashed where inferred)
- Background Wells
- Streams, Ditches, and Drainages
- Rocky Flats Plant Site and Security Zone Boundaries
- Rocky Flats Buffer Zone Boundary
- Surface Water Impoundments

N

Scale = 1 : 20400
1 inch = 1700 feet

850 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

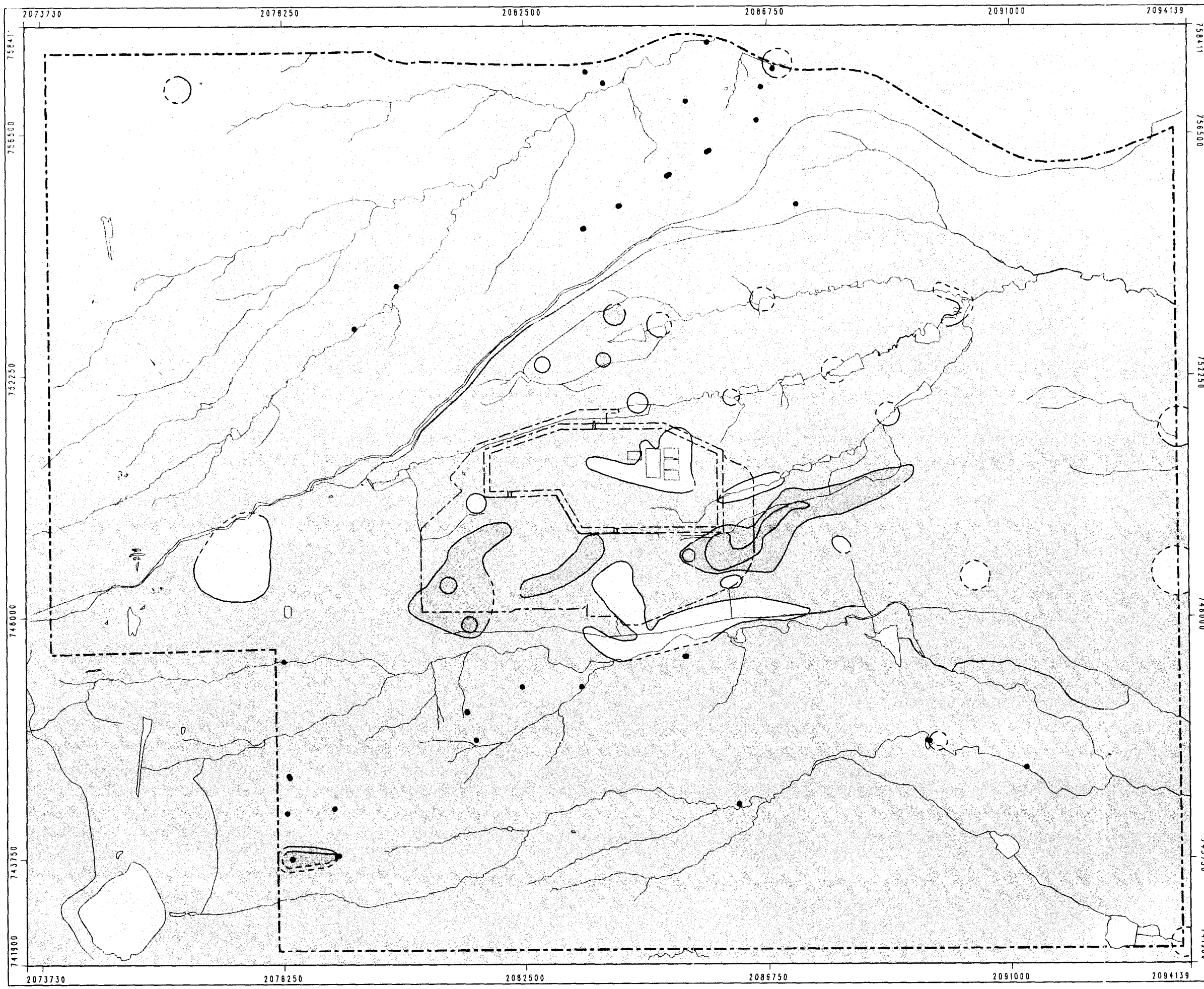
EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Dissolved Zinc
in Upper Hydrostratigraphic Unit
Groundwater

Groundwater Geochemistry Report

January 1995 | Figure 6-39



EXPLANATION

- > 10
- 5 - 10
- 1 - 5
- < 1

Isoconcentration Lines
(dashed where inferred)

Background Wells

Streams, Ditches, and Drainages

Rocky Flats Plant Site and Security Zone Boundaries

Rocky Flats Buffer Zone Boundary

Surface Water Impoundments

Scale = 1 : 20400
1 inch = 1700 feet

850 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

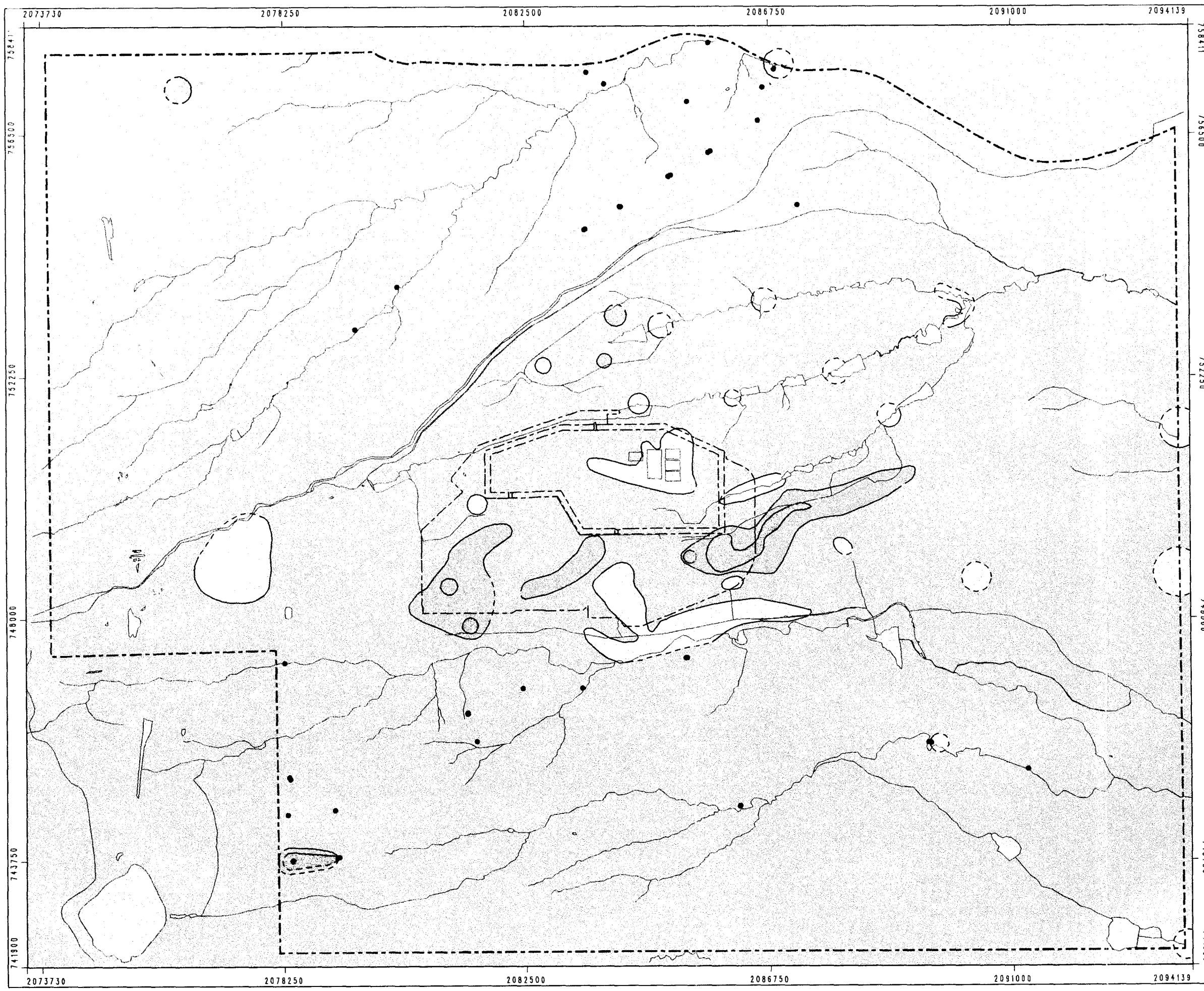
Rocky Flats Site, Golden, Colorado

Ratio of Dissolved Ca/Na in Upper Hydrostratigraphic Unit Groundwater

Groundwater Geochemistry Report

January 1995

Figure 6-40



EXPLANATION

- > 10
- 5 - 10
- 1 - 5
- < 1

Isoconcentration Lines
(dashed where inferred)

Background Wells

Streams, Ditches, and Drainages

Rocky Flats Plant Site and Security Zone Boundaries

Rocky Flats Buffer Zone Boundary

Surface Water Impoundments

N

Scale = 1 : 20400
1 inch = 1700 feet

850 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

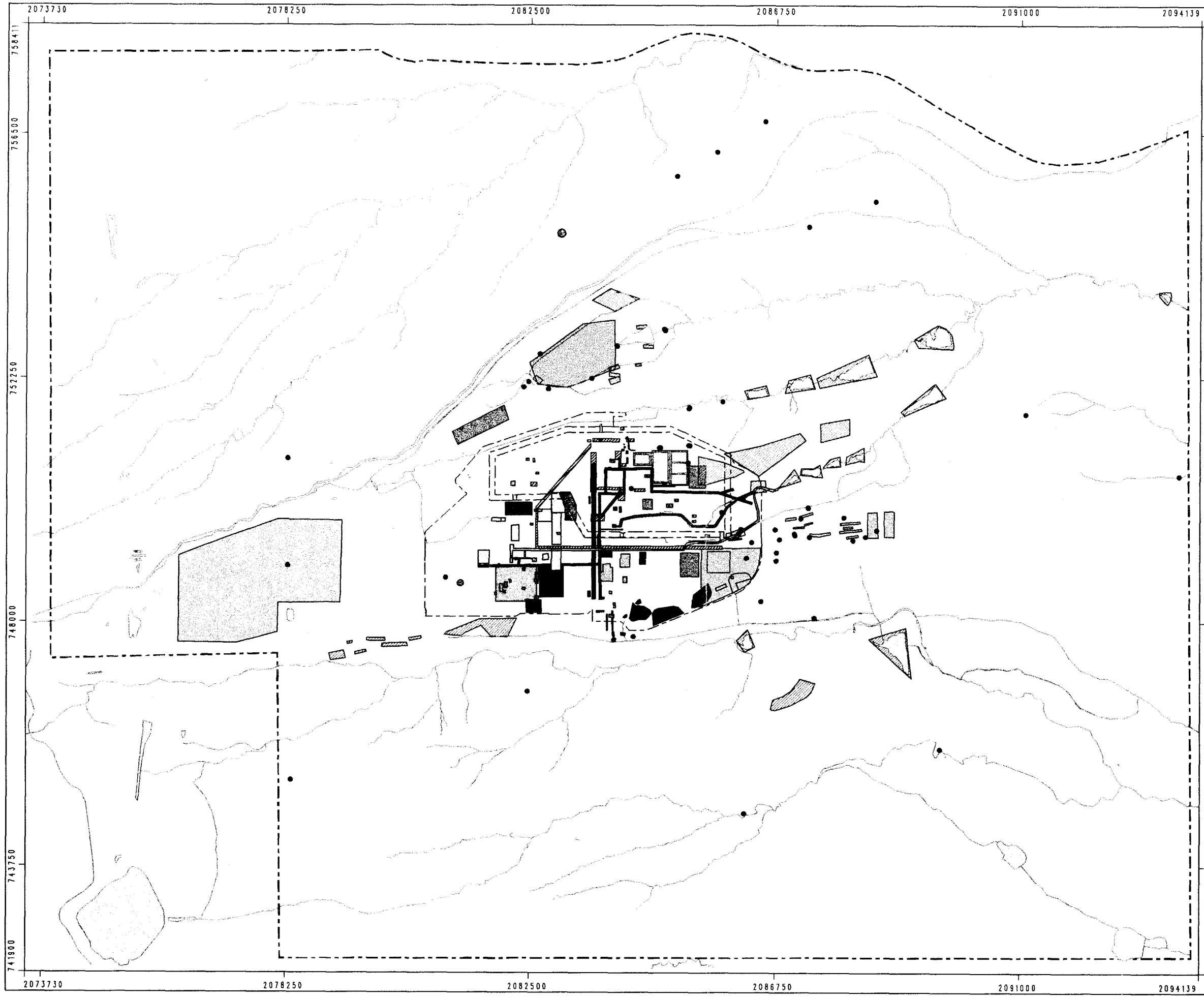
Rocky Flats Site, Golden, Colorado

Ratio of Dissolved Ca/Na in Upper Hydrostratigraphic Unit Groundwater

Groundwater Geochemistry Report

January 1995

Figure 6-40



EXPLANATION

- Operable Unit 1
- Operable Unit 2
- Operable Unit 4
- Operable Unit 5
- Operable Unit 6
- Operable Unit 7
- Operable Unit 8
- Operable Unit 9
- Operable Unit 10
- Operable Unit 11
- Operable Unit 12
- Operable Unit 13
- Operable Unit 14
- Operable Unit 15
- Operable Unit 16
- LHSU Monitoring Wells
- Streams, Ditches, and Drainages
- Rocky Flats Plant Site and Security Zone Boundaries
- Rocky Flats Buffer Zone Boundary
- Surface Water Impoundments

Scale = 1 : 20400
1 inch = 1700 feet

850 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

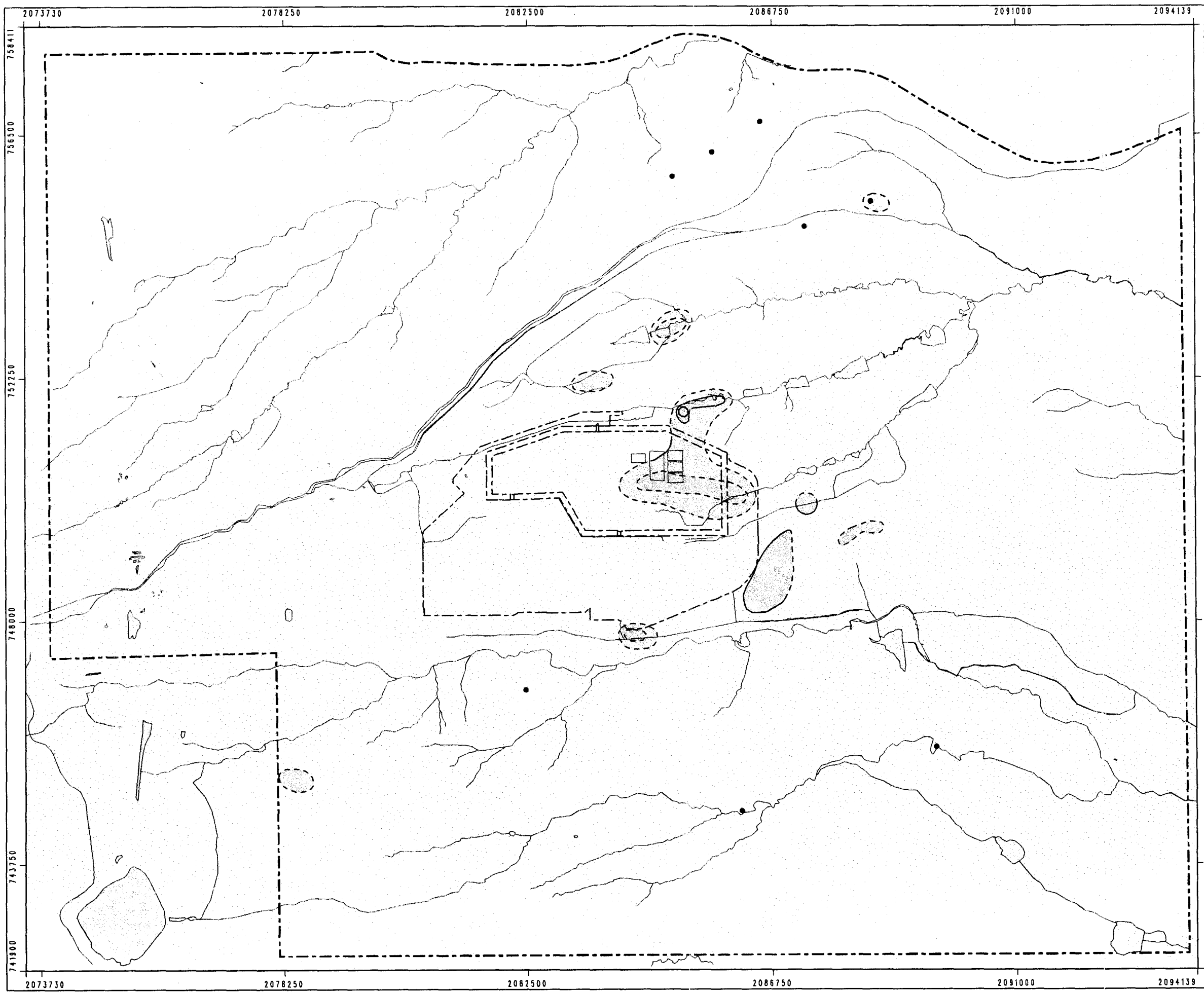
Rocky Flats Site, Golden, Colorado

Locations
of
LHSU
Monitoring Wells

Groundwater Geochemistry Report

January 1995

Figure 6-42



EXPLANATION

- > 500 mg/L
- 100 - 500 mg/L
- 50 - 100 mg/L
- < 50 mg/L

- Isoconcentration Lines (dashed where inferred)
- Background Wells
- Streams, Ditches, and Drainages
- Rocky Flats Plant Site and Security Zone Boundaries
- Rocky Flats Buffer Zone Boundary
- Surface Water Impoundments

N

Scale = 1 : 20400
1 inch = 1700 feet

850 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

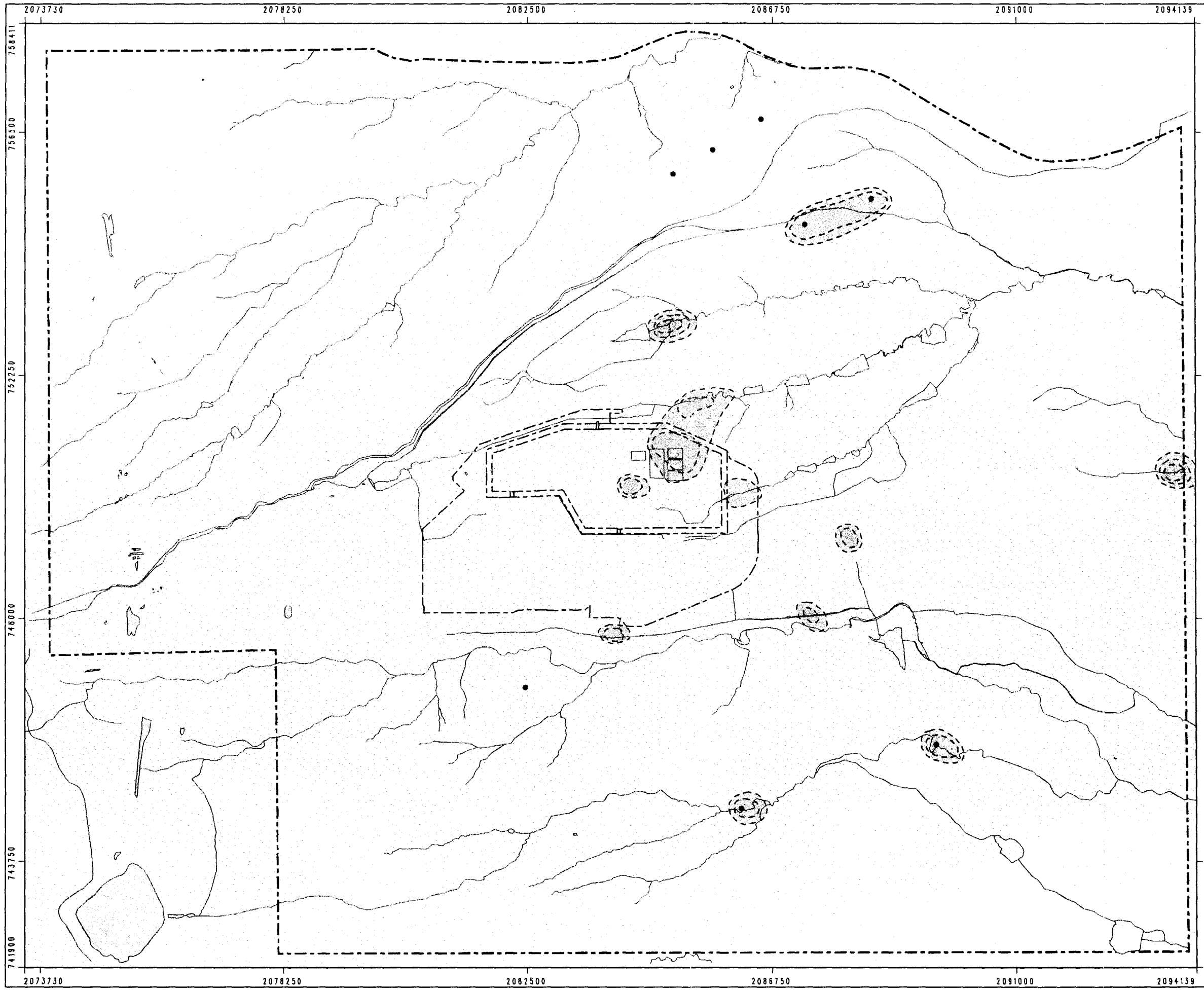
EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Dissolved Calcium
Lower Hydrostratigraphic Unit
Groundwater

Groundwater Geochemistry Report

January 1995 | Figure 6-43



EXPLANATION

- > 500 mg/L
- 100 - 500 mg/L
- 50 - 100 mg/L
- < 50 mg/L

- Isoconcentration Lines (dashed where inferred)
- Background Wells
- Streams, Ditches, and Drainages
- Rocky Flats Plant Site and Security Zone Boundaries
- Rocky Flats Buffer Zone Boundary
- Surface Water Impoundments

N

Scale = 1 : 20400
1 inch = 1700 feet

850 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Chloride

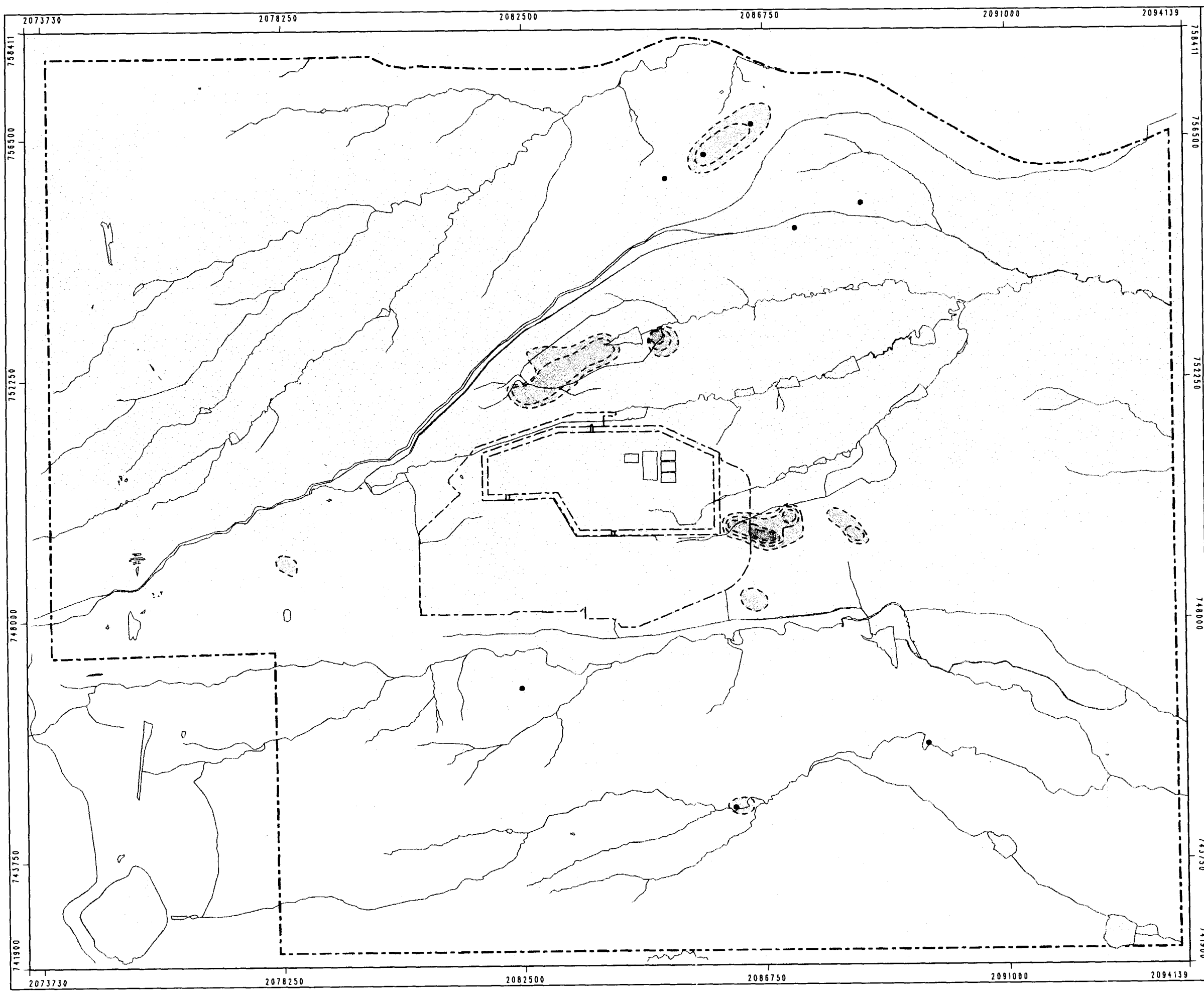
Lower Hydrostratigraphic Unit

Groundwater

Groundwater Geochemistry Report

January 1995

Figure 6-44



EXPLANATION

- > 100 mg/L
- 50 - 100 mg/L
- 10 - 50 mg/L
- 5 - 10 mg/L
- < 5 mg/L

- Isoconcentration Lines
- (dashed where inferred)
- Background Wells
- Streams, Ditches, and Drainages
- Rocky Flats Plant Site and Security Zone Boundaries
- Rocky Flats Buffer Zone Boundary
- Surface Water Impoundments

N

Scale = 1 : 20400
1 inch = 1700 feet

850 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Carbonate
Lower Hydrostratigraphic Unit
Groundwater

Groundwater Geochemistry Report

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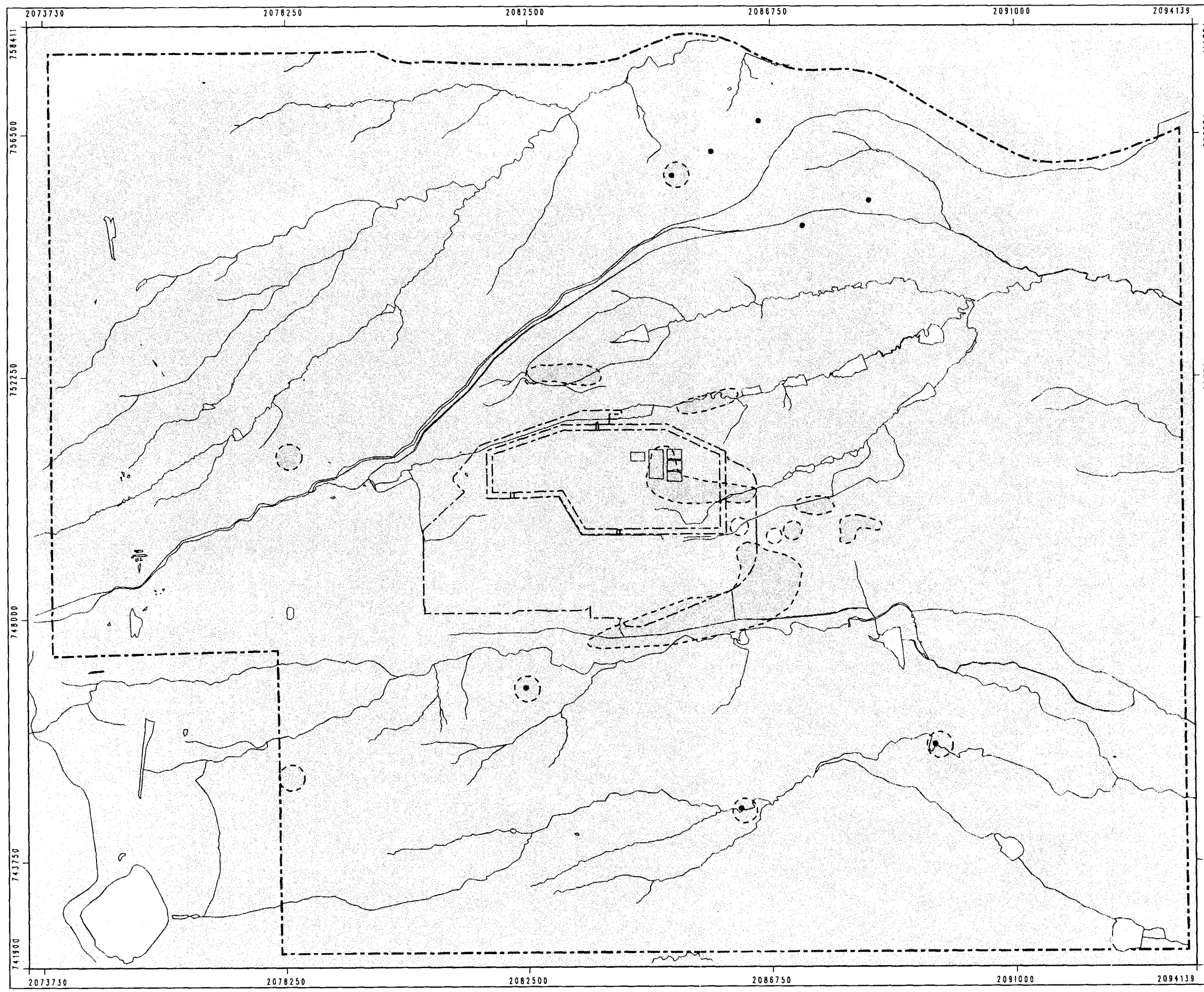

EXPLANATION

- > 200 mg/L
- 100 - 200 mg/L
- < 100 mg/L

- Isoconcentration Lines (dashed where inferred)
- Background Wells
- Streams, Ditches, and Drainages
- Rocky Flats Plant Site and Security Zone Boundaries
- Rocky Flats Buffer Zone Boundary
- Surface Water Impoundments

Scale = 1 : 20400
1 inch = 1700 feet

880 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Bicarbonate

Lower Hydrostratigraphic Unit

Groundwater

Groundwater Geochemistry Report

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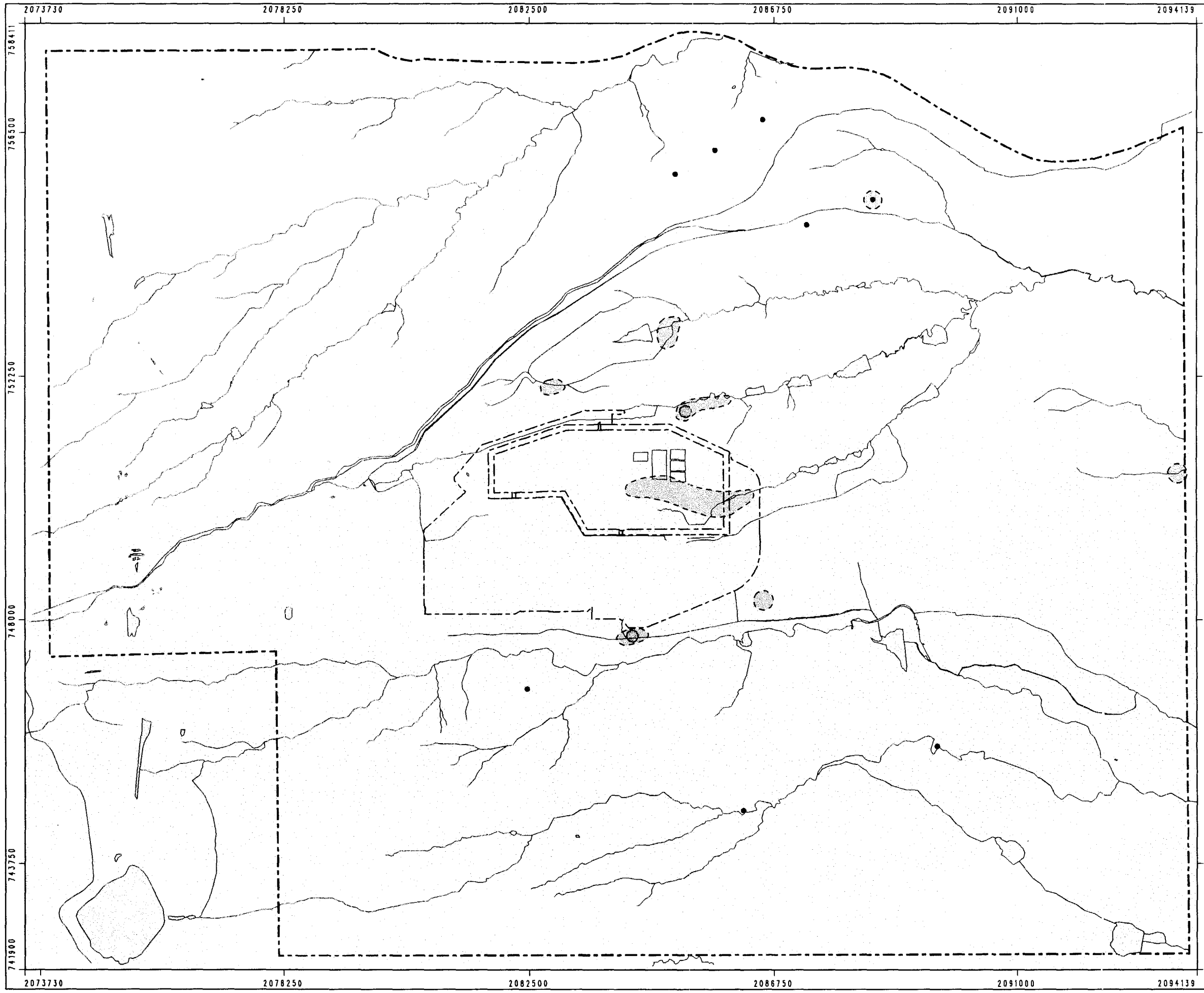


EXPLANATION

> 10 mg/L

5 - 10 mg/L

< 5 mg/L

Isoconcentration Lines (dashed where inferred)

Background Wells

Streams, Ditches, and Drainages

Rocky Flats Plant Site and Security Zone Boundaries

Rocky Flats Buffer Zone Boundary

Surface Water Impoundments

N

Scale = 1 : 20400
1 inch = 1700 feet

850 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Dissolved Potassium

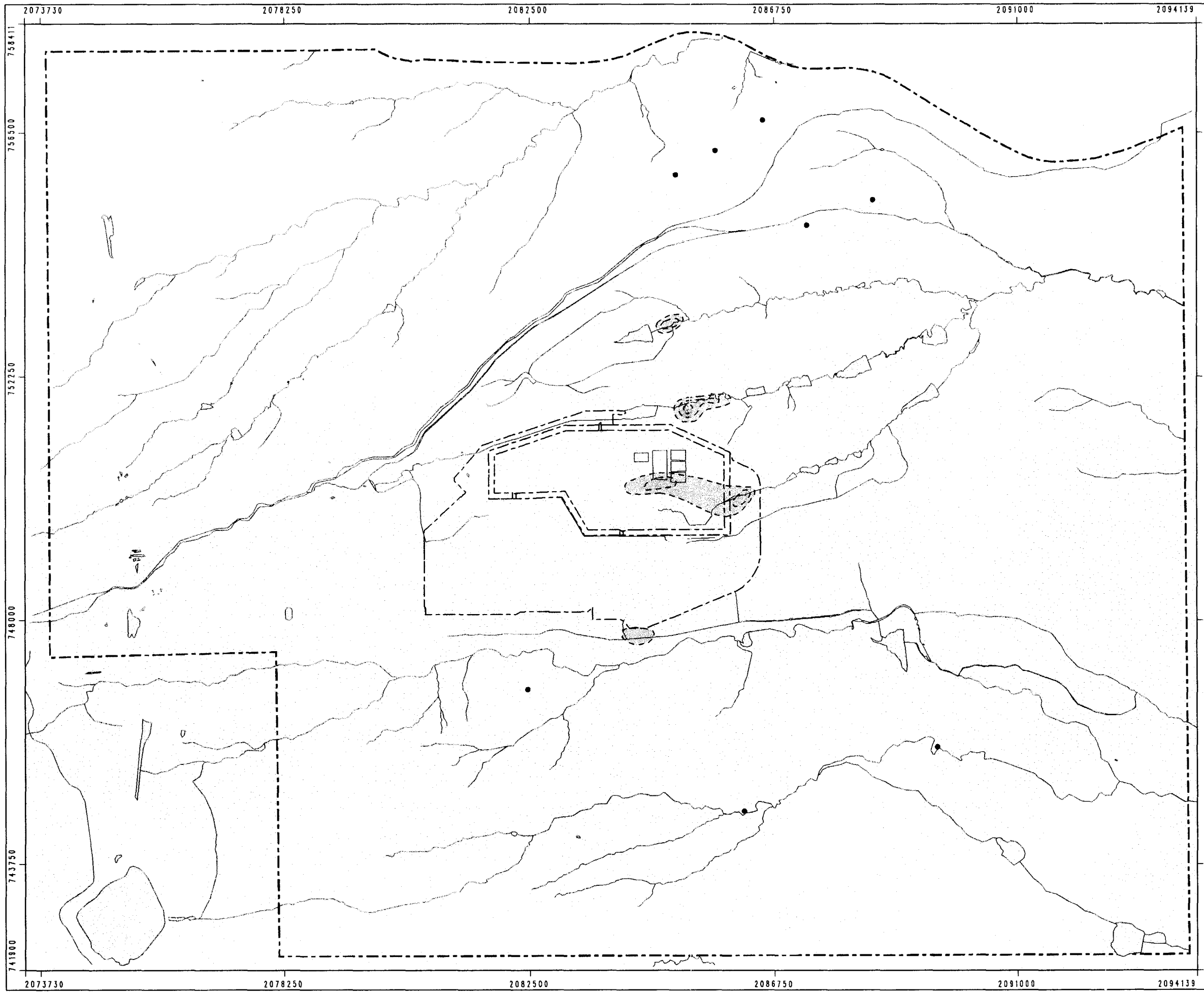
Lower Hydrostratigraphic Unit

Groundwater

Groundwater Geochemistry Report

January 1995

Figure 6-47



EXPLANATION

- > 100 mg/L
- 50 - 100 mg/L
- 25 - 50 mg/L
- < 25 mg/L

- Isoconcentration Lines (dashed where inferred)
- Background Wells
- Streams, Ditches, and Drainages
- Rocky Flats Plant Site and Security Zone Boundaries
- Rocky Flats Buffer Zone Boundary
- Surface Water Impoundments

N

Scale = 1 : 20400
1 inch = 1700 feet

880 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Dissolved Magnesium
Lower Hydrostratigraphic Unit
Groundwater

Groundwater Geochemistry Report

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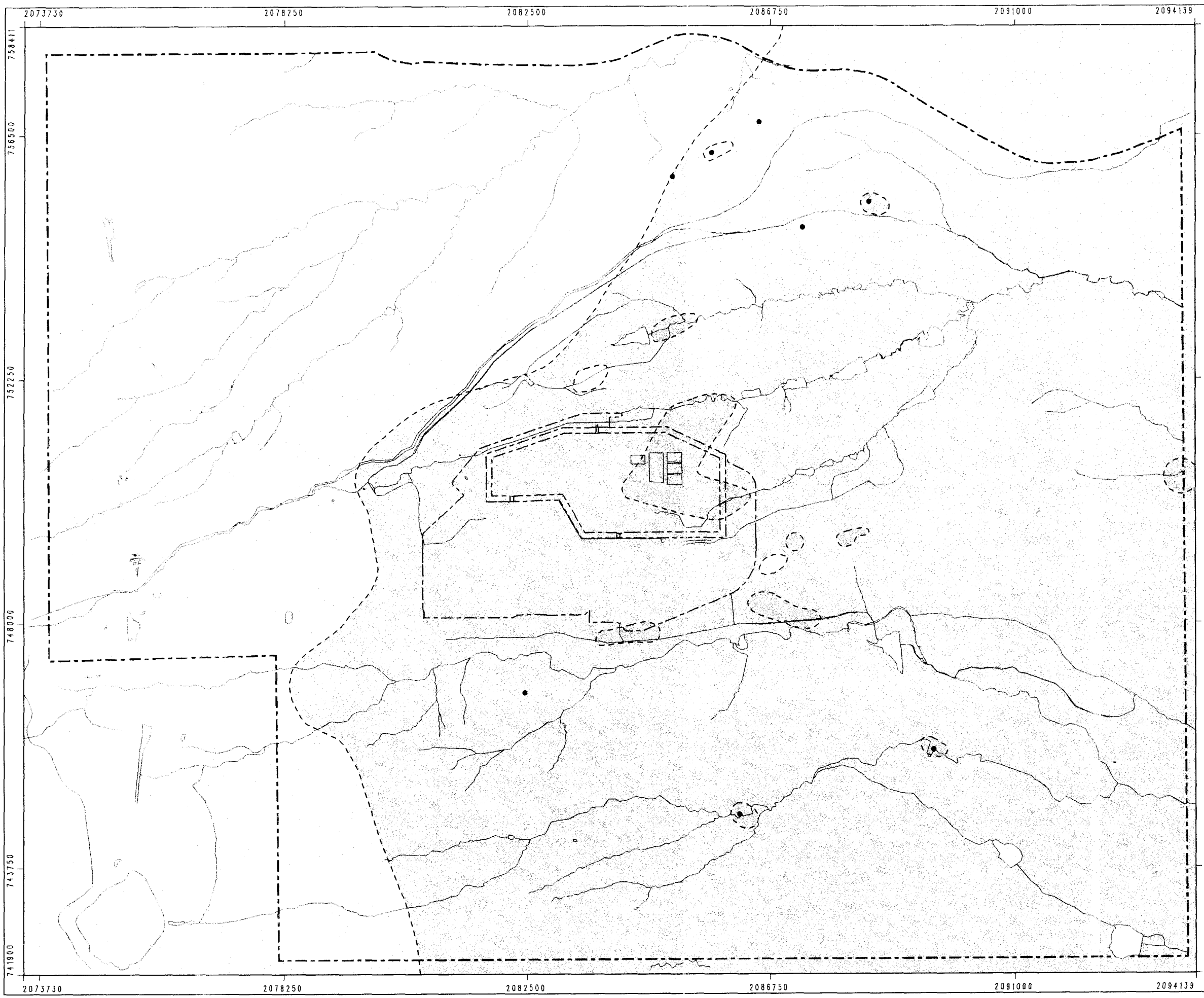


EXPLANATION

> 100 mg/L

50 - 100 mg/L

< 50 mg/L

Isoconcentration Lines
(dashed where inferred)

Background Wells

Streams, Ditches, and Drainages

Rocky Flats Plant Site and Security Zone Boundaries

Rocky Flats Buffer Zone Boundary

Surface Water Impoundments

N

Scale = 1 : 20400
1 inch = 1700 feet

850 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Dissolved Sodium

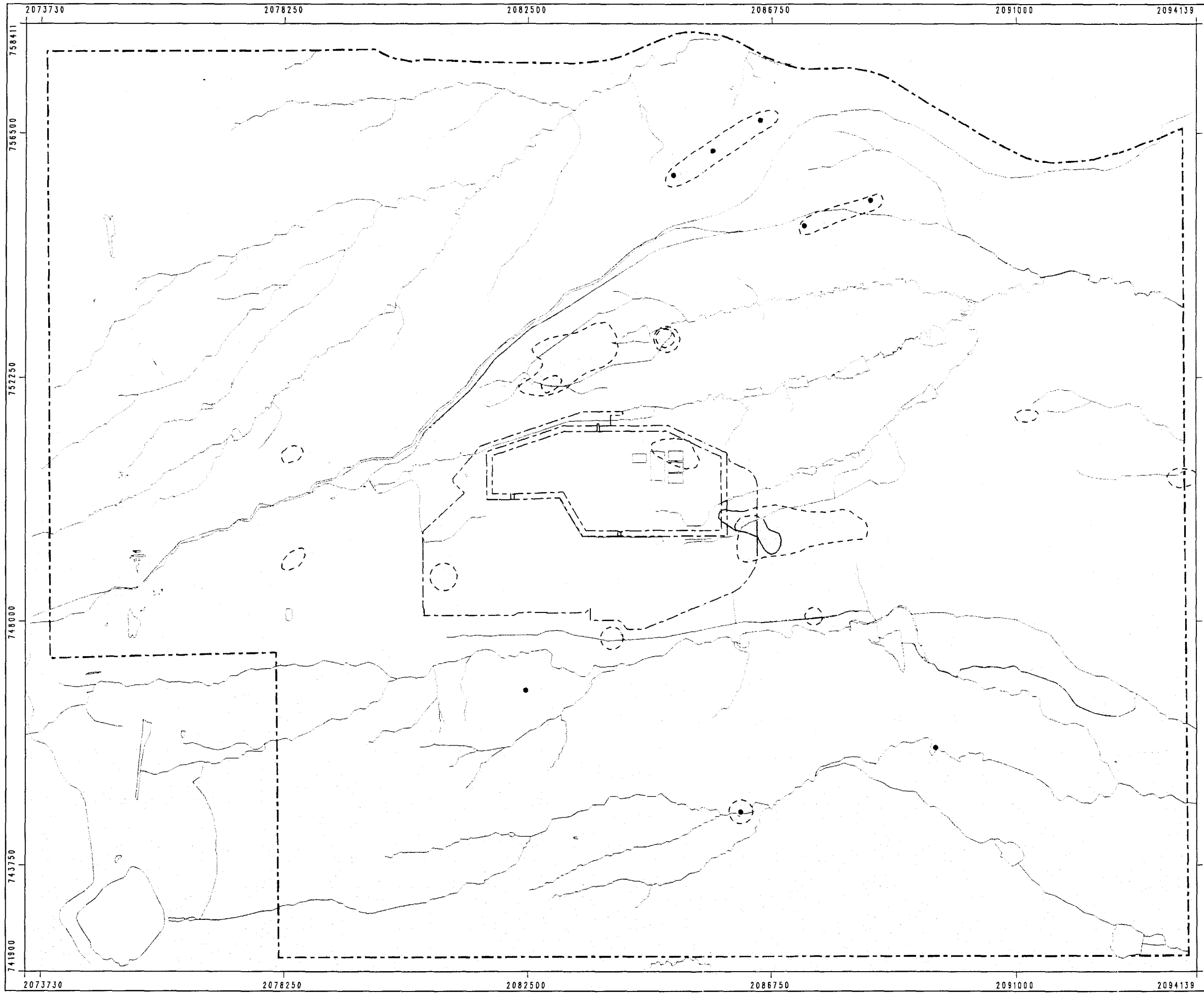
Lower Hydrostratigraphic Unit

Groundwater

Groundwater Geochemistry Report

January 1995

Figure 6-49



EXPLANATION

- > 10 pH
- 8 - 10 pH
- < 8 pH

- Isoconcentration Lines (dashed where inferred)
- Background Wells
- Streams, Ditches, and Drainages
- Rocky Flats Plant Site and Security Zone Boundaries
- Rocky Flats Buffer Zone Boundary
- Surface Water Impoundments

Scale = 1 : 20400
1 inch = 1700 feet

850 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

pH

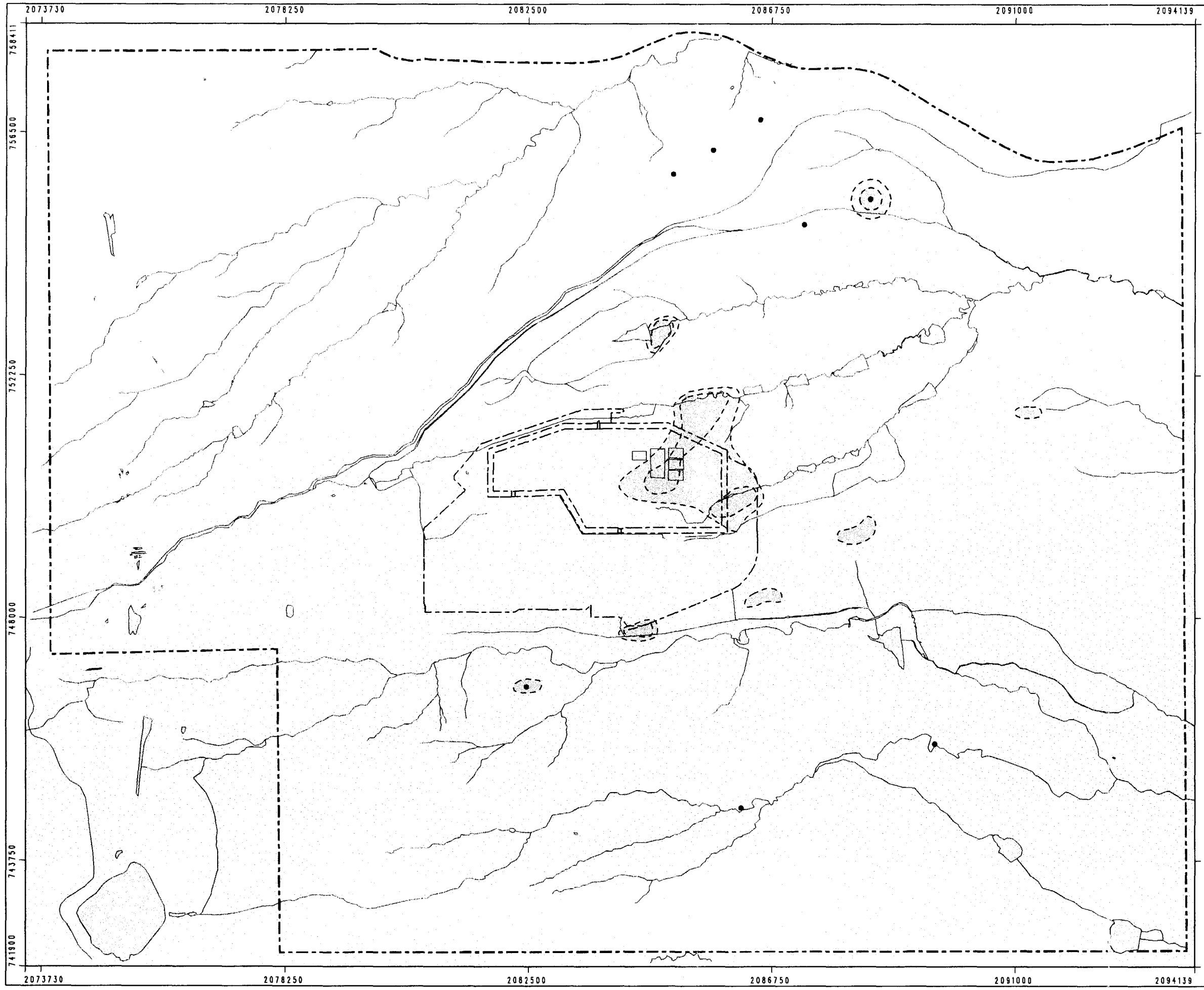
Lower Hydrostratigraphic Unit

Groundwater

Groundwater Geochemistry Report

January 1995

Figure 6-50



EXPLANATION

- > 500 mg/L
- 100 - 500 mg/L
- < 100 mg/L

- Isoconcentration Lines (dashed where inferred)
- Background Wells
- Streams, Ditches, and Drainages
- Rocky Flats Plant Site and Security Zone Boundaries
- Rocky Flats Buffer Zone Boundary
- Surface Water Impoundments

N

Scale = 1 : 20400
1 inch = 1700 feet

850 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Sulfate

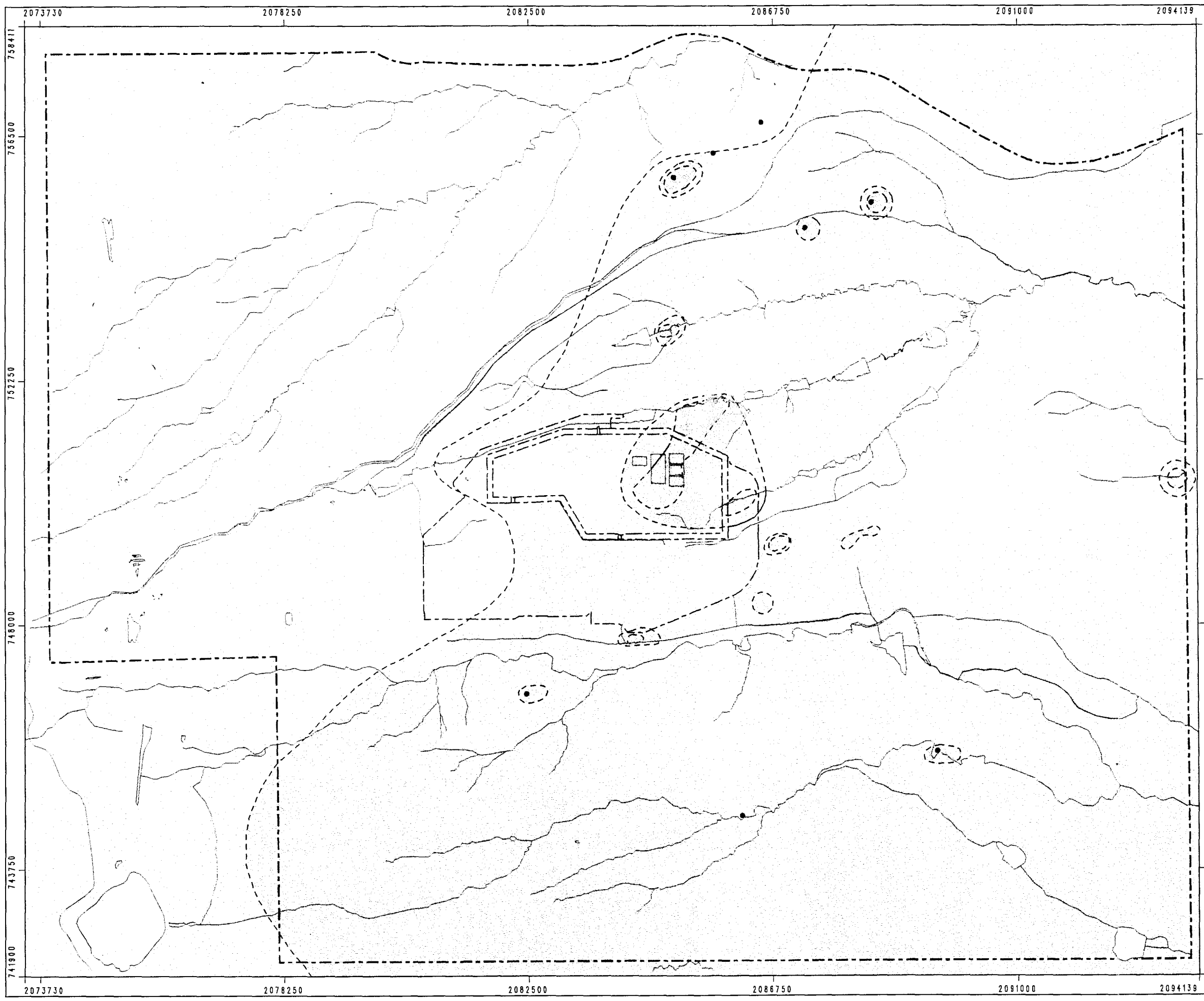
Lower Hydrostratigraphic Unit

Groundwater

Groundwater Geochemistry Report

January 1995

Figure 6-51



EXPLANATION

- > 1,000 mg/L
- 500 - 1,000 mg/L
- 250 - 500 mg/L
- < 250 mg/L

- Isoconcentration Lines (dashed where inferred)
- Background Wells
- Streams, Ditches, and Drainages
- Rocky Flats Plant Site and Security Zone Boundaries
- Rocky Flats Buffer Zone Boundary
- Surface Water Impoundments

Scale = 1 : 20400
1 inch = 1700 feet

850 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

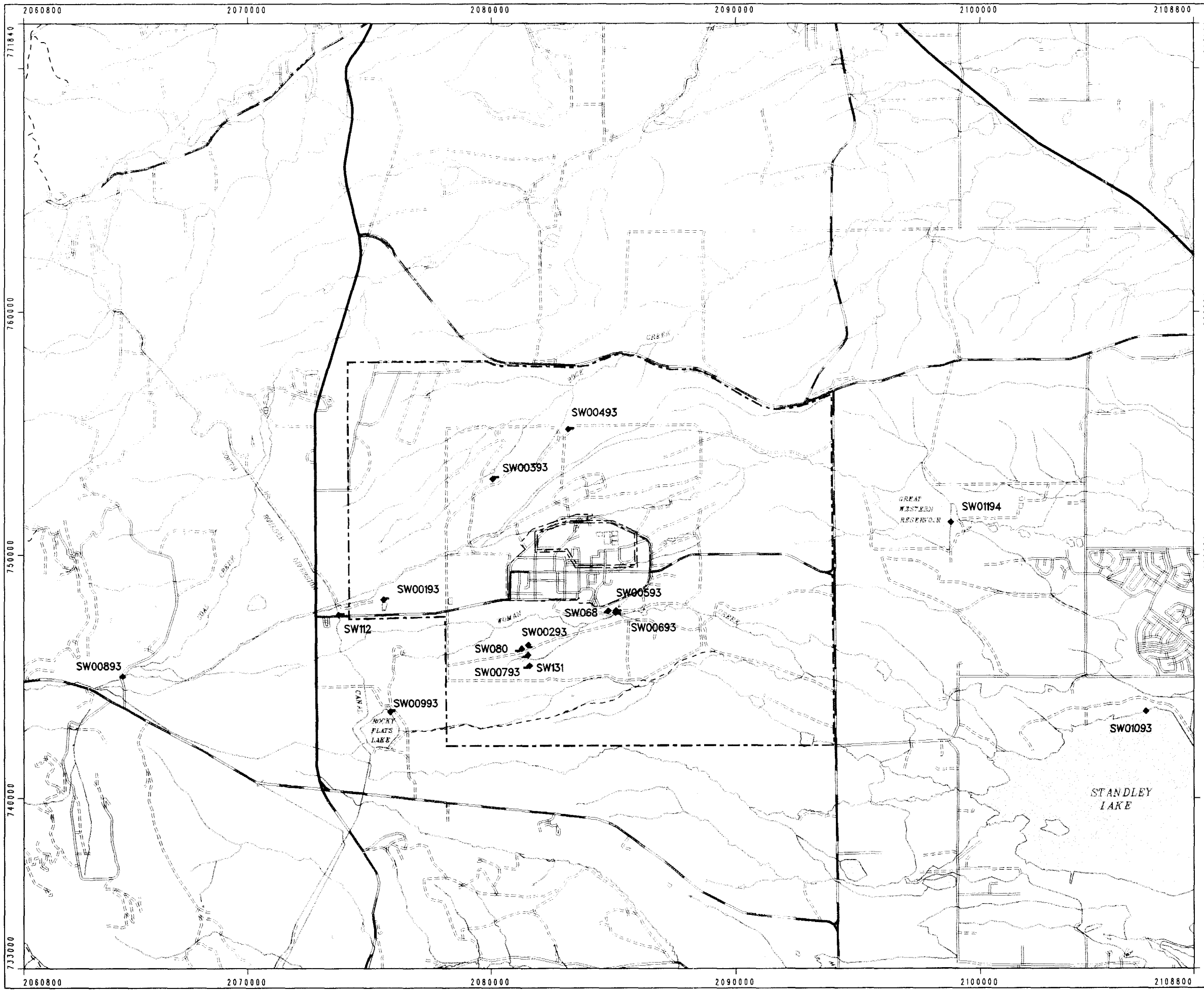
EG&G ROCKY FLATS

Rocky Flats Site, Golden, Colorado

Total Dissolved Solids
Lower Hydrostratigraphic Unit
Groundwater

Groundwater Geochemistry Report

January 1995 | Figure 6-52



EXPLANATION

- Surface Water Sampling Location
- Streams, Ditches, and Drainages
- Primary Roads
- Secondary Roads
- Lightduty Roads
- Unimproved Roads
- Industrial Area Security Zone Boundaries
- Buffer Zone Boundary
- Surface Water Impoundments

Scale = 1 : 48000
1 inch = 4000 feet

2000 0 4000ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

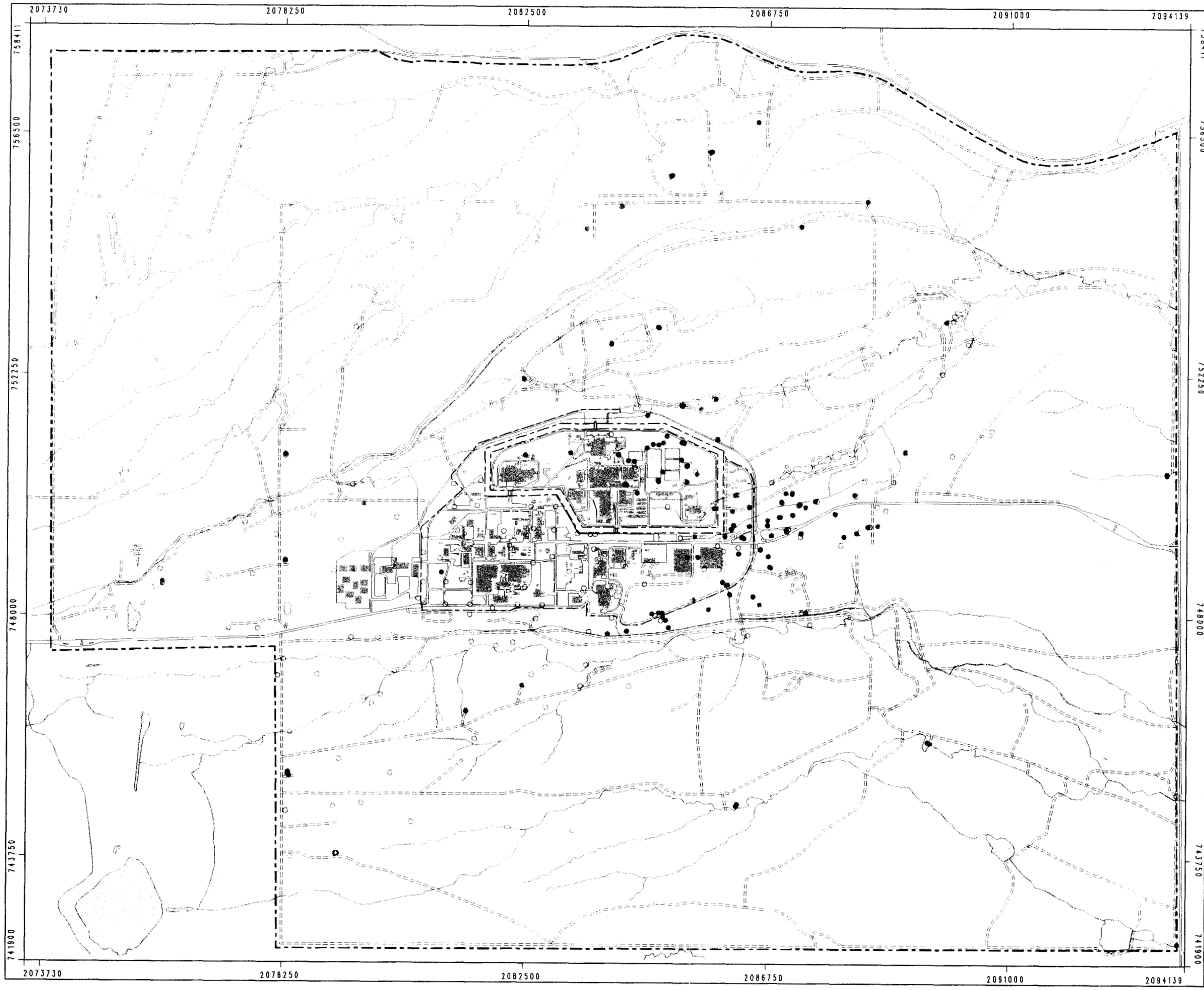
Rocky Flats Site, Golden, Colorado

Surface Water Sampling Locations for Stable Isotope Data

Groundwater Geochemistry Report

January 1995

Figure 7-1



EXPLANATION

- Lithologic Unit
- Surficial Deposits (UHSU)
- Weathered Bedrock (UHSU)
- Unweathered Bedrock (LHSU)
- Streams, Ditches, and Drainages
- Paved Roads
- Dirt Roads
- Industrial Area and Security Zone Boundaries
- Buffer Zone Boundary
- Surface Water Impoundments
- Buildings

Scale = 1 : 20400
1 inch = 1700 feet

880 0 1700ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS

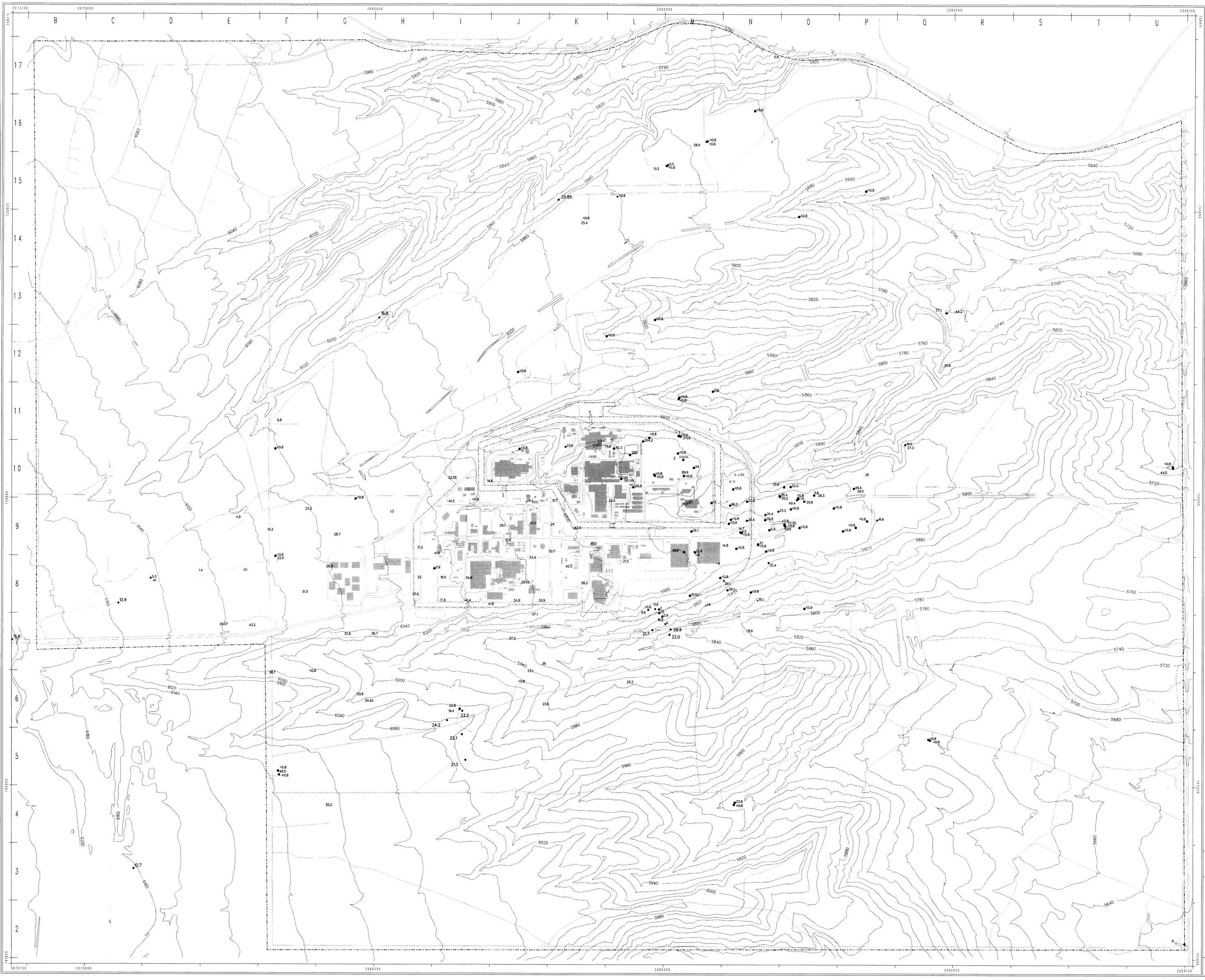
Rocky Flats Site, Golden, Colorado

Monitoring Wells Sampled for Isotopic Analyses

Groundwater Geochemistry Report

January 1995

Figure 7-2



EXPLANATION

Wells With Tritium Data

UHSU - Surficial Deposits

UHSU - Weathered Bedrock

LHSU - Unweathered Bedrock

Surface Water Sampling Station

Note: For locations with more than one sample measured, mean values are reported.

Symbology

Topographic Contours

Streams and Drainages

Paved Roads

Dirt Roads

Industrial Area and Security Zone Boundaries

Buffer Zone Boundary

Surface Water Impoundments

Buildings

Tritium concentrations reported in TU (Tritium Units) as measured by liquid-scintillation counting. Detection limit is 0.8 TU. (One TU is equivalent to 3.19 pCi/L of water.)

Scale = 1 : 6000
1 inch = 500 feet

250 0 500 1000 1500ft

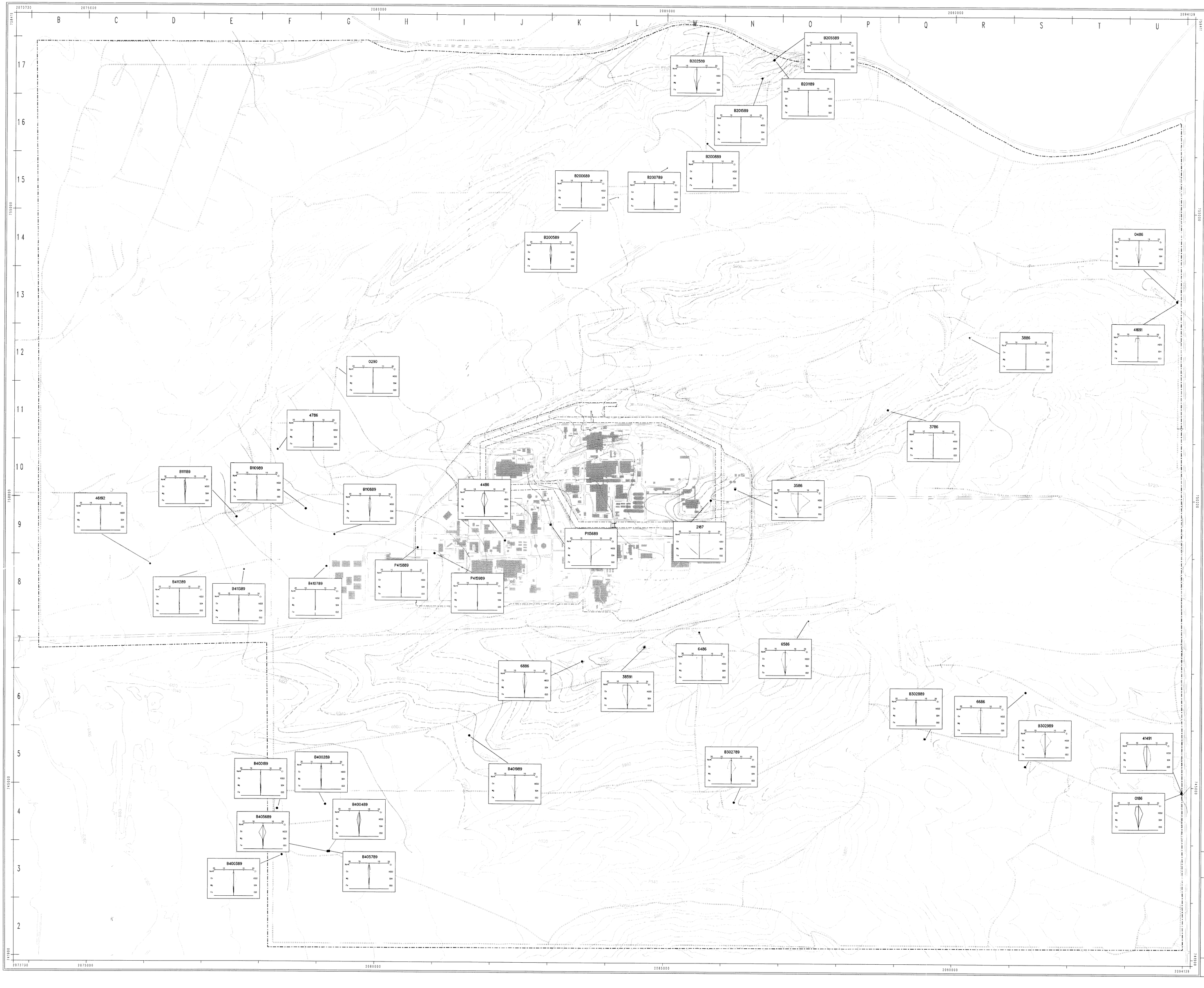
State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado

Spatial Variations in Tritium Content of Groundwater

Groundwater Geochemistry Report

January 1995 | Plate 4



EXPLANATION

B205589

Diagram of dissolved major-ion concentrations ("Stiff plot") for selected wells. Concentrations are in milliequivalents per liter.

Potentiometric-Surface Contours (2nd Quarter, 1993), from Hydrogeologic Characterization Report (Volume II).

Upper Hydrostratigraphic Unit Monitoring Well

Symbology

Streams and Drainages

Paved Roads

Dirt Roads

Industrial Area and Security Zone Boundaries

Buffer Zone Boundary

Water Level Contour

(dashed where inferred)

Unsaturated Areas

(dashed where inferred)

Surface Water Impoundments

Buildings

Scale = 1 : 6000
1 inch = 500 feet

250 0 500 1000 1500ft

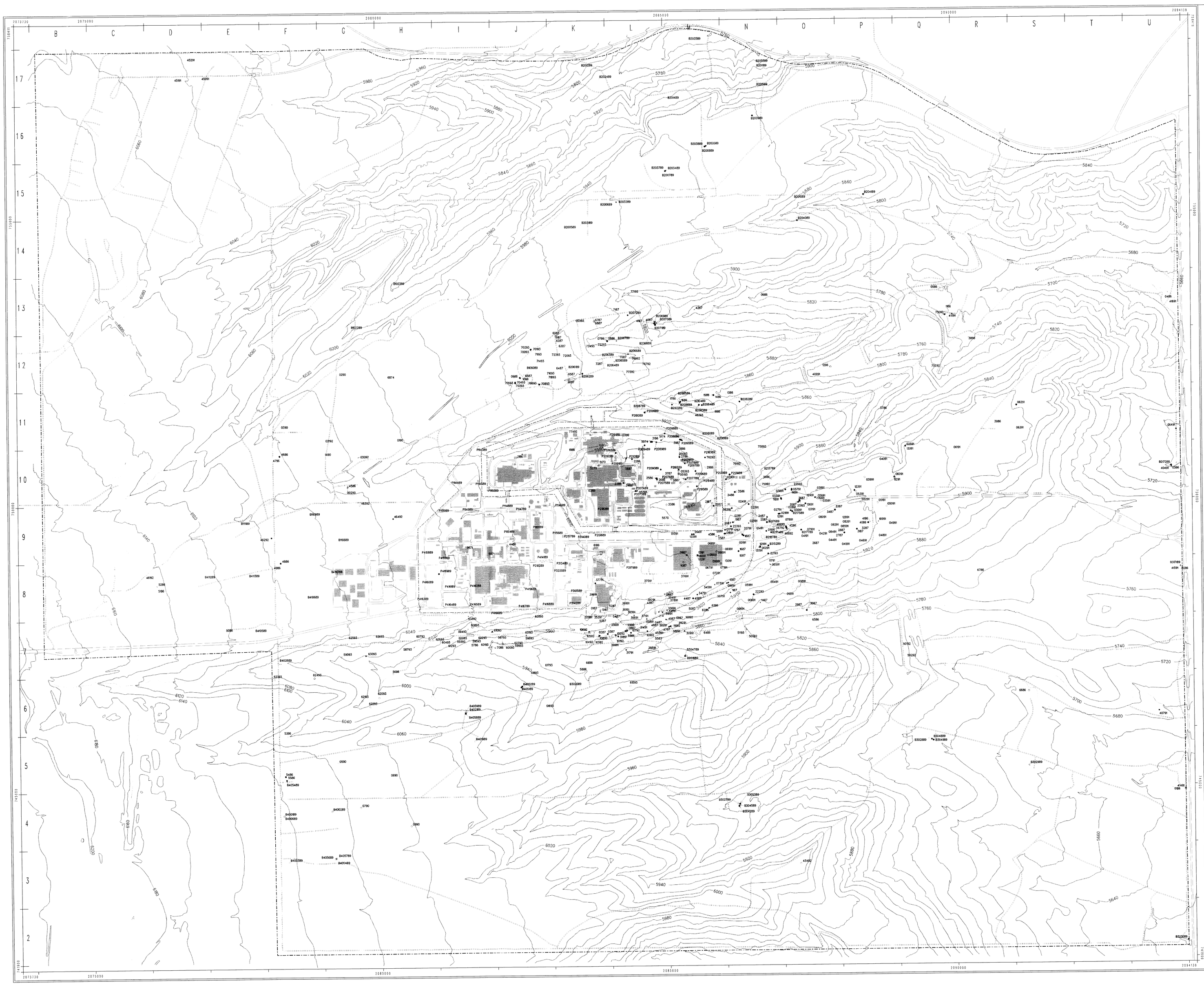
State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado

Major Ion Concentrations in UHSU Groundwater for Selected Sitewide Flow Paths

Groundwater Geochemistry Report

January 1995 | Plate 2



EXPLANATION

Upper Hydrostratigraphic Unit Monitoring Wells

- Bedrock
- Alluvium
- Alluvium/Bedrock

Lower Hydrostratigraphic Unit Monitoring Wells

- Bedrock

Symbology

- Topographic Contours
- Streams and Drainages
- Paved Roads
- Dirt Roads
- Industrial Area and Security Zone Boundaries
- Buffer Zone Boundary
- Surface Water Impoundments
- Buildings

Scale = 1 : 6000
1 inch = 500 feet

250 0 500 1000 1500ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado

Groundwater Monitoring Well Location Map

Groundwater Geochemistry Report

January 1995 | Plate 1

EXPLANATION

UHSU Monitoring Wells

Surficial Deposits

● Weathered Bedrock

◆ Surface Water Sampling Station

-14.5 $\delta^{18}O$ (SMOW) values

Note: For locations with more than one sample measured, mean values are reported.

Symbology

- Topographic Contours
- Streams and Drainages
- Paved Roads
- Dirt Roads
- Industrial Area and Security Zone Boundaries
- Buffer Zone Boundary
- Surface Water Impoundments
- Buildings

Scale = 1 : 6000
1 inch = 500 feet

250 0 500 1000 1500ft

State Plane Coordinate System
Colorado Central Zone
Datum: NAD27

EG&G ROCKY FLATS
Rocky Flats Site, Golden, Colorado

Spatial Variations in $\delta^{18}O$ of UHSU Groundwater

Groundwater Geochemistry Report

January 1995 | Plate 3