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GROUND-WATER ASSESSMENT PLAN ADDENDUM

U.S. DEPARTMENT OF ENERGY

Rocky Flats Plant
Golden, Colorado

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 **EG&G ROCKY FLATS**

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1.0 INTRODUCTION

This addendum to the Rocky Flats Ground Water Assessment Plan responds to specific issues raised by the Colorado Department of Health (CDH) at a meeting on April 4, 1990. The subject of the meeting was the Notice of Violation (NOV) issued by the CDH for perceived inadequacies in the Rocky Flats Ground Water Assessment Plan. The NOV requested additional information on site characteristics, contaminant migration and ground water monitoring at many of the regulated units.

As the first part of the response to the CDH concerns, CDH requested the following information for three of the regulated units:

1. Description of the current monitoring activities and data evaluation procedures
2. Proposed changes in monitoring activities or data evaluation procedures
3. Description of the data management plans
4. Discussion of the schedules for monitoring, analysis, data validation and reporting

The three regulated units are the West Spray Field, the Solar Evaporation Ponds, and the Present Landfill.

The following sections present the information requested by CDH for each of these units. This addendum should be used as a basis for understanding what is currently being done and what is proposed to be done at each of these units. Discussions regarding proposed changes to monitoring programs and data management represent the current changes being considered.

2.0 SITE SPECIFIC INFORMATION FOR THE WEST SPRAY FIELD

The West Spray Field is located in the western portion of the Rocky Flats Plant buffer zone. Rock Creek drainage is to the north of the spray field and the Woman Creek drainage is to the south. The Walnut Creek drainage flows across the site. The spray field covers approximately 105 acres and was in operation from April 1982 to October 1985. Excess liquids from the Solar Evaporation Ponds were periodically pumped to the West Spray Field via pipeline. The liquids pumped to the spray field consisted of treated sanitary effluent and recovered ground water, at least some of which contained hazardous constituents.

The West Spray Field is no longer in operation and will be closed in accordance with the closure plan prepared by DOE.

Previous site investigations have characterized the nature and extent of ground water contamination at the spray field. The following summarizes the pertinent site specific information concerning the geology and hydrogeology at and adjacent to the West Spray Field, the nature and extent of known ground water contamination, current ground water monitoring activities and any proposed modifications to the ground water monitoring program at the West Spray Field.

2.1 KNOWN HYDROGEOLOGIC CONDITIONS AND POTENTIAL CONTAMINANT TRANSPORT MECHANISMS

2.1.1 Geologic Description

The surficial material at the West Spray Field is the Rocky Flats Alluvium. The soil in the spray field is the Flatirons Series which is derived from the Rocky Flats Alluvium. The soil horizon is a deep, well drained soil composed of stony to gravelly and loamy material, and is approximately five feet deep.

The Rocky Flats Alluvium at the West Spray Field unconformably overlies the Laramie Formation, and consists of poorly sorted gravel, cobbles, and boulders with layers of clay,

silt and sand. The thickness of the alluvium varies from roughly 60 feet to 100 feet. Thickness is generally greater to the west, and thins to the east.

The underlying Laramie Formation consists predominantly of steeply dipping (42 to 45 degrees) claystone with occasional zones of interbedded siltstones and sandstones. The claystone is generally encountered immediately beneath the surficial deposits, although some of the interbedded sandstones may subcrop beneath the Area 2 spray application area, and just west of the spray field. At the spray field weathering of the claystones penetrates approximately 31 feet to 61 feet.

The Laramie Formation Sandstones range from less than one foot thick to approximately 27 feet thick. These sandstones are composed of very fine-grained to medium-grained silica cemented sands, with clays and silts common.

2.1.2 Hydrogeology

Ground water occurs in the alluvium and bedrock sandstones at the West Spray Field. The "uppermost aquifer" for the spray field is considered to be primarily the alluvial ground water system. Although the bedrock sandstones may be hydraulically connected to the alluvium, there does not appear to be any contamination of the ground water within the sandstones (Section 2.1.4).

Unconsolidated Deposits

Recharge to the alluvium is from precipitation infiltration, lateral ground water flow from the west, and recharge from Walnut Creek during periods of high precipitation. Ground water flows to the east, with components of flow to the southeast and northeast, toward the two drainages. Discharge areas for the alluvial ground water are springs and seeps, and discharges to the major drainages. Depth to ground water in the alluvium varies considerably, but generally ranges between 40 to 50 feet below ground surface. Portions of the alluvium are not saturated year round.

Hydraulic conductivity values for the alluvium are shown in Table 2 1, and range from approximately 5.3×10^{-4} centimeters per second (cm/s) to approximately 2.1×10^{-5} cm/s.

Bedrock

Recharge to the bedrock ground water system in the West Spray Field area may come from downward leakage from the alluvial system and/or recharge from drainages during high flow periods. Little is known about the ground water flow direction or gradient since there is no more than one well completed in a specific bedrock water bearing unit. Concurrent water level data indicates that there is a very slight downward gradient, at least during part of the year. During times of the year when portions of the alluvium are unsaturated or when alluvial water levels are low, there could potentially be a slight upward gradient. The bedrock water level data indicates that ground water occurs under confined conditions at the locations where the monitoring wells were installed.

Hydraulic conductivity values for the bedrock water bearing units are shown in Table 2 2 range from 5.4×10^{-7} cm/s to 4×10^{-8} cm/s.

2 1.3 Types of Contaminants

Sampling of the source water which was applied at the spray field has been performed periodically from 1984 to 1988. Although the spray field ceased operation in 1985, it is believed that subsequent samples of the source water are typical of what was applied historically.

The source water sample analyses (EG&G, 1990a) indicate that the applied water had low concentrations of metals, other inorganics and volatile organics (low ppb organic concentrations), but that there were elevated concentrations of nitrate, gross alpha and gross beta.

Of these potential contaminants, nitrate is one of the more conservative (mobile), and serves as a good indicator parameter for the presence or absence of ground water contamination

2.1.4 Potential Pathways and Transport Mechanisms

The potential source of contaminants to the ground water systems is from percolation of applied effluent in the spray areas. Contaminants may then enter the alluvial ground water system and be transported eastward and toward the adjacent drainages. Contaminants may also be transported vertically downward into the bedrock ground water system, although there is not any indication to date that this has occurred. Vertical migration could take place through small fractures or through the sandstone subcrops, although current data indicates that the sandstone is not significantly more permeable than the bedrock claystone (Section 2.1.2).

Given the permeabilities of the bedrock units, the predominant contaminant transport mechanism is probably by transport through the alluvial ground water system as dissolved contaminants.

2.2 DESCRIPTION OF CURRENT GROUND WATER MONITORING ACTIVITIES

2.2.1 Monitoring Wells

Approximately 21 alluvial monitoring wells (including well 56-86) and 3 bedrock wells are sampled routinely at the West Spray Field. Seven of the alluvial wells are pre-1986 wells. The distribution of these monitoring wells provides adequate coverage to detect ground water contamination along the probable pathways.

2.2.2 Field Measurements

Water levels are measured in each monitoring well monthly and at the time of sampling. The water level measurements taken at the time of sampling are used to calculate the amount of water which needs to be purged from the well prior to sampling. Monthly water level measurements are used to evaluate seasonal changes in ground water flow direction and gradient.

Field water quality indicator parameters are also measured at the time of sampling. These parameters include pH, specific conductance and temperature. The Rocky Flats Environmental Database System (RFEDS) (Section 5.0) allows input and tracking of these field parameters for comparison to laboratory values of pH and total dissolved solids.

Significant variations between field pH and laboratory pH can indicate that reactions may be occurring in the sample prior to analysis. Some examples may be the loss of carbon dioxide and/or precipitation of metals and ions. These reactions are important to identify since they can significantly affect data interpretation.

Although a direct comparison of specific conductance to total dissolved solids can not be made, the ratio of these values can be compared, along with simple cation/anion balances to determine whether significant ions are not being analyzed. Cation/anion balances are performed as part of the data validation process. When enough data has been collected, a relationship between these values can be established which can allow a reasonable estimation of the total dissolved solids concentration to be made based on specific conductance values.

2.3 PROPOSED MODIFICATIONS

2.3.1 Monitoring Wells

Additional source area investigations are proposed as part of the Phase I RFI/RI for the West Spray Field. These investigations will be performed in the following areas:

- Spray Application Area 1
- Spray Application Area 2
- Spray Application Area 3
- Runoff and Wind Spray Affected Areas

A radiation walk-over survey will be conducted in each of these areas. A total of five soil borings will be drilled and sampled in the three spray application areas as shown in Figure 2-1. The locations of the borings were selected to provide soil and ground water data in areas not previously sampled.

Each borehole will be drilled ten feet into ground water. Soil samples will be collected at ground surface and from each borehole for three purposes (1) to identify the borehole lithology; (2) to collect discrete samples for laboratory geochemical analysis; and (3) to collect discrete samples for laboratory geotechnical analysis

Monitoring wells will be constructed in each of the five boreholes. The wells will be completed in the alluvium. The screened portion of the well will extend from approximately 10 feet below the water table to 5 feet above the water table. A ground water sample will be collected from each well and analyzed for the analytes in Table 6 1 The results of these analyses will be used to determine whether additional ground water investigation is warranted, and whether these monitoring wells should be included in the quarterly monitoring program

In addition to installation of these five alluvial monitoring wells, a high resolution seismic survey will be conducted to delineate the extent of the basal sandstone of the Arapahoe Formation. The total length of the survey runs will be approximately 1500 feet While not part of the Phase I RFI/RI, the information from this seismic survey will be used to better define the relationship of this sandstone to the alluvium, and to assist in siting any additional bedrock wells, if it is determined that they are warranted. The seismic survey is scheduled for May 1990 A data interpretation report is expected to be completed in October 1990

2 3 2 Field Measurements

Ground water levels will be measured at all monitoring wells during the first week of each quarter No other significant revisions, other than entry of the data into RFEDS, are proposed for field measurements.

3.0 SITE SPECIFIC INFORMATION FOR THE SOLAR EVAPORATION PONDS

The Solar Evaporation Ponds are located on the northeast side of the Perimeter Security Zone (PSZ). North Walnut Creek lies to the north of the Solar Evaporation Ponds. South Walnut Creek lies to the east of the ponds. The Solar Evaporation Ponds unit consists of five ponds and a french drain system. The ponds were constructed to store and evaporate low level radioactive process wastes containing high nitrate concentration. The french drain system was constructed on the hillside north of the ponds to prevent natural ground water seepage and pond leakage from entering North Walnut Creek.

3.1 KNOWN HYDROGEOLOGIC CONDITIONS AND POTENTIAL CONTAMINANT TRANSPORT MECHANISMS

3.1.1 Geologic Description

Surficial materials at the Solar Evaporation Ponds consist primarily of the Rocky Flats Alluvium. Some colluvium and valley fill alluvium are present in the drainages to the north and east of the Solar Evaporation Ponds. The Rocky Flats Alluvium at the Solar Evaporation Ponds consists of sand, clay, silt, gravel, cobble, and occasional boulder deposits. Calcium carbonate caliche is also present in the alluvium at this location. The alluvium unconformably overlies the Arapahoe Formation, and ranges in thickness from approximately 3 feet to over 15 feet.

The Arapahoe Formation underlies the surficial deposits at the Solar Evaporation Ponds. The Arapahoe Formation consists of claystone with interbedded lenticular sandstones and siltstones. The claystone is generally encountered beneath the surficial deposits, although subcrops of the Arapahoe Formation sandstones occur in the western portion of the Solar Evaporation Pond area. It is possible that the upper sandstone which subcrops in the area is a channel sandstone. Weathering of the claystone has penetrated approximately 10 to 40 feet into bedrock. The weathered claystone is blocky and slightly fractured.

3 1 2 Hydrogeology

Ground water occurs in the alluvium, weathered claystone, and sandstones in the Solar Evaporation Pond area. For purposes of RCRA ground water monitoring, the uppermost aquifer at the Solar Evaporation Ponds consists of the alluvium, weathered claystone, and sandstone units within the Arapahoe Formation.

Unconsolidated Deposits

Recharge to the alluvium occurs from precipitation infiltration, lateral ground water flow from the west, and from leakage from the Solar Evaporation Ponds. Portions of the surficial materials north, east and south of the ponds are unsaturated. Perched ground water conditions also exist in the alluvium and is evidenced by the seeps on the hillside north of the ponds. The natural ground water flow direction in the alluvium is toward the east and northeast with a component toward the southeast. Ground water flow is locally influenced by bedrock topography, the french drain system, and potentially by local mounding due to leakage from the Solar Evaporation Ponds. There also is a bedrock high near the center of the Solar Evaporation Pond area which tends to divert ground water toward the north. This results in unsaturated areas to the east and south. Operation of the french drain system results in local dewatering of the alluvium and weathered bedrock north of the ponds. The extent of unsaturated alluvium is greatest during the dry parts of the year.

Ground water in the alluvium discharges as evapotranspiration and seepage into creeks, ditches and the french drain system. There also is some vertical leakage into the bedrock ground water system.

Hydraulic conductivity values for the alluvium at the Solar Evaporation Ponds are shown in Table 3 1, and range from 4×10^{-8} cm/s to 9×10^{-6} cm/s

Bedrock

Recharge to the bedrock units occurs primarily through downward leakage from the alluvium. Ground water flow occurs predominantly in the weathered claystone and

sandstone units. Ground water in the bedrock occurs under both confined and unconfined conditions, and is largely dependent upon the saturation of the overlying surficial materials. Horizontal ground water flow within individual sandstone units is from west to east at an average gradient of 0.09 ft/ft, based on wells completed in the same sandstones and on regional data. Horizontal ground water flow in the weathered bedrock is to the east and northeast beneath the ponds. Downgradient of the ponds to the north, the ground water flow direction in the weathered bedrock is more to the north-northwest. There is a downward vertical hydraulic gradient between the saturated alluvium and the bedrock water bearing units. The magnitude of the gradient varies, and ranges between 0.01 to 0.95 ft/ft.

Hydraulic conductivities for the bedrock units are shown in Table 3.2. The hydraulic conductivities for the sandstone units range from 1.12×10^{-8} cm/s to 3×10^{-6} cm/s.

3.1.3 Types of Contaminants

Numerous samples of the pond liquids and sludges from each pond have been analyzed to identify the types of contaminants present. The types and concentrations of contaminants vary somewhat between ponds, as various ponds receive different waste streams. Taken as a whole, the pond contents have had elevated concentrations of nitrate, metals, major cations, and radionuclides including plutonium and americium. Ponds 207-A and 207-C generally contain the highest concentration of contaminants. The pH of water stored in pond 207-A was alkaline, with a pH ranging from 8.3 to 10.

3.1.4 Potential Pathways and Transport Mechanisms

The major source for ground water contaminants in the Solar Evaporation Ponds area is from past and/or present leakage from the ponds. The Original Solar Evaporation Pond and the Original Process Waste Lines may also have contributed to ground water contamination. Contaminants which enter the alluvial ground water system can be transported either in perched ground water or non-perched alluvial ground water toward North Walnut Creek and South Walnut Creek, and vertically downward into the bedrock ground water system.

Monitoring indicates that the ground water within the alluvium and the weathered bedrock have been impacted by leakage from the ponds. The major contaminants in these water-bearing units are:

- Total dissolved solids (TDS)
- Nitrate
- Sulfate
- Chloride
- Uranium
- Sodium
- Strontium
- Magnesium.

Some of the observed contaminants are very mobile in the ground water system. The mobility for others, such as uranium, can be very dependent upon pH and Eh conditions. Contamination by volatile organic compounds is limited to the area south of pond 207-C. This contamination may be related to the Original Solar Evaporation Pond or to the Original Process Waste Lines system.

Figure 3-1 shows the concentration of Total Dissolved Solids in the vicinity of the Ponds. This figure indicates that contamination may have migrated somewhat to the west and south of the ponds, possibly as a result of mounding. There may also be some contaminant contribution in this area from the Original Process Waste Lines System. Migration of contaminated perched alluvial, and weathered bedrock ground water to the north and into the North Walnut Creek drainage has occurred, but is controlled to some degree by the french drain system. Migration to the east appears to be limited to approximately 600 feet east of the ponds by unsaturated conditions in the alluvium. There does, however, appear to be a continued potential for migration to the northeast in the alluvium and/or weathered bedrock toward North Walnut Creek, at least during portions of the year. This is based on ground water level data from May 1989 (Figure 3-2). It is apparent that at least during some portions of the year, the french drain system is not totally effective in dewatering the alluvium and/or the weathered bedrock in this area.

Migration of contaminants to the east could occur through the weathered bedrock and sandstone water bearing units

3.2 DESCRIPTION OF CURRENT GROUND WATER MONITORING ACTIVITIES

3.2.1 Monitoring Wells

Approximately 14 Rocky Flats Alluvium wells, 9 colluvium wells, 5 valley fill alluvium wells, 6 weathered sandstone wells, and 17 weathered claystone wells are monitored and sampled routinely.

3.2.2 Field Measurements

Water levels are measured in each monitoring well monthly and at the time of sampling. The water level measurements taken at the time of sampling are used to calculate the amount of water which needs to be purged from the well prior to sampling. Monthly water level measurements are used to evaluate seasonal changes in ground water flow direction and gradient.

Field water quality indicator parameters are also measured at the time of sampling. These parameters include pH, specific conductance and temperature. The RFEDS (Section 5.0) allows input and tracking of these field parameters for comparison to laboratory values of pH and total dissolved solids.

Significant variations between field pH and laboratory pH can indicate that reactions may be occurring in the sample prior to analysis. Some examples may be the loss of carbon dioxide and/or precipitation of metals and ions. These reactions are important to identify since they can significantly affect data interpretation.

Although a direct comparison of specific conductance to total dissolved solids can not be made, the ratio of these values can be compared, along with simple cation/anion balances to determine whether significant ions are not being analyzed. Cation/anion balances are currently performed as part of the data validation process. When enough data has been collected, a relationship between specific conductance and total dissolved solids can be

established which can allow a reasonable estimation of the total dissolved solids concentration to be made based on specific conductance values

3.3 PROPOSED MODIFICATIONS

3.3.1 Monitoring Wells

Various activities are proposed in the Solar Evaporation Pond Phase I RFI/RI to further characterize the nature and extent of contaminant releases from the Solar Evaporation Ponds. Although no additional monitoring wells are planned as part of the Phase I RFI/RI tasks, several of the proposed activities are relevant to obtaining a better understanding of the sources and extent of ground water contamination at this unit. The following describes these proposed activities

French Drain

There are numerous potential sources of ground water which is collected by the french drain system. Liquid samples will be collected from the french drain to evaluate the types and concentrations of contaminants occurring in the french drain system and, ultimately, to differentiate between the potential sources. The areas which will be sampled include

- The pump well at the western extent of the drain system
- The french drain system manhole located immediately north of Pond 207-A
- The interceptor trench pumphouse at the northern extent of the french drain system
- Other access points selected in the field.

Vadose Zone Characterization

In addition to borings through the pond liners, a total of 27 soil/vadose zone borings will be drilled in the vicinity of Ponds 207-A, 207-B (north, central, and south), 207-C, and in the property just north of the RCRA Waste Management Area. The locations of these borings, as well as existing monitoring wells and piezometers, are shown in Figure 3-3. The description of the boring locations along with the basis for choosing each location is summarized in Table 3-3

The vadose zone boreholes will be installed using a truck-mounted and/or a skid-mounted or trailer-mounted hollow-stem auger drilling rig, as may be required for access. Samples will be collected for geologic description for the entire borehole depth at each location. Samples will be continuously dry-cored using a 5-foot-long split-barrel sampler in the lead auger. Drilling, sampling, and borehole logging methods will be in accordance with EG&G Standard Operating Procedures (SOPs).

Discrete soil and rock samples will be submitted for laboratory chemical, physical, and radiological analyses (Table 3.4). These samples will be selected from the continuous core at a minimum of 5-foot intervals from near the ground surface to the top of the unweathered Arapahoe Formation. Additional samples will be selected at changes in lithology and from zones that have indications of contamination as determined from visual inspection of the sample or field instrument screening for organics and radionuclides. Sample selection will be performed by site personnel in accordance with EG&G SOPs.

Estimated target drilling depths for the vadose zone borings are presented in Table 3.5. The estimated target depths are provided for purposes of evaluating the approximate investigation work scope; drilling will be terminated in the field at depths corresponding to the top of unweathered Arapahoe Formation as determined in the field by the site hydrogeologist. The weathered Arapahoe Formation, for the purpose of this investigation, is characterized as the upper formation materials which, because of natural weathering processes, are expected to have a higher hydraulic conductivity relative to immediately lower portions of the formation. The portion of the weathered formation having higher hydraulic conductivities is assumed to be the upper ten feet of the formation for all of the vadose zone borings. This assumption is based on recent geologic studies at the site that indicate that the depth of weathering in the Arapahoe Formation, as determined from depth of iron oxide staining, ranges from 10 to 40 feet at the site (Rockwell International, 1990c, EG&G, 1990).

Ground Water

If free subsurface water is encountered, a discrete water sample will be collected for chemical and radiological analyses. If free subsurface water is encountered as indicated by saturated cuttings or core, the advancement of the drilling augers will be halted for a period of up to 30 minutes or as determined by the site hydrogeologist. During this period, the site hydrogeologist will determine whether there is a sufficient quantity of water to allow sampling. An attempt will be made to collect enough volume for both filtered and unfiltered samples. Determination of the water quantity will be performed by measuring the rise of the water within the augers using a decontaminated water-level indicator deployed from the ground surface. If sufficient water is available for sampling, then the site hydrogeologist will sample the water through the hollow-stem augers using a Teflon bailer with a ball-valve. If the water quantity is insufficient, the boring will continue to be advanced to the next sample depth, until there is either evidence of sufficient water for sampling or until the target borehole termination depth is reached, whichever is the lesser depth. Borehole water sampling will be performed in accordance with EG&G SOPs.

In addition to these Phase I RFI/RI activities, two geophysical activities are proposed to delineate the extent of the basal sandstone of the Arapahoe Formation and to determine the lateral extent of the french drain system, and whether it is keyed into bedrock. Approximately 3,000 feet of high resolution seismic lines will be surveyed to delineate the sandstone. Ground Penetrating Radar will be used to evaluate the french drain system. These activities are proposed to start in July 1990, with a data report completed in September 1990.

3.3.2 Field Measurements

Ground water levels will be measured at all monitoring wells during the first week of each quarter. No other significant revisions, other than entry of the data into RFEDS, are proposed for field measurements.

4.0 SITE SPECIFIC INFORMATION FOR THE PRESENT LANDFILL

The landfill is located to the north of the plant security area on an unnamed ephemeral tributary of North Walnut Creek. Numerous site investigations have been performed at the landfill. The results of these previous investigations, as well as a detailed history of landfill operations are discussed in detail in the Landfill Closure Plan (Rockwell International, 1988a). Additional field investigations of the landfill are also planned as part of the Phase I RFI for this operable unit.

The following summarizes the pertinent site specific information concerning the geology and hydrogeology at and adjacent to the landfill, the nature and extent of known ground water contamination, current ground water monitoring activities and proposed modifications to the ground water monitoring program at the landfill.

4.1 KNOWN HYDROGEOLOGIC CONDITIONS AND POTENTIAL CONTAMINANT TRANSPORT MECHANISMS

4.1.1 Geologic Description

Surficial materials at the landfill area consist of the Rocky Flats Alluvium, colluvium, valley fill alluvium, artificial fill, and disturbed ground. These natural surficial deposits unconformably overlie the bedrock units of the Arapahoe Formation at the site.

The Rocky Flats Alluvium ranges in thickness between 6 and 27 feet in the landfill area. The alluvium is comprised of clay, silt, sand, gravel, and cobbles. The colluvium in the area is located downgradient of the landfill and is comprised of clay with sandy clay and gravel layers. The valley fill alluvium is present in the drainage bottoms downgradient of the landfill.

The Arapahoe Formation underlies the surficial materials at the landfill site. The bedrock is predominantly claystone with interbedded sandstones and siltstones. The claystone is generally encountered immediately beneath the surficial deposits, although some interbedded sandstones subcrop within the unit boundary. Weathering of the top 2 to 11

feet of the claystone is typical. The interbedded sandstones are lenticular fine-grained sands and silts.

4.1 2 Hydrogeology

Ground water occurs in the alluvium (Rocky Flats and valley fill), colluvium, weathered bedrock and bedrock sandstones in the landfill area. For purposes of RCRA ground water monitoring, these water bearing units comprise the "uppermost aquifer" at the landfill. Portions of the landfill wastes are also believed to be saturated as a result of precipitation infiltration and possibly ground water inflow.

Unconsolidated Deposits

Recharge to the alluvium is from infiltration of precipitation, infiltration of water from land application (north of the east pond) of east pond water, some lateral inflow of ground water, and infiltration from ephemeral drainages when these are flowing. The natural ground water flow direction in the Rocky Flats Alluvium is to the east and toward the major site drainages. The horizontal ground water gradient is approximately 0.044 ft/ft, based on second quarter 1989 data. The presence of the east landfill pond, the ground water interceptor trench and the two slurry walls have induced local variations in the local alluvial ground water flow patterns at the landfill. Portions of the valley fill alluvium downgradient from the east pond are dry during periods of the year.

Hydraulic conductivity values for the Rocky Flats Alluvium at the landfill are shown in Table 4.1, and range from 1.3×10^{-3} cm/s to 1.6×10^{-5} cm/s. The geometric mean of hydraulic conductivity values from ten wells completed in the Rocky Flats Alluvium is 2.4×10^{-4} cm/s. There currently are no hydraulic conductivity data for the valley fill alluvium.

Bedrock

The main water bearing units within the bedrock are the weathered claystones and lenticular sandstones. Recharge to the bedrock is predominantly from the saturated unconsolidated water bearing deposits, and potentially from seepage from the east pond. Water level data from nine wells completed in the weathered bedrock in the landfill area

indicates that the weathered bedrock is generally not saturated. There is a downward vertical gradient between the unconsolidated water bearing deposits and the bedrock water bearing units of approximately 1.9 ft/ft, based on well pair 64-87 (alluvium) and B2026189 (weathered sandstone). There are likely variations in the magnitude of the downward gradient, both spatially and temporally.

Hydraulic conductivities for the water bearing bedrock units are shown in Table 4.2, and range from 4×10^{-8} cm/s to 3.1×10^{-7} cm/s. Ground water flow in the bedrock units is generally toward the east. Very few of the existing bedrock wells are completed in the same stratigraphic unit. As a result, there is not any current information regarding horizontal gradients within each unit.

4.1.3 Types of Contaminants

The results of monitoring at the landfill indicate that the ground water in the unconsolidated deposits and the bedrock water bearing units are contaminated to varying degrees. Comparisons were made of the concentrations of the analyzed parameters between landfill upgradient monitoring wells, Rocky Flats Plant background ground water quality (Section 7.1), and wells within and downgradient of the landfill. The comparisons were made for each water bearing unit and are described in the 1989 Annual RCRA Ground-Water Monitoring Report (EG&G, 1990a).

The types of ground water contaminants found in the monitoring wells at the landfill are generally typical of sanitary landfills, and it seems clear that the landfill is the probable source of these contaminants. The contaminants observed in the ground water at the landfill include major ions, iron, manganese, zinc and other metals. In addition to these typical contaminants, there are areas of elevated uranium and tritium concentrations in the alluvial wells, and elevated concentrations of nitrate, lithium, molybdenum, selenium and strontium in some of the bedrock wells. The elevated concentrations of at least some of these constituents appear to be unrelated to the landfill, and for constituents such as strontium and chloride, are related more to mineralogical differences between water bearing units.

Several volatile organic compounds have been observed sporadically in the alluvium. These volatile organics are primarily chlorinated organics, such as Trichloroethene and 1,1,1 - Trichloroethane, and are present in low part per billion concentrations.

4.1.4 Potential Pathways and Transport Mechanisms

The main pathways for contaminant migration from the landfill are through the alluvial ground water system, with either continued migration to the east, or discharge to drainages, and through the bedrock ground water systems. There are several control mechanisms in place to contain contaminated alluvial ground water within the landfill area. These mechanisms consist of slurry trenches, ground water diversion trenches, leachate collection system, and the east pond.

To some extent, the effectiveness of the ground water diversion and leachate collection system may be judged based on existing water level data. The investigation for the Present Landfill Hydrogeologic Characterization Report (Rockwell International, 1988b) included constructing three alluvial monitoring wells along a section just upgradient (west) of the west end of the ground water diversion and leachate collection system and seven alluvial monitoring wells along an approximate north-south section through the approximate center of the landfill. A potentiometric surface map based on May 1989 ground water level data is presented in Figure 4-1.

In general, the water level data indicate the ground water is drawn down toward the ground water diversion and leachate collection system. However, water level data are not available on this section just downgradient (east) of the system. Therefore, it cannot be determined if the system is collecting and diverting all alluvial ground water at this location. Similarly, no conclusions can be drawn as to the effectiveness of the leachate collection system at this location.

In general, the ground water level data from the seven wells along the centerline of the landfill show water levels within the landfill similar to, but somewhat lower than those outside of the ground water diversion and leachate collection system. Data for the three

wells across the southern landfill boundary indicate apparent cyclic fluctuations of about 10 to 12 feet in the water level just inside the landfill. The water levels in the two wells just outside of the southern landfill boundary were near the water levels north of the north landfill boundary. Rockwell International (1988d) concluded that the lack of ground water in Well No 63-87 at the time of the first measurement in 1987 and the fluctuations in water level in Well No. 64-87 may have indicated the ground water diversion and leachate collection system was functioning intermittently. Additional data indicate water levels in Well No. 63-87 are relatively stable and that Well No. 64-87 has undergone a number of significant fluctuations. The fluctuating levels in Well 64-87 may be in direct response to precipitation events although this has not yet been evaluated. The original plans for the system indicate the maximum water levels in Well No 64-87 are near the original ground surface elevation in that area. This indicates the potential for ground water within the landfill to have exited to the south above the top of the clay barrier separating the ground water diversion component from the leachate collection component of the system. There may also be a potential for ground water inflow to occur into the landfill through alluvial materials beneath the system along the northwest and southwest sides of the landfill.

In addition to the ground water diversion and leachate collection system, slurry trenches excavated into rock were constructed on the north and south sides of the east portion of the landfill. These slurry trenches were constructed to increase the area surrounded by ground water controls to allow lateral expansion of the landfill. The purpose of the slurry trenches is to impede the flow of ground water across them.

The well pair 67-87 and 68-87 straddle the north slurry trench. Water levels for well pair 67-87 and 68-87 indicate the water levels are generally within approximately 0.2 to 0.3 foot of each other.

There is not a well pair straddling the south slurry trench. Consequently, evaluation of the effectiveness of the south slurry trench would be difficult. Well No. 70-87 was dry January through March 1988, but had a saturated thickness of approximately seven feet in April 1988. Water has been found at varying levels, when checked, since then.

Subcropping sandstone was identified in Well Nos. 72-87 and 70-87 (Rockwell International 1988d) It was estimated (Rockwell International 1988d) that approximately 40 percent of the south slurry trench is underlain by subcropping sandstone This suggests that some degree of hydraulic continuity may extend across the eastern portion of the south slurry trench when saturated alluvium is present

In summary, the preliminary evaluation of the effectiveness of these control mechanisms indicates the following

- 1 The ground water intercept system is diverting ground water away from the west end of the landfill, but is not diverting ground water away from the north and south sides of the landfill This can result in increased flow through the wastes.
- 2 The slurry walls are containing ground water and preventing it from exiting the landfill to the west and north, but the slurry well on the south side is ineffective, allowing contaminated ground water to leave the landfill in this direction at times.
- 3 The leachate collection system appears to function intermittently on the north side of the landfill
4. Ground water in the landfill generally flows toward the east pond, where it can be collected and evaporated, or spray evaporated north of the pond.
- 5 Contaminated ground water from the landfill may reach the valley fill alluvium by recharging the ground water intercept system, which in turn can discharge into the unnamed tributary

As represented by these preliminary findings, the alluvial ground water control mechanisms have not yet achieved complete diversion of clean ground water from the landfill wastes or containment of contaminated alluvial ground water in the lateral direction It appears that there may also be several areas where the slurry walls are keyed into sandstone subcrops. These subcrop areas and any other areas where the slurry walls are not keyed into low permeability bedrock can present potential vertical pathways for contamination migration The rate of vertical migration in these areas should, however, still be relatively slow, given the permeability of the weathered claystone and sandstone

Pumping tests are being planned to further evaluate the effectiveness of the slurry walls. These pump tests are tentatively planned to be conducted as part of the Phase II RFI/RI activities.

There also may be general downward leakage of contaminated ground water into the bedrock units through sandstone subcrops, small fractures and the weathered claystone beneath the landfill. There currently are not any control measures for containment of any contaminated ground water in the bedrock.

4.2 DESCRIPTION OF CURRENT GROUND WATER MONITORING ACTIVITIES

4.2.1 Monitoring Wells

Approximately 22 alluvial and 13 bedrock wells have been routinely sampled at the landfill site since 1986. Seventeen of these wells are completed in the Rocky Flats Alluvium, 5 in the valley fill alluvium, 7 in the weathered claystone, 2 in the weathered sandstone, and 4 in the unweathered sandstone.

4.2.2 Field Measurements

Water levels are measured in each monitoring well monthly and at the time of sampling. The water level measurements taken at the time of sampling are used to calculate the amount of water which needs to be purged from the well prior to sampling. Monthly water level measurements are used to evaluate seasonal changes in ground water flow direction and gradient.

Field water quality indicator parameters are also measured at the time of sampling. These parameters include pH, specific conductance and temperature. The RFEDS (Section 5.0) allows input and tracking of these field parameters for comparison to laboratory values of pH and total dissolved solids.

Significant variations between field pH and laboratory pH can indicate that reactions may be occurring in the sample prior to analysis. Some examples may be the loss of carbon

dioxide and/or precipitation of metals and ions. These reactions are important to identify since they can significantly affect data interpretation

Although a direct comparison of specific conductance to total dissolved solids can not be made, the ratio of these values can be compared, along with simple cation/anion balances to determine whether significant ions are not being analyzed. Cation/anion balances are performed as part of the data validation process when enough data has been collected, a relationship between these values can be established which can allow a reasonable estimation of the total dissolved solids concentration to be made based on specific conductance values

4.2.3 Monitoring Wells

Additional soil borings, piezometers, and monitoring wells will be drilled and installed within the landfill, primarily along its longitudinal axis, parallel to ground water flow. The purpose of these borings and wells is to provide additional information on the horizontal ground water gradient, the effectiveness of the existing containment systems, the distribution of contamination, and the waste physical characteristics.

Samples of the waste will be visually classified during drilling but will not be saved for testing. After drilling to the bottom of the wastes, an 8- to 10-inch diameter temporary casing will be inserted and sealed at the bottom to isolate the underlying samples from the leachate in the wastes. If the soil beneath the waste is coarse granular material judged to have a permeability on the order of or greater than that of the waste, the casing will be sealed at the top of the weathered bedrock after the soil is sampled as described below.

Soil below the waste in Boring Nos. 1, 3, 4, 5, 7, 8, 9, 10, 11, 12, and over the entire depth in Boring Nos. 13, 14, and 15 will be sampled using hollow-stem auger continuous coring techniques. Boring No. 12 is located to penetrate the buried west pond. Care will be taken that continuous auger sampling is started at a sufficiently high elevation in Boring No. 12 to sample the pond sediments. In addition, a sample retainer device will be fitted in the tip of the continuous sampler when necessary to assist sample recovery. NX rock core

sampling techniques using carbide or diamond bits which will utilize potable water from an approved source as the drilling fluid will be used in at least the bottom 10 feet of each boring. A pump-in borehole permeability test (packer test) will be conducted in the NX-cored section of each boring. From the continuous soil and weathered rock samples, discrete samples will be submitted for laboratory chemical analysis at 2-foot increments in soil and 4-foot increments in weathered rock. During drilling, all cuttings and soil samples will be screened with field instruments for radiation and volatile organic compounds.

The exception to the above sampling design will be in Boring Nos. 2 and 6. These two borings will be drilled only for the purpose of classifying soil types and installing standpipe piezometers. Sampling in these borings will consist of standard split-spoon or California drive samples obtained at 5-foot intervals to a depth of approximately 10 feet below the ground water level. Analytical testing will not be conducted on samples from Boring Nos. 2 and 6.

Four-inch diameter ground water monitoring wells will be constructed in Boring Nos. 1, 3, 4, 5, 7, 8, 9, 10, 11, and 12 (Figure 4-2). These wells will be constructed for the purpose of sampling leachate and soil vapor from the wells. For wells with a saturated thickness of waste of more than 13 to 15 feet, the lower 5 feet of the well will be screened and the upper portion of the well from 5 feet below the water level to within 3 feet of the ground surface will be screened. Therefore, prior to construction of the wells, the portions of the borings below the bottom of the waste will be required at the time of well construction.

In wells where the saturated thickness of the waste is in the range of 13 to 15 feet or less, the entire length of the well will be screened from the bottom to within 3 feet of the ground surface. This will allow sampling of both leachate and soil vapor from the wells. For wells with a saturated thickness of waste of more than 13 to 15 feet, the lower 5 feet of the well will be screened and the upper portion of the well from 5 feet below the water level to within 3 feet of the ground surface will be screened. The portion of the well

annulus between the upper and lower screened sections will be sealed. Based on available information, it is anticipated Well Nos 10, 11, and 12 will be of this variety. To isolate the upper from the lower screened section, purging and sampling these wells will require the use of packers and pumps which can be used to pump water from below the inserted packer. The purpose of double screening the larger saturated thicknesses is to reduce contaminant dilution in the event of contaminants with concentration gradients with depth. Table 4.3 presents a summary of the proposed monitoring well information.

Four rounds of ground water and well headspace soil gas samples will be collected during the Phase I RFI/RI process. The first round will occur following installation and development of the new wells. The next three rounds will be conducted over approximately the following year, however, the timing will be developed considering previous well hydrographs to sample at times of water level highs and lows. Water levels will be measured monthly in each of the wells.

Ground water samples will be analyzed for the analytes in Table 6.1, with the addition of Target Compound List semi-volatile organic compounds and pesticides. Well headspace gas will be analyzed by GC to test for methane, hydrogen sulfide, TCE, toluene, 1,1,1-TCA, benzene, methylene chloride, and chloroform.

Piezometers

The cross sections described by Boring Nos 2, 3, and 4, and by Boring Nos. 4, 5, and 6, intersect the portions of the ground water diversion and leachate collection system which may not be keyed into the bedrock. The profile sheets in the construction plans indicate the bottom of the system to be above the bedrock surface at these locations. Ground water levels along the section described by Well Nos. 10-86, 58-87, B106089, and the new Boring No. 1 will be compared with the ground water profiles described by the water levels in Well Nos. 2 through 6 to evaluate whether ground water infiltration is occurring beneath the ground water diversion and leachate collection system. One-inch diameter standpipe piezometers will be installed in Boring Nos. 2 and 6. These piezometers will be used solely to measure alluvial ground water levels. They will not be used for obtaining ground

water quality samples. Accordingly, they will be screened from the bottom (approximately 10 feet below the ground water level) to within 5 feet of the ground surface. Water levels will be measured monthly

Information from these additional monitoring wells will also be used to determine whether additional information on vertical contaminant migration into the bedrock water bearing units is needed. If warranted, bedrock investigations would be conducted during Phase II of the RFI/RI process. In addition to these proposed activities, a Ground Penetrating Radar survey was conducted in late 1989 to identify drainage pipes and valve vaults. The interpretive report is scheduled to be completed in July 1990.

4.2.4 Field Measurements

Ground water levels will be measured at all monitoring wells during the first week of each quarter. No other significant revisions, other than entry of the data into RFEDS, are proposed for field measurements.

5.0 DATA MANAGEMENT SYSTEM

Numerous past and present investigations at the Rocky Flats Plant have resulted in a need for a computer-based environmental information management system which can store and process a large number of data related to environmental investigations and corrective actions under RCRA and CERCLA, permit documents and regulatory information. The RFEDS is being developed using the ORACLE Relational Database Management System to address these needs.

In this section the RFEDS' capabilities for management of field and analytical data are presented.

5.1 RFEDS RELATIONAL DATABASE

RFEDS is a state-of-the-art environmental information management system that can be used to store analytical and geological characterization information from a wide variety of environmental activities. RFEDS has unique menu driven routines and features, including

- Menu driven, user friendly data entry routines which allow the user to enter field and analytical data. Field data can be entered from remote stations at Rocky Flats, providing access to the data in a timely manner.
- The capability to import electronically transmitted analytical data directly from the laboratory into the project database
- Sample tracking routines to trace and protect the integrity of the samples collected and shipped to the laboratory
- Provide a reference database containing physical, chemical and regulatory information on over 2,000 substances. The physical and chemical information include CAS numbers, molecular formula, molecular weight, solubility, boiling point, melting point, vapor pressure, Henry's Law constant, organic carbon partition coefficient and octanol-water ratio. A regulatory compliance and reporting module consists of waste inventory, permit tracking, SARA Title III reporting and compliance standards
- Capability to generate boring logs, well construction diagrams, well location sketches, contour maps, contaminant concentration maps, and user defined two or three dimensional plots via interfaces with graphical software

packages such as AutoCad, Surfer, Grapher, Quicksurf, and Dynamic Graphics

- Capability of listing and reporting complete or partial field and analytical data by using one of the standard report formats or a user-defined format. There are five different standard formats for reporting water levels and four different categories of standard formats for reporting analytical data.
- Capability to create summary statistical tables and statistical analysis of the selected data via SAS software package. The selected data can be transferred to a SAS format. The statistical summary tables will contain a number of detections, mean, median, standard deviation, coefficient of variation, maximum value, and minimum value. The data can be selected to create summary tables by wells, by chemical data, by date or any of the combination of all three. Selected data can also be analyzed in SAS to detect contaminant releases by interwell and intrawell comparisons.

RFEDS is very flexible via ORACLE-relational database programming language. The system can therefore be modified to manage a wide variety of environmental data.

5.2 LABORATORY INTERFACE

Analytical data generated in the laboratory can be entered into RFEDS either manually or electronically.

- Manual data entry: The analytical data is entered into one of the standard data entry forms which has been developed as a data entry template. Each parameter is entered individually.
- Electronic Transfer: The analytical data generated in the laboratory can be transmitted by a floppy diskette or by modem in a predefined file format. Any file that adheres to this format can be directly uploaded to the project database by selecting one of the options from the menu. As soon as the files are loaded to project files, the data reporting, query or analysis part of the program will include the new data in its routines.

5.3 DATA QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

The laboratory and the field data which are entered manually to the project database will be checked against the original data to assure that all of the entries made are accurate. If errors are noted or a modification is required, RFEDS provides an edit option to make corrections for any record. In addition, the quality level of the data, as determined

according to the procedures described in Section 6.0, will be entered in the system for each parameter. Data which have not been validated will be indicated as such

The data which are transmitted electronically will be checked by the laboratory personnel before transmittal. Only the finalized and checked data will be transmitted. In order to make sure that the reported values are reasonable and consistent, simplified checking procedures will be performed after the data are merged to project files. The validation levels for the reported results will be determined separately and entered to the system

RFEDS also allows manual entry or electronic transmittal of all of the laboratory QA/QC data. As a result, whenever the validity of the results need to be checked or reported, the QA/QC information related to the specific samples can be accessed by the user. The major information which can be entered into RFEDS include entries of the following:

- Matrix spike and matrix spike duplicate
- Surrogate spikes
- Method blanks
- Analysis date
- Duplicate analysis

Specific QA/QC procedures addressing the issues discussed above are currently under development. When finalized, they will provide validation of data entry and checking of the accuracy of previously entered data.

5.4 IMPLEMENTATION SCHEDULE

RFEDS is scheduled to be on-line with existing analytical data by June 15, 1990. Borehole information is scheduled to be incorporated by August 31, 1990. Procedures to verify data entry of the existing data are scheduled for completion by June 15, 1990 and complete validation of the data is scheduled to be completed by August 31, 1990. Procedures governing database integrity and verification of ongoing data entry are scheduled to be in-place by June 30, 1990

6.0 LABORATORY ANALYSES, DATA VALIDATION, AND DATA REPORTING

6.1 LABORATORY ANALYSES

Ground water samples have been collected and analyzed for various parameters since 1960. As site studies progressed and the need for additional analytical information increased, changes were made in the analytical program. At various times, ground water samples have been analyzed for the EPA Contract Laboratory Program (CLP) Hazardous Substance List (HSL), Target Compound List (TCL), Target Analyte List (TAL), and other inorganic and radiochemical parameters. These samples have historically been analyzed by both on-site laboratories and outside laboratories. Currently the majority of the ground water analyses are performed by outside contract laboratories.

The following discusses the parameters (analytes) which are currently analyzed in ground water samples, and the approximate schedule for analysis.

6.1.1 Analyte List

Ground water monitoring wells are currently sampled on a quarterly basis for the analytes listed in Table 6.1. This list provides comprehensive coverage of the types of ground water contaminants which might be found at the Rocky Flats Plant. This analyte list was instituted in 1989 for all ground water monitoring wells which are sampled as part of the Rocky Flats Ground Water Assessment Program.

As the Operable Unit investigations proceed, more will be known about the occurrence of specific contaminants in each of the known or suspected source areas. As a result, it will be feasible to tailor the current monitoring program to provide Operable Unit specific data as well as general site data more cost effectively.

A phased approach to future ground water sampling and analyses will be used to ensure that adequate spatial coverage is provided and that appropriate analytes are used for specific source areas and the plant site as a whole, while maintaining cost effectiveness. The phased approach will consist of the following:

Operable Unit Monitoring

1. Source area samples in each affected media will be analyzed for the analytes listed in Table 6.1, unless documentation is available to substantiate a reduced or modified analyte list
2. First year ground water samples from each water bearing unit in the "uppermost aquifer" will be analyzed for the same analytes
3. The analytical data from the source area samples and first year ground water samples will be evaluated. As a result of this evaluation, the analyte list will be modified to include only those contaminants (and their potential degradation/daughter products) detected in the source area samples and first round ground water samples. Ground water samples would be analyzed for this new analyte list for one year
4. After one year, the available analytical information will be reevaluated to determine whether it is feasible to select a reduced analyte list comprised of indicator compounds. If feasible, the indicator compounds would then be analyzed on a quarterly basis, with the more comprehensive analyte list being analyzed annually
5. Ground water samples from appropriate monitoring wells will be analyzed for 40 CFR Part 261 Appendix IX constituents at regulated units which go into Post Closure Care compliance monitoring.

General Plant Monitoring

1. Downgradient plant perimeter wells, as well as the site background monitoring wells, will continue to be analyzed on a quarterly basis for the analytes in Table 6.1
2. Other general plant ground water monitoring wells would either be placed on an annual sampling schedule for Table 6.1 analytes and/or would be analyzed on a quarterly basis for a less extensive indicator analyte list.

6.1.2 Turnaround Times

To date, analyses of the ground water samples have generally been performed by one contract outside laboratory and the on-site laboratory. EG&G is currently negotiating to have additional contract analytical laboratories provide services for analysis of ground water and other environmental samples. This will significantly improve the turnaround times for ground water samples. It is anticipated that most analyses will be completed

within a 4 to 6 week timeframe from the date of sample receipt. This turnaround time, combined with the capability to electronically transmit the analytical data into the RFEDS, will permit data to be available for interpretation approximately two months after the sample date (includes data validation time)

It is expected that the agreements with the additional contract laboratories will be completed in 1990

6.2 DATA REPORTING

The results of the ground water monitoring program will continue to be evaluated quarterly as required by 6 CCR 1007-3 and 40 CFR 265.94(b). Comprehensive data evaluation reports will be submitted to the Colorado Department of Health (CDH) annually. The annual reports will include.

- Tables indicating the sampling dates and the types of analyses performed on samples from each well;
- Data validation results, including assigned data quality levels and identification of any problems (e.g., holding time exceedances, laboratory interferences),
- Analytical and field data summary tables which provide the data in a format for easy comparison of historical quality data from the same well, in addition to interwell comparisons at the same Operable Unit,
- Statistical summary tables which evaluate variation in contaminant concentrations from background concentrations,
- Graphical representations of ground water quality data showing temporal variations and comparisons to the proposed concentration limits; and
- Narrative discussions concerning the nature and extent of ground water contamination, proposed revisions or modifications to either plant-wide or Operable Unit monitoring activities, and whether any interim remedial measures are warranted at any unit based on the ground water monitoring program results

The annual report will be submitted prior to the end of the first quarter in the year following the reporting period

6.3 DATA VALIDATION

Prior to data interpretation, the validity of all ground water chemical data is determined to establish whether the data are quantitatively usable. This data validation process involves a review of sampling records and analytical quality control results to determine whether the documentation and analytical control limits meet established requirements. As a result of the validation process, all chemical results are assigned one of the following validation codes:

- V - valid
- A - acceptable for use with qualification(s)
- R - rejected (unacceptable)

Only level V data are of quantitative quality suitable for use in statistical determination of contamination, as described in Section 7.0 below. Certain kinds of level A data can be used qualitatively for determination of contamination. For example, level A data consisting of positive detects of organics are ordinarily indicative of contamination because such organics do not occur naturally. Rejected data (level R) are unusable for determination of contamination in the RCRA ground water monitoring program.

The data validation procedure is described in detail in the Quality Assurance Project Plan for the Environmental Restoration Program (EG&G, 1990c). The data validation criteria are based on the Rocky Flats Plant sampling documentation requirements and analytical method references for the various analytical parameter suites. Analytical QC results are based on both field QC sample results, such as field blanks and field duplicates, and internal laboratory QC results, such as method blanks, and surrogate and matrix spike recoveries. Organic and metals data are validated according to the EPA laboratory data validation functional guidelines for the Contract Laboratory Program (EPA, 1988a, 1988b), and the CLP Statement of Work (EPA 1988c, 1988d). For major ions and radiochemicals, which do not have EPA data validation criteria, specific validation methods have been established for the Environmental Restoration Program (EG&G, 1990c).

Data validation is performed upon completion of the full laboratory data package, including CLP documentation as appropriate. The data validation process takes approximately two

to four weeks to accomplish, at which time the data are coded by validation level and are ready for interpretive uses

7.0 DATA INTERPRETATION PROCEDURES

The usable ground water quality data are evaluated to determine contamination by (a) identifying the presence of hazardous constituents, or (b) an increase in concentration of chemical constituents which are either naturally occurring (natural background), or are present in upgradient wells (ambient background)

To assess the presence of inorganic contamination at the regulated units, site-specific chemical data are compared to the background tolerance intervals or the maximum detected value if a tolerance interval could not be calculated. A constituent concentration that is greater than the upper limit of the one-sided 95 percent tolerance interval at the 95 percent confidence level will be preliminarily considered to represent contamination. For organic analytes, concentrations at or above the detection limits defined in the Environmental Restoration Program Quality Assurance Project Plan (EG&G, 1990c) are considered potential contamination.

Many of the ground water parameters that are analyzed are RCRA hazardous constituents as defined in 40 CFR Part 261, Appendix VIII. With the exception of the Safe Drinking Water Act (SDWA) metals, all hazardous constituents must be at background concentrations at the compliance point unless alternate concentration limits are proposed. SDWA metals may be present above background but not above National Primary Drinking Water Standards [40 CFR 264.94(a)(2)]. These background concentrations and drinking water standards are known as proposed concentration limits and are shown in Table 7.1.

Section 7.1 describes the background geochemical characterization program at the Rocky Flats Plant to determine natural background levels of chemicals in various media, including ground water. Section 7.2 describes the statistical evaluation of unit-specific water quality data for determination of contamination, including comparison with the natural background data. Section 7.3 presents the geochemical data evaluation of ground water data for determining the changes in the geochemistry of ground water for the background and the downgradient wells.

7.1 BACKGROUND GROUND WATER QUALITY PROGRAM

The Rocky Flats Plant is conducting a background geochemical characterization program to document the spatial and temporal variations of natural chemical concentrations in ground water, as well as other environmental media. The program has implemented the installation of 50 monitoring wells in background (unaffected) areas of the Rocky Flats Plant. The background wells have been installed in various geological deposits, including Rocky Flats Alluvium, colluvium, valley fill alluvium, weathered sandstone and claystone, and unweathered sandstone. To date, the results of one sampling round conducted from April through July 1989 have been published (Rockwell, 1989a). In that round, 35 wells were sampled and the others were dry or had too little water to sample. Additional sampling rounds are being conducted at quarterly intervals.

The background ground waters are analyzed for the indicator and inorganic parameters listed in Table 7.2. CLP organics are not analyzed because they do not occur naturally and should not be present in unaffected natural waters.

The range of background concentrations is being quantified through the calculation of tolerance intervals assuming a normal distribution. The upper limit of the tolerance interval or the maximum detected value for each parameter in ground waters from Round 1 are provided in Table 7.3. Maximum detected values are used where there is insufficient data to calculate tolerance intervals. This condition results from there being an insufficient number of samples, or where there is an insufficient number of detectable concentrations for a given analyte. Alternative statistical methods are identified, such as ANOVA (analysis of variance) or test of proportionality, to determine whether nonbackground data significantly differs from the background population where tolerance intervals have not been calculated. These procedures are discussed in more detail in Appendix A.

Tolerance intervals can also be constructed when the data are not normally or lognormally distributed. These types of tolerance intervals are called nonparametric tolerance intervals. The assumption for this method is that the data from each well come from the same continuous distribution and hence have the same median concentrations of a specific

constituent. The nonparametric tolerance interval require a large number of observations to provide a reasonable coverage and tolerance coefficient. Since background data are still being collected, nonparametric tolerance intervals will not be applied until enough data are collected from the site

As depicted in Table 7 3, high sodium, sulfate, and total dissolved solids concentrations distinguish the unweathered (deep) sandstone ground water from the other shallow ground water subgroups. The shallow ground water subgroups are similar in chemistry, nonetheless, the ground water of the Rocky Flats Alluvium is less saline than any of the other shallow ground water subgroups which it recharges.

It is anticipated for ground waters that there will be temporal variations in concentrations because of (1) natural variations in water quality, and (2) changes in the number and spatial representation of various background hydrogeological conditions due to seasonal fluctuations of the water table. At least two years of water quality data will be needed to perform the temporal tests (trend testing and control charts). For these reasons, further evaluations of background ground water quality will be performed to.

- Evaluate statistical distributions of data for their appropriateness for use in statistical analysis;
- Use multi-variate analysis of variance to evaluate the appropriateness of the present division of ground water populations and thus the potential for combining data from these populations into fewer water groups; and
- Investigate principal component analysis as a method to identify factors which may influence the distribution and concentration of analytes within background samples

7 2 PROCEDURES FOR STATISTICAL DETERMINATION OF CONTAMINATION

To detect contaminant releases to ground water from units, unit-specific data are compared to the range of background concentrations (tolerance intervals), and to previous well-specific data. Contamination may be identified by the presence of hazardous constituents or the increase in concentration of naturally occurring constituents. Determination that a constituent concentration in ground water represents contamination is based on (1)

comparison of new data to the background tolerance interval, (2) trend testing, and/or (3) use of control charts. These methods are used to

- Compare site downgradient/upgradient data to background concentrations of constituents at different stations,
- Compare a station's current concentrations of constituents to past concentrations so that the station serves as its own control,
- Compare a station's current concentrations to a constant compliance limit [maximum concentration limits (MCL) and alternate concentration limits (ACL)]

For water, one comparison alone is not sufficient for all monitoring situations, so it is necessary that multiple comparisons be made. The step-by-step procedure for using tolerance intervals, a test for trends, and control charts to achieve monitoring objectives, i.e., to determine hydrogeochemical changes and impacts from units at Rocky Flats Plant, is presented in Appendix A. A synopsis of the statistical procedures follows. These procedures may be revised as the background ground water quality evaluation proceeds.

Interwell Comparisons

Downgradient and background wells will be compared on a quarterly basis. The results of this comparison will be presented in the Annual RCRA Ground Water Monitoring Report for Regulated Units. Each downgradient concentration will be compared to the range (where range is defined as a statistical tolerance interval) of concentrations in background stations. A tolerance interval defines, with a specified probability, a range of values that contain a discrete percentage of the population. Downgradient wells whose concentrations fall outside the tolerance interval may indicate an impact to ground water has occurred.

In order to obtain reliable results, a high level of confidence (95 percent) and a high percentage of the population within the interval (95 percent) are chosen as statistical parameters. The number of sampling stations in the background area determines the width of the tolerance interval, i.e., the more background wells, the narrower the interval and the more likely it will be that contamination in downgradient locations will be detected. Tolerance limits can be used to detect distinct differences between upgradient and

downgradient conditions for a single monitoring event. Control charts and trend tests can be used to detect gradual changes over longer time periods.

Intrawell Comparisons

Comparing current concentrations in a well with historic concentration in the same well (intrawell comparison) is an effective way to detect changes over time. After a sufficient data history is available to establish the chemical pattern of a station, the observed concentrations are compared. A pattern that takes the form of a trend in concentrations over time is evidence of changing conditions which may indicate an impact.

Intrawell comparisons will be performed using graphs and statistical control charts. A control chart is a graphical procedure for determining whether the current concentration is above or below control limits established for the station.

The control limits are based on past variability in concentrations at the station and define typical behavior for the well when trends are not present. The graph itself can often indicate a trend, depending on its magnitude and linearity. The presence of seasonal data can also be indicated, and accounted for, in the analysis.

Comparisons with MCLs or ACLs

This procedure is appropriate when monitoring aims at determining whether ground water concentrations of constituents below or above fixed concentration limits (Table 7.1). The method applicable to this type of comparison includes confidence intervals or tolerance intervals.

A confidence interval for the mean concentration is constructed from the sample data for each compliance well individually. Generally, there should be at least four observations for each well from four different sampling periods. The confidence interval is constructed with the true or population mean with specified confidence. If this interval does not contain the specified compliance limits, then the mean concentration must differ from the

compliance limits. If the lower end of the interval is above the compliance limit, then the mean concentration must be significantly greater than compliance limits, indicating noncompliance.

When tolerance interval is used for comparisons, the tolerance intervals are constructed from the compliance well data with 95 percent confidence. If the upper limit of this interval exceeds the selected compliance limit, then the contamination is statistically evident.

7.3 GEOCHEMICAL DATA INTERPRETATION

Chemistry of ground water is altered as ground water moves along flowlines by the effects of a variety of geochemical processes. Some of the major processes are precipitation, dissolution, complexation, oxidation, reduction ion-exchange, and adsorption. These processes are influenced strongly by biological activities, physical factors such as climate and temperature, mineralogy of aquifer materials, and anthropogenic factors.

The ground water will be routinely monitored to detect any changes in the general chemistry. As an aid in interpreting the results, some graphical techniques will be utilized. Equilibrium concentrations of different phases will be estimated by equilibrium models such as WATEQ (Truesdell and Jones, 1974), PHREEQE (Parkhurst, et al., 1980) and MINTEQ (Felmy, et al, 1984). The output from these models will aid in interpreting the changes of ground water chemistry. The quality of the data will also be checked by cation/anion balance and electrical conductance-ionic sum relationships. The data with poor quality will not be used in interpretation process.

7.3.1 Anion/Cation Balance

The sum of the cations in equivalent parts per million (epm) should equal to the sum of anions in epm in water since water is electrically neutral. The balance will be calculated by the following equation

$$\text{Balance} = \frac{\sum \text{cations} - \sum \text{anions}}{\sum \text{cations} + \sum \text{anions}} \times 100$$

According to Keith, et al. (1983), the acceptable balance will approach 2 percent for a sample with total cations and anions of 20 epm, 3 percent with a total of 7 epm and 12 percent with a total of 0.9 epm. The balances higher than these values for each total cation/anion will be considered poor balance. The poor balance in the ground water may indicate an error in the analysis or reported data, or an incomplete analysis. Unless the reason for the unbalance in the data is known, the results associated with that sample will not be used for data interpretation.

7.3.2 Electrical Conductance -- Ionic Sum Relationship

The ionic sum of a complete analysis is the half the sum of anions plus cations in epm. Electrical conductance (EC in micromhos/cm) is a measure of the ability of water to conduct an electrical current. The relationship between EC and ionic sum (IS) is developed as a check on the analysis of major ions (Keith, et al., 1983). In general, this relationship on poor cation/anion balance data will indicate whether errors are in cations or anions.

The relationships for different IS values are defined as follows:

- When IS is less than 1.0 epm, $EC = 100 (IS)$
- When IS is between 1.0 and 3.0 epm, $EC = 12.27 + 86.38 (IS) + 0.835 (IS)^2$
- When IS is between 3.0 and 10.0 epm, $EC = IS [95.5 - 5.54 (\log IS)]$
- When IS exceeds 10 and HCO_3 is the dominant anion, $EC = 123 (IS)^{0.939}$
- When IS exceeds 10 and SO_4 is the dominant anion, $EC = 101 (IS)^{0.949}$

If EC measurement is not within the range of calculated EC value, the IS can be calculated using EC measured value. Calculated IS value should be equal to the sum of anions or cations. If one of these sums are considerably different than calculated IS then it can be assumed there is an error or missing information in the data for that fraction.

7.3.3 Graphical Presentation of Geochemical Data

Expressing data graphically aids in interpretation and presentation of geochemical data. The various graphical methods will be used routinely to determine the differences, similarities or changes between wells. The following graphical methods will be employed:

- Stiff diagrams
- Trilinear diagrams
- Ion Ratio plots
- Contour maps

Stiff Diagrams. The data can be presented in a manner that facilitates rapid comparison as a result of distinctive graphical shapes. Stiff diagrams are easy to construct and provide quick visual comparison of limited number of individual chemical analyses.

Trilinear Diagrams. These diagrams permit a large number of sample results plotted on a single graph so that major groupings and trends in the data can be easily visualized.

Ion Ratio Plots: The plots of certain ion ratios provide information related to the type of water based on the major constituents (e.g., HCO_3 or SO_4 waters). The most commonly used ratios are calcium to magnesium or sodium to chloride.

Contour Maps. Contour map of certain anions or cations will be prepared to show the areal distribution within the specified hydrological unit.

7.4 Data Interpretation Order

The following order of data interpretation procedure will be performed for the ground water monitoring:

- Data collection and analysis
- Data validation
- Geochemical interpretation of data
 - anion/cation balance
 - EC-ionic sum relationship

- Graphical interpretation
- Interwell comparison to determine the changes within the well
- Background comparisons
- If different from background, comparison of the results for the well with specified MCL to determine if the levels are exceeded

8.0 GROUND WATER MONITORING SCHEDULE

Table 8.1 presents a monitoring well schedule for the West Spray Field, Solar Evaporation Ponds, and Present Landfill monitoring wells. The schedule is based on the order by which these ground water monitoring wells were sampled during the first quarter 1990.

In general, this order is maintained for each quarter. However, efficiency considerations, such as sampling other wells during extended purge recovery periods for low-yield wells and well accessibility, can change the order. Second quarter sampling is currently being performed by four sampling teams simultaneously sampling the following areas:

- Plant interior including all operations areas and the Solar Pond wells contained within the Perimeter Security Zone
- Northeast buffer zone including the Present Landfill and the Solar Pond wells outside of the Perimeter Security Zone
- Southeast buffer zone including the 881 Hillside, 903 Pad, Mound, and East Trenches
- The background zone including all background wells north of the landfill, east of the East Trenches, south of Woman Creek, and west of the plant interior

The sampling order outlined in Table 8.1 is being revised by the sampling team coordinator. Therefore, during second quarter 1990, sampling schedules for each of the above areas are being reviewed and issued every two weeks. Comprehensive sampling schedules for each area will be available for third quarter 1990 but will change each quarter as wells are added or removed.

LIST OF REFERENCES

Cohen, A.C., Jr., 1961, Tables for Maximum Likelihood Estimates· Singly Truncated and Singly Censored Samples Technometrics 3, pp. 535-541

Doctor, P.G., R.O Gilbert, and R.R Kennison, 1986, Ground-Water Monitoring Plans and Statistical Procedures to Detect Leaking at Hazardous Waste Facilities, Draft Report for U.S Environmental Protection Agency, Pacific Northwest Laboratories, Richland, Washington.

EG&G Rocky Flats, Inc , 1990a, "1989 Annual RCRA Ground-Water Monitoring Report for Regulated Units at Rocky Flats Plant," Golden, Colorado, March 1, 1990.

EG&G Rocky Flats, Inc., 1990b, "Phase I RFI/RI Work Plan Solar Evaporation Ponds (Operable Unit No. 3)," draft, April 1990.

EG&G Rocky Flats, Inc., 1990c, "Quality Assurance Project Plan," Environmental Restoration Program, Rocky Flats Plant, in preparation

EPA, 1988a: Laboratory Data Validation, Functional Guidelines for Evaluating Organic Analyses, February 1988.

EPA, 1988b: Laboratory Data Validation, Functional Guidelines for Evaluating Inorganics Analyses, July 1988

EPA, 1988c: Contract Laboratory Program, Statement of Work for Organic Analysis, February, 1988.

EPA, 1988d: Contract Laboratory Program, Statement of Work for Inorganics Analysis, July, 1988.

EPA, 1989, Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities: Interim Final Guidance. EPA/530-SW-89-026

Felmy, A.R., Girvin, D C , and Jenne, E A , 1984, "MINTEQ - A Computer Program for Calculating Aqueous Geochemical Equilibria," U S. Environmental Protection Agency, Athens, GA, EPA-600/3-84-032

Keith, S.J., M.T. Frank, C. McCarty, and G Mossman, 1983, "Dealing with the Problem of Obtaining Accurate Ground-Water Quality Analytical Results," in Proceedings of the Third National Symposium on Aquifer Restoration and Ground-Water Monitoring, National Water Well Association, Worthington, OH

Parkhurst, D.L., D C. Thorstenson, and L N Plummer, 1980, "PHREEQE - A Computer Program for Geochemical Calculations," Water Resources Investigations 80-96, U S Geological Survey, Reston, VA

Rockwell International, 1989a, "Background Geochemical Characterization Report," US DOE Rocky Flats Plant, Golden, Colorado, draft December 15, 1989.

Rockwell International, 1988a, "Present Landfill Closure Plan, USDOE Rocky Flats Plant," Golden, Colorado, July 1988

Rockwell International, 1988b, "Present Landfill Hydrogeologic Characterization Report," prepared by Roy F Weston, Inc , Golden, Colorado, July 1988.

Rockwell International, 1988c, "Closure Plan: Solar Evaporation Ponds," U.S DOE, Rocky Flats Plant, Golden, CO, Volumes I-IV

Truesdell, A H. and B F. Jones, 1974, "WATEQ - A Computer Program for Calculating Chemical Equilibria of Natural Waters," J. Res. U S. Geological Survey 2. 233-248.

APPENDIX A
STATISTICAL METHODS FOR COMPARISON OF
GROUND WATER QUALITY DATA WITH BACKGROUND LEVELS

A.1 INTRODUCTION

The logic for selecting the appropriate method of statistical comparison between background and non-background is charted in Figure A-1. As indicated within this flowchart, the primary determinant for use of the appropriate statistical method is the percentage of values above analytical detection limits. If there are less than 10 percent detects for a particular parameter, tolerance intervals based on the Poisson distribution are appropriate, if greater than 10 percent and less than 50 percent detects occur, a test of proportions is appropriate; and if greater than 50 percent detects are encountered, tolerance intervals or analysis of variance (ANOVA) are appropriate (EPA, 1989). Tolerance intervals will be calculated if the number of samples collected is equal to or greater than seven, while ANOVA will be reserved for analytes when the number of samples collected is less than seven.

A.2 COMPUTATION OF NORMAL TOLERANCE INTERVAL STATISTICAL METHODS

A tolerance interval will be computed for a constituent concentration in a background water type based on the latest quarterly data. Tolerance intervals define a range that contains at least p percent of a population with P percent probability (level of confidence), i.e., upon repeated sampling, P percent of the calculated intervals will contain p percent of the population. Tolerance intervals answer the question: where do most of the observations lie?

For the tolerance interval to be useful in decision making, both " p " and " P " are chosen to be large, in this case, $p = 0.95$ and $P = 0.95$. A site-related or downgradient concentration that lies outside this interval will be evaluated as a potential release from a unit.

A tolerance interval is either one-sided or two-sided. A two-sided tolerance interval is appropriate whenever a concentration either larger or smaller than background may be associated with a contaminant release, e.g., pH. One-sided tolerance intervals are appropriate for all other constituents for which an increase over background concentrations are indicative of releases. A two-sided interval is defined by two limits (L_1 and L_2) where a proportion "p" of the population is contained between the limits L_1 and L_2 with probability "P". An upper (or lower) one-sided tolerance limit is defined so that P percent of the population is less than (or greater than) the upper limit L_2 (or the lower limit L_1).

Criteria for the use of tolerance intervals based on normal distribution are (1) a 50 percent or greater rate of detection among samples (EPA, 1989), and (2) a sample size of seven or more. Tolerance interval calculations will be restricted to seven or more samples in order to obtain a 95 percent interval (95 percent of the population within a one-sided interval) with a tolerance factor of 3.4 (one-sided) at the 95 percent confidence level (Table A.1). (The Background Hydrogeochemical Characterization Monitoring Plan (BHCMP) calls for nine samples to achieve a tolerance factor of 3.0, however, for preliminary use, if seven samples are available a tolerance interval will be calculated). When a sample set size is less than seven, the mean plus three standard deviations will be calculated for comparison with other tolerance intervals. When comparing these values, it must be emphasized that the mean plus three standard deviations reflects less than a 95 percent confidence level and/or less than 95 percent of the population.

Parametric tolerance intervals are calculated assuming a normal probability distribution. Assumption of a normal probability distribution is consistent with new EPA regulations for RCRA ground water monitoring (EPA, 1989). If a given constituent's concentration ranges over more than three orders of magnitude, then a lognormal tolerance interval will be used (Doctor, et al., 1986). The other criterion used to determine if the data are normally distributed is the calculation of the coefficient of variation. The coefficient of variation is the standard deviation divided by the mean [or adjusted mean as developed by Cohen (1961)]. If the coefficient of variation resulted in a value greater than one or less than

zero, the data are assumed to be lognormally distributed, therefore, lognormal tolerance intervals are proposed.

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

$$L_1 = \bar{x} - Ks \text{ and}$$
$$L_2 = \bar{x} + Ks,$$

where:

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

Table A 1 presents tolerance factors K for two-sided and one-sided tolerance intervals at 95 percent population and 95 percent confidence. With the exception of pH, one-sided tolerance intervals (L_2) will be calculated for all analytes. For a small number of samples, the K value is large, leading to tolerance intervals that probably would not detect releases from units. As the number of samples increases, the value of K decreases, which leads to narrower tolerance intervals. Narrower background tolerance intervals will be more sensitive to detecting releases to the environment from units.

Many Inorganic Target Analyte List constituents will be undetected in both background and downgradient wells. Special procedures are thus needed to compute the mean and standard deviation of a population when a significant number of the observations are below the detection limit. A data set is termed censored when not detected (ND) observations are present in a data set, and some assumption must be made about the statistical distribution for the entire data set. A technique for calculation of the mean and standard deviation of such a data set was developed by Cohen (1961) and can be used if the data are normally distributed.

The Cohen procedure is as follows (Doctor, et al, 1986)

Let

n = the total number of observations for a constituent
 k = number of actual measurements out of n (not NDs)
 x_o = the detection limit of the constituent

Then:

- 1) Compute $h = (n-k)/n$ (the proportion of measurements below the detection limit)
- 2) Compute $x_u = (\text{Sum of } x_i \text{ for } i = 1 \text{ to } k)/k$.
- 3) Compute $s_u^2 = (\text{Sum of } (x_i - x_u)^2 \text{ for } i = 1 \text{ to } k)/k$.
- 4) Compute $t = s_u^2 / (x_u - x_o)^2$
- 5) Obtain an estimate of Lambda from Table A 2 using h and t
- 6) Estimate the mean and variance of the population from which the censored data set was drawn by computing

$$x = x_u - \lambda^2 (x_u - x_o)$$

and

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

With regard to radiochemistry data, a measurement error, equal to two standard deviations (2s) of the measurement is associated with the results. It is necessary to consider propagation of error when interpreting the mean value computed from a series of radiochemical results, i.e., the precision of each measurement must be considered in order to define the precision of the mean value. This is accounted for by computing the variance (S^2) of the mean value.

It is noted that the variance of the sum of n observations each with variance $s_{x_i}^2$ is simply the sum of the variances:

$$y = x_1 + x_{1+1} + \dots + x_n$$

$$s_y^2 = s_{x_1}^2 + s_{x_{1+1}}^2 + \dots + s_n^2$$

When coefficients are involved, the relationship is as follows

$$y = ax_c + bx_{c+1} + kx_n$$

$$s_y^2 = a^2 s_{x_1}^2 + b^2 s_{x_{i+1}}^2 + k^2 s_{x_n}^2$$

Computation of mean implies the coefficients are each equal to $1/n$. Therefore, the variance of the mean is

$$s_x^2 = 1/n^2 (s_{x_1}^2 + s_{x_{i+1}}^2 + s_n^2)$$

The relationship has been used to calculate the error associated with the mean, where the error is $2s_x$.

TABLE A 1

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

n	<u>Two-Sided</u>	<u>One-Sided</u>
2	37.67	
3	9.916	7.655
4	6.370	5.145
5	5.079	4.202
6	4.414	3.707
7	4.007	3.399
8	3.732	3.188
9	3.532	3.031
10	3.379	2.911
11	3.259	2.815
12	3.162	2.736
13	3.081	2.670
14	3.012	2.614
15	2.954	2.566
16	2.903	2.523
17	2.858	2.486
18	2.819	2.453
19	2.784	2.423
20	2.752	2.396
21	2.723	2.371
22	2.697	2.350
23	2.673	2.329
24	2.651	2.309
25	2.631	2.292
26	2.612	
27	2.595	
28	2.579	
29	2.554	
30	2.549	2.220
35	2.490	2.166
40	2.445	2.126
45		2.092
50	2.379	2.065
60	2.333	
80	2.272	
100	2.233	
200	2.143	
500	2.070	
1000	2.036	
inf	1.960	

TABLE A 2

Values of Lambda for Estimating the Mean and Variance of a Normal Distribution when MD Values are Present

h	Tau	.25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.80	.90	h
0.00	0.00	0.318620	0.402100	0.494100	0.596100	0.709600	0.836800	0.980800	1.145000	1.336000	1.561000	2.176000	3.283000	0.00
0.05	0.05	0.327930	0.413000	0.506600	0.610100	0.725200	0.854000	0.999400	1.166000	1.358000	1.585000	2.203000	3.310000	0.05
0.10	0.10	0.336620	0.423300	0.518400	0.623400	0.740000	0.870300	1.017000	1.185000	1.379000	1.608000	2.229000	3.345000	0.10
0.15	0.15	0.344800	0.433000	0.529600	0.636100	0.754200	0.884000	1.035000	1.204000	1.400000	1.630000	2.255000	3.376000	0.15
0.20	0.20	0.352550	0.442200	0.540300	0.648300	0.767800	0.901200	1.051000	1.222000	1.419000	1.651000	2.280000	3.405000	0.20
0.25	0.25	0.359930	0.451000	0.550600	0.660000	0.781000	0.915800	1.067000	1.240000	1.439000	1.672000	2.305000	3.435000	0.25
0.30	0.30	0.367000	0.459500	0.560400	0.671300	0.793700	0.930000	1.083000	1.257000	1.457000	1.693000	2.329000	3.464000	0.30
0.35	0.35	0.373790	0.467600	0.569900	0.682100	0.806000	0.943700	1.098000	1.274000	1.476000	1.713000	2.353000	3.492000	0.35
0.40	0.40	0.380330	0.475300	0.579100	0.692700	0.816900	0.957000	1.113000	1.290000	1.494000	1.732000	2.376000	3.520000	0.40
0.45	0.45	0.386630	0.483100	0.588000	0.702900	0.829500	0.970000	1.127000	1.306000	1.511000	1.751000	2.399000	3.547000	0.45
0.50	0.50	0.392760	0.490400	0.596700	0.712900	0.840800	0.982600	1.141000	1.321000	1.528000	1.770000	2.421000	3.575000	0.50
0.55	0.55	0.398700	0.497600	0.605100	0.722300	0.851700	0.995000	1.155000	1.337000	1.545000	1.788000	2.443000	3.601000	0.55
0.60	0.60	0.404470	0.504500	0.613300	0.732000	0.862500	1.007000	1.169000	1.351000	1.561000	1.806000	2.465000	3.628000	0.60
0.65	0.65	0.410080	0.511400	0.621300	0.741200	0.872900	1.019000	1.182000	1.364000	1.570000	1.824000	2.486000	3.654000	0.65
0.70	0.70	0.415550	0.518600	0.629100	0.750200	0.883200	1.030000	1.195000	1.380000	1.593000	1.841000	2.507000	3.679000	0.70
0.75	0.75	0.420900	0.524500	0.636700	0.759000	0.893200	1.042000	1.207000	1.394000	1.608000	1.858000	2.528000	3.705000	0.75
0.80	0.80	0.426120	0.530400	0.644100	0.767600	0.903100	1.053000	1.220000	1.408000	1.624000	1.875000	2.548000	3.730000	0.80
0.85	0.85	0.431220	0.537000	0.651500	0.776100	0.912700	1.064000	1.232000	1.422000	1.639000	1.892000	2.568000	3.754000	0.85
0.90	0.90	0.436220	0.543000	0.658600	0.784400	0.922200	1.074000	1.244000	1.435000	1.653000	1.908000	2.588000	3.779000	0.90
0.95	0.95	0.441120	0.549000	0.665600	0.792300	0.931400	1.085000	1.255000	1.448000	1.668000	1.924000	2.607000	3.803000	0.95
1.00	1.00	0.445920	0.554800	0.672400	0.800500	0.940600	1.095000	1.267000	1.461000	1.682000	1.940000	2.626000	3.827000	1.00

TABLE A 2 con't

Values of Lambda for Estimating the Mean and Variance of a Normal Distribution when MD Values are Present

h	tau	01	02	03	04	05	06	07	08	09	10	15	.25>	h
0.00	0.00	0.010100	0.020400	0.030902	0.041583	0.052507	0.063627	0.074953	0.086486	0.098240	0.110200	0.173420	0.242680	0.00
0.05	0.05	0.010551	0.021294	0.032225	0.043350	0.054670	0.066189	0.077909	0.089634	0.101970	0.114310	0.179350	0.250330	0.05
0.10	0.10	0.010950	0.022082	0.033398	0.044902	0.056596	0.068483	0.080568	0.092852	0.105340	0.118040	0.184790	0.257410	0.10
0.15	0.15	0.011310	0.022798	0.034466	0.046318	0.058356	0.070586	0.083009	0.095629	0.108450	0.121480	0.189650	0.264050	0.15
0.20	0.20	0.011642	0.023459	0.035453	0.047629	0.059990	0.072539	0.085280	0.098216	0.111350	0.124690	0.194600	0.270310	0.20
0.25	0.25	0.011952	0.024076	0.036377	0.048858	0.061522	0.074372	0.087413	0.100650	0.114080	0.127720	0.199100	0.276260	0.25
0.30	0.30	0.012243	0.024658	0.037249	0.050018	0.062969	0.076106	0.089433	0.102950	0.116670	0.130590	0.203380	0.281930	0.30
0.35	0.35	0.012520	0.025211	0.038077	0.051120	0.064345	0.077756	0.091355	0.105150	0.119140	0.133330	0.207470	0.287370	0.35
0.40	0.40	0.012784	0.025738	0.038866	0.052173	0.065660	0.079332	0.093193	0.107250	0.121500	0.135950	0.211390	0.292600	0.40
0.45	0.45	0.013036	0.026243	0.039624	0.053182	0.066921	0.080845	0.094958	0.109260	0.123770	0.138470	0.215170	0.297650	0.45
0.50	0.50	0.013279	0.026728	0.040352	0.054153	0.068135	0.082301	0.096657	0.111210	0.125950	0.140900	0.218820	0.302530	0.50
0.55	0.55	0.013513	0.027196	0.041054	0.055089	0.069306	0.083708	0.098298	0.113080	0.128060	0.143250	0.222350	0.307250	0.55
0.60	0.60	0.013739	0.027649	0.041733	0.055995	0.070439	0.085068	0.099887	0.114900	0.130110	0.145520	0.225780	0.311840	0.60
0.65	0.65	0.013958	0.028087	0.042391	0.056874	0.071538	0.086388	0.101430	0.116660	0.132090	0.147730	0.229100	0.316300	0.65
0.70	0.70	0.014171	0.028513	0.043030	0.057726	0.072605	0.087670	0.102920	0.118370	0.134020	0.149870	0.232340	0.320650	0.70
0.75	0.75	0.014378	0.028927	0.043652	0.058556	0.073643	0.088917	0.104380	0.120040	0.135900	0.151960	0.235500	0.324890	0.75
0.80	0.80	0.014579	0.029330	0.044258	0.059364	0.074655	0.090133	0.105800	0.121670	0.137730	0.154000	0.238580	0.329030	0.80
0.85	0.85	0.014775	0.029723	0.044848	0.060153	0.075642	0.091319	0.107190	0.123250	0.139520	0.155990	0.241580	0.333070	0.85
0.90	0.90	0.014967	0.030107	0.045425	0.060923	0.076606	0.092477	0.108540	0.124800	0.141260	0.157930	0.244520	0.337030	0.90
0.95	0.95	0.015154	0.030483	0.045989	0.061676	0.077549	0.093611	0.109870	0.126320	0.142970	0.159830	0.247400	0.340910	0.95
1.00	1.00	0.015338	0.030850	0.046540	0.062413	0.078471	0.094720	0.111160	0.127800	0.144650	0.161700	0.250220	0.344710	1.00

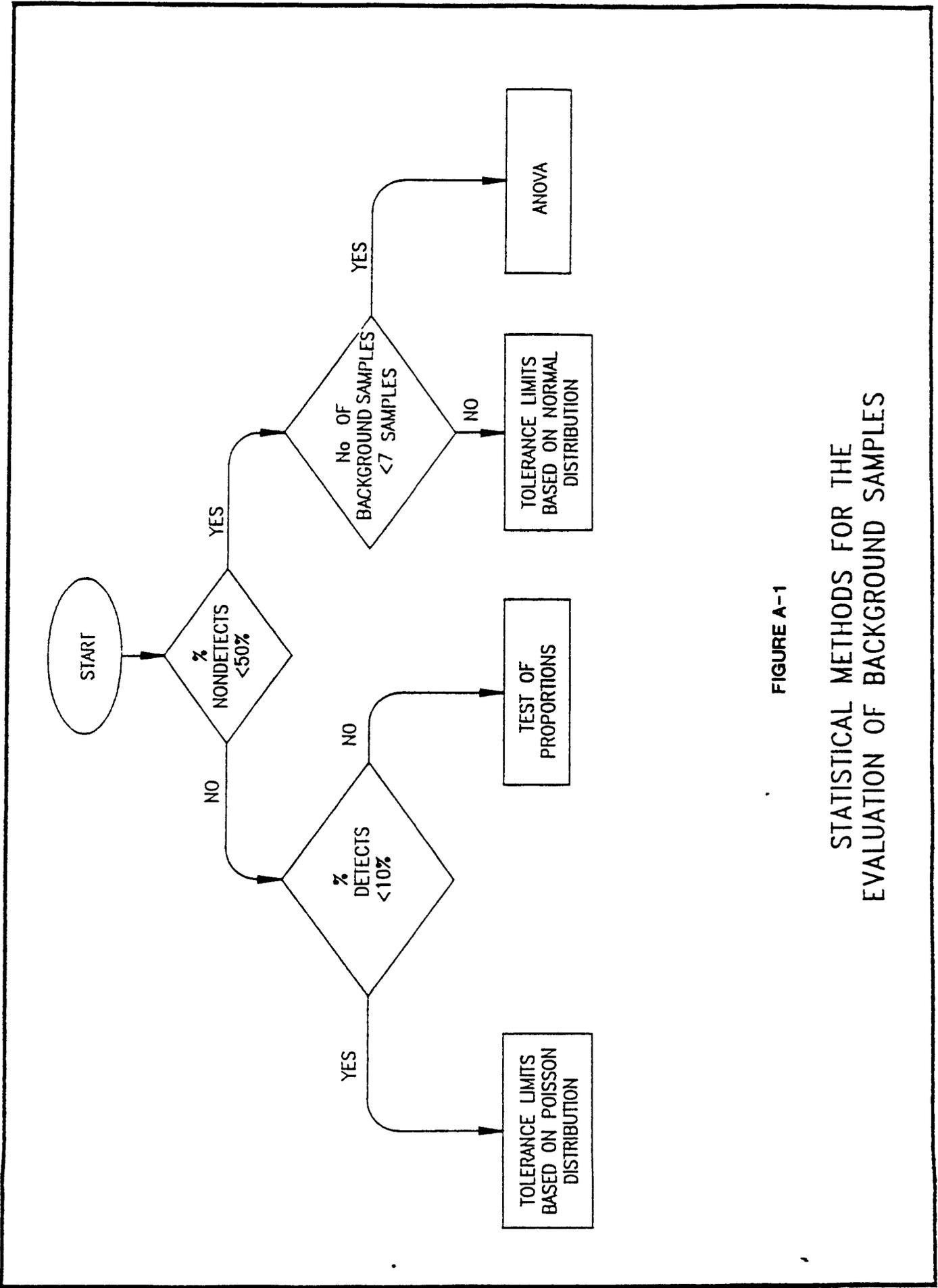


FIGURE A-1

STATISTICAL METHODS FOR THE EVALUATION OF BACKGROUND SAMPLES

TABLE 2 1

WEST SPRAY FIELD
RESULTS OF HYDRAULIC CONDUCTIVITY TESTS
IN THE ROCKY FLATS ALLUVIUM

Well	Lithology	Drawdown Recovery Test (cm/s)	Hydraulic Conductivities		Ground Water velocity* (ft/yr)
			Slug Test (cm/s)		
-5 86	Gravel, sand, silt		2.1×10^{-5}		3.5
-7 86	Gravel, silt	2.6×10^{-5}			4.3
-9-26	Gravel, sand, silt		9.7×10^{-5}		16.1
50 86	Gravel, sand, silt		5.3×10^{-4}		87.8
55 86	Boulders + Silt		5.0×10^{-5}		8.3
3- 0589	Sand and Gravel		2.3×10^{-4} 2.7×10^{-4}		38.1 48.0
3- 0689	Sand and Gravel		7.5×10^{-4} 9.1×10^{-4}		26 151
34-0739	Sand, Gravel		5.4×10^{-4} 9.8×10^{-4}		89.4 162
31-0889	Gravel, Sand		3.0×10^{-3} 3.4×10^{-3} 3.0×10^{-3} 3.4×10^{-3}		497 563 497 563
3- 0989	Gravel, Sand		7.3×10^{-4} 7.6×10^{-4}		21 126
31-1 29	Gravel Sand		1.0×10^{-4} 3.0×10^{-4}		6.6 49.7
3- 139	Sand and Gravel		1.9×10^{-5} 1.6×10^{-5}		3.1 5.0
34-1 339	Sand and Gravel		7.0×10^{-5} 3.5×10^{-5}		11.6 18.1

Horizontal ground-water velocity. Velocities are calculated from the hydraulic conductivity, the average horizontal gradient of 0.016 ft/ft, and an assumed effective porosity of 0.1. The equation used is

$$GW \text{ Velocity (ft/yr)} = K(\text{cm/s}) (0.016 \text{ ft/ft}) (1.035 \times 10^5 \text{ ft-sec/cm-yr}) / (0.1)$$

where K = hydraulic conductivity (cm/s)

TABLE 2 2

WEST SPRAY FIELD RESULTS OF HYDRAULIC CONDUCTIVITY TESTS
IN THE ARAPAHOE FORMATION

Well	Lithology	Hydraulic Conductivities		
		Drawdown Recovery Test (cm/s)	Slug Test (cm/s)	Packer Test ^a (cm/s)
-o 26	Claystone			4×10^{-8}
	Siltstone	5×10^{-8}		4×10^{-8}
-8 26	Siltstone & Sandstone		5.4×10^{-7}	
	Siltstone			1.5×10^{-8}
	Sandstone			6×10^{-8}
	Geometric Mean (cm/s)			
	Sandstone			9×10^{-8}
	Siltstone	5×10^{-8}		3×10^{-8}
	Claystone			4×10^{-8}

^a Represents the geometric mean of three test at several intervals

TABLE 3 1

SOLAR EVAPORATION PONDS
RESULTS OF HYDRAULIC CONDUCTIVITY TESTS IN SURFICIAL MATERIALS

<u>Well Number</u>	<u>Formation</u>	<u>Lithology Screened</u>	<u>Drawdown Recovery Test (cm/s)</u>
17-86	Q _{vf}	Gravel	4.8 x 10 ⁻⁶
22-86	Q _{rf}	Gravel	8.7 x 10 ⁻⁶
26-86	Q _{rf}	Gravel and Sand	4 x 10 ⁻⁶

Q_{rf} = Rocky Flats Alluvium

Q_{vf} = Valley Fill Alluvium

TABLE 3 2
RESULTS OF HYDRAULIC CONDUCTIVITY TESTS
IN ARAPAHOE FORMATION

Well	Lithology	Drawdown Recovery Test (cm/s)	Slug Test (cm/s)	Packer Test (cm/s)
14-86	Sandstone Claystone	1.9×10^{-7}		2.2×10^{-6} 1.3×10^{-6}
16-86	Siltstone & Sandstone* Siltstone Claystone	6×10^{-8}		6.1×10^{-7} 5.3×10^{-6}
23-86	Sandstone Siltstone Claystone		1×10^{-8}	6.9×10^{-7} 2.4×10^{-7}
25-86	Claystone & Sandstone* Sandstone Claystone	7×10^{-8}		3.4×10^{-7} 1.2×10^{-7}
27-86	Sandstone Siltstone Claystone	1.9×10^{-7}		1.4×10^{-7} 2.4×10^{-7}
32-86	Sandstone & Claystone* Claystone	9×10^{-8}		2.2×10^{-7}
34-86	Sandstone Claystone	3.1×10^{-6}		3.3×10^{-6} 1.3×10^{-6}
	Geometric Mean (cm/s)			
	Sandstone:	4.8×10^{-7}	1×10^{-8}	1.4×10^{-6}
	Siltstone:			3.9×10^{-7}
	Claystone:			5.4×10^{-7}

* Mixed lithology tests not used in calculating geometric means.

TABLE 3 3'
BOREHOLE LOCATION RATIONALE

<u>Borehole Identification Number</u>	<u>Description of Borehole Location</u>	<u>Location Rationale</u>
Downgradient of French Drain System		
SEP-01-SB90 SEP-02-SB90 SEP-03-SB90 SEP-04-SB90 SEP-21-SB90 SEP-26-SB90 SEP-27-SB90	Located near the lateral extent of the interpreted nitrate plume in unconfined groundwater system ^a	Evaluate lateral extent of vadose zone contamination and relationship between groundwater contaminant plume and soils/vadose zone contaminants
SEP-05-SB90	Located downgradient of French drains and near longitudinal axis of the interpreted nitrate plume in the unconfined groundwater system ^a	Same as for boreholes 1, 2, 3, and 4
SEP-06-SB90	Located downgradient of French drains and near fringe of interpreted sulfate plume in the unconfined groundwater system ^b	Same as for boreholes 1, 2, 3, and 4
Between Ponds and French Drain System		
SEP-07-SB90 SEP-08-SB90 SEP-09-SB90 SEP-10-SB90	Located on a line perpendicular to the apparent longitudinal axis of the interpreted nitrate and sulfate plumes in the unconfined groundwater system ^{a b}	Evaluate lateral extent of vadose zone contamination between Solar Evaluation Ponds and French Drain System

TABLE 3 3
(continued)

<u>Borehole Identification Number</u>	<u>Description of Borehole Location</u>	<u>Location Rationale</u>
Near Solar Evaporation Ponds		
SEP-11-SB90	Located north of Pond 207-A	Evaluate contaminant concentration profile near historical source (leakage from pond)
SEP-12-SB90	Located between Ponds 207-A and 207-B	Same as for borehole 11
SEP-13-SB90	Located near fringe of nitrate plume and near abandoned pond in SW portion of waste man- agement area ^a	Same as for borehole 11 and to evaluate lateral extent of vadose zone contamination and rela- tionship between ground- water contaminant plume and soils/vadose zone contaminants
SEP-14-SB90	Located near outer fringe of the interpre- ted nitrate plume in unconfined ground- water system in the SE portion on the waste management area ^a	Same as for borehole 13
SEP-15-SB90	Located north of Pond 207-C	Evaluate potential contam- inant north of the pond and potential leakage from the pipelines
SEP-16-SB90	Located south of Pond 207-A	Evaluate vadose zone contamination from pond leakage potentially moving to the south

TABLE 3 3
(continued)

<u>Borehole Identification Number</u>	<u>Description of Borehole Location</u>	<u>Location Rationale</u>
SEP-17-SB90	Located southeast of Pond 207-B south	Evaluate lateral extent of vadose zone contamination and relationship between groundwater contaminant plume and vadose zone contaminants
SEP-18-SB90	Located southwest of Pond 207-A	Same as for SEP-17-SB90
SB-20-SB90	Located east of Pond 207-B (north)	Same as for SEP-11-SB90
SEP-19-SB90	Located outside of the interpreted nitrate plume ^a and within the interpreted Arapahoe sandstone ^c paleo-channel	
In French Drain System Area		
SEP-22-SB90 SEP-23-SB90 SEP-24-SB90 SEP-25-SB90	Located between individual French drain lines	Evaluate nature and extent of contaminant in vadose zone in the area of French Drain System

^aNitrate plume in unconfined groundwater system from EG&G, 1990f, Figure 2-10

^bSulfate plume in unconfined groundwater system from EG&G, 1990f, Figure 2-11

^cArapahoe sandstone interpreted channel from EG&G, 1990g

TABLE 3 4
ANALYTE LIST FOR SOLAR EVAPORATION POND INVESTIGATION^a

<u>Radionuclides</u>	<u>Inorganics^b</u>
Plutonium 239, 240	Nitrate/Nitrite
Americium 241	Ammonia (as N) ^c
Cesium 137	Sulfate
Uranium 233, 234, 235, and 238	Total sulfur ^b
Strontium 90	Hydroxide
Tritium ^c	Fluoride
Gross alpha	Chloride ^c
Gross beta	
Radon ^d	<u>Volatile Organics^b</u>
<u>Metals</u>	Chloromethane
Aluminum	Bromomethane
Antimony	Vinyl Chloride
Arsenic	Chloroethane
Barium	Methylene Chloride
Beryllium	Acetone
Cadmium	Carbon Disulfide
Calcium	1,1-Dichloroethene
Cesium	1,1-Dichloroethane
Cobalt	1,2-Dichloroethene (total)
Chromium	Chloroform
Copper	1,2-Dichloroethane
Iron	2-Butanone
Lead	1,1,1-Trichloroethane
Lithium ^h	Carbon Tetrachloride
Magnesium	Vinyl Acetate
Manganese	Bromodichloromethane
Mercury	1,1,2,2-Tetrachloroethane
Nickel	1,2-Dichloropropane
Potassium	cis-1,3-Dichloropropene
Selenium	Trichloroethene
Sodium	Dibromochloromethane
Silver	1,1,2-Trichloroethane
Thallium	Benzene
Tin ^h	trans-1,3-Dichloropropene
Vanadium	Bromoform
Zinc	2-Hexanone
	4-Methyl-2-pentanone
	Tetrachloroethene
	Toluene

TABLE 3 4
(continued)

Volatile Organics (continued)

Chlorobenzene
Ethyl Benzene
Styrene
Xylenes (Total)
Methylethyl Ketone Peroxide^h

Semivolatile Organics^g

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

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

TABLE 3 4
(continued)

Miscellaneous

Acidity^c
Alkalinity^c
pH^c
Specific conductance^e
Dissolved Oxygen^{c,f}
Oxidation reduction potential^{c,f}

^aModified after the Draft Interagency Agreement, Attachment 4, "Hazardous Substance List "

^bSoil/sediment matrix only

^cWater matrix only

^dGroundwater samples only.

^eBoth field and laboratory determinations

^fField determination only

^gFor water matrix, perform analysis on unfiltered sample only

^hFrom Draft Interagency Agreement, Attachment 4, "Hazardous Substance List "

TABLE 3 5
ESTIMATED TARGET DEPTHS
FOR VADOSE ZONE BORINGS

<u>Borehole</u>	<u>Ground Surface Elevation (Feet)^a</u>	<u>Top of Bedrock Elevation (Feet)^a</u>	<u>Assumed Thickness of Weathered Arapahoe Formation (Feet)^b</u>	<u>Estimated Target Depth of Boring (Feet)</u>
SEP-01-SB90	5,900	5 900	10	10
SEP-02-SB90	5,860	5,840	10	30
SEP-03-SB90	5,850	5,840	10	20
SEP-04-SB90	5,885	5 882	10	13
SEP-05-SB90	5 885	5 880	10	15
SEP-06-SB90	5,900	5,890	10	20
SEP-07-SB90	5,955	5,946	10	19
SEP-08-SB90	5,960	5,948	10	22
SEP-09-SB90	5 940	5 940	10	10
SEP-10-SB90	5 940	5,940	10	10
SEP-11-SB90	5 970	5 965	10	15
SEP-12-SB90	5,970	5,958	10	22
SEP-13-SB90	5 975	5,968	10	17
SEP-14-SB90	5,960	5,950	10	20
SEP-15-SB90	5,960	5,960	10	10
SEP-16-SB90	5,975	5,963	10	22
SEP-17-SB90	5,970	5 960	10	20
SEP-18-SB90	5,980	5,965	10	25
SEP-19-SB90	5,950	5,945	10	15
SEP-20-SB90	5,960	5,950	10	20
SEP-21-SB90	5,925	5,920	10	15
SEP-22-SB90	5,920	5,900	10	30
SEP-23-SB90	5,910	5,890	10	30
SEP-24-SB90	5,920	5,910	10	20
SEP-25-SB90	5,930	5,920	10	20
SEP-26-SB90	5,880	5,875	10	15
SEP-27-SB90	5,940	5 930	10	20
SEP-28-SB90	5,975	5,965	10	20
SEP-29-SB90	5,980	5,970	10	20
SEP-30-SB90	5,975	5,967	10	18
SEP-31-SB90	5,970	5,967	10	13
SEP-32-SB90	5,970	5,965	10	15
SEP-33-SB90	5,965	5,965	10	10
SEP-34-SB90	5,965	5 960	10	15
SEP-35-SB90	5,970	5,963	10	17
SEP-36-SB90	5,970	5,963	10	17
SEP-37-SB90	5,970	5 960	10	20
SEP-38-SB90	5,973	5,963	10	20
SEP-39-SB90	5 975	5,965	10	20
SEP-40-SB90	5,975	5,965	10	20
SEP-41-SB90	5,965	5,955	10	20
SEP-42-SB90	5,960	5,948	10	22
SEP-43-SB90	5,963	5,955	10	18
SEP-44-SB90	5,965	5,957	10	18

TABLE 3 5
ESTIMATED TARGET DEPTHS
FOR VADOSE ZONE BORINGS
 (continued)

<u>Borehole</u>	<u>Ground Surface Elevation (Feet)^a</u>	<u>Top of Bedrock Elevation (Feet)^a</u>	<u>Assumed Thickness of Weathered Arapahoe Formation (Feet)^b</u>	<u>Estimated Target Depth of Boring (Feet)</u>
SEP-45-SB90	5,962	5 952	10	20
SEP-46-SB90	5,965	5 957	10	18
SEP-47-SB90	5,965	5 955	10	20
SEP-48-SB90	5,965	5 956	10	19
SEP-49-SB90	5 968	5,959	10	19
SEP-50-SB90	5,970	5,960	10	20
SEP-51-SB90	5,970	5,960	10	20
SEP-52-SB90	5,970	5 960	10	20
SEP-53-SB90	5,970	5,962	10	18
SEP-54-SB90	5,975	5 963	10	22
SEP-55-SB90	5 975	5,960	10	15

^a Elevations interpreted from EG&G, 1989 RCRA Groundwater Monitoring Report Fig 2-7, Top of Bedrock Elevation

^b Thickness of weathered Arapahoe Formation estimated based on information provided in EG&G, 1988, Solar Evaporation Pond Closure Characterization Report

TABLE 4 1

PRESENT LANDFILL RESULTS OF HYDRAULIC CONDUCTIVITY TESTS
IN SURFICIAL MATERIALS

Well No	Formation	Lithology Screened	Drawdown Recovery Test (cm/s)	Slug Tests (cm/s)
45-86	Grf	Sand and poorly sorted gravel	2.1×10^{-3}	
53-87	Grf	Sand, poorly sorted gravel, and clayey sand	1.6×10^{-5}	
50-87	Grf	Sand and gravel grading to clayey sand and clay		1.3×10^{-3}
51-87	Grf	Sand		9.9×10^{-4}
52-87	Grf	Sand and gravel, clayey sand and clay		6.2×10^{-4}
53-87	Grf	Sand and gravel, sandy clay		5.7×10^{-4}
55-87*	Grf, Kass	Clayey sand, sandstone		4.6×10^{-4}
66-87	Grf	Sand and sandy clay		1.8×10^{-4}
67-87	Grf	Clayey sand		5.4×10^{-5}
71-87	Grf	Clayey sand grading to sandy clay		6.6×10^{-4}
Geometric Mean for Rocky flats Alluvium			1.8×10^{-5}	4.6×10^{-4}

Grf = Rocky Flats Alluvium

Kass = Arapahoe Sandstone

Geometric Mean for Grf

1.3×10^{-3}

4.6×10^{-4}

* Completed in two formations. Not used in calculation of geometric mean.

Note To convert from cm/s to ft/year, multiply by

$$\frac{365.25 \text{ day}}{\text{year}} \times \frac{86400 \text{ s}}{\text{day}} \times \frac{\text{ft}}{30.48 \text{ cm}}$$

TABLE 4 2

PRESENT LANDFILL RESULTS OF HYDRAULIC TESTS IN THE ARAPANOE FORMATION

Well No	Lithology	Drawdown Recovery Test (cm/s)	Slug Test (cm/s)	Packer Test ^a (cm/s)
8 86	Claystone Unweathered Sandstone	- 7×10^{-8}	-	5.7×10^{-7}
9 86	Siltstone Unweathered Sandstone	- 4×10^{-8}	-	2.0×10^{-6} 7.0×10^{-6}
W1 87BR	Claystone Unweathered Sandstone	-	2.78×10^{-8}	5.7×10^{-7} 3.1×10^{-7}
3206589BR	Weathered Sandstone	-	5.8×10^{-6} 5.8×10^{-6}	-
3207089BR	Weathered Siltstone	-	2.3×10^{-9}	-
3207189BR	Unweathered Siltstone	-	1.4×10^{-7} 1.5×10^{-7}	-

^a Represents geometric mean value from three tests at various intervals

TABLE 4 3
PROPOSED BORING SUMMARY

Boring	Well*	Piezometer**	ESTIMATED ELEVATIONS (ft)***				Estimated Saturated Waste Thickness (ft)***	Estimated Total Boring Depth (ft)****/*****	Estimated Well/Piezometer Depth (ft)
			Ground	Water	Bottom of Waste	Top of Bedrock			
1	X		5992	5980	5977	5968	34-64	15	
2		X	5988	5980	NA	NA	13-43	18	
3	X		5988	5977	5981	5975	23-53	7	
4	X		5988	5975	5969	5969	29-59	19	
5	X		5990	5977	5985(?)	5977	23-53	5	
6		X	5990	5980	NA	NA	15-45	20	
7	X		5986	5970	5966	5958	38-68	20	
8	X		5987	5970	5968	5961	36-66	19	
9	X		5986	5970	5965	5965	31-61	21	
10	X		5983	5965	5951	5951	42-72	32/13	
11	X		5983(?)	5960	5940	5935	58-88	43/28	
12	X		5983(?)	5955	5938	5930	63-93	45/33	
13			5922	5921	NA	5918	14-44	NA	
14			5886	5885	NA	5880	16-46	NA	
15			5910	5905	NA	5900	20-50	NA	

* Wells screened in wastes (see text)

** Standpipe piezometers screened from bottom to within 5 feet of ground surface

*** Approximate values based on review of available data

**** Based on 10 to 40 feet of bedrock penetration

*****Two separate wells

TABLE 6 1

GROUND WATER ASSESSMENT ANALYTE LIST

FIELD PARAMETERS

pH
Specific Conductance
Temperature

INDICATORS

Total Dissolved Solids
pH (1)

METALS

Target Analyte List

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

Cesium
Lithium (2)
Molybdenum
Strontium
Tin (1)

ANIONS

Carbonate
Bicarbonate
Chloride
Sulfate
Nitrate
Cyanide (3)

ORGANICS (7)

Target Compound List - Volatiles

Chloromethane
Bromomethane
Vinyl Chloride
Chloroethane
Methylene Chloride

TABLE 6 1

(continued)

ORGANICS (7) (continued)

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

RADIONUCLIDES (4)

Gross Alpha
 Gross Beta
 Uranium 233 + 234, 235, and 238
 Americium 241
 Plutonium 239 + 240
 Strontium 89 + 90 (5)
 Cesium 137
 Tritium
 Radium 226, 228 (6)

- (1) Not analyzed prior to 1989.
- (2) Prior to 1989, lithium was only analyzed during fourth quarter 1987 and first quarter 1988
- (3) Cyanide was not analyzed during fourth quarter 1987
- (4) Dissolved radionuclides replaced total radionuclides (except tritium) beginning with the third quarter 1987
- (5) Strontium 89 + 90 was not analyzed during first quarter 1988
- (6) Not analyzed prior to 1989 and only analyzed if gross alpha exceeds 5 pCi/l
- (7) Not analyzed in background samples in 1989

NOTES

- Total suspended solids and phosphate were analyzed in 1986 only
- Chromium (VI) was analyzed during fourth quarter 1987 only

TABLE 7.1

PROPOSED GROUND WATER CONCENTRATION LIMITS

<u>Constituent</u>	<u>Concentration</u>
Dissolved Metals (mg/l)	
++Ag	BKG*
Al	5 0
++As	0 05**
++Ba	1 0**
+Be	BKG
Ca	NS
++Cd	0 01**
+Co	BKG
++Cr	0 05**
Cs	BKG***
+Cu	BKG
Fe	0 3***
++Hg	0.002***
K	NS
+Li	BKG
Mg	NS
Mn	BKG**
Mo	0.1**
Na	NS
+N ₁	BKG
++Pb	0 05**
+Sb	BKG
++Se	0 01**
Sr	BKG***
+Tl	BKG
+V	BKG
+Zn	BKG
Other Inorganics (mg/l)	
HCO ₃	NS
Cl	250***
SO ₄	250***
NO ₃	10***
TDS	400**

**TABLE 7.1
(continued)**

Dissolved Radionuclides (pCi/l)

<u>Constituent</u>	<u>Concentration</u>
Gross Alpha	11 ^{**+}
Gross Beta	19 ^{**+}
Pu 239, 240	0.05 ^{**+}
Am 241	0.05 ^{**+}
Total Uranium	5 ^{**+}
Sr 89,90	8 ^{++*}
Cs 137	NS
H3	500 ^{**+}

* See Table 7.3 for upper limit of background range

** Primary Drinking Water Standard

*** Although not Appendix VIII constituents, health based standards do not exist and therefore the proposed concentration limit for cesium and strontium is background

*++ Unweathered sandstone ground water has a background concentration (upper limit of range) less than 0.05 mg/l, the CDH ground water standard. Therefore, for this ground water the CDH standard is the proposed concentration limit

**+ Colorado Surface Water Standard

++* Colorado Ground Water Standard

+ Appendix VIII constituent

++ Appendix VIII constituent and SDWA metal

BKG Background

NS No standard

TABLE 7.2

BACKGROUND GROUND WATER SAMPLING PARAMETERS

FIELD PARAMETERS

pH
Specific Conductance
Temperature

INDICATORS

Total Dissolved Solids
pH

METALS - DISSOLVED

CLP Inorganic Target Analyte List

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

Other Metals

Cesium
Lithium
Molybdenum
Strontium
Tin

TABLE 7.2
(continued)

ANIONS

Carbonate
Bicarbonate
Chloride
Sulfate
Nitrate (as N)
Cyanide

RADIONUCLIDES- DISSOLVED

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

* Decision tree. If the Gross Alpha value was >5 pCi/l then the sample was analyzed for Ra 26, 228.

TABLE 7 3
BACKGROUND GROUND WATER (ROUND 1)
TOLERANCE INTERVAL UPPER LIMITS
MAXIMUM DETECTED VALUE

Analyte	Units	Rocky flats Alluvium (11 Samples)	Colluvium (2 Samples)	Valley fill Alluvium (8 Samples)	Weathered Claystone (4 Samples)	Weathered Sandstone (2 Samples)	Unweathered Sandstone (7 Samples)
Dissolved Metals							
Aluminum	mg/l	MD	MD	MD	MD	MD	0 327*
Antimony	mg/l	MD	MD	MD	MD	MD	MD
Arsenic	mg/l	MD	MD	MD	MD	MD	0 0186*
Barium	mg/l	MD	MD	MD	MD	MD	MD
Beryllium	mg/l	MD	MD	MD	MD	MD	MD
Cadmium	mg/l	MD	MD	MD	MD	MD	MD
Calcium	mg/l	85	76 8*	138	73 4*	65 7*	64 6
Cesium	mg/l	MD	MD	MD	MD	MD	MD
Chromium	mg/l	MD	MD	MD	MD	MD	MD
Chromium	mg/l	MD	MD	MD	MD	MD	MD
Cobalt	mg/l	MD	MD	MD	MD	MD	MD
Copper	mg/l	MD	MD	MD	MD	MD	MD
Copper	mg/l	0 266*	MD	0 94*	MD	MD	MD
Iron	mg/l	MD	MD	MD	MD	MD	MD
Iron	mg/l	MD	MD	MD	MD	MD	MD
Lead	mg/l	MD	MD	MD	MD	MD	MD
Lead	mg/l	MD	MD	MD	MD	MD	MD
Lithium	mg/l	MD	MD	MD	MD	MD	MD
Lithium	mg/l	MD	MD	MD	MD	MD	MD
Magnesium	mg/l	5 79*	15 3*	26 57	45 3*	9 41*	MD
Magnesium	mg/l	MD	MD	MD	MD	MD	MD
Manganese	mg/l	0 365	0 686*	0 686*	0 126*	0 292*	0 0182*
Manganese	mg/l	MD	MD	MD	MD	MD	MD
Mercury	mg/l	MD	MD	MD	MD	MD	MD
Mercury	mg/l	MD	MD	MD	MD	MD	MD
Molybdenum	mg/l	0 0136*	MD	MD	MD	MD	MD
Molybdenum	mg/l	MD	MD	MD	MD	MD	MD
Nickel	mg/l	0 0432*	MD	MD	MD	MD	MD
Nickel	mg/l	7.73*	MD	MD	MD	MD	MD
Potassium	mg/l	MD	MD	MD	MD	MD	MD
Potassium	mg/l	MD	MD	MD	MD	MD	MD
Selenium	mg/l	MD	MD	MD	MD	MD	MD
Selenium	mg/l	MD	MD	MD	MD	MD	MD
Silver	mg/l	13 4	98 7*	88	36 9*	25 6*	599
Silver	mg/l	MD	MD	MD	MD	MD	MD
Sodium	mg/l	0 159*	MD	MD	MD	MD	MD
Sodium	mg/l	MD	MD	MD	MD	MD	MD
Strontium	mg/l	MD	MD	MD	MD	MD	MD
Strontium	mg/l	MD	MD	MD	MD	MD	MD
Thallium	mg/l	MD	MD	MD	MD	MD	MD
Thallium	mg/l	MD	MD	MD	MD	MD	MD
Tin	mg/l	MD	MD	MD	MD	MD	MD
Tin	mg/l	MD	MD	MD	MD	MD	MD
Vanadium	mg/l	MD	MD	MD	MD	MD	MD
Vanadium	mg/l	0 141*	0 0212*	0 107*	MD	MD	MD
Zinc	mg/l	MD	MD	MD	MD	MD	0 564

TABLE 7 3 con't

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

Analyte	Units	Rocky Flats Alluvium (11 Samples)	Colluvium (2 Samples)	Valley Fill Alluvium (8 Samples)	Weathered Claystone (4 Samples)	Weathered Sandstone (2 Samples)	Unweathered Sandstone (7 Samples)
<u>Other</u>							
Total Dissolved Solids	mg/l	352	520*	947	320*	170*	1761
Carbonate	mg/l	MD	MD	MD	MD	MD	49
Bicarbonate	mg/l	436	470*	719	400*	140*	412
Chloride	mg/l	15 6	20*	40 29	11*	15*	607
Sulfate	mg/l	45 1	86*	150	44*	16*	950
Nitrate	mg/l	2 98	0 18*	0 69*	0 58*	1 6*	0 610
Cyanide	mg/l	0038*	MD	MD	0 0036*	MD	MD
pH	----	8 6 (5 98)	7 4* (7 1)**	8 68 (6 12)	8 2* (7 4)**	7 5* (7 2)**	10 57 (7 43)
<u>Dissolved Radionuclides</u>							
Gross Alpha	pCi/l	12 543	27±12*	13 515	12±4*	7±5*	13±5*
Gross Beta	pCi/l	14 570	12±5*	18 530	7±2*	2±3*	15±4*
Uranium 233, 234	pCi/l	1 647	11±1*	6 481	5 8±0 6*	1 1±0 3*	12 936
Uranium 235	pCi/l	0 000	0 3±0 1*	0 232	0 2±0 1*	0±0 1*	0 135
Uranium 238	pCi/l	0 195	7 7±0.7*	5 004	3 2±0 5	0 6±0 2*	3 3507
Strontium 89, 90	pCi/l	0 552	0 1±0 4*	0 878	0 1±0 5	-0 1±0 6*	0 2±5*
Plutonium 239, 240	pCi/l	0 009	0±0 01*	0 012	0 03±0 02	0 01±0 01*	0 000
Americium 241	pCi/l	0 000	0±0 01*	0 012	0±0 01	0 01±0 01*	0 019
Cesium 137	pCi/l	0 603	0 2±0.6*	0 776	0 4±0 6	0 3±0 7*	0 7±0 5*
Tritium	pCi/l	309 149	100±150*	505 111	100±160	100±210*	751 876

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

TABLE 8 1 GROUND WATER MONITORING SCHEDULE

WEST SPRAY FIELD

WELL NUMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
0881			X			X			X			X
0981			X			X			X			X
1081			X			X			X			X
0582			X			X			X			X
0682			X			X			X			X
0782			X			X			X			X
4586			X			X			X			X
4686			X			X			X			X
4786			X			X			X			X
4886		X			X			X			X	
4986			X			X			X			X
5086			X			X			X			X
5186		X			X			X			X	
5286		X			X			X			X	
5686	X			X			X			X		
B410589			X		X	X		X	X		X	X
B410689		X			X			X			X	
B410789		X			X			X			X	
B110889			X			X			X			X
B110989			X			X			X			X
B111189			X		X	X		X	X		X	X
B411289		X			X			X			X	
B411389		X			X			X			X	

TABLE B 1 GROUND WATER MONITORING SCHEDULE

SOLAR EVAPORATION PONDS

WELL NUMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
0260			X			X			X			X
0460			X			X			X			X
1386		X			X			X			X	
1486			X						X			X
1586		X			X							
1686			X			X			X			X
1786		X		X			X			X		
1886	X			X						X		
2086	X			X						X		
2286		X			X							
2386			X			X			X			X
2486	X			X			X			X		
2586		X			X			X			X	
2686		X			X			X			X	
2786		X			X			X				
2886	X	X			X		X					
2986	X			X						X		
3086		X			X					X		
3186	X			X			X					
3286	X		X			X			X			X
3386	X			X			X			X		
3486	X			X			X			X		
3586	X			X			X			X		
3686	X			X			X			X		
2187												
2287BR												
3787		X			X				X		X	
3887		X			X						X	
3987BR	X			X			X			X		
5687		X			X							
P207389			X			X			X			X
P207489			X			X						X
P207589		X			X						X	
P207689	X			X			X			X		
P207789		X			X						X	
P207889		X			X						X	
P207989		X			X						X	
B208089		X			X						X	

TABLE 8 1 GROUND WATER MONITORING SCHEDULE

SOLAR EVAPORATION PONDS

WELL NUMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
B208189		X			X			X			X	
B208289		X			X			X			X	
B208389	X			X			X			X		
B208489	X			X			X			X		
B208599			X			X		X				X
B208699			X			X		X				X
B208799		X			X			X			X	
P208899		X			X			X			X	
P208999			X			X		X				X
P209099			X			X		X				X
P209199	X					X				X		
P209299				X			X					
P209399	X			X		X		X		X		
P209499	X			X		X		X		X		
P209599												
P209699			X			X		X				X
P209799			X			X		X				X
P209899			X			X		X				X
P209999	X			X			X			X		
P210099					X						X	
P210199			X			X		X				
B210399		X			X						X	
B210499		X			X			X			X	

