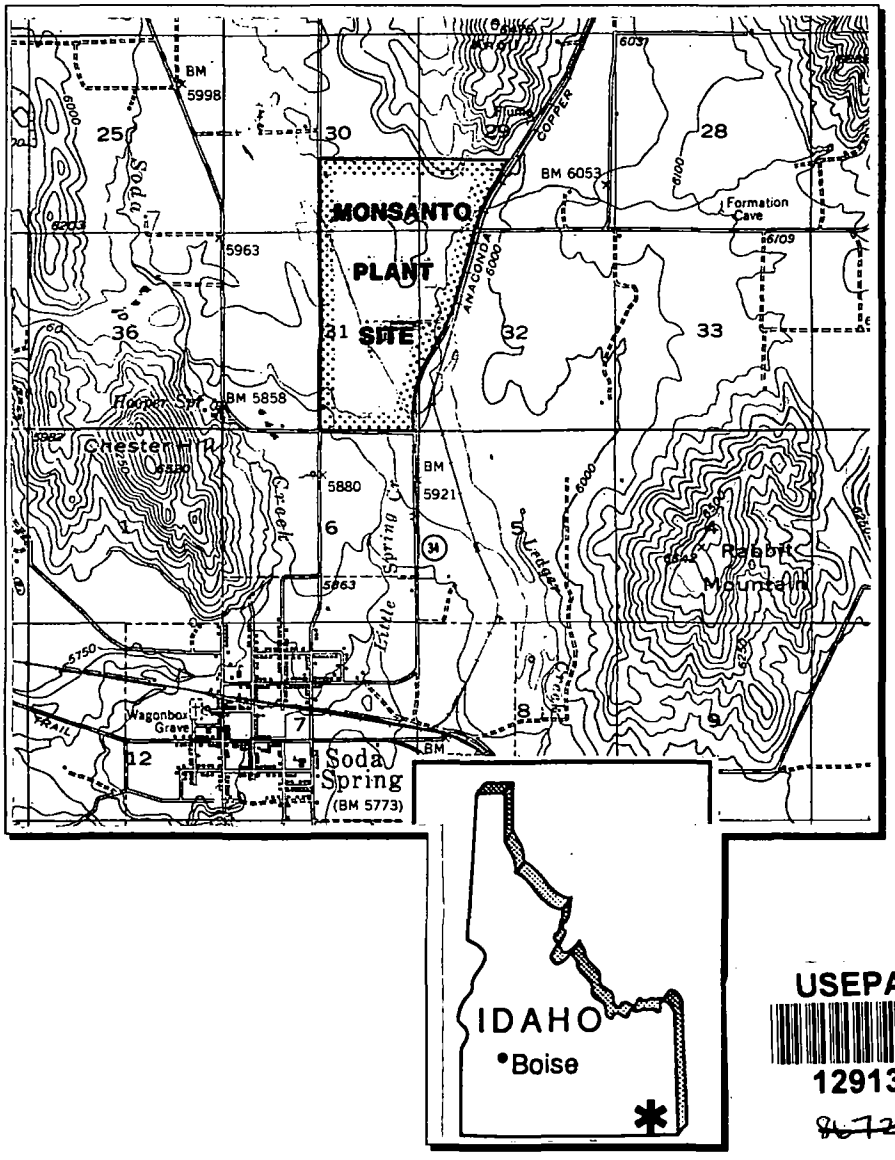
Submitted to:

Monsanto

Phase I Remedial Investigation/Feasibility Study
Preliminary Site Characterization Summary Report

for the Soda Springs Elemental Phosphorus Plant



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PRELIMINARY SITE CHARACTERIZATION SUMMARY REPORT FOR THE MONSANTO SODA SPRINGS PLANT

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April 23, 1992

913-1101.212

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1. INTRODUCTION

In August, 1990, the United States Environmental Protection Agency (EPA) placed the Monsanto Company (Monsanto) elemental phosphorous plant in Soda Springs, Idaho, on the National Priorities List (NPL), which is contained within Appendix A of the National Oil and Hazardous Substance Pollution Contingency Plan (NCP, 40 CFR 300). The EPA took this action pursuant to their authority under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, 42 USC §9601 et seq.). (Note: All regulatory and statutory citations within this report refer to the version of the regulation or statute in effect, as amended, on the date of report publication.)

An Administrative Order on Consent (AOC) was issued by EPA, Region 10 (EPA-10), and agreed to by Monsanto on March 19, 1991, for the performance and preparation of a remedial investigation and feasibility study (RI/FS) for the Soda Springs Plant. Monsanto subsequently authorized Golder Associates Inc. (Golder) to prepare the Phase I RI report (Preliminary Site Characterization Summary Report) contained herein.

1.1 Purpose of Report

The purpose of the Monsanto Soda Springs Plant RI is to gather and develop a sufficient amount of the necessary information required to support the development and analysis of remedial alternatives during the feasibility study (FS). The remedial alternatives analysis will, in turn, be used to make a risk-management-based selection of remedies for releases of constituents found to have occurred from the Monsanto Soda Springs Plant.

The Monsanto Soda Springs Plant RI/FS is being conducted in a concurrent, interactively phased manner. The data collected and evaluated during the RI provides the information needed to develop and analyze remedial alternatives in the FS, while the preliminary FS analyses provide a focus for further RI activities. The goal of the first phase of the RI is to increase the initial understanding of the Monsanto Soda Springs Plant by characterizing the nature and extent of the threat to human health and the environment posed by releases of constituents from the site.

The purpose of this report is to document the findings of the Phase I RI, focus the project, determine the need for any further RI activities, and initiate the FS. This Phase I RI report is consistent with the statutory requirements of CERCLA and the regulatory requirements of the NCP.

This Phase I RI report presents an interim interpretation of the Monsanto Soda Springs Plant conditions. The primary purpose of this report is to facilitate open communication among project personnel from Monsanto and all regulatory organizations involved. Comments that arise from the review of this report will be considered in the development of a Phase II RI work plan and will be incorporated, along with Phase II RI findings, into a final RI report.

1.2 Report Organization

This Phase I RI report for the Monsanto Soda Springs Plant is organized in a format similar to that recommended by EPA (1988a). This section assists the reader in understanding the presentation format and in locating information of specific interest. The Phase I RI report, in addition to this introduction, consists of six chapters and associated appendices.

The introduction, specifically Section 1.3, provides a general history and background of the Monsanto Soda Springs Plant and Plant operations. Included in Section 1.3 are a summary of previous studies performed at the Monsanto Plant and a summary of the current regulatory status of the site and Plant operations.

An outlined description of the Soda Springs Plant Phase I RI data collection activities is presented in Chapter 2. This information is derived from the RI/FS work plan (Golder 1991) and is presented by environmental medium. The purpose of this presentation is to concisely summarize the initial data collection activities so that the actual work performed in the first phase of the RI is documented and deviations from the work plan are explained. Chapter 2 also contains specific references to the validated data (contained in appendices, or published literature, as appropriate) that were used to develop the site characterizations presented in subsequent chapters.

Chapter 3 initiates the presentation of Phase I RI findings with a description of the relevant physical characteristics of the Soda Springs Plant. The setting of the Plant and its vicinity is described, by environmental medium, on the basis of information gathered during project scoping and implementation of Phase I RI activities.

The nature and extent of site-related constituents in each environmental medium is presented in Chapter 4. The concentrations of these constituents are statistically compared to control concentrations to determine what constituents are elevated in each environmental medium. These elevated constituents are then put through a preliminary risk screening to determine the constituents of potential interest that will undergo more intensive evaluations in Chapter 5.

The findings presented in Chapters 3 and 4 are evaluated to develop interpretations of the environmental fate and transport of the site constituents of potential interest. These interpretations are presented in Chapter 5. Potential site constituent migration pathways are documented, constituent characteristics relevant to migration are assessed. Transport modeling is applied to estimate current and future constituent concentrations in the air medium.

Concise summaries of the Phase I RI findings related to the site characteristics, the nature and extent of constituent releases, constituent fate and transport, and human health and environmental risks are provided in Chapter 6. This chapter includes a discussion of the applicable or relevant and appropriate requirements (ARARs) that may be used in the RI/FS. Remedial action objectives are outlined, and recommendations for removal actions, additional RI activities, and initial FS activities are also included.

References cited within the body of the report are provided in Chapter 7. Appendices are used to present letters and memoranda cited (Appendix A), concise data validation summaries, and detailed technical analyses needed to confirm the findings contained within the text. Other relevant information that is published and readily available to Monsanto and regulatory project personnel is incorporated by reference.

The RI/FS work plan (Golder 1991) identified specific deliverables that were outlined in the AOC. Many of these deliverables are incorporated in this report, subsequent RI reports, or in the FS study reports as described below.

The Preliminary Site Characterization Summary Report is contained herein. Chapter 5 (Constituent Fate and Transport Analysis) incorporates the Technical Memorandum on Modeling of Site Characteristics as part of the discussion on air modeling. Chapter 6 (Summary and Conclusions) incorporates the Memorandum on Remedial Action Objectives as a part of the results and conclusions from the Phase I RI.

The findings of the Phase I FS, conducted concurrently with the RI, will be documented in a Phase I FS Report, targeted to be completed by May 24, 1992. The Phase I FS report will incorporate the Identification of Candidate Technologies Memorandum and the Memorandum on Development and Preliminary Screening of Alternatives, Assembled Alternatives Screening Results and Final Screening. Remedial action objectives will be further identified and defined in the Phase I FS Report.

The second phase of investigations will be described in a Phase II RI/FS work plan. This phase of activities will be done to further characterize the site based on the findings of the Phase I RI. Any necessary treatability investigations will be incorporated in this phase of work. The Preliminary Draft Remedial Investigation Report will summarize the findings of all Phase I and II activities. If treatability studies are conducted, they will be documented in this report. The EPA will prepare the Risk Assessment Report based on the information presented in the Preliminary Draft Remedial Investigation Report. The Draft Remedial Investigation Report will be prepared that will incorporate the results of the two reports described above.

The findings of the Phase II FS will be documented in two reports: the Report on Comparative Analysis will summarize the results of comparative analysis between the remedial alternatives, and the Draft Feasibility Study Report will document the overall FS process.

1.3 Monsanto Soda Springs Plant Background

The Monsanto Soda Springs Plant is located in southeastern Idaho, approximately one mile north of the City of Soda Springs, Idaho (Figure 1-1). The Plant occupies approximately 540 acres in a tributary valley to the Bear River at an elevation ranging from 5,880 feet to 5,990 feet above mean sea level (amsl). The valley is drained by Soda Creek and is broad and rural, bordered on the east by the Aspen Range and on the west by the Soda Springs Hills and Chesterfield Range (see Figure 1-1).

The climate in southeastern Idaho is semi-arid with hot summers and cold winters. A National Weather Service weather station at Conda, located four miles northeast of the Monsanto Plant, reports approximately 19 inches of precipitation annually.

The valley has mixed agricultural, residential, and industrial uses. The largest population center in the area is the City of Soda Springs, with a population of approximately 3,000 (see Figure 1-2). A number of other industrial sites are located in the valley. These include:

- Kerr-McGee Chemical Corporation (production of vanadium compounds), located directly across State Highway 34 from the Monsanto Plant;
- Evergreen Resources (fertilizer products), located about 1,000 to 2,000 feet southeast of the Monsanto Plant;
- Soda Springs Phosphate Industries (fertilizer products) located adjacent to Evergreen Resources;
- Nu-West Industries (phosphoric acid production and fertilizer products), located approximately four miles to the north of the Monsanto Plant; and
- N.A. Degerstrom (gallium and silver extraction), located approximately two miles north of the Monsanto Plant.

Groundwater derived from wells in the area is used for domestic and public drinking supplies, irrigation, and industrial purposes. This groundwater provides potable water to approximately 400 people (350 of which are served by the Monsanto well PW-4, discussed in Section 3.6 (Hydrogeological Characteristics) within a three-mile radius of the Plant. The City of Soda Springs obtains its municipal water from two springs located in the east portion of the valley (Formation Spring and Ledger Spring). These springs serve a population of about 3,000 people.

1.3.1 Site Description and Overview of Operations

Monsanto purchased the Plant site in 1952 and initiated elemental phosphorus production on the property. This site was previously used for agricultural and domestic purposes. The Monsanto Plant produces elemental phosphorus using electric-arc furnaces. The phosphorus

is shipped off site, where it is primarily used for the production of phosphoric acid. The layout of the Plant facility is shown in Figure 1-3.

The two general phases of phosphorus production are ore extraction and beneficiation, and processing. These phases are summarized below. Further details about materials storage and disposal are presented in Chapters 3 (Physical Characteristics) and 4 (Nature and Extent of Constituent Releases).

1.3.1.1 Phosphorus Extraction and Beneficiation

The beneficiation of the phosphate ore occurs in a rotary kiln. Phosphate ore, which is extracted (mined) nearby, is blended with underflow solids (a recycled by-product of the beneficiation process) and fed into the kiln to drive off moisture and fuse the ore. The kiln operates in a rolling fashion that produces nodules of ore which are sized and stored for further beneficiation or processing. The fine material that does not nodulize in this phase is temporarily placed in a nodule fines pile and is recycled through the kilns. Some heavy metals and other constituents are driven off and the gases from the kiln are scrubbed (Monsanto 1991).

Underflow solids are fine-grained materials that are blown out of the kiln as a result of the convection currents in the kiln. These materials are treated to remove moisture and returned to the beneficiation process as described above. A discussion of the underflow solid process stream is presented in Section 3.1 (Source and Facility Characteristics).

1.3.1.2 Processing Elemental Phosphorus

The processing of the ore occurs in electric-arc furnaces. The nodules from the kiln are blended with raw materials, including coke and silica (quartzite), and sent to an electric-arc furnace. The carbon (from the coke) and the silica produce a reducing chemical environment which liberates gaseous elemental phosphorus. The gas is collected and sent through an electrostatic precipitator, cooled and liquified. The liquid phosphorus is stored in tanks to await shipment off-site. The phosphorus is always stored and transported under water because exposure to air results in a rapid oxidation reaction (Monsanto 1991).

Quartzite reacts in the furnace to give the proper composition and flow properties to the calcium silicate slag which is produced as a by-product. This slag is tapped out of the bottom of the furnace and stored on-site in piles. A dense layer of ferrophosphorus slag is produced in a smaller quantity as a result of the naturally occurring iron and other metals in the ore. The ferrophosphorus slag is tapped out of the furnace below the calcium silicate slag, and is sold to Kerr-McGee for vanadium extraction (Monsanto 1991).

The furnace gases contain elemental phosphorus, carbon monoxide, and entrained dust. These gases pass first through a dust collector to remove particulates, and then into a spray tower where the phosphorus is condensed. The residual gas is re-routed into the kiln as supplemental fuel. Treater dust is generated from the electrostatic precipitator in the furnace. This material is collected and transported to a chamber where any residual phosphorus is oxidized (Monsanto 1991).

Non-contact cooling water is used to cool the exterior of the furnaces. This water is temporarily stored in a surface impoundment to settle out solids and cool prior to discharge, under a National Pollutant Discharge Elimination System (NPDES) permit, to Soda Creek (see Paragraph 1.3.3.4, Water Quality).

Electrode-seal water is used in the furnace to provide a seal where the electrodes enter the furnace. This seal prevents the phosphorus and dust in the furnace from escaping to the atmosphere (Monsanto 1991). This water is stored in the seal-water pond and recycled.

The water that directly contacts phosphorus in the process is known as phossy water, which is produced from a variety of sources. Phossy waters are treated in the hydroclarifier to remove residual elemental phosphorus, and are subsequently recycled. Phossy water is continuously cycled in and out of the phossy-water pond.

Scrubber blowdown wastewater is the liquor that comes off the various collectors (taphole collectors) of the scrubber system. This wastewater is collected in a sump and sent to the hydroclarifier for treatment (Monsanto 1991).

1.3.2 Previous Environmental Investigations and Remedial Measures

A summary of environmental investigations, by environmental media, and remedial measures conducted at the Monsanto Plant is presented below.

1.3.2.1 Previous Groundwater Investigations

Monsanto installed five groundwater monitoring wells in 1978 (TW-2, TW-3, TW-4, TW-5, and TW-6), and initiated a quarterly groundwater sampling program that continued until 1984. Two additional wells (TW-7 and TW-8) were installed downgradient of the first five wells in 1982. Some off-site spring sampling was conducted by Monsanto in 1983.

A hydrogeological and surface-water investigation was conducted by Golder in 1984 (Golder 1985) to assess the effect of past and current operations on groundwater and surface-water quality. This investigation expanded the scope of groundwater monitoring at the Plant with the installation of additional monitoring wells, and the continuation of quarterly sampling. The investigation included the following components:

- Literature Survey — to develop a geological, hydrogeological and hydrogeochemical database on the Soda Springs region, local area, and Plant;
- Geological and Aerial Reconnaissance — within one to two miles of the Plant in order to develop a conceptual geologic model;
- Preliminary Field Studies — involving the pump testing and geophysical logging of seven pre-existing test wells and pump testing of the three Plant production wells (PW-1, PW-2, and PW-3) to develop a conceptual hydrogeological model for the site;

- Installation of New Test Wells — involving drilling and installation of 32 test wells at selected locations within the Plant boundaries to refine the conceptual geologic model;

- Additional Hydrogeological Testing — involving geophysical logging of all test wells, pump testing of most new test wells, and water-level measurements to refine the conceptual hydrogeological model for the site;

- Sampling and Analysis of Groundwater — at all test wells, production wells, the Plant effluent and springs on two occasions during the project (November, 1984 and February, 1985) to determine the potential affects to the subsurface- and surface-water quality from Plant practices; and

- Quality Assurance — involving standards calibration, internal laboratory replicate analysis, spike samples, and external equipment and travel blanks, replicates, and spiked samples to determine sample precision, accuracy, completeness and representativeness.

Subsequent to the 1984 investigation, Monsanto abandoned four monitoring wells in accordance with Idaho State standards (TW-3, TW-4, TW-5, and TW-6) that had poor seals allowing inter-aquifer communication, and installed several additional monitoring wells and a new production well at the Plant (Golder 1987, 1988a, and 1988b). Monsanto continued to perform water-quality sampling of test wells, production wells, and springs between 1985 and 1989.

The results of the Golder investigations indicated that groundwater beneath the Plant contained elevated concentrations of several metals and anions, including cadmium, selenium, fluoride, and sulfate. The sources of these constituents were determined to be the old underflow solids ponds, the northwest pond, and the hydroclarifier. The investigation also concluded that groundwater under the southeastern portion of the Plant contained elevated concentrations of vanadium and other constituents which, based on groundwater flow directions and geochemical data, are considered to be from an off-site source located to the east of the Monsanto Plant.

In April, 1988, a CERCLA site inspection was carried out and documented by EPA-10 (Ecology and Environment 1988a). The findings of the site inspection report, which included the results of additional groundwater sampling and analysis, were consistent with Monsanto's earlier findings (Golder 1985).

1.3.2.2 Previous Air Investigations

Air dispersion modeling of cadmium and fluoride emissions from a limited number of sources was completed by Monsanto in 1988 (Cheng, C.K., Monsanto [Memo to F.R. Johannsen, Monsanto] April 12, 1988 and May 17, 1988). The sources modeled included the three furnace taphole fume collectors, the nodule crushing and screening venturi scrubber, the kiln cooler spray tower, the four nodule kiln venturi scrubbers, and fugitive emissions from the slag

dumping area. The modeling was conducted using the long-term version of the EPA Industrial Source Complex Model.

The calculated annual average concentrations of cadmium and hydrogen fluoride in the surrounding community and at specific geographic locations were below the Threshold Limit Values (TLVs) recommended by the American Conference of Governmental Industrial Hygienists (ACGIH) for workplace exposure levels (ACGIH 1991). The estimated annual average community air concentration for cadmium was a factor of 1,500 less than the ACGIH TLV. For fluoride, the estimated annual average community air concentration was a factor of 40,000 less than the ACGIH-permitted level for worker exposure, while the annual average concentrations for most exposed individuals in the community was calculated to be a factor of 300 less than the permitted worker exposure level. However, it was recognized that more precise studies of emission rates were required to validate the emission values used in the dispersion calculations.

A detailed series of particulate stack monitoring tests were conducted by American Services Associates in 1990 for the following sources:

- Kiln venturi scrubbers;
- Nodule cooler spray tower;
- Scale room baghouse outlet;
- Nodule crushing and screening venturi scrubber; and
- Nos. 7, 8, and 9 taphole fume collectors.

In addition, tests were conducted for fugitive particulate emissions from the nodule stacking and reclaim area, and for stack emissions of radionuclides at the four kiln venturi scrubbers (an earlier study of radionuclide emissions was conducted by the EPA in 1982). The evaluation of mass elemental composition for sources was conducted in 1991.

Ambient air quality monitoring data for particulates are available from three monitoring stations operated by the Idaho Department of Health and Welfare, Division of the Environment, Bureau of Air Quality (IDHW-BAQ) in the immediate vicinity of the Monsanto Plant (see Figure 1-4). These include 24-hour measurements of total suspended particulates (TSP) using high volume air samplers at:

- The Harris Ranch (Station 13-0420-026), south of the Monsanto property, from January, 1986, to May, 1988;

- Two miles north of Hooper Springs (Station 13-029-0029), northwest of the Monsanto property, from January, 1986, to September, 1988; and

- Soda Springs Hospital (Station 13-0420-021), located approximately two miles southwest of the Monsanto property, from January, 1986, to September, 1988.

Ambient concentrations of inhalable particulates (PM_{10}) have been measured at the Terrace Acres Mobile Court (Station 16-029-0030) south of the Monsanto property, since November, 1989.

Ambient monitoring data are also available from the following two monitoring stations located near Conda, northeast of the Monsanto facility:

- The Torgeson residence (Station 13-029-0002) — TSP monitoring from January, 1986, to September, 1988; and

- 1.2 miles east of State Highway 34 (Station 13-0420-027) — TSP monitoring from January, 1986, to September, 1988, and PM_{10} monitoring from January, 1987, to June, 1989.

Apart from ambient air concentrations, the Utah State University Foundation conducted a series of studies of fluoride in vegetation samples collected within a five-mile radius of the Monsanto facility from 1985 to 1988 (Miller and Pushnik 1985, Miller 1986, Miller 1987, Miller 1990). The studies were prepared for the IDHW-BAQ.

1.3.2.3 Previous Ecological Investigations

The State of Idaho reports that Hooper Springs — a natural, sodic spring outside of the Plant boundaries — has a natural but severe impact on the aquatic life in Soda Creek (Perry, J., IDHW-Division of Environment [Memo to G. Hopson, IDHW-Division of Environment] March 22, 1976). Hooper Spring discharges into Soda Creek to the west of the Monsanto Plant, well above the point of confluence with Monsanto's NPDES-permitted, non-contact cooling water discharge into Soda Creek.

The IDHW study indicates that the diversity of the Soda Creek benthic macroinvertebrate community is decreased by the highly mineralized and carbonated Hooper Spring water. The creek slowly recovers from this impact, which is noted down to and beyond the confluence of the Plant discharge.

The IDHW study also included a fish survey. No fish were noted within the upper portions of Soda Creek in the vicinity of the Plant discharge. The absence of fish in this portion of the stream was interpreted as an indication of a population that was, at the least, severely reduced due to the harsh environmental conditions imposed by Hooper Spring. Small numbers of fish (salmonids) were noted in the lower reaches of the creek, about one mile above the confluence with the Bear River. The study concluded that the Soda Creek ecosystem in proximity to the Plant consists of only "other aquatic life," and that no adverse environmental effects could be found to be attributable to the Monsanto discharge.

To assess the potential affects of the permitted, non-contact cooling water discharge into the Soda Creek ecosystem, Monsanto conducted a fathead minnow static bioassay (Grothe 1980). During the 96-hour duration of this test, no mortality was observed. Therefore, based on the review of existing data (the IDHW study and the Monsanto bioassay), no adverse effects to the environment have been attributed to the Monsanto non-contact cooling water discharged to Soda Creek.

Terrestrial ecological data are available from a report by Severson and Gough (1979). The researchers sampled and analyzed soils and vegetation — big sagebrush and bluebunch wheatgrass — in the vicinity of the Monsanto Plant. This study found that:

- Elevated plant tissue concentrations of cadmium, chromium, fluorine (as fluoride), selenium, uranium, vanadium, and zinc were associated with phosphate-processing operations in Soda Springs (with cadmium and zinc being the most elevated);

- Elevated plant tissue concentrations of lithium, nickel, phosphorus, and sodium may also be associated with processing operations;

- Only chromium, zinc, and possibly fluorine (as fluoride) were found within ranges documented as being toxic to some plants;

- Only cadmium and fluorine (as fluoride) might have been present in sufficiently high concentrations, at some times and under certain conditions, to be toxic to grazing animals, and concentrations of chromium, vanadium, and zinc could potentially be high enough to be toxic;

- Elevated plant tissue concentrations were found predominantly within 2.5 miles (4 kilometers) of the Monsanto Plant;

- Sagebrush generally accumulated higher concentrations of these elements than did grass; and

- Much of the element accumulation occurs on the external portions of plants, and periodic precipitation events probably cleanse the vegetation.

1.3.2.4 Previous Remedial Measures

During and subsequent to the investigations, Monsanto independently instituted a number of remedial measures at the Plant. EPA-10 and the State of Idaho were advised of these measures prior to or during their implementation, although no determination as to their adequacy or effectiveness has been made by either agency. The measures included the following:

- The hydroclarifier, which was suspected as potentially affecting groundwater, was replaced in August, 1985, with a unit that included a synthetic liner, a leachate collection system, and a monitoring well network.

- An old coke and quartzite dryer and wet scrubber was replaced with a more efficient dryer and baghouse dust collector in 1986, resulting in an emission reduction of over 95 percent.

- A pollution control project was installed in September, 1987, to provide additional scrubbing of kiln exhaust emissions. This installation is comprised of four parallel

high energy venturi scrubbers, four separators, four fans and four stacks. The parallel arrangement of equipment effectively reduces upset/breakdown emissions that would occur if only one or two fans existed. This project resulted in a reduction of particulate emissions in the 95 percent range. This equipment, coupled with a five-deck spray tower and dust dropout chamber located upstream, provides a cumulative cleaning efficiency of 99.9 percent.

- Four wells (TW-3, TW-4, TW-5, and TW-6), which were discovered to be creating hydraulic communication between upper and lower aquifers due to poor construction, were abandoned (by drilling them out and sealing them to the surface with a cement/bentonite grout) in 1987, in accordance with regulatory guidelines (Golder 1987).

- The old underflow solids ponds, sources suspected to be affecting groundwater, were taken out of service in 1983. The solids (essentially low-grade ore) were subsequently excavated and recycled. The ponds were filled with molten slag and sealed with a bentonite cap in 1988 to isolate the ponds, and the residual material in them, from the groundwater recharge system.

- The northwest pond, which was also suspected to be affecting groundwater, was excavated to remove affected soils. Measurements were taken to determine the depth that soils were affected, and soils were removed to that depth and deposited in the old underflow solids ponds. The base of the pond was sealed with bentonite in 1988. This area is currently permitted by the IDHW to receive Plant sanitary solid waste.

- A new Plant drinking water well (PW-4) was installed upgradient of all known and suspected source areas to prevent affects to the Plant potable water supply. A new independent potable water distribution system was installed at the same time as the new well, thus preventing cross-connection of potable and raw process water at the Plant.

- Several wells were also installed around the hydroclarifier and used as recovery wells to intercept affected groundwater. The groundwater was pumped into the new hydroclarifier. Three wells were pumped intermittently at a rate of approximately 12 gallons per minute (gpm) per well from 1985 to 1989. The pumping of these wells was stopped in the spring of 1989 based on potential listing of the Plant for the NPL. In addition, pumping of PW-1 to supply process make-up water for the Plant intercepts groundwater migrating from the hydroclarifier.

- Fugitive emissions from the baghouse dust disposal pile located in the north end of the plant have been reduced through improved handling procedures and the placement of crushed slag on the surface of unused portions of the pile. These practices were begun in 1990.

Because of the nature of the operation of the Monsanto Plant and the high process demand for electricity, transformers and other electrical equipment containing insulating fluids have been used extensively. A complete file dating back to 1978 is maintained at the Plant. This file includes a history of service, inspections, fluid characteristics, and the retirement of the fluids and the transformers.

Efforts have progressed over the last several years to have the Plant become polychlorinated-biphenyl- (PCB-) free by initiating a comprehensive sampling program and replacing PCB-containing equipment. As transformer fluids were found to contain regulated levels of PCBs, accepted methods of treatment or off-site incineration were contracted to reputable companies who specialize in PCB/transformer management.

As part of the Plant's spill prevention, control, and countermeasures (SPCC) plan an addendum has been included to cover the storage locations for PCBs and PCB items for disposal. Specific secured locations within the Plant boundary have been designated for temporary storage of PCB items until proper disposal arrangements can be made. An inspection interval has also been designated to ensure that these materials are not leaking and that timely disposal is accomplished.

During the summer of 1991, EPA-10 completed a PCB inspection at the Plant. All records from the past five years were inspected and found to be in order. Monsanto received notification from EPA-10 (Haselberger, G., EPA-10 [Letter to R. Mahoney, Monsanto] September 25, 1991) regarding the inspection. EPA-10 informed Monsanto that there were no apparent violations of the PCB regulations, and that the Plant case was closed.

Finally, four underground storage tanks were replaced with above-ground tanks with concrete sumps in 1986. These tanks were removed solely to comply with new regulations, and there was no indication — either in the inventory control process, or during the inspection upon removal — that they had leaked.

1.3.2.5 Pending Remedial Measures

Monsanto is currently planning to institute further remedial measures at the Plant. Measures that are currently scheduled include:

- The sewage lagoon will be taken out of service in the summer of 1992. The Plant will be hooked into the City of Soda Springs sewer system at that time.
- The nodule reclaim area will undergo emission controls to reduce fugitive emissions in the summer of 1992.

1.3.3 Current Environmental Regulatory Status

The current regulatory status of environmental activities at the Plant is summarized below.

1.3.3.1 Hazardous Substance Response

The Monsanto Plant was placed on the CERCLA NPL in August, 1990, primarily due to the potential effects on groundwater from past operational practices. An AOC was issued in March, 1991, detailing the agreement between EPA-10 and Monsanto to perform an RI/FS for the Plant. This Phase I RI report was prepared in compliance with the AOC.

1.3.3.2 Solid and Hazardous Waste

The Resource Conservation and Recovery Act (RCRA) lists solid wastes that are regulated as hazardous wastes in 40 CFR 261.3, Solid wastes (including slag from elemental phosphorus production) generated from the extraction, beneficiation, and processing of ores (restricted to selected activities) are excluded from this listing (40 CFR 261.4). Monsanto has evaluated all of the processing waste streams and activities throughout the Plant for hazardous waste characterization. Appropriate measures have been made to comply with RCRA requirements regarding non-exempt waste streams that were characterized as hazardous. A RCRA permit for the Plant was deemed not necessary, based on current operations and regulations.

The Plant is currently regulated as a small quantity generator of hazardous wastes (40 CFR 262.34) for generation of spent solvents. This status allows the Plant to generate hazardous wastes at a range of 100 to 1,000 kilograms/month and store these wastes on-site (for subsequent recycling off-site) for up to 180 days without a permit.

The hydroclarifier is considered to be part of the beneficiation process at the Plant and thus does not fall under RCRA jurisdiction.

A sanitary landfill was created at the old northwest pond area for disposal of Plant refuse, including construction debris. A landfill operating permit was issued by IDHW, and regular inspections are made by the Southeastern Idaho Health District to ensure compliance requirements are maintained. The Plant landfill is also permitted by EPA-10 to allow disposal of asbestos materials from Plant operations.

Calcium silicate slag is under scrutiny by EPA because of the presence of trace amounts of radium which carries through from the ore. The EPA conducted a study of radionuclide exposures in southeastern Idaho (EPA 1990a) that concluded that the population is at a significant risk from the low-level gamma radiation resulting from the use of slag as aggregate for construction purposes. The issue was reviewed by the EPA Science Advisory Board (SAB) which determined that the study did not provide the necessary data to evaluate risk-based exposures to gamma radiation. The SAB recommended that EPA prepare a plan for obtaining reliable exposure determinations, and provide the plan for technical review (EPA 1991a).

1.3.3.3 Air Quality

The Monsanto Plant is situated within a respirable particulate non-attainment area designated by the IDHW-BAQ. The Plant is in attainment for sulfur dioxide and fluoride emissions, and the State of Idaho has discontinued fluoride vegetation monitoring. Other Clean Air Act

constituents, such as lead, ozone, and nitrogen oxides are not associated with the Plant and are thus not monitored by the State.

The nodule screening and crushing area is out of compliance with Idaho regulatory standards for fugitive dust emissions. Monsanto has initiated corrective measures under an agreement with the State and EPA, to reduce these emissions.

The National Emission Standards for Hazardous Air Pollutants (NESHAPs) (40 CFR 61.122) states that polonium-210 emissions from nodulizing kilns at elemental phosphorus plants shall not exceed a total of 2.0 Curies per year. Radionuclide emissions from the kiln spray tower and venturi scrubbers have been tested since 1985. Recent testing results indicate that emissions from this tower are 0.6 Curies/year, which is well below the NESHAPS standard.

Because of the recent amendments to the Clean Air Act, a comprehensive air emissions inventory of all Plant area fugitive and point sources is being assembled by Monsanto.

1.3.3.4 Water Quality

There is a NPDES-permitted discharge of non-contact cooling water to Soda Creek. Process waters are recycled within the Plant. All unlined ponds at the Plant have been retired, and the only ponds currently in use are bentonite-lined ponds. Sanitary wastewaters are discharged to State-approved, non-over-flow lagoons for evaporation, and occasionally used as spray irrigation on agricultural land west of the Monsanto Plant. Monsanto is currently in the process of tying the Plant sanitary wastewater system into the City of Soda Springs sanitary plant. This action will result in the eventual elimination of the lagoon.

1.3.3.5 Occupational Health

Significant steps have been taken to protect worker safety and health and to comply with Occupational Safety and Health Act (OSHA) regulations. Programs have been implemented and employees trained in hazard communication, respiratory protection, hearing conservation, personal protective equipment, confined space entry, asbestos removal, and others. Respiratory protection is currently required in the furnace area pending the placement of engineering controls.

1.3.3.6 Toxic Substances

The Plant has instituted an aggressive program to eliminate the use of PCB-regulated equipment. The EPA-10 conducted an inspection under the Toxic Substances Control Act (TSCA) in June, 1991, and confirmed that there were no PCB violations, and that Plant operations were in compliance with TSCA. The Plant is continuing to eliminate PCB - regulated equipment and plans to be free of PCB-regulated items by the end of 1992.

Section 2

2. MONSANTO PLANT PHASE I REMEDIAL INVESTIGATION DATA COLLECTION ACTIVITIES

An RI consists of numerous data collection and data evaluation activities. Necessary data can be collected by compiling existing relevant site information, interviewing persons possessing pertinent knowledge about a site, and performing various environmental measurements at a site.

The first phase of the Monsanto Soda Springs Plant RI was conducted in accordance with the site Phase I RI/FS Work Plan (Golder 1991). The purpose of this chapter is to provide the reader with an understanding of the various data collection activities that were actually undertaken during the course of the initial phase of the Monsanto Plant RI. Interpretations of these data are provided in subsequent chapters of this report.

As with any major environmental investigative effort, the evaluation of the early Phase I data indicated a need for minor modifications to the work plan. These modifications were necessary to adhere to the original overall intent and scope of the plan. Procedure alteration checklists were completed in the field to document modifications to the work plan. These checklists are provided in Appendix R, specific modifications are discussed in the appropriate sections below.

Phase I RI data collection activities are presented in the subsequent sections by the following environmental-medium- or environmental-discipline-specific task categories:

- Source facilities associated with potential constituent releases (Section 2.1);
- Meteorology (Section 2.2);
- Surface hydrology, including surface water and stream sediments (Section 2.3);
- Geology, including characteristics and structure of bedrock and unconsolidated sediments (Section 2.4);
- Pedology, including surface soil and vadose zone (Section 2.5);
- Hydrogeology, including groundwater, springs, and hydrostratigraphy (Section 2.6); and
- Ecology, including potential human and non-human receptor organisms (Section 2.7).

These categories, with one exception, represent environmental compartments within which site constituents can potentially reside or be transported. The exception, geology, is included to allow for an integrated assessment of unsaturated and saturated soil and bedrock information pertinent to the Monsanto site. There are no absolute boundaries between the geological, pedological, and hydrogeological media nor, for that matter, between any given

environmental media discussed in this report. They are recommended by EPA (1988a) and are adopted in this report. A similar environmental-medium format is used in Chapters 3 and 4 to present interpretations of the physical characteristics of the Monsanto site and the nature and extent of constituent releases, respectively.

Data collection activities conducted during the Phase I RI are presented within each medium-specific investigation category. A brief summary is presented under each activity that describes what the data collection activity consisted of, why it was conducted, where it was conducted, when the activity was conducted, how it was conducted, and where detailed results can be found. Data evaluation procedures employed during the Phase I RI (e.g., statistical evaluations, and modeling methodologies) are described in Chapters 3 through 5, as appropriate.

All environmental measurement activities were conducted under a quality assurance project plan (QAPP) approved by EPA and Monsanto. Additional details on the environmental measurement methods used during the Phase I RI are found in the QAPP, which is appended to the Phase I RI/FS work plan (Golder 1991). The QAPP cites the specific procedures used. In situations where two or more options were specified in a particular procedure, the options actually implemented are indicated in the methods summaries within this chapter.

2.1 Source Investigation

The overall objective of this task was to collect data in order to evaluate chemical, radiological, and physical parameters of the potential sources of releases at the Monsanto Plant. These potential sources include stacks, slag piles, landfills, underflow solids, baghouse dust, cokedust and quartzite slurry ponds, and quartz, coke, phosphate ore, and treater dust stockpiles and the non-contact cooling water effluent. The purpose of this task was to determine whether these process stockpiles and streams could be sources for air or water emissions from the Plant. Source sampling was conducted during the Phase I RI, as a modification to the work plan, as described below. The result of the modifications was to augment the scope of work to allow for an enhanced air investigation.

The source investigation consisted of the following data collection activities:

- Existing source data compilation; and
- Source sampling and analysis.

Both of these activities are summarized below. The results of the evaluations of the collected source data are presented in Sections 3.1 (Source Facility Characteristics) and 4.1 (Sources of Constituent Releases).

2.1.1 Source Information Compilation

Existing source information was compiled to supplement data gathered during implementation of the first phase of the Monsanto source investigation. This included the compilation of the published documents discussed below.

Primary information sources included: previous Monsanto site investigation reports (Golder 1985, 1987, 1988a, and 1988b; Ecology and Environment 1988a); an aerial photographic analysis (consisting of photographs covering a 46-year period [1945 to 1990]) used in monitoring physical conditions and activities at the Monsanto Plant and which shows source facility locations (EPA 1990b), raw materials analytical data (Geddes, R.L., Monsanto [Memo to C. Yates, Golder] March 20, 1992), facility records and archived photographs, and employee interviews.

2.1.2 Source Sampling and Analysis

The purpose of this activity was to sample and analyze selected process by-product piles and material stockpiles to determine their potential to affect air quality with respect to fugitive dust emissions. Source sampling took place on two different dates. A total of 12 samples, for both physical and chemical analyses, were collected October 28, 1991. Another 10 samples, for physical analyses only, were collected November 4, 1991; these additional samples were needed to provide data for air modeling efforts. The location of the source samples are shown in Figure 2-1. Sample locations were selected from representative portions of the respective by-product pile or material stockpile.

Non-contact cooling water effluent is also considered a potential source of constituent release and was sampled October 25, 1991. A description of the non-contact cooling water was presented in Subsection 1.3.1 (Site Description and Overview of Operations). The cooling water effluent was sampled in conjunction with Soda Creek surface water. The effluent sampling procedures are discussed in Subsection 2.3.2 below.

Samples were collected using a stainless-steel trowel, or a shovel in the materials that were hard-packed. The constituents analyzed in source samples are listed in Table 2-1. Chemical analyses were performed on the #200 sieve fraction only in order to determine the characteristics of the potentially wind-blown portion of the source material samples. Table 2-2 lists all the source samples that were collected during this sampling round and includes duplicate samples, sampling dates, and the chemical and physical parameters that were analyzed.

All samples were transported via overnight delivery to the appropriate analytical laboratory in sealed coolers or boxes. Source physical analytical results are provided in Appendix B, and results are discussed in Section 3.1 (Source and Facility Characteristics). Chemical analytical results are provided in Appendix C, and results are discussed in Section 4.1 (Sources of Constituent Releases).

2.2 Meteorological Investigation

The purpose of this investigation is to evaluate the meteorologic conditions at and surrounding the Plant to identify the potential effects of climatic conditions on the past or present airborne transport of constituents either from the Plant stacks or as fugitive dust from the by-product or material stockpiles. The results of the evaluations of the meteorological data collected are presented in Sections 3.2 (Meteorological Characteristics) and 4.2 (Air Quality).

The sole meteorological data collection activity, compilation of existing data, is summarized in Subsection 2.2.1 below.

2.2.1 Meteorological Information Compilation

A meteorological monitoring station was installed on the Monsanto property in December, 1987. The station is located just north of the Plant entrance as shown on Figure 1-3. The station consists of a 120-foot tower equipped with temperature, wind speed, and direction sensors at 33 feet and 120 feet above ground. The complete data record from December 14, 1987, to October 3, 1991, was obtained from Monsanto for the Phase I RI air dispersion evaluation. A summary of the meteorological data collected is provided in Appendix D. The meteorological data record for the calendar year 1990, the year used in the dispersion modeling, was complete.

Either the standard deviation of the horizontal wind direction (Sigma A) or the temperature difference between the two levels can be used to determine atmospheric stability. For the purpose of the Phase I RI, the Sigma A method was used in accordance with the EPA recommended guidelines for on-site meteorological programs (EPA 1990c) to calculate atmospheric stability for 1990 as input to the atmospheric dispersion model.

Mixing heights for 1990 were obtained from the National Climate Center archives for Boise, Idaho. Consideration was given to the use of upper air data from Salt Lake City, Utah. However, a review of seasonal mixing height isopleths in historical data (Holzworth 1972) indicated that the Boise data were more representative of the area around Soda Springs.

2.3 Surface Hydrological Investigation

The overall objective of this task was to collect data in order to evaluate the potential affects on water quality in Soda Creek resulting from the discharge of effluent from the Monsanto Plant. Samples were collected to determine the water quality of the Plant's non-contact cooling water effluent, and the ambient water quality and sediment quality in Soda Creek upstream and downstream of the effluent outfall.

The surface hydrological investigation consisted of the following data collection activities:

- Existing surface hydrological information compilation; and
- Effluent, surface water, and sediment sampling and analysis.

Each of these activities is summarized below. Interpretation of the surface hydrological data are presented in Sections 3.3 (Surface Hydrological Characteristics) and 4.3 (Surface-Water and Sediment Quality).

2.3.1 Surface Hydrological Information Compilation

Existing regional and local surface hydrological information was compiled to supplement data gathered during implementation of the first phase of the Monsanto Plant surface hydrological investigation. This included the compilation of the published documents discussed below.

Regional literature reviewed included: a proposed stream-flow data program for Idaho, providing information on current, discontinued, and proposed gaging stations with corresponding drainage areas (Thomas and Harenberg 1970); an atlas showing hydrologic data and water supply information of the Great Basin region of Idaho, Nevada, Utah, and Wyoming (Price and Eakin 1974), a short discussion concerning the need to begin an investigation of the water resources of the Bear River drainage of Idaho (Barnett 1967), an early hydrologic model of the Bear River Basin including the Oneida and Soda Springs sub-basins and containing sub-basin outflow information for the years 1954 through 1956 (Hill et al. 1970), an atlas showing quality of surface water in the Bear River Basin (Waddel and Price 1972), and a survey of water quality from 1974 in the Bear River Basin to determine point and non-point source loading and the cause and effect relationship between major waste sources and receiving water quality (Schmidt and Beck 1975).

More local information is provided by: the 7.5-minute United States Geological Survey (USGS) topographic map (USGS 1982); USGS stream gaging station information for Soda Creek and Bear River (EarthInfo Inc. 1990); Monsanto internal memoranda on local surface hydrology (Soda Creek Reservoir, Soda Creek, irrigation, weirs, and the fish hatchery); and a hydrologic budget analysis of Blackfoot River, Soda Creek, and Bear River which discusses leakage from Blackfoot Reservoir (Dion 1974).

2.3.2 Effluent, Surface Water, and Sediment Sampling and Analysis

The purpose of this activity was to sample and analyze the Monsanto Plant non-contact cooling water effluent discharged to Soda Creek, and to sample and analyze water and sediment from Soda Creek downstream and upstream of the effluent discharge. The objective of the sampling was to determine whether the Soda Creek ecosystem is affected by the effluent discharge. The actual sample locations are shown on Figure 2-2. Sampling took place on October 25, 1991.

A total of nine surface-water samples and five sediment samples were collected under this activity. At the time of sampling, the water from Soda Creek was being diverted from the creek into the irrigation canal at a point approximately 100 feet downstream of the effluent

discharge. The steel irrigation canal did not contain sediments and Soda Creek did not contain an appreciable amount of water at the time of sampling (the flow due to leakage of the diversion dam was on the order of a few gallons per minute). Therefore, the downstream surface-water and sediment samples were not collected at the same location. The downstream surface-water samples were collected from the irrigation canal, but the downstream sediment samples were collected from the bed of Soda Creek below the irrigation canal diversion dam. These modifications to the work plan were documented on Procedure Alteration Checklists provided in Appendix R.

Three effluent samples were taken directly above the weir of the effluent ditch, which is approximately 3-feet wide and 1-foot deep and is located in the southwest corner of the Plant. Three surface-water samples were collected from Soda Creek approximately 400 feet upstream from the effluent discharge—one along the east bank, one in the middle of the creek, and one along the west bank. Soda Creek, at the upstream sampling location, is approximately 30-feet wide and 3-feet deep. Three surface-water samples were taken at the flume (the North Weir) in the irrigation canal approximately 300 feet downstream of the effluent discharge. The irrigation canal at the sampling location is approximately 5-feet wide and 4-feet deep.

Three sediment samples were collected approximately 400 feet upstream of the effluent discharge at the same location as the upstream surface-water samples. One sediment sample was collected from Soda Creek approximately 100 feet downstream of the effluent discharge, directly below the diversion dam. Another sediment sample was collected from Soda Creek approximately 300 feet downstream of the effluent discharge.

The effluent and surface water samples were collected by submerging the appropriate sample container directly into the water with the container's mouth positioned upstream and the sampling personnel standing downstream of the sample point (EPA 1987). Sediment samples were collected using either a stainless-steel trowel or shovel. All in-stream water and sediment sampling progressed from a downstream to upstream direction to assure sample representativeness.

The constituents analyzed in surface-water, effluent, and sediment samples are listed in Tables 2-3 and 2-4. Field measurements for pH, Eh, specific conductance, temperature, and turbidity were taken during the effluent and surface-water sampling. Field dissolved oxygen measurements were not taken due to instrument malfunction. Samples were not filtered because sample turbidities were less than five nephelometric turbidity units (NTUs).

Tables 2-5 and 2-6 list the effluent and surface water samples and the sediment samples that were collected during this sampling round and includes the quality assurance/quality control (QA/QC) samples, the sampling date, and the chemical and physical parameters that were analyzed. Duplicate and split samples for each analytical parameter were collected immediately following the collection of the field sample for that same parameter. Duplicate samples are identical samples collected at the same time, in the same way, and contained and transported in the same manner to the same analytical laboratory as the field sample. Split samples are also identical samples except that they are sent to an alternate laboratory as a performance audit of the primary laboratory.

The results from the sediment physical analyses are provided in Appendix F and are discussed in Section 3.3 (Surface Hydrological Characteristics). All samples were transported via overnight delivery to the appropriate analytical laboratory in sealed coolers or boxes. The results of the chemical analyses of the Phase I RI Monsanto effluent, surface water, and sediment sampling are provided in Appendix G and are discussed in Section 4.3 (Surface-Water and Sediment Quality).

2.4 Geological Investigation

The overall objective of this task was to collect data in order to evaluate the geological features of the Monsanto site and regional area surrounding the site. Geological characteristics evaluated included geologic units, geologic contacts, stratigraphy, structure, and faults. The purpose of this task was to: 1) develop a conceptual geologic model; and 2) evaluate possible geologic controls on groundwater movement.

The investigation consisted of the following data collection activities:

- Existing geological information compilation; and
- Geological reconnaissance.

Both of these activities are summarized below. Interpretations developed from the geological information are presented in Section 3.4 (Geological Characteristics).

2.4.1 Geological Information Compilation

Existing geological information was compiled to supplement data gathered during implementation of an earlier Monsanto geological investigation (Golder 1985). This included the compilation of the documents discussed below.

Regional geologic literature included: preliminary or geological reconnaissance reports on the phosphate deposits and geology of Idaho, Wyoming, and Utah (Gale and Richards 1909; Schultz and Richards 1911, Mansfield and Roundy 1916, Schultz 1918, Intermountain Association of Petroleum Geologists 1953, Sheldon 1957, AAPG 1972, and Oriel and Platt 1980); reports on the structure and faults of the Basin and Range, Bannock Thrust, Blackfoot River, Bear River Range, Caribou Range, and Snake River Plain (Mansfield 1921); a report on the structure of the Wasatch-Great Basin region including Laramide folds and Basin and Range faults (Eardley 1939); and a report on an east-dipping thrust zone in the American Falls Pocatello area of Idaho west of the Bannock thrust (Carr and Trimble 1962).

Additional regional geologic literature obtained included: a regional gravity survey of the eastern part of the Snake River Plain in Idaho (Lafehr and Pakiser 1962); an interpretation of the Bannock thrust, associated faults and age of structural movements (Armstrong and Cressman 1963), stages of tectonic development including deposition, folds, thrust faults and block faults of southeastern Idaho and western Wyoming (Armstrong and Oriel 1965,

Mountjoy 1966, and Oriel and Armstrong 1966); seismic activity along the Cache Valley faults in Idaho and Utah (Glass et al., 1976); a report of the origin and stratigraphy of Gem Valley, Idaho (Oriel et al., 1965); a report of the occurrence of anticlines in Caribou and Teton counties, Idaho (Kirkham 1922); and mineralogy and petrology of the volcanic rocks in Caribou County, Idaho (Fiesinger et al. 1982 and Perkins and Fiesinger 1979).

Local geologic information obtained included: a geologic reconnaissance of the Monsanto Plant area and drilling logs by Golder (1985 and 1988a); reports on the geology and structure of the Soda Springs area which includes detailed local descriptions (Richards and Mansfield 1910 and Armstrong 1969); an investigation of the Blackfoot Lava Fields and Bear River Valley which includes local descriptions of the Soda Springs area (Mansfield 1927); a geologic report of the Johnson Creek quadrangle, 5 miles east of Soda Springs (Gulbrandsen et al. 1956); geophysical field investigations of the Soda Springs region using gravity and magnetic surveys (Mabey and Oriel 1970); detection and delineation of faults by surface resistivity measurements at the Conda Mine, 5 miles northeast of Soda Springs (Stahl 1975); an abstract on the basalt lava flows and faults in the Soda Springs Valley (Stearns 1936); a report of the occurrence of earthquake epicenters near Palisades Reservoir and Soda Springs (Schleicher 1975); geophysical logging results for the Kerr-McGee facility (Ecology and Environment 1988b); and an aerial photographic and fracture trace analysis of the Soda Springs area (EPA 1990b). The borehole logs from previously installed monitoring wells, production, and some domestic wells at the Monsanto Plant and vicinity were used in this investigation and are provided in Appendix H.

The findings from this literature review are discussed in Section 3.4 (Geological Characteristics).

2.4.2 Geological Reconnaissance Field Mapping of Surficial Features

The purpose of this activity was to locate and identify surficial geologic features that may provide a structural control on groundwater movement, especially in the area to the east and south of the Plant site.

Prior to field investigations, a literature review of the regional and local geology (Section 2.4.1) and a photogeologic analysis was conducted. The photogeologic analysis of the area was conducted using existing United States Department of Agriculture (USDA) black-and-white aerial photographs taken July 20, 1970, at a scale of approximately 1:21,000 (frames CXP-4LL-65 to -68 and -85 to -87). In addition to analyzing possible geologic structures, contacts, outcrops, and springs, the geology of Armstrong (1969) and the fracture traces identified by EPA (1990b) were enlarged and transferred to photographic overlays for field evaluation.

Possible structural controls on groundwater movement were investigated in the area east of the Plant between Formation Spring and Ledger Creek Springs (which provide drinking water to the City of Soda Springs). The presence of springs in the Little Spring Creek drainage south of the Plant, and Big Spring Creek just south of Soda Springs (see Figure 1-2) were also investigated. The geologic mapping was conducted from October 28 to 31, 1991. The following features were visited as part of the reconnaissance:

- Finch Spring fault and associated structures east of the Monsanto Plant entrance; Ledger Creek Springs graben, which is subparallel and adjacent to the southern part of the Finch Spring fault; and a fault approximately 0.7 miles northeast of Ledger Creek Springs graben. The characteristics of the basalt and travertine deposits (rock texture, rock composition, jointing, and contacts) and the characteristics of the faults, vertical separation, strike, and displacement direction were investigated; and

- The Formation Cave area to the west of Formation Spring, Little Spring Creek, and Big Spring Creek.

The results of the geologic field reconnaissance are provided in Section 3.4 (Geological Characteristics).

2.5 Pedological Investigation

For the purpose of this report, the term pedology is applied in a manner consistent with the meaning of the word among the international community of soil scientists: the study of the nature, properties, formation, distribution, classification, function, and uses of soils.

The overall objective of this task was to collect data in order to: 1) evaluate the soil quality surrounding the Monsanto Plant (outside of the Plant property boundary) to determine whether airborne emissions from the Plant may have affected soil quality; and 2) evaluate whether the vadose zone beneath potential sources has the potential to affect groundwater quality.

The investigation consisted of the following data collection activities:

- Existing soil information compilation; and
- Surface-soil sampling and analysis.

Both of these activities are summarized below. Interpretations of the soil and vadose-zone data are presented in Sections 3.5 (Pedological Characteristics) and 4.4 (Soil Quality).

2.5.1 Soil Information Compilation

Existing regional and local soil information was compiled to supplement data gathered during implementation of the first phase of the Monsanto Plant soil investigation. This included the compilation of the published documents listed below.

Regionally, literature is available describing the impact of cadmium on soils and vegetation (Page et al. 1972; Fleischer et al. 1974), the conditions and trends of soil, water, and related resources of non-federal lands in Idaho by the USDA Soil Conservation Service (SCS 1991),

and information on soil moisture depletion at three sites in the Bear River basin (Allen and Brockway 1982).

Locally, literature includes investigations on the impact of elemental emissions from industrial processing of phosphatic shale on the chemistry of vegetation and soil near both Soda Springs and Pocatello (Gough and Severson 1976, Hutchison et al. 1979, Severson and Gough 1979, Johnson et al. 1980), and the hydrogeologic investigation by Golder (1985), which concluded that the soils below the hydroclarifier and the underflow solids ponds were oversaturated with respect to cadmium carbonate and calcium fluoride, respectively. Regional and local soils maps were obtained from the Caribou County office of the USDA SCS (Kukachka, B., SCS [Personal communication] November 26, 1991).

2.5.2 Soil Sampling and Analysis

Surface soils surrounding the Monsanto Plant were sampled and analyzed to determine whether the soils could be affected by fugitive dust or stack emissions from the Plant, or other nearby industrial operations, and to estimate control concentrations. Sampling took place on October 19, 1991, and on October 28, 1991.

Soil samples were originally collected at 6 locations. At all locations, samples were collected from the 0-1 inch horizon and the 0-6 inch horizon. At the request of EPA-10 oversight personnel, five of these locations were re-sampled, and the samples from a sixth location were not analyzed. The location of the final soil samples are shown in Figure 2-3. Soil sample locations were selected in order to ensure that a relatively undisturbed variety of land uses were represented (e.g., plowed field, range land, and grass land). Three control locations were sampled in an adjacent valley approximately 10 to 13 miles southwest of the Monsanto Plant (south of Grace, Idaho) in order to avoid any significant influence from the Monsanto Plant. The locations of control samples were based on selecting areas with similar soil types as those surrounding the Monsanto Plant. The control locations are shown in Figure 2-4.

Samples were collected using a stainless-steel trowel which was rinsed with distilled water between each sampling event. All samples were homogenized over the interval of interest. The constituents analyzed in soil samples are listed in Table 2-7. Table 2-8 lists all the soil samples that were collected during this sampling round and includes the QA/QC samples, the sampling date, and the chemical and physical parameters that were analyzed. An equipment blank was collected by rinsing the trowel with distilled water and collecting the rinse water for analysis.

As discussed above, several locations were re-sampled at the request of EPA-10 oversight personnel to ensure that a variety of land uses were represented in the suite of samples. Sampling location S-2 was deleted altogether; sampling locations S-3, S-5, S-6, S-9, and S-11 were moved slightly and re-sampled. Analysis of the original samples for these locations were canceled at the laboratory.

All samples were transported via overnight delivery to the appropriate analytical laboratory in sealed coolers or boxes. Surface-soil physical analytical results are provided in Appendix I

and discussed in Section 3.5 (Pedological Characteristics). Chemical results are provided in Appendix J and discussed in Section 4.4 (Soil Quality).

2.6 Hydrogeological Investigation

The overall objective of this task was to collect data in order to evaluate the groundwater conditions in the vicinity of the Plant and to determine the nature and extent of constituent releases to groundwater and springs.

The hydrogeological investigation consisted of the following data collection activities:

- Existing hydrogeological information compilation;
- Existing groundwater quality data compilation;
- Geodetic survey; and
- Groundwater sampling and analysis.

Each of these activities is summarized below. Interpretation of the hydrogeological data are presented in Sections 3.6 (Hydrogeological Characteristics) and 4.5 (Groundwater Quality).

2.6.1 Hydrogeological and Data Compilation

Existing regional and local hydrogeological information was compiled to supplement data gathered during the Phase I hydrogeological field data collection. This included the compilation of the published documents discussed below.

Regionally, literature included: a hydrological investigation which includes information on the hydrogeologic units in the Great Basin region of Idaho, Nevada, Utah, and Wyoming (Price and Eakin 1974); a study which provides water-quality data representative of several different regional aquifers and relates the data to natural and manmade environmental controls (Seitz and Norvitch 1979); a study of thermal and non-thermal groundwater flow systems in the thrust zone of southern Idaho and western Wyoming, and hydrogeologic and hydrochemical data collection and interpretation on several springs in the Soda Springs area (Ralston et al. 1983); a discussion of the water resources of the entire Bear River drainage in Idaho (Barnett 1967); and an evaluation of groundwater resources in Lower Dry Valley at a potential open pit mine, 10 miles east of Soda Springs (Robinette and Ralston 1976).

Locally, information included: an investigation of groundwater flow patterns in the Meade thrust allochthon, southeastern Idaho, using geochemical and isotopic techniques, including analyses of 38 spring and well samples (Mayo et al. 1985); a discussion and study of the spring-water geochemistry in the Blackfoot Reservoir region of southeastern Idaho, including geochemical information on springs in the Soda Springs area (Mitchell 1976; Hutsinpiller 1979, and Hutsinpiller and Parry 1985); a discussion of groundwater resources and movement in the area between Soda Springs and Conda, Idaho (Anderson and Kelley 1967); a study on the

leakage from Blackfoot Reservoir and how it affects the water yield of both Soda Creek and Bear River (Dion 1974); reports documenting test well abandonments and installations at the Monsanto Plant, including well logs (Golder 1987 and 1988a); a geophysical study of 29 test wells at the Monsanto Plant (Poeter and Weber 1984); a hydrogeological investigation at the Monsanto Plant that includes hydrostratigraphy information, geophysical borehole logs, well pump testing data, and water quality sampling results (Golder 1985 and 1988b); an EPA site inspection report for the Monsanto Plant (Ecology and Environment 1988a); and an EPA site inspection report of the Kerr-McGee site (Ecology and Environment 1988b).

A well inventory for the Monsanto Plant vicinity was compiled by Golder for a 24 square-mile area surrounding the Monsanto Plant. The information is contained in Appendix K. The results of this inventory are discussed in Section 3.6 (Hydrogeological Characteristics).

2.6.2 Geodetic Survey

Each of the monitoring wells, water-supply wells, and springs selected for use in the Monsanto Phase I RI sampling activities were geodetically surveyed by a licensed surveyor (A.A. Hudson and Associates of Soda Springs) for both horizontal location and elevation. Geodetic surveying results are provided in Appendix L. Horizontal locations were specified using the Monsanto Plant coordinate system. A conversion to the Idaho state plane coordinate system is also provided with the results. Elevations are specified as feet amsl, and are accurate to within 0.01 feet; coordinates are accurate to within 0.001 feet.

The surveyed sampling locations were incorporated onto a base map provided by Monsanto. This base map was used to develop the various figures presented throughout this report.

2.6.3 Groundwater Sampling and Analysis

The purpose of this activity was to sample and analyze groundwater from monitoring (test) and domestic wells, water supply (production) wells, and springs in the vicinity of the Plant. The objective of the sampling was to determine the groundwater quality at the site and to utilize naturally-occurring isotopes to better characterize groundwater flow patterns. Samples were taken from a total of 58 locations: 40 at wells and 18 at springs or other groundwater-fed surface-water bodies (Formation Cave ponds and related creek, Southwest Spring wetland area, Kelly Park springs wetland area).

The locations of all on-site wells are shown in Figure 2-5. Off-site wells, springs, and other surface water bodies are shown in Figure 2-6. Well completion information is listed in Appendix M and includes coordinates and elevation of each well, water-level measuring point information, well construction details, and screened geologic formation. The sampling occurred over a two-week period from October 15 to 28, 1991. An additional environmental isotope sample was collected on December 4, 1991.

Table 2-9 lists the wells of interest at or in the vicinity of the Monsanto Plant and presents well purging information for the wells that were sampled during the Phase I RI. Prior to

purging the wells, water levels were measured. Water level meters, along with any other non-dedicated equipment that was lowered down the wells (such as depth sounders or bailers), were decontaminated with a non-phosphate detergent wash and a distilled water rinse. Groundwater elevation measurements are provided in Appendix N.

Test wells were purged and sampled using a dedicated submersible pump, except test wells TW-30, TW-38 and TW-43 which were purged using a bailer because of insufficient water quantity. Pumping the test wells consisted of connecting the pump motor's electrical system to a gasoline powered generator and attaching a dedicated polyvinyl chloride (PVC) sampling assembly, equipped with a bleed valve and a purge valve, to the well-head. Pump information and specifications for the test wells and the production wells are listed in Table 2-10.

Purged water was either contained in a water tank or was disposed of on the ground, depending on knowledge of water quality from previous sampling periods. Contained water was later disposed of in the seal water pond at the Plant. Flow rates during purging ranged from 0.5 to 15 gpm, using the highest rate possible without the water level in the well dropping below the pump intake to prevent air entrainment in the sample. Samples were collected after approximately three well volumes had been purged. Samples, except for radon, were taken directly from the bleed valve of the sampling assembly. Radon samples were collected by filling a glass funnel with sample water and using a glass syringe to transfer the sample into sample vials. This procedure minimized the occurrence of air bubbles in the sample.

The four production wells at the Plant (PW-1, PW-2, PW-3, and PW-4), test well TW-2 which is used to supply water to a Plant building, and the nearby domestic well (Lewis), are generally pumping continuously or intermittently. If in an intermittent mode at the time of sampling, the pumps were turned on (except for well TW-2 which automatically switches on at frequent intervals) and allowed to run for approximately 10 minutes prior to obtaining the sample. Samples from these wells were collected directly from a faucet at or near the well-head.

The springs are shown in Figure 2-6. A summary of the springs are listed in Table 2-11 showing their uses and any alternative names. Surface-water samples were obtained at selected springs to better define the characteristics and water quality of the springs. Three samples were taken at and in the vicinity of Formation Springs — one at the intake to the treatment building, one at the creek near the road, and one at a lower percolation pond (Figure 2-7). Three samples were taken around Ledger Spring, each from a different spring box (Figure 2-8). Three samples were also taken near and at Mormon Springs. Springs were sampled by either submerging the appropriate container directly into the water or by using a glass beaker to transfer the sample to the sample containers.

The constituents analyzed in groundwater and spring samples are listed in Table 2-12. Metals, selected ions, radiochemical, and water-quality parameters were analyzed for all samples. Environmental isotopes were analyzed from selected wells and springs for groundwater age-dating purposes. Total petroleum hydrocarbons (TPH) were analyzed from selected wells to screen for synthetic organic compounds. Biological oxygen demand (BOD)

and chemical oxygen demand (COD) analyses were conducted for selected wells downgradient of the former and present Plant landfills to determine whether the landfills are potential sources of constituent releases.

Table 2-13 lists the water and QA/QC samples collected during this sampling round, the sample identification numbers, the sampling dates, and the analysis parameters. QA/QC duplicate and split samples for each analytical parameter were collected immediately following the collection of the field sample for that same parameter. Duplicate and split samples are identical to the field samples and are collected as a check on the analytical laboratory. Duplicates were sent with the field samples to the primary laboratory (Chen-Northern) and split samples were sent to the alternative laboratory (Core Laboratories). The equipment blank sampling procedure consisted of pouring distilled water through a bailer, a well-head sampling assembly, the beaker used in sampling springs, or the filter apparatus (with filter paper installed), and collecting the resulting discharge into sample containers. The equipment blank collected from the filter apparatus was analyzed for the same parameters as filtered samples (radiochemicals and metals). Field blanks were collected at different well locations around the Plant by pouring distilled water directly into sample containers. Locations of field blanks were selected in order to give a good overall representation of the site. Tables 2-14 and 2-15 are summaries of the field samples, duplicates, splits, and equipment blanks collected. Field blanks were collected every other day, as a modification to every day as stated in the work plan, as documented on a Procedure Alteration Checklist provided in Appendix R.

Field measurements for pH, Eh, specific conductance, temperature, and turbidity were taken concurrently with sampling. Dissolved oxygen field measurements were not taken due to instrument malfunction. This modification to the work plan is documented in Appendix R. Radiochemical (excluding radon) and metal samples with a turbidity greater than 5 NTU were filtered using a vacuum filter apparatus and 0.45 micrometers (μm) filter paper. Preservatives were added to the samples after filtering and both an unfiltered and a filtered sample were submitted to the laboratory.

All samples were transported via overnight delivery to the appropriate analytical laboratory in sealed coolers or boxes. The field measurements taken at the time of sampling are included in the Sample Integrity Data Sheets provided in Appendix P. The results from the laboratory analyses of the Phase I RI Monsanto groundwater and spring samples, and related chain-of-custody forms are provided in Appendices O and Q, respectively, and the results are discussed in Section 4.5 (Groundwater Quality).

2.7 Ecological Investigation

The ecological investigation for the first phase of the Monsanto RI consisted of collection of data related to the characterization of potential receptor populations, both human and wildlife, in the vicinity of the Plant. (In this report, the term wildlife refers to non-domesticated populations of both plants and animals, and to those that inhabit both terrestrial and aquatic habitats.)

Human and wildlife investigational activities are described in further detail below. An interpretation of the ecology of the site, from both a human and wildlife perspective, can be found in Section 3.7 (Ecological Characteristics).

2.7.1 Human Ecological Investigation

All data collection activities related to characterization of the human populations within the Plant vicinity were conducted by compiling existing information. Published documents were reviewed and appropriate state, regional, county, city, and Monsanto Plant employees were interviewed. Site visits conducted by project personnel supplemented the information obtained during this process.

The human ecological investigation for the Monsanto Plant consisted of the compilation of:

- Land use information;
- Water use information; and
- Cultural (i.e., archeological and historical) information.

Each of these data collection activities is described below.

2.7.1.1 Land Use Data Compilation

The City of Soda Springs zoning ordinance (Title 17) and the Caribou County zoning ordinance (Caribou County Zoning Board 1986) were obtained to determine restrictions on land use in the vicinity of the Monsanto Plant. Photographs of up-to-date city and county zoning maps, which are posted in the respective administrative buildings located in Soda Springs, were obtained. The regional comprehensive land use and water quality plan (Caribou County 1977) and a county economic development profile (Southeast Idaho Council of Governments 1990) were obtained to determine long-range, local government planning goals for the area near the Plant. Regional and local demographic information was obtained from 1980 and 1990 census data (Bureau of the Census 1991).

During the course of the initial phase of the RI, the following city and county officials were interviewed to gather information pertaining to current and anticipated future land use and demography in the vicinity of the Monsanto Plant:

- Mr. Clayton Schmitt, City Administrator, City of Soda Springs;
- Mr. Kirk Hansen, Mayor, City of Soda Springs;
- Mr. Robert Anderson, Commissioner, Caribou County; and
- Mr. Ray Nelson, Chairman, Caribou County Planning and Zoning Commission.

These interviews are among those documented in Appendix A (Wright, B., Golder [Memo to Monsanto Soda Springs Plant Phase I RI File] November 12, 1991).

Aerial photographs of the Plant were reviewed to obtain and verify relevant local land use information. Site visits also provided information on this topic. The information obtained in

the overall land use data compilation process is presented within Section 3.7 (Ecological Characteristics).

2.7.1.2 Water Use Data Compilation

Water use can be divided into ground water and surface water uses. State of Idaho Department of Water Resources (IDWR) well records were obtained for wells within a 24 square-mile area surrounding the Plant to determine ground water withdrawal points within the vicinity of the Monsanto Plant and production wells within the Plant. These records are provided in Appendix K. The results of this inventory are discussed in Section 3.7 (Ecological Characteristics).

Surface water use in the vicinity of the Monsanto Plant was determined by site visits, and topographic map reviews conducted to determine the location of water intakes, records of water use by City of Soda Springs, recreational areas, and other relevant facilities.

In addition to the city and county officials mentioned in sub-subsection 2.7.1.2 above, the following regional and state officials were interviewed to obtain any pertinent information regarding ground water and surface water use and related health monitoring:

- Mr. Thomas Hepworth, Environmental Health Specialist, Southeastern Idaho District Health Department; and
- Mr. Dennis Dunn, Senior Water Resource Agent, Idaho Department of Water Resources.

Interview summaries are provided in Appendix A (Wright, B., Golder [Memo to Monsanto Soda Springs Plant Phase I RI File] November 12, 1991), and results of all water use data compilation activities are presented in Section 3.7 (Ecological Characteristics).

2.7.1.3 Cultural Data Compilation

The regional comprehensive land use and water quality plan (Caribou County 1977) was reviewed to determine the presence of any known, significant archeological or historical sites within the vicinity of the Monsanto Plant. This information is needed to prevent potential disturbances of any valued cultural resources during any subsequent remediation efforts. Findings on this issue are presented in Section 3.7 (Ecological Characteristics).

2.7.2 Wildlife Ecological Investigation

Data gathered for the wildlife ecological investigation for the Monsanto Plant Phase I RI included the compilation of existing biological information and a reconnaissance survey of the Plant vicinity. These two activities are summarized below.

2.7.2.1 Biological Data Compilation

Existing biological information was compiled to develop a general understanding of the wildlife ecology of the Plant vicinity. Some of the sources of data for this review include a State environmental overview (Montgomery 1975), an assessment of special mineral processing wastes (EPA 1990d), a compendium of State rare, threatened, and endangered species (Mosely and Groves 1990), and papers on the impact of source emissions from phosphate processing (Gough and Severson 1976; and Severson and Gough 1976 and 1979).

At Monsanto's request, the United States Fish and Wildlife Service, Boise Field Station (FWS-BFS) performed a survey of Idaho's endangered and threatened Plant and animal species (Lobdell, C., FWS-BFS, [Letter to W. Wright, Golder] December 2, 1991) to determine the presence of any such species or the presence of their critical habitats potentially in the vicinity of the Plant. The FWS-BFS survey included access to the Natural Heritage Program Database maintained by the Idaho Conservation Data Center. The FWS-BFS also provided information on other sensitive species to allow identification of sensitive habitats in the area under consideration.

Officials from the following state and federal agencies (in addition to the city, county, regional, and State officials mentioned in Paragraphs 2.7.1.1 and 2.7.1.2 above) were interviewed as part of the biological data compilation effort:

- Mr. Bob Kukachka, Soil Survey Project Leader, SCS;
- Mr. Tony Varilone, District Ranger, United States Forest Service (USFS);
- Mr. Carl Anderson, Regional Wildlife Biologist, Idaho Department of Fish and Game;
- Mr. Jim Mende, Regional Fishery Biologist, Idaho Department of Fish and Game;
- Mr. Wallace Evans, Area Manager, United States Bureau of Land Management (BLM);
- Mr. Jeff Cundick, Mining Engineer, BLM;
- Mr. Chuck Lobdell, Field Supervisor, FWS-BFS; and
- Dr. Robert Parenti, Botanist/Ecologist and Tri-State Plant Program Manager, FWS-BFS.

Summaries of these interviews in a project memorandum (Wright, B., Golder [Memo to Monsanto Soda Springs Plant Phase I RI File] November 12, 1991), and the results of the overall biological data compilation effort are presented in Section 3.7 (Ecological Characteristics).

2.7.2.2 Field Habitat Reconnaissance

The Phase I RI/FS work plan for the Monsanto Plant (Golder 1991) called for a field habitat reconnaissance of any critical or sensitive habitats, within a 1.6-mile (2-kilometer) radius of the Monsanto Plant, identified during the biological data compilation activity. As the data compilation effort identified Soda Creek as the only sensitive habitat, and no critical habitats were identified within this distance (see Section 3.7), the field reconnaissance was restricted to the creek. Section 3.7 (Ecological Characteristics) incorporates the observations noted during the reconnaissance.

Section 3

3. PHYSICAL CHARACTERISTICS OF THE MONSANTO PLANT

This chapter provides a description of the relevant physical characteristics of the Monsanto Soda Springs Plant. The physical setting of the Plant and its vicinity is presented by seven environmental media: Section 3.1 describes the characteristics of the sources and the Monsanto facility; Section 3.2 provides a meteorological characterization; Section 3.3 focuses on surface water near the Plant; Section 3.4 describes the geological setting; Section 3.5 contains a discussion of soil characteristics; Section 3.6 describes groundwater characteristics; and Section 3.7 provides a description of potential receptor organisms within and near the Plant.

Each environmental-medium-specific discussion, with the exception of Section 3.1 (Source and Facility Characteristics), is initiated with a characterization of the regional setting, which in turn is followed by a description of the local setting. The regional setting for the Monsanto Plant varies in scale, depending upon the environmental medium under discussion; however, it can generally be visualized as consisting of the Bear River Basin in southeastern Idaho, or the tributary valley to the Bear River (described further in Section 3.4) in which the Monsanto Plant is located. The local setting is generally considered to be that area within an approximate two-mile radius of the Monsanto Plant.

The focus of Chapter 3 is to describe the physical characteristics of the Monsanto Plant. The chemical characteristics of process materials from the Plant are described in Chapter 4 (Nature and Extent of Monsanto Plant Constituent Releases).

3.1 Source and Facility Characteristics

The purpose of this section is to provide a physical description of the Monsanto Plant facilities and the sources of constituent releases. Physical characteristics consist of such factors as nearby surface features, facility security, types of engineered structures, and source types, properties, and locations. A summary of other potentially significant facilities and constituent sources in the vicinity of the Monsanto Plant is presented in Section 3.1.3. Known chemical characteristics of the sources are presented in Section 4.1 (Sources of Constituent Releases).

3.1.1 Monsanto Plant Facility and Vicinity

The Monsanto Soda Springs Plant is located in southeastern Idaho, approximately one mile north of the City of Soda Springs, Idaho (Figure 1-1). The Plant occupies portions of Sections 29, 30, 31, and 32 of Township 8 South and Range 42 East. The Plant encompasses approximately 540 acres in a tributary valley to the Bear River at an elevation ranging from 5,880 feet to 5,990 feet amsl. Monsanto also owns the Kackley property to the southwest of the Plant and the Harris and Ponderosa properties to the south of the Plant as indicated on Figure 1-2.

The valley is broad and rural, bordered on the east by the Aspen Range and on the west by the Soda Springs Hills and Chesterfield Range. The mountain ranges rise 700 to 1,300 feet above the valley floor, which occurs at an elevation of between 5,800 to 6,100 feet amsl. The valley has mixed agricultural, residential, and industrial uses. The largest population center in the area is the City of Soda Springs, with a population of approximately 3,000.

State Highway 34 runs roughly north-south forming the eastern boundary of the Plant, and is the primary access to the Plant. The western boundary is formed by Third East Street (Government Dam Road) which runs directly north-south. An un-named Caribou County road runs east-west, forming the southern Plant boundary. The northern boundary borders agricultural land. Plant access is also available via a railspur from the Union Pacific Railroad, which roughly parallels State Highway 34.

Natural surface-water features in the Plant vicinity include: 1) Soda Creek, which passes within 2,000 feet west of the Plant; 2) two wetlands, one located immediately northwest of the Plant, and the other immediately southwest of the Plant; and 3) numerous springs located within a two-mile radius of the Plant (Figure 1-2). Each of these aquatic features is discussed in more detail in Section 3.3 (Surface Hydrological Characteristics).

Monsanto purchased the Plant site in 1952 and initiated elemental phosphorus production on the property. The Monsanto Plant is completely fenced and security is maintained by controlling and monitoring access to the Plant along main access routes and through locked or guarded gates.

Engineered facilities within the Plant include buildings, paved and unpaved areas, railroad tracks, dirt roads, various utilities, ore stockpiles, by-product piles, and man-made ponds. A map of the Plant is presented in Figure 1-3.

3.1.2 Physical Characteristics of Potential Sources of Constituent Releases

The purpose of this subsection is to summarize the information gathered regarding past disposal and storage practices at the Monsanto Plant, and to identify areas where potential constituent releases may have occurred.

The elemental phosphorus production process at the Monsanto Plant was summarized in Subsection 1.3.1 (Site Description and Overview of Operations). This summary described the primary materials used in and the by-products resulting from the production of elemental phosphorus. Further details regarding the storage and disposal and the physical characteristics of these materials are presented below. A summary of the process stream of materials and by-products is provided in Table 3-1.

Particle-size distributions of the raw materials and process by-products are shown in Table 3-2, which also identifies the Unified Soil Classification System (USCS) classes assigned to the materials and by-products that were analyzed. The USCS class designations used below are defined in the table. Results of the physical characterization are shown in Appendix C.

3.1.2.1 Phosphate Ore, Coke, and Quartzite Stockpiles

Phosphate ore, which is mined nearby, is stockpiled in the northeast portion of the Plant along the railroad tracks. This pre-processing ore is stockpiled in two piles by blend. Blend 1 accounts for about 67% of the stockpiled material, whereas Blend 2, which is a lower grade of ore, accounts for the remainder. The two stockpiles cover an area of approximately 1,200 feet by 600 feet and are about 40-feet high; they contain a mass of approximately 500,000 tons.

Coke and quartzite are stockpiled in the eastern portion of the Plant, south of the phosphate ore stockpiles. Currently, there are approximately 22,000 tons of coke and 150,000 tons of quartzite stockpiled.

The phosphate ore is a coarse-to-fine sand with some silt and some gravel (Table 3-2). The USCS class is SM. The coke is predominantly fine gravel with some sand. The USCS class varies between GW and GP. The quartzite is coarse-to-fine gravel and the USCS class is GP.

3.1.2.2 Nodule Fines Piles

The nodule fines resulting from the nodulizing of the phosphate ore in the kiln are piled at the northeast corner of the Plant, just south of the phosphate ore stockpiles. These materials are recycled in the kiln with the phosphate ore during the beneficiation process.

The nodule fines are coarse-to-fine sand.

3.1.2.3 Calcium Silicate Slag Piles

This slag consists primarily of calcium silicate and constitutes the greatest quantity of waste material produced and stored by the Plant. An estimated 23 million tons of slag are stockpiled at the Plant. The slag is poured as a molten material and cools as a solid mass; therefore, particle-size distribution of the slag (Table 3-2) is an artifact of the sampling procedure, as samples for physical and chemical testing were collected by breaking pieces from a solid mass or collecting pieces that were crushed on site.

Prior to 1990, slag was sold as a by-product of the production of elemental phosphorus. In the past its uses have been primarily for road construction, railroad ballast, and fill material. Monsanto voluntarily stopped selling the slag due to recent concerns raised by EPA regarding its natural radiation content.

3.1.2.4 Ferrophosphorus Slag Piles

In addition to elemental phosphorus gas and calcium silicate slag, a smaller quantity of material, known as ferrophosphorus slag , is generated in the furnace as a result of the naturally occurring iron and other metals in the ore. The ferrophosphorus slag is cooled in pots. It is sold as a by-product to Kerr-McGee for vanadium extraction and is transported to that facility after production and sizing.

3.1.2.5 Dusts

The various dusts that are generated during the beneficiation and processing of the ore are described below.

Baghouse Dust

Baghouse dust is a generic name given to dust collected by the many air pollution control units associated with the process. This dust primarily consists of small-size fractions of phosphate ore, nodules, coke and quartzite. It has been stockpiled at the northern boundary of the Plant. Baghouse dust is generally coarse-to-fine sand and silt, or silt with some fine sand (SM or ML), although one sample included gravel.

Treater Dust

Treater dust is the fine-grained material separated by the electrostatic precipitators as the phosphorus gas is condensed into a liquid. The dust is augured into a chamber where the residual phosphorus is oxidized (Geddes, R.L., Monsanto [Memo to D. Banton, Golder] March 23, 1992). This material is subsequently stockpiled in the north-central portion of the facility. Approximately 51,000 tons of treater dust is stockpiled on-site and then sold and transported to N. A. Degerstrom, Inc., where a process was in development to use this by-product as a raw material source for gallium and silver extraction (see subsection 3.1.3.5). The dust is coarse-to-fine sand and silt with a USCS class of SM.

3.1.2.6 Underflow Solids

The rotary-kiln exhaust gas contains considerable fine-grained matter. This particulate is removed by a spray tower scrubber followed by high-energy venturi scrubbers, resulting in a wet slurry. The slurry is settled and dewatered in the hydroclarifier, resulting in underflow solids. The underflow solids are returned to the manufacturing process to recover the residual phosphorus values (approximately 20% of the feed to the process is composed of underflow solids) (Monsanto 1991). This material is stockpiled at the northern portion of the Plant prior to recycling. Samples collected from the underflow solids piles are clayey silt with some coarse-to-fine sand (USCS class ML).

3.1.2.7 Underflow Solids Ponds

Prior to 1983, the dewatering of the kiln off-gas slurry took place in the two old underflow solids ponds. These ponds were located in the northwestern portion of the Plant. These ponds were taken out of service in 1983, and the solids were reclaimed and recycled. The ponds were filled with molten slag, sealed with a bentonite cap, and covered with crushed slag in 1988. Approximately 35,000 tons of underflow solids (low-grade phosphate ore) were estimated to remain in the ponds when they were capped (Monsanto 1989).

Five sealed ponds were constructed from 1975 to 1977 in the north-central portion of the Plant to facilitate the dewatering of underflow solids. However, operating problems at these ponds necessitated the occasional use of the old underflow solids ponds until 1983, when the

ponds were taken out of service (Geddes, R.L., Monsanto [Memo to D. Banton, Golder] March 23, 1992).

A filter press was constructed at the Plant in 1985 to mechanically dewater underflow solids, thereby eliminating routine use of the five sealed ponds. At present the ponds are used only when the filter press is inactive due to mechanical failure or maintenance.

The northwest pond, located northwest of and adjacent to the two old underflow solids ponds, was created between 1956 and 1964 (EPA 1990). This pond was constructed as a back-up to the old underflow solids ponds; however, it was never used for that purpose. Process water was stored in the northwest pond at times when the hydroclarifier was taken out of service for maintenance. The northwest pond remained semi-active until 1983. The contaminated soils were excavated in 1988 and placed in the old underflow solids ponds prior to their closure. The northwest pond was sealed with a bentonite cap and permitted by the IDHW as a solid-waste sanitary landfill in 1988, and currently accepts solid wastes from the Plant (Geddes, R.L., Monsanto [Memo to D. Banton, Golder] March 23, 1992).

3.1.2.8 Phossy-Water Surge Pond and Seal Water Pond

The furnace spray tower, storage, and rail-car displacement waters which directly contact the phosphorus are known as phossy water. Phossy water is sent to the hydroclarifier for lime treatment to remove any residual elemental phosphorus prior to being recycled. A bentonite-lined pond, located in the north-central part of the Plant, is used for surge capacity and for storage at times when the capacity of the hydroclarifier is exceeded.

The furnaces have a separate water system which provides a seal between furnace gases and the atmosphere. This seal water is cooled in the bentonite-lined seal water pond prior to being recycled.

3.1.2.9 Hydroclarifier

The hydroclarifier accepts the kiln dust off-gas scrubber slurry, phossy water, and treated scrubber blowdown for lime treatment and settling (see Paragraphs 3.1.2.6 and 3.1.2.8 above). The hydroclarifier previously in use at the Plant was an open-topped steel tank. An interpretation of 1976 aerial photographic records noted evidence of surface staining (EPA 1990) near the hydroclarifier.

Hydrogeologic investigations in 1984 (Golder 1985) indicated that the hydroclarifier was leaking, and it was replaced by a new hydroclarifier with a liner and leachate collection system in 1985. This hydroclarifier is currently is excluded from RCRA regulations and permitting due to its ore beneficiation function (40 CFR 261.4).

3.1.2.10 Coke and Quartzite Dust Slurry Pond

Coke and quartzite dust was originally collected by a wet scrubber system associated with the coke and quartzite dryer. This wet slurry was directed to a dewatering pond located along the western edge of the Plant. This pond was taken out of service in 1987 when a new coke

and quartzite dryer was completed and operational. The new dryer is complimented with a dry scrubber/baghouse system, thus eliminating the need for the slurry dewatering pond. Coke and quartzite dust currently collected from pollution control equipment at the dryer is stockpiled at the northern boundary of the Plant (see Subsection 3.1.2.5). The dewatering pond sediments are fine sand and silt or clayey silt with a USCS class of SM or CL.

3.1.2.11 Water Supply and Non-Contact Cooling Water Effluent

The drinking water supply for the Plant was provided by production well PW-3 until 1989. In response to a concern regarding the potential for elevated cadmium concentrations, use of PW-3 for drinking water purposes was discontinued and a new well (PW-4) was installed hydraulically upgradient at the northern edge of the Plant. This new well and dedicated distribution system provides drinking water to approximately 350 individuals working at the Plant.

The Plant currently uses groundwater from on-site production wells PW-1, PW-2, and PW-3 for non-contact cooling purposes and for process water. Following use, the cooling water passes through an effluent settling pond (located in the southwest corner of the Plant) for particulate removal and is subsequently discharged, via a subsurface pipeline, to Soda Creek under an NPDES permit issued pursuant to the Clean Water Act. The rate of discharge ranges from about 600 to 1,200 gpm, or 1.3 to 2.7 cubic feet per second (cfs). An irrigation canal diversion is located approximately 100 feet downstream of the point of effluent discharge into Soda Creek.

3.1.3 Other Facilities in the Monsanto Plant Vicinity

There are several other significant facilities in the vicinity of the Monsanto Plant, where materials are generated or disposed of, that have the potential to affect the immediate environment. These facilities include:

1) Kerr-McGee Chemical Corporation vanadium pentoxide plant;
2) Evergreen Resources fertilizer plant;
3) Soda Springs Phosphate Industries fertilizer plant;
4) Nu-West Industries phosphoric acid production and fertilizer plant; and
5) N. A. Degerstrom gallium and silver extraction plant.

In addition to these facilities, which are described below, nearby transportation corridors and agricultural activities serve as potential sources that may affect the environment.

3.1.3.1 Kerr-McGee Chemical Corporation

Kerr-McGee operates a vanadium pentoxide production plant located directly across State Highway 34 from the Monsanto Plant. Wastewater generated by the plant is discharged into surface impoundments on-site. Releases to the shallow groundwater system from the impoundments have been documented by Montgomery and Dames and Moore (1991).

3.1.3.2 Nu-West Industries

Nu-West Industries is located approximately four miles to the north of the Monsanto Plant. The facility produces phosphoric acid and fertilizer products. The major waste product at this facility is phospo-gypsum. The products from this industry include di-ammonium and mono-ammonium phosphate fertilizer, phosphoric acid, and super-phosphoric acid.

3.1.3.3 N.A. Degerstrom

N. A. Degerstrom is located approximately two miles north of the Monsanto Plant. The operation at this facility shut down as of March, 1992. The facility was previously developing a process to use a by-product from phosphorus production as a raw material source for gallium and silver extraction. A solvent extraction process was used for gallium, and a cyanide leach process was used to recover silver. Some by-products were sold locally as a feedstock for phosphate fertilizer.

3.1.3.4 Other Industries

Evergreen Resources is located about 1,000 to 2,000 feet southeast of the Monsanto Plant. The facility produces fertilizer products. Soda Springs Phosphate Industries is located adjacent to Evergreen Resources and also produces fertilizer products.

3.2 Meteorological Characteristics

The meteorological characteristics are summarized below. There were no new meteorological data collected during the Phase I RI, therefore existing data were used to determine meteorological characteristics at both the regional and local levels.

3.2.1 Regional Meteorology

Regional meteorology includes data from southern Idaho which were used to evaluate general, wide-ranging trends in meteorology.

Although the on-site meteorological station on the Monsanto property was installed in late-1987, substantial portions of the data record have been irretrievably lost due to data recording and storage problems with the recording and display system. There were insufficient data to compute annual average statistics for the station in 1988 and 1989. The 1990 data records (used in dispersion modeling), as well as the 1991 data, were essentially complete.

Temperature, wind speed, and wind direction at the 33-foot level were used to define the average annual, site-specific meteorological dispersion conditions. A review of the QA/QC program for the Monsanto station meteorological data is presented in Appendix D. Mean

morning and afternoon mixing heights for 1990 were obtained from the National Climate Center for Boise, Idaho, for use in dispersion modeling.

3.2.2 Local Meteorology

Local meteorology includes data from the Monsanto meteorological station which were used to determine Plant-specific trends in meteorology.

3.2.2.1 Surface Winds

Figure 3-1 depicts the annual average wind speed and frequency of occurrence by direction for winds recorded at the 33-foot level in 1990 at the Monsanto station. The most frequent winds recorded were from the north-northeast (13.36%) and south-southwest (11.44%). In general, the airflow at the facility is centered along north-northeast to south-southwest axis, with very infrequent winds recorded from the west through northwest and east-northeast through east-southeast.

Table 3-3 lists the average monthly wind speed for all directions. There was little variation in the mean monthly wind speeds during most months of 1990. The month with the lowest average wind speed was September, with 2.5 meters/second (m/s), while the highest average monthly wind speed was recorded in July at 3.9 m/s. The average annual wind speed for all directions was 3.5 m/s, while the highest average annual wind speeds were recorded for southeast winds at 7.2 m/s (Figure 3-1).

A multi-year comparison of the wind regime at Soda Springs was not possible due to the spotty data record for 1988 and 1989. Comparison of 1990 data with 1991 data shows that the average annual wind speed of 3.3 m/s in 1991 was almost identical with the average annual wind speed of 3.5 m/s in 1990. On a seasonal basis, there were some significant differences in wind direction frequencies between 1990 and 1991 (Tables 3-4 and 3-5), particularly in the months of October to December. There was a higher frequency of winds from the north and north-northeast (14.9% and 17.1%, respectively) in 1991 than in 1990 (8.8% and 10.2%), and a correspondingly lower frequency of winds from the south and south-southwest (10.4% and 9.1%) in 1991 compared with 1990 (12.8% and 16.0%). However, the average annual frequency distributions were similar in 1990 and 1991.

In a comparison of 1990 wind data for Pocatello with average data for the six-year period of 1985 to 1990, it was determined that the 1990 data at Pocatello were fairly representative of long-term average conditions at that station (Appendix E). Therefore, from a climatological perspective, it has been assumed that the 1990 wind data at Soda Springs were also likely to be representative of long-term average conditions at Soda Springs as well.

3.2.2.2 Atmospheric Stability

Pasquill-Gifford stability categories for the Soda Springs meteorological data were determined using the Sigma-A method as defined in the EPA guidance for on-site meteorological data used in regulatory model applications (EPA 1990c). The Sigma-A method is a turbulence-

based method of defining atmospheric stabilities which uses the standard deviation for the horizontal wind direction fluctuations in conjunction with the scalar wind speed.

Table 3-6 lists the annual average frequency of occurrencé for the six stability classes at Soda Springs in 1990. For comparison, the frequency of occurrence of stability classes as determined using the Turner method by the National Weather Service for Pocatello are also listed both for 1990 as well as for a five-year period from 1986 to 1990.

Although the stability classes for the two sites were computed using different methods, the frequency distributions for the classes were very similar for the two sites in 1990. The Soda Springs data had a slightly higher frequency of A stability compared with Pocatello, but the combined frequencies for the unstable classes (A, B, and C) were similar — 19% at Soda Springs and 21% at Pocatello. Soda Springs had a slightly higher frequency of neutral stability (56.7%) compared with Pocatello (49%), and a correspondingly lower frequency of stable classes (E and F), amounting to about a 5% difference in occurrence frequency.

Table 3-6 also lists the five-year average frequency of occurrence of stability classes at Pocatello. The 1990 data are almost identical to the five-year average. On this basis, it is concluded that the data for 1990 at Pocatello were fairly representative of long-term average conditions. By extension, it may be assumed that the 1990 data at Soda Springs were fairly representative of long-term average conditions at that site, as well.

3.2.2.3 Temperature

Table 3-7 lists the mean daily minimum, maximum, and mean temperatures for each month in 1990 at Soda Springs. The lowest mean daily temperature recorded in 1990 was -33.9°C in December. The highest maximum daily temperature was 31.7°C in August. Mean daily temperatures ranged from a low of -10.9°C in December to a high of 18.9°C in July. There were insufficient data to evaluate the representativeness of this data with respect to climatic normals for the region, and comparisons with Pocatello are not useful due to the large difference in elevation between Soda Springs and Pocatello.

3.2.2.4 Mixing Heights

Table 3-8 lists the mean monthly mixing heights at Boise, Idaho, for 1990. For comparison, Table 3-9 lists the mean seasonal mixing heights for the period from 1960 to 1964 as determined by Holzworth (1972). The data show that the mixing heights during 1990 were quite representative of average mixing heights for Boise.

Mean monthly morning mixing heights ranged from as low as 109 m in September, up to 521 m in February. The low mixing heights in September, in conjunction with the low mean monthly wind speeds recorded during this month (i.e., 2.5 m/s), are probably indicative of early morning stagnant inversion conditions in late-summer and early-fall.

The lowest maximum afternoon mixing heights were recorded in December at 604 m, while the highest afternoon mixing heights occurred in July at 3,289 m. The average annual afternoon mixing height was 1,862 m.

3.3 Surface Hydrological Characteristics

This section provides a characterization of surface-water hydrology, regionally within the Bear River Basin and locally in the vicinity of the Monsanto Plant. Water-quality characteristics and the known nature and extent of surface-water quality associated with the Monsanto Plant are presented in Section 4.3 (Surface-Water and Sediment Quality).

Within the vicinity of the Monsanto Plant, surface water occurs in one major river, three reservoirs, three streams, several natural ponds, wetlands, and several man-made ponds and ditches. The characteristics of the numerous springs in the area will be discussed in Section 3.6 (Hydrogeological Characteristics). Figure 3-2 provides the locations of gaging stations on various surface-water bodies. Gaging station data were collected by individual districts of the USGS (EarthInfo 1990). Physical aspects of these surface-water bodies are discussed below.

3.3.1 Regional Surface Hydrology

The regional surface waters include the Bear River, Alexander and Blackfoot Reservoirs, and associated tributaries. These surface-water features (excluding Blackfoot Reservoir, which is 12 miles north of the Plant) are presented in Figure 1-2.

3.3.1.1 Bear River

The major river in the vicinity of the Monsanto Plant is the Bear River, which flows from its source in the Uinta Mountains of Utah, crosses through Wyoming into Idaho, flows northwestward from Bear Lake past Soda Springs to Alexander, where it turns southward to the Great Salt Lake in Utah.

Yearly average flow rates for the Bear River, over a 36-year period from 1954 to 1989, range from approximately 390 to 1,900 cfs (Figure 3-3) (EarthInfo 1990). Monthly averages for the same time period range from approximately 510 to 1,340 cfs (Figure 3-4). These measurements were collected at a gaging station approximately four miles south-southeast of the Monsanto Plant (Figure 3-2).

3.3.1.2 Reservoirs

The Bear River flows to the northwest, towards the City of Soda Springs, into Alexander Reservoir. Yearly average storage capacities for Alexander Reservoir, immediately west of the City of Soda Springs, for 1986 and 1988 are 12,410 and 12,607 acre-feet, respectively (EarthInfo 1990). Monthly average storage capacities for the same years range from approximately 11,180 to 13,220 acre-feet (Figure 3-5). The reservoir is used primarily to generate hydroelectric power (Dion 1974). Water storage data for Alexander Reservoir were obtained from a station located just upstream of the spillway, approximately one mile from the town of Alexander.

Blackfoot Reservoir is located approximately 13 miles north of the City of Soda Springs and 12 miles north of the Monsanto Plant. The reservoir is filled by water from the Blackfoot River, which rises in the mountain ranges near the Idaho-Wyoming border and flows northwestward to the Snake River. Water from the Blackfoot Reservoir, which is situated in the Snake River drainage basin, is assumed to be leaking into the Bear River Basin via fractured basalt flows (Dion 1974). According to the study conducted by Dion, the amount of leakage from Blackfoot Reservoir is about 10 cfs.

3.3.2 Local Surface Hydrology

Three streams (Soda Creek, Ledger Creek, and Big Spring Creek), one reservoir (Soda Creek Reservoir), several natural ponds, wetlands, and several man-made ponds and ditches are located in the local vicinity of the Monsanto Plant (see Figure 1-2).

3.3.2.1 Streams

Soda Creek is a tributary to the Bear River and forms the main surface-water drainage feature of the valley in which the Monsanto Plant is located. Soda Creek rises near Fivemile Meadows, flows southward into a small reservoir (Soda Creek Reservoir) about one mile west of the Monsanto Plant, then continues flowing southward into Alexander Reservoir at a point immediately west of the City of Soda Springs. At its closest, Soda Creek passes within 2,000 feet of the Monsanto Plant.

Soda Creek is used for power generation (in collaboration with Soda Creek Reservoir), irrigation, and livestock watering. Three powerhouses are located on Soda Creek approximately 5,000 feet, 10,000 feet, and 11,000 feet, respectively, below the spillway of Soda Creek Reservoir. Two irrigation diversion points are located on Soda Creek. The first diversion dam is located approximately 100 feet downstream of the point where Monsanto's effluent discharges into Soda Creek. This dam diverts Soda Creek's water into an irrigation canal for approximately six months out of every year. Most of the water is channeled back into the lower reaches of Soda Creek via the second and third powerhouses mentioned above. The second diversion point is located approximately 2,000 feet below the third powerhouse and diverts some of Soda Creek's water into the Soda Canal irrigation system. The remainder water continues to flow southwest into Alexander Reservoir.

The particle-size distribution of sediment samples collected along Soda Creek (Figure 2-2) are shown in Table 3-10. The samples show variable particle sizes depending on sample location.

Yearly average flow rates for Soda Creek, collected from a gaging station at Fivemile Meadows (approximately three miles northwest of the Monsanto Plant) range from approximately 6 to 35 cfs for the years 1965 to 1986 (Figure 3-6). Monthly averages for the same time period range from approximately 11 to 28 cfs (Figure 3-7).

Ledger Creek originates from several springs located less than one mile southeast of the Monsanto Plant. Ledger Creek flows south, to the east of the City of Soda Springs into Bear River.

Big Spring Creek, located immediately south of the City of Soda Springs, joins Bear River prior to entering Alexander Reservoir. Big Spring Creek is used for fish production.

Little Spring Creek, to the south of the Plant, is a slight, man-made drainage depression for a former irrigation diversion from Soda Creek, but no longer contains surface water.

3.3.2.2 Soda Creek Reservoir

The primary purpose of Soda Creek Reservoir is to accumulate water for irrigation. In the process, a supply of water is maintained to supply power to the City of Soda Springs. The small power plants are located on Soda Creek downstream of the spillway. The elevation of Soda Creek Reservoir spillway is 5,959 feet (Geddes, R.L., Monsanto [Memo to R.F. Kossik, Golder] February 4, 1992). The approximate capacity of the reservoir is 2,500 acre-feet. A weir (the South Weir) is located at the spillway.

3.3.2.3 Natural Ponds

Formation Spring surfaces at the base of the hills to the east of the Plant, forming surface water in the area known as Formation Cave. About eight ponds are situated in the vicinity of Formation Cave, located a little more that one mile east of the Monsanto Plant. These ponds have only one surface water outlet with pond water eventually infiltrating into the ground. Travertine deposits are common features surrounding these ponds.

There are several small ponds that are fed by Finch, Boy Scout, and Spring Box springs near Kelly Park. There is one pond situated on an upthrown basalt block north of Ledger Creek.

3.3.2.4 Wetlands

Immediately northwest and immediately southwest of the Monsanto Plant are two wetland areas. The area to the northwest covers approximately 1 acre and contains surface water only during wet periods of the year, usually as a result of snowmelt. This area of standing water has, in the past, spread southeastward extending onto the Monsanto Plant property. The area to the southwest is much larger, covering approximately 16 acres, and is marshy the year around. This marshy area is the source of Southwest Spring (Figure 1-2).

3.3.2.5 Man-Made Ponds and Ditches

There are several man-made ponds and one ditch at the Monsanto Plant. The ponds at the Plant consist of the seal-water pond, the phossy-water surge pond, five underflow solids ponds, the effluent-settling pond, and two sewage evaporation ponds (Figure 1-3).

The seal water pond is bentonite-lined and contains water used in the furnaces as a seal between furnace gases (phosphorus). The water is cooled in the seal water pond prior to being recycled. The phossy water surge pond is also bentonite-lined and is part of the recycle loop for water that has been in contact with phosphorus. These waters, from a number of different sources (see Paragraph 3.1.2.8 [Phossy-Water Surge Pond and Seal Water Pond]), are recycled from the process water/hydroclarifier/phossy water pond system.

The Plant uses groundwater from on-site production wells PW-1, PW-2, and PW-3 for non-contact cooling purposes and for process water. Following use, the non-contact cooling water passes through the effluent settling pond for particulate removal prior to being discharged, under an NPDES permit, via an effluent ditch and a subsurface pipeline, to Soda Creek. The effluent ditch is located in the southwest corner of the Plant.

The sewage evaporation ponds are located in the southwest corner of the plant. These ponds are lined, but are designed for minor leakage.

3.4 Geological Characteristics

This section provides a description of the regional and local geological characteristics of the Monsanto Plant vicinity. Pertinent geologic information presented includes geomorphology, stratigraphy, lithology, and structure of the bedrock units. Descriptions of the physical characteristics of the site soils and hydrogeology can be found in Section 3.5 (Pedological Characteristics) and Section 3.6 (Hydrogeological Characteristics).

3.4.1 Geomorphology

The Monsanto Plant is located near the southern end of the Blackfoot Lava Field in southeastern Idaho. The geomorphology and physiography of the area is typical of the Basin and Range province where normal faulting and subsequent erosional processes have created the majority of the geomorphic features seen today. Extrusion of the lava flows that have filled the valley floor and subsequent intrusion of rhyolite domes have also been important processes in shaping the present land surface.

The Blackfoot Lava Field occupies a generally north-northwest trending valley that is approximately three to six miles wide in the Plant area. This valley is bordered by rugged mountains of the Chesterfield Range and Soda Springs Hills on the west, and by the Aspen Range on the east. The broad valley floor is at an elevation of approximately 6,150 feet adjacent to the Aspen Range; it slopes gradually to the southwest at approximately 100 feet per mile to join the Bear River valley at about elevation 5,800 feet. Elevations of the surrounding ranges vary from over 6,800 feet in the west to over 7,500 feet in the east.

The typically low relief of the Blackfoot Lava Field valley floor is interrupted by isolated topographic highs created by cinder cones, rhyolite domes, and upthrown horst blocks. China Hat, a rhyolite dome which is located approximately 8 miles north of the Plant, is the most prominent topographic feature in the valley, and has a summit elevation of 7,164 feet. Threemile Knoll, an upthrown horst block of older sedimentary rocks which is located adjacent to the northeast corner of the Plant, has a summit elevation of 6,475 feet. North-to-northwest-trending linear escarpments that have between 20 and 70 feet of near vertical relief are present in the Plant area. These escarpments are Quaternary normal faults that have ruptured the surface of the Blackfoot Lava Field.

3.4.2 Regional Geology

A summary of the regional geology is presented below and includes a discussion of the stratigraphy (Paragraph 3.4.2.1) and structure (Paragraph 3.4.2.2). The local geology and structure of the Monsanto Plant area is discussed in Subsection 3.4.3.

3.4.2.1 Regional Stratigraphy

A regional geologic map is provided in Figure 3-8. A regional geologic cross-section is provided in Figure 3-9.

The Monsanto Plant is located near the southern end of the Blackfoot Lava Field which has infilled a structural and topographic valley that is bounded on the east and west by upthrown fault blocks of older deformed sedimentary rocks (Armstrong 1969 and Oriel and Platt 1980). The oldest rocks in the area are Cambrian to Mississipian sedimentary rocks which are exposed in the mountains of the Chesterfield Range and Soda Springs Hills on the west side of the valley. These rocks include the Ute Limestone, Blacksmith Limestone, Bloomington Formation, Nounan Limestone, St. Charles Formation, Garden City Limestone, Swan Peak Quartzite, Fish Haven Dolomite, Laketown Dolomite, Jefferson Dolomite, Lodgepole Limestone, and Chesterfield Range Group. Lithologically, these rock units are primarily limestone, dolomite, shale, sandstone, and quartzite (Armstrong 1969 and Oriel and Platt 1980). A generalized stratigraphic column for the area is shown in Table 3-11.

The mountains of the Aspen Range on the east side of the valley expose Mississipian to Tertiary, primarily sedimentary rocks, which include the Chesterfield Range Group, Wells Formation, Phosphoria Formation, and Dinwoody Formation. These rock units are primarily limestone, sandstone, and shale. A few Tertiary olivine basalt dikes intrude these sedimentary rocks (Armstrong 1969 and Oriel and Platt 1980). The Phosphoria Formation contains phosphate-bearing beds that produce the ore which is being processed at the Monsanto Plant.

The Triassic Thaynes Limestone is exposed within the valley in Threemile Knoll, an upthrown horst block which is located adjacent to the northeast corner of the site (Figure 3-8). The valley is partly filled by the Pliocene Salt Lake Formation, which also is locally exposed in the adjacent ranges and forms Rabbit Mountain south of the site area. The Salt Lake Formation is composed of sandstone, conglomerate, and limestone, all of which may be tuffaceous (Armstrong 1969).

The youngest, most widespread rocks in the valley are Quaternary olivine basalt flows of the Blackfoot Lava Field, which unconformably overlie the Salt Lake Formation (Armstrong 1969) (Figures 3-8 and 3-9). Well logs indicate that the basalts are at least several hundred feet thick in the center of the field, but thin toward the edges where they lap onto older strata. Armstrong (1969) and Mabey and Oriel (1970) indicate that the basalts may locally be as much as 1,000 feet thick. The Blackfoot Lava Field contains eruptive vents marked by scoriaceous basalt cones, as well as rhyolite domes such as at China Hat (Oriel and Platt 1980).

Holocene spring deposits composed of tufa and travertine overlie parts of the Blackfoot Lava Field (Armstrong 1969) (Figure 3-8). These deposits are well developed at springs along the eastern and western margins of the valley adjacent to the bounding normal faults (Armstrong 1969). The spring deposits are also locally present within the valley, such as Three Mile Knoll, Ledger Creek Springs, and Rabbit Mountain. Other localized Holocene deposits include alluvial fan deposits adjacent to the ranges, alluvium in creeks and drainages (Armstrong 1969), and a thin surficial overburden layer composed of windblown loess and the weathering products derived from older rock units.

3.4.2.2 Regional Structure

The Monsanto Plant is situated in the transition zone between two geologic provinces which each have a distinctive structural geology (Oriel and Platt 1980 and Dixon 1969). To the east lies the overthrust belt which is part of the Cordilleran Rocky Mountain system in western Wyoming, southeastern Idaho, and northern Utah. The overthrust belt is characterized by folds that are overturned to the east and gently west-dipping thrust faults (Dixon 1969). To the west lies the Basin and Range province, which extends to Oregon and eastern California. The Basin and Range Province is characterized by generally north striking, high-angle, normal faults which have produced major upthrown (horst) ranges and adjacent downthrown (graben) valleys. The overthrust belt of the Rocky Mountain system formed during the Cretaceous age Laramide orogeny, whereas the Basin and Range province began forming in the late-Tertiary period. Deformation in the Basin and Range province continues today, as indicated by the seismicity of the region (Smith and Sbar 1974).

The Monsanto Plant is located within the Bear River Valley graben, which is bordered on the west by the Soda Springs Hills horst and on the east by the Aspen Range horst (Armstrong 1969) (Figures 3-8 and 3-9). A series of north-northwest-trending normal faults extend from southeast of the Plant site northward to the Blackfoot Reservoir (Armstrong 1969, Oriel and Platt 1980). These normal faults exhibit both west side down and east-side-down displacements.

The Plant is underlain by an extension of the Paris Thrust fault. This fault was apparently active during formation of the overthrust belt and it does not displace the Pliocene Salt Lake Formation or the Quaternary Blackfoot Lava Field basalts (Armstrong 1969) (Figures 3-8 and 3-9).

3.4.3 Local Geology

The description of the geology of the Monsanto Plant presented below is based on the initial studies reported in Golder (1985), and the geologic investigations completed in accordance with the Phase I RI/FS work plan (Golder 1991).

3.4.3.1 Local Stratigraphy

The stratigraphy of the Monsanto Plant has been investigated by field reconnaissance mapping, a review of well logs, a drilling program for well installation, and a borehole

geophysical logging program (Golder 1985). The results of this investigation program indicate that a thin veneer of overburden soils overlies basalt flows of the Blackfoot Lava Field at the Plant.

The overburden materials consist primarily of between 3 to 20 feet of silty clay. In places within the Plant, this silty clay is mantled by a veneer of gravel fill or slag. The greatest thickness of fill (24 to 27 feet) was identified in the barrel storage area (wells TW-25, TW-26, and TW-27). In the northeast Plant area, well TW-13 encountered 42 feet of overburden soils varying in composition from silty clay to sandy gravel. Sands and gravels within the overburden soils were also observed in well TW-31 along the eastern margin of the Plant.

Based on the drilling and borehole geophysical logging results (Golder 1985), five basalt flows are present beneath the site. These flows have been designated Flow I, II, III, IV and V in ascending order, and are delineated on the basis of changes in lithology or abrupt changes in the natural gamma log response (Golder 1985). The basalt flows vary in thickness from less than 10 feet to 80 feet, and each successive flow is separated by sedimentary interbeds or weathered basalt zones from 1-to-23-feet thick. Based on these stratigraphic correlations, the basalt flows generally strike approximately north 60° west and dip at 2 degrees or less to the southwest.

The drilling program indicated that most of the basalt sequence is vesicular and that vesicles are occasionally infilled with zeolites. Although the basalt flows are generally fresh and show little evidence of weathering, some thin (less than 15-feet thick), red-stained, weathered basalt zones are present within the sequence. In some of these zones, the basalt is nearly completely weathered, with only fragments of basalt remaining in a silty-sand- and gravel-sized matrix.

The basalt flows are separated by sedimentary interbeds composed of scoriaceous cinders, silty clay, clayey silt, or sand and gravel. These sedimentary interbeds vary in thickness from less than 1 to 23 feet. The cinder zones are composed of unconsolidated sub-angular gravel- to cobble-size clasts, ranging from less than 0.5 inch to greater than 6 inches in diameter. The cinders are red/brown to gray and contain numerous vesicles, which are occasionally infilled with zeolites. Clays and silty clays are occasionally present in the cinder zones, but are more usually found as discrete strata. The clays are generally red/brown and sometimes gray.

Data from wells TW-1 and TW-2 indicate that the basalt thins towards the northeast where it laps onto Threemile Knoll. Test well TW-2 encountered 224 feet of basalt and cinders overlying "a white and yellow formation," inferred to represent the Salt Lake Formation. Well TW-1 encountered 45 feet of basalt and cinders overlying 255 feet of sandstone, shale and clay (Golder 1985). Well TW-13 encountered a light brown, fairly well indurated silty conglomerate at a depth of 73 feet bgs which was interpreted to be part of the Salt Lake Formation.

The field reconnaissance mapping indicated that the Blackfoot Lava Field basalts in the site area are typically fine-grained and vesicular, with well-developed columnar joints. The vertical columnar joints are typically spaced 2 to 10 feet apart, with 0.5-inch to 1-inch wide apertures. Basalt exposures north of the Plant displayed horizontal joints that were spaced

9 to 12 inches apart, with 0.5-inch to 1-inch wide apertures. Some of the horizontal joints were continuous for hundreds of feet (Golder 1985). A composite description of the surface basalt flow exposures in the site area, which follows the Brown (1981) rock description method, is as follows:

> Fresh to slightly weathered, vesicular (vesicles 1 to 20 millimeters (mm) some infilled with calcium carbonate) to columnar-jointed (columns 2 to 10 feet across), medium dark gray (N4), microcrystalline to very-fine-crystalline groundmass with very-coarse-crystalline plagioclase phenocrysts (to 6 mm), and coarse-crystalline olivine phenocrysts, strong to very strong, olivine BASALT (Blackfoot Lava).

Rock-color identifications are obtained from the chart prepared by the Rock-Color Chart Committee (1984).

The nature of the basalt/travertine contact was visible at two localities. In the east cliff of the Ledger Creek Springs valley, calcium carbonate has been deposited in the basalt joints and fractures near the base of the cliff. At the easternmost mapped fault (Paragraph 3.4.3.2), excellent exposures show that the travertine overlies the basalt, and has been displaced by the fault. Open solution cavities in the travertine up to 2 feet in diameter are present at the basalt/travertine contact. Further north from this fault, low outcrops of basalt and travertine consistently show that the travertine overlies the basalt, and is therefore younger. A composite description of the travertine deposits in the site area is as follows:

> Slightly weathered, oolitic to vuggy to banded with some solution cavities, yellowish gray (5 Y 8/1 to 5 Y 7/2), coarsely crystalline, weak to strong, TUFA and TRAVERTINE (spring deposits).

3.4.3.2 Local Structure

The literature review, aerial photograph interpretation, and field reconnaissance mapping indicate that a discontinuous zone of normal faults is present in the site area. The zone consists of north trending, en-echelon normal fault scarps that extend from southeast of the site northward, towards the west side of Blackfoot Reservoir. These normal fault scarps display both west and east-side-down relative displacement, and commonly form narrow grabens that are 1,000 to 1,500 feet wide and up to 2.5 to 3 miles long; several of the grabens contain ponded water. Individual faults within the site area are shown in Figure 3-10 and are discussed below. A local structure block diagram is shown in Figure 3-11.

A prominent northwest trending, southwest-facing fault scarp enters the Plant near the northwest corner and appears to die out just west of the southeast corner of the site (Figures 3-8 and 3-10). This fault scarp strikes approximately north 29° west and decreases in height from 40 feet in the northwest Plant area to about 20 feet at the south end. The scarp slope angle was measured between 15 and 17 degrees. Most of the scarp within the central portion of the Plant is obscured by slag piles and fill.

Three geologic cross-sections were developed for this investigation from the drilling and borehole geophysical data collected in earlier investigations (Golder 1985, 1987, 1988a and

1988b). The locations of the cross-sections are shown in Figure 3-12. Cross-section A-A' (Figure 3-13A) indicates that this fault has between 20 and 80 feet of vertical separation (west-side down) on the site. This fault displacement has offset permeable cinder zones and weathered basalt horizons against less permeable, unweathered basalt flow interiors. A northwest-southeast cross-sectional view (B-B') of the area east of this fault is shown in Figure 3-13B). A subsidiary fault located approximately 1,500 feet to the southwest of the main Plant fault was inferred to have approximately 5 feet of vertical separation (west-side down) based on the stratigraphic correlations developed from the borehole data (Golder 1985). This subsidiary fault was also inferred to die out near the southern boundary of the Plant (Figures 3-10 and 3-11). A cross-sectional view of the area between the main fault and the subsidiary fault is shown in Figure 3-13C (Cross-section C-C')

Just east of the main Monsanto Plant entrance is a prominent fault scarp that trends north 50° west to north 25° east and is about 1.65 miles long (Figures 3-10 and 3-11). Near the middle of this fault, Finch Spring emanates from the base of the footwall cliff, so this feature is herein called the Finch Spring fault. The Finch Spring fault has a measured minimum vertical separation of 20 to 70 feet with the west-side down. The surface displacement on this fault appears to diminish to the north, opposite the Plant. The prominent cliff escarpment exposes basalt colonnade and an upper flowtop; no evidence of multiple flows was found along the fault scarp.

At the north end of the Finch Spring fault, a subsidiary subparallel fault about 0.6 mile long has a vertical separation of about 10 feet (east-side down) and forms a small graben. Approximately 600 to 800 feet east of the northern part of the Finch Spring fault, is a north-20°-west-to-north-30°-east trending, 0.8-mile-long fault scarp that has a measured minimum vertical separation of 11 feet (west-side down). No evidence of this fault was found in the Finch Spring fault scarp where this fault appears to curve toward the Finch Spring fault. Along the northern projection of the 0.8-mile long fault is an 0.3-mile long lineament that in two places is an open fissure in the basalt. On the north side of the road to Formation Spring, the fissure has a horizontal separation of 2.5 feet.

Adjacent to the southern part of the Finch Spring fault, is the 0.6-mile-long Ledger Creek Springs graben (Figures 3-10 and 3-11). The graben is subparallel to the Finch Spring fault, is about 200 to 300 feet wide, and is bordered by prominent fault scarps that have an estimated 40 to 60 feet of vertical separation. The vertical separation appears to diminish to the north. As in the Finch Spring fault scarp, the fault scarps of the Ledger Creek Springs graben expose basalt colonnade and an upper flowtop; no evidence of multiple flows was found along the graben. Numerous springs, based on the location of the covered reservoirs, emanate from the base of the eastern fault scarp. The narrow horst block between the western side of the Ledger Creek Springs graben and the Finch Spring fault is characterized by numerous open tension cracks which have exploited the colonnade joints.

A small subsidiary fault with 10 feet of vertical separation down to the west is located about 400 feet east of the Ledger Creek Springs graben. About 800 feet north of the northern end of the Ledger Creek Springs graben, is a north 5° west trending, 0.2-mile-long fault scarp that has an estimated vertical separation of about 40 feet, down to the east. A spring (or springs) emanate from this scarp and provide water to the pond north of Ledger Creek Springs

graben. Two possible spring locations (marked by stands of dense vegetation) northeast of this pond were dry during the 1991 field investigation.

Approximately 0.7 miles northeast of the Ledger Creek Springs graben is a north-0°-to-10° east trending, 0.7-mile-long fault scarp that has a measured minimum vertical separation of 22 feet, down to the west (Figures 3-10 and 3-11). Basalt colonnade and an upper flowtop are exposed in this scarp, but no evidence of multiple flows was found. The northeast-trending topographic slope to the west of this fault appears to be a flow edge of the uppermost basalt flow. Armstrong (1969) considered this fault to be an extension of the eastern boundary fault of the Threemile Knoll horst, and showed displacement on this fault to be down to the east (Figures 3-10 and 3-11). The field evidence for west-side down displacement at the fault scarp is unequivocal, so if an extension of this fault also bounds the Threemile Knoll horst, the fault must change its sense of displacement to the north to be an east-side down normal fault.

An east-west trending lineament identified by EPA (1990b) east of the Monsanto Plant was investigated during the aerial photograph and field investigation program. No evidence could be found to suggest that this anomalous trend was due to geologic structure such as a contact, flow edge, flow feature, or faulting, and it appears that this lineament may be cultural in origin.

Based on the site geologic model developed from the results of the investigations presented above, several preliminary conclusions regarding the possible geologic controls on groundwater movement east of the Monsanto Plant have been developed:

1) Geologic controls on groundwater flow east of the Plant may include normal fault scarps, an open fissure, a basalt flow edge, and solution cavities in the travertine deposits at the contact with the underlying basalt.

2) Normal fault displacement has offset permeable cinder zones and weathered basalt horizons against less permeable unweathered basalt flow interiors which may interrupt lateral groundwater flow and create springs.

3) The groundwater surfacing at Ledger Creek Springs seems to be coming primarily from the area east of the Finch Spring fault, based on the locations of springs along the eastern fault of the Ledger Creek Springs graben.

4) The west-side-down displacement on the Finch Spring fault and the east-side-down displacement on the western fault of the Ledger Creek Springs graben may act as hydraulic barriers such that groundwater west of the Finch Spring fault may not flow into the Ledger Creek Springs area.

3.5 Pedological Characteristics

Regional and local pedological characteristics for the area around the Monsanto Plant are discussed below. The nature and extent of known constituents releases to the soil at and near the Monsanto Plant are presented in Section 4.4 (Soil Quality).

3.5.1 Regional Pedology

The soils of Caribou County, Idaho, are in the process of being mapped by the USDA-SCS. An advanced copy of the general soils map of Caribou County (Kukachka, B., SCS, [Personal communication], 26 November 1991) was used to identify major soil groups in the area surrounding the Monsanto Plant. Land owned by the USFS is not being mapped by the SCS at this time.

A portion of the Caribou County general soils map is shown in Figure 3-14. This map displays general patterns of soils with similar characteristics across the landscape. It is not meant to convey site-specific data. According to this map there are five major soils groups in the area around Soda Springs. These five soil groups are differentiated by topography, drainage, soil depth, and landscape position.

Soil Group 1

This unit contains soils that are nearly level, moderately-well-to-very-poorly drained, very deep, and found on floodplains and low stream terraces. Average annual precipitation ranges from 12 to 25 inches. Present uses include hayland, pastureland, and wildlife refuge. The principal limitations to use are flooding and high water table.

Soil Group 2

This unit contains soils that are gently sloping to steep, well drained, very deep and found on lake terraces and terrace breaks. Average annual precipitation ranges from 13 to 16 inches. Present uses include irrigated and non-irrigated cropland, hayland, and pastureland. The principal limitations to use include slope and a water erosion hazard.

Soil Group 3

This unit contains nearly-level-to-gently-rolling, well drained, moderately-deep to very-deep silty soils that are found on basalt plains and alluvial plains. Average annual precipitation ranges from 13 to 22 inches. Present uses include irrigated and non-irrigated cropland, hayland, pastureland, and rangeland. Limitations to use include water and wind erosion hazards and rock outcrops.

Soil Group 4

This unit contains soils that are nearly level to moderately steep, very deep, well drained, and found on fan terraces and hill slopes. Average annual precipitation ranges from 13 to 22 inches. Present uses include irrigated and non-irrigated cropland, hayland, pastureland, and rangeland. Limitations to use include water erosion hazard and steep slopes.

Soil Group 5

This unit contains soils that are strongly-sloping-to-very-steep, shallow-to-very-deep, well-drained soils on mountainsides and hillsides. Annual precipitation ranges from 12 to 28 inches. Present uses include non-irrigated cropland, rangeland, and woodland. Limitations to use include slope, water erosion hazard, areas of low permeability, and areas with thin soil overlying bedrock.

3.5.2 Local Pedology

To date, the SCS has not finalized the delineation of soils around the Monsanto Plant. Based on mapping to date, however, they have identified five soil types for the land adjoining the Plant. These soil types are: Lantonia-Crow Creek complex, 4-to-12-percent slopes (Map unit 485C); Rexburg-Ririe complex, 4-to-12-percent slopes (Map Unit 700A); Rexburg-Ririe complex, 4-to-8-percent slopes (Map Unit 700B); and Rin-Lantonia complex, 1-to-4-percent slopes (Map Unit 705A). Each of these soils is discussed below in Paragraph 3.5.2.1. Soils within the Plant are disturbed and cannot be correlated with soils that surround the Plant. Measured physical properties of soils collected around the Monsanto Plant are discussed in Paragraph 3.5.2.2.

3.5.2.1 Soil Types

The areal distribution of the five soil types identified on land adjacent to the Plant are shown in Figure 3-15. Many of the soils in the Caribou County soil survey area are not distinguishable at the scale of mapping; therefore, many of the map units are called complexes.

MAP UNIT 293A: DUMPS, MINES. Due to the disturbance of soils within the boundaries of the Plant, the entire facility was mapped as a disturbed site.

MAP UNIT 485C: LANTONIA-CROW CREEK COMPLEX, 4-to-12% SLOPES. This map unit is composed of Lantonia soil and similar inclusions (55%), Crow Creek soil and similar inclusions (30%), and contrasting inclusions (15%). It is found on loess covered basalt plains and basins. The Lantonia soil is found on north- and east-facing smooth and concave slopes and the Crow Creek soil is found on south- and west-facing convex slopes. Slopes range from 4 to 12 percent.

The Lantonia soil is very deep and well drained. Permeability is moderate. Typically the surface layer is brown and yellowish silt loam about 28-inches thick. The subsoil is

pale-brown and light-yellowish-brown silt loam about 17-inches thick. The substratum is very pale brown silt loam about 15-inches thick.

The Crow Creek soil is very deep and well drained. Permeability is moderate. Typically, the surface soil is brown silt loam about 11-inches thick. The upper part of the subsoil is pale-brown silt loam about 4-inches thick, and the lower part of the subsoil is very-pale-brown and pale-brown silt loam about 40-inches thick. The substratum is light-yellowish-brown silt loam about 10-inches thick.

MAP UNIT 700A: REXBURG-RIRIE COMPLEX, 1-to-4% SLOPES. This map unit is composed of Rexburg soil and similar inclusions (55%), Ririe soil and similar inclusions (35%), and contrasting inclusions (10%). It is found on loess-covered basalt plains. The Rexburg soil is on slightly-concave-to-smooth slopes on east, west, and north aspects. The Ririe soil is located on smooth-to-convex slopes and south aspects. Slopes range from 1 to 4 percent.

The Rexburg soil is very deep and well drained. Permeability is moderate. Typically, the surface soil is brown silt loam about 13-inches thick. The upper part of the subsoil is brown silt loam about 12-inches thick, and the lower part of the subsoil is pale-brown silt loam about 6-inches thick. The substratum is very-pale-brown silt loam about 29-inches thick.

The Ririe soil is very deep and well drained. Permeability is moderate. Typically, the surface soil is 12 inches of brown silt loam. The subsoil is about 36 inches of pale-brown silt loam. The substratum is very-pale-brown silt loam about 12-inches thick.

MAP UNIT 700B: REXBURG-RIRIE COMPLEX, 4-to-8% SLOPES. The only substantial difference between this map unit and MAP UNIT 700A is the slope. This map unit is found on steeper slopes and is therefore more susceptible to runoff and water erosion.

MAP UNIT 705A: RIN-LANTONIA COMPLEX, 1-to-4% SLOPES. This map unit is composed of Rin soil and similar inclusions (60%), Lantonia soil and similar inclusion (35%), and contrasting inclusions (5%). It is found on loess covered basalt plains. The Rin soil is located on north and east-facing concave slopes and the Lantonia soil is found on south- and west-facing, smooth-to-convex slopes.

The Rin soil is very deep and well drained. Permeability is moderate. Typically, the surface soil is dark-grayish-brown and brown silt loam about 24-inches thick. The subsoil is pale-brown, light-yellowish-brown, and very-pale-brown silt loam about 36-inches thick.

The Lantonia soil is very deep and well drained. Permeability is moderate. Typically, the surface soil is brown and yellowish-brown silt loam about 28-inches thick. The subsoil is pale-brown and light-yellowish-brown silt loam about 17-inches thick. The substratum is very-pale-brown silt loam about 15-inches thick.

All soils mapped around the Plant are similar in morphology. Although soils at the Plant cannot be directly correlated with the SCS soil survey due to disturbance, it is unlikely that before Monsanto Plant operations began the soils were any different than the soils that surround the Plant now. In general, the soils would have been deep to very deep, well drained, with a silt loam texture, and formed from a loess parent material.

Soils at the control sites (where background soil samples were collected) were mapped as Rexburg-Ririe complex (map unit 700A). Thus, they are directly comparable to the soils that exist around the Plant.

3.5.2.2 Soil Physical Properties

Soil samples were collected from 21 locations around the perimeter of the Plant (Figure 2-3) and from three control (background) locations located near the City of Grace, Idaho, approximately 11 miles southwest of the Plant (Figure 2-4). Each location was sampled at two depths: 0-to-1 inch and 0-to-6 inches from the ground surface. Physical analyses were conducted to determine grain-size distribution. Results for each sample are summarized by particle-size classes together with the USCS classification in Table 3-12. Complete analytical results are shown in Appendix J.

Grain-Size Distribution in Soils Around the Plant Site

Grain-size distributions were completed on 21 samples from the 0-to-1-inch depth and 21 samples from the 0-to-6-inch depth. In general, most samples were classified as clayey silt with some sand and a trace of gravel. There was no appreciable difference between samples collected from the 0-to-1-inch depth and samples collected from 0-to-6-inches depth. The dominant particle-size class was silt-sized, which is consistent with a loess parent material.

Grain-Size Distribution in Control Soils

Grain-size distributions were completed on three samples from the 0-to-1-inch depth and four samples from the 0-to-6-inch depth. Soils were generally classified as clayey silt with some sand. There was no appreciable difference between samples collected at the 0-to-1-inch depth and samples collected at the 0-to-6-inch depth. The dominant particle-size class was silt-sized, which is consistent with a loess parent material.

3.6 Hydrogeological Characteristics

This section presents the regional and local hydrogeology for the Monsanto Plant. The discussion on regional hydrogeology summarizes groundwater conditions primarily in the Blackfoot Lava Field, detailing the primary aquifers and providing the regional context necessary to understand the local hydrogeology. The local hydrogeology discussion, relying on data collected during this Phase I RI and on previous investigations, addresses hydrostratigraphy and local flow system characteristics, including groundwater age dating.

3.6.1 Regional Hydrogeology

Geologic structures and stratigraphy have a major influence on hydrogeology in the Blackfoot Lava Field and have been reviewed in detail in Section 3.4 (Geological Characteristics) and in previous investigations (Golder 1985). In summary, Soda Springs and the surrounding area are located in a transition zone between the overthrust belt of the Cordilleran Mountains to the west and the Basin and Range Province to the east. The Cordilleran Mountain system is characterized by folds overturned to the east and gently west-dipping thrust faults. The Basin and Range Province is characterized by north-trending, high-angle, normal faults producing horst and graben-type structures.

The Monsanto Plant is located at the southern end of the Blackfoot Lava Field. The Blackfoot Lava Field occupies the northern part of the Bear River Graben, a generally north-northwest to south-southeast trending downthrown basin bordered on the west by the Chesterfield Range and Soda Springs Hills, and to the east by the Aspen Range. The elevation of the basin floor ranges from 5,800 feet amsl in Soda Springs to approximately 6,100 feet amsl at the valley sides. Elevations of the surrounding ranges vary from 6,800 feet amsl to nearly 7,400 feet amsl.

Studies by Dion (1974), Hutsinpiller (1979), Ralston et al. (1983), and Seitz and Norvitch (1979) have inferred three dominant flow systems in the Soda Springs region. The three regional flow systems are:

1) The Shallow Groundwater System which moves locally through the upper elevations of the basaltic lithologies of the Blackfoot Lava Field;

2) The Mead Thrust Aquifer System, which discharges along the eastern margins of the valley; and

3) The Chesterfield Range Aquifer System, which discharges along the western portions of the valley.

Each flow system is discussed below.

3.6.1.1 The Shallow Groundwater System

The Blackfoot Lava Field is a thick sequence of basalts probably of mid-Pleistocene age. Well logs indicate the basalts to be at least several hundred feet thick in the center of the field. The basalts are underlain by tuffaceous sandstones, conglomerates and limestones of the Salt Lake Formation, which are of Tertiary age. The Salt Lake Formation in turn is underlain by older rocks of Permian and Carboniferous age. These older rocks are exposed along the flanks of the Blackfoot Lava Field. The rocks of the Salt Lake Formation and the pre-Tertiary rocks yield variable amounts of groundwater for domestic and stock purposes, and are unpredictable as a water-supply source. These rocks are not considered part of the Shallow Groundwater System.

The Shallow Groundwater System flows through the upper stratigraphic unit of the basalts and surficial Quaternary alluvium. The basalts of the Blackfoot Lava Field contain the most productive aquifers in the region. Groundwater occurs primarily between individual basalt flows in the sedimentary interbeds and weathered zones. Groundwater from the basalts is used for industrial, domestic, and agricultural purposes. Groundwater also occurs in the surficial deposits. Due to the predominantly silty and unsaturated nature of these deposits, production is limited and groundwater is used primarily for domestic and stock purposes.

Recharge to the surficial deposits and the basalts occurs by infiltration of snowmelt, precipitation, irrigation, and leakage from the Blackfoot Reservoir. Dion (1974) estimated that approximately 10 cfs of Blackfoot Reservoir water was leaking into the underlying basalt aquifer and moving southward toward Soda Springs. Recharge to this flow system also occurs by infiltration of water into the subsurface at Formation Cave. This water originally surfaces at Formation Springs via high-angled normal faults and flows above-surface to Formation Cave where it re-enters the groundwater-system. Discharge from the Shallow Groundwater System is to Soda Creek, Alexander Reservoir, and down the valley, within the basalt sequence itself, toward the Bear River.

The regional direction of groundwater movement in the basalts is generally to the southwest, although this pattern is locally affected by the northwest-southwest-trending faults and pumping of industrial production wells that exist in the area.

3.6.1.2 The Mead Thrust Aquifer System

This system is apparently recharged by precipitation over the mountains to the east of the Monsanto Plant, which include the Aspen Range, Schmid Ridge, Dry Ridge, and Webster Range (Ralston et al. 1983). Groundwater flow is apparently westward along permeable sedimentary beds, with the Mead Thrust Fault possibly acting as a hydraulic conduit for much of the flow. Discharge from the flow system is apparently along the eastern side of the Blackfoot Lava Field via deep, high-angle, vertical extension faults. Numerous springs exist on the eastern margin of the Lava Field and, apparently, mixing occurs with the groundwater of the Shallow Groundwater System. Formation Spring is an example of discharge from this flow system. Water from this spring has been age-dated for previous investigations, using carbon-14 methods, and was found to be approximately 10-to-20-thousand years old (Ralston et al. 1983). This agrees with age-dating analyses performed for this investigation, which are discussed in Paragraph 3.6.2.4 (Groundwater Flow Characteristics).

3.6.1.3 The Chesterfield Range Aquifer System

The recharge for this flow system is unknown, but it probably receives recharge from the Chesterfield Range to the west of the Monsanto Plant. These mountains have a dominant limestone lithology, but are not the same formations composing the mountains to the east of the Plant. Groundwater within this flow system probably flows eastward, discharging along the western side of the Blackfoot Lava Field through deep, high-angle, vertical extension faults, where it may mix with groundwater of the Shallow Groundwater System. An example of the discharge from this flow system is Hooper Spring, located at the western margin of the valley.

3.6.2 Local Hydrogeology

The hydrogeologic system underlying the Monsanto Plant is generally congruent with the regional hydrogeologic model of the Blackfoot Lava Field. Within the immediate Plant vicinity, information on the local hydrostratigraphy and groundwater flow systems is available from well-drilling records, water-level monitoring data, pump tests, and well and spring water-quality analyses. Local hydrostratigraphy and groundwater flow systems are discussed below. Groundwater quality characteristics, as pertaining to the differentiation of local flow systems, are discussed in Paragraph 3.6.2.4 (Groundwater Flow Characteristics). Groundwater quality, as pertaining to constituent releases, is discussed in Section 4.5 (Groundwater Quality).

A total of 54 test and production wells have been drilled at the Monsanto Plant. Not all of the wells, however, are presently available for data collection. Test well TW-1 is abandoned and is buried beneath the underflow solids pile in the northeast corner of the Plant. Test wells TW-3 through TW-6, inclusive, were drilled out and sealed with grout because the wells created hydraulic communication between the various aquifer zones wells. Well TW-25 and TW-27 were also abandoned because excavations in their vicinity dropped the ground elevations approximately 20 feet below the well heads. Well TW-44 was sealed with grout during drilling because of hole instability and was replaced by TW-44A. Well TW-46 and TW-47 were never drilled. Well TW-52 was renamed PW-4 and completed with a permanent pump for production purposes. The well logs from these 54 wells are available in Appendix H and were used to evaluate the hydrogeology of the Plant.

3.6.2.1 Hydrostratigraphy

Four local hydrostratigraphic zones have been identified beneath the Monsanto Plant: the Surficial Deposit Zone; the Upper Basalt Zone (UBZ); the Lower Basalt Zone (LBZ); and the Salt Lake Zone. The Surficial Deposit Zone is 10-to-40-feet thick and is only known to be present in the northeast quadrant of the Plant. The Salt Lake Zone was also only identified in the north-central and northeast portions of the Plant, but is probably present at depth beneath the LBZ. Neither the Surficial Deposit Zone nor the Salt Lake Zone produce large amounts of groundwater. Table 3-13 summarizes the hydrostratigraphic zones for the Monsanto wells.

The UBZ is the principal aquifer and is found in most places beneath the Plant to a depth of about 100 feet below ground surface (bgs). The UBZ thins to less than 30 feet in the northeast portion of the Plant. The depth to the water table varies across the Plant from about 20 feet bgs in the northeast corner to about 100 feet bgs in the center of the Plant. In general, there are two and at some locations three highly-permeable interbed horizons within the UBZ, separated by basalt flows. Potentiometric and geochemical data suggest that these interbed horizons behave as a single hydrostratigraphic unit beneath the Plant.

The LBZ underlies the UBZ to depths of at least 250 feet bgs. The LBZ is composed of several moderately permeable interbed horizons and three or four low-permeability basalt flows. Figures 3-16 and 3-17 identify the wells screened in the UBZ and the LBZ, respectively.

Well hydraulics testing at the Plant was conducted in 1984 (Golder 1985) and involved short-term pump testing or airlift testing of test wells and longer-term testing of production wells. The testing was carried out primarily for the purpose of determining aquifer hydraulic parameters (hydraulic conductivity and storativity). The testing was also conducted to provide information on potential hydraulic boundaries. Table 3-14 presents a summary of the pump testing carried out by Golder in 1984.

The 1984 investigation determined that the interbed horizons of the UBZ were very permeable, with hydraulic conductivities ranging from 100 to 10,000 feet per day. The horizontal hydraulic gradient was between 0.006 and 0.05 and was generally in a southerly direction. The horizontal hydraulic gradient, as determined from water-level measurements taken in October, 1991 is between 0.005 and 0.06 and is also in a general southerly direction. The groundwater velocity is estimated at between 20 and 2,000 feet per day.

The 1984 investigation determined that the interbed horizons of the LBZ were found to be much less permeable than in the UBZ, with hydraulic conductivities on the order of 1 foot per day. The horizontal hydraulic gradient in the LBZ was found to be between 0.006 and 0.03, also in a southerly direction. The horizontal hydraulic gradient for the LBZ, as determined from water-level measurements taken in October, 1991, is between 0.005 and 0.035 and is also in a southerly direction. The groundwater velocity was estimated at between 0.6 to 30 feet per day in the permeable interbed horizons. Lower velocities are likely within the less permeable basalt flows.

3.6.2.2 Groundwater Flow Systems

Groundwater flow in the UBZ and the LBZ is influenced by faulting, regional hydrogeological conditions, and pumping of the Plant production wells. Figures 3-18 and 3-19 are two-dimensional conceptual flow models for the UBZ and the LBZ, respectively, as determined from potentiometric and groundwater quality data collected during this RI. These two figures are similar to the 1984 investigation results (Golder 1985). The potentiometric surface, however, is currently up to 10 feet lower than the 1984 elevation.

To facilitate the description of the local flow systems, the UBZ has been divided into five regions and the LBZ have been divided into four regions based primarily on hydrogeological controls and groundwater quality. The four main regions in the UBZ correspond location-wise to approximately the same regions in the LBZ. The fifth UBZ region does not correspond to a region in the LBZ. Table 3-13 lists the regions where the Monsanto wells are located. The regions are defined as follows:

UBZ-1 & LBZ-1	the immediate southwestern corner of the Plant bounded by the subsidiary fault to the northeast and, for the UBZ, includes the springs and Harris well located in the vicinity southwest of the Plant;
UBZ-2 & LBZ-2	the southwestern portion of the Plant bounded by the major and subsidiary faults and, for the UBZ, includes the Lewis Well located south of the Plant;

UBZ-3 & LBZ-3	the eastern and southeastern portions of the Plant (influenced by Kerr-McGee operations);
UBZ-4 & LBZ-4	the remaining portions of the Plant which are not mentioned above, primarily consisting of the northern and central portions of the Plant; and
UBZ-5	the springs located to the east of the Plant (Formation Spring) and to the southeast of the Plant (Ledger, Finch, Boy Scout, Spring Box, and Kelly Park springs).

The groundwater flow direction and characteristics of the nine regions are discussed in detail in Subsections 3.6.2.3 and 3.6.2.4 below.

3.6.2.3 Groundwater Flow Direction

The groundwater flow direction beneath the Plant is generally to the south and southwest (Figures 3-18 and 3-19) parallelling the geological structure. Both the major fault and the subsidiary fault running through the Plant appear to act as barriers to groundwater flow for their length beneath the Plant. To the south of the Plant, however, fault displacement decreases and the faults may no longer be acting as barriers.

Upper Basalt Zone. The groundwater in UBZ-1 appears to flow primarily southward (Figure 3-18) with the subsidiary fault acting as a barrier to the east-northeast. Groundwater in UBZ-2 flows primarily south-southeastward and flow appears to be restricted by the subsidiary fault to the west and the major fault to the east. The groundwater flow direction in UBZ-3 is to the southwest and south.

Groundwater in UBZ-4 flows to the southeast and the southwest (Figure 3-18) with the major fault acting as a barrier to the west. The pumping of the Plant production wells (PW-1, PW-2, and PW-3) creates a cone of depression in the UBZ-4 area, intercepting groundwater flowing from the north, northwest, and northeast of the Plant. Also, PW-4 and TW-2 appear to have created a small cone of depression in the northern portion of UBZ-4.

The groundwater in the vicinity of Formation Spring appears to be flowing in a southwestward direction (see Figure 3-18 for groundwater elevations in this area) and eventually discharging in the vicinity of Ledger Spring. Flow in the vicinity of Ledger Spring is complicated by the presence of several faults. Groundwater in this area appears to be flowing primarily southwestward with seepage at the base of the faults forming Finch, Boy Scout, Spring Box, and Kelly Park springs.

Formation Spring has deposited a large travertine (calcium carbonate) terrace. Travertine terraces are also found surrounding Ledger Spring, between Ledger Spring and the City of Soda Springs, and on the lower elevations of Rabbit Mountain. The travertine terraces indicate areas where active or former springs have surfaced from the frontal faults associated with the Aspen Range (Ralston et al. 1983). Travertine is not found associated with the springs on the west side of the valley.

Lower Basalt Zone. Only one well-nest is located in LBZ-1 and, therefore, information on the flow direction in LBZ-1 is limited (Figure 3-19). Groundwater flow in LBZ-1, however, is probably similar to that in UBZ-1 and is most likely in a southward direction. Groundwater flow in LBZ-2 is in a south-southeastward direction parallel to the subsidiary fault to the west and the major fault to the east. The groundwater flow direction in LBZ-3 is to the southwest and south.

The groundwater in LBZ-4 flows in a similar manner as UBZ-4 to the southeast and the southwest. Groundwater in this region is also intercepted by the production wells in the central portion of the Plant (Figure 3-19).

3.6.2.4 Groundwater Flow Characteristics

The groundwater qualities of each of the nine local regions mentioned above correspond to one of the three regional flow systems (Shallow Groundwater System, Mead Thrust Aquifer System, and Chesterfield Range Aquifer System) or a mixture of these systems. The hydrogeology of the three regional systems were described in Subsection 3.6.1 (Regional Hydrogeology).

The water quality of the three regional flow systems can be described simply as either fresh or sodic. The Shallow Groundwater System and the Mead Thrust Aquifer System are considered to be generally good and "fresh". The Chesterfield Range Aquifer System is considered to be poor or "sodic". A comparison of average concentrations of typical chemical parameters found in fresh and sodic waters is presented in Table 3-15. Data were obtained from wells and springs which were not affected by any source of constituents release. Figures 3-20 and 3-21 delineate the areas in the Monsanto Plant vicinity in which fresh and sodic waters are found.

Groundwater flow within the Shallow Groundwater System comes into contact with surface soils and basaltic stratigraphic units. The Shallow Groundwater System water quality is characterized by low dissolved solids (generally < 550 mg/L), low carbon dioxide concentrations, calcium/magnesium ratios greater than 1.0, and generally elevated nitrate/nitrite (as N) concentrations (> 2.5 mg/L). The water is considered to be young due to the suspected shallow flow and because of the low total dissolved solids (TDS).

Groundwater flow within the Mead Thrust Aquifer System receives recharge from the mountains to the east of the Monsanto Plant, which include the Aspen Range, Schmid Ridge, Dry Ridge, and Webster Range (Ralston et al. 1983) and is in contact with limestone country rock. This system discharges along the eastern margin of the Blackfoot Lava Field via deep, high-angled vertical extension faults. The groundwater quality is characterized by low dissolved solids (generally < 500 mg/L), high carbon dioxide concentrations (due to contact with the limestone country rock), calcium/magnesium ratios greater than 2.5, relatively high calcium concentrations (> 120 mg/L), and generally low nitrate/nitrite concentrations (< 1 mg/L). The water is considered to be relatively old with respect to the Shallow Groundwater System. Specific ages will be discussed below.

The quality of the two fresh water flow systems differs by the magnitude of their nitrate/nitrite concentrations and their ages. Nitrate/nitrite concentrations are greater in the Shallow Groundwater System.

The groundwater qualities of the sodic flow system corresponds to the regional Chesterfield Range Aquifer System which receives recharge from the Chesterfield Range to the west of the Monsanto Plant. These mountains have a dominant limestone lithology and groundwater within this flow system appears to discharges along the western side of the Blackfoot Lava Field through deep, high-angle vertical extension faults. This water is considered the oldest of the three flow systems.

The water quality is characterized as magnesium-bicarbonate water, high dissolved solids (generally > 900 mg/L), high carbon dioxide concentrations, elevated concentrations of iron, calcium/magnesium ratios less than 1.0, and relatively low levels of nitrate/nitrite.

The characteristics of fresh water systems (the Shallow Groundwater System and the Mead Thrust Aquifer System) and sodic water system (the Chesterfield Range Aquifer System) discussed above were used to identify and describe the nine local regions.

To supplement the inorganic qualities that were used to describe the nine local regions, it is worthwhile to briefly describe another tool, environmental isotopes, that was used. In hydrogeology, the term environmental isotope is normally used to describe isotopes that occur naturally in the groundwater. Environmental isotopes were used in this study to provide a signature for particular water types and to provide groundwater-age information.

Four environmental isotopes were measured at selected locations during the October, 1991, sampling round:

- Tritium (^{3}H)
- Carbon-14 (^{14}C)
- Oxygen-18 (^{18}O)
- Deuterium (^{2}H or D)

In general terms, carbon-14 data can be used to estimate the time at which the dissolved carbon in the water became isolated from the sources of atmospheric carbon-14. The estimated age, of course, is modified by any mixing which might take place in the flow system (e.g., due to recharge). Tritium, which is elevated in precipitation subsequent to 1952 due to nuclear testing, can provide an indication of the degree of recent recharge. The stable isotopes (oxygen-18 and deuterium) can be difficult to interpret (as their concentrations in precipitation are controlled by vapor pressures and can vary significantly), but can provide groundwater signatures.

Using both inorganic parameters and environmental isotopes, the local flow regions were characterized and are discussed below.

UBZ-1

Sodic water (Chesterfield Range Aquifer System water) is found in this region in Hooper, Doc Kackley, and Southwest springs. A mixture of fresh (Shallow Groundwater System water) and sodic water is found in this region in TW-10, Calf and Mormon A, B, and C springs and the Harris well.

Environmental isotope samples were analyzed from TW-10, Hooper Spring, and Doc Kackley Spring. Carbon-14 data (Table 3-16) indicates ages of 20,000 years or more for the two sodic springs sampled (Doc Kackley and Hooper) (Table 3-16). TW-10 data indicate an age of only 8,600 years, which is consistent with an elevated tritium concentration, suggesting dilution from recent recharge. Recharge to TW-10 may be occurring from infiltration of sewage evaporation pond water. This theory is substantiated by elevated levels of chloride found in TW-10. Oxygen-18 and deuterium concentrations for the UBZ-1 sampling points are quite similar and distinctly different from the two fresh flow systems.

UBZ-2

UBZ-2 is assumed to consist of fresh water (Shallow Groundwater System water). However, there are no sampling locations upgradient of this region to verify that the background water is fresh.

Environmental isotopes were analyzed from this flow system at two different locations (TW-20 and Lewis Well). Carbon-14 data indicates ages ranging from approximately 7,000 years for TW-20 to 12,000 years for Lewis Well (Table 3-16). Tritium data ranges from 17 tritium units (TU) in Lewis Well to more than 20 TU in TW-20. Lewis Well data are consistent with results from TW-15 which is also screened in the Shallow Groundwater System and is upgradient of any known sources of dilution and, therefore, samples from TW-15 are considered representative of the flow system.

Tritium results from TW-20 and Lewis Well are consistent with the carbon-14 results, indicating that TW-20 water has been diluted with recent recharge. Relatively high oxygen-18 and deuterium values for TW-20 also support this hypothesis.

UBZ-3

Groundwater quality in UBZ-3 appears to be a mixture of the two fresh water types, Mead Thrust Aquifer System type water which has mixed with Shallow Groundwater System water. The groundwater in this region, however, is influenced by operations at the Kerr-McGee Plant, located hydraulically upgradient and to the east of the Monsanto Plant.

Only one environmental isotope sample was collected in this region (TW-12). The carbon-14 data indicate an age of 13,570 years and the tritium results indicate 6.2 TU. These results are consistent with the hypothesis of mixing. Oxygen-18 and deuterium results for both types of fresh water are approximately the same and are similar to those found in TW-12.

UBZ-4

UBZ-4 groundwater quality is that of the Shallow Groundwater System. Only one environmental isotope sample was collected in this region from well TW-15. Well TW-15 sample data can be considered representative of the Shallow Groundwater System since it is upgradient of any known sources of dilution. Carbon-14 results indicate an age of 12,775 years and tritium results indicate a value of 7.2 TU.

UBZ-5

The Mead Thrust Aquifer System is the source for Formation Springs. The groundwater discharging at springs southeast of the Plant is considered a mixture of Mead Thrust Aquifer System water and Shallow Groundwater System water. The water that surfaces at Formation Spring re-enters the groundwater system in the vicinity of Formation Cave and is diluted with Shallow Groundwater System type water before discharging at Boy Scout, Finch, Ledger A, B, and C, and Kelly springs. The springs further to the west (downgradient) are more diluted with water from the Shallow Groundwater System. Formation Spring, Ledger Spring, and Kelly Park Spring waters have calcium/magnesium ratios of > 3.5, 2.8, and 2.2, respectively (Table 3-15).

Environmental isotopes were analyzed in ten samples from this region (Table 3-16). Carbon-14 data indicate ages between 10,000 and 18,000 years. The groundwater is "oldest" to the east and is "younger" to the southwest further downgradient indicating mixing with recent recharge. Of the spring water in this region, Formation Spring water has been dated at 17,620 years, Ledger Spring water has been dated at about 16,000 to 17,000 years, and Kelly Park and Spring Box spring water is dated at 11,000 years. Tritium data are inconclusive and difficult to interpret (with values ranging from less than 1 to more than 10 TU). Oxygen-18 and deuterium values were very similar for all samples in this region indicating the sampling locations appear to be within the same overall flow system.

The City of Soda Springs obtains its municipal water supply from Formation Spring and Ledger Spring. Formation Spring is located hydraulically upgradient from and approximately two miles east of the Monsanto Plant at an elevation of between 6,000 and 6,100 feet amsl; Ledger Spring (consisting of several different springs) is located just under one mile southeast of the Plant at an approximate elevation of between 5,900 feet and 5,920 feet amsl. Based on existing hydrogeologic information, Ledger Spring is not downgradient of any potential sources at the Monsanto Plant, and, based on age-dating is not threatened by plant activities.

LBZ

Regions LBZ-1, LBZ-2, and LBZ-4 groundwater types consist of sodic water (Figure 3-21). Data, however, are not available for some areas of LBZ-4. LBZ-3 groundwater type is derived from the Mead Thrust Aquifer System but is influenced by operations at the Kerr-McGee Plant, located upgradient and to the east of the Monsanto Plant.

Lower Basalt Zone environmental isotope sampling was conducted in TW-18 in LBZ-4. Carbon-14 results indicate a groundwater age of 7,930 years and tritium results indicate a

value of 25.7 TU. Both results are drastically different than those found in other sodic samples (Hooper and Doc Kackley Springs), which have water ages of greater than 20,000 years (Table 3-16). This suggests that groundwater in the vicinity of TW-18 could be influenced by mixing of deeper Chesterfield Range Sodic water and recent recharge from the Shallow Groundwater Flow System upgradient of the Plant.

3.7 Ecological Characteristics

This section provides a description of the potential receptor populations that exist in and around the Monsanto Plant vicinity. Human and non-human populations are addressed in Subsections 3.7.1 (Human Ecology) and 3.7.2 (Wildlife Ecology), respectively.

3.7.1 Human Ecology

The description of the human ecology associated with the Monsanto Plant focuses on issues pertaining to land use (Paragraph 3.7.1.1), water use (Paragraph 3.7.1.2), and cultural resources (Paragraph 3.7.1.3). Demography is addressed within the land-use discussion below.

3.7.1.1 Land Use

The utilization of land around the Monsanto Plant is presented below. This paragraph includes land use zones, and the demography of the area, both on a regional and a local scale.

Regional Land Use

The region surrounding the Monsanto Plant includes the incorporated City of Soda Springs and surrounding communities within Caribou County. The dominant land uses in this county are woodland and rangeland. The estimated land uses for 1990 (projected in a 1977 county land use plan) are approximately 38% woodland, 36% rangeland, and 21% cropland. Approximately 51% of the land in Caribou County is in federal or state ownership. The Caribou National Forest, and the Cache National Forest cover almost 400,000 acres (about 36% of the total land) in Caribou County (Caribou County 1977).

The land-use map for Caribou County (see Figure 3-22) designates the area surrounding the Monsanto Plant, and other areas north of the City of Soda Springs as heavy industrial. This area includes the Monsanto Plant and Kerr-McGee Plant. The City of Soda Springs is incorporated into an Impact Area, as is the City of Grace to the southwest of Soda Springs. The agricultural land in Caribou County is currently zoned for residential use at a density of one home per 40 acres. Any residential densities greater than this must undergo formal subdivision. Most of the area in the county is an unallocated land use by the County Planning Board (Wright, B., Golder [Memo to Monsanto Soda Springs Phase I RI file] November 12, 1991).

Most industrial activities in the region are associated with the chemical and allied products industry, including phosphate mining (Caribou County 1977).

The western and central regions of Caribou County are mostly agricultural lands, with primary crops of barley, wheat, or other grains. Rangeland, used mostly for cattle grazing, is located along the north and east-central portion of the county.

Caribou County is largely rural, with a population density of approximately four people per square mile. Residential land use is concentrated around the incorporated areas. The total population of Caribou County was 6,963 in 1990 (Bureau of Census 1991). The county population has increased at a rate of 0.3% per year since 1970, when the county population was 6,534 (Caribou County 1977). County planners estimate the county population to remain stable with very little to no growth in the foreseeable future (Wright, B., Golder [Memo to Monsanto Soda Springs Phase I RI file] November 12, 1991).

Local Land Use

The City of Soda Springs, located less than one mile south of the southern boundary of the Monsanto Plant, is the largest city in Caribou County with a population of 3,111 in 1990 (Bureau of Census 1991). The city's population has declined by approximately 1,000 people within the last ten years, and projections indicate that the city anticipates no significant growth in the foreseeable future (Wright, B., Golder [Memo to Monsanto Soda Springs Phase I RI File] November 12, 1991).

Land use within the city limits is mostly residential (single-family, combined, and multiple-family) with a strip of commercial and light industrial zones extending east-west through the center of the city (see Figure 3-23). A light and heavy industrial zone extends from the north end of the city along Route 34 towards the Monsanto Plant. The Plant is located outside the city limits.

The following is a summary of the land-use zones currently in use in the City of Soda Springs (Soda Springs Title 17):

- Agricultural Use (A-1) — including agriculture, golf courses, single-family residential areas on the fringe of the community; areas important for the preservation of rural standards;

- Single-Family Residential Use (R-1) — including low-density, single-family dwellings;

- Combined Residential Use (R-2) — including medium-density, combination of R-1 district use and multiple-family dwellings limited to not more than four units;

- Multiple-Family Residential Use (R-3) — including medium-to-high-density residential development limited to not more than six units; also includes hospitals, boarding houses, convalescent homes, etc.;

- Neighborhood Commercial (C-1) — including local commercial services, used to restrict incompatible uses or highway-oriented shopping areas from residential neighborhoods;

- Community Commercial (C-2) — including general shopping center retail services and travel- or highway-related services;

- Light Industrial (M-1) — including manufacturing, processing, assembling, etc.; industries that are unobtrusive and non-detrimental to surrounding commercial or residential uses; and

- Heavy Industrial (M-2) — including heavy industrial uses substantially free from residential or retail commercial activities.

The area where the Monsanto Plant is currently located was primarily agricultural, with crops of wheat and hay, before Monsanto purchased the land in 1952. Five residential or farm-related buildings were present in this area before the property was purchased by Monsanto.

The northern portion of the property was in operation in the early 1950s. The southern portion of the Plant was gradually covered with slag piles and some settling ponds from the 1950s to the 1970s (EPA 1990b). The current Plant operations and land uses are described in Section 3.1.

A vanadium production plant owned by Kerr-McGee is adjacent to the Monsanto Plant on the opposite side of State Highway 34, and has been in operation since 1963. This particular area was not used for industrial purposes prior to that time (Ecology and Environment 1988b). A phosphoric acid production plant owned by Nu West Industries is located approximately four miles north of the vanadium plant.

The workforce population at the Monsanto Soda Springs Plant is a total of approximately 400 employees. The Kerr-McGee plant employs approximately 80 persons.

The residential population demographics for the area surrounding the Monsanto Plant are summarized as follows (Ecology and Environment 1988a):

One-mile radius	27 residents
Two-mile radius	1,400 residents
Three-mile radius	3,100 residents

In summary, the land use within the boundaries of the Monsanto Plant and Kerr-McGee is industrial, surrounded by open agricultural and range lands. Local county and city planning officials believe that the status of the land use in these areas will remain unchanged for the foreseeable future.

3.7.1.2 Water Use

Water use in the vicinity of the Monsanto Plant is discussed below. Surface-water use is addressed first, followed by a discussion of groundwater use.

Surface-Water Use

The surface hydrology of the region is discussed in Section 3.3 (Hydrological Characteristics). Regional water use includes water storage, irrigation and hydroelectric power generation. Alexander Reservoir, located adjacent to and southwest of the City of Soda Springs, is on the Bear River and is used for the generation of hydroelectric power. Blackfoot Reservoir, located 13 miles to the north and upgradient of the Plant, is owned and operated by the Bureau of Indian Affairs. It is used primarily for irrigation and water storage. Soda Creek Reservoir, located immediately west of the Plant on Soda Creek, is used for irrigation and is the source of hydroelectric power for the City of Soda Springs (Dion 1974).

Locally, Soda Creek (fed by Soda Creek Reservoir), located to the west of the Plant, flows to the south into Alexander Reservoir. Soda Creek is used for irrigation, livestock watering, and power generation. Monsanto currently holds an NPDES permit to allow discharge of non-contact cooling water into this creek at the southwest corner of the Plant (see Section 3.1, Source Characteristics). A weir is located approximately 100 feet downstream of this discharge point that diverts water from Soda Creek into an irrigation canal maintained by the Farmer's Land and Irrigation Corporation. A water rights abstract from the IDWR estimates that over 4,000 acres of land are irrigated with water from Soda Creek (see Table 3-17) (Ecology and Environment 1988a).

A fish hatchery is situated on Big Spring Creek located south of the City of Soda Springs. This hatchery is supplied entirely by groundwater.

Groundwater Use

The hydrogeology of the area — including sources of groundwater, well inventories, and pertinent aquifer systems in the vicinity of the Plant excluding Monsanto wells, and other off-site wells included in this investigation (e.g., Harris, Lewis) — is discussed in Section 3.6 (Hydrogeological Characteristics). The uses of the groundwater in this vicinity are discussed below. Figure 3-24 provides a map of the estimated locations of wells within the vicinity of the Plant. None of these well locations have been verified in the field.

The Monsanto Plant drinking water is supplied by a production well (PW-4) on the northern boundary of the Plant. This well is upgradient of any potential areas of constituent releases at the Plant. Three other production wells (PW-1, PW-2, and PW-3) are located at the Plant that are used only to supply process water through a separate, dedicated, distribution system.

Kerr-McGee previously had a drinking-water supply well located on the Kerr-McGee facility that served 80 employees. This well is currently abandoned, the City of Soda Springs water supply is now used.

The sources of drinking water for the City of Soda Springs are Ledger Spring and Formation Spring. Ledger Spring has five spring houses, located one-half mile from Soda Springs (see Figure 2-6), that pump water into the city's system. These springs are all located hydraulically sidegradient from the Monsanto Plant (hydraulically upgradient of any sources of constituent release). Formation Spring is located four miles northeast of the city and hydraulically upgradient of the Plant. An estimated 3,000 people are served by these sources (Ecology and Environment 1988a).

Several individual groundwater wells are used in the area for domestic drinking water supply. An inventory of such wells in and near the Monsanto Plant was collected to be used, in conjunction with groundwater flow and quality information, to determine areas of future groundwater monitoring. The area covered in this inventory includes wells that may tap groundwater downgradient of the Plant, and upgradient wells that may potentially be used to obtain control data.

The inventory was completed by reviewing the following sources of information: 1) drillers' logs on file with IDWR (obtained from the Boise and the Idaho Falls offices); 2) a listing of water rights on file with the IDWR in Boise; 3) well information obtained from the USGS Water Resources Division in Boise; and 4) published literature from previous investigations. Field verification of the wells was not conducted as a part of this Phase I RI, and the current status of many wells is unknown. The well inventory, including a key to well ownership and use for Figure 3-24, is presented in Appendix K.

As shown on Figure 3-24, the nearest wells to the Plant are the Harris well (#44), located outside of the southwest corner of the Plant, and the Fan Corporation well (#42), located directly below the southeast corner of the Plant. Use of the Harris ranch well was discontinued in 1983 when elevated levels of fluoride were discovered in the water. Monsanto supplied the ranch with bottled water from that time until the ranch could be tied into the city water supply. Well #42 is presumed, based on the location described in the inventory, to be the well owned by Washington Construction. This well was abandoned in the Spring of 1991.

3.7.1.3 Cultural Use

Some portions of the Oregon Trail remain visible through the City of Soda Springs and areas south and west of the Plant. These areas are considered areas of special historical interest (Caribou County 1977). Hooper Spring is a 40-acre park located approximately one-half mile west of the Plant. This soda-water spring is also considered to be an area of special and historical interest (Soda Springs 1976). No other significant cultural resource or archaeological sites are known to exist within the immediate vicinity of the Monsanto Plant.

3.7.2 Wildlife Ecology

Wildlife, as used in this report, refers to non-domesticated populations of plants and animals, both terrestrial and aquatic. The description of wildlife ecology associated with the Monsanto

Plant vicinity focuses, in accordance with the NCP (40 CFR 300, Appendix A) on critical habitats of endangered or threatened species and on sensitive aquatic and terrestrial habitats.

A brief summary of the terrestrial and aquatic ecology of the Monsanto Plant vicinity is presented below on both a regional and local scale. The flora and fauna are described in Paragraphs 3.7.2.1 and 3.7.2.2, respectively, focusing on important and protected (i.e., endangered or threatened) species. On the basis of this information, critical and sensitive habitats in the project vicinity are identified in Paragraph 3.7.2.3.

3.7.2.1 Flora

The Monsanto Plant is situated in the semi-arid, Bear River valley. Most of region is covered by the sagebrush-grass cover type, occurring at elevations of 5,000 to 7,000 feet amsl. This vegetative cover type generally consists of bitterbrush, serviceberry, snowberry, and sagebrush. Squirrel tail, sandberg bluegrass, juniper, and some Indian ricegrass also occur. Grazing often reduces the vegetative cover by compacting the soil and increasing surface runoff and erosion (USGS and USDA 1977).

The FWS-BFS reviewed the Natural Heritage Program Database to identify known sensitive, threatened, endangered, or candidate plant species in the Soda Springs area and identified the hoary willow *Salix Candida* as sensitive species by the USFS (Lobdell, C. FWS-BFS, [Letter to W. Wright, Golder] December 2, 1991). This species is known to exist east of the project area along the Ledger Creek drainage.

3.7.2.2 Fauna

The Idaho Fish and Game Department identifies several big-game species in this region, including elk, mule deer, white-tailed deer, and some black bear. Sage grouse, sharp-tailed grouse, forest grouse, chukar partridge, and hungarian partridge are important game birds in this area (USGS and USDA 1977).

The area north of the Monsanto Plant is considered a mule deer wintering ground and the Plant sits astride a seasonal deer migration route (Wright, B., Golder [Memo to Monsanto Soda Springs Plant Phase I RI File] November 2, 1991).

Significant fish and wildlife habitats near the Monsanto Plant include the Bear River, Alexander Reservoir, and Formation Cave (a property owned by the Nature Conservancy). Gray's Lake National Wildlife Refuge is located 25 miles north of the Plant, well beyond the project boundaries for this RI.

The FWS-BFS identified the following as important species which inhabit the Bear River/ Alexander Reservoir area: bald eagles, white pelicans, Canada geese, and several duck and shorebird species. Approximately 10 to 12 bald eagles winter in the Bear River/Alexander Reservoir area south of the City of Soda Springs. White pelicans feed in Alexander Reservoir. Waterfowl are know to use the sewage evaporation and non-contact cooling water ponds at the Plant throughout the year (Geddes, R., Monsanto [Personal communication] November 2, 1991).

Alexander Reservoir provides a marginal rainbow trout and yellow perch fishery, and the Bear River downstream of the Reservoir provides a rainbow trout fishery (Lobdell, C. FWS-BFS, [Letter to W. Wright, Golder] December 2, 1991). The lower reach of Soda Creek, just above its confluence with the Bear River, also provides a marginal trout fishery for local residents.

The FWS-BFS reviewed the Natural Heritage Program Database to identify known sensitive, threatened, endangered, or candidate animal species in the Soda Springs area and identified the bald eagle *Haliaeetus leucocephalus* as a threatened species that uses the Alexander Reservoir/Bear River area for a wintering ground. (Lobdell, C. FWS-BFS, [Letter to W. Wright, Golder] December 2, 1991).

3.7.2.3 Critical and Sensitive Habitats

Critical habitat is defined under the Endangered Species Act (50 CFR 17). In the project vicinity, the only such habitat identified by FWS-BFS is the wintering ground, along Alexander Reservoir and the Bear River, for the threatened bald eagle.

A regulatory definition of sensitive habitat does not exist. However, guidance can be derived from the CERCLA hazard ranking system (HRS), which is promulgated as an appendix to the NCP (40 CFR 300, Appendix A). Table 4-23 of the HRS provides rating values for various types of sensitive environment, as defined in the HRS, is considered equivalent to a sensitive habitat.

Under this definition, virtually any surface-water body that contains fish must be regarded as a sensitive habitat. Such aquatic habitats in the vicinity of the Monsanto Plant include the lower reach of Soda Creek, the Bear River (including Alexander Reservoir), and the ponds containing non-sustaining populations of trout on the Nature Conservancy property near Formation Springs.

The HRS indicates that certain areas, relatively small in size, that are important to the maintenance of unique biotic communities must also be considered sensitive. While it may be argued that no such area exist in the project vicinity, the Ledger Creek drainage, due to the presence of the hoary willow (a species designated by the USFS as sensitive), will be regarded as a sensitive habitat for the purpose of this report.

Section 4

4. NATURE AND EXTENT OF MONSANTO PLANT CONSTITUENT RELEASES

This chapter provides a description of the nature and extent of constituent releases at the Monsanto Plant. The focus of Chapter 4 is on the empirically-determined chemical and constituent release characteristics of the Plant. A description of the physical characteristics of the Plant is provided in Chapter 3; an analysis of the environmental fate and transport of the Plant constituent releases of potential interest is provided in Chapter 5.

Section 4.1 discusses the potential sources of constituent releases, presents analytical results, and also briefly characterizes other waste streams in the Monsanto Plant vicinity. The empirically-determined nature and extent of Plant constituent releases is addressed in Section 4.2 (air), 4.3 (surface waters and associated sediments), 4.4 (soil), 4.5 (groundwater and springs), and 4.6 (biota). The chapter concludes with a summary of Monsanto Plant constituent releases of potential interest and their respective environmental distributions in Section 4.7.

The results of the chemical and radiochemical analyses used in this Section were validated and blank-adjusted as described in detail in a validation summary report in Appendix S.

Statistical analyses were performed on the analytical results in Sections 4.3 (Effluent, Surface-Water and Sediment Quality), 4.4 (Soil Quality), and 4.5 (Groundwater Quality) to determine Plant-specific control levels, and to determine which constituents were found at concentrations exceeding such levels. Such constituents are defined as elevated constituents.

The elevated constituents were then subjected to a preliminary screening against conservative risk-based benchmarks and where available, regulatory guidelines, to determine if the constituents are present at levels which could conceivably pose a significant threat to human health, welfare, or the environment. Constituents that could pose such threats are defined as constituents of potential interest.

The constituents of potential interest are addressed in detail in Chapter 5 (Constituent Fate and Transport).

4.1 Sources of Constituent Releases

Potential and known sources of constituent releases for the Monsanto Plant and the Plant vicinity are described below. The information presented in this section has been used to assist in validating the findings of the other environmental-medium-specific investigations. The actual nature of constituent releases encountered during the Phase I RI and the anticipated results are compared in Section 4.7.

4.1.1 Monsanto Plant Potential Sources of Constituent Releases

Chemical characteristics for each of the potential sources at the Monsanto Plant are presented below. Sources were sampled and analyzed during the Monsanto Plant Phase I RI, as described in Sections 2.1.2 (Source Sampling and Analysis) and 2.3.2 (Surface-Water, and Sediment Sampling and Analysis). Locations of the source sampling sites are shown in Figure 2-1. Of the 25 total source samples, 10 samples were analyzed for only the physical parameters listed in Table 2-1, 12 samples were analyzed for both the physical and the chemical constituents shown in Table 2-1, and three samples (the non-contact cooling water effluent) were analyzed for the chemical parameters listed in Table 2.3 Results of the source sample chemical analyses are summarized in Table 4-1 and discussed in the following paragraphs. Analytical data sheets are shown in Appendix C except for effluent analytical results which are presented in Appendix G.

4.1.1.1 Phosphate Ore, Coke, and Quartzite Stockpiles

The phosphate ore, coke, and quartzite stockpiles are located in the northeast and east portions of the Plant (Figure 1-3). The phosphate ore stockpiles cover an area of approximately 1,200 feet by 600 feet by 40 feet high, and consists of approximately 500,000 tons. The coke and quartzite stockpiles consist of approximately 22,000 tons and 150,000 tons, respectively.

Fugitive dust is the main concern with the phosphate ore, coke, and quartzite stockpiles. Table 4-2 shows representative chemical analyses for each of these stockpiles (Geddes, R.L., Monsanto [Memo to C. Yates, Golder] March 20, 1992). Chemical analyses for the phosphate ore, quartzite and coke raw material stockpiles were provided by Monsanto.

4.1.1.2 Nodule Fines Pile

Nodule fines are stored in piles located near the phosphate ore stockpiles in the northeast portion of the Plant. These piles cover an area of approximately 100 feet by 80 feet. Fugitive dust is also the main concern with the nodule fines piles. Samples collected from these piles were analyzed for physical parameters only; however, the chemical composition should be similar to the phosphate ore.

4.1.1.3 Calcium Silicate Slag Piles

Calcium silicate slag constitutes the greatest quantity of waste material produced and stored by the Plant. Slag piles cover most of the southern portion of the Plant. There is an estimated 23 million tons of slag stockpiled at the Plant.

The anticipated constituents of interest associated with these piles include naturally-occurring metals and radionuclides. Previous analyses on slag samples indicate that slag passes toxicity characteristic leaching procedures (TCLP) tests (Golder 1991). Three samples were collected from the slag piles at various locations (Figure 2-1) for chemical analysis. Analytical results for these samples are summarized in Table 4-1.

The summary statistics in Table 4-1 show slag sample variability was very high for most radiological constituents. Sample variability of the non-radiological constituents was generally less than for radionuclides, except for constituents such as zinc and lead.

4.1.1.4 Ferrophosphorus Slag Piles

This product is sold to Kerr-McGee Chemical Corporation for vanadium extraction. Samples were not collected from the ferrophosphorus slag piles for either physical or chemical analysis.

4.1.1.5 Dusts

Baghouse dust samples were collected from piles in the northeast corner of the Plant. Three samples were collected from the baghouse dust piles at various locations (Figure 2-1) for chemical analysis. Results of chemical analysis are summarized in Table 4-1. These results show that the analyzed constituents are highly variable, but are generally less than quantities found in other source samples.

Treater dust piles consist of approximately 51,000 tons of material located in the north-central portion of the Plant. No samples were collected for chemical analysis.

4.1.1.6 Underflow Solids

Three underflow solids piles exist in the northeast corner of the Plant and cover an area of approximately 2,000 feet by 750 feet. Three samples were collected from these underflow solids piles at various locations (Figure 2-1) for chemical analysis. Results of chemical analyses are summarized in Table 4-1.

4.1.1.7 Underflow Solids Ponds

The original underflow solids ponds in the northwest corner of the Plant were completely filled by 1988. Approximately 35,000 tons of essentially low-grade ore remain in the ponds under the capped material. The northwest pond, located northwest of and adjacent to the original ponds, was excavated and, in 1988, was sealed with bentonite (Geddes, R.L., Monsanto [Memo to D. Banton, Golder] March 23, 1992).

4.1.1.8 Phossy Water Surge Pond and Seal Water Pond

These are lined ponds, therefore samples were not collected from the phossy water surge pond or the seal water pond for chemical analysis.

4.1.1.9 Hydroclarifier

The hydroclarifier has a steel lining and a leachate collection system. No leakage has been detected since modification in 1985, therefore no samples were collected from the area surrounding the hydroclarifier for chemical analysis.

4.1.1.10 Coke and Quartzite Dust Slurry Pond

The coke and quartzite dust slurry pond is located in the southwest corner of the Plant and occupies an area of approximately 175,000 square feet. There are no free liquids in the pond.

4.1.1.11 Non-Contact Cooling Water Effluent

Non-contact cooling water effluent is discharged into Soda Creek at an average annual rate of 2,000 gpm. Three samples of effluent were collected for chemical analysis. Analytical results are included in Appendix G and summarized in Table 4-1. Radionuclides were not detected in the effluent and are therefore not reported in Table 4-1.

4.1.2 Other Potential Sources of Constituent Release in the Monsanto Plant Vicinity

Several nearby facilities in the vicinity have been identified as known or potential sources of constituent releases. These include: 1) Kerr-McGee Chemical Corporation vanadium pentoxide plant; 2) Evergreen Resources fertilizer facility; 3) Soda Springs Phosphate Industries fertilizer facility; 4) Nu-West Industries phosphoric acid production and fertilizer facility; and 5) N.A. Degerstrom gallium and silver extraction plant. The physical characteristics of each of these facilities are briefly summarized in Subsection 3.1.3 (Other Facilities in the Monsanto Plant Vicinity).

An RI/FS is in progress at the time of this report at the Kerr-McGee plant. Potential constituent releases from this plant are expected to be similar to the Monsanto Plant. Current and previous studies at Kerr-McGee indicate that elevated concentrations of aluminum, arsenic, chloride, chromium, copper, lead, molybdenum, nitrate, sulfate, vanadium, and zinc have been identified in groundwater below the site (Dames and Moore 1992).

4.2 Air Quality

Data from existing air monitoring stations in the immediate vicinity of the Monsanto Plant and in the southeastern Idaho region are evaluated in this section. Because some existing data are available, no formal air sampling was conducted as a part of the initial phase of the RI. The existing air monitoring data include a rather extensive body of information on ambient particulate levels, both total and respirable. In addition, particulate emission rates were available from stack sampling conducted during 1990 by American Service Associates (ASA) for permitted stack sources at the Plant (ASA 1990).

Results of the stack sampling indicate that cadmium and fluoride are the constituents of most interest at the Plant. Therefore, the first phase RI air investigation focuses on these two substances, as well as the indicator parameters TSP and PM_{10}. In addition, chemical characteristics of several of the fugitive dust sources at the Plant were characterized during this phase of the RI (see Subsection 4.1.1). The ambient air-quality data recorded for TSP and

PM_{10} are discussed below to give a general description of the extent of particulate effects associated with the Monsanto Plant.

Comparisons between observed annual average and maximum 24-hour TSP and PM_{10} concentrations at these stations and predicted concentrations due to emissions from the Monsanto Plant are discussed in Subsection 5.3.1 to provide an indication of the air quality affects associated with Plant operations.

4.2.1 Total Suspended Particulates

Ambient air quality monitoring data for particulates are available from three monitoring stations operated by the IDHW-BAQ in the immediate vicinity of the Monsanto Plant (see Figure 1-4). These include 24-hour TSP measurements using high volume air samplers at:

- The Harris Ranch (Station 13-0420-026), located south of the Monsanto Plant (January, 1986, to May, 1988);
- Two miles north of Hooper Springs (Station 13-029-0029), located northwest of the Monsanto Plant (January, 1986, to September, 1988); and
- Soda Springs Hospital (Station 13-0420-021), located approximatrely two miles southwest of the Monsanto Plant (January, 1986, to September, 1988).

The average concentration levels recorded at these monitoring stations are discussed below.

4.2.1.1 Soda Springs

Table 4-3 lists the geometric mean annual concentrations for the above three monitoring stations near Soda Springs from 1986 to 1988. The period of record at the Harris Ranch station for 1988 ends in May, while the records for the Soda Springs Hospital and for the station north of Hooper Springs, as well those as for Conda (see Paragraph 4.2.12), end in September. Therefore, an annual geometric mean could not be calculated at these stations in 1988. In addition, the monitoring data from the Harris Ranch and from the Hospital appear to contain some anomalously high readings for the period August 31 to October 12, 1987, which were recorded during a period when a nearby county road was being upgraded with particularly dusty river gravel and at a time when stubble in a field adjacent to the Harris Ranch station was being burned. The circumstances for these anomalous readings have been reportedly documented with the IDHW-BAQ.

Table 4-3 lists the geometric means both with and without these high readings. Regardless of whether the anomalous values are included or excluded from the analysis, the mean annual concentrations at all three stations were below the primary and secondary standards (40 CFR 50) of 0.075 mg/m^3 and 0.060 mg/m^3, respectively.

Examination of the observed mean annual concentrations shows that the control TSP concentrations, as recorded at the Soda Springs Hospital, are generally about 0.030 mg/m^3. By

comparison, the concentrations at the Harris Ranch, the station closest to the Monsanto Plant, had geometric mean annual concentrations from 0.004 to 0.010 mg/m^3 higher than the control station. However, the geometric mean annual concentrations at the station north of Hooper Springs were about 0.007 to 0.008 mg/m^3 lower than the control concentrations at the hospital station, even though the station north of Hooper Springs was designated a source-oriented monitoring station. On this basis, the monitoring station north of Hooper Springs could equally be considered a control station, in which case the difference in ambient concentrations between control levels and monitoring data from the Harris Ranch is about 0.012 to 0.017 mg/m^3 (based on annual geometric means).

The data records from the three stations reveal a distinct seasonal component to variations between the recorded concentration levels. From late-April/early-May to about mid-October, differences between the mean levels recorded at the Harris Ranch versus either the Hospital station or the station north of Hooper Springs are generally in the order of 0.022 mg/m^3 to 0.030 mg/m^3. On the other hand, during the colder months of the year, from mid-October to April/May, there is little or no difference between the mean concentrations recorded at the Harris Ranch and the Soda Springs Hospital, but the differences between the Harris Ranch and the station north of Hooper Springs are about 0.004 mg/m^3 to 0.019 mg/m^3. These seasonal differences most likely reflect the mediating effects of moisture and cold temperatures in reducing fugitive dust emissions from the Monsanto Plant, as well as from other sources in the general area during the cold season.

The arithmetic mean difference between individually paired concentration levels recorded on the same days at the Harris Ranch and the Soda Springs Hospital during the warmer months of the year (i.e., May to mid-October) is 0.027 mg/m^3. The mean difference between similarly paired monitoring data for the Harris Ranch and the monitoring station north of Hooper Springs is 0.023 mg/m^3. During the colder months of the year (i.e., mid-October to May), the differences are respectively 0.002 mg/m^3 and 0.018 mg/m^3. The significantly greater mean difference between the Harris Ranch and the station north of Hooper Springs during the colder months of the year than between the Harris Ranch and the station at the Soda Springs Hospital appears to indicate that the station north of Hooper Springs probably provides a better measure of control TSP levels than does the station at the hospital.

Maximum 24-hour concentration levels at these monitoring stations are also listed in Table 4-3. The highest recorded level at the Soda Springs Hospital was 0.115 mg/m^3 (September, 1988), while the highest level at the station north of Hooper Springs was 0.122 mg/m^3 (August, 1988). By comparison, the highest 24-hour concentration recorded at the Harris Ranch was 0.305 mg/m^3, but this occurred during the period of road upgrading referred to above in September, 1987. Excluding this period, the highest concentration at the Harris Ranch was 0.147 mg/m^3 (June, 1986). All of the exceedences of the primary and secondary standards (by 0.260 mg/m^3 and 0.150 mg/m^3 in excess of the standards, respectively), occurred during the periods of road upgrading and by field burning.

4.2.1.2 Conda

The two TSP monitoring stations at Conda are included in this analysis because they are within the same regional area. However, their distance from the Monsanto Plant (over three

miles) (see Figure 1-4) renders them less suitable for comparison with dispersion modeling results, especially because there appear to be local influences on the recorded TSP levels which are not associated with Monsanto's operations. The Torgeson residence monitoring station and the station approximately 1.2 miles east of Highway 34 (see Figures 1-2 and 1-4) are located south of the Nu-West facility tailings ponds.

Table 4-4 lists the geometric mean annual concentrations recorded at the two stations from 1986 to 1988. On a calendar year basis, the mean annual concentrations at the Torgeson residence were similar to those recorded at the Soda Springs Hospital (Table 4-3), but were significantly higher on a seasonal basis during the period of May to September, 1988. By comparison, the second station at Conda, south of the tailings ponds, recorded mean annual ambient concentrations 0.020 mg/m^3 to 0.023 mg/m^3 higher than at the Torgeson residence, and from 0.008 mg/m^3 to 0.016 mg/m^3 higher than at the Harris Ranch. On a seasonal basis, these differences are even more pronounced during the warmer months of the year (May to mid-October), and are present in two out of the three winter seasons in the data records.

Differences between the two monitoring stations at Conda and the three stations near Soda Springs are also noticeable in the number of exceedences of ambient 24-hour standards, and the magnitude of the maximum 24-hour concentrations. Extremely high values and frequent exceedences were particularly noticeable during the summer of 1988, with concentrations up to 0.499 mg/m^3 at the station 1.2 miles east of Highway 34 near the Nu-West facility. High concentrations were also recorded at the Torgeson residence, although not as frequently.

In the absence of more detailed information concerning the sources of the high particulate concentrations, it is difficult to speculate about the likely causes. However, the lack of similarly high concentrations at the Soda Springs stations appears to indicate that the source of the higher concentrations at Conda is localized, and not associated with the Monsanto Plant.

4.2.2 Inhalable Particulates

Ambient PM_{10} concentrations have been measured at the Terrace Acres Mobile Court south of the Monsanto Plant (Station 16-029-0030) since November, 1989 (see Figure 1-4).

Ambient monitoring data are also available from two additional monitoring stations located near Conda, northeast of the Monsanto Plant (see Figure 1-4):

- The Torgeson Residence (Station 13-029-0002), TSP monitoring from January, 1986, to September, 1988; and
- 1.2 miles east of Highway 34 (Station 13-0420-027), TSP monitoring from January, 1986, to September, 1988, and PM_{10} monitoring from January, 1987, to June, 1989.

The average concentrations recorded at these monitoring stations are discussed below.

4.2.2.1 Soda Springs

The high-volume TSP samplers at Soda Springs were removed in the summer (Harris Ranch) and fall (Soda Springs Hospital and north of Hooper Springs) of 1988. A PM_{10} monitor was installed at the Terrace Acres Mobile Court near Highway 34 in November, 1989. The period of record available for this analysis was from November 12, 1989, to December 19, 1990.

For the calendar year 1990, the arithmetic mean annual concentration was 0.027 mg/m^3. On a quarterly basis, the highest average 3-month concentration occurred in the months of July through September with 0.031 mg/m^3. On a seasonal basis, the average concentrations were:

November, 1989 to April, 1990	0.029 mg/m^3
May, 1990 to October 14, 1990	0.031 mg/m^3
October 15, 1990 to December 19, 1990	0.018 mg/m^3

The maximum 24-hour PM_{10} concentration recorded was 0.096 mg/m^3 in May 1990. Therefore, there were no exceedences of the primary standard of 0.150 mg/m^3 (40 CFR 50). Similarly, there were no exceedences of the primary standard of 0.050 mg/m^3 (40 CFR 50) for the annual average concentrations.

4.2.2.2 Conda

In addition to the PM_{10} sampler near the Nu-West facility, a TSP monitoring station was installed in January, 1988. The two samplers were run simultaneously until September 18, 1988, when the TSP high-volume sampler was removed. The PM_{10} sampler continued to operate until the end of June, 1989, when sampling was interrupted until the end of the year. Sampling was resumed in January, 1990, and continued until the end of July, 1990.

Sampling frequency varied from once every six days during the first nine months (January to September, 1988), to almost daily for the next six months (October, 1988, to March, 1989), approximately every two days for two periods (April to June, 1989, and January to April, 1990), and back to once every six days to the end of July, 1990, when the sampler was removed.

Due to the interruptions in sampling, there is only one complete calendar year of sampling data (1988) for comparison with ambient air quality standards. For the year, the arithmetic mean PM_{10} concentration was 0.039 mg/m^3. For the partial year of data recorded in 1989 and 1990, the mean annual concentrations were 0.028 and 0.033 mg/m^3, respectively. Thus, there were no exceedences of the primary standard of 0.050 mg/m^3 annual average, and these levels are comparable with the concentrations reported for the shorter period of record at the Terrace Acres Mobile Court near Soda Springs. There was only one exceedence of the 24-hour primary standard of 0.150 mg/m^3, which occurred in October, 1988.

For the period of January to September, 1988, when the TSP and PM_{10} samplers were operated simultaneously, the data show that the mean ratio of PM_{10} to TSP was 0.36. The median ratio was 0.33. Therefore, at least for the Terrace Acres Mobile Court station, the

inhalable particulates constitute approximately one-third of the total suspended particulate matter.

4.3 Surface-Water and Sediment Quality

A conceptual model of potentially significant exposure pathways for the Monsanto Plant was developed and discussed in the Phase I RI/FS work plan (Golder 1991). The conceptual model indicated that direct discharge from the effluent pond to Soda Creek is a potential pathway that may expose humans or biota to potentially affected water via ingestion or direct contact. In order to evaluate this potential pathway, sampling activities and a habitat reconnaissance of Soda Creek were included in the Phase I RI investigation.

Surface water from Soda Creek and the irrigation canal, associated sediments, and Monsanto Plant effluent were sampled and analyzed, both chemically and physically, as described in Subsection 2.3.2 (Effluent, Surface-Water, and Sediment Sampling and Analysis). Locations of the sampling sites are shown in Figure 2-2. The physical analyses are discussed in Section 3.3.2 (Local Surface-Water Hydrology), with results provided in Appendix F. The chemical analyses are discussed below and results are provided in Appendix G.

Soda Creek surface-water quality is assessed in Subsections 4.3.1 and 4.3.2. Statistical analyses were performed on the analytical data to determine whether the downstream sample group of each constituent was statistically different then the upstream (control) group. Downstream parameters that exceed and significantly differ from the upstream levels are regarded as elevated constituents. Statistical analyses and identification of elevated constituents are discussed in detail in Subsection 4.3.1.

Each elevated constituent is subjected to a conservative preliminary risk screening in which calculated risk-based benchmarks or regulatory guidelines, where available, were used to develop conservative, constituent-specific, risk-screening criteria. This process, which is described in detail in Subsection 4.3.2, is used to identify those constituents of potential interest.

Following the characterization of surface-water conditions, sediment quality in Soda Creek is assessed. A similar process of identifying elevated constituents was completed for the sediments. The statistical methods and identification of elevated constituents and constituents of potential interest are discussed in Subsection 4.3.3.

4.3.1 Elevated Constituents in Surface Water

Sampling of Soda Creek, both upstream and downstream of the effluent discharge, was conducted to determine ambient water quality. A total of six samples were collected (two sample groups with three samples in each group). Three samples were collected from Soda Creek, upstream of the effluent discharge into Soda Creek, and three samples were collected from the irrigation canal, below the diversion dam, downstream of the effluent discharge.

Comparisons between upstream and downstream sample groups were performed on the data to determine which constituents attributable to the Monsanto Plant are present at elevated concentrations downstream of the effluent discharge. The constituents that were not detected in the downstream samples were not analyzed statistically. Such non-detected constituents included arsenic, beryllium, cadmium, chromium, copper, iron, lead, manganese, nickel, selenium, silver, vanadium, zinc, ammonium, carbonate, hydroxide, phosphorus, gross alpha, radium-226, radium-228, radon-222, and uranium (see Appendix G for complete analytical results).

Statistical analysis was performed on the constituents presented in Table 4-5. Statistical analysis was performed for constituents where at least one of the three samples was detected in the downstream sample group. Undetected constituent values were represented by one-half the sample quantitation limit (SQL) in the statistical analysis in order to obtain an unbiased estimate of the actual concentration in these instances.

The statistical analysis performed on the surface-water chemical data was a one-sided t-test. The test procedure for comparing the upstream and downstream population means assumes that samples were taken from normal populations with different means but identical variances. However, in the case of non-identical variances, the calculated confidence coefficient remains relatively stable if sample distributions are mound-shaped and the sample sizes are approximately equal (Ott 1977).

The t-test was performed on the sample groups data to test for differences between the means of the sample groups by comparing calculated values (t) (Table 4-5) with a tabulated value. For this sampling round, the tabulated t-value is based on df = 4 and $\alpha = 0.05$ and is equal to 2.132. In order for the t-test to reject the null hypothesis that the population means are equal, calculated values need to be greater than 2.132.

Of the constituents statistically analyzed, the constituents which are regarded to have no affect on downstream surface water in the Soda Creek irrigation canal are the ones which have calculated t values less than or equal to the tabulated t value. These constituents include aluminum, magnesium, potassium, bicarbonate, fluoride, and field pH.

The constituents with elevated concentrations in the Soda Creek irrigation canal are the ones which have calculated t values greater than the tabulated t values. The downstream elevated constituents include:

- Elevated constituents in surface water

  calcium
  sodium
  chloride
  nitrate/nitrite as N
  sulfate
  total dissolved solids

Elevated constituents consist mainly of anions. The only metals that were detected at elevated concentrations are calcium and sodium. Calcium and sodium are both essential nutrients that are considered to be essentially non-toxic at the concentrations encountered at the Plant, and are thus eliminated from further consideration in this report. Total dissolved solids are a secondary criteria and have no health risks associated with them and are also eliminated from further consideration in this report.

4.3.2 Surface-Water Constituents of Potential Interest

A preliminary risk screening was used to evaluate the elevated constituents found in all downstream surface-water samples to determine the constituents of potential interest. Calculated risk-based benchmarks or regulatory guidelines, where available, are used during the preliminary screening to develop conservative, constituent-specific, screening criteria. The maximum concentrations of each elevated constituent detected are compared against the criteria to ensure the retention of all constituents of potential interest for further consideration in Chapter 5 (Constituent Fate and Transport Analysis). For risk analysis purposes, each constituent is first evaluated to determine if it is an essentially non-toxic substance under typical environmental conditions, if it is not, it is evaluated as a systemic toxin and/or a carcinogen. Substances that are systemic toxins and carcinogens are subjected to further preliminary screening evaluation.

Systemic toxicity is evaluated in terms of a published EPA reference dose (RfD). Surface-water concentrations resulting in a dose equivalent to a fraction of the applicable RfD are calculated. Since no more than two constituents have similar critical effects for systemic toxicity (e.g., chromium and selenium both have liver effects, zinc and nitrate can both have effects on the blood), a benchmark equal to one-half of a hazard quotient (HQ) has been selected as a preliminary screening criterion.

Carcinogens are evaluated in terms of their constituent-specific lifetime incremental cancer risk (LICR), based on a published EPA carcinogenic slope factor (SF). A LICR of 1E-06 or less is regarded as an indication of an insignificant carcinogenic hazard. Carcinogens are also evaluated, as appropriate, for their potential to cause systemic toxicity.

Therefore, the screening criteria used are those concentrations that would be necessary to attain a dose equivalent to one-half of the RfD, for system toxins (i.e., 0.5 HQ), or a risk equivalent to a LICR of 1E-06 (i.e., 1E-06/SF), for carcinogens. All surface-water screening criteria concentrations are derived using conservative, on-site residential exposure factors assumptions from EPA (1989a) and EPA-10 (1991). The generic equation for calculating each screening criterion concentration is:

Screening criterion =

$$\frac{(\text{Intake})(\text{BW})(\text{AT})}{(\text{CR})(\text{ED})(\text{EF})}$$

For surface-water oral ingestion of systemic toxins, the parameters used for calculations are:

Intake	= 0.5 (RfD)
BW	= body weight (70 kilograms (kg))
AT	= averaging time (365 days/year)(30 years)
CR	= contact rate (2 liters/day)
ED	= exposure duration (350 days/year)
EF	= exposure frequency (30 years)

For carcinogens, the parameters used are:

Intake	= 1E-06/SF
BW	= 70 kg
AT	= (365 days/year)(70 years)
CR	= 2 liters/day
ED	= 350 days/year
EF	= 30 years

The exceedance of such a conservative screening criterion does not necessarily establish the existence of a significant risk. Criterion exceedance, at this point in the overall analysis, simply indicates the need to retain a given constituent for further evaluation with respect to constituent fate and transport, taking more realistic assumptions into account, in Chapter 5. On the other hand, if a constituent does not exceed the conservative screening criteria, it may be eliminated from further consideration, on an environmental-medium-specific basis, with a high degree of confidence that the constituent poses either no, or only insignificant, risk to human health and the environment. Consequently, conservative risk screening at this point in the process is useful and meaningful in that it serves to focus attention and effort on those constituents that could potentially pose such risks.

Table 4-6 presents a summary of the preliminary risk screening for downstream Soda Creek surface-water. None of the constituents exceed preliminary risk screening criteria for downstream Soda Creek surface water.

4.3.3 Elevated Constituents in Sediment

Stream sediments were collected at three locations described in Subsection 2.3.2 (See Figure 2-2) for chemical analysis. Analysis was conducted for constituents listed in Table 2-4. Analytical data sheets are included in Appendix G.

The mean and standard deviation was calculated for each constituent that was analyzed in sediments, based on samples collected from upstream control sediments. A one-sided upper tolerance limit (UTL) was calculated for the 95th percentile ($\alpha = 0.05$) for the normal distribution of each constituent. Two-sided upper and lower tolerance limits (LTL) (at the 2.5th and 97.5th percentiles) were calculated for pH. A normal distribution is conservatively assumed, as data are of insufficient quantity to substantiate non-normality. The method for the calculation of the tolerance limits is adapted from EPA (1989b).

The tolerance limits were calculated by:

$$UTL = (Mean) + K(Standard\ Deviation)$$

and for pH:

$$UTL\ or\ LTL = (Mean) \pm K(Standard\ Deviation)$$

where:

UTL = upper tolerance limit
LTL = lower tolerance limit
K = tolerance factor based on the number of control samples (one-sided factors from EPA 1989b, two-sided factors from Hines and Montgomery 1980).

If a given parameter was not detected in a given set of control samples, the highest reported SQL for the parameter is used as a surrogate UTL.

The maximum detected concentrations found in sediment samples, collected downstream in Soda Creek, were compared to the tolerance limits to screen out the constituents falling within control parameters. Any constituent with a maximum (or, in the case of pH, minimum) concentration exceeding the tolerance limits was considered an elevated constituent (i.e., with respect to control conditions). This is a conservative and objective screening procedure that does not evaluate environmental effects.

Summaries of these calculations and the elevated constituents for sediments are presented in Table 4-7. The elevated constituents in the sediments collected from Soda Creek (approximately 100 feet downstream of the effluent discharge), based on comparison to calculated tolerance limits, are listed below:

- Elevated constituents in sediments, 100 feet downstream of the effluent discharge

  cadmium
  copper
  nickel
  selenium
  silver
  vanadium
  polonium-210

Soda Creek sediment samples were also collected further downstream, approximately 300 feet downstream of the effluent discharge. Elevated constituent for these sediment samples are listed below.

- Elevated constituents in sediments, 300 feet downstream of the effluent discharge

  selenium
  silver
  vanadium

At the present time there are no screening criteria, either risk-based calculations or regulatory guidelines, on which to judge the elevated constituents. Therefore, all elevated constituents in stream sediments will be examined in Chapter 5 (Constituent Fate and Transport).

4.4 Soil Quality

The following sections discuss analyses of chemical constituents (radionuclides, metals, nitrogen, and pH) for soil samples collected at two depths. Surface soil samples (A group) were collected from the 0-to-1-inch depth increment and the subsurface soil samples (B group) were collected from the 0-to-6-inches depth increment from points at control locations and around the Plant, as described in Section 2.5 and shown in Figure 2-4. Results of physical analyses are discussed in Section 3.4

Soil samples were first evaluated statistically to determine if there were any significant differences between the two sampling depths (0-to-1-inch and 0-to-6-inches). Mean constituent concentrations in soil samples collected from two depths were compared using a t-test (Hines and Montgomery 1980) with the Type I error at $\alpha = 0.05$ for both the control sample locations and for the sample locations around the Monsanto Plant. The results showed that, with the exception of copper, there was no difference in constituent concentration between the two sample depths in soil samples from the control locations. Thus, analytical chemistry data from samples collected at the control locations from two sample depths can be pooled.

The same conclusion was not valid, however, for soil samples collected from around the Plant. For these samples, there was a sufficient number of constituents for which the mean concentration from the two depths were significantly different. Thus, there was a meaningful difference in constituent chemistry between the soil samples collected at different depths. The analysis performed does not take into account the natural heterogeneity of the soils, however; based on these statistics, and to remain consistent, the analytical chemistry data for the two sampling depths from either sampling location (control or Plant) were not pooled and the soils data from each sampling depth were evaluated separately for risk screening.

4.4.1 Elevated Constituents

Statistical evaluations were performed to determine the elevated constituents, as described in Subsection 4.3.3, for each soil group. A one-sided UTL was calculated for the 95th percentile ($\alpha = 0.05$) for the normal distribution of each constituent. Two-sided UTLs and LTLs (at the 2.5th and 97.5th percentiles) were calculated for pH. A normal distribution is conservatively assumed, as data are of insufficient quantity to substantiate non-normality. The method for the calculation of the tolerance limits is adapted from EPA (1989b).

If a parameter was not detected in a given sample in a set of control samples, one-half of the SQL is used as a surrogate value in the statistical calculations. If a given parameter was not detected in a given set of control samples, the highest reported SQL for the parameter is used as a surrogate UTL.

The maximum detected concentrations found in soil sample data for each soil group was compared to the tolerance limits to screen out the constituents falling within control parameters. Any constituent with a maximum concentration exceeding the tolerance limits was considered an elevated constituent (i.e., with respect to control conditions). This is a conservative and objective screening procedure that does not evaluate environmental effects. Each elevated constituent was subjected to conservative preliminary risk screening to determine if it is a constituent of potential interest (see Subsection 4.4.2).

Summaries of these calculations and the elevated constituents for each soil group are presented in Tables 4-8 (A Group Soils) and 4-9 (B Group Soils). The elevated constituents in the A Group and the B Group, based on comparison to calculated tolerance limits, are listed below:

- Surface-soil elevated constituents in A Group soils (0-1 inch)

  aluminum
  arsenic
  beryllium
  cadmium
  chromium
  copper
  manganese
  selenium
  silver
  sodium
  vanadium
  zinc
  lead-210
  polonium-210
  radium-226
  thorium-230
  uranium

- Subsurface-soil elevated constituents in B Group soils (0-6 inches)

  aluminum
  arsenic
  beryllium
  cadmium
  chromium
  copper
  iron
  manganese
  selenium
  silver
  vanadium
  zinc
  lead-210
  polonium-210
  radium-226
  thorium-230
  thorium-232
  uranium

Aluminum and iron are common constituents of soils and the maximum concentrations found at the site do not exceed the normal ranges for these constituents in soils within the United States (Brady 1974). Therefore, these constituents are eliminated from further consideration (for the soil medium) in this report. Sodium is an essential human nutrient and is considered to be non-toxic at the concentrations found in soils around the Monsanto Plant (EPA 1989a). Thus, sodium is also eliminated from further consideration.

4.4.2 Constituents of Potential Interest

Each elevated constituent is subjected to a conservative preliminary risk screening using calculated risk-based benchmarks or regulatory guidelines, where available, the process for which is described in detail in Section 4.3. No soil cleanup guidelines are available at present for any of the elevated constituents in soils at this site.

The soil screening criteria concentrations are derived using conservative risk assessment assumptions from EPA (1989) and EPA-10 (1991). The generic equation for calculating the risk-based screening criteria concentrations for ingestion of soils is:

Screening Criteria =

$$\frac{(\text{Intake})(AT)(CF)}{\left[\frac{IR \times ED \times EF}{BW}\right]_{adult} + \left[\frac{IR \times ED \times EF}{BW}\right]_{child}}$$

For oral soil ingestion of systemic toxins, conservative assumptions used for calculations are:

Intake	= 0.5 (RfD)
AT	= (365 days/year)(30 years)
CF	= conversion factor (1E+06 mg/kg)
IR	= intake rate: adult (100 mg/day), child (200 mg/day)
EF	= 350 days/year
ED	= adult (24 years), child (6 years)
BW	= adult (70 kg), child (15 kg)

For carcinogens, the conservative assumptions are:

Intake	= 1E-06/SF
AT	= (365 days/year)(70 years)
CF	= (1E+06 mg/kg)
IR	= adult (100 mg/day), child (200 mg/day)
EF	= 350 days/year
ED	= adult (24 years), child (6 years)
BW	= adult (70 kg), child (15 kg)

Soil criteria are similarly derived for the inhalation of fugitive dust generated from soil with elevated constituents. The generic equation for calculating the screening criteria concentrations for inhalation of fugitive dusts is:

$$\text{Screening Criteria} = \frac{(\text{Intake})(\text{BW})(\text{AT})(\text{RF})}{(\text{IR})(\text{ED})(\text{EF})}$$

For fugitive dust inhalation of systemic toxins, conservative assumptions used for calculations are:

Intake	= (RfD)(0.5 HQ)
BW	= 70 kg
AT	= (365 days/year)(30 years)
RF	= respirable factor [1/(50 μg/m^3) (0.25) (1E-09 kg/μg)] = 8E+07 m^3/kg
IR	= 20 m^3/day
EF	= 350 days/year
ED	= 30 years

For carcinogens, the conservative assumptions are:

Intake	= 1E-06/SF
BW	= 70 kg
AT	= (365 days/year)(70 years)
RF	= 8E+07 m^3/kg
IR	= 20 m^3/day

EF = 350 days/year
ED = 30 years

Published inhalation RfDs and SFs are used to calculate the screening criteria. Conservative assumptions regarding particulate concentrations are used. It is assumed that airborne particulates are at the maximum annual national ambient air quality standard of 0.05 mg/m^3 (40 CFR 50). In accordance with Cowherd et al. (1985), 25% of this concentration (i.e., 0.013 mg/m^3) is assumed to be retained in the lungs. The constituent concentration in the respirable fraction is assumed to correspond to the concentration of the constituent found in the parent soil and all respirable particulate is assumed to be derived entirely from the parent soil. Appropriate conversion factors are used as necessary.

The dermal exposure route rarely, if ever, represents a significant risk relative to those posed by the oral and inhalation routes under environmental exposure scenarios when conservative ingestion and inhalation parameters are used for inorganic constituents. In addition, the present analytical techniques for quantifying dermal absorption risks are not well developed. Consequently, the dermal exposure route is not used to screen elevated constituents at the Monsanto Plant.

For radionuclides, the equations for determining risk-based benchmark concentrations are different, depending on exposure pathways. The generic equation to calculate risk-based screening concentrations for ingestion of soil with elevated radionuclides is:

Screening Criteria =

$$\frac{(\text{Intake})(\text{CF})}{[(\text{IR})(\text{EF})(\text{ED})]_{\text{child}} + [(\text{IR})(\text{EF})(\text{ED})]_{\text{adult}}}$$

where:

Intake = 1E-06/SF
CF = 1E+03 mg/g
IR = adult (100 mg/day), child (200 mg/day)
EF = 350 day/year
ED = adult (24 years), child (6 years)

For the inhalation of fugitive dust generated from soil with elevated radionuclides, the generic equation for calculating the screening criteria concentration is:

Screening Criteria =

$$\frac{(\text{Intake})(\text{RF})(\text{CF})}{(\text{IR})(\text{EF})(\text{ED})}$$

where:

Intake = 1E-06/SF
RF = 8E+07 m^3/kg
CF = 1E-03 kg/g

IR	= 20 m^3/day
EF	= 350 days/year
ED	= 30 years

For the external exposure to soils with elevated radionuclides, the generic equation for calculating the screening criteria concentration is:

Screening Criteria =

$$\frac{(\text{Intake})}{(\text{IR})(\text{CF})(\text{EF})(\text{ED})}$$

where:

Intake	= 1E-06/SF
IR	= 24 hours/day
CF	= 1.14E-04 year/hour
EF	= 350 days/year
ED	= 30 years

The results of the preliminary risk screening for metals are shown in Tables 4-10 and 4-11 for A Group and B Group soils, respectively. The results of the radionuclide preliminary risk screening are shown in Table 4-12 for both A and B Group soils. The following is a list of the constituents of potential interest in both the A and B soil groups:

- Constituents of potential interest in A Group soils (0 to 1 inch)

  arsenic
  beryllium
  cadmium
  lead-210
  polonium-210
  radium-226
  thorium-230
  uranium

- Constituents of potential interest in B Group soils (0 to 6 inches)

  arsenic
  beryllium
  manganese
  lead-210
  polonium-210
  radium-226
  thorium-230
  uranium

The spatial distribution of soil samples which contain constituents of potential interest are shown in Figures 4-1 and 4-2. Although not every constituent shows the same spatial pattern, many of the constituents of potential interest are clustered around the north end of the Plant and the south end of the Plant. Although there are a number of constituents of potential interest, the evidence at present is not conclusive to determine that activities at the Monsanto Plant are solely responsible for the elevated constituent levels.

4.5 Groundwater Quality

Groundwater from wells and springs at and in the vicinity of the Monsanto Plant were sampled and chemically analyzed during this Phase I RI investigation as discussed in Section 2.6 (Hydrogeological Investigation). The results from this round of sampling, coupled with existing groundwater data, are used in this Section to identify any sources which may still be active, delineate the extent of affected groundwater, identify how plumes are behaving temporally, and observe trends in constituent concentrations over time.

The locations of on-site wells are shown in Figure 2-5. Off-site wells and springs are shown in Figure 2-6. Borehole logs are provided in Appendix H and well-completion information is provided in Appendix M. A total of 40 well samples and 18 spring samples were collected. The samples were analyzed for the constituents listed in Table 2-12. The results of this groundwater quality investigation are provided in Appendix O.

The turbidities observed during this sampling round varied from 0.3 to >100 NTU (see Appendix O). Such variability causes a comparability problem for unfiltered samples. In order to maintain comparability among the groundwater samples from different wells (i.e., to factor out variabilities attributable to well construction, development, and sampling), samples with turbidities greater than 5 NTU were filtered. Although both filtered and unfiltered samples were analyzed from the high-turbidity wells (see Table 2-13 for identification of filtered samples), only the filtered analyses were used to evaluate groundwater quality. Filtered analytical results are considered more representative of actual groundwater quality, as particulate groundwater transport (ignoring colloidal material) does not occur under typical laminar aquifer flow conditions (Freeze and Cherry 1979).

A total of 11 samples were filtered. The filter diameter used to obtain filtered water samples was 0.45 μm. This pore size lies near the mid-point of the colloidal size range (Stumm and Morgan 1981). A filtered sample, therefore, over-estimates the dissolved fraction of a constituent in a water medium, as (at a first approximation) about half of all colloidal particles present (i.e., those less than 0.45 μm in size) are represented in the sample.

Monsanto Plant control groundwater quality is described in Subsection 4.5.1. For the purpose of this report, control groundwater quality is separated into fresh (the Shallow Groundwater and the Mead Thrust Aquifer systems) and sodic (the Chesterfield Range Aquifer System) as discussed in Paragraph 3.6.2.4 (Groundwater Flow Characteristics) in order to define flow systems. Subsection 4.5.1 discusses locations of control points used in statistical analyses and the effects on the groundwater due to sources of constituent release.

Following the characterization of control conditions, Subsection 4.5.2 assesses groundwater-quality conditions for both the Upper and Lower Basalt Zones. A statistical analysis was performed to determine the UTLs for control samples. These limits are used to determine constituents with concentrations which exceed control concentrations. As with the surface water and soil presentations in Sections 4.3 and 4.4, those parameters are regarded as elevated constituents.

Each elevated constituent was then subjected to a preliminary risk screening to determine constituents of potential interest. These evaluations are discussed in detail in subsection 4.5.3. Subsection 4.5.4 discusses the extent and the temporal characteristics of the constituents in groundwater at the Monsanto Plant.

4.5.1 Control Groundwater Quality

Control data were obtained from wells and springs upgradient of any known sources of constituent releases on the Monsanto Plant. Groundwater samples which provided control data for statistical analyses were obtained from the following wells and springs: five wells which produce water considered to be generally fresh (obtained from the Shallow Groundwater system) (PW-4, TW-2, TW-13, TW-15, and TW-48) and two wells and two springs which produce what is considered to be sodic (from the Chesterfield Range Aquifer System) (TW-28, TW-29, Doc Kackley Spring, and Hooper Spring). A general comparison of fresh and sodic water quality as discussed in Paragraph 3.6.2.4 (Groundwater Flow Characteristics) and is provided in Table 3-15.

A breakdown, by flow systems, of wells and springs used as control points and as monitoring points for statistical analyses is provided in Table 4-13. Because of the influence of the Mead Thrust Aquifer flow system by Kerr-McGee operations, control data for samples collected downgradient of the Kerr-McGee Plant were obtained from Kerr-McGee wells (Dames and Moore 1992).

4.5.2 Elevated Constituents in Groundwater

Statistical evaluations were performed to determine the elevated constituents, as described in Subsection 4.3.3, for each of the three flow systems. A one-sided UTL was calculated for each parameter based on the control well and spring analytical results for each flow system. The UTLs were for the 95th percentile ($\alpha = 0.05$) for the normal distribution of each parameter. Two-sided UTLs and LTLs (at the 2.5th and 97.5th percentiles) were calculated for pH. A normal distribution is conservatively assumed, as data are of insufficient quantity to substantiate non-normality. The method for the calculation of the tolerance limits is adapted from EPA (1989b).

The tolerance limits were calculated by:

$$UTL = (Mean) + K(Standard\ Deviation)$$

and for pH:

UTL or LTL = (Mean) ± K(Standard Deviation)

If a parameter was not detected in a given sample or set of control samples, one-half of the SQL is used as a surrogate value in the statistical calculations. If a given parameter was not detected in a given set of control samples, the highest reported SQL for the parameter is used as a surrogate UTL. If analytical results were available for only one, or none of the control data points, then there is insufficient data to calculate a statistical characterization of control conditions.

The chemical analytical results for the well and spring sample data for each flow system was compared to the tolerance limits to screen out constituents that were within the calculated tolerance limits. Any constituent concentration that exceeded the tolerance limits was considered an elevated constituent (i.e., with respect to control conditions). This is a conservative and objective screening procedure that does not evaluate environmental effects. Each elevated constituent was subjected to conservative preliminary risk screening to determine if it is a constituent of potential interest (see Subsection 4.5.3).

Summaries of these calculations and the elevated constituents for each flow systems are presented in Tables 4-14 (Shallow Groundwater System — fresh) and 4-15 (Chesterfield Range Aquifer System — sodic).

Statistical analyses were not performed on data from the Mead Thrust Aquifer System because Kerr-McGee Plant operations influence the groundwater quality in this system and would result in statistically-calculated UTLs that are larger than concentrations found in samples from the Monsanto Plant.

The following is a list of the elevated constituents for the Shallow Groundwater System and the Chesterfield Range Aquifer System based on comparison to calculated tolerance limits:

- Elevated constituents in the fresh groundwater (Shallow Groundwater System)

  arsenic
  cadmium
  calcium
  magnesium
  manganese
  nickel
  potassium
  selenium
  sodium
  zinc
  specific conductance
  total dissolved solids
  ammonium as N
  bicarbonate

chloride
fluoride
nitrate/nitrite as N
sulfate
phosphorus
radium-226

- Elevated constituents in sodic groundwater (Chesterfield Range Aquifer System)

  cadmium
  magnesium
  nickel
  selenium
  sodium
  zinc
  chloride
  fluoride
  sulfate
  phosphorus

Calcium, magnesium, potassium, and sodium are essential nutrients and are thus eliminated from further consideration in this report. Bicarbonate is also an essentially non-toxic substance, and specific conductance is an indicator of a more specific problem (as shown by the number of elevated constituents in fresh groundwater); these two substances are thus also eliminated from further consideration in this report.

4.5.3 Constituents of Potential Interest

Each elevated constituent was subjected to a conservative preliminary risk screening to determine the constituents of potential interest. In addition to risk-based benchmarks, the following regulatory water-quality standards and criteria are employed for the preliminary groundwater risk screening:

- Primary maximum contaminant levels (1° MCLs) (40 CFR 141);
- Maximum contaminant level goals (MCLGs) (40 CFR 141);
- Human water quality health criteria, based on the consumption of both water and fish (WQC-HH) (EPA 1986a);
- Chronic freshwater quality criteria (WQC-FWC) (EPA 1986a);
- Secondary maximum contaminant levels (2° MCLs) (40 CFR 143); and
- Human water quality welfare criteria (WQC-HW) (EPA 1986a).

The calculations for determining risk-based screening criteria are identical to those used in Section 4.3 (Surface Water). For the oral ingestion of groundwater with elevated radionuclides, the generic equation for calculating the screening criteria concentration is:

$$\text{Screening Criteria} = \frac{(\text{Intake})}{(\text{IR})(\text{EF})(\text{ED})}$$

where:

Intake	=	1E-06/SF
IR	=	2 liters/day
EF	=	350 days/year
ED	=	30 years

Tables 4-16 and 4-17 present summaries of this screening for fresh and sodic groundwater, respectively. Constituents which exceed the screening criteria are regarded as constituents of potential interest; such constituents are listed below:

- Constituents of potential interest in fresh groundwater (Shallow Groundwater System)

  arsenic
  cadmium
  manganese
  nickel
  selenium
  zinc
  total dissolved solids
  ammonium as N
  chloride
  fluoride
  nitrate/nitrite as N
  sulfate
  phosphorus
  radium-226

- Constituents of potential interest in sodic groundwater (Chesterfield Range Aquifer System)

  cadmium
  selenium
  fluoride
  sulfate
  phosphorus

The constituents that are only of potential interest because of welfare considerations are not expected to pose unacceptable health or ecological risks, and are therefore eliminated from further consideration with respect to fate, transport, and detailed risk evaluation. These constituents are manganese, total dissolved solids, chloride, and sulfate. These constituents will, however, be considered in the evaluation of potential ARARs in Chapter 6 (Summary and Conclusions).

The phosphorus analysis performed for this Phase I investigation measured total phosphorus in water. The actual form found in the groundwater is likely phosphate (PO_4), a soluble essential nutrient that is considered to be non-toxic at the concentrations found in groundwater. The screening criterion used for phosphorus in this assessment are applicable for elemental forms of phosphorus, therefore, phosphorus in groundwater is eliminated from further consideration in this report.

4.5.4 Extent and Temporal Characteristics of Constituent Plumes

Chemical analyses of groundwater from the Lower and Upper Basalt Zones, conducted for the October, 1991, and previous investigations, have shown elevated concentrations of various constituents which appear to originate from past operations at or near the Monsanto Plant.

The nature, extent, and temporal changes of the constituent plumes for each of the two basalt zones are discussed below. The plumes are discussed in terms of elevated constituents (concentrations greater than the appropriate UTL) rather than in terms of constituents of potential interest (constituents which exceeded the preliminary risk screening criterion) in order to observe the extent and direction of the plumes and to facilitate a comparison with past plume behavior.

4.5.4.1 Upper Basalt Zone

Concentration contour plots within the UBZ for October, 1991 of selected representative constituents (metals — cadmium, manganese, selenium, vanadium, and zinc; non-metallic ions — ammonium as N, chloride, fluoride, and sulfate; and radon) are shown in Figures 4-2 through 4-11 (Tables 4-14 and 4-15 list all the constituents found at elevated levels in both the UBZ and the LBZ). The concentration contours (isopleths) and the corresponding values from the sampled wells and springs on which the isopleths are based are shown on the isopleth plots (see Figure 3-16 for location of wells in the UBZ). Previous plots from 1987 and 1984/1985 are found in Golder (1985 and 1988a).

These plots show that plumes of specific constituents are migrating from sources in the northwest and north-central portions of the Plant southeastward. The sources were identified during the original Golder (1985) investigation as the northwest pond, the old underflow solids ponds, and the old hydroclarifier (see Figure 2-5 for on-site well locations with respect to sources of constituent releases). For chloride, sulfate, vanadium, ammonium as N, and radon; the data indicate that a source exists east of the Monsanto Plant.

A view of temporal behavior in the UBZ is provided in concentration versus time graphs for several key wells and constituents. These graphs are presented in Figures 4-12 through 4-48 and are also discussed below.

The UBZ and LBZ have been divided into smaller regions, based primarily on hydrogeological controls and groundwater quality as discussed in Paragraph 3.6.2.2 (Groundwater Flow Systems), in order to facilitate the description of the local flow systems and the characterization of the plumes with respect to the sources of constituent releases. The breakdown of the UBZ and LBZ regions is reiterated below, including source locations:

UBZ-1 & LBZ-1	the immediate southwestern corner of the Plant bounded by the subsidiary fault to the northeast and, for the UBZ, the springs and Harris well located in the vicinity southwest of the Plant; includes the coke and quartzite dust slurry pond, the effluent settling pond and effluent ditch, and the sewage evaporation ponds;
UBZ-2 & LBZ-2	the southwestern portion of the Plant bounded by the major and subsidiary faults and, for the UBZ, includes the Lewis Well located south of the Plant; also includes the old underflow solids ponds;
UBZ-3 & LBZ-3	the eastern and southeastern portions of the Plant (influenced by Kerr-McGee operations);
UBZ-4 & LBZ-4	the remaining portions of the Plant which are not mentioned above, primarily consisting of the northern and central portions of the Plant; also includes the northwest pond and the old hydroclarifier; and
UBZ-5	the springs located to the east of the Plant (Formation Spring) and southeast of the Plant (Ledger, Finch, Boy Scout, Spring Box, and Kelly Park springs).

Each region will be discussed individually below.

UBZ-1

The wells and springs used as sampling points in this region include TW-10, Harris well, and Hooper, Doc Kackley, Southwest, Calf, Mormon A, B, and C, and Homestead Springs. Control groundwater quality for this region consists of sodic water and mixed sodic and fresh water (see Table 3-15 for definitions of water-quality types). Table 4-13 breaks down the sampled wells and springs by flow systems and by well or spring use (as a control or a potentially-affected area monitoring function).

Of the selected constituents mentioned at the beginning of Paragraph 4.5.4.1, elevated concentrations (concentrations greater than the appropriate UTL for fresh or sodic water) of cadmium, selenium, chloride, and fluoride were found in this region. Tables 4-14 and 4-15 list UTLs for fresh and sodic waters, respectively, for all constituent that were analyzed; and

Figures 4-2 through 4-11 are isopleth plots of the selected constituent that provide chemical concentrations at each sampled well and spring location.

Elevated concentrations of selenium are found only in Southwest Spring. The temporal trend for selenium concentrations in the region has been somewhat sporadic but shows an overall decline since 1986 (Figures 4-12 and 4-13) to undetectable concentrations.

The elevated concentrations of cadmium are found in Calf and Mormon A, B, and C springs (Figure 4-2). The concentration in Calf Spring (0.006 mg/L), however, is just above the UTL (0.005 mg/L). The temporal trend for cadmium concentrations shows that a small jump in concentration (> 0.01 mg/L) occurred in Calf Spring, TW-10, and Harris well in 1987, but the concentration has been declining since (Figures 4-14 and 4-15). A large jump in cadmium concentration (0.19 mg/L) occurred in Harris well in 1985, but appears to be an isolated incident. The temporal trend for cadmium in Mormon A Spring is steadily decreasing (Figure 4-14).

Elevated concentrations of chloride and fluoride were found in this region (see Figures 4-8 and 4-9 for extent of plumes) which suggests that the sewage evaporation ponds are affecting the groundwater quality at the water table in this area. The temporal trend for chloride (Figures 4-16 and 4-17) shows an initial decrease in concentration at some monitoring locations in this region but reverses around 1985 for TW-10 and 1986 for Calf and Mormon A springs. The temporal trend of chloride recorded at Harris well was an exception and showed a steady decline throughout (Figure 4-17).

The temporal trend for fluoride indicates a steady decline throughout the region since around 1984 and has reached an equilibrium (Figures 4-18 and 4-19). However, the extent of the plume appears to be migrating south as shown by elevated levels of fluoride in most of the region (Figure 4-9).

Elevated levels of sulfate are not found in this region but the extent of detectable sulfate levels also indicates that a plume is migrating south (Figure 4-10). The temporal trend of sulfate concentrations in the region has been decreasing overall, however, slight increases of 23 mg/L, 27 mg/L, and 46 mg/L are evident since 1987 at TW-10, Calf Spring and Mormon A Spring, respectively (Figures 4-20 and 4-21).

UBZ-2

The wells used as sampling points in this region include TW-20, TW-22, TW-36, TW-37, TW-39, and Lewis Well. The control-groundwater quality in the UBZ for this region is assumed to be fresh (Shallow Groundwater System). This assumption is based on the fact that a well downgradient of this region (Lewis Well) is used as a drinking-water supply. There are, however, no wells located upgradient of the region. TW-29 is located to the north of the region, and produces sodic water, but, for this report, is considered to be within region UBZ-4. It is possible that upgradient water relative to UBZ-2 water may be sodic.

Of the selected constituents mentioned at the beginning of Paragraph 4.5.4.1, several constituents (cadmium, manganese, selenium, zinc, ammonium as N, chloride, fluoride, and

sulfate) appear at elevated concentrations (Figures 4-2 through 4-11 and Table 4-13). Based on available groundwater elevation and chemical data, the plumes which appear to be emanating from the old underflow solids ponds have migrated off-site (Figures 4-2 through 4-11). Elevated levels of cadmium, selenium, chloride, fluoride, and sulfate are found in the wells located along the southern Plant boundary downgradient of the source area.

Temporal trends at TW-37 (source area) show concentrations decreasing (Figures 4-22 through 4-25) with the exception of fluoride (Figure 4-26). Fluoride concentrations appear to have reached an equilibrium in the source area. Temporal trends for chloride and sulfate at TW-20, TW-36, and TW-39 (located near or along the southern Plant boundary) are generally increasing and indicate that the mobile constituents in the plume emanating from the old underflow solids ponds have reached the southern Plant boundary (Figures 4-27 and 4-28). Cadmium (Figure 4-29), manganese, and selenium (Figure 4-30), which appear to be retarded with respect to groundwater transport, do not show an increasing trend in concentrations along the southern boundary.

Chloride and sulfate appear at elevated concentrations at Lewis Well (Figures 4-8 and 4-10, Table 4-14 lists the UTLs for chloride and sulfate for fresh groundwater). Temporal trends for chloride and sulfate are somewhat sporadic (Figure 4-31), but appear to have reached an equilibrium. Since about 1979, chloride and sulfate concentrations have declined by approximately 25 mg/L and 40 mg/L, respectively.

In the past, higher vanadium and ammonium as N concentrations were reported in the Lewis Well. Concentrations presently are undetectable (Figures 4-5 and 4-7). The temporal trend for vanadium shows an overall decline in concentration (Figure 4-32). The ammonium as N concentration trend is somewhat sporadic, but is presently declining. None of the elevated constituents detected in the Lewis Well are in excess of relevant drinking water standards.

UBZ-3

The wells used as sampling points in this region include TW-12, TW-33, and TW-38. Background-water quality in the UBZ for this region is assumed to be that of the Mead Thrust Aquifer System (Table 4-13), but is influenced by operations at the Kerr-McGee Plant, located to the east of the Monsanto Plant.

Based on available groundwater elevation and chemical data, plumes of vanadium, ammonium as N, chloride, and sulfate, which appear to be emanating from east of the Plant, have migrated onto the Plant and south of the Plant (Figures 4-5, 4-7, 4-8, and 4-10). Detectable levels of manganese were also found, but only in TW-12.

Statistical analyses of chemical data was not deemed necessary for this region because the concentrations detected on the Monsanto property were less than those detected in the upgradient Kerr-McGee wells. The constituent concentrations in the Monsanto wells will not exceed the UTLs that would result from statistical calculations.

The Kerr-McGee data was obtained from wells KM-8, KM-9, and KM-13, all located on the western boundary of the Kerr-McGee property. The Kerr-McGee results, for the constituents found at detectable levels on the Monsanto property, are listed in Table 4-18. Data for ammonium was not listed in the Kerr-McGee preliminary chemical analysis database (Dames and Moore 1992). Both KM-8 and KM-13 concentrations exceed the concentrations of all constituents detected in the Monsanto wells. Manganese, vanadium, chloride, and sulfate, therefore, are not found in elevated concentrations is this region at the Monsanto Plant. Ammonium is also considered not elevated in this region as ammonium is not associated with Monsanto Plant operations in the eastern and southeastern portions of the Plant but is associated with Kerr-McGee operations. Detectable levels of ammonium as N are found in TW-12, TW-38, and TW-33 (Figure 4-7). The temporal trend for ammonium shows an increase in concentration (Figure 4-33).

The temporal trend for vanadium shows an increase in TW-33 of approximately 2.5 mg/L since 1987 and a slight increase of less than 0.1 mg/L in TW-38. The vanadium temporal trend in TW-12 appears to have reached an equilibrium (Figure 4-34).

Concentrations of chloride and sulfate appear to be increasing (Figures 4-35 and 4-36). This demonstrates that there is a continued source of affected groundwater emanating from the east (off-site) of the Monsanto Plant.

UBZ-4

The control groundwater quality for this region in the UBZ is primarily fresh (mostly Shallow Groundwater System), however, the groundwater quality in the immediate northwestern corner of the Plant (TW-29) is sodic. The wells used as sampling points for this region consist of most of the wells, completed in the UBZ, located in the northern and central portions of the Plant, excluding the wells located in UBZ-1, UBZ-2, or UBZ-3.

Of the selected constituents mentioned at the beginning of Paragraph 4.5.4.1, several were found at elevated concentrations within this region. These constituents include cadmium, manganese, selenium, zinc, chloride, fluoride, and sulfate.

Based on available groundwater elevations and chemical data, the plumes emanating from the northwest pond and the old hydroclarifier are captured by the production wells located in the center of the Plant, preventing further southeasterly plume migration (Figures 4-2 through 4-11).

Overall, the temporal trends for cadmium, selenium, chloride, fluoride, and sulfate concentrations in the source areas (the northwest pond is just upgradient from TW-16 and the old hydroclarifier is adjacent to and upgradient of TW-40, TW-42, and TW-43) are generally decreasing (Figures 4-37 through 4-41).

Temporal trends at the PW-1 and PW-2 are somewhat sporadic (Figures 4-42 through 4-46).

UBZ-5

The springs used as sampling points in this region include Formation A, B, and C, Finch, Boy Scout, Spring Box, Ledger A, B, and C, and Kelly Park springs. The control groundwater quality for Formation Spring (northeast of the Plant) is fresh (Mead Thrust Aquifer System type). Background quality in the vicinity southeast of the Plant is a mixture of the two fresh flow systems (Mead Thrust Aquifer System and Shallow Groundwater System).

Based on available groundwater elevation and chemical data, the plumes of vanadium, ammonium, chloride, and sulfate, which are emanating from east of the Monsanto Plant and were discussed for region UBZ-3 above, appear to be migrating south and may influence groundwater quality at Finch Spring. Figures 4-5, 4-7, 4-8, and 4-10 show the extent of plume migration. Chloride and ammonium concentrations in Finch Spring appear to be increasing with time (Figures 4-47). Vanadium and sulfate concentrations are presently decreasing with time (Figure 4-48).

4.5.4.2 Lower Basalt Zone

Concentration contour plots within the LBZ for October, 1991 of selected representative constituents (metals — cadmium, iron, manganese, vanadium, zinc; non-metallic ions — ammonium as N, chloride, fluoride, and sulfate; and radon) are shown in Figures 4-49 through 4-58.

A view of temporal behavior in the LBZ is provided in concentration versus time graphs for selected wells. These graphs are presented in Figures 4-59 through 4-69.

The LBZ underneath the Plant has been divided into four regions (LBZ-1, LBZ-2, LBZ-3, and LBZ-4), as discussed in Paragraph 4.5.4.1 (Upper Basalt Zone).

LBZ-1

Only one well (TW-9) in this region was used as a sampling point. Background groundwater quality for this region is sodic. Of the selected constituents, none were found at elevated levels (concentrations greater than the appropriate UTL for sodic groundwater).

LBZ-2

The wells used as sampling points in this region include TW-21, TW-34, TW-35, TW-23, and TW-45. Background groundwater quality for this region is also sodic.

Of the selected constituents, cadmium, zinc, chloride, fluoride, and sulfate were found at elevated levels. These same constituents are also present at elevated concentrations in the UBZ at the same location.

Two former monitoring wells in this area (TW-5 and TW-6) were found in the past to have poor seals, allowing direct hydraulic communication between the UBZ and LBZ (Golder 1985). The well bore served as a conduit for the downward migration of affected groundwater. TW-

5 and TW-6 were subsequently drilled out and the boreholes grouted to prevent direct inter-aquifer communication.

Temporal trends in the source area (TW-45) and approximately 800 feet downgradient of the source area (TW-23) show an overall decline (Figures 4-59 through 4-63) in constituent concentrations.

LBZ-3

The wells used as sampling points in this region include TW-11 and TW-32. Background groundwater quality for this region is Mead Thrust Aquifer System type but is influenced by operations at the Kerr-McGee Plant.

Of the selected constituents, vanadium, ammonium as N, chloride, and sulfate were found in detectable levels (concentrations greater than the SQL) in this region. As discussed for UBZ-3, the concentrations of detected constituents in this region are less than those found in Kerr-McGee wells (Table 4-18) and, therefore, the concentrations found on the Monsanto property in this region are not considered elevated. These same constituents are also present at detectable levels in the UBZ at the same location.

Temporal trends TW-11 and TW-32 generally show an increase in concentrations for the constituents mentioned above except for ammonium (Figures 4-64 through 4-67). The extent of the plume to the south of the Plant is unknown but appear to be migrating off-site (Figures 4-55 and 4-57).

LBZ-4

The wells used as sampling points in this region include PW-1, PW-2, PW-3, PW-4, TW-2, TW-18, TW-28, and TW-44. The four production wells and TW-2, however, are opened to both the LBZ and the UBZ. Background groundwater quality for this region is primarily sodic. Water quality data is unknown in the northeastern and immediate center portions of the Plant (Figure 3-22).

Of the selected constituents, cadmium, chloride, fluoride, and sulfate were found at elevated levels in this region. However, these constituents were found at elevated levels only in the productions wells located in the central portion of the Plant (PW-1, PW-2, and PW-3) which produce groundwater primarily from the UBZ, due to higher UBZ hydraulic conductivities as discussed in Subsection 3.6.2.1 (Hydrostratigraphy). The elevated constituents are, therefore, assumed to be found in the UBZ and not the LBZ for this region.

The temporal trends in TW-44 for cadmium and sulfate show a large initial decline (about 0.4 mg/L for cadmium and 150 mg/L for sulfate) and have since reached somewhat of an equilibrium. The temporal trend for chloride shows a decline (Figures 4-68 and 4-69).

4.6 Biotic Quality

Potential affects to critical and sensitive habitats identified in Paragraph 3.7.2.3 (Critical and Sensitive Habitats) are addressed in Section 5 (Fate and Transport) and (Baseline Risk Assessment).

4.7 Nature and Extent of Constituent Release Summary

This section provides a summary of the known nature and extent of constituent releases at the Monsanto Plant within the environmental media — air, surface water and sediments, soil, and groundwater — subjected to evaluation during the first phase of the RI. Constituents of potential interest are identified for each environmental medium, with the exception of sediments where elevated constituents are identified with no further screening. Constituents of potential interest are those attributable to Plant operations (except in soils where this is inconclusive) which were encountered at concentrations elevated above control levels, and that did not pass the preliminary conservative risk-based screening. In general, the constituents of potential interest for the Plant are subsets of those anticipated based on reviews of scoping information and early investigative efforts.

Table 4-19 provides a matrix of constituents of potential interest occurrence by each sampled environmental medium.

4.7.1 Air Quality Summary

Mean annual control TSP concentrations in the Soda Springs area have been measured from 1986 to 1988 at 0.020 mg/m^3 to 0.032 mg/m^3 (based on geometric means). The average annual TSP concentrations measured at the Harris Ranch were typically 0.032 mg/m^3 to 0.042 mg/m^3, and the average difference between mean annual control levels and ambient concentrations at the Harris Ranch were about 0.012 mg/m^3 to 0.017 mg/m^3. There were no exceedences of the primary or secondary ambient air quality criteria of 0.075 mg/m^3 and 0.060 mg/m^3, respectively, for the period of record.

The average difference between individually-paired TSP concentrations at the Harris Ranch and the two control monitoring stations indicates that the average arithmetic mean difference is about 0.023 mg/m^3 to 0.027 mg/m^3. This difference represents the maximum potential average annual affects of emissions from the Monsanto Plant on air quality at the Harris Ranch. The actual affects of Plant emissions are likely to be lower, however, because the measured incremental difference of 0.023 mg/m^3 to 0.027 mg/m^3 includes emissions from other sources not associated with the Monsanto Plant such as roads, agricultural activity in adjacent fields, and emissions from other industrial sources in the vicinity. Therefore, for the purposes of dispersion modeling assessment of Plant emissions discussed in Section 5.3.1, the incremental difference of 0.023 mg/m^3 to 0.027 mg/m^3 represents the upper bound limit of anticipated effects at the Harris Ranch due to Plant emissions.

Average annual and seasonal PM_{10} concentration levels measured at the Terrace Acres Mobile Court approximately one mile south of the Monsanto Plant are typically less than 0.030 mg/m^3. There are no control monitoring data for PM_{10} to determine potential incremental differences between the levels at the mobile court and control levels. The average arithmetic mean annual concentration of 0.0268 mg/m^3 measured in 1988 was well below the ambient air quality criterion of 0.050 mg/m^3.

4.7.2 Surface-Water and Sediment Quality Summary

None of the constituents analyzed in this RI exceeded preliminary risk-based screening criteria for surface water in Soda Creek downstream of the non-contact cooling water effluent discharge.

The sediments in Soda Creek were statistically compare to determine which constituents in the sediments downstream of the non-contact cooling water effluent discharge were elevated. There were seven elevated constituents identified in the sediments in Soda Creek 100 feet downstream of the effluent discharge, and three elevated constituents identified in sediments 300 feet downstream of the effluent discharge. There are no criteria for sediments at present with which to conduct preliminary screening; therefore the elevated constituents in Soda Creek stream sediments will be considered in Chapter 5 (Constituent Fate and Transport). These elevated constituents are listed below:

- Elevated constituents in sediments, 100 feet downstream of the effluent discharge

  cadmium
  copper
  nickel
  selenium
  silver
  vanadium
  polonium-210

- Elevated constituents in sediments, 300 feet downstream of the effluent discharge

  selenium
  silver
  vanadium

The number of elevated constituents in Soda Creek sediments decreases with distance downstream.

4.7.3 Soil Quality Summary

The soils from two sampling depths (0 to 1 inch and 0 to 6 inches) in the Plant vicinity were statistically determined to have significant differences in concentrations for many constituents.

Therefore, preliminary screening was done on these two discrete groups. A total of eight constituents of potential interest were identified for each of the soils groups as listed below:

- Constituents of potential interest in surface-soil (0-to-1-inch) group

  arsenic
  beryllium
  cadmium
  lead-210
  polonium-210
  radium-226
  thorium-230
  uranium

- Constituents of potential interest in subsurface-soil (0-to-6-inch) group

  arsenic
  beryllium
  manganese
  lead-210
  polonium-210
  radium-226
  thorium-230
  uranium

The constituents of potential interest are the same in the two groups except that the surface soils do not have manganese, and the subsurface soils do not have cadmium.

4.7.4 Groundwater Quality Summary

Groundwater in the Monsanto vicinity has been separated into three distinct flow systems. There are two fresh groundwater systems (Shallow Groundwater and Mead Thrust Aquifer systems) and one sodic groundwater system (Chesterfield Range Aquifer system). The results for wells in the Mead Thrust Aquifer System on and downgradient of the Monsanto Plant were not subjected to statistical analysis because this system is affected by operations at the Kerr-McGee facility (see subsection 4.5.1 Control Groundwater Quality). The fresh and sodic groundwater systems (represented by the Shallow Groundwater and the Chesterfield Range Aquifer systems, respectively) were each subjected to preliminary risk screening to identify the constituents of potential interest for each system. There were nine and four constituents of potential interest identified for the fresh and sodic flow systems, respectively, as listed below:

- Constituents of potential interest in fresh groundwater (Shallow Groundwater System)

arsenic
cadmium
nickel
selenium
zinc
ammonium as N
fluoride
nitrite/nitrate as N
radium-226

- Constituents of potential interest in sodic groundwater (Chesterfield Range Aquifer System)

  cadmium
  selenium
  fluoride

The UBZ and the LBZ were each divided into smaller regions based on hydrogeologic controls and groundwater quality as discussed in Paragraph 3.6.2.2 (Groundwater Flow Systems). These regions were evaluated separately to characterize plumes of constituents with respect to sources of constituent releases in each region.There are four plumes identified in the UBZ, one in each region (UBZ-1, UBZ-2, UBZ-3, and UBZ-4), and two plumes identified in the LBZ, in regions LBZ-2 and LBZ-3.

The temporal trend in UBZ-1 indicates a decrease in concentration with respect to cadmium but an increase with respect to chloride and sulfate which suggests that the evaporation sewage ponds are affecting groundwater quality in UBZ-1. The mass of the plume appears to be migrating off-site in a southerly direction.

Concentrations at the source area (old underflow solids ponds) in UBZ-2 have been decreasing with time, with the exception of fluoride which has reached an equilibrium. The mobile constituents in the plume have migrated in a southerly direction as indicated by increased concentrations along the southern Plant boundary.

The plume in UBZ-3 originates off-site to the east of the Monsanto Plant. The plume is increasing in concentration and is also migrating to the south off-site. The plume in UBZ-4 is decreasing in concentration and is being captured by the production wells located in the central portion of the Plant, preventing further southeasterly plume migration.

The groundwater quality in LBZ-2 was affected in the past by poor well-completion, which caused hydraulic communication between UBZ-2 and LBZ-2. The faulty wells have since been abandoned and the resulting plume in LBZ-2 appear to be decreasing in concentration.

The plume in LBZ-3 originates east of the Monsanto Plant, is increasing in concentration and appears to be migrating off-site.

Section 5

5. CONSTITUENT FATE AND TRANSPORT ANALYSIS

This chapter provides an analysis of the environmental fate of the constituents of potential interest that were identified in Chapter 4 (Nature and Extent of Monsanto Plant Constituent Releases). The transport of these constituents, through various pertinent environmental media, is also analyzed within this chapter. Thus, the known nature and extent of constituent releases, as determined from empirical observation (see Sections 4.2, 4.4, and 4.5), are extrapolated to provide a detailed conceptual model of the types and distributions of the constituents within the environment.

Section 5.1 discusses potentially significant (results in adverse effects) constituent migration pathways and identifies those that may be operative at the Monsanto Plant. Constituent fate is discussed in Section 5.2. This discussion addresses the anticipated physical, chemical, or biochemical transformations a particular constituent may be subjected to under environmental conditions. The chapter concludes with an analysis (Section 5.3) of constituent transport via the air migration pathway. Only the air pathway was evaluated quantitatively because data needed to model constituent transport through other media were insufficient.

5.1 Potential Pathways of Constituent Migration

A constituent migration pathway is a specific transport process, often involving multiple environmental media, that terminates (in terms of a hazardous substance response perspective) in human or environmental receptor exposure, or at least the potential for such exposure. Each exposure pathway consists of the following five elements (EPA 1986b):

- A constituent source;
- A constituent release mechanism;
- An environmental transport medium (or media);
- An exposure route; and
- A receptor.

Figure 5-1 illustrates the potentially significant pathways for human and wildlife exposure to constituents of potential interest through the air, soil, and water media. Direct exposure routes to humans are via:

- Ingestion of affected groundwater; and
- Inhalation of fugitive dust and stack emissions.

In addition, humans are receptors for a biological transport pathway:

- Consumption of affected beef.

Physical and chemical properties of the constituent sources at the Monsanto Plant are described in Sections 3.1 and 4.1, respectively. Receptor populations are described in Section

3.7. This section focuses on constituent release mechanisms and environmental transport media of interest for the Monsanto Plant.

Each potentially significant constituent migration pathway at the Monsanto Plant is discussed qualitatively below by the predominant environmental medium involved: air (Subsection 5.1.1), surface water (Subsection 5.1.2), surface soil (Subsection 5.1.3), groundwater (Subsection 5.1.4), and biota (Subsection 5.1.5).

5.1.1 Air Pathways

For the air pathway to be operative, at least one of two release mechanisms must exist: emission of vapors or emission of fugitive dusts. The Monsanto Plant contains several permitted stacks having vaporous emissions, and there are several sources of fugitive dust emissions at the Plant. No ambient air or stack monitoring was performed during the Phase I RI, but previous investigations have demonstrated that cadmium and fluoride are two substances of most interest in this medium (see Section 4.2) Therefore, these two substances, along with total suspended particulates (TSP) and respirable particulates (PM_{10}), are subjected to preliminary transport evaluation in Subsection 5.3.1.

Section 4.4 shows there are elevated concentration of several constituents in the surface soils around the perimeter of the Plant. Although the surface soil sampling design was not specific to the Monsanto Plant, preliminary risk-based screening has indicated that, under worse case condition, inhalation of fugitive dust generated from these soils could perhaps pose an unacceptable risk. This specific pathway, however, is not evaluated further. Total emissions (both fugitive dust and from stacks) from the Plant as a whole will obviously overwhelm any contributions from resuspended off-site soils.

5.1.2 Surface-Water and Sediment Pathways

Wastes generated by the Monsanto Plant are discharged to surface water; therefore, this medium must be considered in terms of it being a potentially significant constituent migration pathway. Surface water pathways for constituent migration are evaluated for the permitted discharge of non-contact cooling water to Soda Creek, as well as for non-discharging lagoons such as the permitted sanitary-waste lagoons and the phossy-water pond.

The sanitary-waste lagoons serve as habitat for some local waterfowl (ducks). These lagoons only receive human wastes generated on-site; therefore, the composition of the effluent and sludges in the lagoons should have a similar quality to other small municipal sanitary waste lagoons. The use of sanitary waste lagoons as habitat by waterfowl is a common occurrence throughout the western United States. The widespread nature of this usage, together with the lack of observed ill-effects in the local waterfowl population, suggest that the sanitary waste lagoons at the Monsanto Plant have little environmental consequence. Therefore the sanitary waste lagoons are not regarded as a significant pathway and, as a result, are not given further consideration in this report.

Monsanto has never noted any use of the lined phossy-water pond by waterfowl (Wright, B., Golder [Memo to Monsanto Soda Springs Plant Phase I RI File] November 2, 1991). Therefore, this pond is also excluded from further evaluation. Waterfowl, however, do use the non-contact cooling water retention ponds in addition to the nearby sanitary lagoons. Waterfowl usage of the non-contact cooling water retention ponds is regarded as an insignificant pathway because ducks are not regarded as sensitive species (as defined in section 3.7), the population involved is small, and there have been no ill-effects observed in this population.

Groundwater from production wells located at the Plant are used for non-contact cooling water. The non-contact cooling water is discharged to Soda Creek under terms of an NPDES permit. No constituents of potential interest are found in the water column of Soda Creek below the non-contact cooling water effluent discharge point (see Section 4.3). One can conclude, therefore, that there is no adverse effect, associated with the water column, to either human health or the environment attributable to this permitted discharge. The Soda Creek water column pathway is therefore regarded as insignificant and not evaluated further.

Sediments collected downstream of the effluent discharge were found to have elevated constituent levels (see Subsection 4.3.3). The elevated constituents found in sediments collected 100 feet downstream of the non-contact cooling water effluent discharge point are cadmium, copper, nickel, polonium-210, selenium, silver, and vanadium. The elevated constituents found in sediments collected 300 feet downstream are selenium, silver, and vanadium. Although the sediments are a potentially significant transport medium, there is no effective way, in the absence of established sediment quality criteria, to determine likely effects to the environment during this phase of the remedial investigation. Even though environmental effects of these elevated constituents are not evaluated, it should be noted that the portion of Soda Creek known to be affected is not regarded as a sensitive habitat (see Section 3.7).

Furthermore, although based on only two data points, the number of elevated constituents appears to decrease rapidly downstream (at 300 feet, compared to 100 feet, below the effluent discharge point, only selenium, silver and vanadium are elevated). If this likely trend persists, it is highly probable that there is an absence of elevated constituents in the stream sediments in the lower, more sensitive reach of Soda Creek.

5.1.3 Soil Pathways

Potentially significant migration pathways for constituents of potential interest found in the surface soils include physical transport of surface soil constituents in air, direct contact with and incidental ingestion of surface soils, and constituent transport through the food chain, including human consumption of food crops (e.g., wheat or barley) or herbivores (e.g., cattle).

The physical transport of surface soil constituents is qualitatively addressed under air transport in Subsection 5.3.1.

The transport of constituents of potential interest from the soil to the food chain can generally occur through two related pathways. The first food-chain pathway involves:

- Uptake by forage crops of constituents of potential interest found in the soil root zone (0 to 6 inches);
- Ingestion of affected forage crops by herbivores; and
- Ingestion of affected herbivores by humans.

A second possible food-chain pathway involves:

- Uptake by food crops of constituents of potential interest found in the soil root zone; and
- Ingestion of affected food crops by humans.

When the primary route of human exposure is through food, the people most likely to receive the highest exposure are the farmers who eat their own product (Fries 1988). Exposure of the general population will be several orders of magnitude lower because typically agricultural products (meat, dairy products, and crops) are distributed widely, and food containing constituents of potential interest will be diluted by food grown elsewhere.

Principal crops grown in the vicinity of the Monsanto Plant include alfalfa and barley for animal feed, and wheat for human consumption. Wheat is a commodity crop that is highly refined and widely distributed. Therefore, it is unlikely that wheat grown in the area around the Monsanto Plant will pose any risk to human health. Consequently, the pathway judged most likely to have a potential for impact to human health is human consumption of beef cattle that are fed forage grown on soil with constituents of potential interest.

Although mule deer, a game species consumed by humans, occasionally use the area to the north of the Plant (see Subsection 3.7.2), this species is not included in the biotic transport pathway evaluation. Human consumption of herbivores that are fed forage grown on soil with elevated levels of constituents of potential interest is judged to have a greater potential for affect to human health.

5.1.4 Groundwater Pathways

The subsurface constituent migration pathway involves migration in both the vadose-zone and the saturated zone. Constituents transported downward through the vadose zone eventually reach the water table and are transported further through the saturated zone. Thus, for the subsurface pathway to be operative there must first be a release to the soil, with a sufficient amount of subsequent infiltration to allow constituents to reach the water table.

Constituents of potential interest have been found in the groundwater (Section 4.5). The same constituents have also been identified in the source materials at the Monsanto Plant. Therefore, the subsurface constituent migration pathway must be considered in more detail.

There are two constituent plumes identified at the Plant (Section 4.5). The constituent plume (originating from the northwest pond and the old hydroclarifier) in the center of the Plant is currently captured by the production wells. Consequently, there is no risk assumed for this particular plume. The region of groundwater with constituents of potential interest that requires further consideration is located between the major fault and the subsidiary fault underlying the Plant (see Figure 3-10). The potential for downgradient migration of these constituents through groundwater flow is evaluated in this section.

For the purposes of this investigation there is one potential pathway that may result in adverse effects to human health. This pathway includes:

- Groundwater transport from the Monsanto Plant to a drinking water supply well; and

- Human ingestion of groundwater from such a well.

The only known drinking water supply well hydraulically downgradient of the Monsanto Plant is Lewis Well (see Paragraph 3.7.1.2). Currently, the only constituents of potential interest detected in Lewis Well are ammonium-N, fluoride, nitrate/nitrite-N, and zinc. None of these constituents exceed potentially relevant drinking water standards at this time. Constituents of potential interest currently found in groundwater beneath the Plant are ammonium-N, arsenic, cadmium, fluoride, nickel, nitrate/nitrite-N, radium-226, selenium, and zinc.

Other wells of unknown use are shown to exist between the Plant and the Bear River (see Figure 3-24), but given the locations and the likelihood that all residences within the City of Soda Spring are tied into the city water supply system (which obtains water from springs located upgradient of any sources of constituent release on the Monsanto Plant), these additional wells are assumed to not serve as drinking water supplies.

5.1.5 Biotic Pathways

The identification of potentially significant biotic pathways has been incorporated into the above discussions of the various physical pathways. There are, however, two sensitive habitats not addressed in the above discussions:

- The Nature Conservancy's Formation Cave property, which consists of ponds containing non-sustaining populations of trout; and

- Ledger Creek, which provides habitat of the sensitive hoary willow (see Subsection 3.7.2).

These two habitats are not evaluated further because of their location with respect to the Monsanto Plant — they are both situated hydraulically upgradient of any Plant-specific sources of constituent release to the groundwater.

5.2 Constituent Fate

This section provides information on the environmental fate of the Monsanto Plant constituents of potential interest identified in Chapter 4. The Monsanto Plant constituents of potential interest (or elevated constituents, for aquatic sediments) and the environmental media in which they are found are:

ammonium-N	groundwater (fresh)
arsenic	soil (A group and B group), groundwater (fresh)
beryllium	soil (A group and B group)
cadmium	sediment, soil (A group), groundwater (fresh and sodic)
copper	sediment
fluoride	groundwater (fresh and sodic)
lead-210	soil (A group and B group)
manganese	soil (B group)
nickel	sediment, groundwater (fresh)
nitrate/nitrite-N	groundwater (fresh)
polonium-210	sediment, soil (A group and B group)
radium-226	soil (A group and B group), groundwater (fresh)
selenium	sediment, groundwater (fresh and sodic)
silver	sediment
thorium-230	soil (A group and B group)
uranium	soil (A group and B group)
vanadium	sediment
zinc	groundwater (fresh and sodic)

A discussion of the environmental fate of each is presented below. Elevated concentrations of copper, silver, and vanadium were only found in Soda Creek sediments 300 feet downstream of the non-contact cooling water effluent discharge point. These constituents are discussed below for completeness, but are not evaluated further for potential risk to the environment or human health due to an absence of established sediment quality criteria.

5.2.1 Ammonium-N

Ammonia is both a natural and manmade chemical. It is a key intermediary in the natural nitrogen cycle, and microbial production is the major source of ammonia in the world. Soil is the major source of naturally occurring ammonia.

The ammonium ion (NH_4^+) is the dominant form of ammonia (NH_3) in soils and water at environmentally significant pHs. Ammonia and ammonium are in dynamic equilibrium,

however, at pH <8.25, more than 90% of the ammonia will be ionized as ammonium (Syracuse Research Corp. 1989a).

The ammonium ion is subject to transport and partitioning processes and undergoes transformation and degradation reactions. The ammonium ion is subject to sorption processes, however, the ammonium ion is only weakly retained by most soils or sediments. Generally, sorption will increase with increasing organic-matter content and decrease with increasing pH. Other factors include the presence of metallic ions, microbial population, certain clay minerals, and its uptake by plants. Ammonium sorption is also influenced by the rate of ammonia volatilization from the media. Because of the equilibrium between ammonia and the ammonium ion, any volatilization of ammonia will result in a decrease in ammonium content. Ammonia is a nutrient source that can be utilized by plants and microbes and converted to inorganic and organic nitrogen compounds.

Ammonium is subject to volatilization as ammonia, with the rate of volatilization increasing with pH and temperature. In the atmosphere, the ammonia is readily removed by rain or snow washout.

As a nutrient, ammonium is readily taken up by plants. It is possible for very high localized concentrations of ammonia to become toxic to plants and microbiota, however, other physicochemical processes (e.g. volatilization or ammonia-ammonium equilibrium) act to return ammonia to tolerable levels. In general, ammonium in aerobic soils is readily converted to nitrite that is subsequently converted to nitrate by the microbiota and seldom accumulates to toxic concentrations.

In aquatic environments, ammonia can become toxic to fish at concentrations greater than 0.2 to 1 mg/L NH_3, but there is little or no evidence to suggest a toxic effect due to ammonium (Rand and Petrocelli 1985). There is no indication that ammonia or ammonium bioaccumulates in aquatic organisms.

5.2.2 Arsenic

Arsenic is a naturally occurring element in the earth's crust and can be released to the environment by natural processes (e.g., volcanoes, erosion of natural deposits). Anthropogenic activities (e.g., metal smelting, chemical production), however, account for much of the current arsenic in the environment (Life Systems, Inc. 1991a).

Arsenic is a semi-metal, having multiple valence states: -3, 0, +3, +5. Of these valence states, arsenic (V) is characteristic of aerobic environments and forms various hydrated complexes of the arsenate (AsO_4^{3-}) anion. Complex anions of trivalent or pentavalent arsenic are the most mobile forms of arsenic. Arsenic in the environment may undergo a complex cycle of chemical conversions and transfers between media, but its biogeochemical behavior resembles phosphate to a large degree (Kabata-Pendias and Pendias 1984a).

Arsenic released to land is relatively immobile, due to sorption on soil particles. Complexation and chelation by organic material, iron, aluminum, or calcium are important

processes that can fix arsenic in insoluble forms. Although rainwater or snowmelt may leach soluble arsenic forms into surface water or groundwater, transportation is limited to short distances because of sorption to soils or sediments (Life Systems, Inc. 1991a). Leaching of arsenic is usually important only near the soil surface (<12 inches) and its mobility in soils is reported to be proportional to the amount of arsenic added and inversely proportional to residence time and to iron and aluminum content (Kabata-Pendias and Pendias 1984). Thus, arsenic transport in soils is a function of quantity, valence state, chemical speciation, and other site factors. In aerobic conditions, arsenic mobility is limited. As oxidation potentials decrease, reduced forms of arsenic dominate and mobility increases. At very low oxidation-reduction potentials, it is possible for soil microorganisms to reduce small amounts of arsenic to volatile forms (e.g., arsine, AsH_3).

The transport and partitioning of arsenic in water depends on oxidation-reduction potential, pH, counterion concentration, temperature, salinity, and type of biota present. Arsenic chemistry is complex; shifts in oxidation states in either direction can dramatically alter solubility and mobility. Arsenic can exhibit high mobility depending on the prevailing equilibrium-controlling reactions (Callahan et al. 1979). Arsenic species can readily adsorb onto sediments, especially clays, iron oxides, aluminum hydroxides, manganese compounds, and organic material. The transport of sediment-bound arsenic depends on water flow characteristics. Sediment-bound arsenic can be released back into the water by chemical or biological interconversions of arsenic species (Life Systems, Inc. 1991a). Arsenate anions are the predominant form of arsenic in surface waters and groundwater. Other reduced forms of arsenic may dominate depending on environmental conditions such as microbial activity, water chemistry, and surrounding geology. Volatilization of arsenic in water occurs only at low oxidation-reduction potentials in the presence of specialized microbiota.

Arsenic in the atmosphere occurs primarily as particulate matter. Its occurrence is due to the wind erosion of contaminated soils or the volatilization of arsenic species from soil, surface water, or groundwater. Arsenic released to the atmosphere is primarily arsenic trioxide (As_2O_3) or less frequently as volatile organic compounds, such as arsine. Trivalent arsenic and arsine undergo oxidation to pentavalent arsenic, and arsenic in the atmosphere is a mixture of trivalent and pentavalent forms. The residence time in the atmosphere depends on particle size and meteorological conditions, but an average residence time of nine days is estimated (Life Systems, Inc. 1991a). Arsenic in particulate form is removed from the atmosphere by rain washout and dry fallout.

Bioconcentration of arsenic occurs in aquatic organisms, primarily in algae and invertebrates. Arsenic bioconcentration factors (BCFs) measured in freshwater invertebrates and fish typically ranged from 0 to 17 (Life Systems, Inc. 1991a), although EPA (1986b) reports a fish BCF of 44. Although some fish and invertebrate species can contain high levels of arsenic compounds, much of the arsenic exists in an organic form that is noncarcinogenic and essentially nontoxic (Life Systems, Inc. 1991a).

Linear relationships between arsenic content of vegetation and soil, for both total and soluble arsenic, suggest that plant uptake of arsenic is a passive process that occurs with mass flow. Arsenic is translocated within the plant because it is found in grain; however, highest arsenic concentrations generally occur in older leaves and in roots (Kabata-Pendias and Pendias 1984).

Arsenic phytotoxicity is commonly noted in plants growing on mine waste, soils treated with arsenical pesticides, or soils amended with sewage sludge. The arsenic tolerance limit in mature leaf tissue for most plants ranges from 5 to 20 mg/kg dry weight (Kabata-Pendias and Pendias 1984).

5.2.3 Beryllium

Beryllium is widely distributed in the earth's crust, but generally comprises less than 10 mg/kg of the major rock types. This metal is likely to concentrate in acid magmatic rocks and argillaceous shales and sediments. During rock weathering, beryllium usually remains in the residuum (Kabata-Pendias and Pendias 1984). The major anthropogenic emission source to the environment is the combustion of coal and fuel oil (Life Systems, Inc. 1991).

In soils, beryllium usually occurs as the divalent cation (Be^{2+}), although complex ions [$(BeO_2)^{2-}$, $(Be_2O_3)^{2-}$, and $(BeO_4)^{6-}$)] are also known to occur (Kabata-Pendias and Pendias 1984). The biogeochemical cycle of beryllium is similar to aluminum. Thus, it is expected to adsorb onto clay surfaces at low pHs and remain sorbed as insoluble complexes at higher pHs (Callahan et al. 1979). Therefore, beryllium is expected to have limited mobility in soils. Likely transformation reactions in soils include hydrolysis of soluble salts, anion exchange reactions, and ligand complexation, all of which are responsive to soil pH.

In surface water and groundwater environments, most beryllium is expected to be associated with sediments, rather than in dissolved forms, due to sorption onto clay particles or the formation and precipitation of insoluble complexes. A high percentage of beryllium will have low mobility in water due to association with sediments; although in very alkaline environments, beryllium solubility and mobility can increase due to the formation of soluble polynuclear hydroxide complexes (Callahan et al. 1979).

Beryllium emitted to the atmosphere exists as beryllium oxide (BeO). The transport of beryllium from the atmosphere to terrestrial and aquatic surfaces occurs through wet and dry deposition. Although aerosol particle deposition is a function of particle size, wind speed, and surface roughness, the average atmospheric residence time for beryllium is approximately 10 days.

Significant bioconcentration of beryllium by aquatic organisms is not likely due to low uptake from water. Reported BCFs for fish, aquatic invertebrates, and freshwater and marine plants range from 19 to 100 (Life Systems, Inc. 1991b; Callahan et al. 1979). It is possible that bottom-feeding organisms could accumulate beryllium from sediments and show higher BCFs than freshwater fish.

Beryllium can be easily taken up by plants when it occurs in soluble forms in soils. Absorption mechanisms of plants for beryllium are similar to those involved in the uptake of magnesium (Mg^{2+}) and calcium (Ca^{2+}), and beryllium is able to replace magnesium in some plants. The plant uptake factor for beryllium is about 0.2 based on a study reported in Kabata-Pendias and Pendias (1984). Plant toxicity to beryllium is also reported at relatively low soil solution concentrations of beryllium (Be^{2+}) ranging from 10^{-3} to 10^{-4} mol/L. Toxic

beryllium concentrations in mature leaves range from 10 to 50 mg/kg (dry weight) depending on plant species and growth conditions.

5.2.4 Cadmium

Cadmium abundance in magmatic and sedimentary rocks is approximately 0.3 mg/kg, but the metal can be concentrated in argillaceous and shale deposits. Its geochemistry is strongly associated with zinc, but exhibits a higher mobility than zinc in acid environments and has a higher affinity for sulfur (Kabata-Pendias and Pendias 1984). Small amounts of cadmium enter the environment from natural weathering of minerals. Major anthropogenic sources of cadmium in the environment include smelting and fossil fuel combustion (Life Systems, Inc. 1991c).

During weathering, cadmium readily goes into solution, and in the natural environment divalent cadmium (Cd^{2+}) is the predominant form. It is also possible, however, for cadmium to form complex ions with other ions such as chloride (Cl^-), hydroxide (OH^-), bicarbonate (HCO_3^-), or organic chelates.

Important factors that control cadmium mobility in soils are pH, cation exchange capacity, and organic matter content. Cadmium is most mobile in acidic soil (pH 4.5 to 5.5), with organic matter and sesquioxides (iron and aluminum) controlling solubility. In alkaline soils, cadmium is relatively immobile and precipitation of cadmium compounds is the likely control factor in cadmium equilibria (Kabata-Pendias and Pendias 1984).

In aquatic environments, cadmium is more mobile than most other heavy metals, such as lead. Its concentration in water is inversely related to pH and the organic matter concentration in water (Callahan et al. 1979). Cadmium typically exists in natural waters as the hydrated divalent ion ($Cd^{2+} \bullet 6H_2O$), or in polluted waters possibly as a complex with humic acids. Precipitation and sorption to mineral surfaces and organic matter are the most important removal processes for soluble cadmium (Life Systems, Inc. 1991c).

Cadmium does not form volatile compounds; therefore, cadmium in the atmosphere exists as suspended particulate matter. It is typically associated with very small particles ($<10\ \mu m$), which are subject to long-range transport. Residence times in the atmosphere range from 1 to 10 days. Removal processes from the atmosphere are due to wet or dry deposition (Life Systems, Inc. 1991c).

Cadmium bioaccumulates at all levels of the food chain; however, the accumulation characteristics of cadmium (in organs rather than muscle tissue) in animals make biomagnification unlikely (Life Systems, Inc. 1991c). In general, there is a direct linear relationship between cadmium in plant material and cadmium in soil. Soluble species of cadmium are easily available to plants, but total and relative uptake of cadmium are controlled by soil pH. Although it is a nonessential element in plants, cadmium is readily adsorbed by both leaf and root systems. Cadmium accumulates in the root tissue, however, even when cadmium is applied foliarly (Life Systems, Inc. 1991c). Cadmium concentrations

greater than 5 mg/kg (dry weight) in either soils or mature plant tissue are considered phytotoxic (Kabata-Pendias and Pendias 1984).

In fresh and marine waters, cadmium is concentrated by animals to concentrations hundreds to thousands of times higher than water (Callahan et al. 1979). Bioconcentration factors for aquatic invertebrates range from 113 to 18,000, and from 3 to 2,213 for fish (Life Systems, Inc. 1991c).

5.2.5 Copper

In the earth's crust, copper is most abundant in mafic and intermediate rocks and forms several sulfide minerals that are readily soluble during weathering processes, especially in acid environments. Natural dispersion of copper in the environment occurs as windblown dust and volcanic eruptions. Major anthropogenic releases of copper are due to mining operations (e.g., copper smelters and ore processing facilities) and agriculture (Syracuse Research Corp. 1989b).

In the surface environment, copper is usually present as the divalent ion (Cu^{2+}), although it readily forms hydrolysis products ($CuOH^+$ and $Cu_2(OH)_2^{2+}$) below pH 7, and anionic hydroxy complexes ($Cu(OH)_3^-$ and $Cu(OH_4^{2-}$) above pH 8. The overall solubility of cation and anion species decreases between pH 7 and 8. The most common forms of soluble copper, however, are organic chelates that are soluble over a wide range of pH (Kabata-Pendias and Pendias 1984).

In general, copper is a rather immobile element in soils, and a common characteristic of its distribution in soils is its accumulation in the surface horizons (Syracuse Research Corp. 1989b, Kabata-Pendias and Pendias 1984). Copper shows a great affinity to interact with mineral and organic components of the soil, and readily precipitates with various anions such as sulfide, carbonate, and hydroxide or is readily sorbed to mineral and organic particle surfaces. Although copper is one of the least mobile heavy metals in soils, copper concentrations in soil solutions depend not only on reactions with active groups at solid phase surfaces, but also with specific substances found in soil solution (Kabata-Pendias and Pendias 1984).

In aqueous environments (surface water or groundwater) copper undergoes reactions similar to those occurring in soil. Depending on pH and ligand concentration, copper can form soluble complexes with organic and inorganic ligands. Copper is, however, strongly sorbed to organic and inorganic sediments, which generally results in low copper concentrations in solution and low copper mobility (Syracuse Research Corp. 1989b).

Copper released to the atmosphere occurs as particulate matter. There are no volatile forms of copper in the natural environment. In the atmosphere, copper remains strongly sorbed to particulate matter and its removal is due to both wet and dry deposition processes. The importance of wet to dry deposition increases with decreasing particle size, although large particles can show a seasonal dependence due to effective scavenging by snow. Mean

residence time for copper sorbed to sub-micron particles ranges from 7 to 30 days (Syracuse Research Corp. 1989b).

Copper is an essential element in plants, with deficiencies generally occurring at concentrations in mature leaf tissue that range from 2 to 5 mg/kg (dry weight). Copper uptake is generally thought to be a result of passive uptake of dissociated forms through the roots. Copper has a relatively low mobility in plants, compared to other elements, and most copper remains in the roots or leaf tissue until they senesce. Plant toxicity to copper generally occurs at concentrations in soil or mature plant tissue that are greater than 100 mg/kg (dry weight) or 20 mg/kg (dry weight), respectively (Kabata-Pendias and Pendias 1984).

Studies conducted in terrestrial and aquatic environments have shown there is a very low potential for copper to bioaccumulate in the food chain, even at the lowest levels (Syracuse Research Corp. 1989b).

5.2.6 Fluoride

Fluoride is common in igneous rocks. Anthropogenic sources of fluoride include air emissions near fertilizer plants and aluminum and iron smelters. Fluorine (F_2), hydrogen fluoride (HF), and silicon tetrafluoride (SiF_4) are volatile by-products of these industries that are potentially toxic when directly absorbed by plants and animals.

After deposition in the soils, the monovalent fluoride anion (F^-) is the only stable oxidation state. In soil minerals it can substitute, to some extent, for OH^-, and is strongly retained by aluminum and iron hydroxides in acidic soils. Fluoride concentrations in soil solutions, and surface and groundwaters of humid and temperate regions are generally less than 0.1 mg/L. In arid regions, however, the fluoride concentrations in groundwaters can reach 1 mg/L or higher. Soil concentration greater than 200 mg/kg and plant tissue concentrations greater than 50 to 500 mg/kg are considered phytotoxic (Kabata-Pendias and Pendias 1984). The upper limit for fluoride concentration for consideration as toxic for livestock drinking water is 2.0 mg/L (Bohn, et al. 1979).

5.2.7 Lead-210

Lead-210 is a naturally occurring decay product produced by the decay of uranium-235. Although its half-life is only 22.3 years, its concentration in the environment will be relatively constant due to the continual decay of more stable isotopes (e.g., radium-226). Its occurrence in the environment is a function of the distribution of uranium-235 and radium-226. The biogeochemical behavior of lead-210 is expected to be similar to the stable isotope of lead (lead-206), and the following discussion is developed using data for this nonradioactive form of the element.

In the natural environment, the stable ionic species of lead is the divalent form (Pb^{2+}). The geochemical characteristics of lead is similar to other divalent alkaline earth metals (e.g. calcium, potassium, barium, and strontium), and lead has the ability to replace these elements

both in minerals and on sorption sites. Lead is relatively immobile in soils and is considered to be one of the least mobile heavy metals (Kabata-Pendias and Pendias 1984). Its solubility is effectively decreased by its selective sorption to mineral surfaces and the ability to readily form sparingly soluble precipitates with hydroxide, phosphate, carbonate, and stable complexes with organic matter. These processes are affected by soil characteristics such as pH, organic matter content, ion-exchange characteristics, the nature of inorganic colloids, and the amount of lead in soil (Clement International Corp. 1991). Although the downward leaching of lead is very slow under natural conditions, conditions that favor the movement of lead through the soil include lead concentrations that exceed the sorptive capacity of the soil, the presence of materials capable of forming soluble lead chelates, or lower pH.

Because the downward movement of lead in soil can be limited, lead tends to accumulate in the soil surface. Therefore, lead transport from soil can involve processes such as water and wind erosion, that actually remove soil particles from the surface. These processes may result in significant contributions to other environmental media.

The forms of lead in aquatic environments are similar to those in soils, although it is possible for organic lead compounds (e.g., tetralkyl lead) to form by a biologically-mediated process. In general, however, soluble lead in aquatic environments will be limited by the same reactions that occur in soils and a significant fraction of the lead carried in surface water will be in an undissolved form. The amount of lead that remains in solution will depend on the pH of the water and its dissolved salt content, especially sulfate (SO_4^{2-}) and carbonate (CO_3^{2-}). Equilibrium concentrations show that at pH >5.4, the total solubility of lead is about 0.03 mg/L in hard water and about 0.5 mg/L in soft water (Clement International Corp. 1991).

In the atmosphere, lead exists primarily in the particulate form and its removal is subject to wet and dry deposition processes. It exists in the atmosphere primarily as lead sulfate ($PbSO_4$), lead carbonate ($PbCO_3$), or as lead halides (e.g., PbBrCl) (Clement International Corp. 1991).

Lead is not known to have any essential role in plant metabolism. Plant uptake of lead is passive and absorbed mainly by root hairs and stored in cell walls. There is limited translocation of lead from roots to tops. Although lead in soil shows a low bioavailability, it has a high accumulation potential in plant roots. Lead concentrations greater than 100 mg/kg (dry weight) in soil and greater than 30 to 300 mg/kg in mature plant tissue are considered phytotoxic.

There is no evidence yet to suggest that lead is biomagnified in food chains, but it may accumulate in plants and animals. In aquatic organisms, lead concentrations are usually highest in benthic organisms (feeding on sediments) and lowest in upper-trophic level predators (e.g. carnivorous fish). High BCFs (6,600 to 92,000) were found in studies using oysters and freshwater and marine algae (Clement International Corp. 1991).

5.2.8 Manganese

Manganese is a naturally occurring substance found in many types of rocks (highest concentrations in mafics). Manganese may be released by natural weathering processes or anthropogenic activities. Major anthropogenic sources are industrial emissions/discharges, fossil fuel combustion, and landfill leachates (Life Systems, Inc. 1990).

Manganese has physical and chemical properties similar to iron, and readily combines with other elements such as oxygen, sulfur, and chlorine in solid phases (Kabata-Pendias and Pendias 1984). Manganese compounds are soluble in water and low concentrations are normal in lakes, streams, and the ocean. Upon weathering, manganese is oxidized and reprecipitates. It is readily concentrated in the form of secondary manganese minerals soils and relatively high concentrations may be present in soils rich in iron and/or organic matter, and in soils from arid or semiarid regions (Kabata-Pendias and Pendias 1984).

Manganese may exist in four oxidation states 2+, 3+, 4+ and 7+. Divalent (2+) manganese predominates in solution at pH 4 to 7, but at pH greater than 8 or 9, higher oxidation states prevail. In soils, manganese may exist in solution as the divalent cation (Mn^{2+}), or in solid phases as manganese dioxide (MnO_2), manganese sesquioxide (Mn_2O_3), or as manganese carbonate ($MnCO_3$) (Dragun 1988). Manganese oxides or hydroxides will readily form of coatings on soil particles or nodules. The solubility of manganese compounds in soils is mainly dependant on the cation exchange capacity, the soil organic matter content, pH, and redox potential (Kabata-Pendias and Pendias 1984). Sorption by soils may be an irreversible process with low concentrations being fixed by clays (Life Systems, Inc. 1990). Manganese is not uniformly distributed in soil substrata, and it may be locally concentrated with trace elements because of organic fixation.

Manganese solubility is controlled by the pH, Eh, and anion characteristic of the chemical form. In water the primary anion associated with divalent manganese is carbonate (CO_3^{2-}), and the concentration of manganese is therefore limited by the relatively low solubility of $MnCO_3$. In oxidized waters, manganese oxide solubility controls the solubility, and manganese may convert to 3+ or 4+ valence states. Microbiological activity may also mediate manganese oxidation in water. In very reduced waters manganese is less soluble due to the formation of a sulfide. Manganese is transported in rivers as a suspended particulate (Life Systems, Inc. 1990).

Elemental manganese and inorganic manganese compounds do not form volatile compounds, but may exist as suspended particulate matter derived from industrial emissions or the erosion of soils. Residence times in the atmosphere are on the order of days, depending on particulate size and dry or wet atmospheric conditions (Life Systems, Inc. 1990).

Bioconcentration factors of manganese for aquatic organisms range from 2,500 to 6,300 for phytoplankton, 300 to 5,500 for marine algae, 800 to 830 for intertidal mussels, and 35 to 930 for coastal fish, and 10,000 to 20,000 for marine and freshwater plants. In general, lower organisms have higher concentrations than do higher organisms; therefore, biomagnification in the food chain may not be significant (Life Systems, Inc. 1990).

Manganese is an essential plant nutrient. Uptake is metabolically controlled in terrestrial plants and is transported to meristematic tissues. It is concentrated primarily in young expanding tissue, but overall the concentrations vary significantly within plant parts and within the vegetative period. Soluble manganese is easily taken up by plants and manganese concentrations in plants are directly related to the soluble manganese pool in soils. Manganese concentrations in plants show a negative relationship with increasing soil pH, and a positive relationship with soil organic matter. In general, manganese concentrations greater than 500 mg/kg (dry weight) in mature plant tissue or greater than 1,500 mg/kg (dry weight) in soil are considered phytotoxic (Kabata-Pendias and Pendias 1984).

5.2.9 Nickel

Nickel is a naturally occurring element that is common in sedimentary rocks, especially argillaceous shales. Approximately 8,500,000 kg of nickel are naturally released to the atmosphere each year due to wind-blown dust, volcanic eruptions, and vegetation emissions. Major anthropogenic releases of nickel into the environment (estimated to be five times the amount of natural releases) are mainly due to fossil fuel combustion. Other anthrogenic releases are due to industries that use or convert nickel into nickel compounds or alloys and due to trash incinerators (Syracuse Research Corp. 1991).

The geochemistry of nickel is strongly associated with iron and manganese, but exhibits a higher mobility than iron or manganese in acid environments. In terrestrial rocks, nickel occurs primarily in sulfides and arsenides, and most of it is in ferromagnesians, replacing iron. Nickel is also associated with carbonates, phosphates, and silicates. During weathering, nickel readily goes into solution and then coprecipitates mainly with iron and manganese oxides. In the natural environment, divalent nickel (Ni^{2+}) is the predominant form.

Nickel is strongly absorbed by soil, but, to a lesser degree than lead, copper, and zinc. Important factors that control nickel mobility in soils are pH, type and amount of clay minerals, organic matter content, and the presence of iron and manganese oxides and hydroxides (Syracuse Research Corp. 1991). Nickel sorption depends strongly on pH. In alkaline soils, sorption may be irreversible (Syracuse Research Corp. 1991).

In aquatic environments, nickel transport is associated with particulate matter and tends to settle out in areas of active sedimentation. Nickel is strongly sorbed at surfaces of such minerals as the oxides and hydrous oxides of iron, manganese, and aluminum (Syracuse Research Corp. 1991). As Ni^{2+}, nickel is relatively stable in aqueous solutions and is capable of migration over long distances. In natural waters, nickel exists primarily as the hexahydrate. While nickel forms strong, soluble complexes with OH^-, SO_4^{2-}, and HCO_3^-, these species are minor compared with hydrated Ni^{2+} in surface waters and groundwaters with a pH <9 (Syracuse Research Corp. 1991).

Nickel does not form volatile compounds; therefore, nickel in the atmosphere exits as suspended particulate matter. Nickel is broadly distributed among aerosol size groups (Syracuse Research Corp. 1991).

Although nickel is not known to be an essential element for plant growth, it is readily absorbed by plant roots from solution. Nickel uptake by plants is positively correlated with nickel concentrations in the soil. Nickel is considered phytotoxic at concentrations greater than 100 mg/kg (dry weight) in soil or greater than 10 to 100 mg/kg (dry weight) in mature plant tissue (Kabata-Pendias and Pendias 1984).

Apparently, nickel is not accumulated in significant amounts by terrestrial or aquatic organisms. Studies on voles and rabbits and the plants they feed on did not show any nickel accumulation (Syracuse Research Corp. 1991).

5.2.10 Nitrate/Nitrite-N

Nitrogen in the form of dissolved nitrate, is a major nutrient for vegetation and an element essential to all life. Nitrate is produced by numerous natural and anthropogenic processes. Nitrates are formed by the process of nitrification, where ammonium is oxidized to nitrate.

Most common forms of nitrate are soluble in water and are mobile in soils. Some nitrate is utilized by plants, where it remains fixed until the plant dies. Nitrate is not volatile, but at low oxidation-reduction potentials can undergo denitrification, where the gas nitrous oxide and gaseous nitrogen are formed (Bohn et al. 1979).

Nitrates in groundwater are mobile and their concentrations are limited by microbial processes rather than solubility constraints. Nitrates can also be converted to ammonium, but the rate of this biochemical transformation is insignificant. Nitrate migrates through many groundwater and surface-water systems with no transformation and little or no retardation (Freeze and Cherry 1979). Some clays displaying high anion exchange capacities can retard the migration of nitrate slightly.

Little information exists on the bioconcentration potential of nitrates in animals. However, because nitrogen is readily metabolized, bioconcentration is not expected to occur.

Nitrite (NO_2^-) is an unstable intermediary of the nitrification process, during which ammoniacal nitrogen (or other reduced nitrogen forms) is converted to nitrate by soil microbes. The nitrification process is a two step microbial process where ammonium is oxidized to nitrite and then nitrite is further oxidized to nitrate. Under most conditions the transformation of nitrite to nitrate follows the conversion of ammonium to nitrite so closely there is little accumulation of nitrite (Brady 1974). In addition, nitrite is an unstable oxidation state of nitrogen. Nitrogen gas (N_2) is most stable under aerobic conditions and pH <3, nitrate is stable only in aerobic conditions and pH >3, and ammonia is stable only under anaerobic conditions. Nitrite is less stable than any of these compounds (Bohn et al. 1979). Consequently, for the purposes of this report all of the nitrogen reported as nitrate/nitrite will be regarded as nitrate.

5.2.11 Polonium-210

Polonium occurs in the biogeosphere as natural radioisotopes, including polonium-210, and is associated with the radioactive decay of uranium-235. Polonium-210 decays to stable lead-206. The half-life of polonium-210 is 138 days. Polonium has two oxidation states: +4 and +2, however, the quadravalent state is the most stable. There is little information regarding the environmental fate of polonium (Kabata-Pendias and Pendias 1984).

5.2.12 Radium-226

Radium-226 is a naturally occurring isotope that is ubiquitous in the natural environment at low concentrations. Radium-226 is the most prevalent and stable radium isotope. It is formed during the uranium-235 decay process. The use of uranium and fossil fuels (especially coal) has resulted in a significant redistribution of radium throughout the environment. Phosphorus fertilizer manufacturing is another source of radium in the soil.

In soil and aqueous environments, radium exists primarily as the divalent cation (Ra^{2+}). It is not subject to oxidation-reduction reactions, nor does it participate in chemical reactions that result in its transformation (Life Systems, Inc. 1989). Radium is readily sorbed by soils and sediments, however, as with other cationic metals, its sorption to particle surfaces is dependent on pH and is subject to competitive interactions with other ions in solution. Thus, mobility is expected to be higher in alkaline soils or waters, or when total dissolved solids are high.

When radium is released to the atmosphere due to fossil fuel combustion, it may be volatilized. It quickly condenses, however, onto particulate matter. This material is then subject to transport by wind. In air, radium is not subject to transformation or degradation processes except for radioactive decay. The half-life for radium-226 is 1,620 years.

Radium may be concentrated by plants and animals. Radium is readily sorbed by plants, and reported plant uptake factors range from 0.1 for forage and hay to 0.63 for grain. Animal uptake factors for cows are reported to be 6.8×10^{-3}. Aquatic BCFs for fish range from 1 to 60 for flesh and 40 to 1,800 in bone (Life Systems, Inc. 1989).

5.2.13 Selenium

Selenium is a naturally occurring element that is widely, but unevenly, distributed in the earth's crust, and is commonly found in sedimentary rocks. Much of the selenium in rocks is associated with sulfide minerals, or as selenides (Se^{2-})of silver, copper, lead, nickel or other metals. Coals and clay sediments may have elevated levels of selenium resulting from sorption of selenite ions (SeO_3^{2-}) that result from oxidation processes. Selenium is obtained primarily as a by-product of copper refining, and the primary environmental release of selenium comes from coal combustion (Clement Associates, Inc. 1988).

Selenium is stable in four valence states, -2, 0, +4 and +6, and the primary factor determining its fate in the environment is its oxidation state. The state of oxidation and solubility are in turn controlled by the pH and redox of the environment. During weathering, selenium reacts with oxygen to form selenite and selenate (SeO_4^{2-}) ions. Elemental and heavy metal selenides are insoluble in water, whereas inorganic selenites and selenates are soluble. Partitioning of selenium compounds in the environment is affected by pH, redox potential, organic matter, and the presence of metal oxides (Clement Associates, Inc. 1988).

Selenium may exist in the following forms in soil: Se, $HSeO_3^-$, SeO_3^{2-}, $HSeO_4^-$ and SeO_4^{2-} (Dragun 1988). Elemental selenium is essentially insoluble and may represent a major sink in the environment. Heavy metal selenides and selenium sulfides, which are insoluble, predominate in acidic soils and in soils with high amounts of organic matter, and remain immobile in these conditions. Selenides of other metals such as copper and cadmium are of low solubility. Selenites dominate in neutral, well drained mineral soils, and some soluble metal selenites may be found as well. In alkaline (pH >7.5), well-oxidized soils, selenates are the major species. Selenates are very mobile due to their high solubility and low tendency to sorb onto soil particles, and are readily taken up by biological systems or leached through the soil. In acid, neutral or high organic content soils, selenite forms stable ferric oxide-selenite sorption complexes, selenides and selenium-sulfide complexes.

Inorganic selenium compounds can methylated by microorganisms and subsequently volatilized. Microbial-mediated volatilization is directly dependant on the temperature. Generally, microorganisms methylate organic selenium compounds more readily than either selenite or selenate, and elemental selenium is the slowest to be converted (Clement Associates, Inc. 1988).

Selenium concentrations in water are generally low due to its ability to coprecipitate with sediments. Elemental selenium can occur over a wide range of pHs, from mildly oxidizing to reducing conditions. In aerobic surface waters and soil solutions, the more soluble and mobile forms of selenium (selenite and selenate) are equally present. Most selenite salts are less soluble in water than the corresponding selenate salts. Under acidic conditions selenite can be rapidly reduced to elemental selenium by mild reducing agents such as ascorbic acid or sulfur dioxide. Aquatic organisms convert selenium to both inert and soluble forms. Selenate can be converted to selenite or elemental selenium in aquatic systems, but this is a slow process relative to other conversion processes (Clement Associates, Inc. 1988).

Selenium may partition into the atmosphere in volatile inorganic and organic compounds. Volcanic activity is suspected of being a major natural source of atmospheric selenium. Fossil fuel combustion releases selenium dioxide, which should be reduced to elemental selenium by accompanying sulfur dioxide. Hydrogen selenide (H_2Se) is highly reactive in air and rapidly decomposes to elemental selenium and water, but the other volatile selenium compounds can persist in air (Clement Associates, Inc. 1988).

In the aquatic environment, selenium can be bioaccumulated by aquatic organisms. Bioconcentration factors of 150–1,850, and bioaccumulation factors of 1,746–3,975 for freshwater have been reported. In fish, selenium is concentrated in visceral tissue more than in skeletal muscle. Bioaccumulation factors for selenium in skeletal muscle of fish range from

485–1,746, and for visceral tissue values from 1,058–3,980, depending on the species (Clement Associates, Inc. 1988).

Terrestrial plants take up soluble selenate and selenite salts from water and soil and convert this inorganic selenium to organic selenium compounds. In environments that favor soluble forms of selenium, such as alkaline and oxidizing conditions, it can be accumulated by plants. Selenium uptake by plants is influenced by soil and plant type, pH, colloidal content, concentration of organic material, redox potentional in the root environment, and total levels of selenium in the soil. Soluble selenates, principally sodium selenate, appear to be the source of most of the naturally occurring accumulations of selenium in plants, although much of the selenium in soil may be in other forms (Clement Associates, Inc. 1988). The uptake of selenium by plants will be negligible in acid to neutral soils, except that complex anions and organic chelates can greatly modify selenium behavior in soil. Concentration of selenium within plants appears to be mainly in seeds, in growing points, and in roots. In general, selenium in plants shows a positive correlation with pH, salinity, and the calcium carbonate content in soils. Selenium concentrations greater than 5 mg/kg (dry weight) in surface soils and greater than 5 to 30 mg/kg (dry weight) in mature leaf tissue that are considered phytotoxic (Kabata-Pendias and Pendias 1984).

Although selenium is an essential nutrient for humans, animals, and possibly plants, it is possible for plants to accumulate selenium to the point of toxicity to grazing livestock. This is a possibility in soils naturally rich in selenium, poorly drained, or calcareous, soils of arid zones, and soils heavily amended with sewage sludges or fly ashes. Selenium is toxic to human and animals in doses slightly higher than that required for good nutritional status (Kabata-Pendias and Pendias 1984).

5.2.14 Silver

Silver occurs primarily as sulfides, in association with iron, lead, tellurides, and gold. Silver enters the environment naturally through weathering of rocks and soil by wind and rain. Major anthropogenic releases of silver into the environment are mainly due to photographic processing and disposal of sewage sludge and refuse. Other anthrogenic releases to the environment include silver mining, fossil fuel combustion, and trash incineration (Clement Associates, Inc. 1989a).

The major form of silver is the monovalent cation (Ag^+). Important factors that control silver mobility in soils are drainage, oxidation-reduction potential, pH, and organic matter content. Good drainage induces leaching from soil into the groundwater. Acidic conditions increase the leaching rate, whereas pH determines the presence of iron and manganese complexes that tend to immobilize silver (Clement Associates, Inc. 1989a). Silver is apparently immobile in soils when pH >4. Organic matter is known to sorb and complex silver, thus immobilizing it (Kabata-Pendias and Pendias 1984).

Sorption is the dominant process controlling partitioning of silver or silver compounds in water and its movement in sediments. The transport of silver in soils and surface waters is influenced by the particular form of the compound. Under oxidizing conditions, the primary

silver compounds would be bromides, chlorides, and iodides that are relatively soluble; however, relatively insoluble free metal and silver sulfide would predominate under reducing conditions.

Silver does not form volatile compounds, therefore, silver in the atmosphere exits as suspended particulate matter. Silver is broadly distributed among aerosol size groups (Clement Associates, Inc. 1989a).

In pasture plants growing in the vicinity of an airborne source of silver, silver in the leaves is apparently due to deposition of airborne silver, while concentrations in the roots are due to uptake. Silver concentrations greater than 5 to 10 mg/kg in mature plant tissue and greater than 2 mg/kg in soils are considered phytotoxic (Kabata-Pendias and Pendias 1984).

Although bioconcentration factors of 13,000–66,000 have been reported, silver accumulation in marine algae appears to result from adsorption rather than uptake (Clement Associates, Inc. 1989a). In fish, BCFs range from less than 1 to 6 for bluegills, 2 to 10 for largemouth bass, 4 to 7 for fathead minnow, and 7 to 10 in mussels (Clement Associates, Inc. 1989a).

5.2.15 Thorium-230

Thorium is a naturally occurring, radioactive metal element in the earth's crust that is found predominately in acid rocks or concentrated in argillaceous sediments. Small amounts of thorium are present in rocks, soil, surface and groundwaters, plants and animals. Anthropogenic releases of thorium to the water are primarily due to uranium and thorium mining and milling operations, phosphate rock processing, and phosphate fertilizer production. Atmospheric anthropogenic releases include these and coal combustion (Syracuse Research Corp. 1989b).

There are more than 10 different isotopes with more than 99% of natural thorium in the form of thorium-232. Most thorium compounds common in the environment do not dissolve easily in water and do not evaporate from soil or water to the atmosphere (Syracuse Research Corp. 1989b).

Thorium-230 is an intermediate product formed by the decay of uranium-238. The half life of thorium-230 is 7.5×10^4 years. Thorium exists as a quadravalent ion (Th^{4+}) that readily forms hydroxy complexes ($Th(OH)_2^{2+}$, $Th_2(OH)_2^{6+}$, and $Th_3(OH)_5^{7+}$) in solutions above pH 5 (Syracuse Research Corp. 1989b).

With weathering, thorium is easily mobilized in the form of various complex inorganic cations and organic compounds. In soils, thorium exists as either Th^{+4} or ThO_2 and is soluble over a broad range of soil pHs (Dragun, 1988). Concentrations in soil generally increase with the amount of clay or organic matter present. In most circumstances thorium will remain strongly sorbed to soil and its mobility will be minimal. Groundwater leaching is possible, however, in soils with low sorption capacity or with the formation of soluble complexes or ligands. Certain microorganisms present in soil may enhance the dissolution of thorium in

soils (Syracuse Research Corp. 1989b). Thorium mobility may also increase due to increased solubility in the presence of several organic acids (Kabata-Pendias and Pendias 1984).

In water, thorium will be present in suspended matter and sediment, and concentrations of soluble thorium will be low. Sediment resuspension and mixing may control the transport of particle-sorbed thorium in water. The concentration of dissolved thorium in some waters may increase due to formation of soluble complexes with carbonate, humic materials, or other anions and ligands in the water. Marine residence times are reported to be shorter in nearshore waters than in deeper waters, likely due to the greater amount of particulate material. Residence times may be from 1 to 70 days, depending on the season, sediment resuspension rate, and the concentration of iron and manganese compounds (Syracuse Research Corp. 1989b).

Windblown terrestrial dust and volcanic eruptions are two important natural sources of thorium in the atmosphere in addition to anthropogenic sources. The chemical form that thorium has during residence in the atmosphere may be thorium dioxide (ThO_2). Nothing is known of atmospheric chemical reactions, but ThO_2 may convert to throium sulfate ($Th(SO_4)_2$). The rate of atmospheric removal will depend on weather conditions, particle size and density, and the chemical form of thorium particles. Residence times are likely on the order of a few days. Thorium particles (<10 μm) may travel long distances from their emission source (Syracuse Research Corp. 1989b).

Thorium will bioconcentrate significantly in lower trophic levels of aquatic animals. The bioconcentration factor for algae may be as high as 9.8×10^6, and 2×10^4 for zooplankton. For rainbow trout the whole body bioconcentration factor is reported as a maximum of 465. Most of the thorium in fish is localized in the gastrointestinal tract. The lower bioconcentration factors in higher trophic animals indicates that thorium will not biomagnify in the aquatic environment (Syracuse Research Corp. 1989b).

The plant/soil transfer ratio for thorium is less than 0.01, which indicates that thorium will not bioconcentrate in plants from soil. Plants grown at the edge of impoundments of uranium tailings, however, did contain thorium and had plant/soil concentration ratios of about 3. Plant root systems adsorb thorium from the soil, but transport is not very extensive and there may be a hundred-fold difference between the root and the above ground parts (Syracuse Research Corp. 1989b).

5.2.16 Uranium

Uranium is a naturally occurring, radioactive metal element in the earth's crust. Small amounts of uranium are present in rocks, soil, surface water, groundwater, plants, and animals. Uranium is released to the environment by both natural and anthropogenic actions. The natural processes of weathering and volcanic activity release uranium to the atmosphere. Major anthropogenic sources are: uranium mining, milling, and ore processing; phosphate fertilizer production; and improperly disposed uranium-bearing wastes (Syracuse Research Corp 1989d).

Uranium has three isotopes, uranium-234, uranium-235, and uranium-238. More than 99% of natural uranium is uranium-238, with uranium-235 constituting 0.72%. The half life of uranium-238 is 4.5×10^9 years (Syracuse Research Corp 1989d).

With weathering, uranium is easily mobilized as various complex inorganic cations and in organic compounds. Ionic forms of uranium that exist in soil are: UO_2^{2+} and U^{+4} (Dragun 1988). Important reactions of uranium in soil are complexation with anions and ligands, and the reduction of U^{6+} to U^{4+}. These reactions are important in controlling the mobility in soil and water, and are influenced by redox, pH, and the sorbing characteristics of sediments and soils. In most soils, the sorption of uranium is such that it will not leach, particularly in soils containing clay and iron oxide. Maximum sorption occurs when the hydroxy complex of uranium is present. At pH >6 in the presence of high carbonate or hydroxide concentrations, uranium may form anionic complexes such as $[UO_2(OH)_4]^{-2}$. The mobility of anionic uranium complexes in soil will be determined by the nature of the soil (Syracuse Research Corp 1989d). Formation of hydrated uranium cations of UO_2^{+2} will result in solubility over a wide range of pH (Kabata-Pendias and Pendias 1984).

In natural waters, sediments are a sink for uranium, with concentrations in the sediments exceeding soluble concentrations by several orders of magnitude. In a basic, oxygenated water, uranium is likely to be in solution as a carbonate complex. And in acidic water with low concentrations of inorganic ions and high concentrations of dissolved organic matter, uranium will be in solution as soluble organic complexes. In anoxic waters where U^{+6} is reduced to U^{+4}, the concentration of soluble uranium will decrease, since U^{+4} is unable to form complexes as readily as U^{+6}. At lower pH's and higher temperatures, carbonate complexes may dissociate to form cationic uranyl (UO_2^{2+}) salts (Syracuse Research Corp 1989d).

Particulate uranium is removed from the atmosphere by wet and dry deposition, and atmospheric transport is influenced by particle size distribution and density. Residence times are unknown, but are assumed to be on the order of that for atmospheric dust behavior (>1.0 μm). Deposition on surface water and its transport to sediments is probably the ultimate fate of atmospheric uranium (Syracuse Research Corp 1989d).

Transport in water of uranium to organisms primarily occurs through the sediment. Bioconcentration factors for algae are 1,576, and for plankton 459. Bacteria bioconcentration factors range from 2,794 to 354,200. The highest published bioconcentration factors for rainbow trout, lake whitefish, and white and fine-scale suckers is under 38. Levels of uranium in aquatic organisms declines with successive trophic levels because of very low assimilation efficiencies in higher trophic level animalsp; thus, no biomagnification of uranium is expected to occur in the aquatic food chain (Syracuse Research Corp. 1989d).

In plants, uranium uptake may be restricted to the root system and may be transported from the soil only to the outer root membrane, and not to the interior of the root. No significant translocation of uranium from soil to above-ground plant parts has been observed (Syracuse Research Corp. 1989d).

5.2.17 Vanadium

Vanadium is a metal with compounds widely distributed at low concentrations in the earth's crust. Elemental vanadium does not occur in nature, but is associated with over 50 different mineral ores and in fossil fuels. Vanadium replaces other metals such as iron, titanium and aluminum in crystal structures. Natural releases of vanadium to soil result from the weathering of rock-bearing vanadium minerals, precipitation/deposition of vanadium from the atmosphere or water, and plant and animal wastes. Anthropogenic sources of vanadium are: fossil fuel combustion, mining, slag heaps, sewage sludge, and certain fertilizers (Clement Associates, Inc. 1990).

Vanadium has six oxidation states: -1, 0, +2, +3, +4, and +5, with the latter three being the most common. Vanadium can exist in a number of ionic forms in soil: VO_2^+, VO^{2+}, V^{3+}, $V(OH)^+$, VO_3^- VO^+, V_2O_4, V_2O_3, $H_3V_2O_7^-$, $H_2VO_4^-$, $HV_2O_5^-$, and HVO_4^{2-} (Dragun 1988). Vanadium displays a variety of behaviors because it is able to form so many complexes of cationic and anionic oxides and hydroxides. Vanadium, relative to other metals, is fairly mobile in neutral to alkaline soils, but less so in acidic soils. Similarly, in oxidizing unsaturated conditions some mobility is observed, but in reducing saturated conditions vanadium is immobile (Clement Associates, Inc., 1990). The vanadyl cation (VO^{2+}) may be an important form of vanadium in many soils and may result from the reduction of the metavanate anion (VO_3^-). Much of the vanadium in soil, mainly the vanadyl cation, may be mobilized as complexes with humic acids. Anion forms (VO_4^{3-}, VO_3^-) are known to be mobile in soils and to be relatively more toxic to microbiota (Kabata-Pendias and Pendias 1984).

Natural sources of vanadium release to water include wet and dry deposition, soil erosion, and leaching from soil and rocks. Long range transport in the form of a particulate occurs by either solution or suspension in water. In fresh water reduced conditions, vanadium exists as a vanadyl ion (V^{4+}), and in oxidizing conditions as a vanadate ion (V^{5+}). Vanadium species commonly reported in fresh water are VO^{2+} and $VO(OH)^+$, $H_2VO_4^-$ and HVO_4^{2-}. Species most likely to be found in sea water, where vanadium is continuously precipitated from sea water by ferric hydroxides and organic matter, are $(H_2V_4O_{13})^{4-}$, HVO_4^{2-} and VO^{3-}. Partitioning of vanadium between water and sediment is strongly influenced by the particulate in solution. Vanadium species are known to bind strongly to mineral or biogenic surfaces by adsorption or complexing. Once in water nearly all of the vanadium becomes associated with particulate material and is deposited in the sediments, with only a small fraction persisting in a soluble form (Clement Associates, Inc. 1990).

Vanadium may have long range transport and residence times on particles in the atmosphere. An estimated residence time of approximately one day has been proposed for fly ash vanadium pentoxide when associated with hydrogen sulfate. But the average residence time in is unknown due to the range of particle sizes. Vanadium is removed from the atmosphere by wet and dry deposition and dissolution in sea water (Clement Associates, Inc. 1990).

In general, marine plants and invertebrates contain higher levels of vanadium than terrestrial plants and animals with BCFs ranging to 10,000 for marine invertebrates.

For terrestrial plants, bioconcentration is more commonly observed in lower plant phyla than in seed-producing plants, and uptake into above ground plant parts is low. Vanadium levels in plants depend on the amount of water-soluble vanadium, which is in turn related to the soil, pH, and growing conditions. Plant uptake is likely passive. Some results indicate that VO^{2+} species occurring under acid conditions are more rapidly absorbed by roots than are VO_3^- and HVO_4^{2-} species that predominate in neutral and alkaline solutions (Clement Associates, Inc. 1990). Also both cationic and anionic species are capable of being chelated and could contribute substantially to vanadium uptake by plants from soils. Vanadium concentrations exceeding 5–10 mg/kg in mature leaf tissue or 50 mg/kg in soil are considered phytotoxic (Kabata-Pendias and Pendias 1984).

Vanadium appears to be present in all terrestrial animals, with the highest levels found in liver and skeletal tissues. Vanadium concentrations in tissue are generally below detection levels. There are no data regarding

biomagnification in the food chain, but human studies suggest that biomagnification is unlikely. Most of the vanadium absorbed by humans is rapidly excreted in the urine, with no evidence of long-term accumulation (Clement Associates, Inc. 1990).

5.2.18 Zinc

Zinc is a common element in the earth's crust. It is detected in rock, soil, groundwater, surface water, and air. Zinc may be released by natural or anthropogenic activities. Most of the zinc released to the environment partitions to water, soil, and sediments. Major anthropogenic sources are metallurgic wastes from smelter and refining operations, mining drainage, electroplating, smelting, plastics, agricultural practices, and industrial and municipal waste effluents (Clement Associates 1989b).

Zinc occurs in the environment in the divalent (Zn^{+2}) state. In acid, oxidizing environments zinc is especially soluble as the +2 state (Kabata-Pendias and Pendias 1984). Weathering can result in significant releases of zinc to waters where it is primarily adsorbed onto suspended and bed sediments. Zinc in aerobic waters is partitioned to sediments by the sorption onto hydrous iron and manganese oxides, clay minerals, and organic material. Sorption efficiency of these materials varies according to their concentration, pH, redox potential, salinity, concentration of complexing ligands, and the zinc concentration. Zinc precipitation appears to be important only in reducing or highly polluted environments. Coprecipitation of zinc with hydrous oxides may occur when reduced iron or manganese oxides are oxidized. Generally, at low pH values, zinc will remain as a free ion and may adsorb onto suspended particulates. If alkaline (pH > 8) polluted waters are encountered with reducing conditions these particles may settle and zinc may complex with carbonates, hydroxides, and organic ligands. In reducing environments, the precipitation of zinc sulfide limits the mobility of zinc (Clement Associates 1989b).

Surface soil horizons typically will have the greatest zinc concentrations. Zinc may exist in soils as either Zn^{2+} or $Zn(OH)_2$ (Dragun 1988). The mobility of zinc in the soil is determined by the solubility of the compound, soil type, pH and the salinity of the soil. Zinc is likely to

be strongly sorbed in soil, and converted to chemically less active forms (e.g. organically bound or forming inorganic precipitates). The amount of zinc in solution is linear for soils below pH 7 and nonlinear for soils with a pH greater than 7. Desorption of zinc from sediments occurs as salinity increases, this is apparently due to displacement of zinc ions by alkaline earth cations (Clement Associates 1989b).

In the aquatic environment, transport is controlled by the speciation of the ion. In polluted waters, zinc will often form complexes with a variety of organic and inorganic ligands with varying degrees of stability. In natural waters, two reactions can occur: the competition for complexation sites between metal ions, and the competition between different ligands for the same metal ion. Zinc organic/inorganic ligands are soluble in neutral-to-acidic surface water conditions so that zinc is readily transported in most unpolluted natural waters; the solubility of these ligands makes zinc one of the most mobile of the heavy metals. Zinc chloride and sulfide are very soluble in water, but hydrolyze in solution and reduce pH. Biological activity can affect the mobility of zinc in the aquatic environment, although the biota are a minor reservoir of zinc relative to sediments (Clement Associates 1989b).

Zinc released to the atmosphere is commonly converted to stable species such as zinc oxide, and is expected to have a short residence time due to surface deposition. Concentrations in the air are relatively low and constant except near sources, and volatilization is a negligible process for zinc (Clement Associates 1989b).

Zinc is an essential nutrient and is found in all foods. It is often concentrated in the tissues of organisms even in the absence abnormally high background concentrations. Zinc also plays an essential role in plant metabolic activity. Zinc is found to bioaccumulate in freshwater animal tissues from 51–1,130 times the concentration in water. Bioconcentration factors for twelve aquatic species range from approximately 4 to 24,000. Fish and crustaceans can accumulate zinc from both water and food. Microcosm studies generally indicate that zinc is not biomagnified (Clement Associates 1989b).

Bioconcentration factors from soil by terrestrial plants, invertebrates and mammals have been reported respectively as 0.4, 8, and 0.6 (Clement Associates 1989b). Bioconcentration of soil zinc by plants is dependant on the plant species and soil pH. Uptake of zinc in plants has been reported to be linear with concentration in nutrient solution and soil, with the rate of uptake widely varying with both plant species and growth media. It is likely that zinc is concentrated in old leaves, but may also be concentrated in the roots, and may be highly mobile within a plant. Zinc levels in a plant may also fluctuate during the vegetative period. Zinc concentrations greater than 300 mg/kg in surface soils or 100 to 400 mg/kg in mature leaf tissue are considered phytotoxic (Kabata-Pendias and Pendias 1984).

5.3 Constituent Transport

Air transport modeling was conducted for the two constituents of most interest identified in Section 4.2 (Air Quality) to assess the effects of Plant operations on local air quality. These constituents were cadmium and fluoride and the indicator parameters TSP and PM_{10}. This

subsection defines the source areas and summarizes the emissions rates calculated for each source by constituent. These values are then incorporated into mathematical dispersion models to calculate ground-level concentrations of particulate matter, cadmium, and fluoride. Stack and point-source emissions, as well as the thermally-buoyant emissions from slag dumping and nodule reclaim area operations, were evaluated using both long-term and short-term models.

5.3.1 Air Pathways

Air emission sources at the Monsanto Plant consist of the following groups: permitted sources, baghouses, and fugitive emissions. Particulate emission rates were available from stack sampling conducted during 1990 by American Service Associates (ASA) for the permitted sources (ASA 1987 and 1990; and Wind, D.R., Monsanto [Memo to A. Cole, IDHW] November 16,1988; May 24, 1990; May 25, 1990; and September 10, 1990), as well as for the scaleroom baghouse. Some limited sampling data of fugitive emissions were also available for the material handling operations in the nodule reclaim area. All other emission estimates were based on emission factors derived from published sources, primarily the Compilation of Air Pollutant Emission Factors and its supplements (AP-42), published by EPA (1985). The equations and assumptions used are described in the following Paragraphs.

5.3.1.1 Permitted Sources

The permitted air emission source group consists of the following:

- Three taphole fume collectors (#7, #8, & #9);
- The kiln cooler spray tower;
- Four kiln venturi scrubbers (A, B, C, D); and
- The nodule crushing/screening scrubber

Table 5-1 lists the emission rates for the nine permitted sources. The values for TSP are the actual measured emission rates from stack sampling results. The PM_{10} emissions were estimated as a fraction of TSP based on published data for similar processes (EPA 1985). The percent fraction of TSP and reference source for each process are as follows:

Taphole fume collectors — 98%
electric arc furnace emissions for grey iron foundries (EPA 1985, p. 7.10-7)

Kiln cooler spray tower — 53%
calcining and other heat reaction processes for aggregate unprocessed ore (EPA 1985, p. 2-12)

Kiln venturi scrubbers — 78%
venturi scrubber control efficiency for grey iron foundries (EPA 1985, p. 7.10-11)

Nodule crushing/screening scrubber — 6%
uncontrolled particulate emissions from crushing operations of dry material (EPA 1985, p. 8.19.2-4)

Cadmium emission rates were calculated as a fraction of TSP emission rates based on the following conversion factors determined from particulate stack analyses:

Taphole fume collectors	0.00015 (x TSP emission)
Kiln cooler spray tower	0.0005 (x TSP emission)
Kiln venturi scrubbers	0.0641 (x TSP emission)
Nodule crushing/screening scrubber	0.000005 (x TSP emission)

The emissions of fluoride (calculated as hydrogen fluoride) in pounds per hour (lb/hour) were estimated by Monsanto (Hrebenyk, D., SENES [Memo to Monsanto Soda Springs Plant Phase I RI File] April 18, 1990) as follows:

Taphole fume collectors (THFC):

All THFC's: $\frac{(53{,}617\ \text{SCFM})\ (60\ \text{minutes/hour})\ (2\ \text{mg fluoride/SCFM})}{(453{,}590\ \text{mg/lb})}$

= 14.18 lb/hour at inlets to all three furnaces combined.

Assuming 86% control efficiency for scrubbers, total fluoride emissions for all three THFC's is:

(14.18) (0.14) = 2.0 lb/hour

Hours of operation for each furnace in 1990 and proportionate emission rates for fluoride were:

Furnace # 7	8,345 hours	0.70 lb/hour
Furnace # 8	7,986 hours	0.67 lb/hour
Furnace # 9	7,476 hours	0.63 lb/hour
	23,808 hours	2.0 lb/hour

Kiln cooler spray tower:

Method 13B (EPA 1984) stack sampling tests conducted in March, 1988, yielded an emission rate estimate of 0.229 lb/hour.

Kiln venturi scrubbers:

Method 13B (EPA 1984) stack sampling tests conducted in March 1988, yielded an emission estimate for all four stacks combined of 0.7 grams/hour as measured by continuous monitor. Stack-specific emission rates were apportioned based on relative TSP emission rates.

5.3.1.2 Baghouses

The baghouses air emission source group consists of the following:

- The coke/quartzite dryer;
- The stocking system;
- The coke/quartzite satellite;
- The ore satellite;
- The coke handling; and
- The scaleroom.

Stack sampling of particulate emission rates was available for only one baghouse at the Monsanto Plant. The scaleroom baghouse was tested by ASA for particle size distribution in 1987 and again for total particulate emission rate in 1990. Emission rates for the other baghouse sources were estimated based on emission factors for material handling operations where mass material flow rates were available, or on a similarity basis where such information was either lacking or insufficient.

For example, for the coke/quartzite dryer, Monsanto estimated a total material through-put (composed of both coke and quartzite) of 201,290 tons out of a total material feed rate to the furnaces of 237,882 tons quartzite and 145,762 tons coke. Since there were no estimates of the quantities of coke versus quartzite passing through the dryer, all 201,290 tons were treated as coke. The AP-42 uncontrolled emission factor for coal preheating is given as 3.5 lb/ton handled (EPA 1985, p. 7.2-7). Therefore, the total quantity of dust generated in the dryer was estimated at 704,515 lb/year. Assuming a 98% collection efficiency and a 99.5% control efficiency for the baghouse, the total quantity of particulates emitted was estimated at 690 lb/year over 2,580 hours of operation per year (10 hours per day, 6 days per week, 43 weeks per year) (Hrebenyk, D., SENES [Memo to Monsanto Soda Springs Plant Phase I RI File] April 18, 1990). The TSP emission rate is then 0.27 lb/hour, of which 97.5% (EPA 1985) is composed of PM_{10}. This should be considered an overestimate of emissions because not all of the material passing through the dryer was coke, and quartzite would be expected to produce less dust than coke.

For the stocking system baghouse, there was insufficient information about the quantities of materials passing through each transfer point and the physical characteristics of the materials (i.e., moisture content, silt content) to use emission factor equations. The total quantities of materials passing through the stocking system in 1990 were estimated by Monsanto as 919,550 tons of ore, 237,822 tons of quartzite and 145,762 tons of coke. An emission factor of 0.0034 lb/ton/transfer point for crushed stone plants (EPA 1985) was used to estimate total fugitive dust generation at 62 transfer points as follows:

1,303,194 tons x 0.0034 lb/ton x 62 transfer points = 274,713 lb of dust generated

Assuming a collection efficiency of 98% and a 99% control efficiency, the total quantity of dust emitted was estimated at 2,692 lb/year, or 0.31 lb/hour. This emission rate is obviously an overestimate because not all of the material passes through all 62 transfer points. However,

in the absence of information about mass material flows along all conveyor systems, the value of 0.31 lb/ton was used as an estimate of emissions from the stocking system baghouse.

Similarly, there was insufficient information about the mass material transfer rates for the coke handling and coke/quartzite satellites. Therefore, it was assumed that the emission rate from the baghouses at these facilities was approximately the same as for the stocking system (i.e., 0.3 lb/hour). This is probably also an overestimate of actual emissions because the quantity of materials passing through these two facilities is less than one-third that for the stocking system. For the ore satellite, the emission factor of 0.0034 lb/ton for 1,726,247 tons of ore processed was used to estimate an uncontrolled emission rate of 0.67 lb/hour:

1,726,247 tons x 0.0034 lb/ton x 1 / 8760 hours/year = 0.67 lb/hour

Except for the scaleroom baghouse, the estimated emission rates for the other baghouses are largely speculative. However, compared to other sources of particulate emissions at the Plant, baghouse emissions represent a minor incremental addition to Plant emissions, and any errors in the estimate of emissions is unlikely to significantly alter the estimates of off-site effects. Overall, the actual emissions from baghouses are more likely to be lower than those estimated for this assessment.

5.3.1.3 Slag Dumping Fugitives

In previous estimates of particulate emission rates from slag dumping operations, Monsanto used an emission factor of 0.47 lb/ton of slag, and assumed that 60% of these emissions occurred outside the furnace building. Thus, the particulate emission rate was estimated as 0.282 lb/ton of slag dumped to the stockpile. Using this value, the estimated TSP emission rate from slag dumping in 1990 would have been 31.7 lb/hour.

The emission factor of 0.47 lb/ton on which these earlier estimates were based is listed in AP-42 (EPA 1985, p.7.6-13) as an emission rate for slag cooling in the blast furnace for primary lead smelting processes. However, AP-42 also lists an emission factor of 0.026 lb/ton for uncontrolled particulate emissions for high-silt slag dumping among the open fugitive dust sources at iron and steel mills (EPA 1985, p. 7.5-20). Since the former emission factor of 0.47 lb/ton is the estimated emission factor for particulate emissions within the blast furnace when the slag is at its hottest, and the latter value of 0.026 lb/ton is the emission factor listed for open fugitive dust sources in slag dumping, it was felt that the latter figure was more likely to be representative of emission rates from Monsanto's slag dumping operations.

As will be discussed in Subsection 5.3.2, use of the higher emission factor of 0.282 lb/ton (i.e., 0.47 x 0.6) would result in an estimated incremental TSP effect at the Harris Ranch monitoring station from slag dumping alone which exceeds the observed effects at that station from all sources at the Monsanto Plant. In conjunction with emissions from other sources, use of the higher emission rate results in estimated off-site concentrations out of all proportion with measured TSP concentrations.

On the other hand, the predicted average annual TSP concentration from slag dumping operations based on an emission factor of 0.026 lb/ton, in conjunction with incremental effects

from other sources on the Monsanto Plant, provides an estimated total effect at the Harris Ranch which closely approximates observed effects. Therefore based on the modeling results, it is concluded that the emission factor of 0.026 lb/ton provides a reasonably accurate estimate of TSP emission from slag dumping.

For 1990, Monsanto estimated a gross annual slag production rate of 889,140 tons per year, and a total of 44,263 taps from all three furnaces for an average of 20.1 tons/tap. The average number of taps per hour and the associated slag production rates for the three blast furnaces were estimated as follows:

Furnace #7 — (1.7 taps/hour) (20.1 tons/tap) = 34.2 tons/hour
Furnace #8 — (1.8 taps/hour) (20.1 tons/tap) = 36.2 tons/hour
Furnace #9 — (2.1 taps/hour) (20.1 tons/tap) = 42.2 tons/hour
= 112.5 tons/hour

Assuming 0.026 lb TSP/ton of slag dumped, the average hourly TSP emission rate was estimated at 2.9 lb/hour. The associated emission rate for particles less than 30 μm is given in AP-42 as about 50% of the TSP emission rate (EPA 1985). The cadmium emission rate was estimated as a fraction of TSP based on a conversion factor of 0.000002 (x TSP) from slag material testing results (Hrebenyk, D., SENES [Memo to Monsanto Soda Springs Plant Phase I RI File] April 18, 1990).

Estimation of the release of fluoride from the slag dumping operations is somewhat more problematic than for emissions of cadmium. The Chen-Northern material testing results for slag give a ratio of fluoride to slag material as 0.004137, and this is the conversion factor that would be used to estimate fluoride emissions if it could be assumed that the ratio of fluoride to slag material as TSP were the same during slag pouring operations. However, because the slag is molten during pouring, and because fluorides are volatile, the ratio of fluorides to particulates during molten slag dumping is likely to be much higher than 0.004137.

There are no published emission factors for fluoride release from slag. The EPA reference for toxic air pollutant emission factors (EPA 1988b) lists an uncontrolled fluoride emission factor of 3.8 lb/ton (as P_2O_5) in a curing building for normal superphosphate production. By comparison, Monsanto has used a published emission factor of 1.043 lb fluoride per 225 cubic feet of slag (Hrebenyk, D., SENES [Memo to Monsanto Soda Springs Plant Phase I RI File] April 18, 1990) for fluorine evolution of fumes for the taphole fume collectors in the furnace building. Using the latter value, Monsanto has estimated fluoride emissions from slag dumping in 1990 as follows:

Furnace #7 (8346 hour/year)(1.7 taps/hour)(250/225 cubic feet/tap)(1.043 lb fluoride/225 cubic feet) = 16,443 lbs/year
Furnace #8 (7986 hour/year)(1.8 taps/hour)(300/225 cubic feet/tap)(1.043 lb fluoride/225 cubic feet) = 19,991 lbs/year
Furnace #9 (7476 hour/year)(2.1 taps/hour)(350/225 cubic feet/tap)(1.043 lb fluoride/225 cubic feet) = 25,472 lbs/year

Thus, the 1990 total fluoride emission rate from slag would be 61,905 lbs, or an average of 7.8 lbs/hour. However, for the same reason that the fugitive TSP emission rate for slag dumping is lower than the emission rate from slag cooling in the furnace building, one would also assume that the fluoride emission rate during slag dumping would be lower, because of the more rapid cooling after pouring, than the emission factor of 1.043 lbs/225 cubic feet used above. In the absence of a more reliable emission factor, the emission rate for fluoride from slag dumping was estimated as a proportionate ratio between TSP emission rates as follows:

$$\frac{(2.9 \text{ lbs/hour})(7.8 \text{ lb/hour fluoride})}{31.7 \text{ lbs/hour TSP}} = 0.72 \text{ lb/hour}$$

Thus, the estimated fluoride emission rate used in the current modeling study for fluoride emissions from slag dumping is less than one-tenth the estimated emission rate used by Monsanto in the 1988 dispersion modeling assessment. This fact should be born in mind when considering the modeling results presented in Subsection 5.3.2 below.

5.3.1.4 Furnace Building Fugitives

Monsanto estimated that the total particulate matter generated within the furnace building, in 1985, was 576.9 tons. Assuming a 98% collection efficiency within the building, the total estimated building fugitive emissions was calculated at 11.5 tons per year. The total measured stack emission rates for the three taphole fume collectors was estimated at 27 tons/year.

For 1990, the furnace building fugitive emissions were estimated as a ratio of the 1985 emissions based on measured emission rates for the taphole fume collectors. The stack sampling data indicated that the total emissions for the three taphole venturi stacks in 1990 were equal to:

Furnace #7	(3.0 lb/hour) (8,346 hour/year)	= 12.52 tons
Furnace #8	(1.29 lb/hour) (7,986 hour/year)	= 5.15 tons
Furnace #9	(1.35 lb/hour) (7,476 hour/year)	= 5.05 tons
		22.72 tons/year

Therefore, the 1990 furnace building fugitive particulate emissions were estimated as:

$$\frac{(22.72 \text{ tons/year})(11.5 \text{ tons/year})}{(27 \text{ tons/year})} = 9.66 \text{ tons/year.}$$

Thus, the average hourly TSP emission rate was estimated at 2.2 lbs/hour. The cumulative mass percent less than or equal to 10 μm (PM_{10}) particulate emissions estimate was based on the stated size distribution for a furnace with local evacuation (EPA 1985, p. 7.5-12) for iron and steel mills, while the cadmium emission rates was based on the measured ratio of cadmium to blast furnace solids (BFS) particulate matter of 0.00096 (Hrebenyk, D., SENES [Memo to Monsanto Soda Springs Plant Phase I RI File] April 18, 1992), similar to the ratio for underflow solids. The latter is an overestimation because the cadmium concentration should have been based on the cadmium-to-particulate ratio of 0.00015 in taphole fume emissions. Because the cadmium emissions from the Plant are dominated by emissions from the four

kiln venturi stacks, the overestimation of cadmium emissions from the furnace building is not significant in the calculation of off-site effects. The fluoride emission rate was correctly based on the fluoride to particulate ratio of 0.047 in the taphole fume collector emissions.

5.3.1.5 Nodule Reclaim Area

Reports on emissions tests (ASA 1990) provide estimates of particulate emission rates for the following sources:

Screened discharge material (SDM) bunker	16.63 lb/hour
Reclaim hopper	144.87 lb/hour
Nodule pit chute	72.81 lb/hour
	235.31 lb/hour

Assuming continuous operations over approximately 8,100 hours per year (Hrebenyk, D., SENES [Memo to Monsanto Soda Springs Plant Phase I RI File] April 18, 1992), the total annual emissions would be approximately 1,900,000 lbs, of which about 61% would be due to emissions from the reclaim hopper. However, this does not include emissions from some ancillary operations such as clam transport and dump, or loader pickup from the nodule storage pile.

Straightforward application of the ASA emission rates significantly overestimates fugitive dust emissions from these sources. At these rates, the predicted ambient concentrations at the Harris Ranch monitoring station south of the Plant would be 0.340 mg/m^3 for a maximum 24-hour concentration, and the average annual concentration would be 0.065 mg/m^3. The observed average annual TSP concentration (based on geometric means) at the Harris Ranch for TSP from all sources is typically 0.032 mg/m^3 to 0.042 mg/m^3, of which about 0.020 mg/m^3 to 0.032 mg/m^3 can be attributed to control concentrations not associated with emissions from any portion of the Monsanto Plant. The average incremental arithmetic mean difference between measured levels at the Harris Ranch and control stations is about 0.025 mg/m^3. Maximum observed 24-hour concentrations recorded at the Harris Ranch are typically less than 0.150 mg/m^3, except for one 5 week period in 1987 when road work on a nearby county road and burning in a nearby field resulted in ominously high values up to 0.305 mg/m^3. Therefore, the air concentrations predicted with the direct application of the emission estimates from ASA for the nodule reclaim area are not reconcilable with the ambient monitoring data.

The emission sampling study conducted by ASA was performed for maximum material handling operations at the nodule stacking area. Particulate-size samples were collected from the rising plumes of unconfined ducts and the cross-sectional area of the plumes was estimated visually to calculate the hourly emission rates. A number of potential sources of error may have contributed to an overestimation of emission rates, namely:

1) The reported emission rates were based on a single measurement point taken at the center of the rising plumes, and the resultant concentration was assumed to be uniform across the entire width of the plume. This is physically unlikely since the plumes are unconfined and strongly, thermally-buoyant

plumes which suggests that turbulent mixing at the outer edge will entrain clean air causing dilution of the plume concentrations below that which is measured at the center of the plume. However, there is no simple method by which the average plume concentration may be estimated without taking successive measurements along a transect through the plume. For a wide plume such as that above the reclaim hopper (ie. 400 square feet), the concentration at the edge of the plume could easily be an order of magnitude lower than the maximum concentration measured at the center.

2) The cross-sectional areas of the plumes were visually estimated and the areas were multiplied by the measured velocity and concentration to obtain the emission rate. A small error in estimating the width of the plume (eg. 10%) would result in a relatively significant error in estimated emissions (ie. $(1.1r)^2/r = 21\%$).

3) The reported flow velocities of 1 m/s to 1.7 m/s in the plumes may be very low for the measured temperatures ranging from 118°F to 323°F. At these temperatures, it is possible to estimate thermally-induced buoyancy that would (theoretically) produce flow velocities up to 5 m/s. Moderating this effect, however, is the rapid decrease in velocity with entrainment of ambient air. From a dispersion point of view, higher velocities would result in greater dispersion and lower downwind concentrations for the same emission rates. (Note that a large initial dilution would also lead to lower concentrations.)

4) For the reclaim hopper, the estimated emission rate of 144.9 lb/hour was calculated as if the loading operation were continuous instead of being a batch operation occurring 2.5 to 3 times per hour. Although the ASA report makes note of the sporadic nature of the operation and ASA stated that this was taken into account in calculating the hourly emission rate, an examination of the sampling test data listed in the report indicates that this may not in fact be the case. Specifically, ASA reported that the average weight of particulate matter collected over two test runs was 67 mg in 5.5 minutes for a sample volume of 4.33 standard cubic feet (scf). The average concentration of 0.226 grains/scf, times the average estimated flow rate of 74,746 scf/minute, times 60 minutes, yields the reported emission rate of 144.9 lb/hour. However, assuming that the sampling results collected over each 5.5 minute period represents the emissions from one hopper loading operation and that such operations occur on average two and one-half to three times per hour, the average hourly emission rate would be:

0.226 grains/scf x 0.0648 grams/grain x 74,746 scf/minute x 5.5 minutes/load x 3 loads/hour = 18,061.6 grams/hour (39.8 lbs/hour)

This estimate is still conservatively high because it is based on the measured concentration at the center of the plume, as discussed in Item 1 above. It could perhaps be argued that the actual average emission rate could just as easily be an order of magnitude lower than estimated by ASA. Therefore, the measured concentrations and calculated emission rates

presented in the ASA report cannot be relied upon to estimate emissions from the reclaim hopper operations.

Aside from the reclaim hopper, the measured emission rates for the SDM bunker and nodule chute pit are probably more realistic because the operations in these areas are more or less continuous and the resultant plume widths, as estimated by ASA are considerably smaller. However, the reported emission rates were based on maximum material handling throughput rates and should appropriately be corrected for average rates of operation for dispersion modeling purposes. For these two areas, the estimated average emission rates are calculated as follows:

SDM bunker	Maximum	Average
process flows	40 tons/hour	26 tons/hour
particulate emissions	17.63 lb/hour[a]	11.46 lb/hour[b]
Nodule chute pit		
Process flows	444 tons/hour[c]	254 tons/hour[d]
Particulate emissions	72.81 lb/hour[a]	41.65 lb/hour[e]

[a] as estimated in ASA report
[b] 26/40 x 17.63 lbs/hour
[c] 2.5 tons per clam load x 2 loads per minute = 300 tons/hour + 144 tons/hour from chute to pit
[d] 240 tons/hour x 5 hour/8 hour shift
[e] 254/444 x 72.81 lb/hour

Assuming 8,100 hours of operation per year, the total particulate emissions from the two operations is estimated at 92,826 lb for the SDM bunker and 337,377 lb for the nodule chute pit. For the nodule pit chute, this represents an average emission rate of 0.16 lb/ton of material handled. Because this material is similar to the material fed into the reclaim hopper, it is reasonable to assume that the same emission rates could be applied to the hopper loading operations. For an average of three front end loader loads per hour, at 5.9 tons/load, an emission factor of 0.16 lb/ton yields an average hourly emission rate of 2.83 lb/hour. Assuming 8,100 hours of operation per year, the total annual emissions would be 22,939 lb. An equivalent amount of emissions can be assumed to result from the front-end-loader pickup at the nodule storage pile. Material dumping by the clam would result in an additional emission of 194,400 lb/year (240 tons/hour x 0.16 lb/ton x 5 hour/8-hour shift x 8,100 hours/year). Therefore, total emissions from the nodule stacking area are estimated to be:

SDM bunker	92,826 lb/year
nodule pit chute	337,377 lb/year
reclaim hopper	22,939 lb/year
loader pickup	22,939 lb/year
clam dump	194,400 lb/year
	670,481 lb/year

Inhalable particulate emission rates were based upon the reported PM_{10} fractions in TSP measured and reported by ASA as 42% for the SDM bunker, 49% for the nodule chute, and 54% for the reclaim hopper. Cadmium and fluoride concentrations were based on the measured fractions in nodules of 0.000005 for cadmium and 0.00715 for fluoride.

5.3.1.6 Material Handling Fugitives

Material handling operations considered were those operations associated with either continuous or batch drop/pick-up to/from stockpiles, as well as stockpile maintenance operations such as around the active slag tipping area where material is pushed over the edge.

The EPA (1988c) recommended uncontrolled emission factor equation for estimating fugitive emissions for dumping to and reclaim from stockpiles is:

$$e = k(0.0032)\ \frac{(U/5)^{1.3}}{(M/2)^{1.4}}$$

where:

e = emission rate (lb/ton of material handled);
k = 0.74 for particulates less than 30 μm;
U = average wind speed (miles per hour [mph]);
M = moisture content (%).

This equation is considered to be suitable for estimating emissions from batch dumping from trucks, continuous conveyor stacker drop to stockpile, and batch reclaim and drop with front end loaders.

The average wind speed (U) was based on long-term normals for Pocatello of 9.4 mph during the three months of the year when ore is added to the stockpile, and 10.2 mph for the annual average wind speed applicable to all other stockpile operations. In view of the fact that meteorological monitoring data for 1990 shows that wind speeds at Soda Springs may be approximately 1 m/s lower (2.2 mph) on average than in Pocatello, the estimated emissions based on climatic normals for Pocatello may overestimate fugitive dust emissions from material handling operations by up to 35%

The moisture content (M) and quantities of material handled for 1990 were provided by Monsanto as follows:

Material	M	Tonnage	
ore	11.2%	1,369,043	(delivered)
		1,726,247	(reclaimed)
coal/coke	14%	63,000	
quartzite	2%	260,000	
nodules/SDM	5.7%	331,977	
		(774,613)*	

UFS/BFS	28%	332,850
treater dust	5%	8,230
vactor dust	5%	32,920
baghouse dust	0.05%	704.3

*(Approximately 70% of the nodules are routed through the nodule reclaim area, and emissions from these operations are discussed in the preceding Paragraph.)

The particle size distribution recommended by EPA (1988c) for fugitive dust emission from continuous and batch operations is:

Grain size	$\leq$ 30 μm	$\leq$ 15 μm	$\leq$ 10 μm	$\leq$ 5 μm	$\leq$ 2.5 μm
Fraction	0.74	0.48	0.35	0.20	0.11

The fractions of cadmium and fluoride in particulate emissions for material handling operations were based on measured concentrations as follows:

Material	cadmium	fluoride
ore	0.0001	0.0164
nodules	0.000005	0.00715
slag	0.000002	0.004137
UFS/BFS	0.00096	0.013
coke	0.000003	0.000006
baghouse dust	0.000007	0.006735
treater/vactor dust	0.00041	0.00015

5.3.1.7 Road Travel Fugitive Dust

Two types of roads were considered in estimating fugitive dust emissions from road travel on the Plant:

- Unpaved roads — those with exposed aggregate material that can be released; and
- Paved roads — those with an asphalt surface where dust is released from the surface as a result of tracking onto the paved surface from unpaved areas.

The equations used to calculate emissions were based on published emission factor equations for uncontrolled emissions (EPA 1985 and 1988c). For TSP, the equation used for unpaved roads was:

$$E = k(5.9)(s/12)(S/30)(W/3)^{0.7}(w/4)^{0.5}(365-p/235)$$

where:

E = lb/vehicle mile travelled (VMT);
k = 0.8;
s = % silt content;

S = mean vehicle speed (mph);
W = mean vehicle weight (tons);
w = number wheels on vehicle; and
p = number of days with measurable precipitation per year.

For inhalable particulates, the EPA (1988c) recommended uncontrolled emission factor equation is:

$$E = 2.1\ (s/12)(S/30)(W/3)^{0.7}(w/4)^{0.5}(365-p/235)$$

The parameters used for each of the unpaved roads (see Figure 1-3) were as follows:

Road	s	S	W	w	VMT
ore haul-out	8	8	75	50	2,204
quartzite haul	8	15	57.5	18	10,964
slag haul	8	10	73	6	38,562
ferrophosphorus haul	8	8	22.13	10	1,721
2nd West	8	10	7	5	5,389
contractor entrance (west)	8	10	3	4	6,487
service road (east)	8	15	55	6	31,880
service road (west)	8	15	55	6	12,194

The VMT was based on Monsanto's estimate of road usage in 1985 because road usage for 1990 was unavailable. The mean number of days with precipitation was 96 based on long-term climatic normals for Pocatello. In addition, however, haul roads on the Plant are controlled by watering, as required. EPA (1988c) estimates that the maximum control efficiency achievable through watering is 95% control, and all calculated emissions from roads were reduced by this amount.

For paved roads, the EPA (1985 and 1988c) recommended emission factor equations for uncontrolled emissions are as follows:

TSP

$$E = 0.077\ (I)(4/n)(s/10)(L/1000)(W/3)^{0.7}$$

where:

E = emission rate (lb/VMT);
I = industrial augmentation factor (dimensionless);
n = number of traffic lanes;
s = surface material silt content (%);
L = surface dust loading (lb/mile); and
W = average vehicle weight (ton).

PM_{10}

$$E = 0.77\ (sL / 0.35)^{0.3}$$

where:

E = emission rate (lb/VMT); and
sL = silt loading.

Values for parameters I (7.0), s(12.5%), L(169 lb/mile), and sL(12.0 g/m^2) were estimated based on mean values reported for iron and steel mill facilities (EPA 1985). All paved roads were assumed to have two traffic lanes. The average vehicle weight (W) and the estimated road usage (VMT) for each of the paved roads was estimated as follows:

Road	W	VMT
ore haul-in	275	2,982
Phos Avenue	3	7,280
Durrett Avenue	4	3,885
South Street	7	7,800
contractor entrance (east)	3	5,345
delivery	6	3,262
employee entrance	3	2,062

Control efficiency for watering on paved roads was assumed to be 95%, and all calculated emissions were reduced by this amount. From Table 5-9, it is obvious that the primary sources of road dust at the Monsanto Plant are the unpaved haul and services roads. All together, the slag and quartzite haul roads, the service roads (east and west), and the ore haul (out) road account for almost 95% of the estimated road travel fugitive dust emissions from the Plant. The traffic on other roads adds only a minor incremental amount of dust to total annual emissions.

For the purposes of dispersion modeling, only TSP and PM_{10} emissions were considered. No attempt was made to estimate cadmium and fluoride emissions from re-suspension of material deposited on the roads from other sources. The quantities of cadmium and fluoride in road dust are unknown but contributions of these constituents from this source are assumed to be insignificant.

5.3.1.8 Wind Erosion Fugitives from Stockpiles

The EPA (1988c) recommended emission factor equation for wind erosion from active storage piles is:

$$E = 1.7\ (s/1.5)(365-p/235)(F/15)$$

where:

E = TSP emission rate in lb/day/acre;
s = % silt content;
p = number of days with measurable precipitation; and
F = % of time winds $\geq$ 12 mph.

Values for parameters p (96 days) and F (28%) were based on long-term climatic normals for Pocatello. Measured silt contents for the active storage piles were provided by Monsanto as follows:

Ore stockpile	6.2%
Coal/coke stockpile	1.0%
Quartzite	0.11%

The silt content of the quartzite material is so low that wind erosion from this stockpile was considered negligible and was not included in the modeling calculations. The ore stockpile was treated as an active stockpile, for the purposes of estimating wind erosion fugitives for only the three months of the year when material is being added to the stockpile. For the remainder of the year, the value of 0.38 tons/acre/year was used to estimate wind erosion based on reported emission rates for exposed overburden at western surface coal mines (EPA 1985, p. 8.24-8). This value was also used to estimate wind erosion for the slag, UFS/BFS, treater dust, vactor dust, baghouse dust and cold nodules stockpiles, wherein operations that would disturb the surface material are generally limited to adding new material to the stockpile. In such cases, the amount of erodible material from the large portions of undisturbed surfaces is limited due to winnowing effects. In the absence of detailed information on total mass of material available for re-suspension, a value of 0.38 tons/acre/year was assumed to provide a reasonable estimate of emissions due to wind erosion.

Estimated wind erosion emissions were reduced for periods of the year with snowcover. The average period of snow cover for this region is approximately 120 days. Therefore, the estimated average annual emissions were reduced by a factor of 120/365. This is considered to provide a conservative estimate of wind erosion emissions because even without snow cover, the anticipated emissions would be much lower during the winter than during the hot, dry summer.

Air quality monitoring data, discussed in Section 4.2, shows that there is a distinct seasonal difference in observed TSP levels for the period May to mid-October versus mid-October to May. The mean difference between levels measured at the Harris Ranch and control levels is about 0.004 mg/m^3 to 0.019 mg/m^3 lower during the period mid-October to May than during the summer and early fall months of the year. This difference is most likely due to lower fugitive emissions from the Plant. Therefore, for the purposes of the dispersion modeling assessment, the estimated emissions due to wind erosion are considered to provide an overestimation of actual emissions.

The fraction of cadmium and fluoride in particulate emissions for wind erosion of the stockpiles was based on measured concentrations. The ratios used were the same as those listed for stockpile material handling operations in the material handling fugitives discussion above.

The particle-size distribution used for modeling wind erosion fugitives was:

Grain size	$\leq$ 30 μm	$\leq$ 15 μm	$\leq$ 10 μm	$\leq$ 5 μm	$\leq$ 2.5 μm
Fraction	0.74	0.48	0.35	0.20	0.11

as recommended by EPA (1988c), and similar to the particle size distribution used for material handling fugitive emissions.

5.3.1.9 Summary of Estimated Emissions

Tables 5-1 to 5-5 list the measured or estimated average hourly emission rates for all of the sources evaluated. The estimated total annual emissions for 1990 are listed in Tables 5-6 to 5-10. The average annual emission rates used in dispersion modeling are summarized in Table 4-11. It should be noted that the total annual emissions used in the modeling assessment are generally higher than actual estimated emissions.

For the permitted sources, TSP emission rates modeled are approximately 14% higher than estimated actual emission rates because the hourly emission rates listed in Table 5-1 were used to model hour-by-hour concentration levels as if the permitted sources were operating 8,760 hours per year. In actual fact, the furnace operations ranged from 7,476 hours for furnace #9 to 8,346 hours for furnace #7. For the same sort of reason, modeled emissions from the baghouses and furnace building fugitives are approximately 28% higher than actual estimated emissions. Modeled slag dumping emissions are about 10% higher than calculated emissions, while modeled fugitive emissions from road travel are almost 21% higher than estimated using emission factor calculations. Similarly, modeled fugitive emissions from stockpiles are about 32% higher than estimated, and 12% higher for the nodule reclaim area operations. Therefore, in assessing the dispersion modeling results presented in Subsecton 5.3.2 below, the predicted concentrations from Plant emissions should be considered as conservative overpredictions of actual anticipated air-quality effects.

From Table 5-11 it can be seen that the largest source of particulate emissions at the Plant is the nodule reclaim area. The estimated emissions from this area of the Plant alone exceed the estimated emissions from all other sources at the Plant. However, with respect to cadmium, the nodule reclaim area emissions are not as significant as emissions from the permitted sources.

As a group, the permitted sources are the second largest source of particulate emissions, and the primary source of cadmium and fluoride emissions, although nodule reclaim area emissions are also an important source of fluoride emissions. In fact, from Table 5-6 it will be seen that the principal sources of cadmium emissions are the four kiln venturi stacks. Fluoride emissions are mainly associated with exhaust from the taphole fume collectors, but significantly large amounts of fluoride are also present in the emissions from the kiln cooler spray tower and the four kiln venturi stacks. Fugitive emissions of fluoride from slag dumping are also a large source of emissions. Although fugitive emissions due to wind erosion and material handling operations are a large source of particulate emissions, their contribution to off-site concentrations of cadmium and fluoride is relatively minor (i.e., <2%).

Therefore, from the point of view of off-site effects, the principal sources of emissions are the permitted sources, slag dumping and nodule reclaim area operations. Fugitive emissions

from roads and stockpiles are most likely to affect areas within a few hundred meters of the sources, but their significance to more distant areas is overshadowed by emissions from the stack and thermally-buoyant fugitive sources.

5.3.2 Air Transport

The effects of Plant operations on local air-quality were assessed by using mathematical dispersion models to calculate ground level concentrations of particulate matter, cadmium and fluoride. Stack and point source emissions, as well as the thermally-buoyant emissions from slag dumping and nodule reclaim area operations, were modeled using both the long-term and short-term versions of the EPA-approved Industrial Source Complex Model (ISCM). The ISCM is a Gaussian dispersion model specifically designed to permit the analysis of emission sources from complex industrial settings. TRC Environmental Consultants (TRC) demonstrated that the ISCM consistently overpredicts suspended particulate matter concentrations from ground-level fugitive dust sources (TRC 1988). In cooperation with the EPA, TRC developed the Fugitive Dust Model (FDM) to provide a more accurate estimation of suspended dust levels downwind of fugitive dust sources. Like the ISCM, FDM is generally based on the Gaussian plume formulation, but has been specifically adapted to incorporate an improved gradient-transfer deposition algorithm which accounts for plume depletion through deposition in estimating ambient concentration levels. Therefore, FDM was used to model emissions from road traffic, stockpile material handling operations, and wind erosion of exposed surfaces.

Dispersion modeling was conducted using a fine coordinate receptor grid with 100-m spacing over an area of 5-km x 5-km, as well as over a coarser grid spacing (i.e., 1-km spacing) on a 20-km x 25-km grid. The size of the area evaluated was based on a consideration of plume transport from elevated sources such as stacks. Elevated plumes may not reach ground level for a distance of several kilometers from the source, especially under stable atmospheric conditions. However, due to the relatively short stack heights of some of the permitted sources with respect to the heights of associated buildings (e.g., the taphole fume collectors), building wake effects on plume behavior would be expected to reduce the distance to the point of maximum effects. The modeling results indicate that maximum air-quality effects from both the stack and fugitive dust sources occur close to the Plant boundaries within the area covered by the 5-km x 5-km grid.

Both 24-hour and average annual concentrations were calculated for discrete receptor locations as well as for the square coordinate receptor grids. The location of discrete receptors in relation to the Monsanto Plant line is depicted in Figure 5-2. As listed in Table 5-12, the discrete receptors include the nearest residential/commercial properties (Receptors #1—6), the four schools in Soda Springs (Receptors #7—10), the locations of current or historical TSP and PM_{10} monitoring stations around Soda Springs and Conda (Receptors #11—16), the locations of previous fluoride-in-vegetation sampling stations (Receptors #17—32), and four points along the property line (Receptors #33—36). In the discussion of modeling results that follows, the predicted concentrations for the historical fluoride-in-vegetation sampling stations (Miller and Pushnik 1985; Miller 1986, 1987 and 1990) are not included in the tables for discrete receptors. Only the results pertaining to Receptors #1—16

and #33—36 are considered in the assessment. However, the predicted concentrations for these additional receptors are listed in Appendix E for completeness.

5.3.2.1 Methodology

In order to determine the relative importance of emissions from various types of sources at the Plant, the sources were grouped for modeling as follows:

Source Group 1 — Permitted Sources (ISCM)

- taphole fume collectors #7, 8, 9
- kiln cooler spray tower
- kiln venturi scrubbers
- nodule crushing/screening scrubber
- slag dumping

Source Group 2 — Baghouse/Building Fugitives (ISCM)

- coke/quartzite dryer baghouse
- stocking system baghouse
- coke/quartzite satellite baghouse
- ore satellite baghouse
- coke handling baghouse
- scaleroom baghouse
- furnace building fugitives

Source Group 3 — Nodule Reclaim Area (ISCM)

- SDM bunker
- reclaim hopper
- nodule chute
- front-end loader pickup from stockpile
- clam dump to stockpile

Source Group 4 — Roads/Material Handling/Wind Erosion (FDM)

- all roads on Plant
- ore stockpile
- coal/coke stockpile
- quartzite stockpile
- nodules/SDM stockpile
- wind reclaim area (wind erosion only)
- UFS/BFS stockpile
- treater dust stockpile
- vactor dust stockpile
- slag stockpile (wind erosion)
- slag dumping area (maintenance)

- baghouse dust stockpile

Initially, the slag dumping operations were modeled in conjunction with permitted point sources in Source Group 1. However, because this operation is a unique source of emissions at the Plant, the slag dumping emissions were subsequently modeled separately to determine the incremental contribution of these emissions to the predicted concentrations at the discrete receptor locations. In the discussions of results which follow, the slag dumping concentrations are listed separately in the tables for discrete receptors, but are grouped with the permitted sources in the figures showing concentrations for the gridded areas.

Table 5-13 lists the stack heights and exhaust characteristics used to model the point and volume sources listed in Source Groups 1, 2 and 3 above. The data on exhaust flow rates and temperatures were provided by Monsanto as determined from previously conducted stack monitoring. Both the slag dumping and furnace building fugitive emissions were modeled as volume sources. The emissions from the nodule reclaim area could equally have been represented as volume sources due to their inherent thermal buoyancy. However, the 1990 monitoring report for these sources by American Services Associates provided both estimated and measured plume dimensions as well as exhaust temperatures and velocities. Therefore, the sources in the nodule reclaim area were modeled as pseudo-stacks to account for thermal buoyancy using the plume rise algorithm in the ISCM.

5.3.2.2 Long-Term Modeling Results

Tables 5-14 to 5-17 list the predicted average annual concentrations of TSP, PM_{10}, cadmium and fluoride at discrete receptor locations for emissions from all sources modeled. The incremental contributions from individual source groups as well as the total estimated concentrations from all sources are listed in the tables for the nearest neighbors (Receptors #1—6), especially sensitive receptors (Receptors #7—8), stations of current or former air monitoring stations (Receptors #11—16), and at four locations along the property boundary (Receptors #33—36).

Figures 5-3 to 5-6 depict the predicted average annual concentrations for all emission sources modeled using the ISCM. These include the permitted sources, slag dumping, baghouses, furnace building fugitives, and fugitive emissions from the nodule reclaim area (Source Groups 1, 2 and 3). The predicted concentrations arising from fugitive emissions due to road traffic, material handling operations (other than the nodule reclaim area), and wind erosion of exposed surfaces (Source Group 4) modeled using the FDM are depicted in Figures 5-7 to 5-10.

The results for each of the specific constituents modeled are discussed below in detail.

Total Suspended Particulates

From Table 5-14 and Figure 5-3, it is evident that the predicted average annual TSP concentrations using the ISCM are largely dominated by emissions from the nodule reclaim area. The highest average annual concentrations occur north and south of the nodule reclaim area, in accordance with the bimodal distribution of prevailing winds from the north-

northeast and south-southwest through southeast. Peak TSP concentrations occur close to the reclaim area within the Plant property line, and concentrations beyond the property line are less than 0.011 mg/m^3, except along the southwest portion of the property line where the maximum predicted average annual TSP concentrations are about 0.013—0.014 mg/m^3.

By comparison, the predicted average annual concentrations due to fugitive emissions from roads, material handling operations (i.e., stockpiles), and wind erosion modeled using the FDM model tend to occur in the vicinity of the active process and waste stockpiles, principally the ore and underflow solids (UFS) stockpiles and the associated service and haul roads. The general orientation of the predicted concentration isopleths is along the north-northeast to south-southwest axis of prevailing winds. Concentrations along the property line are on the order of 0.005 mg/m^3 to 0.010 mg/m^3 on the east and west sides of the Plant, and 0.010 mg/m^3 to 0.015 mg/m^3 on the north and south sides of the property.

As discussed in Section 4.2, the difference between observed ambient concentrations at the Harris Ranch (Receptor #12) and mean annual control levels during 1986 to 1988 were reported as 0.012 mg/m^3 to 0.017 mg/m^3, based on geometric means, and 0.023 mg/m^3 to 0.027 mg/m^3, based on arithmetic means. The total predicted mean annual TSP concentration at the Harris Ranch for emissions from all sources on the Monsanto Plant are estimated at 0.0245 mg/m^3 (Table 5-14). Thus, the predicted incremental TSP concentration of 0.0245 mg/m^3 from Plant operations falls within the range of observed differences between the Harris Ranch and control levels. However, the observed incremental difference of 0.023—0.027 mg/m^3 from monitoring data at the Harris Ranch includes the additional emissions from other sources of fugitive dust in the area which have not been included in the modeling assessment (i.e., traffic along the nearby roads and agricultural activity in adjacent fields). Consequently, the predicted average annual TSP concentration at the Harris Ranch of 0.0245 mg/m^3, due to emissions from the Monsanto Plant represents a conservative estimate of potential effects in accordance with the conservative estimates of emission rates discussed in Subsection 5.3.1. Actual effects are likely to be somewhat lower than the levels listed in Table 5-14.

Predicted average annual TSP concentrations from Plant emissions at the nearest residential/commercial properties (Receptor #1—6) range from 0.002 mg/m^3 to less than 0.020 mg/m^3. The effect on the TSP levels in Soda Springs (Receptors #7—10 and #13) is about 0.005 mg/m^3 to 0.008 mg/m^3. As discussed in Section 4.2, the average difference in observed mean annual TSP concentrations between the Soda Springs Hospital air monitoring station and the station two miles north of Hooper Springs during 1986 to 1988 was about 0.007 mg/m^3 to 0.008 mg/m^3. Therefore, the predicted concentrations appear to indicate that most of the difference in observed concentrations between these two monitoring stations could be attributable to emissions from the Monsanto Plant. Approximately 55% to 60% (i.e., 0.003 mg/m^3 to 0.004 mg/m^3) of the predicted effect in Soda Springs is estimated to be due to emissions from the nodule reclaim area operations alone.

Based on these results, it is concluded that the incremental effect of Plant emissions, in conjunction with control levels of approximately 0.020 mg/m^3 to 0.032 mg/m^3, will not result in exceedences of primary or secondary ambient air quality criteria of 0.075 mg/m^3 and 0.060 mg/m^3 (40 CFR 50), respectively.

It is also worth noting in Table 5-14 that the predicted effect of emissions from the Monsanto Plant on concentrations recorded at the two monitoring stations near Conda is relatively insignificant. Predicted average annual TSP concentrations from Plant emissions are about 0.001 mg/m^3 as compared with observed TSP levels in 1986 to 1988 of 0.048 mg/m^3 to 0.050 mg/m^3. On the basis of the modeling results, it may be concluded that emissions from the Monsanto Plant are not a significant source of particulates measured near Conda, representing only about 2% of measured concentrations.

Inhalable Particulates

The distribution of predicted average annual PM_{10} concentrations listed in Table 5-15 and depicted in Figures 5-4 and 5-8 is similar to the predicted distribution for TSP discussed above. For the emission sources modeled using ISCM, the concentrations of PM_{10} are dominated by emissions from the nodule reclaim area (Figure 5-4), while the highest predicted PM_{10} concentrations using the FDM occur in the vicinity of the active process and waste stockpiles such as the ore and UFS stockpiles and their associated service and haul roads. Maximum predicted average annual concentrations along the southwestern portion of the property line for sources modeled using ISCM are about 0.013 mg/m^3. Maximum average annual concentrations of 0.010 mg/m^3 for sources modeled using FDM occur along the northern property line (Figure 5-8). The total average annual PM_{10} concentration from all sources occurs on the southwest portion of the property line near the Harris Ranch and is predicted at about 0.020 mg/m^3.

For the discrete receptors (Table 5-15), PM_{10} concentrations at the nearest neighbors (Receptor #1—6) range from <0.002 mg/m^3 to 0.016 mg/m^3. In Soda Springs, the affects of Plant emissions are estimated at <0.004 mg/m^3 to 0.006 mg/m^3 at the four schools and the hospital (Receptors #7-10 and #13). The predicted average annual concentrations at the Terrace Acres Mobile Court air monitoring station (Receptor #16) was 0.0053 mg/m^3 in 1990. Since there are no control PM_{10} monitoring data, the incremental affects of the Plant emissions on measured PM_{10} concentrations at the Terrace Acres station cannot be verified. Based on the ratio of predicted to observed concentrations, it is estimated that the Plant emissions represent approximately 20% of the ambient PM_{10} levels observed at the mobile court monitoring station. Because the observed PM_{10} concentrations are well below the criteria concentration of 0.05 mg/m^3 (40 CFR 50), the affects of Plant operations are unlikely to cause any exceedences of the air quality standard.

As discussed in Section 4.2, the observed average annual PM_{10} concentration near Conda (Receptor #14) in 1988 was 0.039 mg/m^3. The predicted concentration from emissions from Monsanto's operations is estimated to be less than 0.001 mg/m^3 at Conda. Therefore, the effects of the Plant operations on air quality near Conda is relatively insignificant, representing less than 2% of observed concentration levels.

Cadmium

The predicted annual average cadmium concentrations for Plant emissions are depicted in Figure 5-5 for sources modeled using ISC, and Figure 5-9 for sources modeled using FDM. Predicted concentrations at discrete receptor locations are listed in Table 5-16.

Since approximately 99% of cadmium emissions are associated with emissions from the four kiln venturi scrubbers, it is not surprising that the predicted concentration levels are entirely dominated by ISCM results for the permitted sources. Emissions from all other sources at the Plant add a negligible amount to the predicted cadmium concentrations.

The highest predicted annual average cadmium concentrations are estimated at 1.6E-5 mg/m^3 and occur beyond the property line, approximately 700 m to 800 m northwest and southwest of the Plant. However, the concentrations at the nearest neighbors are lower. The predicted concentrations range from 4.0E-6 mg/m^3 to 1.4E-5 mg/m^3 (Receptors #1—6 and #12), while the concentrations in Soda Springs range from 1.2E-5 mg/m^3 to 1.5E-5 mg/m^3 (Receptors #7—10 and #13). In Conda, the predicted cadmium concentrations are estimated at 4.0E-6 mg/m^3.

It is worth noting that the predicted average annual cadmium concentrations reported above are somewhat lower than the concentrations reported previously by Monsanto in 1988 (Cheng, C.K., Monsanto [Memo to F.R. Johannsen, Monsanto] April 12, 1988; and May 17, 1988). In the 1988 effort, the estimated annual average air concentration for the most exposed individual was estimated at 5.0E-5 mg/m^3. Thus, the predicted concentrations at the nearest residential properties (Receptor #1—6 and #12) in the current effort are less than one-third of the concentrations estimated by Monsanto in 1988. These differences in predicted concentrations between the two modeling studies are due to significant differences in estimated emission rates for the slag dumping area. The estimated emission rates for sources used in the two modeling studies are as follows:

Source	Estimated Cadmium Emissions (lb/hour)	
	1990	1988
taphole fume collectors #7	4.5E-4	4.8E-4
taphole fume collectors #8	1.9E-4	1.6E-4
taphole fume collectors #9	2.0E-4	1.6E-4
kiln cooler spray tower	3.3E-3	2.4E-6
nodule crush/screen scrubber	3.5E-3	9.5E-3
kiln venturi scrubbers A	0.227	0.166
kiln venturi scrubbers B	0.168	0.166
kiln venturi scrubbers C	0.166	0.166
kiln venturi scrubbers D	0.201	0.166
slag dumping	5.8E-6	0.044

Although the estimated emissions from the kiln venturi scrubbers (the principal source of cadmium emissions at the Plant) were about 15% higher for the current modeling effort than in the 1988 effort, the total estimated concentrations are much lower for the current effort because the estimated emissions from slag dumping are approximately 7,685 times lower than in the 1988 effort. Consequently, whereas the 1988 modeling effort by Monsanto predicted a maximum fence-line cadmium concentration of 1.97E-4 mg/m^3, the maximum fence-line concentration for the current modeling effort is estimated to be less than 2.0E-5 mg/m^3, or one-tenth the predicted concentration of the 1988 effort.

In the 1988 effort, the maximum annual average cadmium concentration for off-property segment centroids was estimated at 2.2E-5 mg/m^3 from slag dumping activities. Given that

the concentration of cadmium in slag material has been measured at 2 mg/kg, the annual average TSP concentration attributable to slag dumping would have to have been estimated at 10.9 mg/m^3 in the 1988 effort in order to have produced a predicted cadmium concentration of 2.2E-5 mg/m^3. This is unrealistic and it is concluded that the estimated emission rate for cadmium from slag dumping which was used in the 1988 modeling effort was erroneous.

On the other hand, the predicted maximum annual average cadmium concentration for off-property segment centroids in the 1988 effort was 1.2E-5 mg/m^3 for the permitted point sources, which is lower than the maximum annual concentration of 1.6E-5 mg/m^3 predicted for the current modeling effort. The difference in this case is most likely due to the use of somewhat higher emission rates for the kiln venturi scrubbers, which in the current effort are based on actual stack monitoring data measured in 1990. Also, the use of site-specific meteorological data in the current effort as compared with use of Pocatello data in the 1988 effort by Monsanto may have contributed to the somewhat higher estimated ambient concentrations from the kiln venturi stack emissions. Therefore, although the estimated effects for the permitted sources alone are somewhat higher in the current effort than in 1988 effort, the total affects from the Plant as a whole are now seen considerably lower due to the corrected emissions from the slag dumping activities.

Fluoride

Figures 5-6 and 5-10 depict the predicted average annual fluoride concentrations for sources modeled using the ISCM and FDM, respectively. The relative contributions of source groups to the predicted concentrations at discrete receptor locations are listed in Table 5-17. The major sources of fluoride emissions at the Plant are the permitted sources, principally the taphole fume collectors. However, significant emissions are also associated with the kiln venturi scrubbers, the kiln cooler spray tower, the nodule reclaim area fugitives, and fugitives from the slag dumping area. Since all of these sources were modeled using the ISCM, the estimated average annual concentrations depicted in Figure 5-6 show the primary effects of fluoride emissions. Maximum concentrations at the southern property line are estimated at 0.0011 mg/m^3. Concentrations along other portions of the property line generally range from <2.0E-4 mg/m^3 to 7.0E-4 mg/m^3.

The predicted average annual fluoride concentrations at the nearest residences (Receptors #1—6 and #12) range from 6.0E-5 to 0.001 mg/m^3, while the estimated levels in Soda Springs (Receptors #7—10 and #13) are about 1.9E-4 to 3.2E-4 mg/m^3. At Conda, the ambient levels are estimated at 3.0E-5 mg/m^3.

Although monitoring of fluoride in vegetation has been conducted for a number of years (1985 to 1988) around Soda Springs (Miller and Pushnik 1985; Miller 1986 and 1987), and the modeling conducted here, has used the vegetation monitoring stations as discrete receptor locations for predicted concentrations, the observed levels of fluoride-in-vegetation samples cannot be used to estimate ambient concentration levels in air. They only provide a relative scale for comparison. In this respect, it is significant that the fluoride-in-vegetation monitoring reports for 1985 to 1988 state that the highest fluoride concentrations at Soda Springs occurred at stations adjacent to the Monsanto Plant. This is in generally good

agreement with the patterns of predicted ambient concentrations depicted in Figures 5-6 and 5-10.

Comparison of the predicted fluoride concentration for the current modeling effort with those predicted by Monsanto in 1988 shows that the current estimates are much lower. The maximum fence-line concentration estimated by Monsanto in 1988 was 0.0328 mg/m^3, while the maximum concentration at the nearest neighbor was 0.0076 mg/m^3. As stated above, the maximum fence-line concentration in this effort is 0.0011 mg/m^3, while the predicted levels at the nearest neighbors range from 6.0E-5 to 7.3E-4 mg/m^3 at Receptors #1—6 and 0.00104 mg/m^3 at the Harris Ranch (Table 5-5).

The primary reason for the difference in estimated concentrations lies in the method used to estimate emissions from slag dumping operations. For the 1988 modeling effort, the emission rate was estimated at 7.6 lb/hour, while the emission rate in the current effort is estimated at 0.72 lb/hour. In the current effort, the emission, rate for fluoride has been reduced in direct proportion to the reduction in estimated TSP emissions, as discussed in Paragraph 5.3.1.3. Therefore, the estimated emissions of both particulates and fluorides from slag dumping are less than one-tenth the rate used in the 1988 modeling effort.

In the 1988 effort, the predicted maximum annual average concentrations were expected to occur at the southern boundary and to be almost exclusively (i.e., 98%) due to emissions from slag dumping. The current effort estimates that approximately 40% of the predicted maximum concentration at the southern boundary can be attributed to slag dumping; a further 40% is due to emissions from permitted sources, and about 14% is associated with emissions from the nodule reclaim area (a source not included in the 1988 modeling effort).

5.3.2.3 Short-Term Modeling Results

Tables 5-18 to 5-21 list the predicted, second-highest, 24-hour concentrations for TSP, PM_{10}, cadmium, and fluoride at discrete receptor locations for any given day using 1990 meteorological data. The predicted concentrations from each source group are listed separately. However, it should be noted that, unlike the modeling results for average annual concentrations discussed in Subparagraph 5.3.1.2.2, the incremental effects for short-term concentrations resulting from individual source groups are not additive because the predicted maximum concentrations from different source groups may occur on different days of the year depending upon specific meteorological conditions.

For stacks (i.e., elevated point sources), the maximum short-term concentrations will generally occur during unstable (Class A or B) atmospheric stability conditions, which may cause the elevated plumes to reach ground level closer to the source while the plume concentrations are relatively high. Such conditions normally prevail in the summer. On the other hand, maximum fugitive emissions and resultant concentrations from sources such as storage piles occur under neutral (Class D) stability conditions.

Modeling results show that the maximum 24-hour TSP concentrations for fugitive dust sources at the Monsanto Plant occur during the months of December and January. Therefore, the atmospheric conditions which produced a high concentration of 0.0068 mg/m^3

at the Harris Ranch from the permitted sources (see Table 5-18) are not the same conditions which produced the high concentration of 0.0275 mg/m^3 from roads, material handling operations, and wind erosion, and it would be inappropriate to add these numbers. On the other hand, it is reasonable to combine emissions from elevated or thermally-buoyant sources such as the permitted sources, baghouses, or slag dumping emissions, because these are most likely to be affected by meteorological conditions in the same way.

For comparison purposes, Figures 5-11 to 5-22 depict the predicted, second-highest, 24-hour concentrations of TSP, PM_{10}, cadmium, and fluoride. The predicted concentrations from permitted sources, baghouses, slag dumping, and furnace building fugitives are grouped together (Source Groups 1 and 2), while the predicted levels from nodule reclaim area emissions (Source Group 3), as well as fugitive emissions from area sources (Source Group 4), are each shown separately. The results for each of the specific constituents modeled are discussed below.

Total Suspended Particulates

Figures 5-11 to 5-13 depict the predicted, second highest, 24-hour TSP concentrations from Plant emissions. Figure 5-11 shows that the maximum concentrations from thermally-buoyant sources occur within the property line and are mainly centered around the furnace buildings. Maximum concentrations at the fence line occur near the slag dumping area, and are estimated at 0.022 mg/m^3. Elsewhere along the fence line, concentrations range from <0.006 to 0.014 mg/m^3. Table 5-18 shows that concentrations at discrete receptor locations closest to the Plant range from a maximum of 0.020 mg/m^3 at the Harris Ranch (Receptor #12) to <0.004 mg/m^3 at Receptor #6. Maximum concentrations from these sources in Soda Springs are estimated at 0.0044 — 0.0083 mg/m^3 (Receptors #7—10 and #13).

The predicted concentrations from area source emissions (Figure 5-13) are somewhat higher. The maximum 24-hour concentrations at the southern boundary line are estimated at 0.028 mg/m^3, and range between less than 0.010 mg/m^3 to 0.022 mg/m^3 elsewhere along the fence line. At the nearest neighbors and within Soda Springs, predicted concentration range from 0.0024 mg/m^3 to 0.0275 mg/m^3, and from 0.0031 mg/m^3 to 0.0055 mg/m^3, respectively (Table 5-6).

By far, the largest predicted short-term effects for particulate emissions are from the nodule reclaim area operations. Figure 5-12 shows that the maximum predicted, 24-hour concentration at the southwest corner of the property line is about 0.120 mg/m^3, and similarly high concentrations may be expected to occur at or close to other points along the north, east, and west sides of the property. Since TSP emissions from the nodule reclaim area represent the largest single source of particulates at the Plant, maximum short-term effects for this source dominate all other emission effects. Maximum concentrations at the nearest residential stations range from 0.017 mg/m^3 to 0.093 mg/m^3 (Receptors #1—6 and #12). Within Soda Springs, maximum predicted concentrations attributable to Plant emissions range from 0.026 mg/m^3 to 0.043 mg/m^3.

As discussed in Section 4.2, the arithmetic mean difference between individually paired concentration levels recorded on the same days at the Harris Ranch and the Soda Springs

Hospital during the warmer months of the year (i.e., May to October) is 0.027 mg/m^3. The mean difference between similarly paired monitoring data for the Harris Ranch and the monitoring station north of Hooper Springs is 0.023 mg/m^3. Therefore, the average 24-hour effect of the emissions from the Monsanto Plant at the Harris Ranch during the warm summer months when fugitive dust emissions are likely to be highest, is about 0.025 mg/m^3. The maximum TSP concentration recorded at the Harris Ranch monitoring station during 1986 to 1988 was 0.147 mg/m^3 on June 7, 1986. On that date, the TSP level recorded at the Soda Springs Hospital monitoring station was 0.057 mg/m^3, for a maximum recorded difference of 0.090 mg/m^3. The maximum difference between the Harris Ranch and the monitoring station north of Hooper Springs was 0.084 mg/m^3 on May 15, 1987. On the basis of the monitoring data, the potential range of expected maximum short-term effects due to Plant emissions is defined as 0.025 mg/m^3 to 0.090 mg/m^3. The maximum concentrations depicted in Figures 5-11 and 5-13 fall well within this range. However, the maximum predicted effects for emissions from the nodule reclaim area, as depicted in Figure 5-12, appear to overpredict maximum effects for this source when compared with observed maximum effects.

The predicted, second-highest, maximum 24-hour concentration at the Harris Ranch for nodule reclaim area emissions is 0.0927 mg/m^3, making the predicted maximum effect for this source alone equal to the maximum difference between monitoring data recorded at the Harris Ranch and control monitoring stations. Because other sources must be expected to contribute some additional particulate material, the predicted level of 0.0927 mg/m^3 must be regarded as an overprediction. Gaussian plume models such as ISCM are generally regarded to predict short-term concentrations within a factor of two to four of observed levels. Therefore, the degree of overprediction is uncertain, and may be due to a number of sources of error including uncertainties in estimated emission rates, source characterizations, and plume depletion rates through deposition.

Inhalable Particulates

Figures 5-14 to 5-16 depict the predicted second highest 24-hour PM_{10} concentrations for Plant emissions. The affect patterns for the source groupings are similar to those discussed above for TSP. Figure 5-14 shows that the maximum predicted PM_{10} concentrations from permitted sources, baghouses, furnace building fugitives, and slag dumping occur within the property line near the furnace buildings. Maximum concentrations at the property line occur in the southwest corner of the property and are estimated at about 0.016 mg/m^3. Concentrations along other portions of the property line range from 0.005 mg/m^3 to 0.015 mg/m^3. For fugitive dust sources such as roads, stockpiles, and wind erosion of exposed surfaces, maximum predicted concentrations along the property line range from less than 0.005 mg/m^3 to 0.016 mg/m^3. The largest predicted effects are for emissions from the nodule reclaim area, ranging from about 0.015 mg/m^3 to 0.060 mg/m^3. However, as discussed above for TSP, the predicted effects depicted in Figure 5-15 may be regarded as overpredictions of actual expected effects.

There is relatively less PM_{10} monitoring data with which to make comparisons for predicted short-term effects. Maximum 24-hour PM_{10} concentrations recorded during late 1989 and 1990 at the Terrace Acres Mobile Court monitoring station (Receptor #16) (Table 5-19) ranged as high as 0.096 mg/m^3, but there is no control monitoring station against which potential

incremental effects can be estimated. The observed average PM_{10} level at this station in 1990 was 0.0268 mg/m^3. The difference of 0.069 mg/m^3 between the average concentration and the maximum recorded level cannot be accounted for even by summing all of the maximum predicted levels for all sources at the Monsanto Plant, including the high emissions from the nodule reclaim area. Therefore, it may be concluded that emissions from the Monsanto Plant operations are not the source of PM_{10} emissions contributing to observed maximum PM_{10} concentrations at this monitoring station. Similarly, the effects of emissions from Monsanto on the maximum PM_{10} concentrations recorded at Conda are likely to be even less significant. The maximum PM_{10} concentration recorded at Conda during 1988 to 1990 was 0.190 mg/m^3 compared with an average annual concentration of 0.039 mg/m^3. Even by combining all of the predicted maximum 24-hour concentrations for all Monsanto sources for Receptor #14 in Table 5-19 which together total 0.0075 mg/m^3, it is not possible to attribute any significant portion of the 0.151 mg/m^3 difference between mean and maximum PM_{10} concentration at Conda to emissions from Monsanto operations.

Cadmium

Figures 5-17 to 5-19 show the predicted maximum short-term concentrations of cadmium for Plant emissions. Since cadmium emissions from the Plant are dominated by emissions from the four kiln venturi stacks, the concentration levels depicted in Figure 5-17 represent the expected maximum effects.

The second-highest, 24-hour concentration levels are predicted to occur off-site, beyond the northwest corner of the property line. Maximum levels of about 2.4E-4 mg/m^3 may occur for a distance of about 700 m to 800 m beyond the property line. The location of the maximum affected area lies directly downwind of the kiln venturi stacks for southeast winds. The annual wind rose for the on-site meteorological station shows that the highest mean annual wind speeds occur with southeast winds at 7.2 m/s. Therefore, the predicted high concentrations northwest of the Plant are likely caused by the effects of strong winds forcing the exhaust plumes from the venturi stacks to ground level close to the Plant. Since the predominant wind directions lie along the north-northeast to south-southwest axis, the short-term effects depicted in Figure 5-17 do not result in exceptionally high average annual cadmium concentrations northwest of the Plant (see Figure 5-5).

Maximum short-term concentrations at other locations around the Plant generally range from less than 3.0E-5 mg/m^3 to about 0.015 mg/m^3. At the discrete receptor locations listed in Table 5-20, the maximum expected 24-hour concentrations from permitted sources (i.e., mainly the kiln venturi stacks) at the nearest neighbors range from 2.0E-5 mg/m^3 to 1.2E-4 mg/m^3 (Receptors #1—6 and #12). Within Soda Springs, predicted concentrations are generally in the range of 6.0E-5 mg/m^3 to 8.0E-5 mg/m^3, while the expected levels at Conda are about 3.0E-5 mg/m^3 to 4.0E-5 mg/m^3.

Fluoride

The primary sources of fluoride emissions at the Plant are the permitted sources, slag dumping and operations in the nodule reclaim area. The second highest 24-hour concentration levels depicted in Figure 5-20 are mainly due to emissions from the permitted

sources and slag dumping activities. They indicate that maximum short-term concentrations of fluoride are expected to occur along the southwest portion of the property line at about 0.0044 mg/m^3. Elsewhere along the property line, predicted concentrations range from 9.0E-4 mg/m^3 to less than 0.004 mg/m^3. Maximum predicted concentrations for nodule reclaim area emissions are much lower, ranging from 2.0E-4 mg/m^3 to 8.0E-4 mg/m^3. As for TSP, the predicted effects from the nodule reclaim area may be overestimated. Therefore, the actual effects for this source may be much lower than depicted in Figure 5-21.

The maximum predicted fluoride concentrations from fugitive dust sources are relatively small compared to other source effects. Figure 5-22 shows that maximum effects along the property line range from less than 5.0E-5 mg/m^3 to 2.8E-4 mg/m^3, with the highest effects occurring along the northern portion of the property line where emissions from the ore stockpile are likely to have the greatest effect.

Table 5-21 lists the anticipated maximum effects at discrete receptor locations. For the nearest neighbors, the anticipated effects from the permitted sources and slag dumping activities range from 5.0E-5 mg/m^3 to 0.0044 mg/m^3 (Receptors #1—6 and #12). Nodule reclaim area operations may result in maximum concentrations at these receptors of 1.0E-4 mg/m^3 to 7.0E-4 mg/m^3. Within Soda Springs, the expected maximum short-term concentrations are estimated at 7.0E-4 mg/m^3 to 0.0014 mg/m^3 for the permitted sources and slag dumping combined, and 2.0E-4 mg/m^3 to 3.0E-4 mg/m^3 for emissions from the nodule reclaim area.

6. SUMMARY AND CONCLUSIONS

An RI, by its very nature, is a complex, multiple-objective phase of an important regulatory process. It demands the use of a multi-disciplinary investigational approach to define the nature and extent constituent releases from a site, and any other information needed to support an evaluation of remedial alternatives during the FS phase of the project.

In this chapter, a summary of the findings of the initial phase of this complex process for the Monsanto Plant is presented. This summary is presented in Section 6.1. Based on these findings, and the statutory requirements of CERCLA and the regulatory requirements of the NCP, Section 6.2 is used to provide recommendations, as necessary,. for removal actions, additional RI activities, and initial FS objectives at the Monsanto Plant.

6.1 Phase I Remedial Investigation Summary

The Phase I RI for the Monsanto Plant is summarized below in terms of the physical characteristics (Subsection 6.1.1), the nature and extent of constituent releases (Subsection 6.1.2), and information on the fate and transport of constituents released to the environment (with a particular emphasis on air transport) (Subsection 6.1.3). Detailed discussions on these topics are provided in Chapters 3, 4, and 5, respectively.

6.1.1 Physical Characteristics

Monsanto purchased the Soda Springs site in 1952 and initiated elemental phosphorus production on the property. The Plant was designated an NPL site in August, 1990. The Plant facilities include buildings, paved and unpaved areas and roads, railroad tracks, various utilities, ore stockpiles, by-product piles, and man-made ponds. A detailed presentation of the regional and local aspects of the physical characteristics of the Monsanto Plant is provided in Chapter 3. The following summary focuses on the major issues related to sources of constituent releases, meteorology, surface hydrology, geology, pedology, hydrogeology, and ecology. Chemical analyses are discussed in Subsection 6.1.2.

6.1.1.1 Sources of Constituent Releases

The Monsanto Plant contains 11 distinct potential sources of constituent release. Each is briefly described below along with the results of the physical analyses (if sampled):

- Phosphate ore, coke, and quartzite stockpiles — primary materials used in the production of elemental phosphorus, the phosphate ore is a coarse-to-fine sand with some silt and some gravel, the coke is predominantly fine gravel with some sand, and the quartzite is coarse-to-fine gravel (see Paragraph 3.1.2.1);

- Nodule fines piles — fines resulting from the nodulizing of the phosphate ore in the kiln, the nodules fines are considered a coarse-to-fine sand (see Paragraph 3.1.2.2);

- Calcium silicate slag piles — a by-product consisting primarily of calcium silicate and constitutes the greatest quantity of waste material at the Plant, particle-size distribution of the slag is an artifact of the sampling procedure (see Paragraph 3.1.2.3);

- Ferrophosphorus slag piles — a by-product generated in the furnace as a result of the naturally occurring iron and other metals in the ore, sold to Kerr-McGee for vanadium extraction (see Paragraph 3.1.2.4);

- Dust — various dusts generated during ore beneficiation and processing, baghouse dust is generally coarse-to-fine sand and silt, or silt with some fine sand; treater dust is coarse-to-fine sand (see Paragraph 3.1.2.5);

- Underflow solids — particulate matter removed from rotary-kiln exhaust gas by dewatering spray-tower scrubber slurry, underflow solids are generally clayey silt with some coarse-to-fine sand; this material is recycled in the process due to its phosphate ore value (see Paragraph 3.1.2.6);

- Underflow solids ponds — ponds in which dewatering of the underflow solids took place prior to 1985 (see Paragraph 3.1.2.7);

- Phossy water surge pond and seal water pond — man-made recycle ponds containing phosphorus-contacting water (phossy water) and water which provides a seal between furnace gases and the atmosphere (seal water) (see Paragraph 3.1.2.8);

- Hydroclarifier — a facility within the Plant which accepts scrubber blowdown wastes and phossy water treated with lime (see Paragraph 3.1.2.9);

- Coke and quartzite dust slurry pond — a by-product dust generated during ore processing (see Paragraph 3.1.2.10); and

- Non-contact cooling water effluent — water, used to control the furnace temperatures, that contains no process waters, and that is subsequently discharged, under an EPA NPDES permit, to Soda Creek (see Paragraph 3.1.2.11).

The ferrophosphorus slag piles, the treater dust, and the underflow solids ponds were not sampled for chemical or physical analyses. The phossy water surge pond, the seal water pond, and the hydroclarifier are not considered to pose a significant constituent release problem and were not sampled for chemical or physical analyses; the ponds are lined and the hydroclarifier has a steel lining and a leachate collection system.

Fugitive dust is the main concern with the phosphate ore, coke, and quartzite stockpiles and the nodule fines pile, therefore, samples were collected for physical analyses. Chemical analytical results were provided by Monsanto.

There are several other significant facilities in the vicinity of the Monsanto Plant (see Subsection 3.1.3) that have the potential to impact the immediate environment. These include Kerr-McGee, a vanadium pentoxide production plant; two facilities which produce fertilizer products, Evergreen Resources and Soda Springs Phosphate Industries; Nu-West Industries, which produces phosphoric acid and fertilizer products; and N. A. Degerstrom, which is involved with gallium and silver extraction.

6.1.1.2 Meteorology

The Monsanto Plant is situated within an area possessing a semiarid climate with hot summers and cold winters, characterized by relatively low precipitation, high evapotranspiration, and light winds (see Section 3.2).

6.1.1.3 Surface Hydrology

The major river in the vicinity of the Monsanto Plant is the Bear River, located approximately 2 miles to the south and southwest of the Monsanto Plant. Regional man-made surface waters include Alexander Reservoir and Blackfoot Reservoir (see Subsection 3.3.1). Natural local surface-water features in the Monsanto Plant vicinity include Soda Creek, Ledger Creek, Big Spring Creek, two wetland areas, and numerous springs and spring-feed ponds (see Subsection 3.3.2). Local man-made surface-water features include the ponds on the Plant site and Soda Creek Reservoir.

Sediments from Soda Creek, downstream and upstream of the Monsanto Plant's effluent discharge into the creek, were analyzed for both physical and chemical parameters. The physical results will be discussed here. Chemical results will be discussed in Paragraph 6.1.2.3. The particle-size distribution of sediment samples collected along Soda Creek varied with respect to sampling location. Upstream samples along the banks of the creek consisted of medium-to-fine sand and silt, while the sample collected from the middle of the creek consisted of coarse-to-fine gravel and coarse-to-fine sand with some silt. The sample collected from the base of the diversion dam (approximately 100 feet below the effluent discharge) consisted of organic clayey silt with little coarse-to-fine sand. The sample collected approximately 300 feet below the effluent discharge consisted of coarse-to-fine gravel with some coarse-to-fine sand (see Table 3-10).

6.1.1.4 Geology

Regionally, the Monsanto Plant is located near the southern end of the Blackfoot Lava Field which has infilled a generally north-northwest trending valley bordered by the Chesterfield Range and the Soda Hills on the west, and by the Aspen Range on the east. The Plant is located within the Bear River graben. A series of north-northwest-trending normal faults extend from the southeast of the Plant northward to the Blackfoot Reservoir. The Plant is underlain at greater depth by an extension of the Paris Thrust fault (see Subsection 3.4.2).

Locally, the Plant is underlain by a thin veneer of overburden soils which overlie basalt flows of the Blackfoot Lava Field. Five basalt flows, separated by sedimentary interbeds or weathered basalt zones, are present beneath the Plant. The basalt flows vary in thickness from less than 10 feet to 80 feet. The sedimentary units and weathered basalt zones range from 1 to 23 feet thick. The basalt flows overlie the Salt Lake Formation (see Paragraph 3.4.3.1).

Northwest trending, en-echelon normal faults (both west- and east- side-down relative displacement) are present in the Plant area and commonly form narrow grabens that are 1,000 to 1,500 feet wide and up to 2.5 to 3 miles long. Normal fault displacement has often-times offset permeable cinder zones and weathered basalt horizons against less permeable unweathered basalt flow interiors which may interrupt lateral groundwater flow and create springs. A prominent fault scarp enters the Plant near the northwest corner and appears to die out just west of the southeast corner of the Plant. A subsidiary fault parallels this fault approximately 1,500 feet to the southwest (see Paragraph 3.4.3.2).

Several normal faults exist east of the Plant. The Finch Spring fault, a prominent fault scarp that trends approximately north-south and has measured minimum vertical displacement of 20 to 70 feet (west-side down). A subparallel fault forms a small graben at the north end of the Finch Spring fault and adjacent and subparallel to the southern part of the Finch Spring fault is the Ledger Creek Springs graben. The Ledger Creek Spring graben is bordered by prominent fault scarps that have an estimated 40 to 60 feet of vertical separation. The west-side-down displacement of the Finch Spring fault and the east-side-down of the western fault of the Ledger Creek Springs graben may act as hydraulic barriers such that groundwater west of the Finch Spring fault may not flow into the Ledger Creek Springs area (see Paragraph 3.4.3.2).

6.1.1.5 Pedology

The five soil types around the Monsanto Plant are similar in morphology and are primarily classified as mollisols. The soils are largely dominated by the characteristics of the loess parent materials from which they are derived and have similar particle sizes; the dominant particle-size class was silt-sized which is consistent with a loess parent material. The soils are classified as clayey silt with some sand and a trace of gravel. There was no appreciable difference between samples collected from the 0-to-1-inch depth interval and those collected from the 0-to-6-inch depth interval. The control soils were classified as clayey silt with some sand and there was no appreciable difference between the two depth intervals. Soils within the Plant are disturbed and cannot be correlated with the surrounding soils (see Section 3.5.2).

6.1.1.6 Hydrogeology

The Monsanto Plant is located at the southern end of the Blackfoot Lava Field. Of the four local hydrostratigraphic zones which underlie the Monsanto Plant, the UBZ is the principal aquifer and is found most places beneath the Plant to a depth of about 100 feet bgs. The depth to the water table varies across the Plant from about 20 feet bgs in the northeast corner of the Plant to about 100 feet bgs in the center of the Plant. The LBZ is less permeable than

the UBZ (with a hydraulic conductivity of at least three orders of magnitude less) and underlies the UBZ to a depth of at least 250 feet bgs (see Paragraph 3.6.2.1)

Groundwater flow in the UBZ and the LBZ is influenced by faulting, regional hydrogeological conditions, and pumping of the Plant production wells. The groundwater flow direction beneath the Plant is generally to the south and southwest parallelling the geological structures (see Paragraph 3.6.2.3).

The ambient-groundwater quality beneath the Plant correlates to one of the three regional systems (the Shallow Groundwater System, the Mead Thrust Aquifer System, and the Chesterfield Range Aquifer System) or to a mixture of two of the systems and can be described as either fresh or sodic. The Shallow Groundwater System consists of fresh water which comes into contact with surface soil and basaltic units. Based on groundwater quality and age-dating techniques, this water is considered to be relatively young (see Paragraph 3.6.2.4).

The Mead Thrust Aquifer System also consists of fresh water. The system receives recharge from the mountains to the east of the Monsanto Plant where the water is in contact with limestone country rock. This water is considered relatively old compared to the Shallow Groundwater System. The Mead Thrust Aquifer System discharges along the eastern margin of the Blackfoot Lava Field via deep, normal faults (see Paragraph 3.6.2.4).

The Chesterfield Range Aquifer System consists of sodic water. The system receives recharge from the Chesterfield Range to the west of the Plant where the water is in contact with limestone country rock. This water has been proven to be the oldest of the three. The Chesterfield Range Aquifer System discharges along the western side of the Blackfoot Lava Field via deep, normal faults (see Paragraph 3.6.2.4).

6.1.1.7 Ecology

The City of Soda Springs is located less than one mile south of the Monsanto Plant with a population of about 3,000. Land use within the city limits is mostly residential with some commercial and light industrial zones (see Section 3.7.1.1). A light and heavy industrial zone extends from the north end of the city along Route 34 towards the Monsanto Plant.

The Monsanto Plant is located outside of the city limits. The workforce populations for the Monsanto Plant and the adjacent Kerr-McGee Plant, respectively, is approximately 400 and 80 employees. The land use within the boundaries of the Monsanto Plant and the Kerr-McGee Plant is industrial, surrounded by open agricultural and range lands (see Paragraph 3.7.1.1).

The Monsanto Plant drinking water is supplied by production well PW-4 on the northern boundary of the Plant and upgradient of any known potential sources of constituent releases. Kerr-McGee Plant drinking water is supplied, via the City of Soda Springs, by Formation Spring, located to the east and upgradient of the Monsanto and Kerr-McGee plants. The City of Soda Springs obtains its drinking water from Formation Spring and Ledger Spring, located to the southeast of the Monsanto Plant. Formation Spring is located upgradient of any known potential sources of constituent releases. Ledger Spring is side-gradient of the

Monsanto Plant and, based on hydrogeological interpretation and groundwater age-dating, is not threatened from potential sources of constituent releases from the Monsanto Plant. The nearest domestic well located downgradient of the Monsanto Plant is no longer used (see Paragraph 3.7.1.2).

Areas of special historical interest in the vicinity of the Monsanto Plant include portions of the Oregon Trail and Hooper Spring, a soda-water spring (see Section 3.7.1.3). No other significant cultural resource or archaeological sites are known to exist within the vicinity.

The Monsanto Plant region is covered by sagebrush-grass vegetational zone. The hoary willow (Salix Candida) is the only sensitive plant species to exist in the Monsanto Plant vicinity (there are no documented endangered or threatened plants in the vicinity); this species is found along the Ledger Creek drainage (see Paragraph 3.7.2.1).

The Idaho Fish and Game Department identifies several big-game animals in the Monsanto Plant vicinity. Significant fish and wildlife habitats include the Bear River, Alexander Reservoir, and the Formation Cave vicinity (a property owned by the Nature Conservancy). Waterfowl are known to use the sewage evaporation and non-contact cooling water ponds at the Monsanto Plant throughout the year. Several fisheries are located in the area at Alexander Reservoir, the Bear River downstream of the reservoir, and the lower reaches of Soda Creek. After the Natural Heritage Program Database was reviewed by the FWS-BFS, the bald eagle was the only animal identified as a threatened species for the Soda Springs area (see Paragraph 3.7.2.2).

6.1.2 Nature and Extent of Constituent Releases

The nature and extent of constituent releases at the Monsanto Plant are summarized below by the environmental media characterized during Phase I RI field activities: sources of constituent release, air, surface waters and associated sediments, soil, groundwater and springs, and biota.

6.1.2.1 Sources of Constituent Release

Five types of media were evaluated in detail with respect to their potential to be sources of environmental constituent release at the Monsanto Plant. These potential sources include:

- Calcium silicate slag piles;
- Baghouse dust;
- Underflow solids;
- Coke and quartzite dust slurry pond; and
- Non-contact cooling water effluent.

Each potential source is briefly described in Subsection 6.1.1 above. The other potential sources are not given further detailed consideration for reasons specified in Subsection 6.1.1.

The results of the calcium silicate slag pile analyses show slag sample variability was high for most radiological constituents. Sample variability of the nonradiological constituents was generally less than for radionuclides, except for constituents such as zinc and lead (see Paragraph 4.1.1.3). The results of baghouse dust samples show that the analyzed constituents are highly variable, but are generally less than quantities found in other source samples (see Paragraph 4.1.1.5). The analytical results for underflow solids are discussed in Paragraph 4.1.1.6, for the coke and quartzite dust slurry pond solids in Paragraph 4.1.1.10, and for the non-contact cooling water effluent in Paragraph 4.1.1.11.

Of the other nearby facilities mentioned in Subsection 6.1.1, one — the Kerr-McGee Plant — has been identified as a known source of constituent release. Releases to the shallow groundwater system from Kerr-McGee wastewater impoundment ponds have been documented (see Paragraph 3.1.3.1).

6.1.2.2 Air Quality

A formal air sampling investigation was not conducted during the first phase of the RI due to the amount of existing information available. The potential air quality affects of Plant emissions are summarized in Subsection 6.1.3 (Constituent Fate and Transport).

6.1.2.3 Surface-Water and Sediment Quality

Surface water from Soda Creek and the irrigation canal, associated sediments, and Monsanto Plant effluent were sampled and analyzed. Physical results from the sediment samples were discussed in Paragraph 6.1.1.3. Statistical analyses were performed on the water and sediment data to determine which downstream parameters are elevated with respect to upstream concentrations. Each elevated constituent was subjected to a conservative preliminary risk screening to determine which are considered constituents of potential interest (see Section 4.3).

The elevated surface water constituents include:

Calcium,
Chloride,
Sodium,
Nitrate/nitrite as N,
Sulfate, and
Total dissolved solids.

None of these elevated constituents found in Soda Creek downstream of the effluent discharge exceed preliminary risk-based screening criteria (see Subsection 4.3.2). Therefore, no constituents of potential interest are identified for this medium.

Sediments collected from Soda Creek at the diversion dam (approximately 100-feet downstream of the effluent discharge) have elevated levels of the constituents shown below (see Paragraph 4.3.3).

Cadmium,
Copper,
Nickel,
Polonium-210,
Selenium,
Silver, and
Vanadium.

Sediment samples collected further downstream, approximately 300 feet below the effluent discharge, showed elevated levels of only selenium, silver, and vanadium.

At the present time there are no screening criteria, either risk-based calculations or regulatory guidelines, on which to judge the elevated constituents found in the sediment samples. Therefore, all elevated constituents in stream sediments are judged, at this time, to be constituents of potential interest (see Subsection 4.3.3).

6.1.2.4 Soil Quality

Surface and subsurface samples were collected from soils surrounding the Monsanto Plant and from control points located approximately 13 miles southwest of the Plant. Samples were taken from two depth intervals: 0-to-1 inch (A group) and 0-to-6 inch (B group). Results of physical analyses are discussed in Paragraph 6.1.1.5. Results of the chemical analyses are summarized below.

Elevated constituents in the A group and in the B group, based on this screening criterion, are:

- A group (0-to-1-in stratum) —

  aluminum
  arsenic
  beryllium
  cadmium
  chromium
  copper
  manganese
  selenium
  silver
  sodium
  vanadium
  zinc
  lead-210
  polonium-210
  radium-226
  thorium-230
  uranium

- B group (0-to-6-in stratum) —

  aluminum
  arsenic
  beryllium
  cadmium
  chromium
  copper
  iron
  manganese
  selenium
  silver
  vanadium
  zinc
  lead-210
  polonium-210
  radium-226
  thorium-230
  thorium-232
  uranium

The elevated soil constituents that exceeded risk-screening criteria and are thus considered constituents of potential interest are:

- A group (0-to-1-in stratum) —

  arsenic
  beryllium
  cadmium
  lead-210
  polonium-210
  radium-226
  thorium-230
  uranium

- B group (0-to-6-in stratum) —

  arsenic
  beryllium
  manganese
  lead-210
  polonium-210
  radium-226
  thorium-230
  uranium

Although not every constituent shows the same spatial pattern, many of the constituents of potential interest are clustered around the north end of the Plant and the south end of the Plant. Although a number of constituents of potential interest are found in the soils surrounding the Monsanto Plant, it is not conclusive that Plant activities are solely responsible (see Subsection 4.4.2).

6.1.2.5 Groundwater Quality

Groundwater from wells and springs at and in the vicinity of the Monsanto Plant were sampled and chemically analyzed during this Phase I RI. Control data were obtained from both fresh and sodic wells and springs up-gradient of any known sources of constituent releases on the Monsanto Plant. Fresh-quality groundwater exists in both the Shallow Groundwater Aquifer and the Mead Thrust Aquifer System. Sodic-quality water is found in the Chesterfield Range Aquifer System. Because of the influence of the Mead Thrust Aquifer flow system by Kerr-McGee operations, however, control data for samples collected downgradient of the Kerr-McGee Plant were obtained from Kerr-McGee wells (see Subsection 4.5.1).

Statistical analyses were not performed on data collected from wells in the Mead Thrust Aquifer System on and downgradient of the Monsanto Plant because Kerr-McGee Plant operations influence the groundwater in this system and, therefore, statistically-calculated UTLs would be larger than any concentrations found in samples from the Monsanto Plant.

Statistical evaluations were performed to determine which constituents are at elevated levels in the Shallow Groundwater System and the Chesterfield Range Aquifer System. The following is a list of the elevated constituents:

- Elevated constituents - fresh groundwater (Shallow Groundwater System)

  arsenic
  cadmium
  calcium
  magnesium
  manganese
  nickel
  potassium
  selenium
  sodium
  zinc
  specific conductance
  total dissolved solids
  ammonium as N
  bicarbonate
  chloride
  fluoride
  nitrate/nitrite as N
  sulfate

phosphorus
radium-226

- Elevated constituents - sodic groundwater (Chesterfield Range Aquifer System)

  cadmium
  magnesium
  nickel
  selenium
  sodium
  zinc
  chloride
  fluoride
  sulfate
  phosphorus

Calcium, magnesium, potassium, and sodium are essential nutrients and are thus eliminated from further consideration in this report. Bicarbonate is a non-toxic substance and specific conductance is an indicator of a more specific problem (as shown by the number of elevated constituents in fresh groundwater); these two substances are, thus, also eliminated from further consideration in this report (see Subsection 4.5.2).

Constituents which exceeded the screening criteria and are considered constituents of potential interest are listed below:

- Constituents of potential interest - fresh groundwater (Shallow Groundwater System)

  arsenic
  cadmium
  manganese
  nickel
  selenium
  zinc
  total dissolved solids
  ammonium as N
  chloride
  fluoride
  nitrate/nitrite as N
  sulfate
  phosphorus
  radium-226

- Constituents of potential interest - sodic groundwater (Chesterfield Range Aquifer System)

  cadmium

selenium
fluoride
sulfate
phosphorus

Iron, manganese, total dissolved solids, chloride, and sulfate are only of potential interest because of welfare considerations and are not expected to pose unacceptable health or ecological risks. These constituents, therefore, are eliminated from further consideration with respect to fate, transport, and detailed risk evaluation but will be considered in evaluating the potentially applicable or relevant and appropriate requirements (ARARs).

The phosphorus analysis performed for this Phase I investigation measured total phosphorus in water. The actual form found in the groundwater is likely phosphate (PO_4), a soluble essential nutrient that is considered to be non-toxic at the concentrations found in groundwater beneath the Monsanto Plant. The screening criterion used for phosphorus in this assessment are applicable for elemental forms of phosphorus, therefore, phosphorus in groundwater is eliminated from further consideration in this report (see Subsection 4.5.3).

A summary of the nature, extent, and temporal changes of the constituent plumes for the UBZ and the LBZ are discussed here. The temporal trend in UBZ-1 indicates a decrease in concentration with respect to cadmium but an increase with respect to chloride and sulfate which suggests that the evaporation/percolation sewage ponds are affecting groundwater quality in UBZ-1. The mass of the plume appears to be migrating off-site in a southerly direction (see Subsection 4.5.4).

Concentrations at the source area (old underflow solids ponds) in UBZ-2 have been decreasing with time, with the exception of fluoride which has reached an equilibrium. The mass of the plume has migrated in a southerly direction as indicated by increased concentrations along the southern Plant boundary and appears to be migrating off-site (see Subsection 4.5.4).

The plume in UBZ-3 originates off-site to the east of the Monsanto Plant. The plume is increasing in concentration and is also migrating to the south off-site. The plume in UBZ-4 is decreasing in concentration and is being captured by the production wells located in the central portion of the Plant, preventing further southeasterly plume migration (see Subsection 4.5.4).

The groundwater quality in LBZ-2 was affected in the past by poor well-completion, which caused hydraulic communication between LBZ-2 and UBZ-2. The faulty wells have since been abandoned, in accordance with regulatory standards, and the resulting plume in LBZ-2 has been decreasing in concentration.

The plume in LBZ-3 originates east of the Monsanto Plant, is increasing in concentration and appears to be migrating to the west-southwest (see Subsection 4.5.4).

6.1.2.6 Biota Quality

Biotic sampling was not conducted during the first phase of the RI. Potential affects to critical and sensitive habitats will be addressed in Subsection 6.1.3 (Constituent Fate and Transport).

6.1.3 Constituent Fate and Transport

The fate characteristics of 18 constituents of interest — ammonium-N, arsenic, beryllium, cadmium, copper, fluoride, lead-210, manganese, nickel, nitrate/nitrite-N, polonium-210, radium-226, selenium, silver, thorium-230, uranium, vanadium, and zinc — are discussed in Section 5.2. Potentially significant constituent transport pathways for the Monsanto Plant are qualitatively identified in Section 5.1 and, for the air tranport pathway, quantitatively evaluated in Section 5.3.

Potentially significant constituent transport pathways for the Monsanto Plant, taking preliminary risk-based screening results of Chapter 4 into account, are:

- Air transport — inhalation of cadmium and fluoride derived from fugitive dust and stack emissions from the Plant (see quantitative evaluation in Section 5.3).
- Surface-water transport — considered to be insignificant (see qualitative discussion in Subsection 5.1.2).
- Direct contact with soils — ingestion of arsenic, beryllium, cadmium, lead-210, polonium-210, radium-226, thorium-230, and uranium in the soils of the agricultural fields adjacent to the Plant (see qualitative discussion in 5.1.1).
- Soil transport — ingestion of beef fed with crops grown in the adjacent agricultural fields; constituents of potential interest are arsenic, beryllium, lead-210, manganese, polonium-210, radium-226, thorium-230, and uranium (see qualitative evaluation is Subsection 5.1.3).
- Groundwater transport — human ingestion of groundwater at the Lewis Well, derived from the uncaptured, fault-bounded plume under the western portion of the Plant, containing ammonium-N, arsenic, cadmium, fluoride, nickel, nitrate-N, radium-226, selenium, and zinc; at the current time, only fluoride, nitrate, and zinc are detectable in this well, and their current concentrations are well below established drinking water standards (see qualitative discussion in Subsection 5.1.4).

6.2 Phase I Remedial Investigation Conclusion

The results of the Phase I RI for the Monsanto Plant, as summarized in Section 6.1, are used to develop recommendations for conducting and focusing further response activities needed

to comply with the terms of CERCLA and the NCP. Subsection 6.2.1 provides recommendations for removal actions in accordance with the process outlined in 40 CFR 300. Subsection 6.2.2 provides recommendations for Phase II RI activities, in terms of both additional site characterization and treatability investigation. Subsection 6.2.3 recommends remedial action objectives for use in the early stages of the FS, and includes a brief discussion of constituent- and location-specific applicable or relevant and appropriate environmental standards, requirements, criteria, or limitations (ARARs) that might potentially be germain to the Monsanto Plant.

6.2.1 Recommended Removal Actions

At the time of the completion of the first phase of an RI, it is appropriate to conduct an NCP removal site evaluation in accordance with 40 CFR 300.410. This Phase I Report is used, in part, to document such an evaluation for the Monsanto Plant. Taking the factors specified in 40 CFR 300.415(b)(2) into account, along with the guidelines provided in 40 CFR 300.415(d), removal actions at the Monsanto Plant are not necessary at this time.

Although there is no need for removal actions at this time, this evaluation will be repeated at the conclusion of the Phase II RI and at other appropriate points in the remedial response process.

6.2.2 Recommended Further Work for the Remedial Investigation

A Phase II RI is generally used to complete site characterization, as necessary, and conduct treatability investigation to assess the performance of potential remedial technologies, as necessary, to support the analysis of remedial alternatives during the FS (EPA 1988). Based on the Phase I RI results presented in this report, additional site characterization activities are recommended below in Paragraph 6.2.2.1; recommendations regarding the need for a treatability investigation are provided below in Paragraph 6.2.2.2.

6.2.2.1 Additional Site Characterization

The purpose of additional site characterization is to supplement the initial information contained in this report to provide definitive characterization of the nature and extent of constituent-of-potential-interest releases and any human health or environmental threats posed by such releases from the Monsanto Plant. Further characterization must proceed until a sufficient amount of information is available to complete the FS.

Recommendations for additional, necessary Monsanto Plant characterization activities are provided below by environmental medium (i.e., sources, air, surface water and aquatic sediments, geology, soils, groundwater, and biota).

Source Investigation

Further source investigation activities are necessary for the Monsanto Plant to support a complete meteorological investigation. Sampling and analysis of the phosphate ore, nodules, ferrophosphorus slag, and calcium silicate slag dust are recommended. Stack sampling, in addition to existing and ongoing efforts, may also be warranted.

Meteorological Investigation

It is recommended that meteorological data from 1991 are collected and reviewed to supplement the 1990 data used in the air dispersion modeling. Sampling of particulates accumulated at IDHW air sampling stations upwind and downwind of the Monsanto Plant is recommended to allow for model calibration. It is also recommended that all significant emission sources be remodeled following the additional source characterization work.

Surface Hydrological Investigation

No further direct investigation of water quality in Soda Creek is required. Water quality sampling and preliminary risk-based screening in Soda Creek indicate no adverse affect on the creek from the EPA-permitted discharge of non-contact cooling water. However, it is recommended that sediments in Soda Creek — downstream of the Monsanto effluent outfall to its confluence with Alexander Reservoir — be sampled for the elevated constituents encountered in sediments during the initial phase of the RI.

Geological Investigation

No further direct geological investigation activities are necessary. However, compilation of any additional data obtained from groundwater monitoring well installations, and data generated by Kerr-McGee, should be conducted to allow for refinement of the Monsanto Plant conceptual geologic model.

Pedological Investigation

Definition of the areal extent of the constituents of potential interest in off-site soils adjacent to the Monsanto Plant is recommended. The focus for this activity should be on the agricultural fields located to the west and north of the Plant.

Hydrogeological Investigation

The Phase I RI was based on groundwater quality data collected by Monsanto since the mid-1980s plus one sample round as part of the RI. Groundwater monitoring in selected wells should continue on a biannual basis to refine the temporal trends of the constituents of potential interest.

The lateral and vertical extent of the plume observed in the UBZ-2 region should be defined to the south of the Monsanto Plant. This investigation should be augmented by further hydraulic testing of the aquifer for use in the refinement of constituent transport evaluations.

This information may be needed to evaluate potential groundwater remedial alternatives and, perhaps, to design such an alternative.

Physical and chemical data generated by Kerr-McGee will be compiled and incorporated into the Monsanto Phase II RI, as appropriate.

Ecological Investigation

A field verification of the groundwater well inventory compiled in the Phase I RI is warranted to definitively determine potential withdrawal points downgradient of the Plant. Land use surrounding the Monsanto Plant should be documented by field inspection, including crop inventory and subsequent use. The EPA freshwater sediment quality criteria development process should be reviewed to allow for an assessment of the elevated constituents encountered within this medium in Soda Creek.

6.2.2.2 Treatability Investigation

The purpose of a treatability investigation is to assess the performance of specific remedial technologies, as appropriate, so as to provide information necessary to complete the FS (EPA 1988). Such information is usually obtained through a review of existing engineering literature; however, bench-or pilot-scale treatability studies are sometimes required. The need for specific treatability studies is dependent on site-specific conditions and the remedial technologies under consideration in the FS.

It is premature to speculate on the need for treatability studies. Such studies are of an action-specific nature and are dependent on FS development. The determination of the need for any bench- or pilot-scale studies is therefore deferred to the Phase I FS Report.

6.2.3 Recommended Remedial Action Objectives for the Feasibility Study

The initial task of an FS is the development of remedial action objectives. Such objectives establish site remediation goals by taking specific constituents of interest, affected environmental media, and potential constituent pathways into account (40 CFR 300.430(e)(2)(i)). Remedial action objectives, which are subject to refinement throughout the FS, focus the development, screening, and analysis of remedial alternatives to ensure they are protective of human health and the environment.

Recommended remedial action objectives can not be developed until the baseline risk assessment has been completed. However, risk-based benchmark concentrations and potential constituent-specific ARARs, provided in the preliminary risk screening tables throughout Chapter 4, can be viewed as preliminary objectives.

The NCP requires that remediation attain all federal and state ARARs, which will be defined in the site record of decision. Potential constituent-specific ARARs for the various environmental media of interest are tabulated in the preliminary risk-based screening tables

throughout Chapter 4. Drinking water standards could be regarded as relevant at access taps of any water supply systems utilizing groundwater downgradient from the Plant.

In addition to complying with constituent-specific ARARs, a site must be remediated to the extent that the overall cancer risk does not exceed a lifetime incremental cancer incidence risk of 10^{-4}, and that the sum of all reasonable exposure pathways does not pose a systemic toxic hazard to sensitive human populations. The latter requirement can be expressed, mathematically, in terms of a site-specific hazard index that does not exceed unity. The preliminary risk-based screening tables in Chapter 4 allow for the initial development of conservative remedial action objectives in the Phase I FS. When the site-specific results of the baseline risk assessment become available, it is likely that any objectives based upon these tables will be relaxed.

The only location-specific ARARs that could potentially be germain to the Monsanto Plant are related to the protection of cultural resources. Care should be taken to avoid any project-related activities that could adversely affect the remnants of the Oregon Trail, and Hooper Spring and its associated park.

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TABLES

TABLE 2-1

CONSTITUENTS ANALYZED IN SOURCE SAMPLES

Metals	Physical Parameters	Radiochemicals	Others
Aluminum	Hydrometer	Lead-210	Fluoride
Arsenic	Moisture Content	Polonium-210	
Beryllium	Specific Gravity	Potassium-40	
Cadmium	Wet Sieve	Radium-226	
Chromium		Radium-228	
Copper		Thorium-228	
Iron		Thorium-230	
Lead		Thorium-232	
Manganese		Uranium	
Nickel			
Potassium			
Selenium			
Silver			
Sodium			
Vanadium			
Zinc			

Note: Chemical analyses performed on the #200 sieve fraction only.

TABLE 2-2

SOURCE SAMPLING DETAILS - PHASE I

SAMPLE LOCATION	SAMPLE ID	SAMPLE DATE	COMMENTS	PARAMETERS[1]			
				PHYSICAL PARAMETERS	RADIOCHEMICALS	METALS	FLUORIDE
baghouse dust	dust-1	10/28/91		x	x	x	x
baghouse dust	dust-2	10/28/91		x	x	x	x
baghouse dust	dust-3	10/28/91		x	x	x	x
slag pile	slag-1	10/28/91	crushed slag	x	x	x	x
slag pile	slag-2	10/28/91	rock slag	x[2]	x	x	x
slag pile	slag-3	10/28/91	crushed slag	x	x	x	x
coke & quartzite dust slurry pond	slurry-1	10/28/91		x	x	x	x
coke & quartzite dust slurry pond	slurry-2	10/28/91		x	x	x	x
coke & quartzite dust slurry pond	slurry-3	10/28/91		x	x	x	x
underflow solids	underflow-1	10/28/91		x	x	x	x
underflow solids	underflow-2	10/28/91		x	x	x	x
underflow solids	underflow-3	10/28/91		x	x	x	x
coke stockpile	C-1	11/04/91		x			
coke stockpile	C-2	11/04/91		x			
coke stockpile	C-3	11/04/91		x			
quartzite stockpile	Q-1	11/04/91		x			
quartzite stockpile	Q-2	11/04/91		x			
phosphate ore stockpile	PO-1	11/04/91		x			
phosphate ore stockpile	PO-2	11/04/91		x			
phosphate ore stockpile	PO-2R	11/04/91	duplicate of PO-2	x			
phosphate ore stockpile	PO-3	11/04/91		x			
treater dust pile	TD-1	11/04/91		x			

TABLE 2-2 (Cont.)

SOURCE SAMPLING DETAILS - PHASE I

SAMPLE LOCATION	SAMPLE ID	SAMPLE DATE	COMMENTS	PARAMETERS[1]			
				PHYSICAL PARAMETERS	RADIOCHEMICALS	METALS	FLUORIDE
treater dust pile	TD-1R	11/04/91	duplicate of TD-1	x			
nodule fines pile	NDF-1	11/04/91		x			
nodule fines pile	NDF-1A	11/04/91	duplicate of NDF-1	x			

[1] See Table 2-1 for listing of chemical and physical parameters.
[2] Analyses do not include hydrometer testing due to lack of fine material in sample.

TABLE 2-3

CONSTITUENTS ANALYZED IN SURFACE WATER AND EFFLUENT SAMPLES

Metals	Ions	Radiochemicals	Water Quality
Aluminum	Ammonium[1]	Radon	Total Dissolved Solids
Arsenic	Bicarbonate	Radium-226	Specific Conductance[2]
Beryllium	Calcium	Radium-228	pH[2]
Cadmium	Carbonate	Uranium	Eh[3]
Chromium	Chloride	Gross Alpha	Turbidity[3]
Copper	Fluoride		Temperature[3]
Iron	Hydroxide		
Lead	Magnesium		
Manganese	Nitrate/Nitrite as N		
Nickel	Total Phosphorus		
Potassium	Sulfate		
Selenium			
Silver			
Sodium			
Vanadium			
Zinc			

1 The actual constituent analyzed is ammonia, which can be calculated from the ammonium concentration, pH and temperature.
2 Analyzed in field and in laboratory.
3 Analyzed in field only.

TABLE 2-4

CONSTITUENTS ANALYZED IN SEDIMENTS SAMPLES

Metals	Physical Parameters	Radiochemicals	Others
Aluminum	Wet Sieve	Lead-210	Cation Exchange Capacity
Arsenic	Moisture Content	Polonium-210	pH
Beryllium	Hydrometer	Potassium-40	Fluoride
Cadmium	Specific Gravity	Radium-226	
Chromium		Radium-228	
Copper		Thorium-228	
Iron		Thorium-230	
Lead		Thorium-232	
Manganese		Uranium	
Nickel			
Potassium			
Selenium			
Silver			
Sodium			
Vanadium			
Zinc			

TABLE 2-5

EFFLUENT AND SURFACE-WATER SAMPLING DETAILS - PHASE I

SAMPLE	SAMPLE ID	SAMPLE	COMMENTS	CHEMICAL PARAMETERS[1]			
				METALS	RADIOCHEMICALS	IONS	WATER QUALITY
effluent	effluent a	10/25/91	directly above effluent weir	x	x	x	x
effluent	effluent b	10/25/91	directly above effluent weir	x	x	x	x
effluent	effluent c	10/25/91	directly above effluent weir	x	x	x	x
irrigation canal	down a	10/25/91	irrigation flume	x	x	x	x
irrigation canal	down b	10/25/91	irrigation flume	x	x	x	x
irrigation canal	down c	10/25/91	irrigation flume	x	x	x	x
soda creek	up-near	10/25/91	~400' up of outfall (east bank)	x	x	x	x
soda creek	up-middle	10/25/91	~400' up of outfall (middle)	x	x	x	x
soda creek	up-far	10/25/91	~400' up of outfall (west bank)	x	x	x	x

[1] See Table 2-3 for listing of chemical parameters.

TABLE 2-6

SEDIMENT SAMPLING DETAILS - PHASE I

SAMPLE LOCATION	SAMPLE ID	SAMPLE DATE	COMMENTS	PARAMETERS[1]			
				METAL	PHYSICAL PARAMETERS	RADIO CHEMICALS	OTHERS
soda creek	soda N	10/25/91	~300' down of outfall	x	x[2]	x	x
soda creek	soda S	10/25/91	duplicate of soda N	x	x[2]	x	x
soda creek	outflow	10/25/91	~100' down of outfall (dam)	x	x	x	x
soda creek	up-near	10/25/91	~400' up of outfall (east bank)	x	x	x	x
soda creek	up-middle	10/25/91	~400' up of outfall (middle)	x	x	x	x
soda creek	up-far	10/25/91	~400' up of outfall (west bank)	x	x	x	x

[1] See Table 2-4 for listing of chemical and physical parameters.
[2] Analyses do not include hydrometer testing due to lack of fine materials in sample.

TABLE 2-7

CONSTITUENTS ANALYZED IN SOIL SAMPLES

Metals	Physical Parameters	Radiochemicals	Others
Aluminum	Hydrometer	Lead-210	Cation Exchange Capacity
Arsenic	Moisture Content	Polonium-210	Fluoride
Beryllium	Specific Gravity	Potassium-40	pH
Cadmium	Wet Sieve	Radium-226	Soluble Nitrate/Nitrite as N
Chromium		Radium-228	
Copper		Thorium-228	
Iron		Thorium-230	
Lead		Thorium-232	
Manganese		Uranium	
Nickel			
Potassium			
Selenium			
Silver			
Sodium			
Vanadium			
Zinc			

TABLE 2-8

SOIL SAMPLING DETAILS - PHASE I

SAMPLE LOCATION	SAMPLE ID	SAMPLE DATE	COMMENTS	PARAMETERS[1]			
				PHYSICAL	RADIOCHEMICALS	METALS	OTHERS
S-1	S-1a	10/19/91	0-1" sagebrush next to RR tracks	x	x	x	x
S-1	S-1b	10/19/91	0-6"	x	x	x	x
S-2	S-2a	10/19/91	0-1" analyses partially cancelled	x			
S-2	S-2b	10/19/91	0-6" analyses partially cancelled	x		x	x
S-3	S-3a	10/19/91	0-1" analyses partially cancelled	x			
S-3	S-3b	10/19/91	0-6" analyses partially cancelled	x		x	x
S2-3	S2-3a	10/28/91	0-1" sagebrush, 60' S of S-3	x	x	x	x
S2-3	S2-3b	10/28/91	0-6"	x	x	x	x
S-4	S-4a	10/19/91	0-1" grass off of road	x	x	x	x
S-4	S-4b	10/19/91	0-6"	x	x	x	x
S-5	S-5a	10/19/91	0-1" analyses partially cancelled	x			
S-5	S-5b	10/19/91	0-6" analyses partially cancelled	x		x	x
S2-5	S2-5a	10/28/91	0-1" overgrown field 60' S of S-5	x	x	x	x
S2-5	S2-5b	10/28/91	0-6"	x	x	x	x
S-6	S-6a	10/19/91	0-1" analyses partially cancelled	x			
S-6	S-6b	10/19/91	0-6" analyses partially cancelled	x		x	x
S2-6	S2-6a	10/28/91	0-1" pasture, 60' N of S-6	x	x	x	x
S2-6	S2-6b	10/28/91	0-6"	x	x	x	x
S-7	S-7a	10/19/91	0-1" grassy field	x	x	x	x
S-7	S-7b	10/19/91	0-6"	x	x	x	x
S-8	S-8a	10/19/91	0-1" recently plowed field	x	x	x	x
S-8	S-8a-DUP	10/19/91	0-1" duplicate		x	x	x

TABLE 2-8 (Cont.)

SOIL SAMPLING DETAILS - PHASE I

SAMPLE LOCATION	SAMPLE ID	SAMPLE DATE	COMMENTS	PARAMETERS[1]			
				PHYSICAL	RADIOCHEMICALS	METALS	OTHERS
S-8	S-8b	10/19/91	0-6"	x	x	x	x
S-8	S-8b-DUP	10/19/91	0-6" duplicate		x	x	x
S-9	S-9a	10/19/91	0-1" analyses partially cancelled	x		x	x
S-9	S-9b	10/19/91	0-6" analyses partially cancelled	x			
S2-9	S2-9a	10/28/91	0-1" plowed field, 35' W of S-9	x	x	x	x
S2-9	S2-9b	10/28/91	0-6"	x	x	x	x
S-10	S-10a	10/19/91	0-1" grass near field	x	x	x	x
S-10	S-10b	10/19/91	0-6"	x	x	x	x
S-11	S-11a	10/19/91	0-1" analyses partially cancelled	x		x	x
S-11	S-11b	10/19/91	0-6"	x	x	x	x
S-11	S-11b-S	10/19/91	0-6" split		x	x	x
S2-11	S2-11a	10/28/91	0-1" sagebrush, 100' SSW of S-11	x	x	x	x
S2-11	S2-11b	10/28/91	0-6"	x	x	x	x
S-12	S-12a	10/19/91	0-1" grass	x	x	x	x
S-12	S-12b	10/19/91	0-6"	x	x	x	x
S-13	S-13a	10/19/91	0-1" grass	x	x	x	x
S-13	S-13b	10/19/91	0-6"	x	x	x	x
S-14	S-14a	10/19/91	0-1" grass	x	x	x	x
S-14	S-14b	10/19/91	0-6"	x	x	x	x
S-15	S-15a	10/19/91	0-1" plowed field	x	x	x	x
S-15	S-15b	10/19/91	0-6"	x	x	x	x

TABLE 2-8 (Cont.)

SOIL SAMPLING DETAILS - PHASE I

SAMPLE LOCATION	SAMPLE ID	SAMPLE DATE	COMMENTS	PARAMETERS[1]			
				PHYSICAL	RADIOCHEMICALS	METALS	OTHERS
S-16	S-16a	10/19/91	0-1" plowed field	x	x	x	x
S-16	S-16b	10/19/91	0-6"	x	x	x	x
BACKGROUND-1	BACK-1a	10/28/91	0-1" plowed & burned field	x	x	x	x
BACKGROUND-1	BACK-1b	10/28/91	0-6"	x	x	x	x
BACKGROUND-2	BACK-2a	10/28/91	0-1" sagebrush	x	x	x	x
BACKGROUND-2	BACK-2b	10/28/91	0-6"	x	x	x	x
BACKGROUND-3	BACK-3a	10/28/91	0-1" grassy area	x	x	x	x
BACKGROUND-3	BACK-3b	10/28/91	0-6"	x	x	x	x
BACKGROUND-3	BACK-3c	10/28/91	0-6" duplicate of back-3b	x	x	x	x

[1] See Table 2-7 for listing of chemical and physical parameters.

SAMPLE LOCATION	SAMPLE ID	SAMPLE DATE	COMMENTS	CHEMICAL PARAMETERS[1]			
				IONS	RADIOCHEMICALS	METALS	WATER QUALITY
MONSANTO LAB	EB-SPOON	10/29/91	EQUIPMENT BLANK	x	x[2]	x	x

[1] See Table 2-3 for listing of chemical parameters.
[2] A sample for radon analysis was not collected.

TABLE 2-9

WELL PURGING DETAILS - PHASE I

WELL NO.	DEPTH TO WATER BMP (ft)	WELL VOL. (gal)	FLOW RATE (gpm)	PURGED VOLUME (gal)	NO. OF WELL VOLUMES PURGED	PURGING AND SAMPLING METHOD	PURGED WATER DISPOSAL METHOD	COMMENT
TEST WELLS:								
TW-1	-	-	-	-	-	-	-	NS - well abandoned
TW-2	56.52	-	10	-	-	PUMPED	-	pump runs intermittently
TW-3	-	-	-	-	-	-	-	NS - well abandoned
TW-4	-	-	-	-	-	-	-	NS - well abandoned
TW-5	-	-	-	-	-	-	-	NS - well abandoned
TW-6	-	-	-	-	-	-	-	NS - well abandoned
TW-7	-	-	-	-	-	-	-	NS - redundant with TW-10
TW-8	-	-	-	-	-	-	-	NS - redundant with TW-10
TW-9	9.46	168.18	15	330	2.0	PUMPED	GROUND	well pumped dry while purging
TW-10	15.46	12.23	5	50	4.1	PUMPED	TANK	
TW-11	74.04	47.87	10	250	5.2	PUMPED	TANK	
TW-12	76.01	25.50	10	80	3.1	PUMPED	TANK	
TW-13	21.36	60.86	15	180	3.0	PUMPED	GROUND	
TW-14	-	-	-	-	-	-	-	NS - surficial deposit zone
TW-15	21.36	32.90	15	150	4.6	PUMPED	GROUND	
TW-16	65.80	16.00	5	50	3.1	PUMPED	TANK	
TW-17	-	-	-	-	-	-	-	NS - redundant with TW-16
TW-18	63.48	123.25	20	300	2.4	PUMPED	TANK	
TW-19	-	-	-	-	-	-	-	NS - redundant with TW-20
TW-20	31.40	14.53	10	50	3.4	PUMPED	TANK	

TABLE 2-9 (Cont.)

WELL PURGING DETAILS - PHASE I

WELL NO.	DEPTH TO WATER BMP (ft)	WELL VOL. (gal)	FLOW RATE (gpm)	PURGED VOLUME (gal)	NO. OF WELL VOLUMES PURGED	PURGING AND SAMPLING METHOD	PURGED WATER DISPOSAL METHOD	COMMENT
TW-21	26.46	72.90	15	225	3.1	PUMPED	GROUND	
TW-22	73.31	31.24	15	150	4.8	PUMPED	TANK	
TW-23	73.88	85.05	15	225	2.6	PUMPED	TANK	
TW-24	-	-	-	-	-	-	-	NS - well affected by grout
TW-25	-	-	-	-	-	-	-	NS - well abandoned
TW-26	89.20	39.03	10	150	3.8	PUMPED	TANK	
TW-27	-	-	-	-	-	-	-	NS - well abandoned
TW-28	44.46	37.62	15	150	4.0	PUMPED	GROUND	
TW-29	44.38	6.20	15	20	3.2	PUMPED	GROUND	
TW-30	63.07	9.36	-	25	2.7	BAILED	TANK	
TW-31	-	-	-	-	-	-	-	NS - redundant with TW-33
TW-32	31.98	97.14	10	300	3.1	PUMPED	TANK	well pumped dry while purging
TW-33	31.44	33.56	10	200	6.0	PUMPED	TANK	
TW-34	31.35	33.03	1-15	150	4.5	PUMPED	GROUND	well pumped dry while purging
TW-35	34.46	43.40	10-15	145	3.3	PUMPED	GROUND	
TW-36	31.65	19.89	15	75	3.8	PUMPED	TANK	
TW-37	71.76	23.71	10	80	3.4	PUMPED	TANK	
TW-38	97.50	7.88	-	21	2.7	BAILED	TANK	
TW-39	35.18	19.36	7	70	3.6	PUMPED	TANK	
TW-40	88.41	3.62	0.5	10	2.8	PUMPED	TANK	well pumped dry while purging
TW-41	62.71	9.44	5	50	5.3	PUMPED	TANK	

TABLE 2-9 (Cont.)

WELL PURGING DETAILS - PHASE I

WELL NO.	DEPTH TO WATER BMP (ft)	WELL VOL. (gal)	FLOW RATE (gpm)	PURGED VOLUME (gal)	NO. OF WELL VOLUMES PURGED	PURGING AND SAMPLING METHOD	PURGED WATER DISPOSAL METHOD	COMMENT
TW-42	86.07	6.58	0.5	15	2.3	PUMPED	TANK	well pumped dry while purging
TW-43	88.72	3.37	-	15	4.5	BAILED	TANK	
TW-44A	99.29	43.75	2-15	140	3.2	PUMPED	TANK	well pumped dry while purging
TW-45	74.34	109.48	20	300	2.7	PUMPED	TANK	
TW-48	62.59	10.47	3	75	7.2	PUMPED	TANK	well pumped dry while purging
TW-49	73.40	12.27	5	75	6.1	PUMPED	TANK	
TW-50	60.73	29.56	2-10	70	2.4	PUMPED	TANK	well pumped dry while purging
TW-51	-	-	-	-	-	-	-	NS
HARRIS	-	-	10	250	-	PUMPED	GROUND	pump runs intermittently
DOMESTIC WELLS:								
LEWIS	-	-	10	100	-	PUMPED	GROUND	pump runs intermittently
PRODUCTION WELLS:								
PW-1	108.44 bgs	-	<900	-	-	PUMPED	-	pump runs intermittently
PW-2	-	-	<660	-	-	PUMPED	-	pump runs intermittently
PW-3	125.35 bgs	-	1000	-	-	PUMPED	-	pump runs continuously
PW-4	-	-	300	-	-	PUMPED	-	pump runs continuously

NOTE:
BMP = Below measuring point. Depth to water is from measuring point unless otherwise stated.
bgs = Below ground surface.
NS = Not Sampled

TABLE 2-10

WELL PUMP SPECIFICATIONS

WELL	DATE PUMP INSTALLED	DEPTH TO TOP OF PUMP[1] (feet)	PUMP MANUFACTURER	PUMP MODEL NO.	PUMP TYPE	PUMP MOTOR MANUFACTURER	PUMP MOTOR MODEL NO.	ELECTRICAL SUPPLY				COMMENTS
								Voltage	Horsepower	Wire	Phase	
TEST WELLS:												
TW-2	-	-	-	-	-	-	-	-	-	-	-	
TW-9	10/15/91	220	Grundfos	10S07-12	9135	Franklin	214 307 4416	230	3/4	3 Wire	Single	
TW-10	7/07/85	17	Grundfos	SP2-10-S	8517	Franklin	214 305 4416	230	1/2	3 Wire	Single	
TW-11	10/15/91	120	Grundfos	10S05-9	9134	Franklin	214 305 4416	230	1/2	3 Wire	Single	
TW-12	7/07/85	86	Grundfos	SP2-10-S	8517	Franklin	214 305 4416	230	1/2	3 Wire	Single	
TW-13	10/15/91	8	Grundfos	10S05-9	9134	Franklin	214 305 4416	230	1/2	3 Wire	Single	
TW-15	7/07/85	46	Grundfos	SP2-10-S	8521	Franklin	214 305 4416	230	1/2	3 Wire	Single	
TW-16	7/06/85	70	Grundfos	SP2-10-S	8517	Franklin	214 305 4416	230	1/2	3 Wire	Single	
TW-17	7/06/85	92	Grundfos	SP2-10-S	8521	Franklin	214 305 4416	230	1/2	3 Wire	Single	
TW-18	10/22/91	212	Grundfos	SP2-15-S	8519	Franklin	214 307 4416	230	3/4	3 Wire	Single	a
TW-20	7/07/85	35	Grundfos	SP2-10-S	8517	Franklin	214 305 4416	230	1/2	3 Wire	Single	
TW-21	10/14/91	100	Grundfos	10S05-9	9134	Franklin	214 305 4416	230	1/2	3 Wire	Single	
TW-22	7/07/85	97	Grundfos	SP2-10-S	8517	Franklin	214 305 4416	230	1/2	3 Wire	Single	
TW-23	7/07/85	167	Grundfos	SP2-15-S	8519	Franklin	214 307 4416	230	3/4	3 Wire	Single	
TW-26	7/08/85	119	Grundfos	SP2-10-S	8517	Franklin	214 305 4416	230	1/2	3 Wire	Single	
TW-28	7/06/85	72	Grundfos	SP2-10-S	8520	Franklin	214 305 4416	230	1/2	3 Wire	Single	
TW-29	10/14/91	40	Grundfos	10S05-9	9154	Franklin	214 305 4416	230	1/2	3 Wire	Single	
TW-30	10/22/91	69	Grundfos	10S05-9	9136	Franklin	214 305 4416	230	1/2	3 Wire	Single	
TW-32	10/15/91	140	Grundfos	10S07-12	9135	Franklin	214 307 4416	230	3/4	3 Wire	Single	
TW-33	7/09/85	25	Red Jacket	-	036-188	Red Jacket	50N1, 179-314	230	1/2	3 Wire	Single	
TW-34	10/14/91	60	Grundfos	10S05-9	9134	Franklin	214 305 4416	230	1/2	3 Wire	Single	
TW-35	7/12/85	28	Grundfos	SP2-10-S	8524	Franklin	795-169	230	1/2	3 Wire	Single	
TW-36	7/12/85	28	Grundfos	SP2-10-S	8524	Franklin	795-165	230	1/2	3 Wire	Single	b
TW-37	7/09/85	70	Red Jacket	-	036-188	Red Jacket	75N1, 179-315	230	3/4	3 Wire	Single	

Golder Associates

TABLE 2-10 (Cont.)

WELL PUMP SPECIFICATIONS

WELL	DATE PUMP INSTALLED	DEPTH TO TOP OF PUMP[1] (feet)	PUMP MANUFACTURER	PUMP MODEL NO.	PUMP TYPE	PUMP MOTOR MANUFACTURER	PUMP MOTOR MODEL NO.	ELECTRICAL SUPPLY				COMMENTS
								Voltage	Horsepower	Wire	Phase	
TW-39	7/12/85	29	Grundfos	SP2-10-S	8524	Franklin	795-169	230	1/2	3 Wire	Single	
TW-40	-	88	-	-	-	-	-	230	-	2 Wire	Single	
TW-41	10/22/91	68	Grundfos	10S05-9	9138	Franklin	214 305 4416	230	1/2	3 Wire	Single	
TW-42	10/22/91	88	Grundfos	10S05-9	9126	Franklin	214 305 4416	230	1/2	3 Wire	Single	c
TW-43	7/12/85	-	-	-	-	-	-	-	-	-	-	d
TW-44A	7/12/85	97	Red Jacket	-	036-188	Red Jacket	75N1, PT179-315	230	3/4	3 Wire	Single	
TW-45	10/15/91	180	Grundfos	10S07-12	9133	Franklin	214 307 4416	230	3/4	3 Wire	Single	
TW-48	-	-	-	-	-	-	-	230	-	2 Wire	Single	
TW-49	-	-	-	-	-	-	-	230	-	2 Wire	Single	
TW-50	-	-	-	-	-	-	-	230	-	2 Wire	Single	
PRODUCTION WELLS:												
PW-1	1967	NA	Layne & Bowler	19343	-	General Electric	-	480	125	-	-	e
PW-2	1967	NA	Layne & Bowler	-	-	General Electric	-	480	100	-	3	e
PW-3	1967	NA	Layne & Bowler	D-11521	-	General Electric	-	480	200	-	3	e
PW-4	-	NA	-	-	-	-	-	-	-	-	-	

[1] Depth to submersible pump is measured from top of steel casing.
a Submersible pump in TW-18 was originally installed 7/06/85. Pump was pulled 10/17/91 to replace pump motor and was reinstalled 10/22/91.
b TW-36 well casing, well riser, and wiring were damaged by slag. Well was repaired 10/17/91.
c Submersible pump in TW-42 was originally installed 7/08/85. Pump was pulled 10/16/91 to replace both pump and motor.
d Submersible pump in TW-43 was originally installed 7/12/91. Pump was pulled 10/17/91 due to pump malfunction and because of limited amount of water in well.
e Date of pump installation approximate.

NA - Not applicable if surface pump.

- Data not available.

TABLE 2-11

SUMMARY OF SELECTED SPRINGS

NAME	ALTERNATIVE NAME	COMMENTS
Boyscout Spring		
Calf Spring	Stockyard Spring	limited stock water supply; tributary to Soda Creek
Doc Kackley Spring		tributary to Soda Creek
Finch Spring		
Formation Spring A Formation Spring B Formation Spring C		Soda Springs city water supply; tributary to Ledger Creek.
Homestead Spring		
Hooper Spring		local attraction at Hooper Park; tributary to Soda Creek
Kelly Park Spring		
Ledger Spring A Ledger Spring B Ledger Spring C	Ledger Creek Spring	Soda Springs city water supply; tributary to Ledger Creek. Consists of several different springs.
Mormon Spring A Mormon Spring B Mormon Spring C		limited stock water supply; tributary to Soda Creek. Consists of several different springs.
Spring Box Spring		
SW Spring	Southwest Spring	tributary to Soda Creek

TABLE 2-12

CONSTITUENTS ANALYZED IN GROUNDWATER AND SPRING SAMPLES

Metals	Ions	Radio-chemicals	Environmental Isotopes	Water Quality	Others
Aluminum	Ammonium[1]	Radon	Carbon-14[2]	Total Dissolved Solids	BOD[2]
Arsenic	Bicarbonate	Radium-226	Oxygen-18[2]	Specific Conductance[3]	COD[2]
Beryllium	Calcium	Radium-228	Deuterium[2]	pH[3]	TPH[2]
Cadmium	Carbonate	Uranium	Tritium[2]	Eh[4]	
Chromium	Chloride	Gross Alpha		Turbidity[4]	
Copper	Fluoride			Temperature[4]	
Iron	Hydroxide				
Lead	Magnesium				
Manganese	Nitrate/Nitrite as N				
Nickel	Total Phosphorus				
Potassium	Sulfate				
Selenium					
Silver					
Sodium					
Vanadium					
Zinc					

BOD Biological Oxygen Demand
COD Chemical Oxygen Demand
TPH Total Petroleum Hydrocarbons
1 The actual constituent analyzed is ammonia, which can be calculated from the ammonium concentration, pH and temperature.
2 Analyzed at selected locations only (see Table 2-13).
3 Analyzed in field and in laboratory.
4 Analyzed in field only.

TABLE 2-13

GROUNDWATER AND SPRING SAMPLING DETAILS - PHASE I

SAMPLE LOCATION	SAMPLE ID	SAMPLE DATE	COMMENTS	CHEMICAL PARAMETERS[1]					
				TPH	ENVIRON. ISOTOPES	BOD & COD	METALS	RADIOCHEMICALS	IONS & WATER QUALITY PARAMETERS
TEST WELLS:									
TW-2	TW-2-RFK	10/17/91					x	x	x
TW-9	TW-9-RFK	10/17/91					x	x	x
TW-10	TW-10-RFK	10/21/91			x		x	x	x
TW-11	TW-11-RFK	10/27/91					x	x	x
TW-12	TW-12-RFK	10/21/91			x		x	x	x
TW-13	TW-13-RFK	10/20/91					x	x	x
TW-15	TW-15-RFK	10/20/91			x		x	x	x
TW-16	TW-16-RFK	10/23/91		x		x	x	x	x
TW-18	TW-18-RFK	10/23/91				x	x	x	x
TW-18	TW-18-RFK-S	10/23/91	SPLIT			x	x	x	x
TW-20	TW-20-RFK	10/27/91		x			x	x	x
TW-20	TW-20-RFK-A	10/27/91			x				
TW-20	TW-20-RFK-B	10/27/91	DUPLICATE		x				
TW-21	TW-21-RFK	10/18/91					x	x	x
TW-21	TW-21-RFK-S	10/18/91	SPLIT				x	x	x
TW-22	TW-22-RFK	10/22/91		x		x	x	x	x
TW-22	TW-22-RFK-F	10/22/91	FILTERED				x	x[3]	
TW-23	TW-23-RFK	10/22/91				x	x	x	x
TW-26	TW-26-RFK	10/20/91		x			x	x	x
TW-26	TW-26-RFK-DUP	10/20/91	DUPLICATE	x			x	x	x

TABLE 2-13 (Cont.)

GROUNDWATER AND SPRING SAMPLING DETAILS - PHASE I

SAMPLE LOCATION	SAMPLE ID	SAMPLE DATE	COMMENTS	CHEMICAL PARAMETERS[1]					
				TPH	ENVIRON. ISOTOPES	BOD & COD	METALS	RADIOCHEMICALS	IONS & WATER QUALITY PARAMETERS
TW-28	TW-28-RFK	10/17/91					x	x	x
TW-29	TW-29-RFK	10/17/91					x	x	x
TW-30	TW-30-CCY	10/18/91					x	x	x
TW-30	TW-30-CCY-F	10/18/91	FILTERED				x	x[3]	
TW-32	TW-32-RFK	10/26/91					x	x	x
TW-32	TW-32-RFK-F	10/26/91	FILTERED				x	x[3]	
TW-33	TW-33-RFK	10/22/91					x	x	x
TW-33	TW-33-RFK-F	10/22/91	FILTERED				x	x[3]	
TW-34	TW-34-RFK	10/18/91					x	x	x
TW-35	TW-35-RFK	10/21/91					x	x	x
TW-36	TW-36-RFK	10/26/91					x	x	x
TW-36	TW-36-RFK-F	10/26/91	FILTERED				x	x[3]	
TW-37	TW-37-RFK	10/21/91				x	x	x	x
TW-38	TW-38-CCY	10/24/91					x	x	x
TW-38	TW-38-CCY-F	10/24/91	FILTERED				x	x[3]	
TW-39	TW-39-RFK	10/21/91		x			x	x	x
TW-40	TW-40-RFK	10/27/91		x			x	x	x
TW-40	TW-40-RFK-F	10/27/91	FILTERED				x	x[3]	
TW-41	TW-41-RFK	10/29/91		x			x	x	x
TW-42	TW-42-RFK	10/27/91					x	x	x

TABLE 2-13 (Cont.)

GROUNDWATER AND SPRING SAMPLING DETAILS - PHASE I

SAMPLE LOCATION	SAMPLE ID	SAMPLE DATE	COMMENTS	CHEMICAL PARAMETERS[1]					
				TPH	ENVIRON. ISOTOPES	BOD & COD	METALS	RADIOCHEMICALS	IONS & WATER QUALITY PARAMETERS
TW-42	TW-42-RFK-F	10/27/91	FILTERED				x	x[3]	
TW-43	TW-43-CCY	10/28/91					x	x	x
TW-43	TW-43-CCY-F	10/28/91	FILTERED				x	x[3]	
TW-44A	TW-44-RFK	10/20/91					x	x	x
TW-44A	TW-44-RFK-F	10/20/91	FILTERED				x	x[3]	
TW-45	TW-45-RFK	10/21/91				x	x	x	x
TW-48	TW-48-RFK	10/23/91				x	x	x	x
TW-49	TW-49-RFK	10/23/91				x	x	x	x
TW-49	SW-49-RFK	10/23/91	DUPLICATE			x	x	x	x
TW-50	TW-50-RFK	10/23/91		x		x	x	x	x
TW-50	TW-50-RFK-F	10/23/91	FILTERED				x	x[3]	
HARRIS	HARRIS	10/23/91					x	x	x
DOMESTIC WELLS:									
LEWIS	LEWIS	10/23/91					x	x	x
LEWIS	LEWIS WELL	12/04/91			x				
PRODUCTION WELLS:									
PW-1	PW-1-RFK	10/16/91		x			x	x	x
PW-2	PW-2-RFK	10/16/91					x	x	x
PW-3	PW-3-RFK	10/15/91					x	x	x
PW-3	PW-3-RFK-R	10/29/91	RADON RESAMPLE					x[2]	

TABLE 2-13 (Cont.)

GROUNDWATER AND SPRING SAMPLING DETAILS - PHASE I

SAMPLE LOCATION	SAMPLE ID	SAMPLE DATE	COMMENTS	CHEMICAL PARAMETERS[1]					
				TPH	ENVIRON. ISOTOPES	BOD & COD	METALS	RADIOCHEMICALS	IONS & WATER QUALITY PARAMETERS
PW-4	PW-4-RFK	10/16/91					x	x	x
SPRINGS AND SPRING RELATED SURFACE WATERS:									
BOYSCOUT	BOYSCOUT	10/24/91					x	x	x
BOYSCOUT	BOYSCOUT	10/28/91			x				
CALF	CALF SPRING	10/16/91					x	x	x
DOC KACKLEY	DOC	10/25/91			x		x	x	x
DOC KACKLEY	DOC-S	10/25/91	SPLIT				x	x	x
FINCH	FINCH	10/24/91					x	x	x
FINCH	FINCH	10/28/91			x				
FORMATION A	FORMATION A	10/24/91	TREATMENT BUILDING		x		x	x	x
FORMATION B	FORMATION B	10/24/91	CREEK NEAR ROAD		x		x	x	x
FORMATION C	FORMATION C	10/24/91	LOWEST PERCOLATION POND				x		x
FORMATION C	FORMATION C	10/25/91	LOWEST PERCOLATION POND		x			x	
HOMESTEAD	HOMESTEAD	10/17/91					x	x	x
HOOPER	HOOPER	10/20/91			x		x	x	x
KELLY PARK	KELLY A	10/28/91					x	x	x
KELLY PARK	KELLY B	10/28/91	DUPLICATE				x	x	x
KELLY PARK	KELLY	10/28/91			x				
LEDGER A	LEDGER A	10/24/91	UPPER SPRING BOX (#5)		x		x	x	x
LEDGER B	LEDGER B	10/24/91	SECOND BOX FROM UPPER (#4)		x		x	x	x

TABLE 2-13 (Cont.)

GROUNDWATER AND SPRING SAMPLING DETAILS - PHASE I

SAMPLE LOCATION	SAMPLE ID	SAMPLE DATE	COMMENTS	CHEMICAL PARAMETERS[1]					
				TPH	ENVIRON. ISOTOPES	BOD & COD	METALS	RADIOCHEMICALS	IONS & WATER QUALITY PARAMETERS
LEDGER C	LEDGER C	10/24/91	SECOND LOWEST SPRING BOX (#2)				x		x
LEDGER C	LEDGER C	10/25/91	SECOND LOWEST SPRING BOX (#2)		x			x	
MORMON A	MORMON	10/22/91					x	x	x
MORMON B	MORMON B	10/16/91					x	x	x
MORMON C	MORMON C	10/16/91					x	x	x
SOUTHWEST	SOUTHWEST	10/22/91					x	x	x
SPRINGBOX	SPRINGBOX	10/24/91					x	x	x
SPRINGBOX	SPRINGBOX	10/28/91			x				
EQUIPMENT BLANKS:									
TW-30	EB-01-CCY	10/18/91	STAINLESS-STEEL BAILER				x	x	x
TW-10	EB-02-RFK	10/21/91	SAMPLING RISER PIPE				x	x	x
TW-38	EB-03-CCY	10/24/91	ACRYLIC BAILER				x	x	x
KELLY PARK	EB-BEAKER	10/26/91	GLASS BEAKER				x	x	x
LAB	EB-FILTER	10/27/91	FILTER APPARATUS				x	x[3]	
LAB	EB-SPOON	10/29/91	SOIL SPOON				x	x[3]	x
FIELD BLANKS:									
PW-2	FB-01-RFK	10/16/91	DI WATER				x		x
PW-2	FB-01-RFK	10/16/91	DI WATER					x	
TW-2	FB-02-RFK	10/17/91	DI WATER				x		x

TABLE 2-13 (Cont.)

GROUNDWATER AND SPRING SAMPLING DETAILS - PHASE I

SAMPLE LOCATION	SAMPLE ID	SAMPLE DATE	COMMENTS	CHEMICAL PARAMETERS[1]					
				TPH	ENVIRON. ISOTOPES	BOD & COD	METALS	RADIOCHEMICALS	IONS & WATER QUALITY PARAMETERS
TW-2	FB-02-RFK	10/17/91	DI WATER					x	
TW-21	FB-03-RFK	10/18/91	DI WATER				x	x	x
TW-44A	FB-04-RFK	10/20/91	DI WATER				x	x	x
TW-23	FB-05-RFK	10/22/91	DI WATER				x	x	x
TW-42	FB-06-RFK	10/27/91	DI WATER				x	x	x

[1] See Table 2-12 for listing of chemical parameters.
[2] Original radon sample vials were broken in transport. Resampled for radon only.
[3] A sample for radon analysis was not collected. Samples were filtered if turbidity was >5 NTU.

TABLE 2-14

SUMMARY OF GROUNDWATER AND SPRING FIELD QA/QC SAMPLE TYPES

Sample Type	No. of Field Samples	No. of Duplicate Samples	No. of Split Samples	No. of Equipment Blanks	No. of Field Blanks	Total No. of Samples
Wells	40	2	2	4	6	54
Springs	18	1	1	1	0	21

TABLE 2-15

BREAKDOWN OF GROUNDWATER AND SPRINGS
FIELD QA/QC SAMPLES BY ANALYTICAL CATEGORY

Analytical Category	No. of Field Samples	No. of Duplicate Samples	No. of Split Samples	No. of Equipment Blanks	No. of Trip Blanks	No. of Field Blanks	Total No. of Samples
Ions and Water Quality Parameters	58	3	3	4	0	6	74
Phosphorus & ammonium	58	3	3	4	0	6	74
Metals	58	3	3	5	0	6	75
Radiochemicals	58	3	3	5	0	6	75
Radon	58	3	3	4	0	6	74
Environmental Isotopes	17	1	0	0	0	0	18
Carbon-14	17	1	0	0	0	0	18
BOD & COD	9	1	1	0	0	0	11
TPH	9	1	0	0	0	0	10

BOD Biological Oxygen Demand
COD Chemical Oxygen Demant
TPH Total Petroleum Hydrocarbons

TABLE 3-1

MONSANTO PROCESS STREAM SUMMARY

Process/Stream	Storage Location	Containment	Current Status	Quantity
Calcium silicate slag	Pile on ground — vitrified mass	None	Active	700,000 tons/year 23,000,000 tons total
Furnace dust (treater dust)	Pile on ground (sold to N.A. Degerstrom)	None	Active	51,000 tons stockpiled
Ferrophosphorus slag	Pile on ground (sold to Kerr-McGee)	None	Active	less than 20 tons stockpiled
Kiln dust slurry	Hydroclarifier	Pre 1985 — none Post 1985 — synthetic liner and leachate-collection system	Removed Active	1,000,000 gallons
	Old underflow solids ponds (prior to 1983)	Bentonite cap over molten slag placed in 1987	Inactive since 1983	35,000 tons — covered by slag
	New underflow solids ponds (1982 — 1986)	Bentonite liner	Active (backup for hydroclarifier)	
	Underflow solids stockpile	None	Active	1,000,000 tons — recycled to kiln
	Northwest pond	Pre-1988 — none Present — bentonite liner	Active (as permitted sanitary landfill)	

TABLE 3-1 (Cont.)

MONSANTO PROCESS STREAM SUMMARY

Process/Stream	Storage Location	Containment	Current Status	Quantity
Displacement/process water (phossy water from rail cars, storage vessels, and spray tower)	Phossy water surge pond, recycled through plant	Bentonite liner	Active	Water recycled
Furnace electrode seal water	Electrode seal water pond	Bentonite liner	Active	Water recycled
Coke dust and quartzite dust slurry from drier	**Past** - coke and quartzite slurry pond **Present** - collected in baghouse	None	Inactive	
Non-contact plant cooling water	Effluent settling pond (overflow water is discharged to Soda Creek)	None	Active	1,000 gallons/minute

TABLE 3-2

PARTICLE-SIZE DISTRIBUTION OF SOURCE SAMPLES FROM THE MONSANTO PLANT

Sample Location	Sample ID	Gravel-Sized	Sand-Sized	Silt-Sized	Clay-Sized	USCS Class
Baghouse Dust	Dust-1	3.0	29.5	55.9	11.6	silt, some fine sand (ML)
Baghouse Dust	Dust-2	33.4	46.3	14.2	5.5	coarse to fine sand and coarse to fine gravel (SM)
Baghouse Dust	Dust-3	13.9	51.2	25.4	9.5	coarse to fine sand and silt (SM)
Slag Pile	Slag-1	56.1	40.0	2.7	1.2	coarse to fine gravel and coarse to fine sand (GP)
Slag Pile	Slag-2	86.9	12.9	0.2	*	coarse to fine gravel, some coarse to medium sand (GP)
Slag Pile	Slag-3	67.8	31.0	0.6	0.6	fine gravel and coarse to fine sand (GW)
Slurry Ponds	Slurry-1	10.8	68.6	13.6	7.0	medium to fine sand, some silt (SM)
Slurry Ponds	Slurry-2	0.0	54.3	38.2	7.5	fine sand and silt (SM)
Slurry Ponds	Slurry-3	0.1	13.9	59.9	26.1	clayey silt, some fine sand (CL)
Underflow Solids	Underflow-1	0.7	45.6	42.3	11.4	clayey silt and coarse to fine sand (ML)
Underflow Solids	Underflow-2	0.9	42.3	42.8	14.0	clayey silt and medium to fine sand (ML)
Underflow Solids	Underflow-3	0.8	44.2	42.9	12.1	clayey silt and fine sand (ML)
Coke Stockpile	C-1	59.1	40.4	0.5	*	fine gravel and coarse sand (GP)
Coke Stockpile	C-2	66.5	27.9	5.6	*	fine gravel, some coarse to fine sand (GM-GP)
Coke Stockpile	C-3	70.1	26.6	3.3	*	fine gravel, some coarse to fine sand (GW)
Quartzite Stockpile	Q-1	94.1	5.1	0.8	*	coarse to fine gravel (GP)
Quartzite Stockpile	Q-2	98.2	1.2	0.6	*	coarse to fine gravel (GP)
Phosphate Ore Stockpile	PO-1	22.8	47.9	19.1	10.2	coarse to fine sand, some silt, some fine gravel (SM)
Phosphate Ore Stockpile	PO-2	26.0	43.4	16.4	14.2	coarse to fine sand and silt, some fine gravel(SM)
Phosphate Ore Stockpile	PO-2R	24.7	45.6	20.6	9.1	coarse to fine sand, some silt, some coarse to fine gravel(SM)
Phosphate Ore Stockpile	PO-3	16.6	48.8	23.9	10.7	coarse to fine sand and silt, some fine gravel(SM)
Treater Dust Stockpile	TD-1	6.8	58.5	14.2	20.5	coarse to fine sand and silt (SM)
Treater Dust Stockpile	TD-1R	7.6	59.8	14.7	17.9	coarse to fine sand and silt (SM)
Nodule Fines Pile	NDF-1	0.0	98.9	0.5	0.6	coarse to fine sand (SP)
Nodule Fines Pile	NDF-1A	0.0	99.1	0.5	0.4	coarse to fine sand (SP)

*not measured separately from silt-sized material.

TABLE 3-3

SUMMARY OF 1990 MEAN WIND SPEED DATA, SODA SPRINGS, IDAHO

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
AVE. WIND SPEED (m/s)	3.8	3.7	3.6	3.5	3.7	3.6	3.9	3.3	2.5	3.0	3.6	3.7	3.5

TABLE 3-4

SEASONAL SUMMARY OF 1990 WIND DATA, SODA SPRINGS, IDAHO

WIND DIRECTION	SEASONAL WIND SPEED AND PERCENT FREQUENCY BY DIRECTION									
	JAN-MAR		APR-JUN		JUL-SEP		OCT-DEC		ANNUAL	
	m/s	%	m/s	%	m/s	%	m/s	%	m/s	%
N	2.50	12.59	2.80	11.08	2.44	11.37	2.77	8.79	2.62	10.95
NNE	1.99	17.87	2.01	10.03	1.68	15.35	1.86	10.19	1.88	13.36
NE	1.69	5.05	1.49	5.63	1.44	7.43	1.54	4.08	1.53	5.55
ENE	1.61	1.11	1.38	2.47	1.75	2.45	1.20	1.22	1.51	1.82
E	1.77	1.06	1.59	1.60	1.87	1.63	1.29	0.82	1.67	1.28
ESE	2.24	0.83	1.55	1.28	1.83	1.18	1.60	1.00	1.77	1.07
SE	7.38	10.97	6.60	7.23	6.87	9.92	8.00	6.34	7.17	8.62
SSE	4.66	9.72	4.17	8.75	4.43	8.61	3.98	8.97	4.32	9.01
S	3.56	9.58	3.17	7.37	2.79	7.07	3.31	12.82	3.24	9.21
SSW	4.68	9.07	4.68	10.81	4.20	9.83	4.32	15.99	4.45	11.44
SW	3.94	5.56	4.08	7.92	3.51	6.07	3.95	7.38	3.89	6.74
WSW	4.65	5.74	4.35	8.56	3.27	4.62	4.06	6.70	4.15	6.40
W	4.02	1.44	3.86	4.62	3.14	2.08	3.49	1.77	3.66	2.48
WNW	3.62	0.69	4.04	3.02	3.09	2.04	3.36	1.31	3.60	1.77
NW	3.67	1.16	4.23	3.25	3.41	2.76	3.28	2.72	3.67	2.48
NNW	3.23	7.45	3.28	6.32	2.89	7.56	3.03	5.43	3.10	6.69
C	0.00	0.09	0.00	0.05	0.00	0.05	0.00	4.48	0.00	1.15

TABLE 3-5

SEASONAL SUMMARY OF 1991 WIND DATA, SODA SPRINGS, IDAHO

WIND DIRECTION	SEASONAL WIND SPEED AND PERCENT FREQUENCY BY DIRECTION									
	JAN-MAR		APR-JUN		JUL-SEP		OCT-DEC		ANNUAL	
	m/s	%	m/s	%	m/s	%	m/s	%	m/s	%
N	2.31	12.35	3.18	12.68	2.26	9.24	2.26	14.86	2.51	12.28
NNE	1.90	14.53	2.15	7.65	1.91	17.48	1.84	17.12	1.92	14.21
NE	1.59	5.70	1.60	4.95	1.62	7.93	1.53	5.07	1.59	5.92
ENE	1.19	2.08	2.02	2.34	1.96	1.99	1.42	1.49	1.67	1.98
E	1.46	1.09	2.10	2.15	2.13	1.59	1.23	1.22	1.82	1.52
ESE	1.72	0.94	1.85	1.74	2.69	1.45	1.66	1.04	2.03	1.30
SE	6.64	8.04	6.16	7.14	6.16	8.83	5.14	4.53	6.11	7.13
SSE	4.13	10.32	4.12	9.39	4.64	9.47	4.00	8.51	4.23	9.40
S	3.17	10.47	3.33	7.65	3.17	8.33	3.47	10.42	3.29	9.19
SSW	4.19	11.61	4.62	10.03	3.99	10.24	4.25	9.06	4.26	10.20
SW	3.37	5.75	4.43	7.65	3.71	7.79	3.68	5.21	3.85	6.62
WSW	3.82	6.70	4.01	8.38	3.10	4.17	3.82	5.93	3.76	6.28
W	3.10	2.18	3.14	2.93	3.48	1.68	3.14	1.90	3.20	2.17
WNW	3.33	1.14	3.24	1.88	3.11	2.26	3.63	2.13	3.33	1.87
NW	2.62	1.64	3.70	3.16	3.71	2.63	2.45	2.17	3.24	2.41
NNW	2.78	4.76	3.89	10.26	2.91	4.89	2.69	7.97	3.19	7.01
C	0.00	0.69	0.00	0.00	0.00	0.05	0.00	1.36	0.00	0.51

TABLE 3-6

COMPARISON OF ATMOSPHERIC STABILITY CLASS FREQUENCIES:
POCATELLO VS. SODA SPRINGS, IDAHO

	% FREQUENCY OF OCCURRENCE		
STABILITY CLASS	SODA SPRINGS — 1990	POCATELLO — 1990	POCATELLO — 1986 - 1990
A	2.94	0.76	0.65
B	4.41	7.90	7.13
C	11.61	12.70	12.94
D	56.74	48.97	49.53
E	11.51	14.87	14.41
F	12.79	14.78	15.33

STABILITY CLASS

A EXTREMELY UNSTABLE
B MODERATELY UNSTABLE
C SLIGHTLY UNSTABLE
D NEUTRAL STABILITY
E SLIGHTLY STABLE
F EXTREMELY STABLE

TABLE 3-7

SUMMARY OF 1990 MEAN DAILY TEMPERATURE (°C) DATA, SODA SPRINGS, IDAHO

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MINIMUM	-23.4	-26.2	-1.1	-4.2	-4.1	0.1	4.6	4.0	2.2	-17.2	-16.3	-33.9	-33.9
MAXIMUM	7.9	4.3	11.4	20.6	21.1	30.8	30.3	31.7	29.6	21.6	14.7	9.8	31.7
MEAN	-4.7	-6.8	0.9	7.0	8.4	14.5	18.9	18.1	15.8	4.1	0.5	-10.9	5.5

TABLE 3-8

SUMMARY OF 1990 MEAN MIXING HEIGHT (m) DATA, BOISE, IDAHO

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MORNING	428.0	521.1	285.7	403.8	401.8	312.3	161.1	209.5	109.0	261.4	371.0	244.3	309.1
AFTERNOON	617.8	985.3	1791.9	2130.4	2448.0	2857.5	3288.9	2808.4	2124.7	1726.4	960.7	604.0	1861.8

TABLE 3-9

MEAN SEASONAL AND ANNUAL MORNING AND AFTERNOON MIXING HEIGHTS[1] (m) FOR BOISE, IDAHO

	WINTER	SPRING	SUMMER	AUTUMN	YEAR
MORNING	407	424	193	279	326
AFTERNOON	754	2329	2540	1409	1758

[1] 1960 — 1964 (after Holzworth 1972)

TABLE 3-10

PARTICLE-SIZE DISTRIBUTION OF SEDIMENT SAMPLES FROM SODA CREEK.

Sample Location	Sample ID	Gravel-Sized	Sand-Sized	Silt-Sized	Clay-Sized	USCS Class
Soda Creek	Soda N	79.0	20.7	0.3	*	coarse to fine gravel, some coarse to fine sand (GW)
Soda Creek	Soda S	70.1	28.0	1.9	*	coarse to fine gravel, some coarse to fine sand (GW)
Soda Creek	Outflow	0.0	15.0	59.4	25.6	organic clayey silt, little coarse to fine sand (OL)
Soda Creek	Upstream-near	7.9	42.4	34.7	15.0	silt and fine sand, little fine gravel (ML)
Soda Creek	Upstream-middle	40.8	40.2	15.2	3.8	coarse to fine gravel and coarse to fine sand, some silt (GM)
Soda Creek	Upstream-far	0.0	59.1	25.7	15.2	medium to fine sand and silt (SM)

*not measured separately from silt-sized material.

TABLE 3-11

REGIONAL STRATIGRAPHIC COLUMN

System	Group or Formation	Thickness (feet)	Lithology
Quaternary	Stream alluvium, Terrace gravels, Landslide debris, Alluvial fan deposits, Colluvium, Diamictite, Travertine	0—330	unconsolidated, well to poorly sorted, gravel, sand, silt and clay
	Blackfoot Lava Field	0—3,300(?)	dark grey, vesicular, porphyritic, massive olivine basalt
	Rhyolite domes	?	tan weathering, partly devitrified, Quaternary and Tertiary
Tertiary	Salt Lake Formation	0—9,900(?)	conglomerate, volcanic ash, marl, calcareous clay and sandstone
	Basalt dikes	?	olivine basalt
Triassic	Thaynes Limestone	825—990	tan silty and sandy limestone, calcareous siltstone and sandstone; light gray finely crystalline limestone
	Dinwoody Formation	330—1,980	brown,silty, medium-crystalline limestone; light-gray finely crystalline limestone
Permian	Phosphoria Formation	231—330	black to white chert interbedded with black cherty mudstone; dark-brown to black mudstone, limestone and oolitic phosphate rock
Pennsylvanian	Wells Formation	990—2,970	light-gray to reddish-brown sandstone interbedded with light-brown limestone; gray limestone and silty limestone with interbedded sandstone
Mississippian	Chesterfield Range Group	?	thick-bedded limestone; interbedded thin-bedded limestone and buff fine-grained sandstone; phosphatic chert at base
	Lodgepole Formation	660—1,320	medium to dark gray thin bedded, fossiliferous limestone
Devonian	Jefferson Dolomite	626	buff fine-grained sandstone; dark-brown medium crystalline dolomite; white coarsely crystalline dolomite
Silurian	Laketown Dolomite	441	white coarsely crystalline dolomite
Ordovician	Fish Haven Dolomite	1,247	medium-brownish-gray to gray finely to medium crystalline dolomite; chert nodules and lenses in lower part
	Swan Peak Quartzite	512	white fine-grained pure quartzite;sandy limestone near base
	Garden City Limestone	389—951	interbedded light-gray finely crystalline limestone and limestone conglomerate; chert nodules near top and lower part

TABLE 3-11 (Cont.)

REGIONAL STRATIGRAPHIC COLUMN

System	Group or Formation	Thickness (feet)	Lithology
Cambrian	St. Charles Formation	1,010—1,242	medium-brownish-gray to gray, finely to medium crystalline dolomite; interbedded arkosic quartzite, quartzite and arkose
	Nounan Limestone	630	light to dark-gray and tan-gray finely to coarsely crystalline limestone; a few red beds; white coarsely crystalline dolomite; medium-gray finely to medium crystalline dolomite
	Bloomington Formation	1,480	interbedded olive-drab to tan finely micaceous shale and thin-bedded limestone with limestone conglomerate
	Blacksmith Limestone	703—887	oolitic medium to light-gray thin-bedded finely crystalline limestone
	Ute Limestone	111—483	tan-gray and pinkish-gray thin-bedded finely crystalline limestone with interbeds of tan sandy micaceous shale, sandy shale and calcareous sandstone
	Langston Formation	331—463	white coarsely crystalline dolomite; medium to dark-gray limestone;olive-drab micaceous shale and siltstone; olive-green micaceous shale; greenish-tan micaceous sandstone and phyllitic siltstone; green, reddish-gray and brown micaceous sandy quartzite and quartzite
	Brigham Quartzite	137—400+	tan and olive-drab micaceous sandstone and sandy quartzite; green and tan quartzite interbedded with quartzitic sandstone and dolomite; red, brown and purplish-brown quartzite

After Armstrong 1969 and Ralston et al. 1983

TABLE 3-12

PARTICLE SIZE DISTRIBUTION OF SOIL SAMPLES FROM THE PLANT PERIMETER AND CONTROL LOCATIONS.

Sample Location	Sample ID	Depth	Gravel-Sized	Sand-Sized	Silt-Sized	Clay-Sized	USCS Class
S-1	S-1a	0-1	3.2	11.0	64.6	21.2	clayey silt, little medium to fine sand (CL)
S-1	S-1b	0-6	6.1	10.4	58.3	25.2	clayey silt, little medium to fine sand (CL)
S-2	S-2a	0-1	2.6	15.1	65.9	16.4	clayey silt, some medium to fine sand (CL)
S-2	S-2b	0-6	3.5	13.0	72.9	10.6	clayey silt, little medium to fine sand (CL)
S-3	S-3a	0-1	1.1	18.0	78.7	2.2	clayey silt, some coarse to fine sand (CL)
S-3	S-3b	0-6	1.6	13.8	76.6	8.0	clayey silt, some coarse to fine sand (CL)
S2-3	S2-3a	0-1	0.0	14.0	68.2	17.8	silty clay, some medium to fine sand (CL)
S2-3	S2-3b	0-6	2.9	16.2	64.3	16.6	clayey silt, some medium to fine sand (CL)
S-4	S-4a	0-1	0.0	10.2	86.8	3.0	clayey silt, little medium to fine sand (CL)
S-4	S-4b	0-6	4.3	8.5	77.3	9.9	clayey silt, little medium to fine sand (CL)
S-5	S-5a	0-1	0.0	4.3	82.9	12.8	clayey silt, trace medium to fine sand (CL)
S-5	S-5b	0-6	0.0	4.2	83.6	12.2	clayey silt, trace medium to fine sand (CL)
S2-5	S2-5a	0-1	0.0	2.6	72.9	24.5	clayey silt, trace medium to fine sand (CL)
S2-5	S2-5b	0-6	0.0	4.7	81.0	14.3	clayey silt, trace medium to fine sand (CL)
S-6	S-6a	0-1	0.0	8.3	73.2	18.5	clayey silt, little medium to fine sand (CL)
S-6	S-6b	0-6	0.0	5.4	72.6	22.0	clayey silt, little medium to fine sand (CL)
S2-6	S2-6a	0-1	0.0	4.9	78.8	16.3	silty clay, trace fine sand (CL)
S2-6	S2-6b	0-6	0.0	4.3	82.4	13.3	silty clay, trace medium to fine sand (CL)
S-7	S-7a	0-1	0.0	6.3	68.9	24.8	clayey silt, little coarse to fine sand (CL)
S-7	S-7b	0-6	0.3	5.5	69.0	25.2	clayey silt, little medium to fine sand (CL)
S-8	S-8a	0-1	0.0	12.4	70.2	17.4	clayey silt, some fine sand (CL)
S-8	S-8b	0-6	0.9	11.2	71.1	16.8	clayey silt, some fine sand (CL)
S-9	S-9a	0-1	0.0	12.7	68.6	18.7	clayey silt, some fine sand (CL)

TABLE 3-12 (Cont.)

PARTICLE SIZE DISTRIBUTION OF SOIL SAMPLES FROM THE PLANT PERIMETER AND CONTROL LOCATIONS.

Sample Location	Sample ID	Depth	Gravel-Sized	Sand-Sized	Silt-Sized	Clay-Sized	USCS Class
S-9	S-9b	0-6	0.0	9.8	73.6	16.6	clayey silt, little fine sand (CL)
S2-9	S2-9a	0-1	3.2	4.6	67.3	24.9	clayey silt, trace medium to fine sand (CL)
S2-9	S2-9b	0-6	0.0	5.1	84.7	10.2	silty clay, little fine sand (CL)
S-10	S-10a	0-1	5.2	16.1	66.9	11.8	clayey silt, some medium to fine sand (CL)
S-10	S-10b	0-6	1.2	6.9	76.7	15.2	clayey silt, little coarse to fine sand (CL)
S-11	S-11a	0-1	0.0	12.0	72.2	15.8	clayey silt, some medium to fine sand (CL)
S-11	S-11b	0-6	0.0	5.1	77.0	17.9	clayey silt, little fine sand (CL)
S2-11	S-2-11a	0-1	0.0	15.2	78.8	6.0	silty clay, some fine sand (CL)
S2-11	S-2-11b	0-6	0.0	5.6	86.8	7.6	clayey silt, little medium to fine sand (CL)
S-12	S-12a	0-1	0.0	6.3	75.6	18.1	clayey silt, little fine sand (CL)
S-12	S-12b	0-6	0.0	5.4	77.4	17.2	clayey silt, little fine sand (CL)
S-13	S-13a	0-1	0.0	10.8	77.0	12.2	clayey silt, little fine sand (CL)
S-13	S-13b	0-6	0.0	7.7	78.6	13.7	clayey silt, trace fine sand (CL)
S-14	S-14a	0-1	0.0	24.3	70.0	5.7	clayey silt, some fine sand (CL)
S-14	S-14b	0-6	0.0	6.8	82.4	10.8	clayey silt, trace medium to fine sand (CL)
S-15	S-15a	0-1	1.5	36.5	35.4	26.6	clayey silt, and coarse to fine sand (CL)
S-15	S-15b	0-6	0.5	24.2	49.1	26.2	clayey silt, some coarse to fine sand (CL)
S-16	S-16a	0-1	0.0	6.6	77.2	16.2	clayey silt, trace medium to fine sand (CL)
S-16	S-16b	0-6	0.0	7.0	82.4	10.6	clayey silt, little fine sand (CL)
B-1	BACK-1a	0-1	0.0	3.9	71.7	24.4	clayey silt, trace medium to fine sand (CL)
B-1	BACK-1b	0-6	0.0	2.6	73.5	23.9	clayey silt, trace coarse to fine sand (CL)
B-2	BACK-2a	0-1	5.5	2.9	77.5	14.1	silty clay, trace medium to fine sand (CL)
B-2	BACK-2b	0-6	0.0	5.7	73.1	21.2	silty clay, trace coarse to fine sand (CL)

TABLE 3-12 (Cont.)

PARTICLE SIZE DISTRIBUTION OF SOIL SAMPLES FROM THE PLANT PERIMETER AND CONTROL LOCATIONS.

Sample Location	Sample ID	Depth	Gravel-Sized	Sand-Sized	Silt-Sized	Clay-Sized	USCS Class
B-3	BACK-3a	0-1	0.0	14.3	65.6	20.1	clayey silt, some coarse to fine sand (CL)
B-3	BACK-3b	0-6	0.0	17.7	60.7	21.6	clayey silt, some coarse to fine sand (CL)
B-3	BACK-3c	0-6	0.0	20.6	69.9	9.5	clayey silt, some coarse to fine sand (CL)

TABLE 3-13

BREAKDOWN OF WELLS BY HYDROSTRATIGRAPHIC ZONES

WELL	SCREENED INTERVAL (ft. bgs)	HYDROSTRATIGRAPHIC ZONE	REGION	COMMENTS
TW-1	-	-	-	well abandoned
TW-2	75-260	UBZ, LBZ	4	well open over full depth
TW-3	180-250	UBZ	-	well abandoned
TW-4	106-126	LBZ	-	well abandoned
TW-5	200-221	LBZ	-	well abandoned
TW-6	106-126	LBZ	-	well abandoned
TW-7	40-60	UBZ	1	
TW-8	75-90	UBZ	1	
TW-9	236-253	LBZ	1	
TW-10	18-27	UBZ	1	
TW-11	127-137	LBZ	3	
TW-12	84-99	UBZ	3	
TW-13	79-96	SLZ	-	
TW-14	13-21	SDZ	-	
TW-15	48-59	UBZ	4	
TW-16	68-77	UBZ	4	
TW-17	96-107	UBZ	4	
TW-18	219-238	LBZ	4	
TW-19	23-29	UBZ	2	
TW-20	35-44	UBZ	2	
TW-21	105-123	LBZ	2	
TW-22	104-112	UBZ	2	
TW-23	171-190	LBZ	2	
TW-24	73-92	UBZ	2	well affected by grout
TW-25	179-191	LBZ	-	well abandoned
TW-26	135-141	UBZ	4	
TW-27	88-95	UBZ	-	well abandoned
TW-28	76-89	LBZ	4	
TW-29	39-47	UBZ	4	
TW-30	62-69	UBZ	4	
TW-31	22-31	UBZ	3	
TW-32	151-181	LBZ	3	
TW-33	67-75	UBZ	3	

TABLE 3-13 (Cont.)

WELL	SCREENED INTERVAL (ft. bgs)	HYDROSTRATIGRAPHIC ZONE	REGION	COMMENTS
TW-34	67-74	LBZ	2	
TW-35	71-89	LBZ	2	
TW-36	48-54	UBZ	2	
TW-37	93-100	UBZ	2	
TW-38	90-102	UBZ	3	
TW-39	48-56	UBZ	2	
TW-40	82-89	UBZ	4	
TW-41	58-68	UBZ	4	
TW-42	79-89	UBZ	4	
TW-43	84-89	UBZ	4	
TW-44A	133-148	LBZ	4	replaced TW-44
TW-45	216-228	LBZ	2	
TW-48	65-71	UBZ	4	
TW-49	72-82	UBZ	4	
TW-50	72-89	UBZ	4	
TW-51	-	-	4	no well casing installed
PW-1	?	UBZ, LBZ	4	well open over full depth
PW-2	?	UBZ, LBZ	4	well open over full depth
PW-3	?	UBZ, LBZ	4	well open over full depth
PW-4	102-229	UBZ, LBZ	4	well open over full depth
HARRIS WELL (SWG)	58-62	UBZ	1	
LEWIS WELL	85-105	UBZ	2	

SDZ - Surficial Deposit Zone
UBZ - Upper Basalt Zone
LBZ - Lower Basalt Zone
SLZ - Salt Lake Zone
NOTE: Not all wells were used for sampling

TABLE 3-14

RESULTS OF 1984 WELL TESTING[a]

Test Well Number	Analysis Method	Transmissivity ($ft/day^{-1}/ft$)	Storativity (Dimensionless)	Vertical Hydraulic Conductivity (ft/day/ft)
TW-3	Jacob Jacob Theis Recovery	2,350 1,630 1,730	-- -- --	-- -- --
TW-4	Hvorslev	11.1	--	--
TW-5	Jacob Theis Recovery	14.3 10.7	-- --	-- --
TW-6	Jacob Theis Recovery	8,670 9,690	-- --	-- --
TW-7	Jacob Theis Recovery	477 538	-- --	-- --
TW-8	Hvorslev	11.1	--	--
TW-9	Hvorslev	6.9	--	--
TW-10	Jacob Theis Recovery	2,650 2,250	-- --	-- --
TW-19/TW-20	Neuman	--	--	4.7×10^{-5}[b]
TW-25	Hvorslev	0.46	--	--
TW-34	Hvorslev	1.76	--	--
PW-1/PW-2	Theis Drawdown Theis Drawdown Jacob Jacob Theis Recovery	230,000 170,000 210,000 270,000 300,000	3.1×10^{-5} 5.4×10^{-5} -- -- --	-- -- -- -- --

[a] Modified from Golder (1985)
[b] Value for Basalt

NOTES:

Jacob = Jacob Semi-Log Analysis (Cooper and Jacob 1946)
Theis Reecovery = Theis (1935) Recovery Method
Hvorslev = Modified Hvorslev (1951) Method
Theis Drawdown = Theis (1935) Drawdown Type-Curve Method
Neuman = Neuman and Witherspoon (1972) Ratio Method

TABLE 3-15

COMPARISON OF WATER QUALITY TYPES

Spring/well Name	Calcium (mg/L)	Magnesium (mg/L)	Bicarbonate (mg/L)	Qual	Nitrite/ Nitrate As N (mg/L)	Qual	Total Dissolved Solids (mg/L)	Specific Conductivity (µmhos/cm²)	Qual	Carbon-14 (years)	Oxygen-18 (δ ‰)	Deuterium (δ ‰)	Tritium (TU)
FRESH													
UBZ-4													
PW-04	120	58	427		3.8		585	838	J				
TW-02	116	60	472		3.4		631	1020	J				
TW-13	110	46.4	498		1.8		424	774					
TW-15	117	47.2	509		1.5		457	786		12775	-17.8	-137	7.2
TW-48	108	53.1	472		4.2		487	911					
Mean	114	53	476		3		517	866		NA	NA	NA	NA
Standard Deviation	4	5	28		1		78	91					
UBZ-5													
Boyscout	111	48.8	491		0.5	U	414	718		10700	-17.6	-137	2.4
Formation A	162	43.0	599		0.5	U	546	968		17620	-18.0	-136	6.5
Formation B	157	43.6	527		0.5	U	412	718		16415	-18.0	-142	4.6
Formation C	164	44.4	617		0.5	U	488	888		16100	-18.0	-138	1.5
Kelly Park	114	51.0	484		1.1		522	854		10985	-17.7	-137	8.6
Ledger A	127	45.1	527		0.5	U	442	780		15780	-18.0	-138	<2.1
Ledger B	129	46.0	527		0.5	U	410	768		17245	-17.8	-138	5.2
Ledger C	123	43.1	533		0.5	U	460	797		16030	-17.9	-139	11.2
Mean	136	46	538		0.36		462	811		15109	-17.9	-138	5.7
Standard Deviation	20	3	44		0.28		49	81		2532	0.1	2	3.1

TABLE 3-15 (Cont.)

COMPARISON OF WATER QUALITY TYPES

Spring/well Name	Calcium (mg/L)	Magnesium (mg/L)	Bicarbonate (mg/L)	Qual	Nitrite/ Nitrate As N (mg/L)	Qual	Total Dissolved Solids (mg/L)	Specific Conductivity (µmhos/cm²)	Qual	Carbon-14 (years)	Oxygen-18 (δ ‰)	Deuterium (δ ‰)	Tritium (TU)
SODIC													
Doc Kackley	116	133	496		0.5	U	812	1510		19705	-17.2	-133	11.6
Hooper	120	130	1002		0.5	U	812	1460		>25000	-17.0	-132	11.5
TW-09	158	179	1292	J	0.5	U	1090	1910	J				
TW-18	88.5	190	1341		0.5	U	1064	2000					
TW-21	60	264	1416	J	0.5	U	1120	1920	J				
TW-23	145	149	908		0.5	U	1220	1940					
TW-28	203	119	1080	J	1.38		976	1640	J				
TW-29	134	71	611	J	4.25		667	1040	J				
TW-35	59.6	275	1452		0.5	U	1240	2170					
TW-44	53.4	184	1108		0.5		843	1660					
Mean	113.8	169	1071		0.8		984	1725		NA	NA	NA	NA
Standard Deviation	46.3	60	310		1.2		184	315		NA	NA	NA	NA

TU = Tritium units
δ ‰ = Delta units - parts per thousand
J = Estimated value
U = Not detected - value identified is sample quantitation limit

TABLE 3-16

ENVIRONMENTAL ISOTOPE RESULTS FOR GROUNDWATER AND SPRINGS

Sample Location Name	Local Flow Region	Carbon-14 (years)	Error (±)	Oxygen-18 (δ ‰)	Deuterium (δ ‰)	Tritium (TU)	Error (±)
TW-10	UBZ-1	8590	220	-17.1	-132	17.9	2.0
Doc Kackley Spring	UBZ-1	19705	1125	-17.2	-133	11.6	2.1
Hooper Spring	UBZ-1	>25000		-17.0	-132	11.5	1.9
TW-20	UBZ-2	7110	190	-15.8	-124	22.5	2.0
Lewis Well	UBZ-2	12100	520	-17.6	-136	17.0	2.0
TW-12	UBZ-3	13570	380	-17.8	-137	6.2	2.1
TW-15	UBZ-4	12775	360	-17.8	-137	7.2	1.9
Boy Scout Spring	UBZ-5	10700	385	-17.6	-137	2.4	2.1
Finch Spring	UBZ-5	14650	490	-17.9	-136	6.5	1.9
Formation A Spring	UBZ-5	17620	600	-18.0	-136	6.5	1.9
Formation B Spring	UBZ-5	16415	530	-18.0	-142	4.6	2.1
Formation C Spring	UBZ-5	16100	510	-18.0	-138	1.5	2.1
Kelly Park Spring	UBZ-5	10985	405	-17.7	-137	8.6	1.9
Ledger A Spring	UBZ-5	15780	510	-18.0	-138	<2.1	
Ledger B Spring	UBZ-5	17245	750	-17.8	-138	5.2	1.9
Ledger C Spring	UBZ-5	16030	510	-17.9	-139	11.2	2.0
Spring Box Spring	UBZ-5	11660	320	-17.6	-136	8.7	1.9
TW-18	LBZ-4	7930	205	-15.8	-125	25.7	2.1

TU = Tritium units
δ ‰ = Delta units - parts per thousand

TABLE 3-17

SURFACE WATER RIGHTS IN THE MONSANTO PLANT VICINITY

State of Idaho Department of Water Resources Water Rights Abstract								
Owner	Source	Tributary	Irrigated Acres	Diversion Rate (cfs)				Diversion Point
				Irrigation	Stock	Domestic	Total	
Steele, Val	Groundwater		165	3.3	0.09	0.08	3.47	T9S R42E S18 NWNE
Moore, James	Big Spring Creek	Soda Creek	57	1.4	-	-	1.4	T9S R42E S18 NWNW
Moore, Jesse	Big Spring Creek	Soda Creek	110	2.5	-	-	2.5	T9S R42E S18 NWNW
Anderson, Abr	Soda Creek	Bear River	32	0.3	-	-	0.3	T9S R41E S12 NWNE
Farmers Land & Irrig Corp	Soda Creek	Soda Creek	4,040	2.84	-	-	2.84	T9S R42E S6 NWNW[a] T9S R41E S12 SENE[b]
Anderson, Abr	Big Spring Creek	Bear River	77	1.5	-	-	1.5 0	T9S R41E S13 NENE 9S R41E S12 SENE

From Ecology and Environment (1988a)
[a]diversion to irrigation ditch
[b]diversion to irrigation canal

TABLE 4-1

AVERAGE CHEMICAL CONSTITUENT ANALYSES OF SELECTED SOURCES[1]

Radionuclides (pCi/kg)

Source	^{210}Po	^{228}Th	^{230}Th	^{232}Th	^{210}Pb	U	^{226}Ra	^{228}Ra	^{40}K
Slag	4.4 ± 3.57	2.0 ± 2.69	172 ± 223	2.7 ± 2.38	4.8 ± 3.12	44 ± 3.0	48 ± 5.7	0.2 ± 0.40	6.7 ± 0.10
Dust	48 ± 46.5	0.3 ± 0.15	19 ± 16.5	0.3 ± 0.21	47 ± 49.6	20 ± 17.2	20 ± 16.3	0.2 ± 0.20	5.0 ± 2.99
Underflow	160 ± 87.5	0.4 ± 0.06	40 ± 3.2	0.3 ± 0.23	250 ± 10.0	35 ± 5.13	38 ± 3.79	0.7 ± 0.31	10 ± 0.90
Slurry	49 ± 44.2	0.4 ± 0.21	13 ± 5.1	0.8 ± 0.72	62 ± 50.4	12 ± 3.0	13 ± 3.6	0.3 ± 0.25	6.0 ± 3.35

Nonradionuclides (mg/kg)

Source	Al	As	Be	Cd	Cr	Cu	Fe	Pb	Mn	Ni
Slag	17,400 ± 1,662	7.0 ± 5.24	4.7 ± 0.25	34 ± 15.4	361 ± 161.8	52.5 ± 26.39	3,700 ± 1,547	14 ± 10.4	128 ± 12.6	62 ± 29.0
Dust	12,400 ± 6,329	44 ± 37.0	3.3 ± 2.01	210 ± 261	309 ± 251.1	33.5 ± 22.82	7,700 ± 3,005	49 ± 50.7	104 ± 61.5	65 ± 47.7
Underflow	26,000 ± 2,095	233 ± 20.0	5.7 ± 0.25	1,310 ± 364	1,020 ± 78.7	82.8 ± 1.42	10,900 ± 700	168 ± 32.5	179 ± 64.4	151 ± 33.5
Slurry	16,700 ± 10,327	232 ± 247.9	4.0 ± 1.12	285 ± 306	543 ± 413.7	73.6 ± 15.3	10,000 ± 2,343	71 ± 41.2	74 ± 6.6	98 ± 53.0
Effluent (mg/L)	0.08 ± 0.0015	<0.002[2]	<0.001[2]	0.01 ± 0.001	<0.01[2]	<0.01[2]	0.05 ± 0.006	<0.001[2]	<0.005[2]	<0.02[2]

Nonradionuclides (mg/kg)

Source	K	Se	Ag	Na	V	Zn	F	NO_3/NO_2 as N	pH standard units
Slag	6,380 ± 631	1.2 ± 0.55	11 ± 4.5	4,740 ± 1,803	558 ± 288.8	268 ± 245.8	89.6 ± 68.05	1.1 ± 0.23	9.8 ± 0.10
Dust	4,560 ± 3,422	0.4 ± 0.17[2]	9.0 ± 8.00	1,730 ± 1,417	452 ± 375.6	2,100 ± 2,210	136 ± 97.6	9.4 ± 10.08	8.2 ± 0.38
Underflow	13,300 ± 231	<0.6[2]	12 ± 3.6	4,620 ± 346	1,640 ± 158	9,690 ± 1,379	227 ± 167.5	35 ± 38.2	6.3 ± 0.26
Slurry	5,960 ± 3,997	<0.6[2]	16 ± 13.0	1,940 ± 1,131	821 ± 649.9	3,830 ± 3,821	215 ± 116.3	3.4 ± 2.63	7.6 ± 0.21
Effluent (mg/L)	7.5 ± 0.29	<0.003[2]	<0.01[2]	107 ± 4.9	0.15 ± 0.05	0.03 ± 0.006	0.42 ± 0.015	4.68 ± 0.126	6.5

NOTES:

[1] Values shown are mean ± standard deviation for a sample size of three.

[2] Value calculated from one-half of the SQL for results less than SQL, resulting value is less than the SQL.

Complete chemical analytical results are provided in Appendix C.

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TABLE 4-2

CONSTITUENT ANALYSES OF RAW MATERIAL STOCKPILES

Constituent	Sources		
	Quartzite (mg/kg)	Coke (mg/kg)	Phosphate Ore (mg/kg)
Aluminum	1,958	NM	11,700
Arsenic	<20	<3	11
Beryllium	NM	<3	46
Cadmium	NM	<3	137
Calcium	143	2,900	280,000
Chromium	27	10	845
Cobalt	NM	17	<24
Copper	<10	62	110
Fluoride	NM	6	16,400
Iron	504	4,300	8,300
Lead	<10	6	<24
Magnesium	603	<600	1,400
Manganese	<77	<10	87
Mercury	NM	<0.2	0.4
Nickel	<10	8	63
Phosphorus	<218	750	86,700
Potassium	581	<280	3,800
Selenium	NM	3.8	2.9
Silicon	464,000	923	82,000
Silver	NM	<10	14
Sodium	<371	2,270	3,500
Sulfur	<500	NM	NM
Thorium	<10	197[a]	NR
Vanadium	13	<130	1,200

NOTES: NM not measured
NR not reported
[a] reported as pCi/g

Adapted from: Geddes, R.L., Monsanto [Memo to C. Yates, Golder] March 20, 1992)

TABLE 4-3

OBSERVED AMBIENT TSP CONCENTRATION LEVELS (mg/m^3) FOR SODA SPRINGS, IDAHO

	Soda Springs Hospital (13-0420-021)			Harris Ranch (13-042-026)			2 Miles North of Hooper Springs (13-0420-029)		
	Geometric Mean	24-Hour Maximum	Number of Exceedances[a]	Geometric Mean	24-Hour Maximum	Number of Exceedances[a]	Geometric Mean	24-Hour Maximum	Number of Exceedances[a]
Calendar Year									
1986	0.028	0.091	0	0.032	0.147	0	0.020	0.099	0
1987	0.032(0.036)[b]	0.097(0.102)[b]	0	0.042(0.051)[b]	0.123(0.305)[b]	0(7)[c]	0.025	0.099	0
1988	-[d]	0.115	0	-	0.133	0	-	0.122	0
Snow Free Season									
1986 (May—Oct)	0.042	0.074	0	0.061	0.147	0	0.039	0.099	0
1987 (Apr—Aug)	0.032	0.065(0.102)[b]	0	0.062	0.123(0.305)[b]	0	0.036	0.092	0
1988 (May—Sept)	0.061	0.115	0	-	0.133	0	0.054	0.122	0
Cold Season									
1986 (Jan—Mar)	0.019	0.091	0	0.016	0.098	0	0.012	0.035	0
1986 to 1987 (Oct—Apr)	0.029	0.097	0	0.033	0.097	0	0.014	0.099	0
1987 to 1988 (Oct—May)	0.032	0.077	0	0.031	0.102	0	0.015	0.045	0

[a] Exceedences of primary or secondary standards for each parameter.
[b] Numbers in brackets include concentrations recorded during road work and burning stubble in adjacent fields
[c] Exceedence of secondary standard of 0.150 mg/m^3 in 24 hours.
[d] Not available

TABLE 4-4

OBSERVED TSP CONCENTRATION LEVELS (mg/m^3) FOR CONDA, IDAHO

	Torgeson Residence (16-029-0002)			1.2 Miles East of Highway 34 (16-029-0027)		
	Geometric Mean	24-Hour Maximum	Number of Exceedances[a]	Geometric Mean	24-Hour Maximum	Number of Exceedances[a]
Calendar Year						
1986	0.025	0.143	0	0.048	0.256	10
1987	0.030	0.108	0	0.050	0.404	8
1988	-	0.289	3	-[b]	0.499	14
Snow Free Season						
1986 (May—Oct)	0.037	0.100	0	0.074	0.246	5
1987 (Apr—Aug)	0.045	0.108	0	0.086	0.404	8
1988 (May—Sept)	0.111	0.289	3	0.141	0.499	12
Cold Season						
1986 (Jan—May)	0.020	0.143	0	0.043	0.256	5
1986 to 1987 (Oct—Apr)	0.018	0.050	0	0.023	0.084	0
1987 to 1988 (Oct—May)	0.027	0.115	0	0.047	0.222	2

[a] Exceedences of secondary standard of 0.150 mg/m^3 in 24 hours.
[b] Not available

TABLE 4-5

T-TEST FOR SURFACE WATER

Constituent	Calculated t-Value[a]
Aluminum	1.0687
Calcium	2.1973*
Magnesium	-0.9471
Potassium	-0.6187
Sodium	16.7341*
Bicarbonate	-0.8534
Chloride	8.2000*
Fluoride	2.0000
Nitrate/Nitrite	15.0428*
Sulfate	4.0000*
pH	0.0000
Total Dissolved Solids	2.4650*

[a] Calculated t-value is compared to the tabulated t-value (2.132) based on $\alpha=0.05$ and df=4 (Ott 1977).

* Calculated t-value exceeds tabulated t-value.

TABLE 4-6

PRELIMINARY RISK SCREENING OF ELEVATED CONSTITUENTS IN SURFACE WATER

Elevated Constituent	Maximum Concentration (mg/L)	Non-Carcinogenic Effects		Carcinogenic Effects		1° MCL (mg/L)	2° MCL (mg/L)	MCLG (mg/L)	WQC-HH (mg/L)	WQC-HW (mg/L)	WQC-FWC (mg/L)
		Oral RfD (mg/kg·d)	0.5 RfC (mg/L)	Oral SF (kg·d/mg)	RSC (mg/L)						
chloride	30	-	-	-		-	250	-	-	250	-
nitrate/nitrite as N	1.16	1.6[ac]	30	-		10[b]	-	10[b]	-	-	-
sulfate	42	-	-	-		-	250	-	-	250	-

NOTE:

RfD	Reference dose
RfC	Reference concentration
RSC	Risk-specific concentration at lifetime incremental cancer risk (LICR) = 1E-06
SF	Slope factor
MCL	Maximum contaminant level
MCLG	Maximum contaminant level goals
WQC-HH	Water quality criterion for the protection of human health from potential toxic effects associated with the ingestion of aquatic organisms
WQC-HW	Water quality criterion for the protection of human welfare
WQC-FWC	Water quality criterion for the protection of freshwater aquatic life —chronic
-	No data
a	From IRIS (EPA 1992)
b	Surrogate calculated from proposed arsenic unit risk of 5E-05 μg/L from HEAST (EPA 1991)
c	Value for nitrate only

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TABLE 4-7

ELEVATED CONSTITUENTS IN DOWNSTREAM SODA CREEK SEDIMENTS

Constituent	Units	Control Distribution Characteristics				Maximum Detected Concentrations	Number of Downgradient Samples >UTL
		Mean (n=3)	Standard Deviation	Tolerance Factor[a]	UTL		
aluminum	(mg/kg)	6,477	2,842	7.655	28,233	8,780	0
arsenic	(mg/kg)	6.2	2.12	7.655	22	15	0
beryllium	(mg/kg)	3.2	1.04	7.655	11	4.0	0
cadmium	(mg/kg)	11	2.81	7.655	33	61	1
chromium	(mg/kg)	7.3	2.9	7.655	29	19	0
copper	(mg/kg)	2.7	2.1	7.655	19	22	1
iron	(mg/kg)	109,267	13,115	7.655	209,662	197,000	0
lead	(mg/kg)	5.6	3.3	7.655	31	11	0
manganese	(mg/kg)	815	297	7.655	3,089	1,270	0
nickel	(mg/kg)	55	5.8	7.655	99	153	1
potassium	(mg/kg)	10433	3,371	7.655	36,238	14,200	0
selenium	(mg/kg)	N/A	N/A	N/A	0.6[b]	1.2	3
silver	(mg/kg)	N/A	N/A	N/A	0.1[b]	0.5	3
sodium	(mg/kg)	600	265	7.655	2,629	900	0
vanadium	(mg/kg)	23	6.5	7.655	73	208	3
zinc	(mg/kg)	26	20	7.655	179	170	0
fluoride	(mg/kg)	3.5	1.4	7.655	14	4.9	0
pH-upper limit	(std. unit)	7.4	0.26	9.916	10.0	7.9	0
pH-lower limit	(std. unit)	7.4	0.26	9.916	4.8[c]	7.1[d]	0
potassium-40	(pCi/g)	4.7	1.9	7.655	19	8.3	0
lead-210	(pCi/g)	0.40	0.40	7.655	3.5	1.8	0
polonium-210	(pCi/g)	0.67	0.21	7.655	2.3	3.3	1
radium-226	(pCi/g)	0.60	0.20	7.655	2.1	0.8	0
radium-228	(pCi/g)	0.63	0.35	7.655	3.3	2.3	0
thorium-228	(pCi/g)	0.50	0.10	7.655	1.3	0.6	0
thorium-230	(pCi/g)	0.57	0.21	7.655	2.2	1.4	0
thorium-232	(pCi/g)	0.23	0.06	7.655	0.7	0.4	0
uranium	(pCi/g)	0.17	0.29	7.655	2.4	0.6	0

TABLE 4-7 (Cont.)

ELEVATED CONSTITUENTS IN DOWNSTREAM SODA CREEK SEDIMENTS

NOTES: Shaded areas indicate elevated constituents

N/A Not applicable - no detectable concentrations in control samples

UTL Upper tolerance limit

[a] One-sided tolerance factor for the 95th percentile (α = 0.05) is 7.655, and two-sided upper and lower tolerance factors for the 2.5th to 97.5th percentiles (α = 0.05) for pH is 9.916 (Natrella 1963)

[b] Surrogate UTL = highest reported SQL

[c] Lower tolerance limit

[d] Minimum detected value

TABLE 4-8

ELEVATED CONSTITUENTS IN A GROUP (0 TO 1 IN) SOILS

Constituent	Units	Control Distribution Characteristics				Maximum Detected	Number of Samples
		Mean (n=3)	Standard Deviation	Tolerance Factor[a]	UTL		
aluminum	(mg/kg)	16,200	265	7.655	18,229	30,200	10
arsenic	(mg/kg)	5.3	0.58	7.655	10	34	5
beryllium	(mg/kg)	0.7	0.29	7.655	2.9	4.0	8
cadmium	(mg/kg)	6.7	2.58	7.655	26	168	10
chromium	(mg/kg)	15	1.53	7.655	27	325	14
copper	(mg/kg)	17	1	7.655	25	42	7
iron	(mg/kg)	17,000	1,916	7.655	31,667	24,100	0
lead	(mg/kg)	28	9.45	7.655	100	68	0
manganese	(mg/kg)	540	56	7.655	969	1,380	1
nickel	(mg/kg)	38	7.23	7.655	93	87	0
potassium	(mg/kg)	4,933	833	7.655	11,310	8,000	0
selenium	(mg/kg)	0.5	0.29	7.655	2.7	3.2	1
silver	(mg/kg)	0.3	0.06	7.655	0.8	13	14
sodium	(mg/kg)	383	235	7.655	2,182	2,280	2
vanadium	(mg/kg)	33	7.9	7.655	93	467	10
zinc	(mg/kg)	93	26.2	7.655	294	2,670	10
fluoride	(mg/kg)	19	23.6	7.655	200	103	0
nitrate/nitrite as N	(mg/kg)	5.7	6.4	7.655	55	47	0
pH-upper limit	(std.units)	7.6	0.12	9.916	8.8	7.8	0
pH-lower limit	(std.units)	7.6	0.12	9.916	6.4[b]	6.5[c]	0
potassium-40	(pCi/g)	17	3.1	7.655	41	20	0
lead-210	(pCi/g)	2.6	0.51	7.655	6.5	65	12
polonium-210	(pCi/g)	2.9	0.90	7.655	10	77	7
radium-226	(pCi/g)	1.1	0.25	7.655	3.0	17	12
radium-228	(pCi/g)	1.3	0.17	7.655	2.6	1.4	0
thorium-228	(pCi/g)	1.3	0.36	7.655	4.1	1.6	0
thorium-230	(pCi/g)	1.2	0.38	7.655	4.1	18	8
thorium-232	(pCi/g)	1.2	0.44	7.655	4.6	1.7	0
uranium	(pCi/g)	1.1	0.25	7.655	3.0	16	11

TABLE 4-8 (Cont.)

ELEVATED CONSTITUENTS IN A GROUP (0 TO 1 IN) SOILS

NOTES: Shaded areas indicate elevated constituents

UTL Upper tolerance limit

[a] Once-sided tolerance factor for the 95th percentile (α = 0.05) is 7.655, and two-sided upper and lower tolerance factors for the 2.5th to 97.5th percentiles (α = 0.05) for pH is 9.916 (Natrella 1963)

[b] Lower tolerance limit

[c] Minimum detected value

TABLE 4-9

ELEVATED CONSTITUENTS IN B GROUP (0 TO 6 IN) SOILS

Constituent	Units	Control Distribution Characteristics				Maximum Detected Concentration	Number of Samples >UTL
		Mean (n=3)	Standard Deviation	Tolerance Factor[a]	UTL		
aluminum	(mg/kg)	16,350	853	7.655	22,880	45,100	17
arsenic	(mg/kg)	4.7	0.58	7.655	9.1	10	3
beryllium	(mg/kg)	1.2	0.29	7.655	3.4	3.5	1
cadmium	(mg/kg)	5.6	0.75	7.655	11	67	14
chromium	(mg/kg)	15	1	7.655	23	130	18
copper	(mg/kg)	16	0.87	7.655	22	30	2
iron	(mg/kg)	17,850	4095	7.655	49,197	55,500	1
lead	(mg/kg)	30	19.97	7.655	183	81	0
manganese	(mg/kg)	539	38.5	7.655	834	3,440	2
nickel	(mg/kg)	45	7.97	7.655	106	53	0
potassium	(mg/kg)	4,583	653	7.655	9,582	9,500	0
selenium	(mg/kg)	N/A	N/A	N/A	0.3[b]	2.8	17
silver	(mg/kg)	N/A	N/A	N/A	0.2[b]	8.5	21
sodium	(mg/kg)	511	324	7.655	2,991	972	0
vanadium	(mg/kg)	34	7	7.655	88	200	9
zinc	(mg/kg)	72	3.4	7.655	98	2,290	14
fluoride	(mg/kg)	30	31.9	7.655	274	85	0
nitrate/nitrite as N	(mg/kg)	9.4	2.7	7.655	30	22	0
pH-upper limit	(std.units)	7.9	0.32	9.916	11	8.0	0
pH-lower limit	(std.units)	7.9	0.32	9.916	4.7[c]	6.9[d]	0
potassium-40	(pCi/g)	18	2.3	7.655	35	19	0
lead-210	(pCi/g)	1.6	0.40	7.655	4.7	32	10
polonium-210	(pCi/g)	1.8	0.40	7.655	4.9	34	10
radium-226	(pCi/g)	1.2	0.18	7.655	2.5	6.2	12
radium-228	(pCi/g)	1.3	0.21	7.655	2.9	1.5	0
thorium-228	(pCi/g)	1.2	0.26	7.655	3.2	2.3	0
thorium-230	(pCi/g)	1.2	0.30	7.655	3.5	18	7
thorium-232	(pCi/g)	1.3	0.31	7.655	3.6	4.6	1
uranium	(pCi/g)	0.7	0.61	7.655	5.4	6.4	1

TABLE 4-9 (Cont.)

ELEVATED CONSTITUENTS IN B GROUP (0 TO 6 IN) SOILS

NOTES: Shaded areas indicate elevated constituents

N/A Not applicable - no detectable concentrations in control samples

UTL Upper tolerance limit

[a] One-sided tolerance factor for the 95th percentile ($\alpha = 0.05$) is 7.655, and two-sided upper and lower tolerance factors for the 2.5th to 97.5th percentiles ($\alpha = 0.05$) for pH is 9.916 (Natrella 1963)

[b] Surrogate UTL = highest reported SQL

[c] Lower tolerance limit

[d] Minimum detected value

TABLE 4-10

PRELIMINARY RISK SCREENING OF ELEVATED CONSTITUENTS IN A GROUP (0 TO 1 IN) SOILS

Elevated Constituent	Maximum Concentration	Non-Carcinogenic Effects				Carcinogenic Effects				Soil Cleanup Standards (mg/kg)
		Soil Ingestion		Soil Inhalation		Soil Ingestion		Soil Inhalation		
		Oral RfD (mg/kg·d)	0.5 RfC (mg/kg)	Inh RfD (mg/kg·d)	0.5 RfC mg/kg)	Oral SF (kg·d/mg)	RSC (mg/kg)	Inh SF (mg/kg·d)	RSC (mg/kg)	
arsenic	34	0.0003[a]	40.5	-	-	1.75[d]	0.04	50[a]	13.62	-
beryllium	4	0.005[a]	675	-	-	4.3[a]	0.01	8.4[a]	81.07	-
cadmium	168	0.0005[c]	67.5	-	-	-	-	6.3[a]	108.10	-
chromium	325	1[b]	13,5000	-	-	-	-	-	-	-
copper	42	0.04[c]	5,400	-	-	-	-	-	-	-
manganese	1,380	0.1[a]	13,500	0.0001[a]	2,900	-	-	-	-	-
selenium	3.2	0.005[a]	675	-	-	-	-	-	-	-
silver	13	0.005[a]	675	-	-	-	-	-	-	-
vanadium	467	0.007[b]	945	-	-	-	-	-	-	-
zinc	2670	0.2[b]	27,000	-	-	-	-	-	-	-

NOTE: Shaded areas indicate screening criterion exceeded
RfD Reference dose
RfC Reference concentration
SF Slope factor
RSC Risk-specific concentration at lifetime incremental cancer risk (LICR) = 1E-06
\- No data
[a] From IRIS (EPA 1992)
[b] From HEAST (EPA 1991)
[c] Per communication with EPA-10
[d] Surrogate calculated from proposed arsenic unit risk of 5E-05 μg/L from HEAST (EPA 1991)

TABLE 4-11

PRELIMINARY RISK SCREENING OF ELEVATED CONSTITUENTS B GROUP (0 to 6 IN) SOILS

Elevated Constituent	Maximum Concentration (mg/kg)	Non-Carcinogenic Effects				Carcinogenic Effects				Soil Cleanup Standards (mg/kg)
		Soil Ingestion		Soil Inhalation		Soil Ingestion		Soil Inhalation		
		Oral RfD (mg/kg·d)	0.5 RfC (mg/kg)	Inh RfD (mg/kg·d)	0.5 RfC (mg/kg)	Oral SF (kg·d/mg)	RSC (mg/kg)	Inh SF (mg/kg·d)	RSC (mg/kg)	
arsenic	10	0.0003[a]	40.5	-	-	1.75[d]	0.04	50[a]	13.62	-
beryllium	3.5	0.005[a]	675	-	-	4.3[a]	0.01	8.4[a]	81.07	-
cadmium	67.3	0.0005[a]	67.5	-	-	-	-	6.3[a]	108.10	-
chromium	130	1[b]	135,000	-	-	-	-	-	-	-
copper	30	0.04[c]	5,400	-	-	-	-	-	-	-
iron	55,500	-	-	-	-	-	-	-	-	-
manganese	3,440	0.1[a]	13,500	0.0001[a]	2,900	-	-	-	-	-
selenium	2.81	0.005[a]	675	-	-	-	-	-	-	-
silver	8.5	0.005[a]	675	-	-	-	-	-	-	-
vanadium	200	0.007[b]	945	-	-	-	-	-	-	-
zinc	2,290	0.2[b]	27,000	-	-	-	-	-	-	-

NOTE: Shaded areas indicate screening criterion exceeded
RfD Reference dose
RfC Reference concentration
SF Slope factor
RSC Risk-specific concentration at lifetime incremental cancer risk (LICR) = 1E-06
\- No data
[a] From IRIS (EPA 1992)
[b] From HEAST (EPA 1991)
[c] Per communication with EPA-10
[d] Surrogate calculated from proposed arsenic unit risk of 5E-05 μg/L from HEAST (EPA 1991)

TABLE 4-12

PRELIMINARY RISK SCREENING OF ELEVATED RADIOLOGICAL CONSTITUENTS IN SOILS

A GROUP (0 TO 1 IN)

Radiological Constituent	Units	Maximum Concentration	Slope Factors			Inhalation Fugitive Dust RSC (PCi/g)	Ingestion Soil RSC (pCi/g)	External Exposure RSC (pCi/g)
			Inhalation (1/pCi)	Ingestion (1/pCi)	External (g/pCi·yr)			
lead-210	(pCi/g)	65	4.0E-09	6.6E-10	1.6E-10	95	1.2	220
polonium-210	(pCi/g)	77	2.6E-09	1.5E-10	2.9E-11	150	5.3	1200
radium-226	(pCi/g)	17	3.0E-09	1.2E-10	6.0E-06	130	6.6	0.0058
thorium-230	(pCi/g)	18	2.9E-08	1.3E-11	5.4E-11	13	61	640
uranium	(pCi/g)	16	5.2E-08	2.8E-11	3.6E-08	7.3	28	0.97

B GROUP (0 TO 6 IN)

Radiological Constituent	Units	Maximum Concentration	Slope Factors			Inhalation Fugitive Dust RSC (PCi/g)	Ingestion Soil RSC (pCi/g)	External Exposure RSC (pCi/g)
			Inhalation (1/pCi)	Ingestion (1/pCi)	External (g/pCi·yr)			
lead-210	(pCi/g)	32	4.0E-09	6.6E-10	1.6E-10	95	1.2	220.00
polonium-210	(pCi/g)	34	2.6E-09	1.5E-10	2.9E-11	150	5.3	1200.00
radium-226	(pCi/g)	6.2	3.0E-09	1.2E-10	6.0E-06	130	6.6	0.0058
thorium-230	(pCi/g)	18	2.9E-08	1.3E-11	5.4E-11	13	61	640
thorium-232	(pCi/g)	4.6	2.8E-08	1.2E-11	2.6E-11	14	6.6	1300
uranium	(pCi/g)	6.4	5.2E-08	2.8E-11	3.6E-08	7.3	28	0.97

NOTE: Shaded areas indicate screening criterion exceeded
RSC Risk-specific concentration at lifetime incremental cancer risk (LICR) = 1E-06
Slope factors from HEAST (EPA 1991)

CONTROL POINT LOCATIONS AND BREAKDOWN
OF WELLS AND SPRINGS BY FLOW SYSTEM

	Flow System			
	Fresh Water			Sodic Water
	Shallow Groundwater System (UBZ-3,4)		Mead Thrust Aquifer System (UBZ-3,5; LBZ-3)	Chesterfield Range Aquifer System (UBZ-1; LBZ-1,2,4)
Control Well Locations	TW-02 TW-13 TW-15 TW-48 PW-04		KM-08[1] KM-09[1] KM-13[1]	TW-28 TW-29
Control Spring Locations				Doc Kackley Hooper
Well Locations	PW-01 PW-02 PW-03 TW-02 TW-13 TW-15 TW-16 TW-20 TW-22 TW-26 TW-30	TW-36 TW-37 TW-39 TW-40 TW-41 TW-42 TW-43 TW-48 TW-49 TW-50 Lewis Harris	TW-11 TW-12 TW-32 TW-33 TW-38	TW-09 TW-10 TW-18 TW-21 TW-23 TW-28 TW-29 TW-34 TW-35 TW-44 TW-45
Spring Locations	Calf Homestead Mormon Mormon B Mormon C		Boyscout Finch Formation A Formation B Formation C Kelly Ledger A Ledger B Ledger C Spring Box	Doc Kackley Hooper Southwest

Note: See Table 3-6 for definition of fresh and sodic water quality
[1] Kerr-McGee wells —located along the western boundary of the Kerr-McGee Plant.

TABLE 4-14

ELEVATED CONSTITUENTS IN THE FRESH (SHALLOW) GROUNDWATER FLOW SYSTEM

Constituent	Units	Control Distribution Characteristics				Maximum Detected Concentration	Number of Down-gradient Samples >UTL
		Mean (n=5)	Standard Deviation	Tolerance Factor[a]	UTL		
aluminum	(mg/L)	NA	NA	NA	0.23[b]	ND	0
arsenic	(mg/L)	NA	NA	NA	0.002[b]	0.02	8
beryllium	(mg/L)	NA	NA	NA	0.001[b]	ND	0
cadmium	(mg/L)	NA	NA	NA	0.005[b]	8	14
calcium	(mg/L)	114	5.02	4.202	135	372	9
chromium	(mg/L)	0.006	0.002	4.202	0.02	0.01	0
copper	(mg/L)	NA	NA	NA	0.021[b]	ND	0
iron	(mg/L)	NA	NA	NA	0.36[b]	ND	0
lead	(mg/L)	NA	NA	NA	0.001[b]	ND	0
magnesium	(mg/L)	52.9	6.2	4.202	79	184	15
manganese	(mg/L)	NA	NA	NA	0.016[b]	1.33	8
nickel	(mg/L)	NA	NA	NA	0.02[b]	0.14	12
potassium	(mg/L)	4.6	0.9	4.202	8.3	124	19
selenium	(mg/L)	NA	NA	NA	0.003[b]	0.289	12
silver	(mg/L)	NA	NA	NA	0.01[b]	ND	0
sodium	(mg/L)	11.4	4.1	4.202	28.7	275	20
vanadium	(mg/L)	NA	NA	NA	0.04[b]	ND	0
zinc	(mg/L)	0.29	0.62	4.202	2.91	14.1	3
specific conductance	(µmhos/cm²)	866	101.7	4.202	1294	3940	17
total dissolved solids	(mg/L)	517	87.7	4.202	885	2668	13
ammonium as N	(mg/L)	NA	NA	NA	0.31[b]	3.9	2
bicarbonate	(mg/L)	476	31.6	4.202	609	724	4
chloride	(mg/L)	16	2.4	4.202	26	679	21
fluoride	(mg/L)	0.23	0.02	4.202	0.29	19.93	23
nitrate/nitrite as N	(mg/L)	2.95	1.19	4.202	7.93	35.2	6
sulfate	(mg/L)	60	24.5	4.202	163	700	12
phosphorus	(mg/L)	NA	NA	NA	0.17[b]	3.72	11
BOD	(mg/L)	10[d]	NA	NA	100[e]	8	0
COD	(mg/L)	10[d]	NA	NA	100[e]	18	0
TPH	(mg/L)	NA	NA	NA	10[b]	ND	0
field pH -upper	(std units)	7.1	0.2	5.079	7.9	7.4	0
field pH -lower	(std units)	7.1	0.2	5.079	6.3[e]	6.4[f]	0
gross alpha	(pCi/L)	NA	NA	NA	8[b]	ND	0

TABLE 4-14 (Cont.)

ELEVATED CONSTITUENTS IN THE FRESH (SHALLOW) GROUNDWATER FLOW SYSTEM

Constituent	Units	Control Distribution Characteristics				Maximum Detected Concentration	Number of Down-gradient Samples >UTL
		Mean (n=5)	Standard Deviation	Tolerance Factor[a]	UTL		
radium-226	(pCi/L)	NA	NA	NA	0.1[b]	1.3	3
radium-228	(pCi/L)	NA	NA	NA	0.6[b]	ND	0
radon-222	(pCi/L)	276	180	4.202	1034	680	0
uranium	(mg/L)	NA	NA	NA	0.002[b]	ND	0

NOTE: Shaded areas indicate elevated constituents
NA Not applicable —no detectable concentrations in control samples
ND Parameter not detected in this flow system
UTL Upper tolerance limit
[a] One-sided tolerance factor for the 95th percentile (α=0.05); two-sided upper and lower tolerance factors for the 2.5th and 97.5th (α = 0.05) percentile for pH (from EPA 1989)
[b] Surrogate UTL = highest reported SQL
[c] Surrogate UTL = [(Mean) (10)]
[d] n=1
[e] Lower tolerance limit
[f] Minimum detected value

TABLE 4-15

ELEVATED CONSTITUENTS IN THE SODIC (CHESTERFIELD RANGE AQUIFER) GROUNDWATER FLOW SYSTEM

Constituent	Units	Control Distribution Characteristics				Maximum Detected Concentration	Tot Numb of Samp >U
		Mean (n=4)	Standard Deviation	Tolerance Factor[a]	UTL		
aluminum	(mg/L)	NA	NA	NA	0.18[b]	ND	0
arsenic	(mg/L)	0.0013	0.0005	5.145	0.004	0.004	0
beryllium	(mg/L)	NA	NA	NA	0.001[b]	ND	0
cadmium	(mg/L)	NA	NA	NA	0.005[b]	0.03	2
calcium	(mg/L)	143	40.6	5.145	352	158	0
chromium	(mg/L)	NA	NA	NA	0.01[b]	ND	0
copper	(mg/L)	NA	NA	NA	0.005[b]	ND	0
iron	(mg/L)	3.6	4.2	5.145	25.3	16.8	0
lead	(mg/L)	NA	NA	NA	0.001[b]	ND	0
magnesium	(mg/L)	113	28.8	5.145	262	275	2
manganese	(mg/L)	0.15	0.16	5.145	0.98	0.64	0
nickel	(mg/L)	NA	NA	NA	0.02[b]	0.04	7
potassium	(mg/L)	11	4.5	5.145	34	28.2	0
selenium	(mg/L)	NA	NA	NA	0.003[b]	0.009	1
silver	(mg/L)	NA	NA	NA	0.01[b]	ND	0
sodium	(mg/L)	30	6.1	5.145	61	100	1
vanadium	(mg/L)	NA	NA	NA	0.02[b]	ND	0
zinc	(mg/L)	NA	NA	NA	0.009[b]	0.13	1
specific conductance	(μmhos/cm^2)	1413	259.7	5.145	2749	2170	0
total dissolved solids	(mg/L)	816.75	126.3	5.15	1467	1240	0
ammonium as N	(mg/L)	NA	NA	NA	0.6[b]	ND	0
bicarbonate	(mg/L)	797.25	278.1	5.15	2274	1452	0
chloride	(mg/L)	19	3.9	5.145	40	145	4
fluoride	(mg/L)	0.29	0.13	5.145	0.96	1.8	4
nitrate/nitrite as N	(mg/L)	1.53	1.89	5.145	11.3	4.4	0
sulfate	(mg/L)	65	26.1	5.145	199	270	1
phosphorus	(mg/L)	NA	NA	NA	0.37[b]	1.46	2
BOD	(mg/L)	10[f]	NR	NR	100[e]	10	0
COD	(mg/L)	10[f]	NR	NR	100[e]	16	0
TPH	(mg/L)	NR	NR	NR	NR	NR	NR
field pH -upper	(std units)	6.7	0.23	6.37	8.2	7.4	0
field pH -lower	(std units)	6.7	0.23	6.37	5.2[d]	6.2[e]	0

TABLE 4-15 (Cont.)

ELEVATED CONSTITUENTS IN THE SODIC (CHESTERFIELD RANGE AQUIFER) GROUNDWATER FLOW SYSTEM

Constituent	Units	Control Distribution Characteristics				Maximum Detected Concentration	Tot Numb of Samp >U
		Mean (n=4)	Standard Deviation	Tolerance Factor[a]	UTL		
gross alpha	(pCi/L)	NA	NA	NA	8[b]	ND	0
radium-226	(pCi/L)	NA	NA	NA	0[b]	ND	0
radium-228	(pCi/L)	NA	NA	NA	0.3[b]	ND	0
radon-222	(pCi/L)	165.63	162.3	5.145	1001	540	0
uranium	(mg/L)	NA	NA	NA	0.002[b]	ND	0

NOTE: Shaded areas indicate elevated constituents
NA Not applicable — no detectable concentrations in control samples
ND Parameter not detected in this flow system
NR No result
UTL Upper tolerance limit
[a] One-sided tolerance factor for the 95th percentile (α=0.05); two-sided upper and low tolerance factors for the 2.5th and 97.5th (α = 0.05) percentile for pH (from EPA 198
[b] Surrogate UTL = highest reported SQL
[c] Surrogate UTL = [(Mean) (10)]
[d] Lower tolerance limit
[e] Minimum detected value
[f] n=1

TABLE 4-16

PRELIMINARY RISK SCREENING OF ELEVATED CONSTITUENTS IN FRESH (SHALLOW) GROUNDWATER

Elevated Constituent	Maximum Concentration (mg/L)	Non-Carcinogenic Effects		Carcinogenic Effects		1° MCL (mg/L)	2° MCL (mg/L)	MCLG (mg/L)	WQC-HH (mg/L)	WQC-HW (mg/L)	WQC-FWC (mg/L)
		Oral RfD (mg/kg·d)	0.5 RfC(mg/L)	Oral SF (kg·d/mg)	RSC (mg/L)						
arsenic	0.02	0.0003[a]	0.006	1.75[d]	0.00005	0.05	-	0.05	0.00002	-	0.19
cadmium	8	0.0005[a]	0.009	-	-	0.005	-	0.005	0.01[g]	-	0.0042[h]
manganese	1.33	0.1[a]	1.9	-	-	-	0.05	-	-	0.05	-
nickel	0.14	0.02[a]	0.4	-	-	-	-	-	0.1	-	1.2e
selenium	0.289	0.005[a]	0.09	-	-	0.05	-	0.05	0.01	-	0.05
zinc	14.1	0.2[b]	4	-	-	-	5	-	-	5	0.44[h]
total dissolved solids	2668	-	-	-	-	-	500	-	-	-	-
ammonium as N	3.9	4e+04[i]	7.4E+05	-	-	-	-	-	-	-	2.0[i]
chloride	679	-	-	-	-	-	250	-	-	250	-
fluoride	19.93	0.06[a]	1.1	-	-	-	2	4	-	-	-
nitrate/nitrite as N	35.2	1.6[aa]	29.6	-	-	10[c]	-	10[c]	-	-	-
sulfate	700	-	-	-	-	-	250	-	-	250	-
phosphorus	3.72	0.00002[a]	0.0004	-	-	-	-	-	-	-	0.0001
radium-226	3.4[k]	-	-	1.2E-10[e]	0.4[l]	-	-	-	-	-	-

Golder Associates

TABLE 4-16 (Cont.)

PRELIMINARY RISK SCREENING OF ELEVATED CONSTITUENTS IN FRESH (SHALLOW) GROUNDWATER

NOTE:	Shaded areas indicate screening criterion exceeded
RfD	Reference dose
RfC	Reference concentration
RSC	Risk-specific concentration at lifetime incremental cancer risk (LICR) = 1E-06
SF	Slope Factor
MCL	Maximum contaminant level
MCLG	Maximum contaminant level goals
WQC-HH	Water quality criterion for the protection of human health from potential toxic effects associated with the ingestion of aquatic organisms
WQC-HW	Water quality criterion for the protection of human welfare
WQC-FWC	Water quality criterion for the protection of freshwater aquatic life — chronic
-	No data
a	From IRIS (EPA 1992)
b	From HEAST (EPA 1991)
c	Value for nitrate only
d	Surrogate calculated from proposed arsenic unit risk of 5E-05 µg/L from HEAST (EPA 1991)
e	Units in (1/pCi)
f	Units in pCi/L
g	Value represents the former MCL
h	Hardness-dependent criterion- assumes an average hardness of 530.9 mg/L for Soda Creek downstream of effluent discharge
i	Based on the RfD for free ammonia (34 mg/kg·d; EPA 1991). Ratio of ammonium as N to ammonia (1,200) is based on a groundwater temperature of 12°C and pH of 6.5 at the location of maximum ammonium concentration.
j	Temperature- and pH-dependent criteria- assumes temperature=7°C, pH=7.2 for Soda Creek downstream of effluent discharge

TABLE 4-17

PRELIMINARY RISK SCREENING OF ELEVATED CONSTITUENTS IN SODIC (CHESTERFIELD RANGE AQUIFER) GROUNDWATER

Elevated Constituent	Maximum Concentration (mg/L)	Non-Carcinogenic Effects		Carcinogenic Effects		1° MCL (mg/L)	2° MCL (mg/L)	MCLG (mg/L)	WQC-HH (mg/L)	WQC-HW (mg/L)	WQC-FWC (mg/L)
		Oral RfD (mg/kg·d)	0.5 RfC (mg/L)	Oral SF (kg·d/mg)	RSC (mg/L)						
cadmium	0.03	0.0005[a]	0.009	-	-	0.005	-	0.005	0.01[c]	-	0.0042[d]
nickel	0.04	0.02[a]	0.4	-	-	0.1	-	0.1	0.1	-	1.2[d]
selenium	0.009	0.005[a]	0.09	-	-	0.05	-	0.05	0.01	-	0.005
zinc	0.13	0.2[b]	4	-	-	-	5	-	-	5	0.44[d]
chloride	145	-	-	-	-	-	250	-	-	250	-
fluoride	1.8	0.06[a]	1.1	-	-	-	2	4	-	-	-
sulfate	270	-	-	-	-	-	250	-	-	250	-
phosphorus	1.46	0.00002[a]	0.0004	-	-	-	-	-	-	-	0.0001

NOTE: Shaded areas indicate screening criterion exceeded
RfD Reference dose
RfC Reference concentration
RSC Risk-specific concentration at lifetime incremental cancer risk (LICR) = 1E-06
SF Slope factor
MCL Maximum contaminant level
MCLG Maximum contaminant level goals
WQC-HH Water quality criterion for the protection of human health from potential toxic effects associated with the ingestion of aquatic organisms
WQC-HW Water quality criterion for the protection of human welfare
WQC-FWC Water quality criterion for the protection of freshwater aquatic life —chronic
\- No data
[a] From IRIS (EPA 1992)
[b] Surrogate calculated from proposed arsenic unit risk of 5E-05 μg/L from HEAST (EPA 1991)
[c] Value represents the former MCL
[d] Hardness-dependent criterion - assumes an average hardness of 530.9 mg/L for Soda Creek downstream of effluent discharge

TABLE 4-18

CHEMICAL ANALYTICAL RESULTS FOR SELECTED KERR-MCGEE WELLS

WELL	Constituent			
	Manganese (mg/L)	Vanadium (mg/L)	Chloride (mg/L)	Sulfate (mg/L)
KM-8	6.47	24.5	8,170	19,000
KM-9	0.182	3.59	213	441
KM-13	0.131	6.42	656	1,580

From: Kerr-McGee Preliminary Chemical Analysis Data 1992.

TABLE 4-19

SUMMARY OF CONSTITUENTS OF POTENTIAL INTEREST AT THE MONSANTO PLANT

Constituent	Environmental Medium						
	Surface Water	Downstream Sediments[1]		Soils		Groundwater	
		100 ft	300 ft	Surface (0-1 in)	Subsurface (0-6 in)	Fresh	Sodic
Arsenic	-	-	-	X	X	X	-
Beryllium	-	-	-	X	X	-	-
Cadmium	-	X	-	X	-	X	X
Copper	-	X	-	-	-	-	-
Manganese	-	-	-	-	X	-	-
Nickel	-	X	-	-	-	X	-
Selenium	-	X	X	-	-	X	X
Silver	-	X	X	-	-	-	-
Vanadium	-	X	X	-	-	-	-
Zinc	-	-	-	-	-	X	X
Ammonium as N	-	-	-	-	-	X	-
Fluoride	-	-	-	-	-	X	X
Nitrite/Nitrate as N	-	-	-	-	-	X	-
Lead-210	-	-	-	X	X	-	-
Polonium-210	-	X	-	X	X	-	-
Radium-226	-	-	-	X	X	X	-
Thorium-230	-	-	-	X	X	-	-
Uranium	-	-	-	X	X	-	-

X Constituent of potential interest in this medium

[1] Constituents identified for this medium are regarded, at this time, as elevated constituents in the aquatic sediment medium.

TABLE 5-1

HOURLY EMISSION RATES FROM PERMITTED SOURCES

SOURCES	EMMISIONS (lb/hour)			
	PM_{10}	TSP	Cadmium	Fluoride
Taphole Fume				
Collector - #7	2.94	3.00	4.50E-04	0.70
- #8	1.26	1.29	1.90E-04	0.67
- #9	1.32	1.35	2.00E-04	0.63
Kiln Cooler Spray Tower	3.60	6.88	3.29E-03	0.23
Kiln Venturi Scrubbers - A				
- B	2.75	3.54	2.27E-01	0.208
- C	2.04	2.62	1.68E-01	0.154
- D	2.01	2.59	1.66E-01	0.143
	2.44	3.14	2.01E-01	0.185
Nodule Crushing /Screening Scrubber	0.59	9.71	3.50E-03	-

PM_{10} - Inhalable particulate
TSP - Total suspended particulate

TABLE 5-2

HOURLY EMISSION RATES FROM BAGHOUSES

SOURCES	EMISSIONS (lb/hour)			
	PM_{10}	TSP	Cadmium	Fluoride
Coke/Quartz Dryer	0.26	0.27	3.10E-07	6.10E-07
Stocking System	0.25	0.31	2.20E-06	2.10E-03
Coke/Quartz Satellite	0.24	0.30	3.40E-07	6.80E-07
Ore Satellite	0.54	0.67	6.70E-05	1.10E-02
Coke Handling	0.24	0.30	3.40E-07	6.80E-07
Scaleroom	0.64	0.81	5.70E-06	5.50E-03
TOTAL EMISSIONS	2.17	2.66	7.59E-05	0.019

TABLE 5-3

HOURLY FUGITIVE EMISSION RATES
FROM SLAG DUMPING AND FURNACE BUILDINGS

SOURCE	EMISSIONS (lb/hour)			
	TSP	PM_{10}	Cadmium	Fluoride
Slag Dumping	2.9	1.5	5.79E-6	0.72
Furnace Building	2.2	0.53	2.1E-3	0.11

TABLE 5-4

HOURLY FUGITIVE EMISSION RATES FROM ROADS

SOURCE	EMISSIONS (lb/hour)	
	TSP	PM_{10}
Ore Haul Road Out	1.12	0.60
Ore Haul Road In	0.07	0.20
Quartzite Haul Road	1.22	0.66
Slag Haul Road	1.92	1.04
Ferrophos Haul Road	0.04	0.02
Second West	0.05	0.03
Contractor Road (W)	0.03	0.02
Service Road (E)	0.91	0.49
Service Road (W)	0.76	0.41
Phos Avenue	0.01	0.005
Durret Avenue	0.01	0.003
South Street	0.02	0.001
Contractor Road (E)	0.01	0.003
Delivery & Employees	0.07	0.04
TOTAL EMISSIONS	6.24	3.52

TABLE 5-5

HOURLY FUGITIVE EMISSION RATES FROM STOCKPILE
WIND EROSION AND MATERIAL HANDLING OPERATIONS

NO.	SOURCE	EMISSIONS (lb/hour)			
		TSP	PM_{10}	Cadmium	Fluoride
1	Ore	8.06	3.79	0.0008	0.135
2	Coal/Coke	0.16	0.07	4.7E-7	9.7E-7
3	Quartzite Stockpile	0.36	0.17	-	-
4	Nodules/SDM	0.40	0.19	2.1E-6	0.003
5	Nods Reclaim Area	5.20	2.45	2.6E-5	0.037
6	UFS/BFS	1.44	0.68	0.0016	0.019
7	Treater Dust	0.12	0.05	1.8E-5	0.006
8	Vactor Dust	0.34	0.16	0.0001	0.017
9	Slag[1]	4.31	2.03	8.6E-6	0.018
10	Slag Dumping[2]	1.60	0.75	3.2E-6	0.007
11	Baghouse Dust	0.29	0.14	2.1E-6	0.002
TOTAL EMISSIONS		22.28	10.4	0.0026	0.244

[1] - Wind erosion
[2] - Active dumping area maintenance
- No data

TABLE 5-6

ESTIMATED TOTAL ANNUAL EMISSIONS FROM PERMITTED SOURCES

SOURCES	EMMISIONS (tons/year)			
	PM_{10}	TSP	Cadmium	Flouride
Taphole Fume				
Collector - #7	12.3	12.5	0.0019	2.9
- #8	5.0	5.2	0.0008	2.7
- #9	4.9	5.0	0.0007	2.4
Kiln Cooler Spray Tower	13.8	26.3	0.0126	0.9
Kiln Venturi Scrubbers - A	10.5	13.5	0.9	0.8
- B	7.8	10.0	0.6	0.6
- C	7.7	9.9	0.6	0.5
- D	9.3	12.0	0.8	0.8
Nodule Crushing/Screening Scrubber	2.26	37.1	0.0134	-
TOTAL EMISSIONS	73.6	131.5	2.9	11.6

PM_{10} - Inhalable particulate
TSP - Total suspended particulate

TABLE 5-7

ESTIMATED TOTAL ANNUAL EMISSIONS FROM BAGHOUSES

SOURCES	EMISSIONS (tons/year)			
	PM_{10}	TSP	Cadmium	Fluoride
Coke/Quartz Dryer	0.3	0.3	4.0E-7	7.9E-7
Stocking System	1.1	1.4	9.6E-6	0.008
Coke/Quartz Satellite	0.7	0.9	9.9E-7	2.0E-6
Ore Satellite	1.6	2.0	2.0E-4	0.0320
Coke Handling	0.7	0.9	9.9E-7	2.0E-6
Scaleroom	1.9	2.4	1.7E-5	0.016
TOTAL EMISSIONS	6.3	7.9	0.0002	0.056

TABLE 5-8

ESTIMATED TOTAL ANNUAL FUGITIVE EMISSIONS
FROM SLAG DUMPING AND FURNACE BUILDINGS

SOURCE	EMISSIONS (tons/year)			
	TSP	PM_{10}	Cadmium	Flouride
Slag Dumping	11.5	6.0	$2.3X10^{-5}$	2.9
Furnace Building	8.7	2.1	0.008	0.4

TABLE 5-9

ESTIMATED TOTAL ANNUAL FUGITIVE EMISSIONS FROM ROADS

SOURCE	EMISSIONS (ton/year)	
	TSP	PM_{10}
Ore Haul Road Out	1.2	0.7
Ore Haul Road In	0.4	0.2
Quartzite Haul Road	5.3	2.9
Slag Haul Road	8.5	4.5
Ferrophos Haul Road	0.2	0.09
Second West	0.2	0.1
Contractor Road (W)	0.1	0.07
Service Road (E)	4.0	2.2
Service Road (W)	3.3	1.8
Phos Avenue	0.04	0.02
Durret Avenue	0.03	0.01
South Street	0.08	0.01
Contractor Road (E)	0.03	0.02
Delivery & Employees	0.3	0.2
TOTAL EMISSIONS	23.6	12.8

TABLE 5-10

ESTIMATED TOTAL ANNUAL FUGITIVE
EMISSIONS[1] FROM MATERIAL HANDLING OPERATIONS

NO.	SOURCE	EMISSIONS (tons/year)			
		TSP	PM_{10}	Cadmium	Fluoride
1	Ore	11.7	5.5	0.0012	0.1919
2	Coal/Coke	0.7	0.3	2.1E-6	3.6E-10
3	Quartzite Stockpile	1.6	0.7	-	-
4	Nodules/SDM	1.7	0.8	9.0E-6	7.6E-7
5	Nods Reclaim Area	22.2	10.7	0.0001	0.0002
6	UFS/BFS	6.4	3.0	0.0071	7.8E-7
7	Treater Dust	0.5	0.2	0.0001	0.0244
8	Vactor Dust	1.6	0.7	0.0002	0.0732
9	Slag	19.2	8.9	3.8E-5	0.0787
10	Slag Dumping[2]	7.0	3.3	1.4E-5	0.0288
11	Baghouse Dust	1.3	0.6	9.0E-6	0.0087
TOTAL EMISSIONS		73.9	34.7	0.0088	0.4059

[1] - Including wind erosion of stockpiles
[2] - Active dumping area maintenance
- No data

TABLE 5-11

SUMMARY OF ANNUAL EMISSIONS USED IN DISPERSION MODELLING

SOURCES	ANNUAL EMISSIONS (tons/year)			
	PM_{10}	TSP	Cadmium	Fluoride
Permitted Sources	83.0	149.4	3.4	12.8
Slag Dumping	6.6	12.7	0.000025	3.2
Baghouses	9.5	11.7	0.0003	0.08
Furnace Building Fugitives	2.3	9.6	0.0092	0.4
Roads	15.4	28.5	-	-
Material Handling Operations[1]	45.8	97.5	0.011	0.406
Nodule Reclaim Area	185.2	374.6	0.0055	7.8

[1] - Including Wind Erosion

DISCRETE RECEPTOR LOCATIONS

DISCRETE RECEPTORS		UTM COORDINATES	
		Northing (m)	Easting (m)
1.	Merele Cellan Home	4,725,235	450,550
2.	Jorgensen Home	4,724,880	451,975
3.	Johnson Ready Mix	4,724,880	452,220
4.	Bisco Paramount	4,724,610	452,135
5.	M & R Sports	4,724,150	452,200
6.	Tom Cellan Home	4,728,135	453,730
7.	High School	4,723,255	451,440
8.	Junior High School	4,722,255	451,200
9.	Grade School	4,721,855	450,710
10.	(Hooper) School	4,723,000	450,805
11.	13-420-029*	4,728,714	449,762
12.	13-420-026*(Harris Ranch)	4,724,809	451,523
13.	13-420-021 (Hospital)	4,722,283	450,250
14.	13-420-027	4,731,024	454,756
15.	13-420-002	4,732,300	454,000
16.	16-029-0030*	4,723,300	452,075
17.	F #1	4,726,815	453,930
18.	F #2	4,727,000	455,600
19.	F #3	4,728,250	455,524
20.	F #4	4,732,500	454,390
21.	F #4A	4,732,340	454,950
22.	F #6	4,732,695	451,450
23.	F #7	4,732,610	450,390
24.	F #8	4,732,270	449,290
25.	F #11	4,730,725	449,850
26.	F #12	4,730,725	451,250
27.	F #13	4,730,300	451,085
28.	F #14	4,729,250	449,000
29.	F #15	4,726,200	449,875
30.	F #16	4,727,650	449,750
31.	F #17	4,725,650	450,560
32.	F #18	4,724,660	450,675
33.	SE Corner of Property	4,724,935	452,258
34.	East Side of Property	4,726,026	452,538
35.	West Side of Property	4,726,164	451,368
36.	North Side of Property	4,727,026	452,133

NOTE: Receptors No. 17-32 are the locations of former fluoride in vegetation sampling sites from Miller and Pushnik (1985), Miller (1986), Miller (1987) and Miller (1990).

SOURCE CHARACTERISTICS USED IN MODELING SOURCE GROUPS 1, 2 AND 3

SOURCES	STACK PARAMETERS				BLDG. DIMENSIONS (feet)		
	HEIGHT (feet)	Diameter (feet)	Velocity (feet/second)	Temperature	Length	Width	Height
PERMITTED SOURCES							
Taphole Fume Collectors - #7	96	3.0	57.85	108.0	210	132	133
- #8	118	3.0	61.68	105.0	210	132	133
- #9	73	3.1	54.98	110.0	158	158	160
Kiln Cooler Spray Tower	118	12.7	25.5	122.0	540	95	40
Kiln Venturi Scrubbers- A	91	4.6	71.54	159.0	-	-	-
- B	91	4.6	68.02	159.0	-	-	-
- C	91	4.6	62.28	159.0	-	-	-
- C	91	4.6	71.11	159.0	-	-	-
Nodule Crushing /Screening Scrubber	81	11.5	24.2	114.0	80	70	50
Slag Dumping (Volume Source)	-	-	-	-	393.6	49.2	105
BAGHOUSES							
Coke/quartzite Dryer	55	2.5	176.53	200.0	80	40	45
Stocking System	80	2.5	67.89	80.0	40	30	70
Coke/Quartzite Satellite	51	1.8	58.94	70.0	20	20	40
Ore Satellite	25	1.3	41.43	70.0	25	25	20
Coke Handling	60	4.0	76.67	80.0	45	25	50
Scaleroom	60	3.2	32.29	92.2	45	25	50
Furnace Bldg. (Volume Source)	-	-	-	-	394	158	160
NODULE RECLIAM AREA							
SDM Bunker	40	2.0	4.2	220.5	-	-	-
Reclaim Hopper	40	22.6	4.3	123.0	-	-	-
Nodule Chute	40	5.4	5.4	271.5	-	-	-
Loader PickuP from Stockpile	0	5.4	5.4	123.0	-	-	-
Clam Dump to Stockpile	40	5.4	5.4	271.5	-	-	-

- No data

TABLE 5-14

PREDICTED AVERAGE ANNUAL TSP CONCENTRATION

DISCRETE RECEPTORS	PREDICTED TSP CONCENTRATION (mg/m³)					TOTAL
	Permitted Sources	Slag Dumping	Baghouses & Building Fugitives	Nodule Reclaim Area	Roads, Wind Erosion & Material Handling	
1. M. Cellan Home	3.0E-4	5.0E-5	1.5E-4	1.59E-3	1.05E-3	3.1E-3
2. Jorgensen Home	1.37E-3	5.5E-4	8.7E-4	6.58E-3	1.03E-2	1.96E-2
3. Johnson Ready Mix	9.4E-4	2.1E-4	5.7E-4	4.32E-3	5.00E-3	1.10E-2
4. Bisco Paramount	9.3E-4	2.9E-4	5.6E-4	4.90E-3	4.82E-3	1.15E-2
5. M&R Sports	7.2E-4	2.8E-4	4.0E-4	4.20E-3	2.90E-3	8.5E-3
6. T. Cellan Home	2.7E-4	4.0E-5	8.0E-5	1.25E-3	3.6E-4	2.0E-3
7. High School	7.6E-4	3.4E-4	3.6E-4	4.63E-3	2.21E-3	8.3E-3
8. Junor High School	6.1E-4	2.1E-4	2.4E-4	3.53E-3	1.23E-3	5.8E-3
9. Grade School	5.8E-4	1.8E-4	2.1E-4	3.27E-3	1.05E-3	5.3E-3
10. (Hooper) School	7.6E-4	3.1E-4	3.3E-4	4.53E-3	1.86E-3	7.8E-3
11. 2mi N Hooper Springs	4.1E-4	5.0E-5	8.0E-5	1.46E-3	3.7E-4	2.4E-3
12. Harris Ranch	1.42E-3	1.64E-3	9.8E-4	8.55E-3	1.188E-2	2.45E-2
13. Soda Springs Hospital	6.3E-4	1.8E-4	2.3E-4	3.63E-3	1.14E-3	5.8E-3
14. Conda - 1.2 mi E State 34	1.6E-4	2.0E-5	4.0E-5	6.9E-4	1.5E-4	1.1E-3
15. Conda - Torgensen Res.	1.8E-4	2.0E-5	4.0E-5	7.4E-4	1.4E-4	1.1E-3
16. Soda Springs - Terrace Acres Mobile Court	6.5E-4	2.2E-4	3.0E-4	3.85E-3	1.96E-3	7.2E-3
33. SE - Corner Property	9.0E-4	1.5E-4	5.5E-4	3.95E-3	4.78E-3	1.03E-2
34. E - Side Property Line	4.0E-4	1.6E-4	1.7E-4	9.8E-4	5.26E-3	7.0E-3
35. W - Side Property Line	6.4E-4	4.4E-4	2.6E-4	8.6E-4	5.10E-3	7.3E-3
36. N - Side Property Line	1.08E-3	1.6E-4	5.3E-4	6.46E-3	1.03E-2	1.85E-2

TABLE 5-15

PREDICTED AVERAGE ANNUAL PM_{10} CONCENTRATION

DISCRETE RECEPTORS	PREDICTED PM_{10} CONCENTRATION (mg/m^3)					TOTAL
	Permitted Sources	Slag Dumping	Baghouses & Building Fugitives	Nodule Reclaim Area	Roads, Wind Erosion & Material Handling	
1. M. Cellan Home	2.1E-4	3.0E-5	9.0E-5	1.74E-3	8.2E-4	2.9E-3
2. Jorgensen Home	1.18E-3	2.9E-4	5.4E-4	7.99E-3	6.07E-3	1.61E-2
3. Johnson Ready Mix	7.7E-4	1.1E-4	3.6E-4	5.12E-3	3.23E-3	9.6E-3
4. Bisco Paramount	7.7E-4	1.5E-4	3.5E-4	5.41E-3	3.15E-3	9.8E-3
5. M&R Sports	5.8E-4	1.4E-4	2.5E-4	4.10E-3	1.97E-3	7.0E-3
6. T. Cellan Home	1.7E-4	2.0E-5	5.0E-5	8.4E-4	2.7E-4	1.4E-3
7. High School	5.7E-4	1.8E-4	2.1E-4	3.82E-3	1.38E-3	6.2E-3
8. Junor High School	4.3E-4	1.1E-4	1.4E-4	2.61E-3	7.9E-4	4.1E-3
9. Grade School	4.1E-4	9.0E-5	1.3E-4	2.33E-3	6.9E-4	3.6E-3
10. (Hooper) School	5.5E-4	1.6E-4	2.0E-4	3.55E-3	1.21E-3	5.7E-3
11. 2mi N Hooper Springs	2.2E-4	3.0E-5	5.0E-5	9.7E-4	2.6E-4	1.5E-3
12. Harris Ranch	1.21E-3	8.5E-4	6.0E-4	1.0E-2	6.91E-3	1.96E-2
13. Soda Springs Hospital	4.4E-4	9.0E-5	1.4E-4	2.62E-3	7.7E-4	4.1E-3
14. Conda - 1.2 mi E State 34	9.0E-5	1.0E-5	2.0E-5	4.2E-4	1.2E-4	7.0E-4
15. Conda - Torgensen Res.	1.1E-4	1.0E-5	2.0E-5	4.8E-4	1.0E-4	7.0E-4
16. Soda Springs - Terrace Acres Mobile Court	5.0E-4	1.1E-4	1.9E-4	3.24E-3	1.28E-3	5.3E-3
33. SE - Corner Property	7.3E-4	8.0E-5	3.5E-4	4.73E-3	3.06E-3	8.9E-3
34. E - Side Property Line	3.1E-4	8.0E-5	1.1E-4	1.36E-3	4.21E-3	6.1E-3
35. W - Side Property Line	5.3E-4	2.3E-4	1.6E-4	2.92E-3	3.29E-3	7.1E-3
36. N - Side Property Line	6.5E-4	8.0E-5	3.5E-4	7.18E-3	7.64E-3	1.59E-2

TABLE 5-16

PREDICTED AVERAGE ANNUAL CADMIUM CONCENTRATIONS

DISCRETE RECEPTORS	PREDICTED CADMIUM CONCENTRATION (mg/m³)					TOTAL
	Permitted Sources	Slag Dumping	Baghouses & Building Fugitives	Nodule Reclaim Area	Roads, Wind Erosion & Material Handling	
1. M. Cellan Home	4.3E-6	0.0000	0.0000	0.0000	1.0E-7	4.4E-6
2. Jorgensen Home	9.8E-6	0.0000	3.0E-7	0.0000	4.0E-7	1.05E-5
3. Johnson Ready Mix	7.4E-6	0.0000	2.0E-7	0.0000	3.0E-7	7.9E-6
4. Bisco Paramount	8.9E-6	0.0000	2.0E-7	0.0000	3.0E-7	9.4E-6
5. M&R Sports	9.2E-6	0.0000	1.0E-7	0.0000	2.0E-7	9.5E-6
6. T. Cellan Home	5.5E-6	0.0000	0.0000	0.0000	0.0000	5.5E-6
7. High School	1.32E-5	0.0000	1.0E-7	0.0000	1.0E-7	1.34E-5
8. Junor High School	1.22E-5	0.0000	1.0E-7	0.0000	1.0E-7	1.24E-5
9. Grade School	1.22E-5	0.0000	1.0E-7	0.0000	1.0E-7	1.24E-5
10. (Hooper) School	1.44E-5	0.0000	1.0E-7	0.0000	1.0E-7	1.46E-5
11. 2mi N Hooper Springs	7.4E-6	0.0000	0.0000	0.0000	0.0000	7.4E-6
12. Harris Ranch	1.37E-5	0.0000	3.0E-7	0.0000	4.0E-7	1.44E-5
13. Soda Springs Hospital	1.37E-5	0.0000	1.0E-7	0.0000	1.0E-7	1.39E-5
14. Conda - 1.2 mi E State 34	3.7E-6	0.0000	0.0000	0.0000	0.0000	3.7E-6
15. Conda - Torgensen Res.	4.0E-6	0.0000	0.0000	0.0000	0.0000	4.0E-6
16. Soda Springs - Terrace Acres Mobile Court	1.06E-5	0.0000	1.0E-7	0.0000	1.0E-7	1.08E-5
33. SE - Corner Property	6.8E-6	0.0000	2.0E-7	0.0000	3.0E-7	7.3E-6
34. E - Side Property Line	2.5E-6	0.0000	0.0000	0.0000	5.0E-7	3.0E-6
35. W - Side Property Line	4.9E-6	0.0000	1.0E-7	0.0000	2.0E-7	5.2E-6
36. N - Side Property Line	1.14E-5	0.0000	2.0E-7	0.0000	2.9E-6	1.45E-5

TABLE 5-17

PREDICTED AVERAGE ANNUAL FLUORIDE CONCENTRATIONS

DISCRETE RECEPTORS	PREDICTED FLUORIDE CONCENTRATION (mg/m^3)					TOTAL
	Permitted Sources	Slag Dumping	Baghouses & Building Fugitives	Nodule Reclaim Area	Roads, Wind Erosion & Material Handling	
1. M. Cellan Home	5.77E-5	1.35E-5	3.0E-6	2.56E-5	8.4E-6	1.1E-4
2. Jorgensen Home	3.922E-4	1.368E-4	1.79E-5	1.177E-4	6.64E-5	7.3E-4
3. Johnson Ready Mix	2.487E-4	5.25E-5	1.14E-5	7.58E-5	4.16E-5	4.3E-4
4. Bisco Paramount	2.441E-4	7.15E-5	1.11E-5	7.97E-5	3.70E-5	4.4E-4
5. M&R Sports	1.715E-4	6.88E-5	8.2E-6	6.01E-5	2.33E-5	3.3E-4
6. T. Cellan Home	3.57E-5	9.9E-6	1.7E-6	1.22E-5	3.3E-6	6.0E-5
7. High School	1.533E-4	8.49E-5	7.8E-6	5.57E-5	1.64E-5	3.2E-4
8. Junor High School	1.064E-4	5.10E-5	5.3E-6	3.80E-5	9.6E-6	2.1E-4
9. Grade School	9.52E-5	4.39E-5	4.7E-6	3.38E-5	8.0E-6	1.9E-4
10. (Hooper) School	1.418E-4	7.72E-5	7.2E-6	5.17E-5	1.37E-5	2.9E-4
11. 2mi N Hooper Springs	3.99E-5	1.32E-5	1.7E-6	1.43E-5	3.0E-6	7.0E-5
12. Harris Ranch	4.020E-4	4.046E-4	2.06E-5	1.466E-4	6.94E-5	1.04E-3
13. Soda Springs Hospital	1.001E-4	4.40E-5	5.1E-6	3.81E-5	8.6E-6	2.0E-4
14. Conda - 1.2 mi E State 34	1.68E-5	4.7E-6	8.0E-7	6.1E-6	1.3E-6	3.0E-5
15. Conda - Torgensen Res.	1.90E-5	5.2E-6	8.0E-7	6.9E-6	1.3E-6	3.0E-5
16. Soda Springs - Terrace Acres Mobile Court	1.352E-4	5.46E-5	6.3E-6	4.73E-5	1.45E-5	2.6E-4
33. SE - Corner Property	2.355E-4	3.82E-5	1.10E-5	7.02E-5	4.07E-5	4.0E-4
34. E - Side Property Line	9.93E-5	3.85E-5	3.2E-6	2.07E-5	4.45E-5	2.1E-4
35. W - Side Property Line	1.709E-4	1.096E-4	5.1E-6	4.21E-5	3.20E-5	3.6E-4
36. N - Side Property Line	1.778E-4	4.04E-5	1.02E-5	1.054E-4	1.343E-4	4.7E-4

TABLE 5-18

PREDICTED SECOND HIGHEST 24-HOUR TSP CONCENTRATIONS

DISCRETE RECEPTORS	PREDICTED TSP CONCENTRATION (mg/m^3)				
	Permitted Sources	Slag Dumping	Baghouses	Nodule Reclaim Area	Roads & Material Handling
1. M. Cellan Home	1.9E-3	7.0E-4	1.3E-3	2.42E-2	2.6E-3
2. Jorgensen Home	4.7E-3	1.7E-3	3.7E-3	7.04E-2	1.62E-2
3. Johnson Ready Mix	4.7E-3	9.0E-4	3.0E-3	7.56E-2	9.6E-3
4. Bisco Paramount	4.5E-3	1.8E-3	2.2E-3	5.44E-2	1.03E-2
5. M&R Sports	3.8E-3	1.4E-3	1.7E-3	4.05E-2	7.3E-3
6. T. Cellan Home	1.9E-3	5.0E-4	1.3E-3	1.74E-2	2.4E-3
7. High School	3.1E-3	1.5E-3	1.6E-3	3.30E-2	5.4E-3
8. Junior High School	2.4E-3	9.0E-4	1.1E-3	2.59E-2	3.4E-3
9. Grade School	2.7E-3	9.0E-4	1.2E-3	2.62E-2	3.1E-3
10. (Hooper) School	4.2E-3	2.0E-3	2.1E-3	4.28E-2	5.5E-3
11. 2mi N Hooper Springs	3.5E-3	4.0E-4	9.0E-4	2.52E-2	6.0E-4
12. Harris Ranch	6.8E-3	8.6E-3	5.0E-3	9.27E-2	2.75E-2
13. Soda Springs Hospital	3.6E-3	1.3E-3	1.6E-3	3.69E-2	3.5E-3
14. Conda - 1.2 mi E State 34	1.5E-3	3.0E-4	5.0E-4	1.07E-2	8.0E-4
15. Conda - Torgensen Res.	1.5E-3	3.0E-4	4.0E-4	1.10E-2	8.0E-4
16. Soda Springs - Terrace Acres Mobile Court	2.5E-3	1.2E-3	1.3E-3	2.75E-2	3.7E-3
33. SE - Corner Property	5.4E-3	1.1E-3	3.1E-3	6.52E-2	9.0E-3
34. E - Side Property Line	4.6E-3	2.3E-3	2.7E-3	3.78E-2	8.3E-3
35. W - Side Property Line	2.2E-3	1.7E-3	9.0E-4	3.03E-2	1.24E-2
36. N - Side Property Line	4.9E-3	1.2E-3	3.7E-3	1.047E-1	1.78E-2

TABLE 5-19

PREDICTED SECOND HIGHEST 24-HOUR PM_{10} CONCENTRATIONS

DISCRETE RECEPTORS	PREDICTED PM_{10} CONCENTRATION (mg/m^3)				
	Permitted Sources	Slag Dumping	Baghouses	Nodule Reclaim Area	Roads & Material Handling
1. M. Cellan Home	1.9E-3	4.0E-4	9.0E-4	1.15E-2	1.8E-3
2. Jorgensen Home	4.2E-3	8.0E-4	2.2E-3	3.45E-2	9.8E-3
3. Johnson Ready Mix	3.7E-3	5.0E-4	1.9E-3	3.68E-2	6.7E-3
4. Bisco Paramount	3.5E-3	8.0E-4	1.4E-3	2.67E-2	6.4E-3
5. M&R Sports	2.8E-3	7.0E-4	1.1E-3	1.97E-2	4.6E-3
6. T. Cellan Home	2.0E-3	2.0E-4	9.0E-4	8.6E-3	1.7E-3
7. High School	2.3E-3	8.0E-4	1.0E-3	1.61E-2	3.5E-3
8. Junior High School	1.7E-3	5.0E-4	7.0E-4	1.27E-2	2.2E-3
9. Grade School	2.0E-3	5.0E-4	7.0E-4	1.29E-2	2.1E-3
10. (Hooper) School	3.3E-3	1.0E-3	1.3E-3	2.11E-2	3.6E-3
11. 2mi N Hooper Springs	2.1E-3	2.0E-4	6.0E-4	1.23E-2	4.0E-4
12. Harris Ranch	6.6E-3	4.5E-3	3.1E-3	4.53E-2	1.63E-2
13. Soda Springs Hospital	2.7E-3	7.0E-4	1.0E-3	1.82E-2	2.4E-3
14. Conda - 1.2 mi E State 34	9.0E-4	2.0E-4	3.0E-4	5.3E-3	6.0E-4
15. Conda - Torgensen Res.	1.0E-3	2.0E-4	3.0E-4	5.4E-3	6.0E-4
16. Soda Springs - Terrace Acres Mobile Court	1.9E-3	6.0E-4	8.0E-4	1.34E-2	2.3E-3
33. SE - Corner Property	3.6E-3	6.0E-4	2.0E-3	3.22E-2	6.5E-3
34. E - Side Property Line	4.4E-3	1.1E-3	1.4E-3	1.87E-2	5.6E-3
35. W - Side Property Line	2.6E-3	9.0E-4	6.0E-4	1.48E-2	9.3E-3
36. N - Side Property Line	3.8E-3	6.0E-4	2.5E-3	5.13E-2	1.40E-2

TABLE 5-20

PREDICTED SECOND HIGHEST 24-HOUR CADMIUM CONCENTRATIONS

DISCRETE RECEPTORS	PREDICTED CADMIUM CONCENTRATION (mg/m^3)				
	Permitted Sources	Slag Dumping	Baghouses	Nodule Reclaim Area	Roads & Material Handling
1. M. Cellan Home	2.3E-5	0.0000	3.0E-7	0.0000	2.0E-7
2. Jorgensen Home	8.5E-5	0.0000	1.4E-6	1.0E-7	8.0E-7
3. Johnson Ready Mix	1.17E-4	0.0000	1.0E-6	1.0E-7	6.0E-7
4. Bisco Paramount	9.2E-5	0.0000	8.0E-7	1.0E-7	5.0E-7
5. M&R Sports	8.6E-5	0.0000	6.0E-7	1.0E-7	3.0E-7
6. T. Cellan Home	5.8E-5	0.0000	3.0E-7	0.0000	3.0E-7
7. High School	6.8E-5	0.0000	5.0E-7	1.0E-7	3.0E-7
8. Junor High School	6.1E-5	0.0000	4.0E-7	0.0000	2.0E-7
9. Grade School	5.9E-5	0.0000	4.0E-7	0.0000	2.0E-7
10. (Hooper) School	6.5E-5	0.0000	8.0E-7	1.0E-7	3.0E-7
11. 2mi N Hooper Springs	1.11E-4	0.0000	4.0E-7	0.0000	0.0000
12. Harris Ranch	7.2E-5	0.0000	1.7E-6	2.0E-7	1.1E-6
13. Soda Springs Hospital	7.7E-5	0.0000	6.0E-7	1.0E-7	2.0E-7
14. Conda - 1.2 mi E State 34	3.3E-5	0.0000	2.0E-7	0.0000	1.0E-7
15. Conda - Torgensen Res.	4.2E-5	0.0000	1.0E-7	0.0000	1.0E-7
16. Soda Springs - Terrace Acres Mobile Court	5.9E-5	0.0000	5.0E-7	1.0E-7	2.0E-7
33. SE - Corner Property	1.37E-4	0.0000	1.0E-6	1.0E-7	7.0E-7
34. E - Side Property Line	6.6E-5	0.0000	1.4E-6	1.0E-7	1.1E-6
35. W - Side Property Line	2.7E-5	0.0000	5.0E-7	1.0E-7	7.0E-7
36. N - Side Property Line	1.21E-4	0.0000	1.0E-6	2.0E-7	3.5E-6

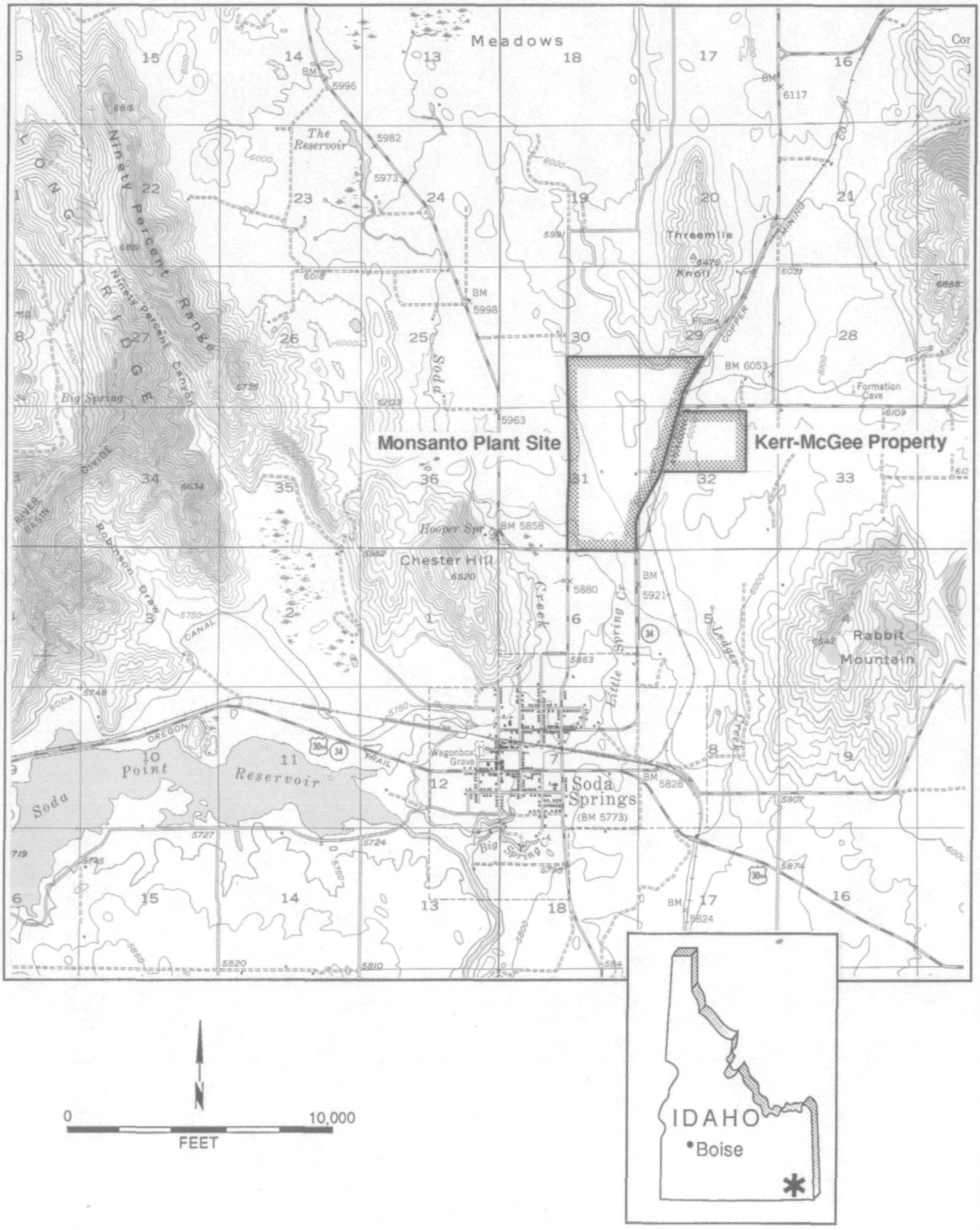
TABLE 5-21

PREDICTED SECOND HIGHEST 24-HOUR FLUORIDE CONCENTRATIONS

DISCRETE RECEPTORS	PREDICTED ANNUAL FLOURIDE CONCENTRATION (mg/m³)				
	Permitted Sources	Slag Dumping	Baghouses	Nodule Reclaim Area	Roads & Material Handling
1. M. Cellan Home	6.0E-4	1.5E-4	2.0E-5	1.7E-4	2.0E-5
2. Jorgensen Home	1.45E-3	3.9E-4	8.0E-5	5.0E-4	1.1E-4
3. Johnson Ready Mix	1.07E-3	3.4E-4	6.0E-5	5.4E-4	9.0E-5
4. Bisco Paramount	8.9E-4	3.0E-4	5.0E-5	3.9E-4	7.0E-5
5. M&R Sports	7.4E-4	2.7E-4	4.0E-5	2.9E-4	5.0E-5
6. T. Cellan Home	4.3E-4	1.2E-4	2.0E-5	1.2E-4	2.0E-5
7. High School	5.6E-4	3.6E-4	3.0E-5	2.4E-4	4.0E-5
8. Junior High School	4.1E-4	2.4E-4	2.0E-5	1.9E-4	3.0E-5
9. Grade School	4.9E-4	2.4E-4	3.0E-5	1.9E-4	2.0E-5
10. (Hooper) School	9.2E-4	4.8E-4	5.0E-5	3.1E-4	4.0E-5
11. 2mi N Hooper Springs	4.0E-4	1.2E-4	2.0E-5	1.8E-4	0.00
12. Harris Ranch	2.35E-3	2.11E-3	1.0E-4	6.6E-4	1.8E-4
13. Soda Springs Hospital	6.4E-4	3.1E-4	4.0E-5	2.6E-4	3.0E-5
14. Conda - 1.2 mi E State 34	2.0E-4	7.0E-5	1.0E-5	8.0E-5	1.0E-5
15. Conda - Torgensen Res.	1.7E-4	5.0E-5	1.0E-5	8.0E-5	1.0E-5
16. Soda Springs - Terrace Acres Mobile Court	5.0E-4	2.4E-4	3.0E-5	2.0E-4	3.0E-5
33. SE - Corner Property	8.5E-4	3.3E-4	6.0E-5	4.7E-4	9.0E-5
34. E - Side Property Line	1.76E-3	6.1E-4	7.0E-5	2.7E-4	9.0E-5
35. W - Side Property Line	6.9E-4	4.0E-4	3.0E-5	2.2E-4	1.5E-4
36. N - Side Property Line	1.35E-3	3.0E-4	6.0E-5	7.5E-4	2.6E-4

Figures

FIGURES



SOURCE: Topographic map of the USGS Soda Springs Quadrangle (1:62,500) 1948.

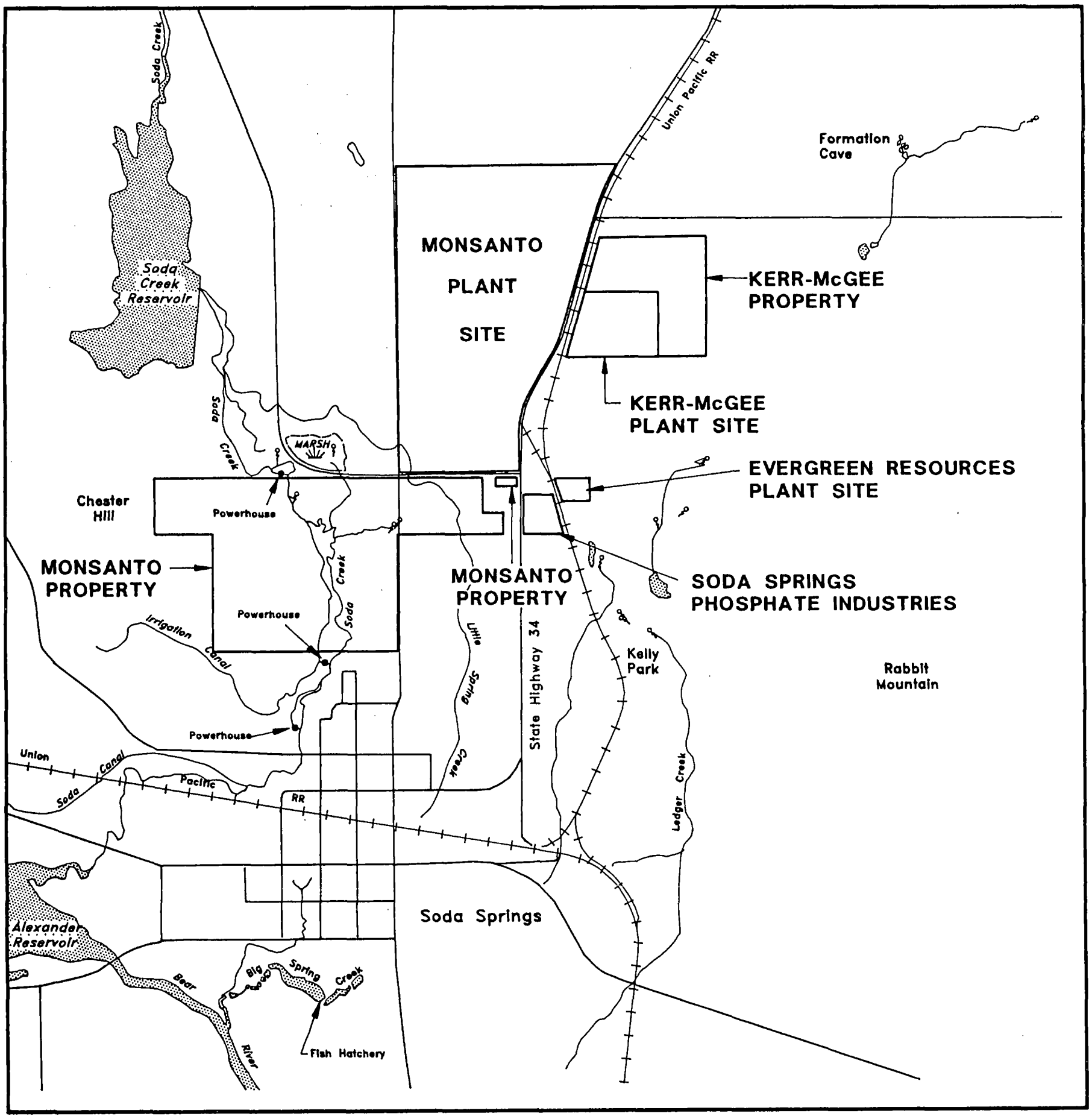
FIGURE **1-1**

LOCATION MAP

MONSANTO/PHASE 1 RI REPORT/ID

PROJECT NO. 913-1101.212 DRAWING NO. 27592 DATE 1/31/92 DRAWN BY EA

Golder Associates



NOTE:
Plant and property boundaries are approximate.

FIGURE **1-2**
MONSANTO PLANT VICINITY
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO 36434 DATE 4-17-92 DRAWN AG/JSS

Golder Associates

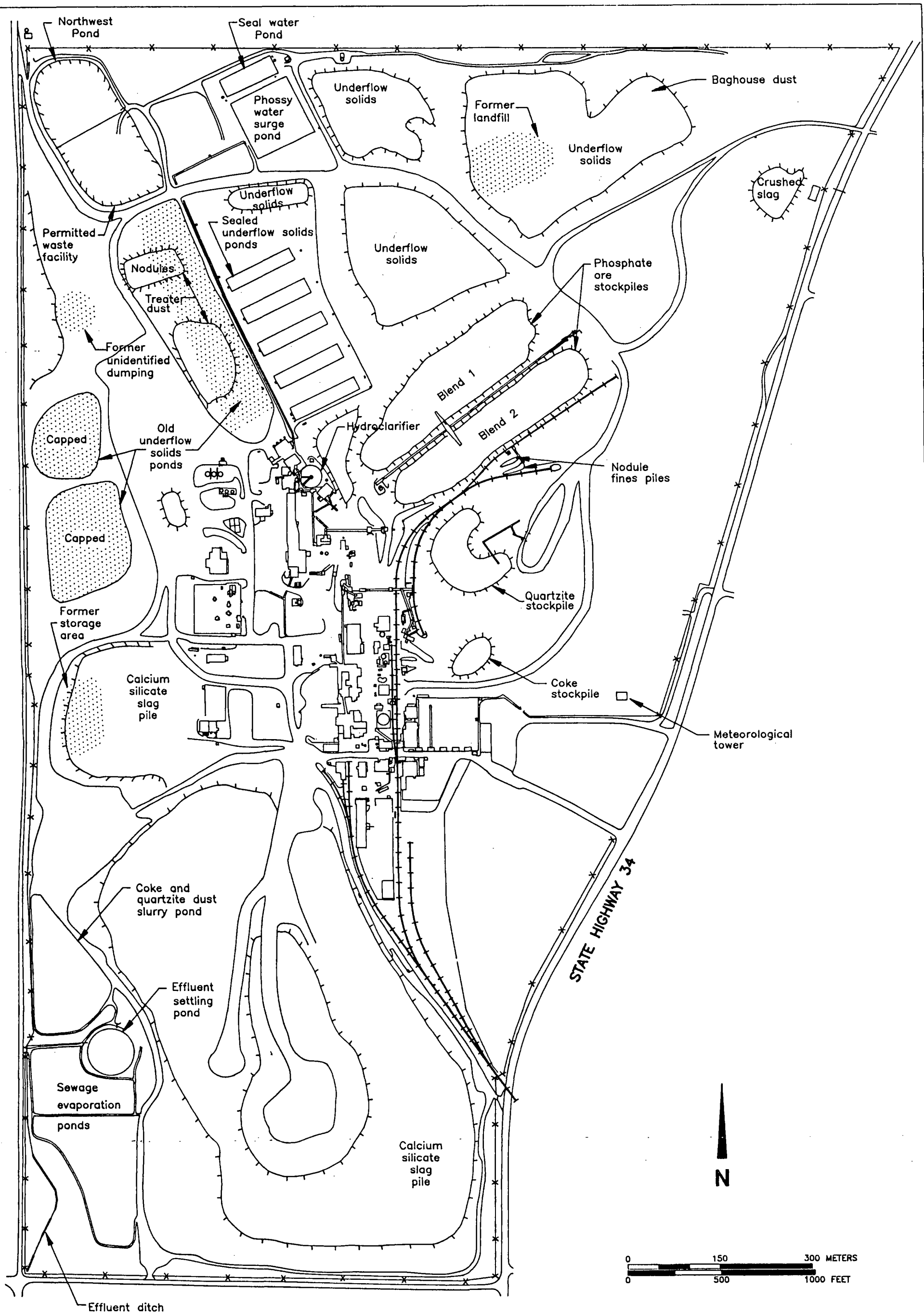


FIGURE **1-3**

MONSANTO FACILITY MAP

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO913-1101.212 DWG NO31122 DATE 4-7-92 DRAWN DH

Golder Associates

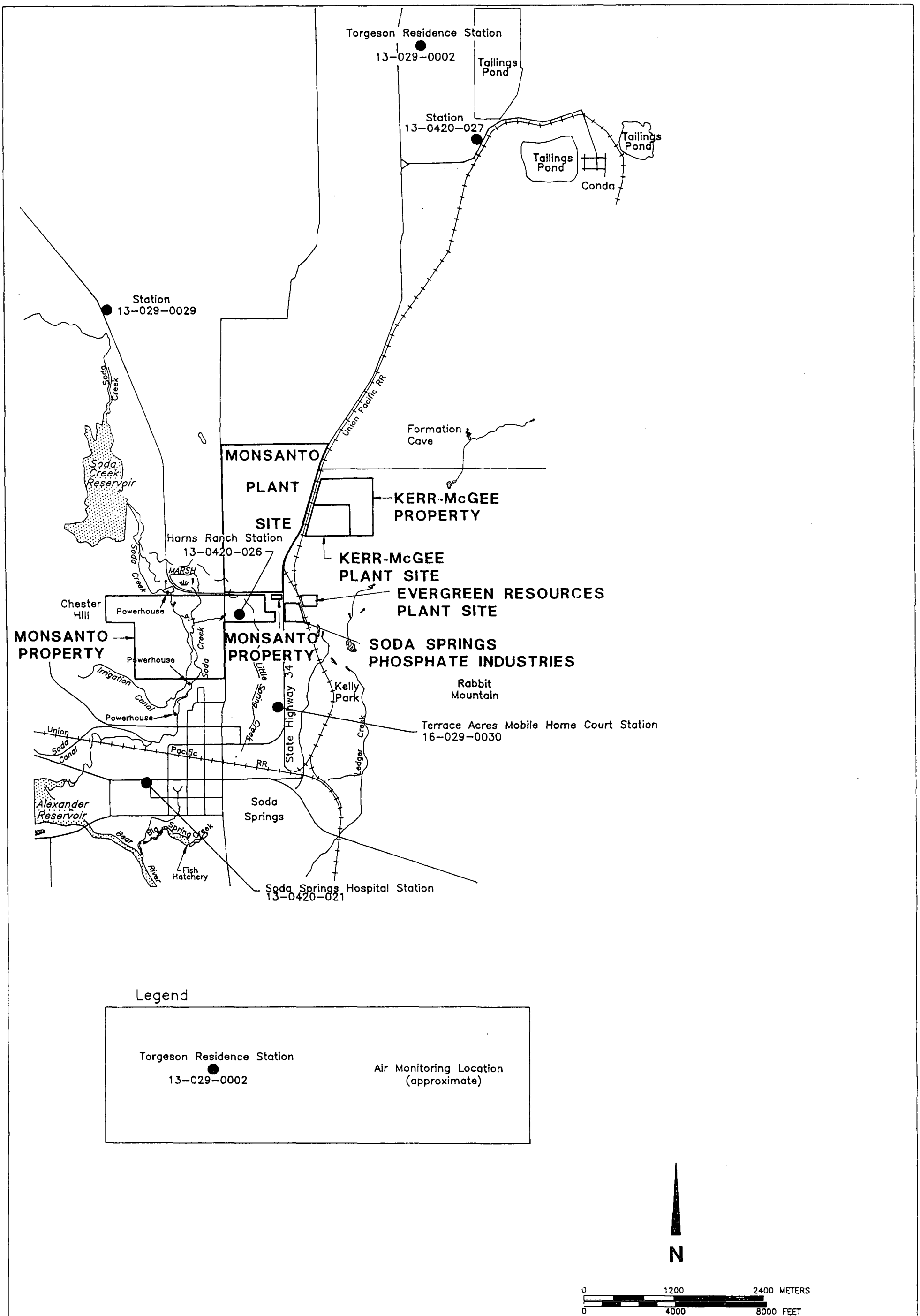


FIGURE **1-4**

AIR MONITORING LOCATIONS

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO 31732 DATE 4-24-92 DRAWN AG/JSS

Golder Associates

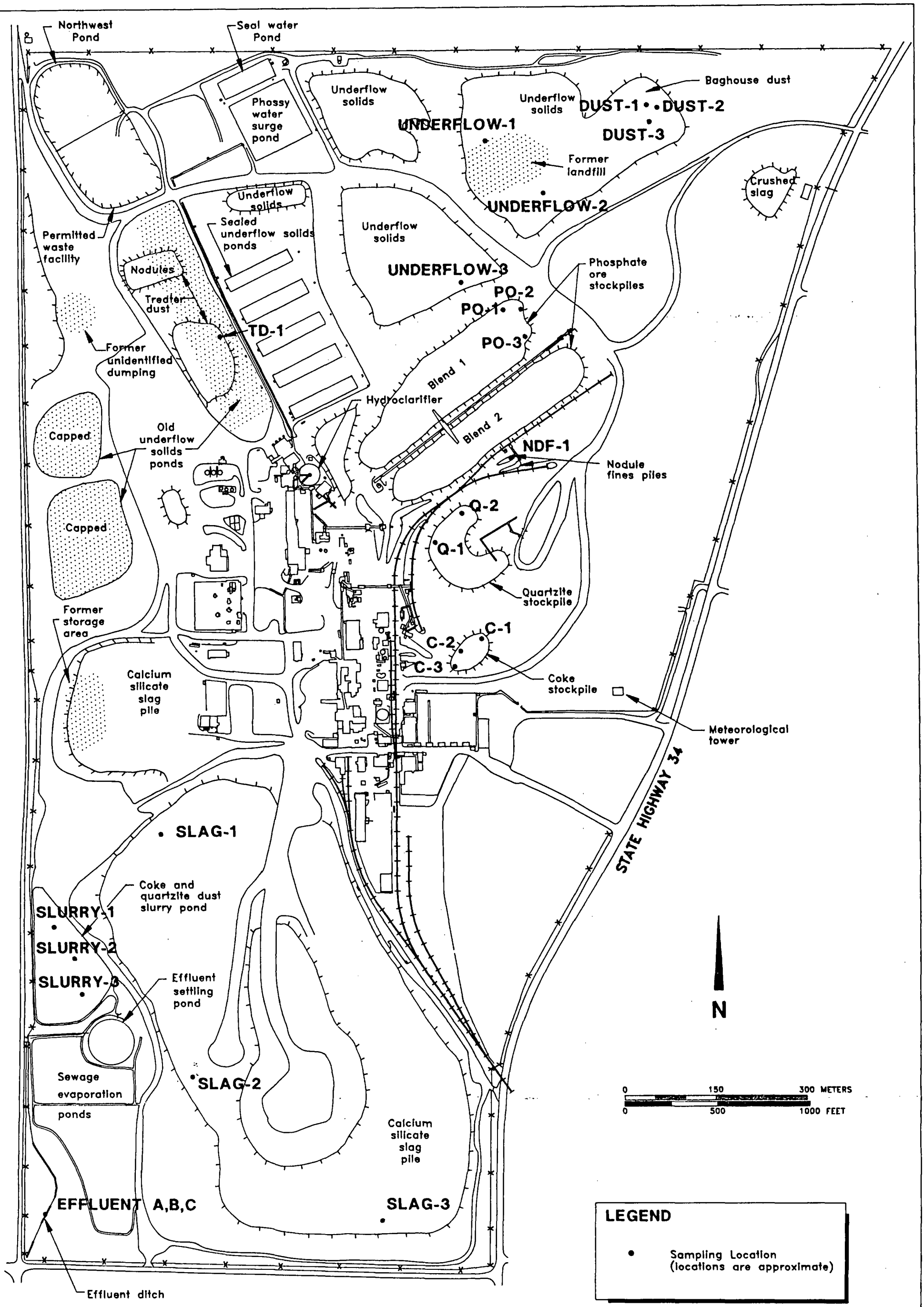
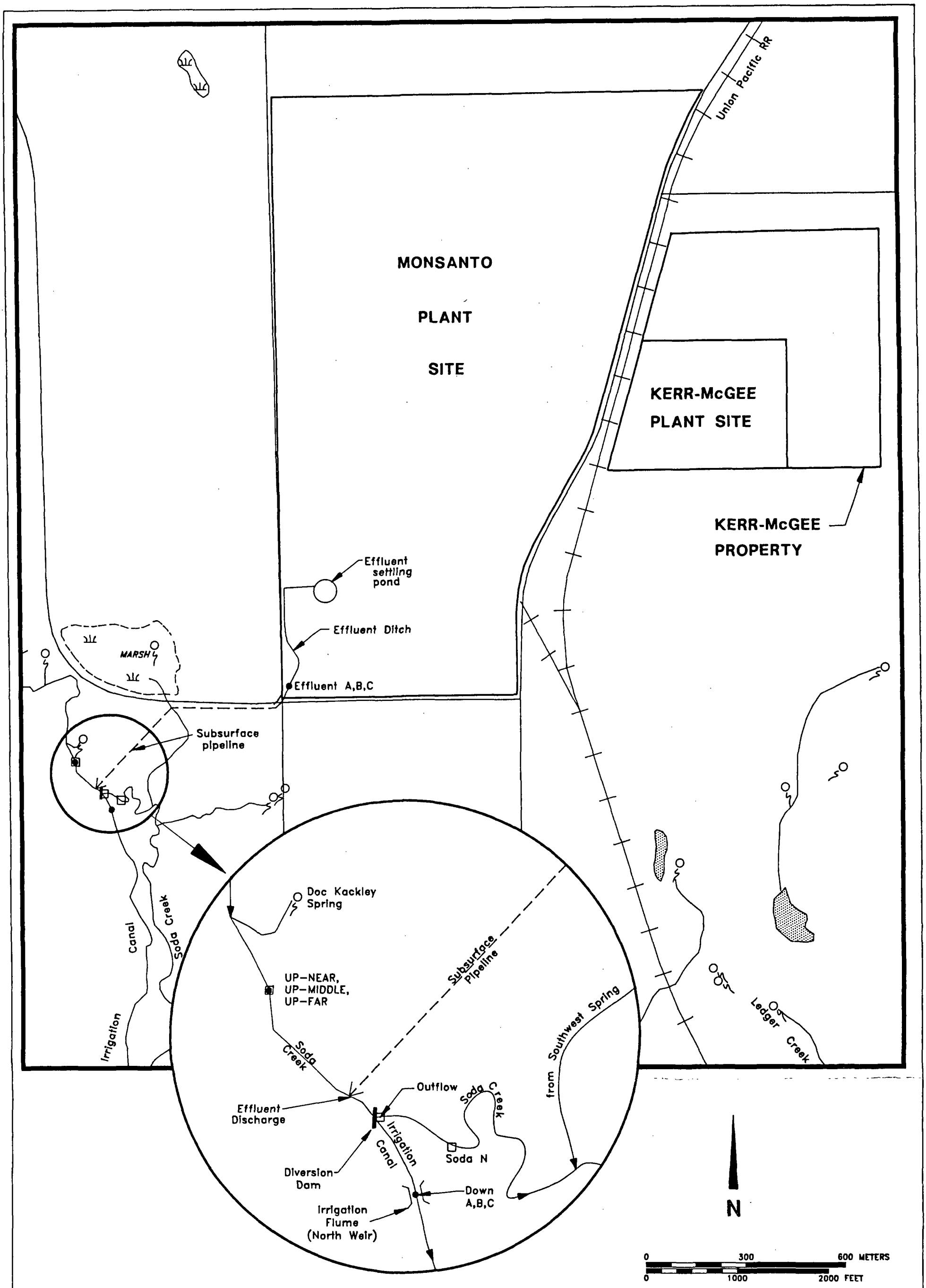


FIGURE 2-1
SOURCE SAMPLING LOCATIONS
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO 31687 DATE 4-7-92 DRAWN JRS

Golder Associates



LEGEND

- ● Surface Water Sampling Location
- □ Sediment Sampling Location

(locations are approximate)

FIGURE **2-2**

EFFLUENT, SURFACE WATER, AND SEDIMENT SAMPLING LOCATIONS

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO913-1101.212 DWG NO31688 DATE 3-25-92 DRAWN JRS

Golder Associates

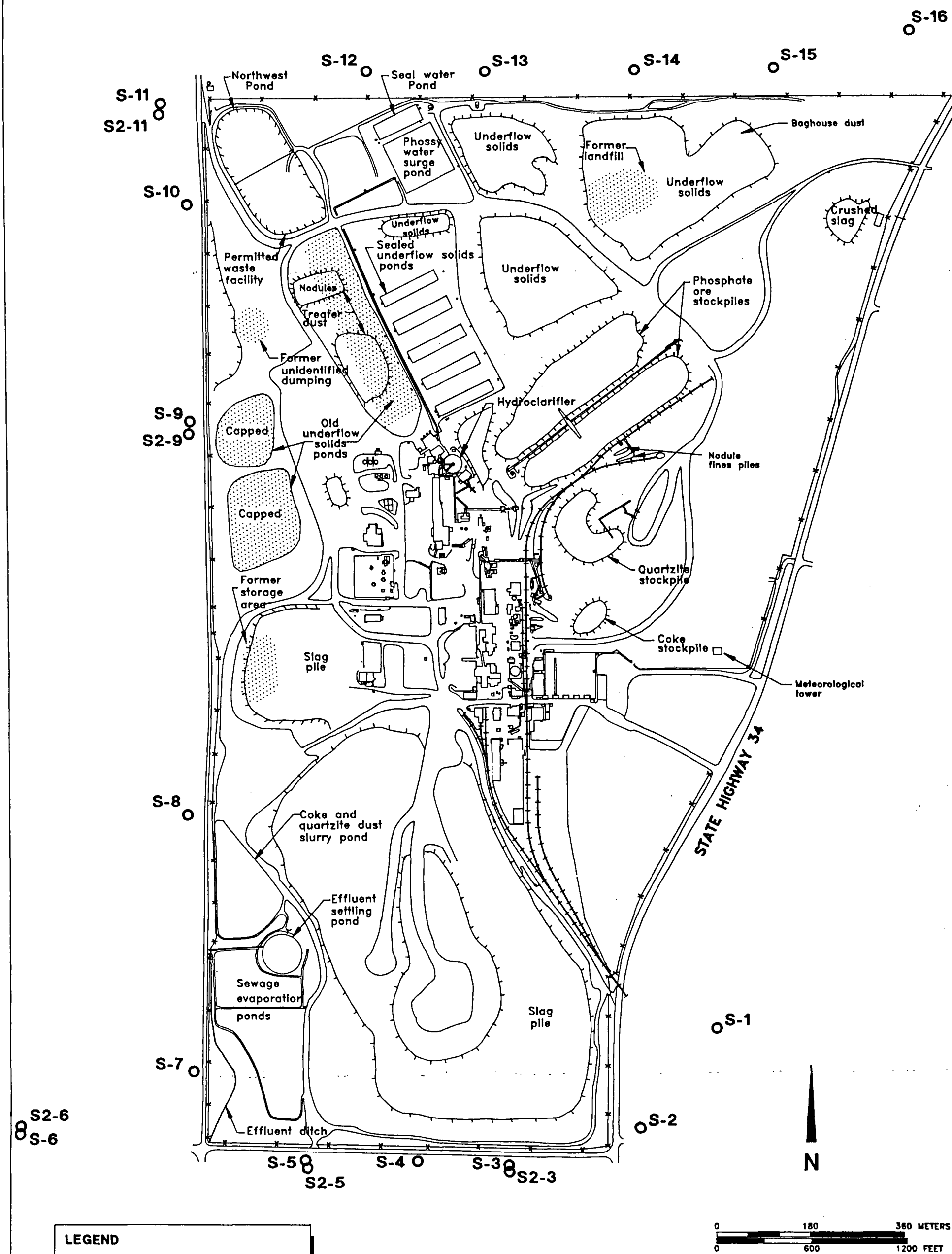
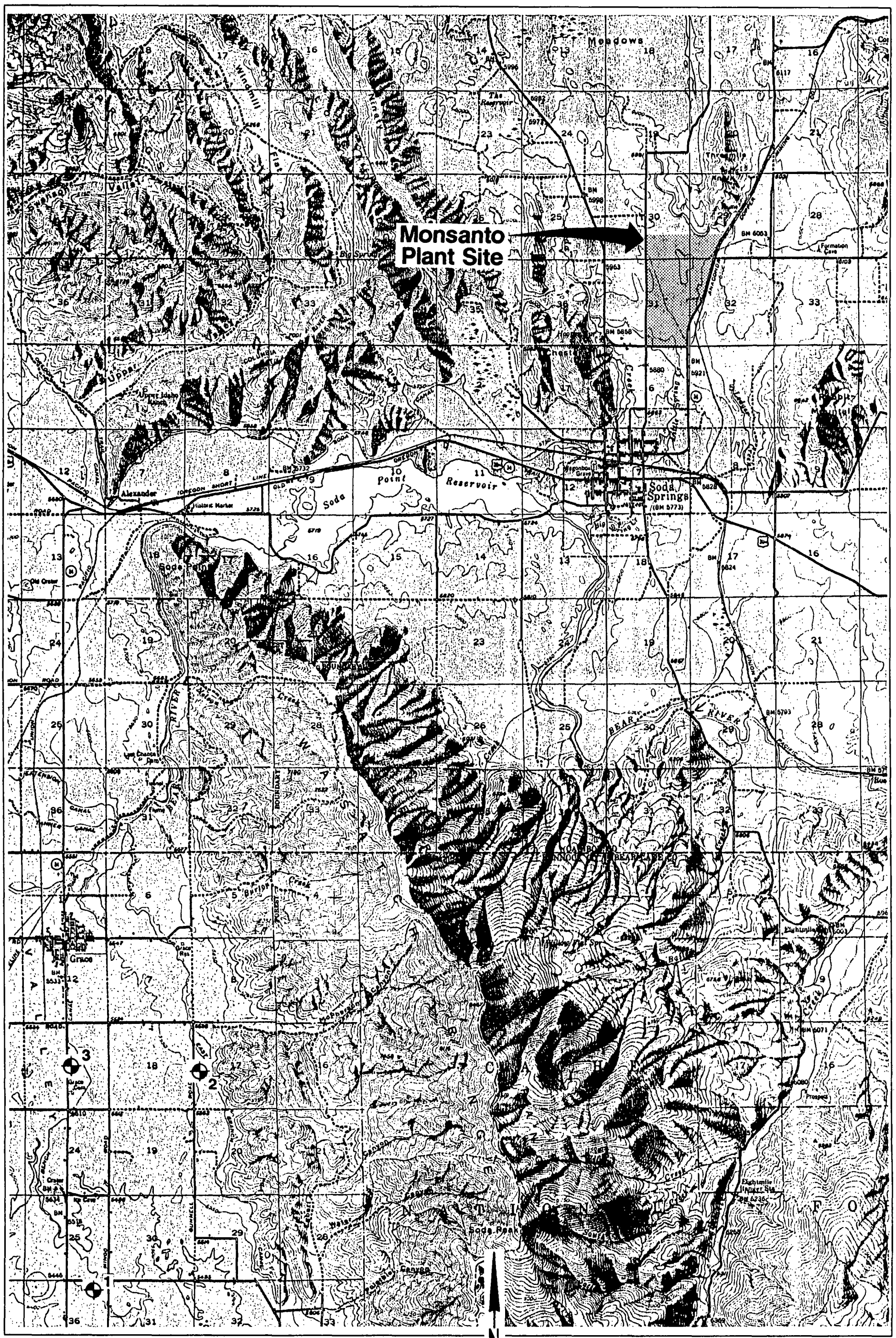


FIGURE 2-3
SOIL SAMPLING LOCATIONS
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO 31713 DATE 4-7-92 DRAWN JRS

Golder Associates



LEGEND

1 Sampling Location - locations are approximate

SOURCE: Topographic map of the USGS Soda Springs Quadrangle (1:62,500) 1949.

FIGURE **2-4**
CONTROL SOIL SAMPLING LOCATIONS
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO. 913-1101.212 DRAWING NO. 28629 DATE 3/3/92 DRAWN BY TK

Golder Associates

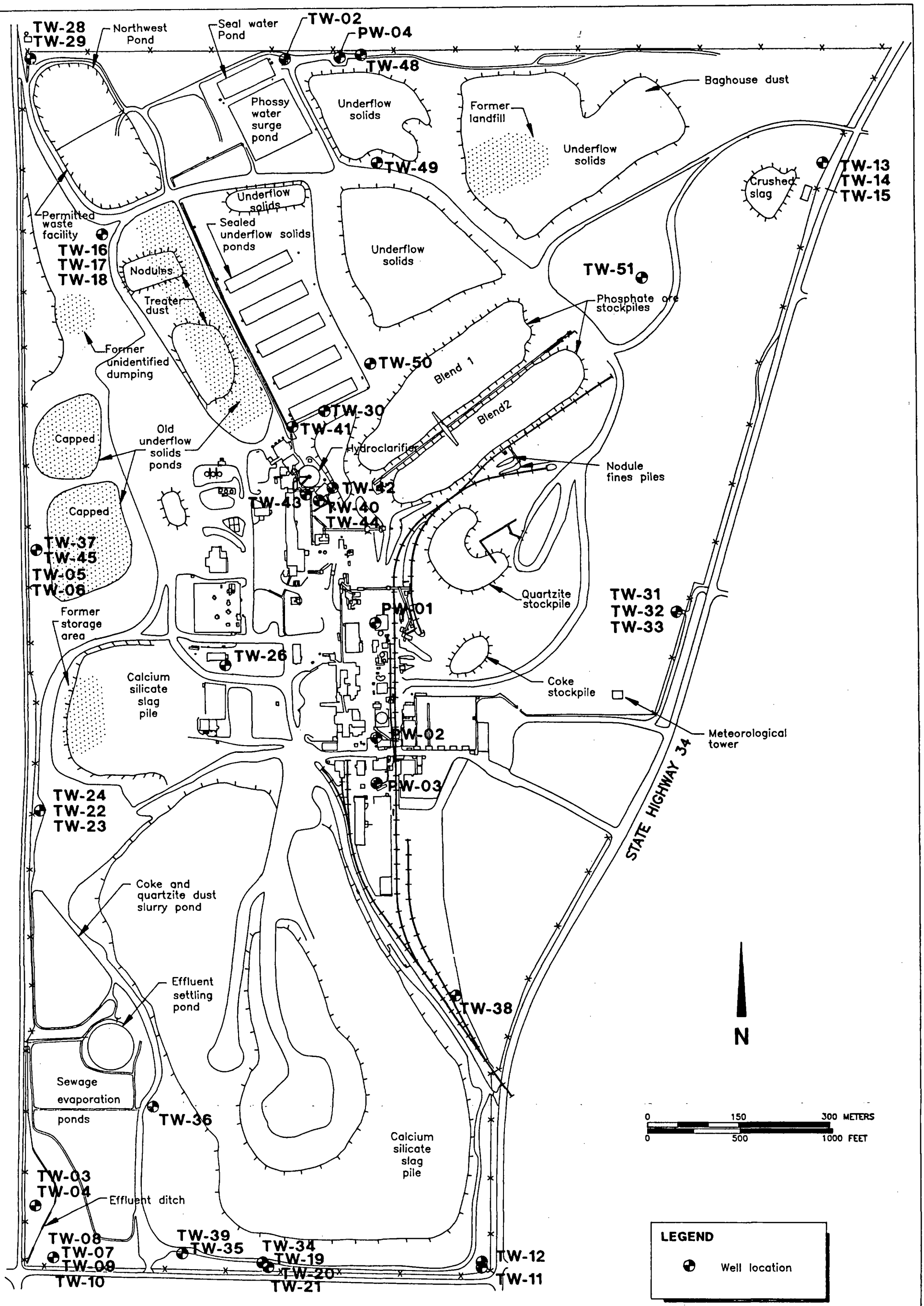


FIGURE 2-5
ON-SITE WELL LOCATIONS
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO 31133 DATE 4-7-92 DRAWN DH

Golder Associates

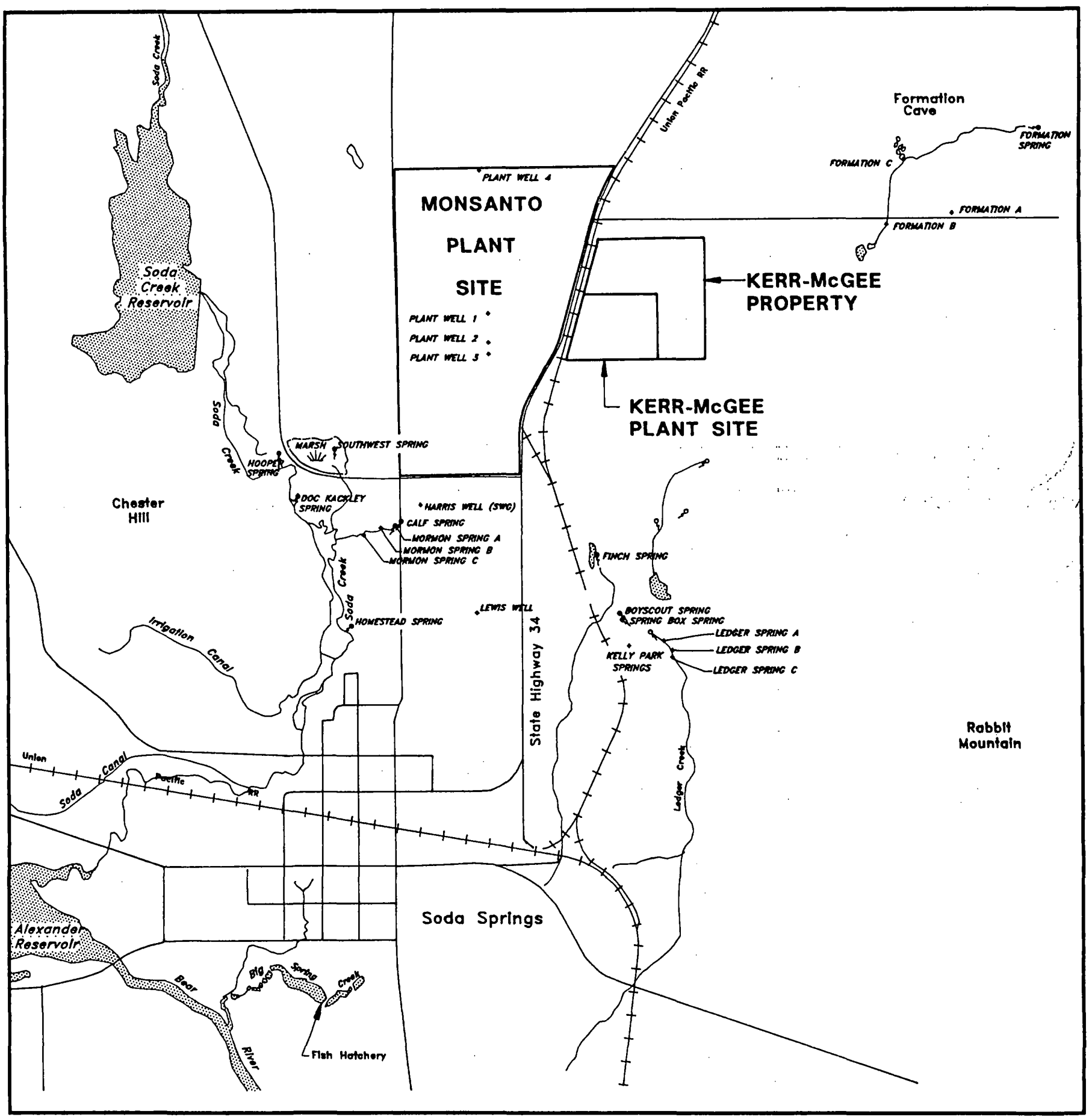
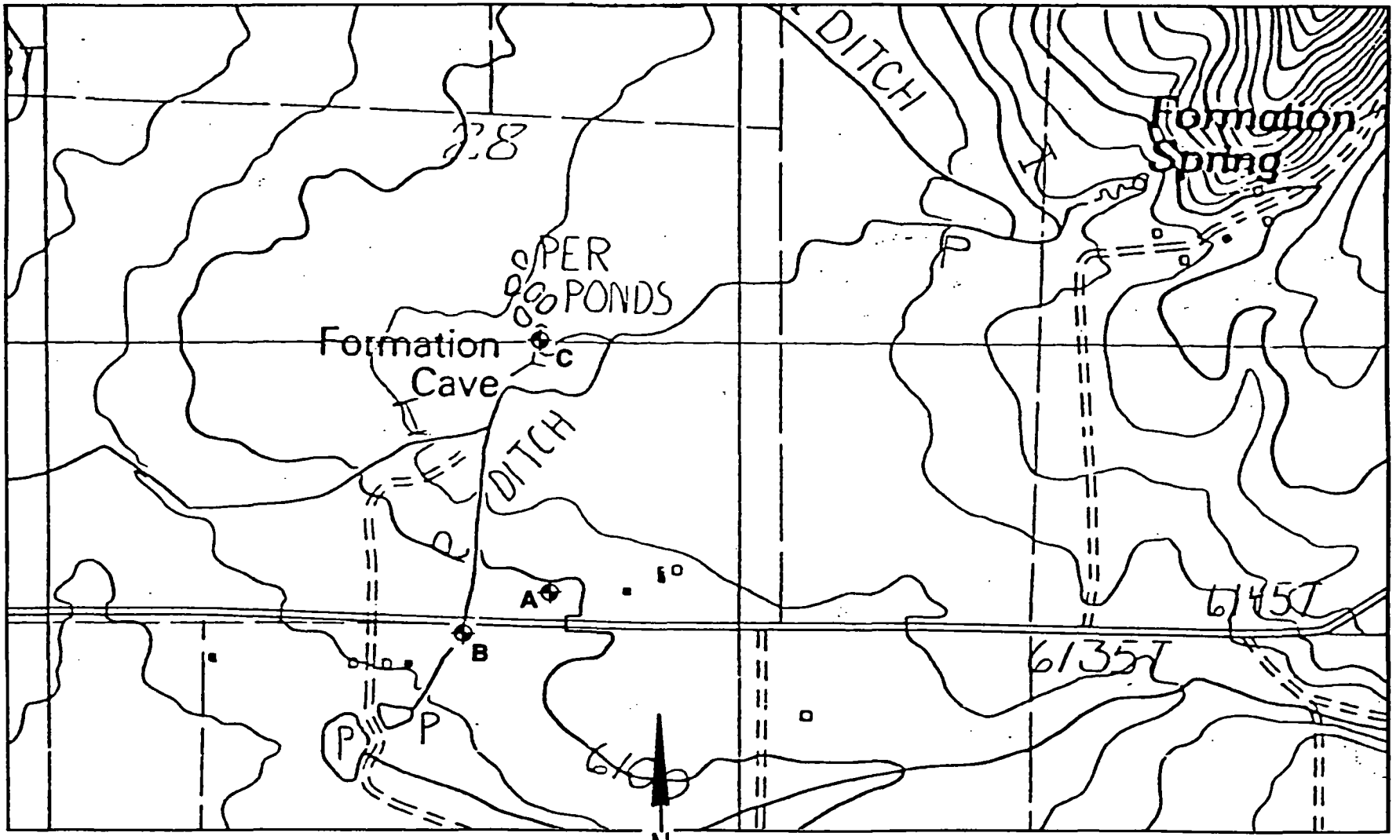


FIGURE 2-6
OFF-SITE WELL AND SPRING LOCATIONS
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO 31134 DATE 4-10-92 DRAWN JRS

Golder Associates



LEGEND

Sampling Location

0 1000 2000

Feet

Source: Topographic map of the USGS Soda Springs Quadrangle, USGS, 1982.

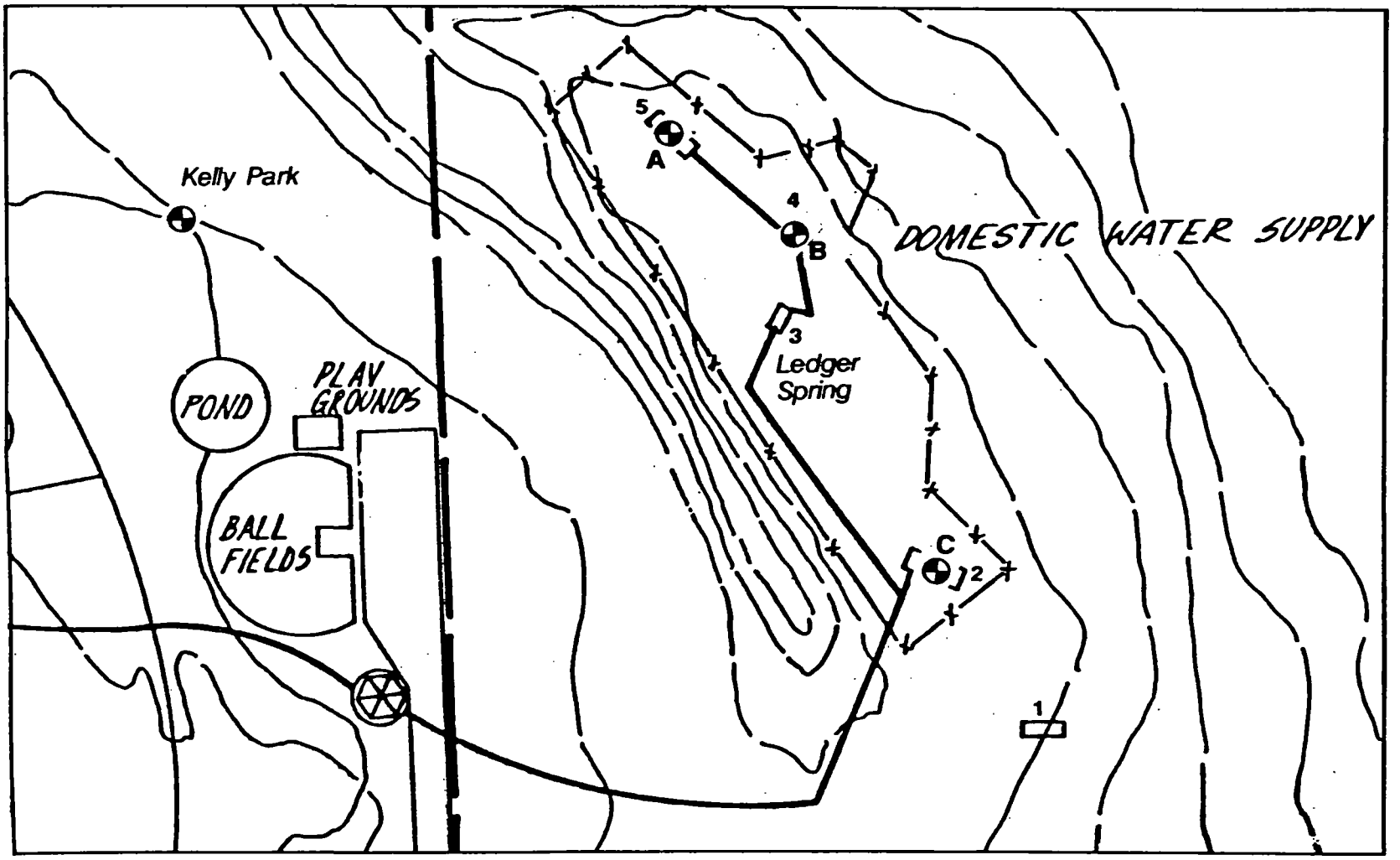
FIGURE **2-7**

FORMATION SPRING SAMPLING LOCATIONS

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO. 913-1101.212 DRAWING NO. 29354 DATE 1/14/92 DRAWN BY TK

Golder Associates



LEGEND

Sampling Location

Spring Box

Not to Scale

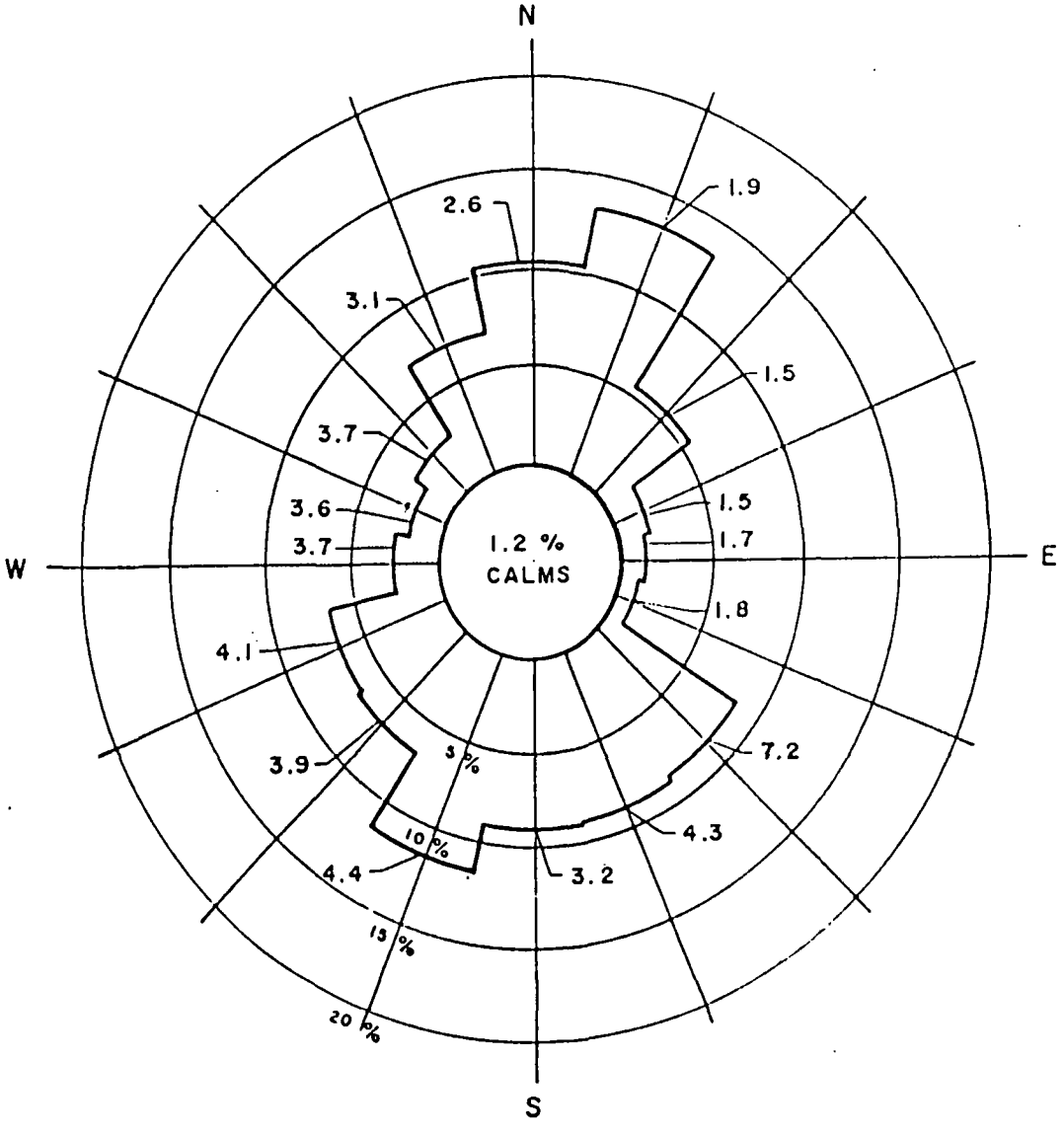
FIGURE **2-8**

LEDGER SPRING SAMPLING LOCATIONS

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO. 913-1101.212 DRAWING NO. 29355 DATE 1/14/92 DRAWN BY TK

Golder Associates

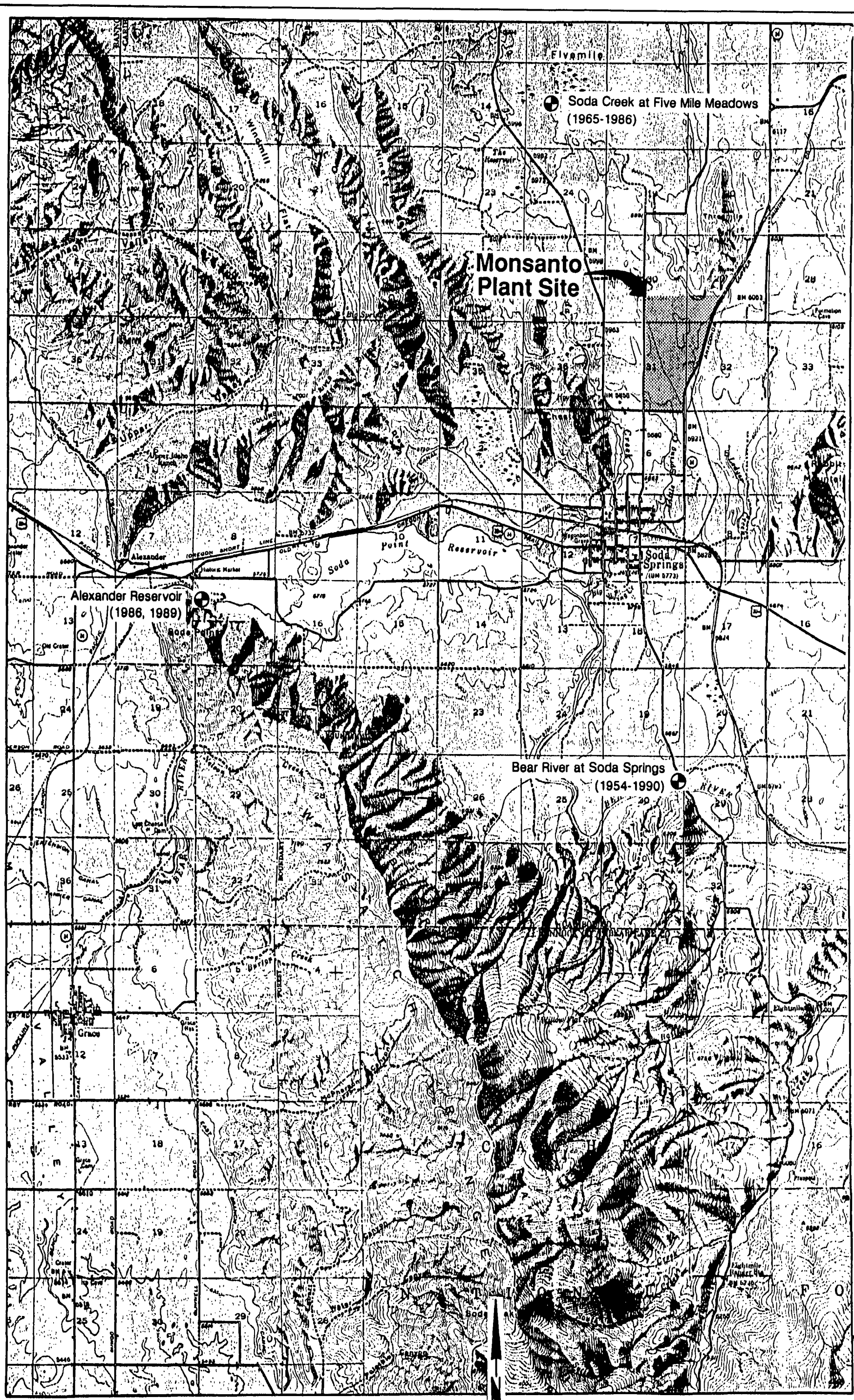


Notes: 1. Record Period: 1990
2. Mean Wind Speed: m/s

FIGURE **3-1**
ANNUAL WIND ROSE FOR SODA SPRINGS, IDAHO
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO. 913-1101 DRAWING NO. 28644 DATE 4/3/92 DRAWN BY TK

Golder Associates



LEGEND

Gaging Station Location - locations are approximate

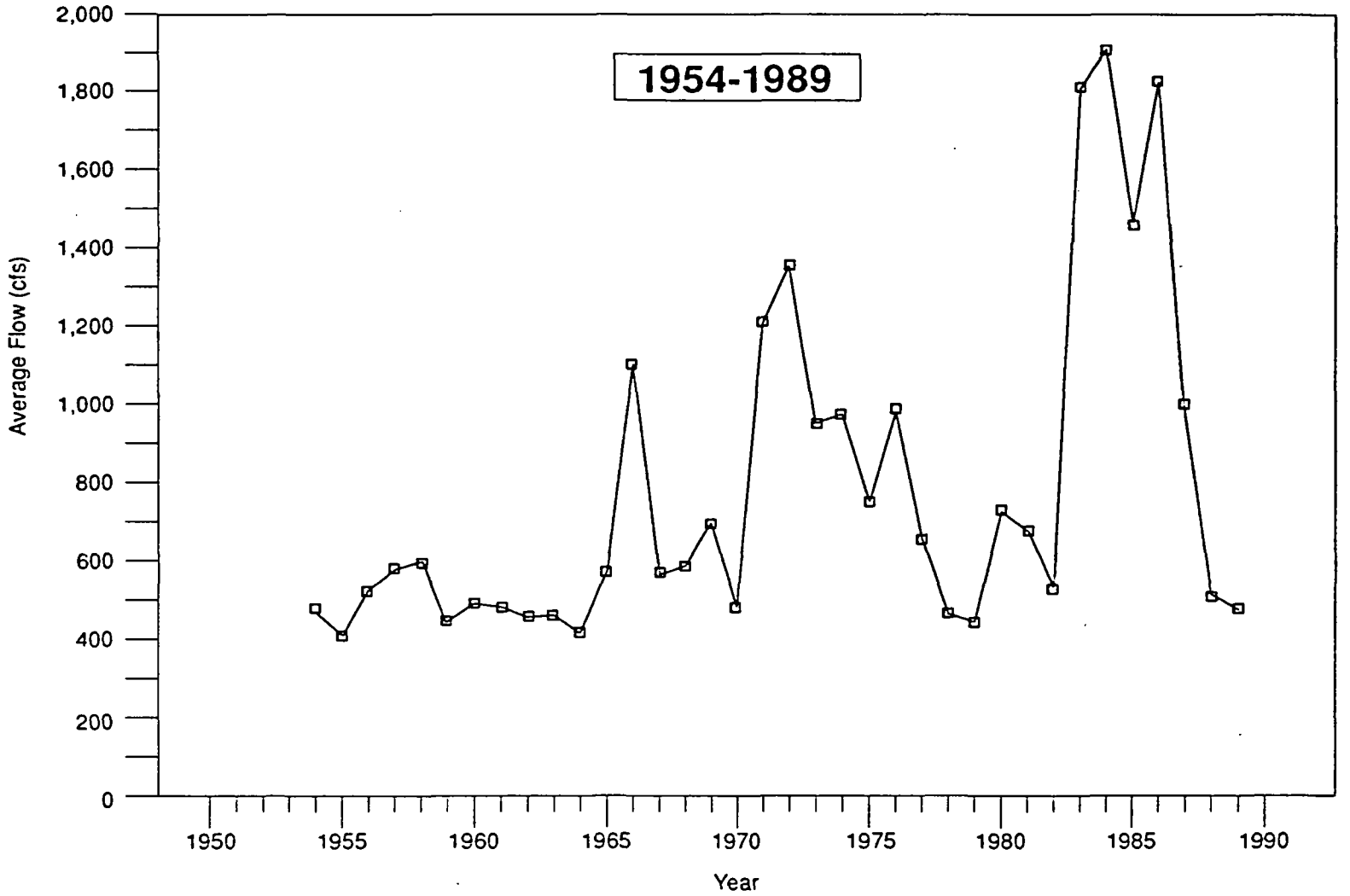
0 1 2 Miles

Source: Topographic Map of the USGS Soda Springs Quadrangle (1:62,500), USGS, 1949

FIGURE 3-2
GAGING STATION LOCATIONS IN THE SODA SPRINGS AREA
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO. 913-1101.212 DWG NO. 29359 DATE 1/15/92 DRAWN BY TK

Golder Associates



SOURCE: USGS data as presented by EarthInfo (1991).

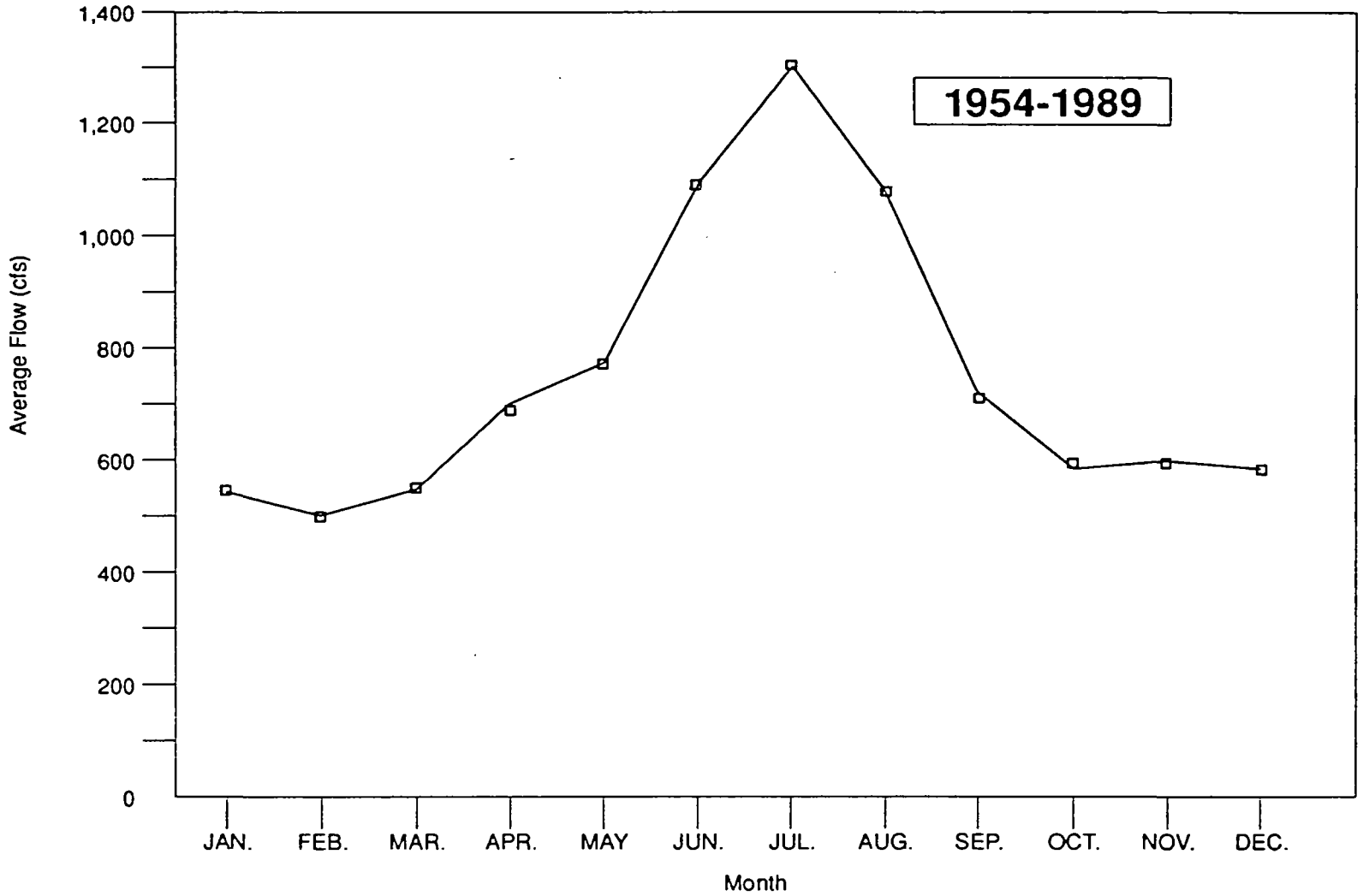
FIGURE **3-3**

YEARLY AVERAGE FLOW IN BEAR RIVER AT SODA SPRINGS

MONSANTO/PHASE 1 RI REPORT/ID

PROJECT NO. 913 1101.212 DRAWING NO. 27796 DATE 4/8/92 DRAWN BY TB

Golder Associates



SOURCE: USGS data as presented by EarthInfo (1991).

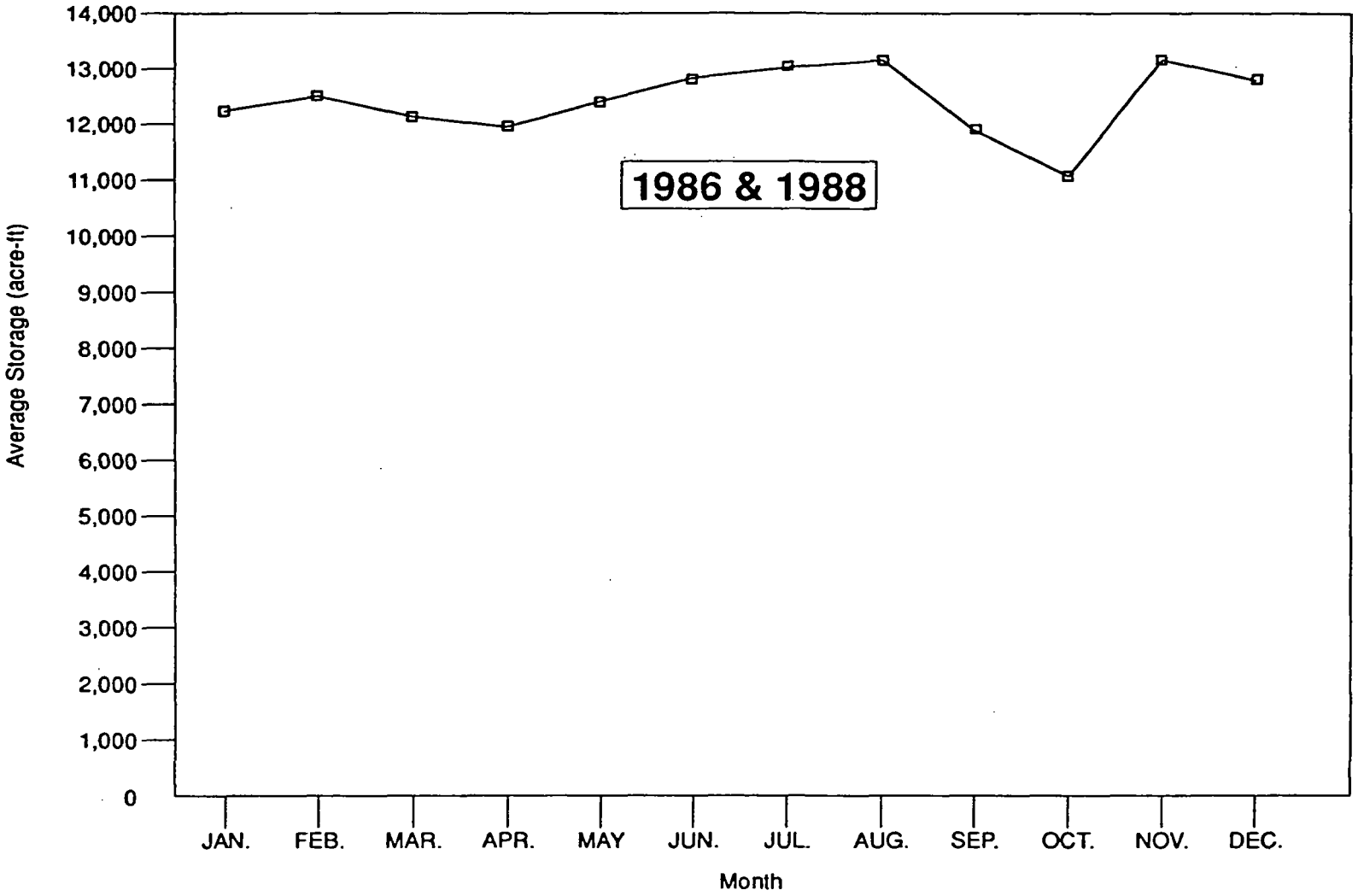
FIGURE **3-4**

MONTHLY AVERAGE FLOW IN BEAR RIVER AT SODA SPRINGS

MONSANTO/PHASE 1 RI REPORT/ID

PROJECT NO. 913 1101.212 DRAWING NO. 27797 DATE 4/8/92 DRAWN BY TB

Golder Associates



SOURCE: USGS data as presented by EarthInfo (1991).

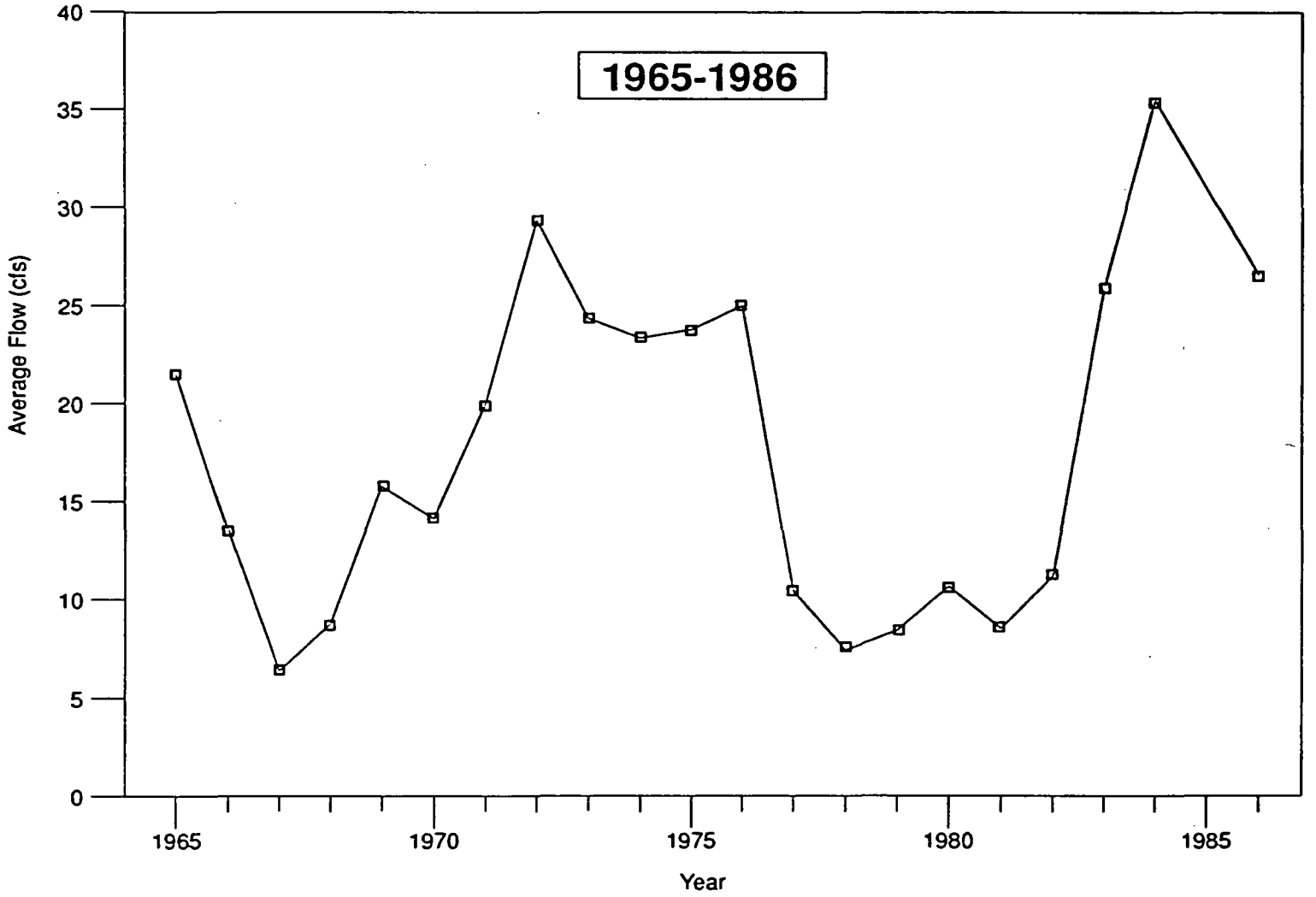
FIGURE **3-5**

MONTHLY AVERAGE STORAGE IN ALEXANDER RESERVOIR

MONSANTO/PHASE 1 RI REPORT/ID

PROJECT NO. 913 1101.212 DRAWING NO. 27782 DATE 4-5-92 DRAWN BY TB

Golder Associates



SOURCE: USGS data as presented by EarthInfo (1991).

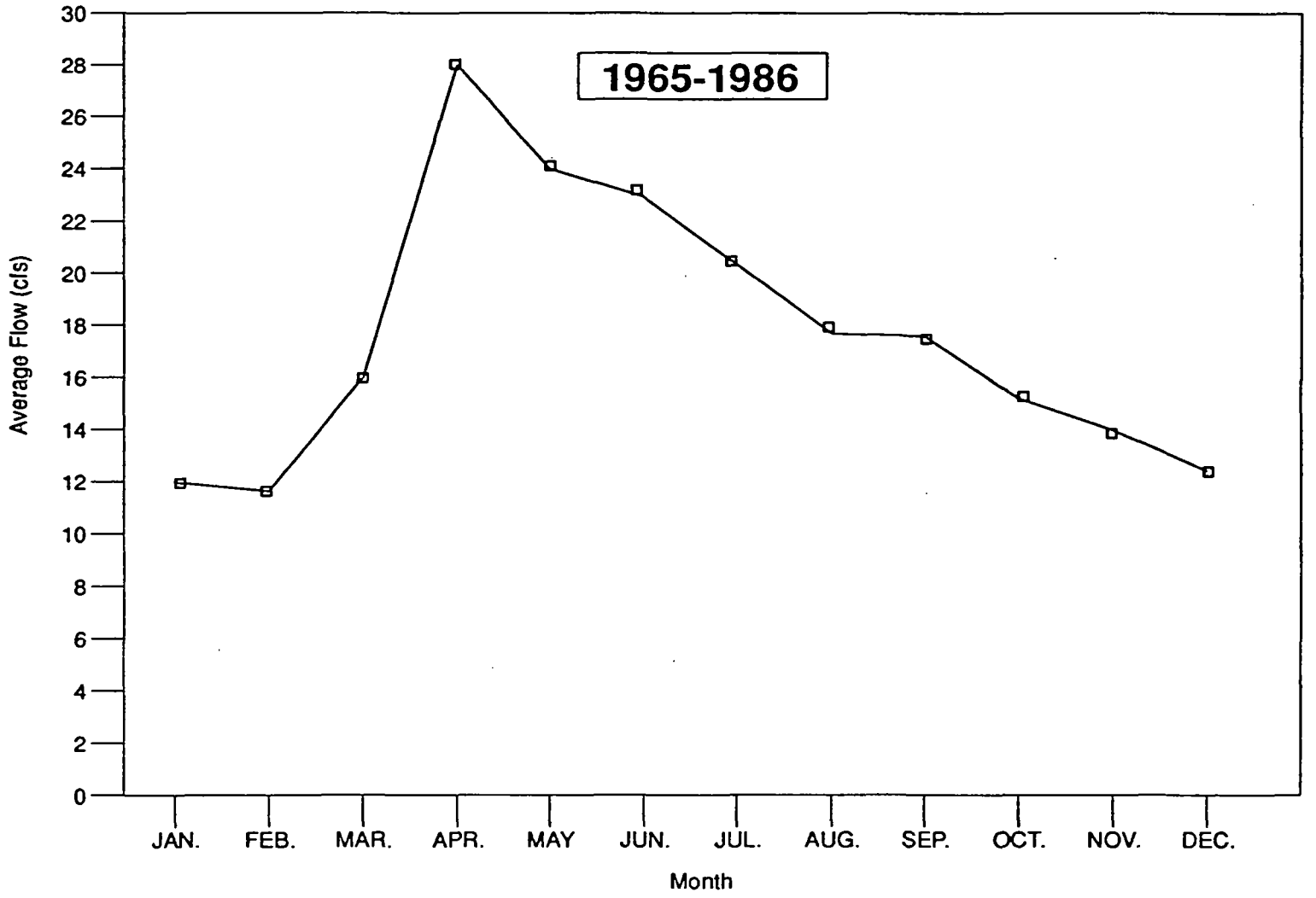
FIGURE **3-6**

YEARLY AVERAGE FLOW IN SODA CREEK AT FIVEMILE MEADOWS

MONSANTO/PHASE 1 RI REPORT/ID

PROJECT NO. 913 1101.212 DRAWING NO. 27790 DATE 4/8/92 DRAWN BY TB

Golder Associates



SOURCE: USGS data as presented by EarthInfo (1991).

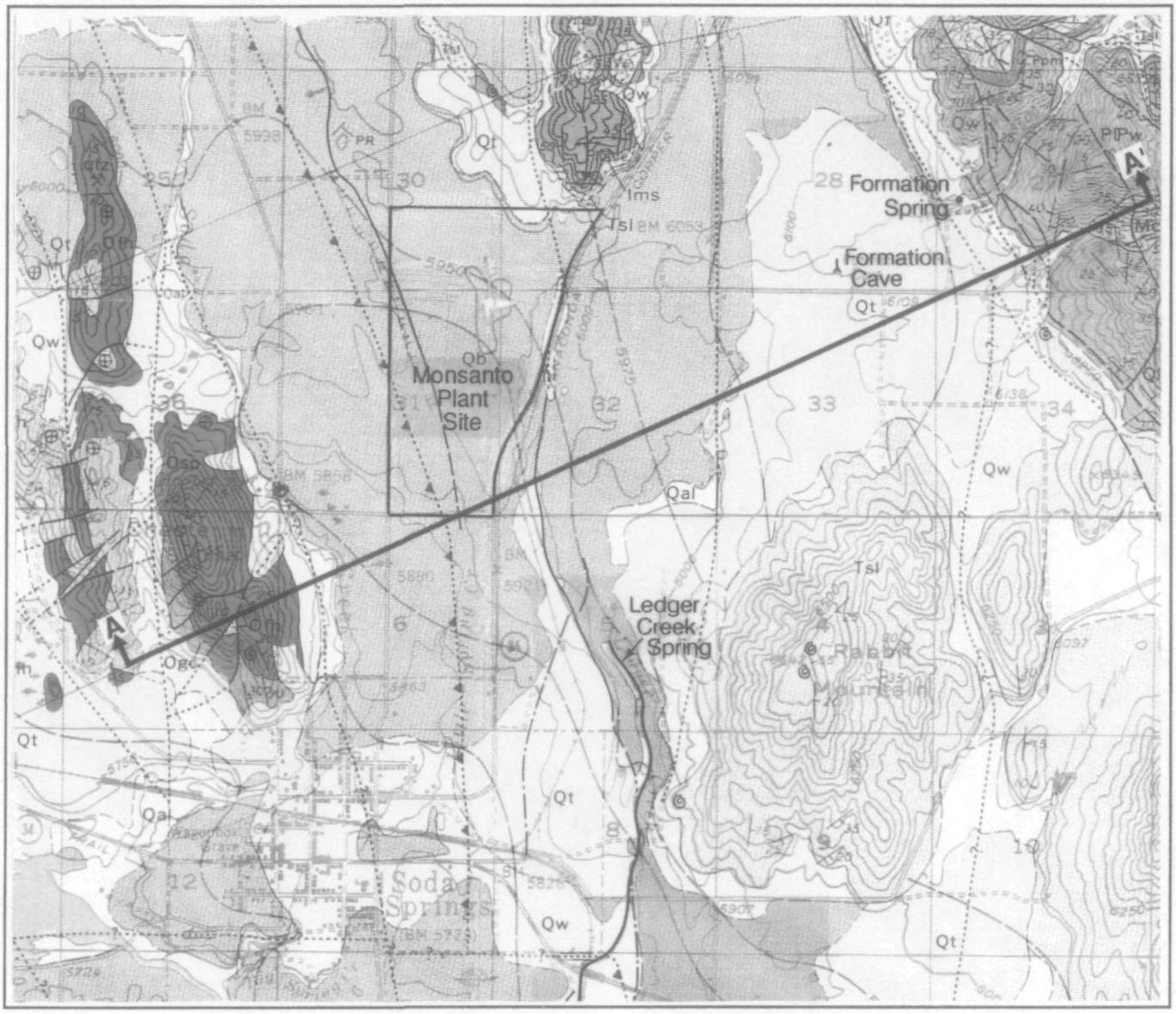
FIGURE **3-7**

MONTHLY AVERAGE FLOW IN SODA CREEK AT FIVEMILE MEADOWS

MONSANTO/PHASE 1 RI REPORT/ID

PROJECT NO. 913 1101.212 DRAWING NO. 27791 DATE 4/8/92 DRAWN BY TB

Golder Associates



EXPLANATION

STRATIGRAPHY

Qal,Qf,Qls	Gravel, sand, and silt	Quaternary
Qt	Calcareous tufa and travertine	Quaternary
Qw	Sand, gravel, and silt	Quaternary
Qb	Olivine basalt	Quaternary
Tsl	Salt Lake Formation	Tertiary
TRt	Thaynes Formation	Triassic
PPw	Wells Formation	Carboniferous
Mc	Chesterfield Range	Carboniferous
Ofh	Fish Haven Dolomite	Ordivician
Osp	Swan Peak Quartzite	Ordivician

Contact

Fault
dashed where approximate or inferred; dotted where covered; queried where doubtful

Concealed thrust fault
sawteeth on side of upper plate

Linear feature on photograph
may coincide with or be extensions of mapped faults; all are interpreted as faults

Monsanto Plant Site

5975 Approximate altitude of piezometric surface (1969) (*taken in part from USGS Water-Supply Papers Nos. 774 and 775*)

N

0 1
MILE

SOURCE: Modified from Geologic Map of the Soda Springs Quadrangle, Armstrong (1969).

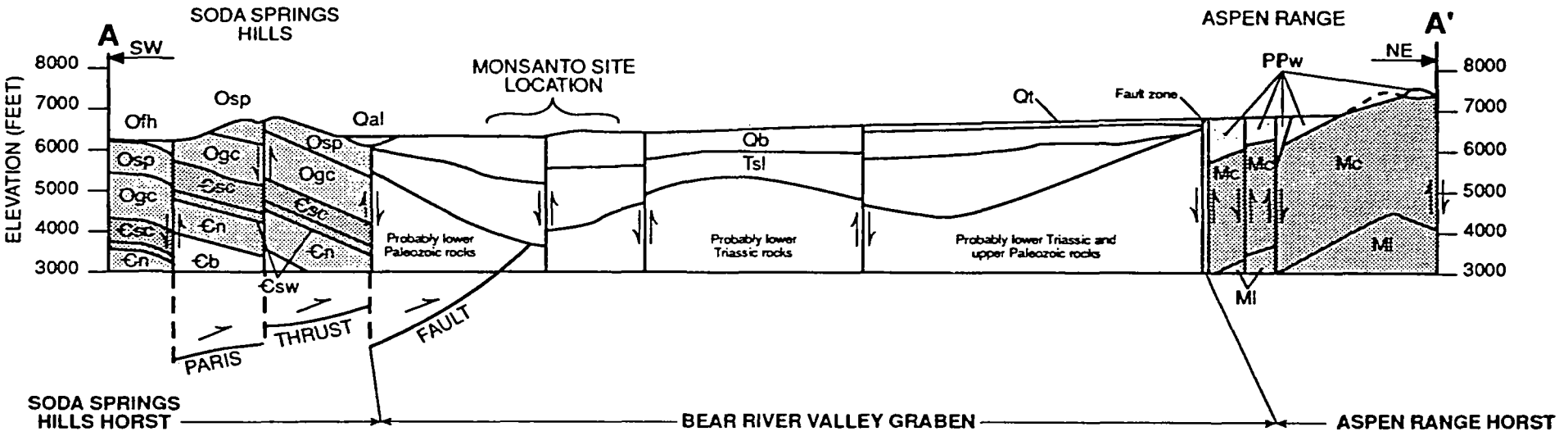
FIGURE **3-8**

REGIONAL GEOLOGIC MAP

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO. 913-1101.212 DRAWING NO. 27853 DATE 3/26/92 DRAWN BY TB

Golder Associates



EXPLANATION

Qal - Alluvium
Qt - Calcareous tufa and travertine
Qb - Olivine Basalt
Tsl - Salt Lake Formation
PPw - Wells Formation and Associated Rocks
Mc - Chesterfield Range Group
Ml - Lodgepole Limestone
Ofh - Fish Haven Dolomite
Osp - Swan Peak Quartzite
Ꞓgc - Garden City Limestone
Ꞓsc - St. Charles Formation
Ꞓsw - St. Charles Formation
Ꞓn - Nounon Limestone
Cb - Bloomington Formation

Note: Modified from Armstrong (1969).

FIGURE **3-9**
REGIONAL GEOLOGIC CROSS SECTION ALONG LINE A-A'
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO. 913-1101.212 DRAWING NO. 27789 DATE 3/6/92 DRAWN BY TB

Golder Associates

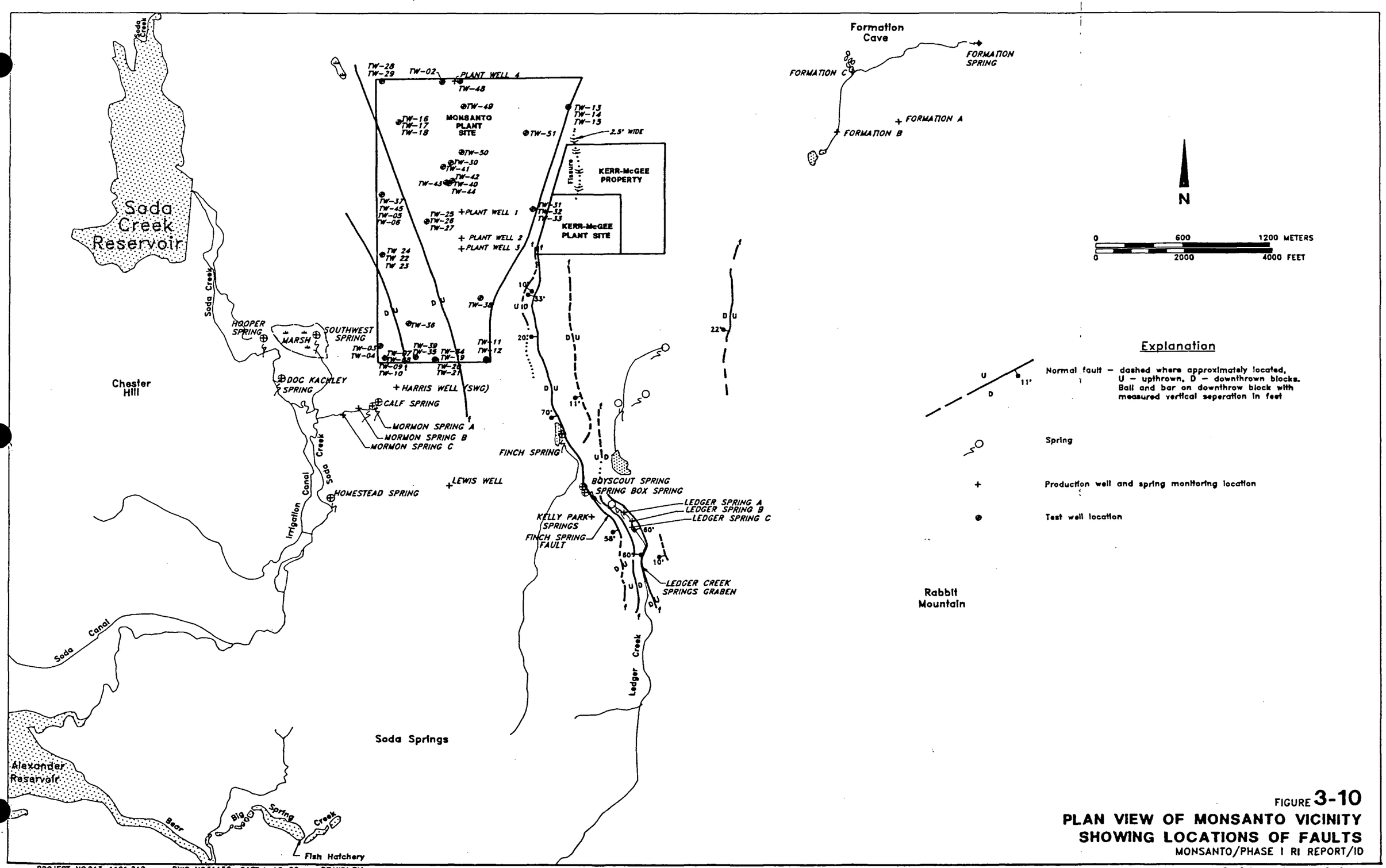


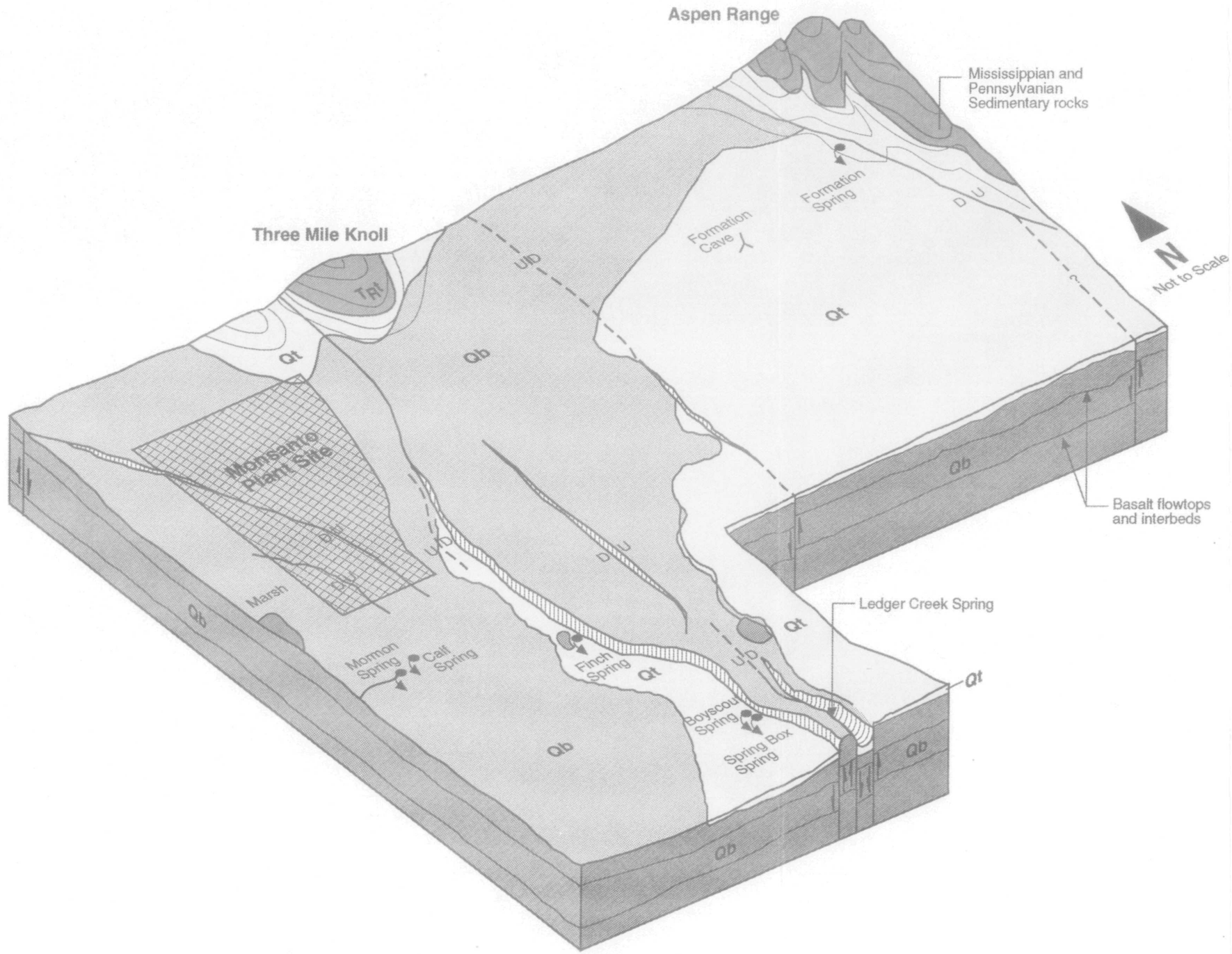
FIGURE 3-10

PLAN VIEW OF MONSANTO VICINITY SHOWING LOCATIONS OF FAULTS

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO 31156 DATE 4-10-92 DRAWN PM

Golder Associates



Explanation

Qt	Tufa and Travertine
Qb	Blackfoot Lava Field Basalts
$T_R t$	Thaynes Limestone

See Figure 3-10 for plan view of faults.

Source: Geology modified from Armstrong (1969) based on field reconnaissance.

FIGURE **3-11**

LOCAL STRUCTURE BLOCK DIAGRAM

MONSANTO/PHASE 1 RI REPORT/ID

PROJECT NO. 913 1101.212 DRAWING NO. 28212 DATE 4/15/92 DRAWN BY CB

Golder Associates

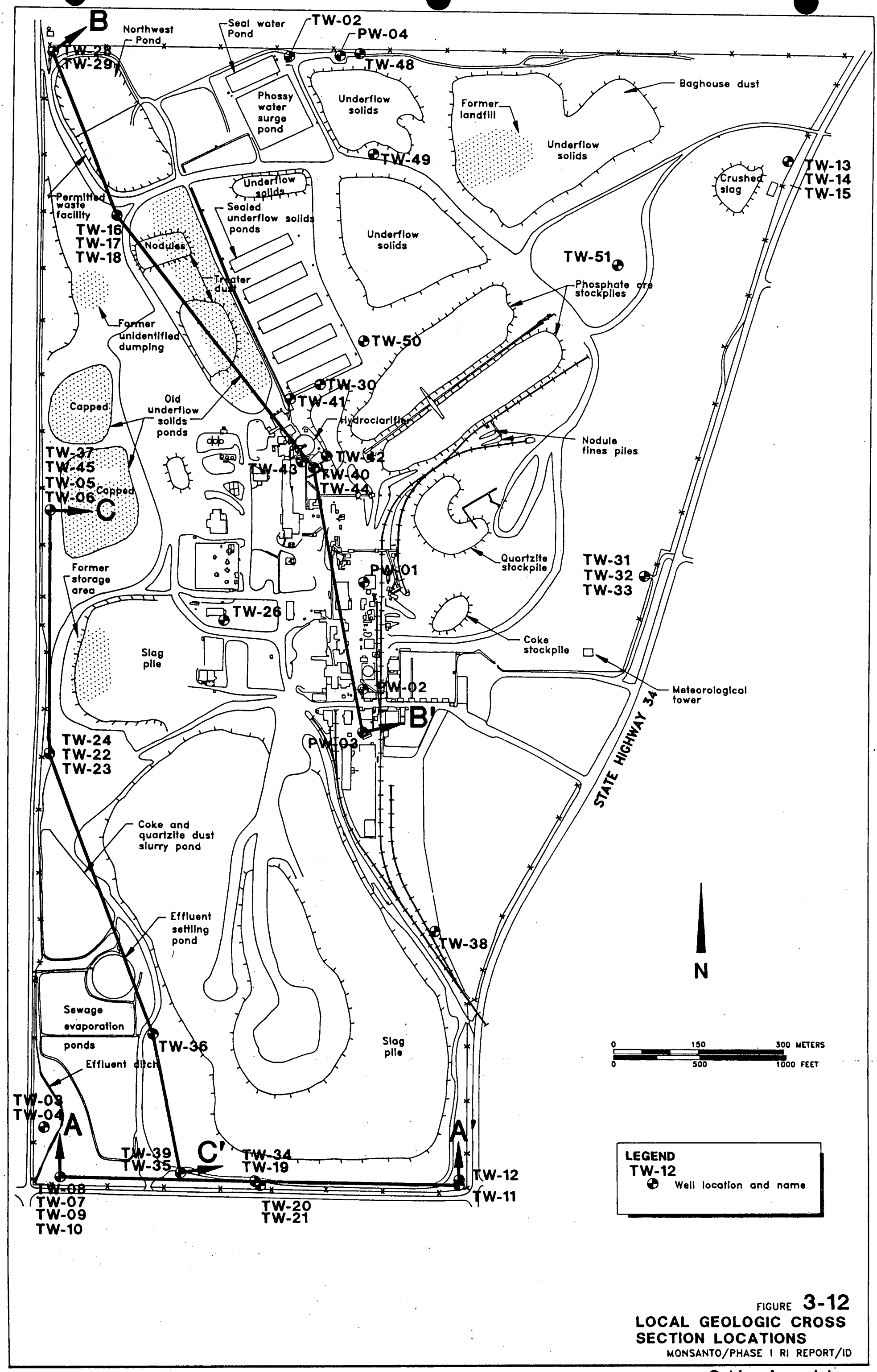
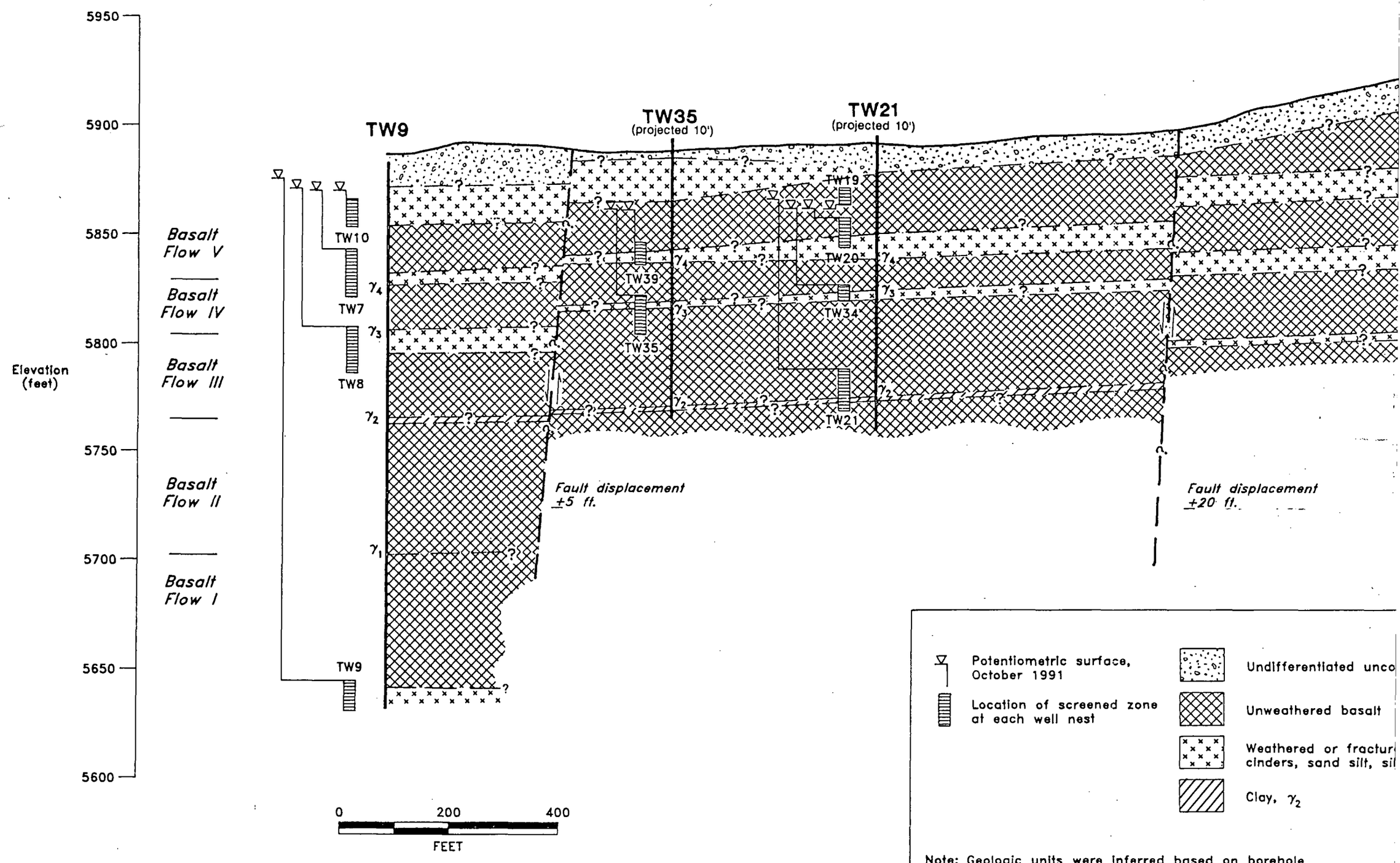


FIGURE 3-12
LOCAL GEOLOGIC CROSS SECTION LOCATIONS
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO 31331 DATE 4-9-92 DRAWN JSS

Golder Associates

A
WEST



Note: Geologic units were inferred based on borehole information only. Actual conditions between boreholes may differ significantly from information shown on this cross section.

SOURCE: Golder (1985, 1987, 1988a, and 1988b)

PROJECT NO 913-1101.212 DWG NO 31297 DATE 3-30-92 DRAWN JRS

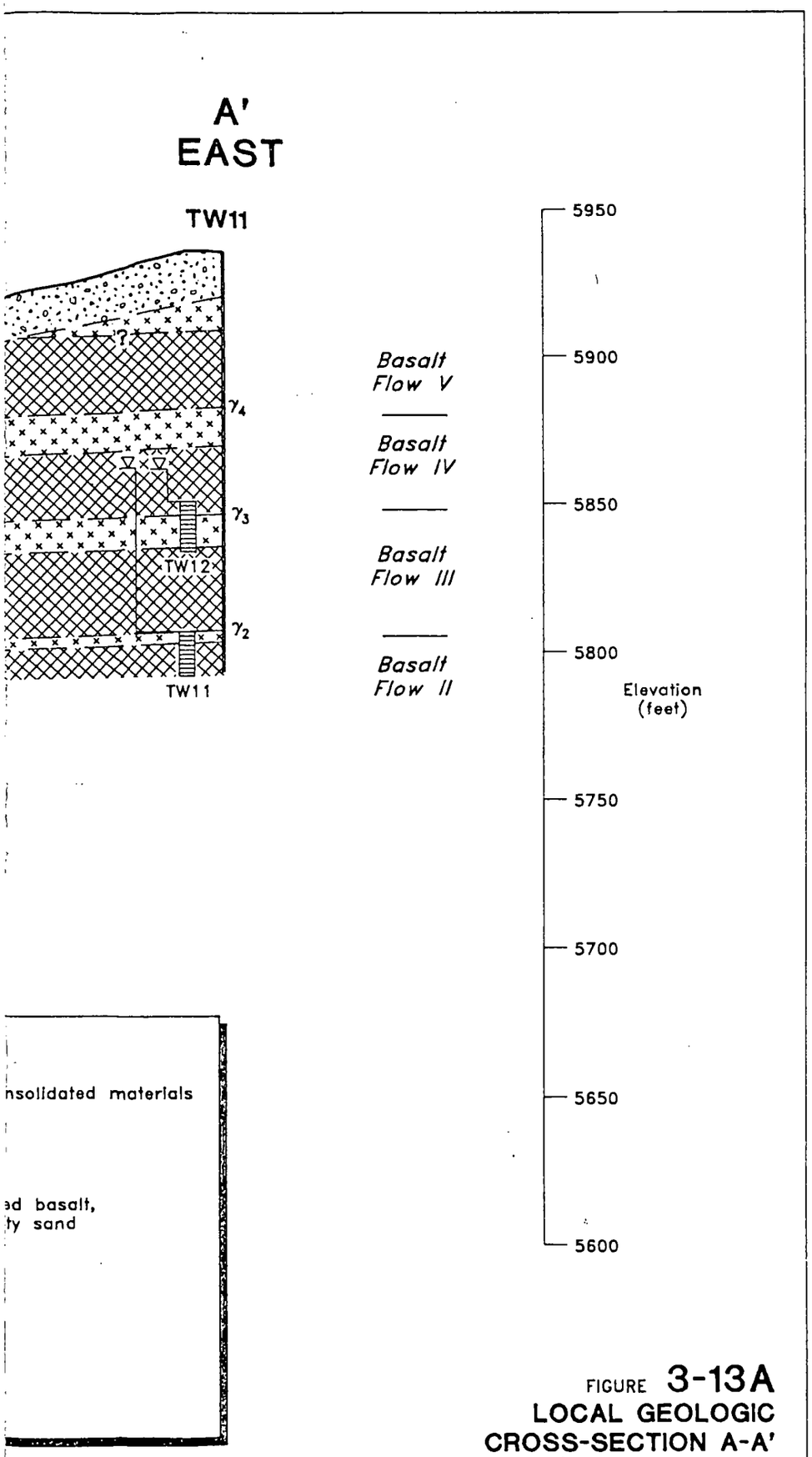
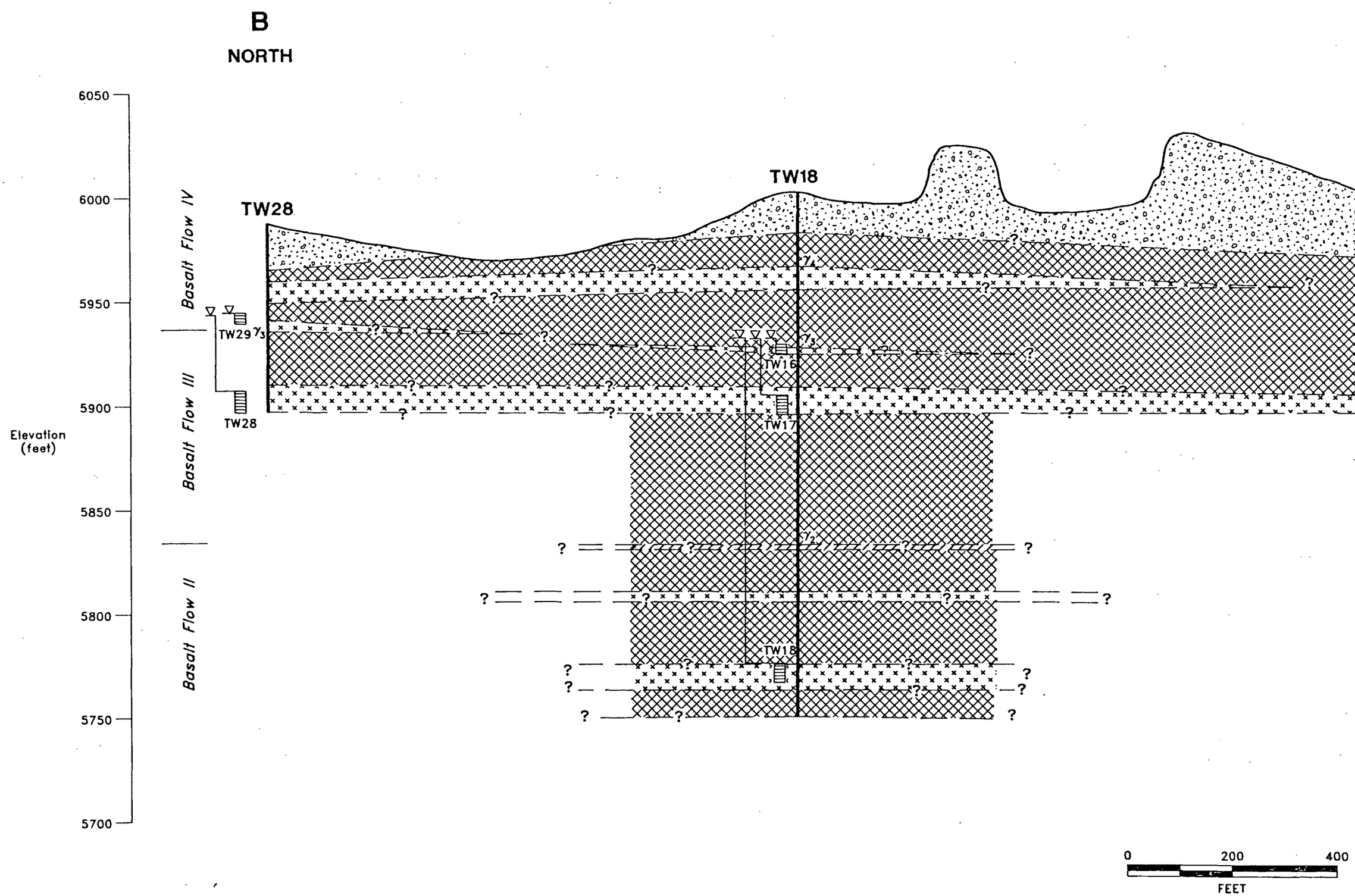


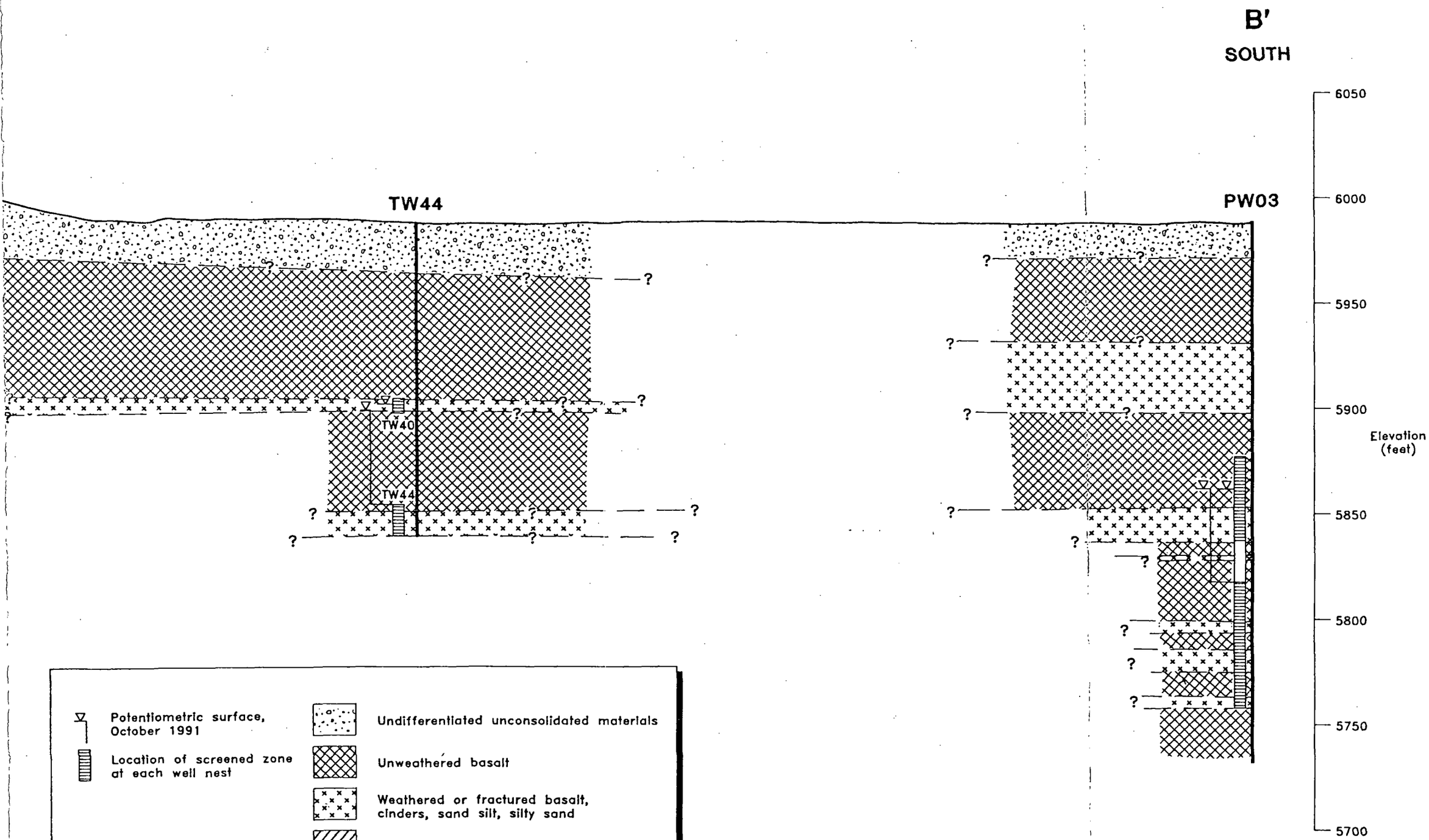
FIGURE 3-13A
LOCAL GEOLOGIC
CROSS-SECTION A-A'
MONSANTO/PHASE I RI REPORT/ID

Golder Associates



SOURCE: Golder (1985, 1987, 1988a, and 1988b)

PROJECT NO 913-1101.212 DWG NO 31295 DATE 3-30-92 DRAWN JRS



Potentiometric surface, October 1991

Location of screened zone at each well nest

Undifferentiated unconsolidated materials

Unweathered basalt

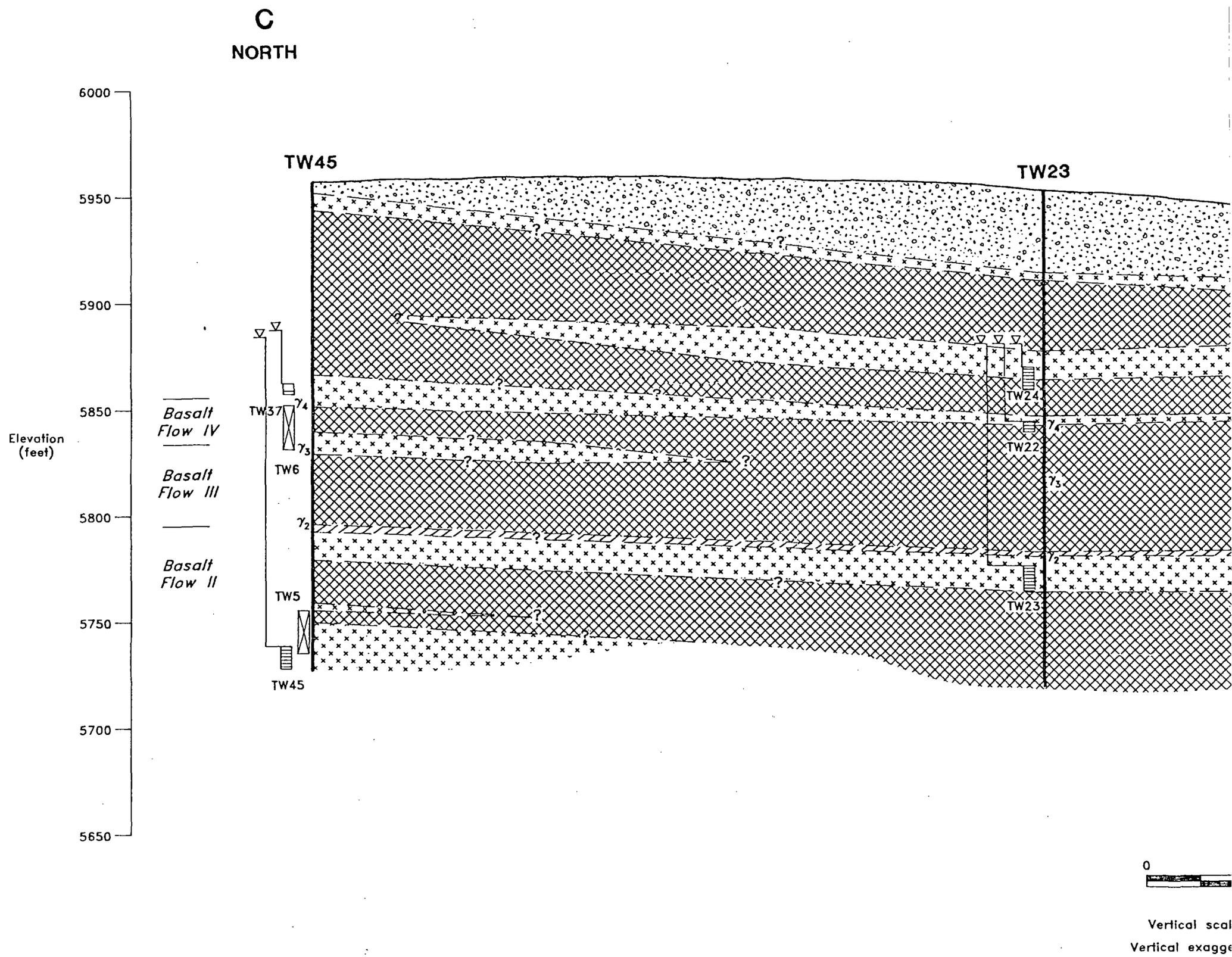
Weathered or fractured basalt, cinders, sand silt, silty sand

Clay, γ_2

Note: Geologic units were inferred based on borehole information only. Actual conditions between boreholes may differ significantly from information shown on this cross section.

FIGURE 3-13B
LOCAL GEOLOGIC CROSS-SECTION B-B'
MONSANTO/PHASE I RI REPORT/ID

Golder Associates



SOURCE: Golder (1985, 1987, 1988a, and 1988b)

PROJECT NO 913-1101.212 DWG NO 31296 DATE 3-30-92 DRAWN JRS

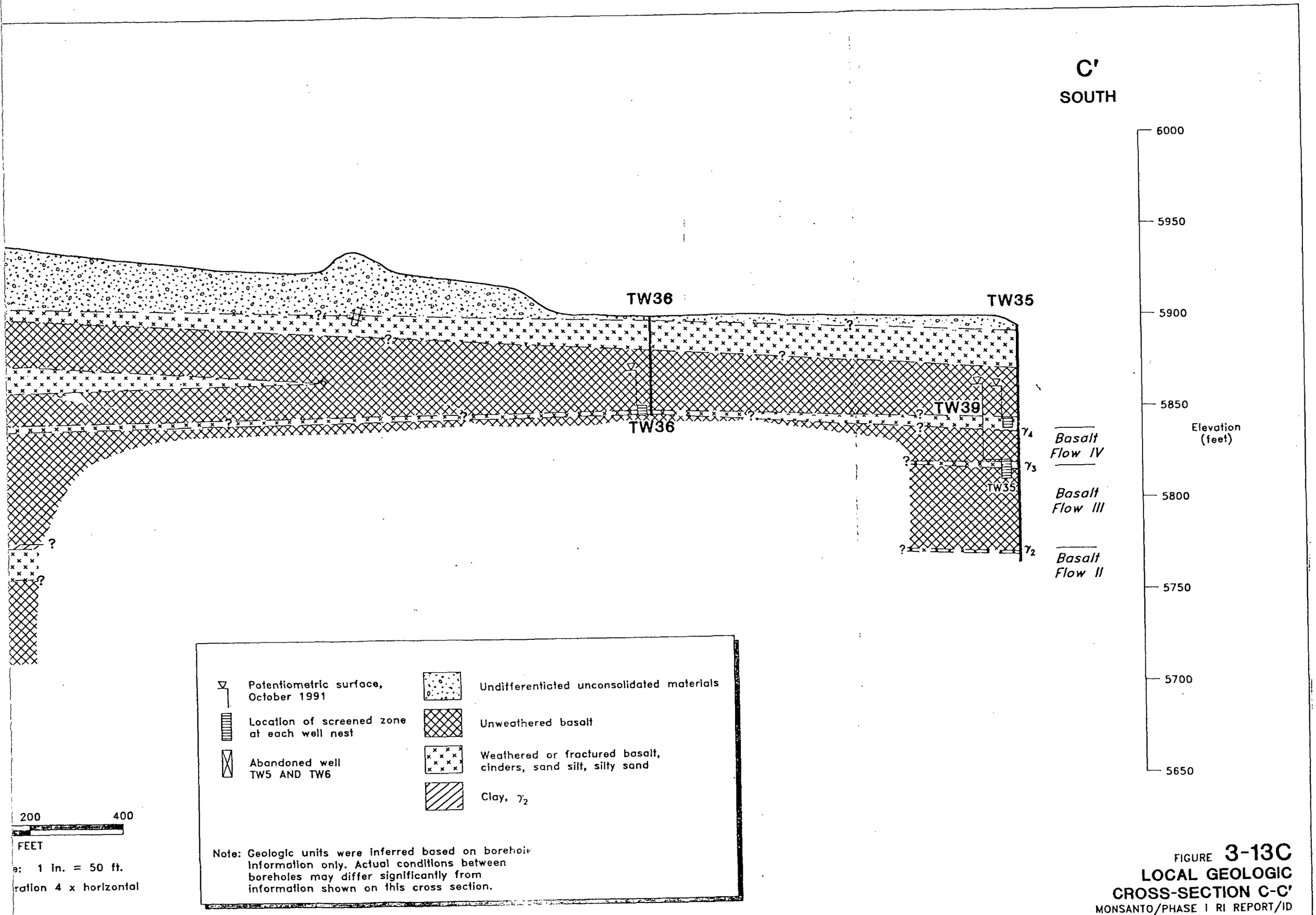
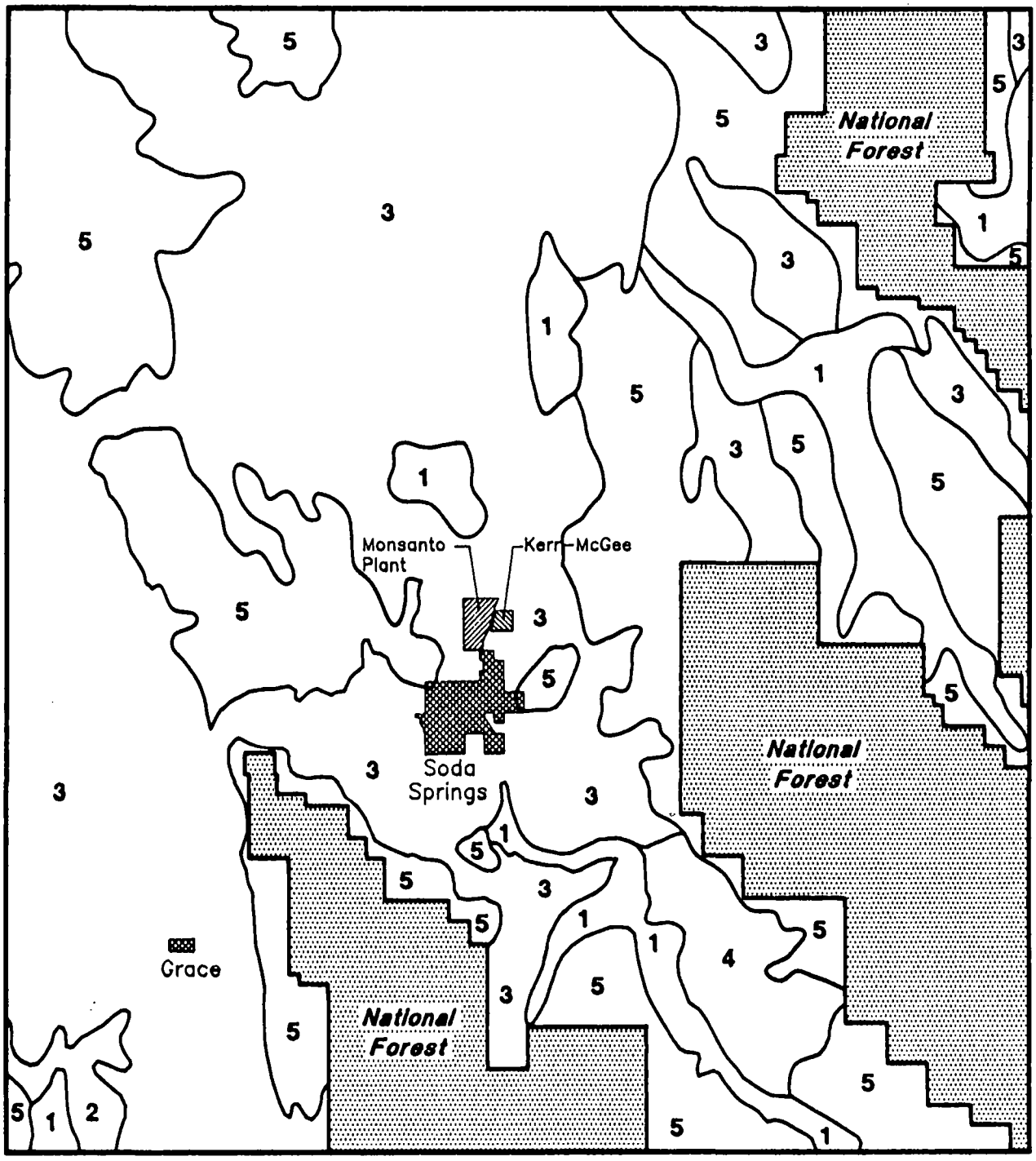


FIGURE 3-13C
LOCAL GEOLOGIC CROSS-SECTION C-C'
MONSANTO/PHASE I RI REPORT/ID

Golder Associates



Soil Group	Description
1	Nearly level soils on flood plains and low stream terraces
2	Gently sloping to steep soils on lake terraces and terrace breaks
3	Nearly level to gently rolling soils on basalt plains and alluvial plains
4	Nearly level to moderately steep soils on fan terraces and hill slopes
5	Sloping to steep soils on mountain sides and hill slopes

0 6000 12000 METERS
0 20000 40000 FEET

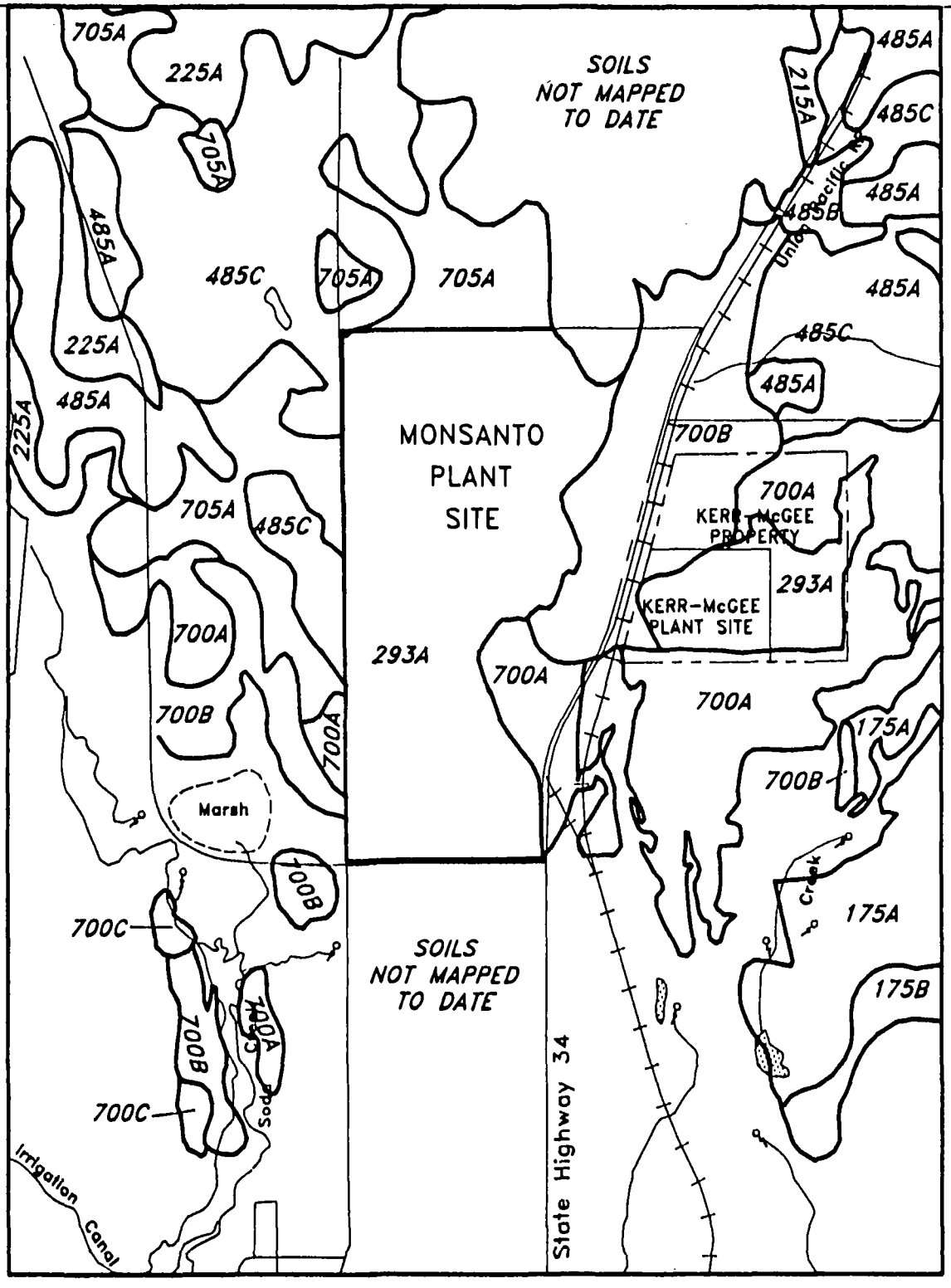
N

Modified from USDA Soil Conservation Service preliminary general soils map of Caribou County (1991).

FIGURE 3-14
GENERAL SOILS MAP
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO 31125 DATE 3-31-92 DRAWN AG

Golder Associates



Legend

175A Chinhill silt loam, 1-to-4% slopes
175B Chinhill silt loam, 4-to-12% slopes
225A Crow Creek-Rin Complex, 4-to-12% slopes
293A Dumps, Mine
485A Lantonia - Chinahat Complex, 1-to-4% slopes
485B Lantonia - Corral Creek Complex, 1-to-4% slopes
485C Lantonia - Crow Creek Complex, 4-to-12% slopes
700A Rexburg - Ririe Complex, 1-to-4% slopes
700B Rexburg - Ririe Complex, 4-to-8% slopes
700C Rexburg - Ririe Complex, 8-to-12% slopes
705A Rin - Lantonia Complex, 1-to-4% slopes

Modified from USDA Soil Conservation Service preliminary soils map of Caribou County (1991).

N

0 2000 4000
SCALE IN FEET

FIGURE **3-15**
SOIL TYPES IN THE MONSANTO PLANT VICINITY
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO 31176 DATE 4-8-92 DRAWN JSS

Golder Associates

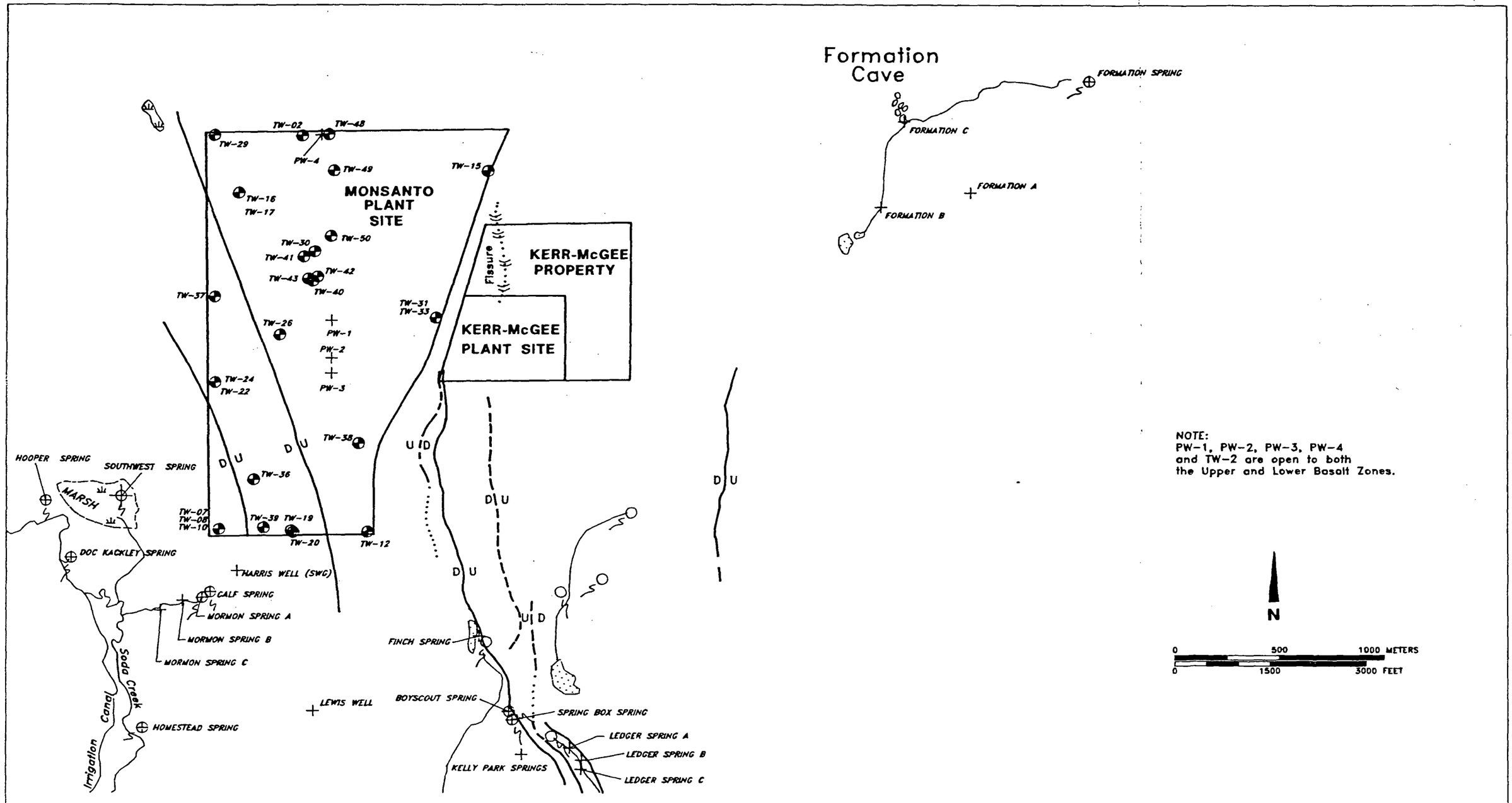


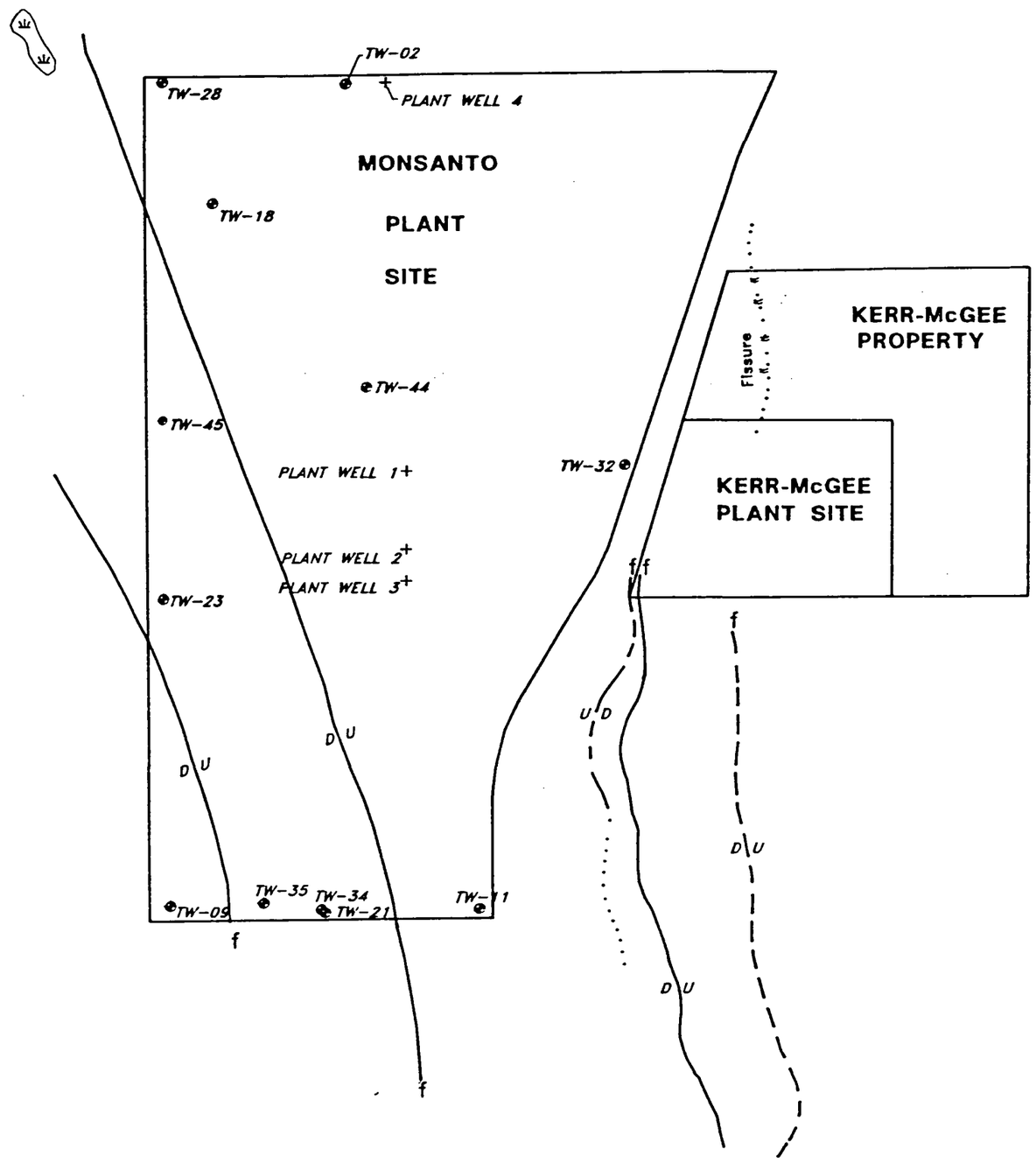
FIGURE **3-16**

LOCATION OF WELLS & SPRINGS IN THE UPPER BASALT ZONE

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101/212 DWG NO 31656 DATE 4-9-92 DRAWN PM/JSS

Golder Associates



NOTE:
PW-1, PW-2, PW-3, PW-4
and TW-2 are open to both
the Upper and Lower Basalt Zones.

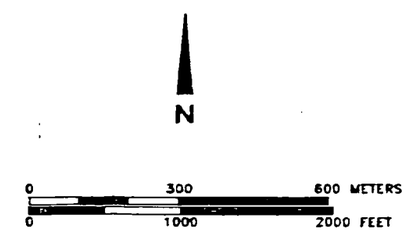


FIGURE **3-17**
LOCATION OF WELLS IN THE LOWER BASALT ZONE
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101\207 DWG NO 31628 DATE 4-9-92 DRAWN PM

Golder Associates

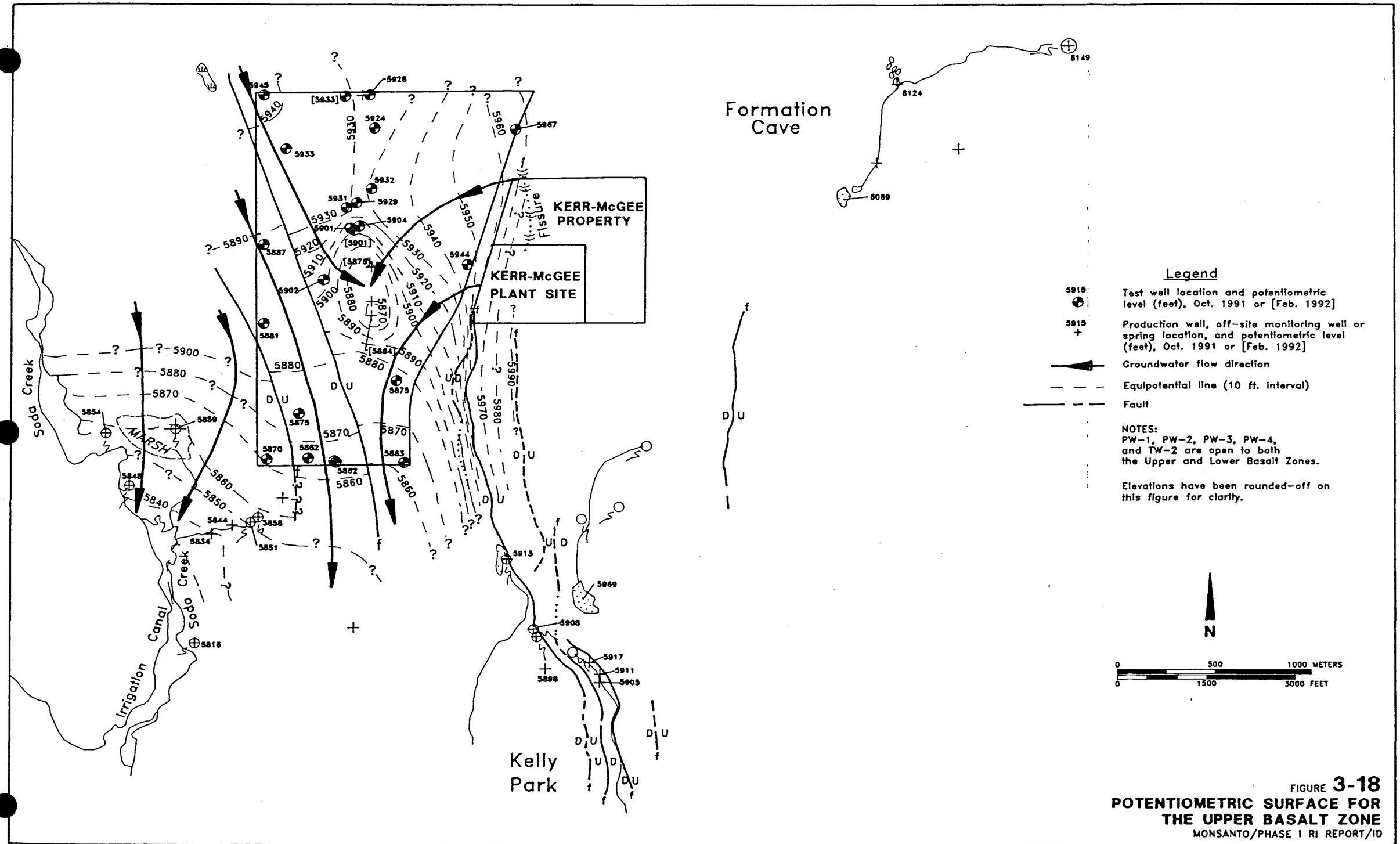
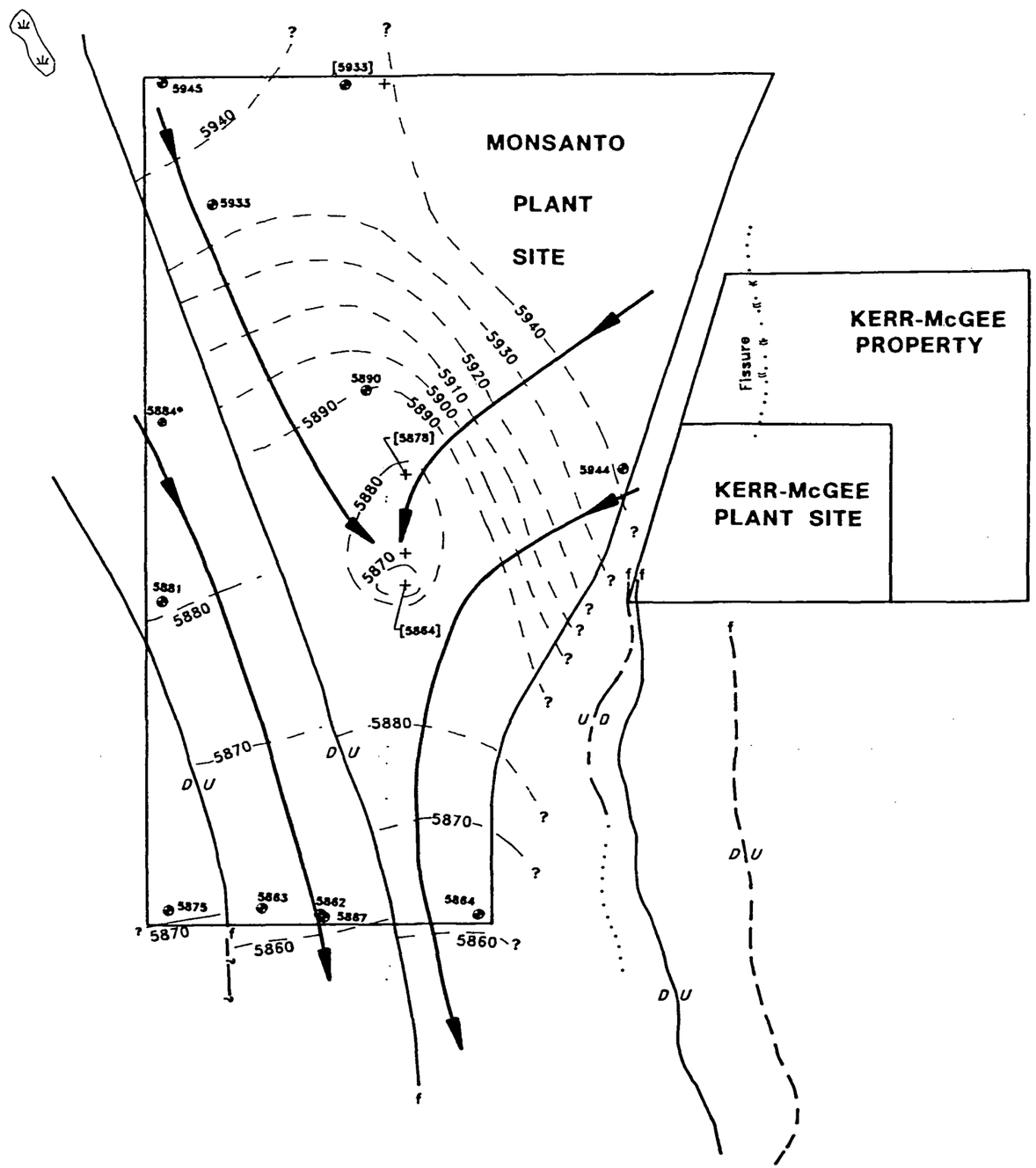


FIGURE 3-18
POTENTIOMETRIC SURFACE FOR THE UPPER BASALT ZONE
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101/212 DWG NO 31718 DATE 4-9-92 DRAWN PM

Golder Associates



Legend

5915 ◕	Test well location and potentiometric level (feet), Oct. 1991 or [Feb. 1992]
5915 +	Production well location and potentiometric level (feet), Oct. 1991 or [Feb. 1992]
▬▶	Groundwater flow direction
— — —	Equipotential line (10 ft. interval)
—— — —	Fault

NOTES:
PW-1, PW-2, PW-3, PW-4, and TW-2 are open to both the Upper and Lower Basalt Zones.

Elevations have been rounded-off on this figure for clarity.

* – Value is approximate.

N

0 300 600 METERS
0 1000 2000 FEET

FIGURE **3-19**
POTENTIOMETRIC SURFACE FOR THE LOWER BASALT ZONE
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101\212 DWG NO 31717 DATE 4-10-92 DRAWN PM

Golder Associates

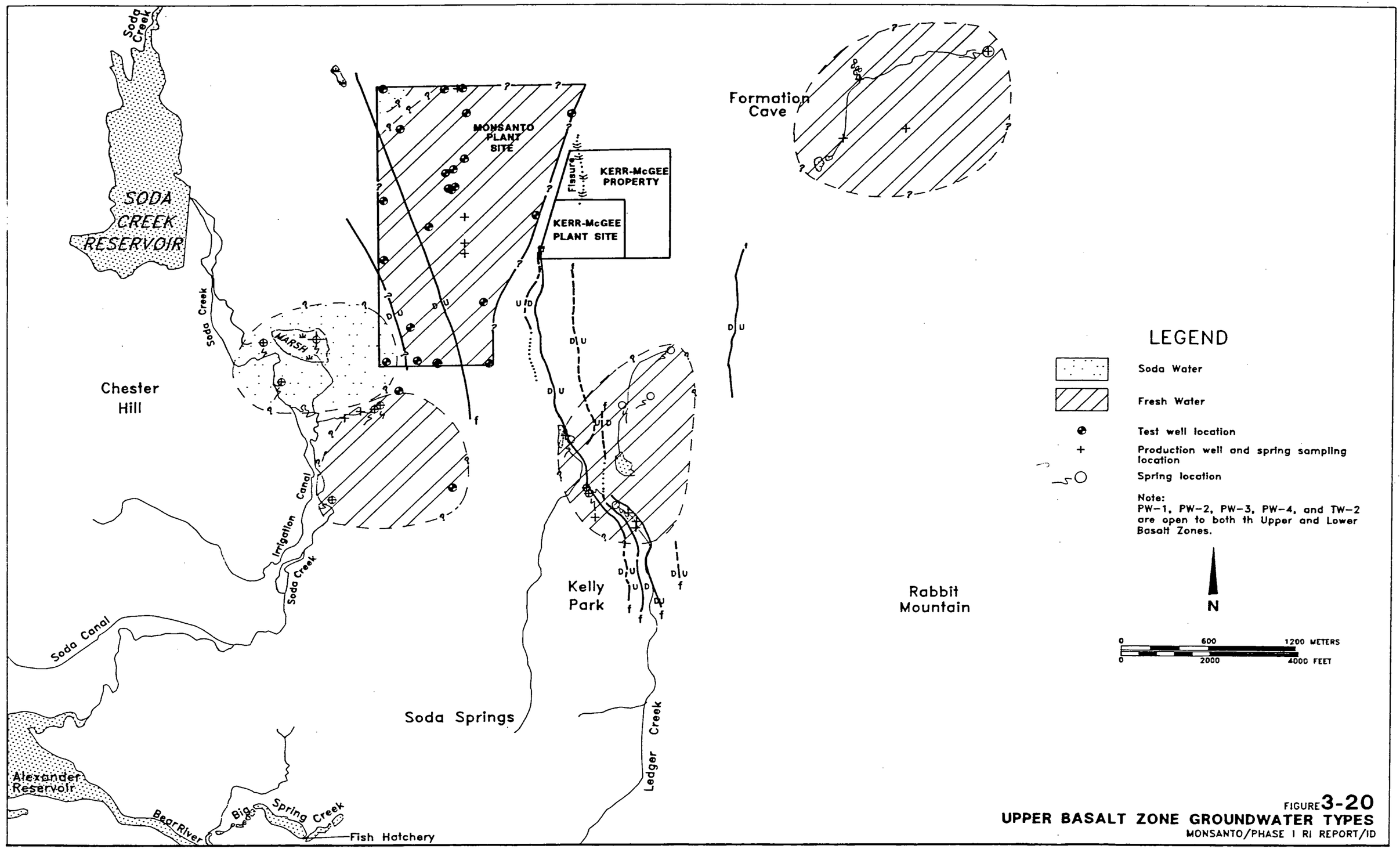


FIGURE 3-20
UPPER BASALT ZONE GROUNDWATER TYPES
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101/212 DWG NO 31696 DATE 4-10-92 DRAWN JRS

Golder Associates

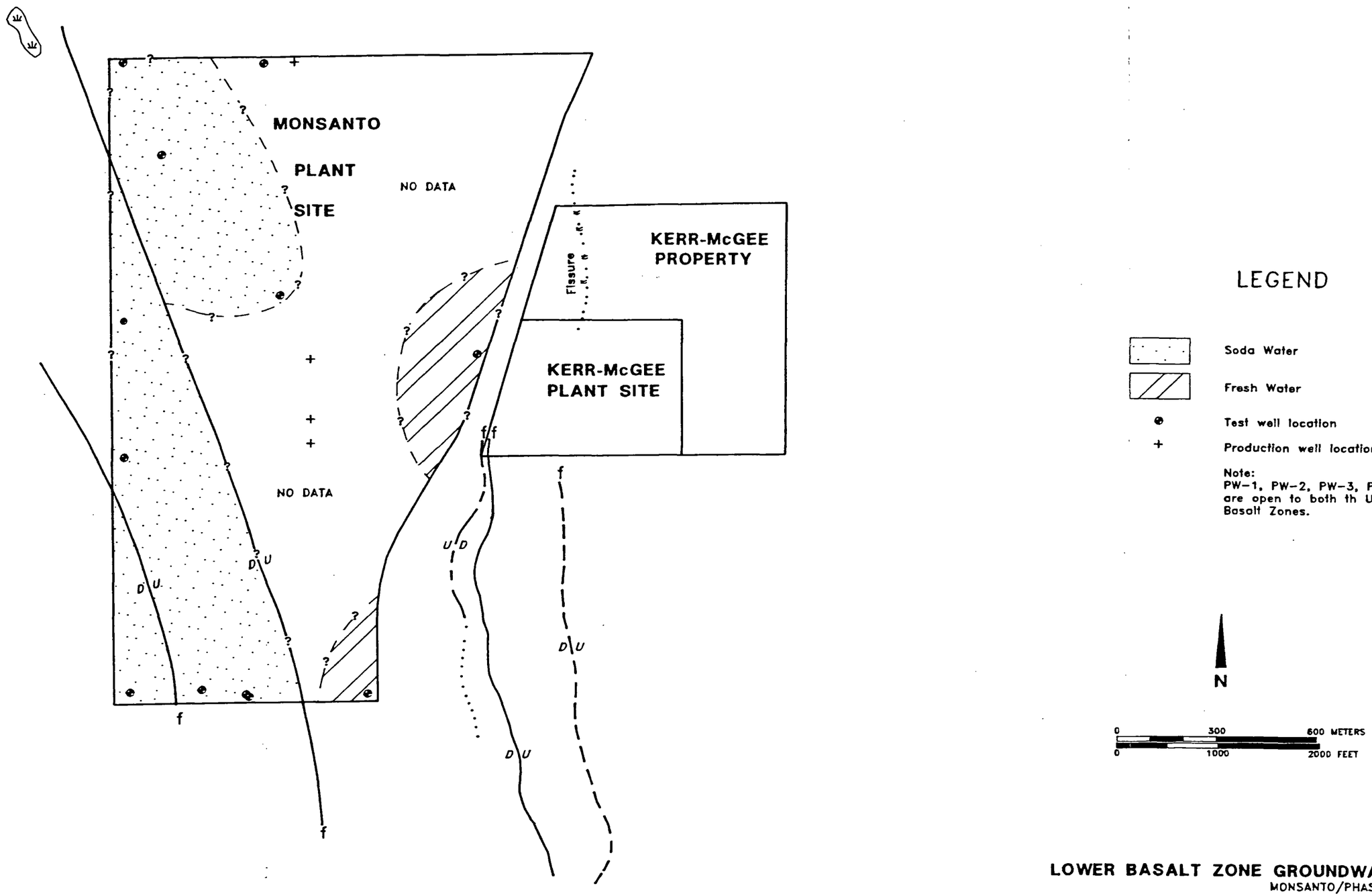


FIGURE **3-21**

LOWER BASALT ZONE GROUNDWATER TYPES

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101\212 DWG NO 31695 DATE 4-9-92 DRAWN PM

Golder Associates

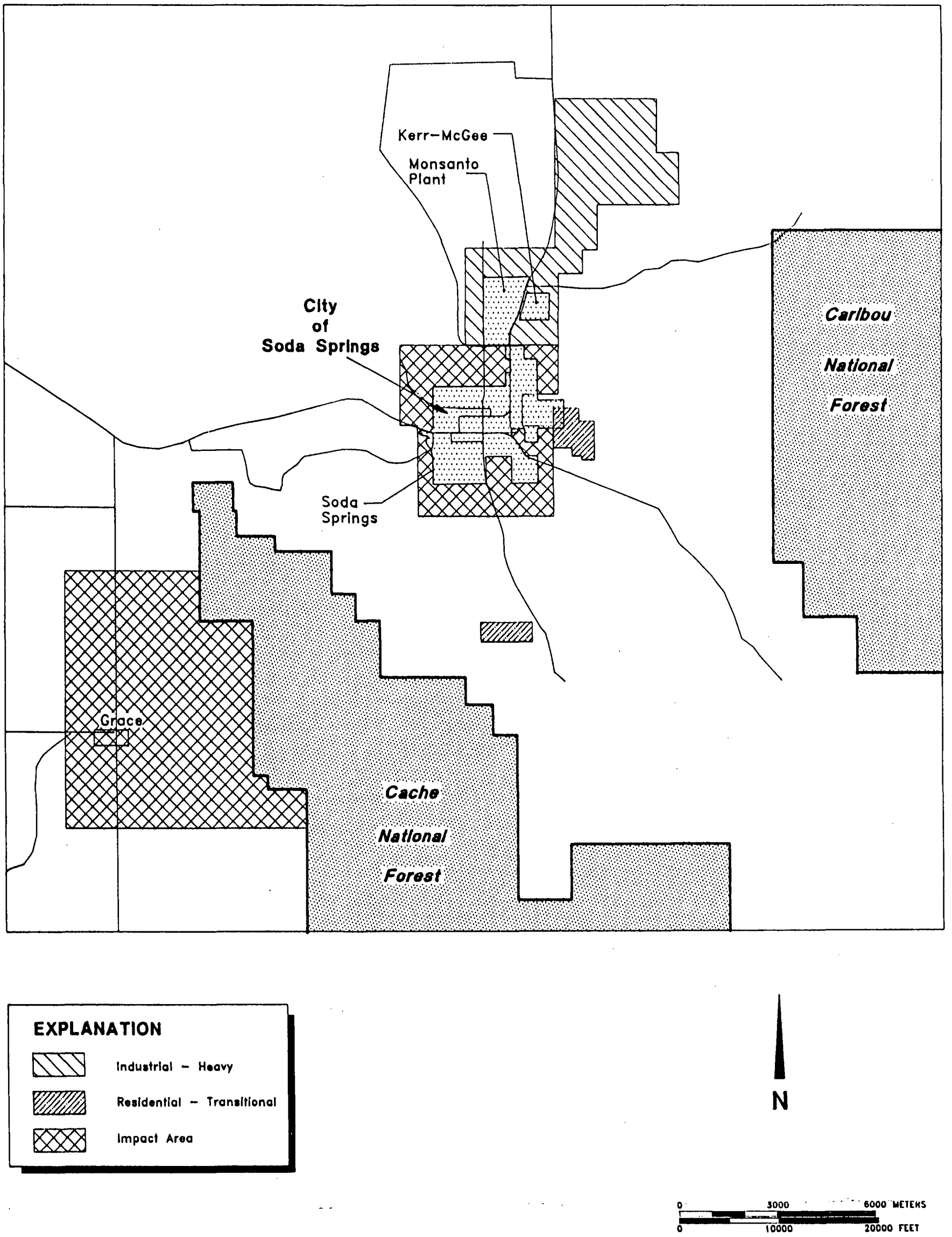
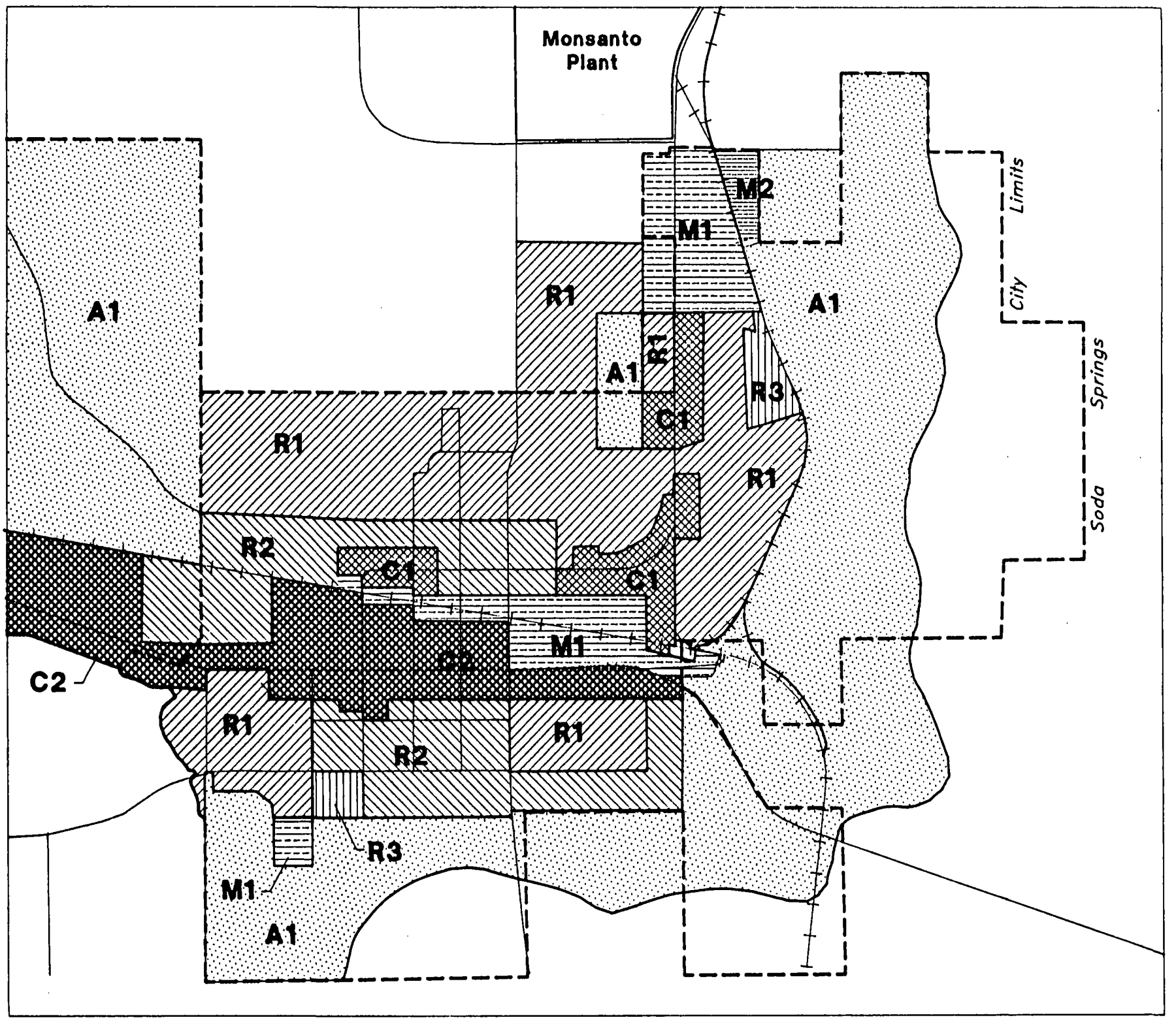


FIGURE 3-22
LAND USE MAP FOR CARIBOU COUNTY
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO 31586 DATE 4-8-92 DRAWN AG

Golder Associates



EXPLANATION

A1	Agricultural
C1	Commercial – Neighborhood
C2	Commercial – Community
M1	Industrial – Light
M2	Industrial – Heavy
R1	Residential – Single Family
R2	Residential – Combined
R3	Residential – Multiple Family

N

0 600 1200 METERS
0 2000 4000 FEET

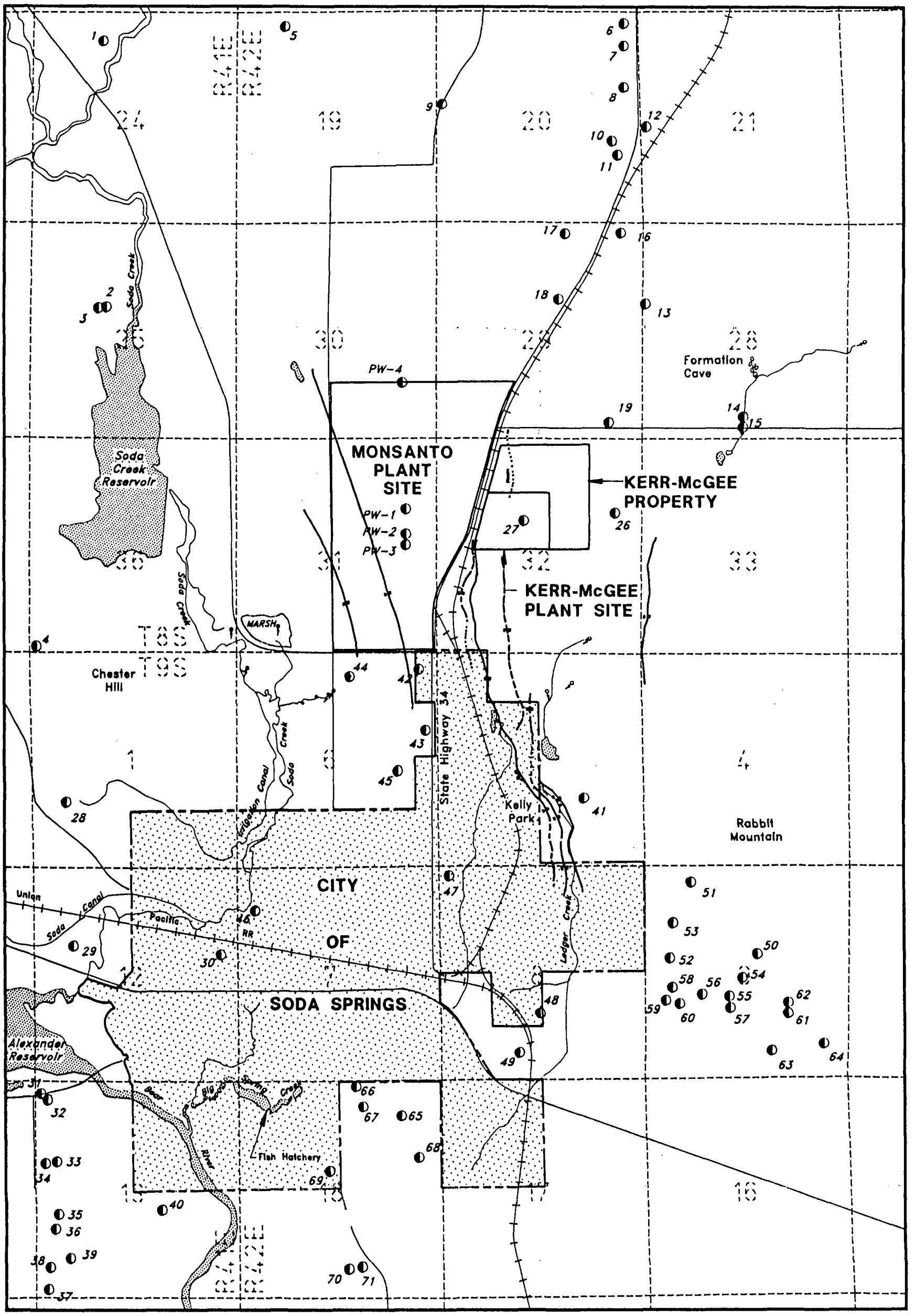
FIGURE 3-23

LAND USE MAP FOR THE CITY OF SODA SPRINGS

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO 31585 DATE 4-9-92 DRAWN AG

Golder Associates



N

0 750 1500 METERS
0 2500 5000 FEET

LEGEND

City of Soda Springs boundary

Section lines

Section number

Potential receptor-well location and designation

Note: Receptor-well inventory does not include the monitoring wells on the Monsanto PLant.

FIGURE 3-24
MONSANTO PLANT VICINITY WELL INVENTORY
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO 36474 DATE 4-10-92 DRAWN AG

Golder Associates

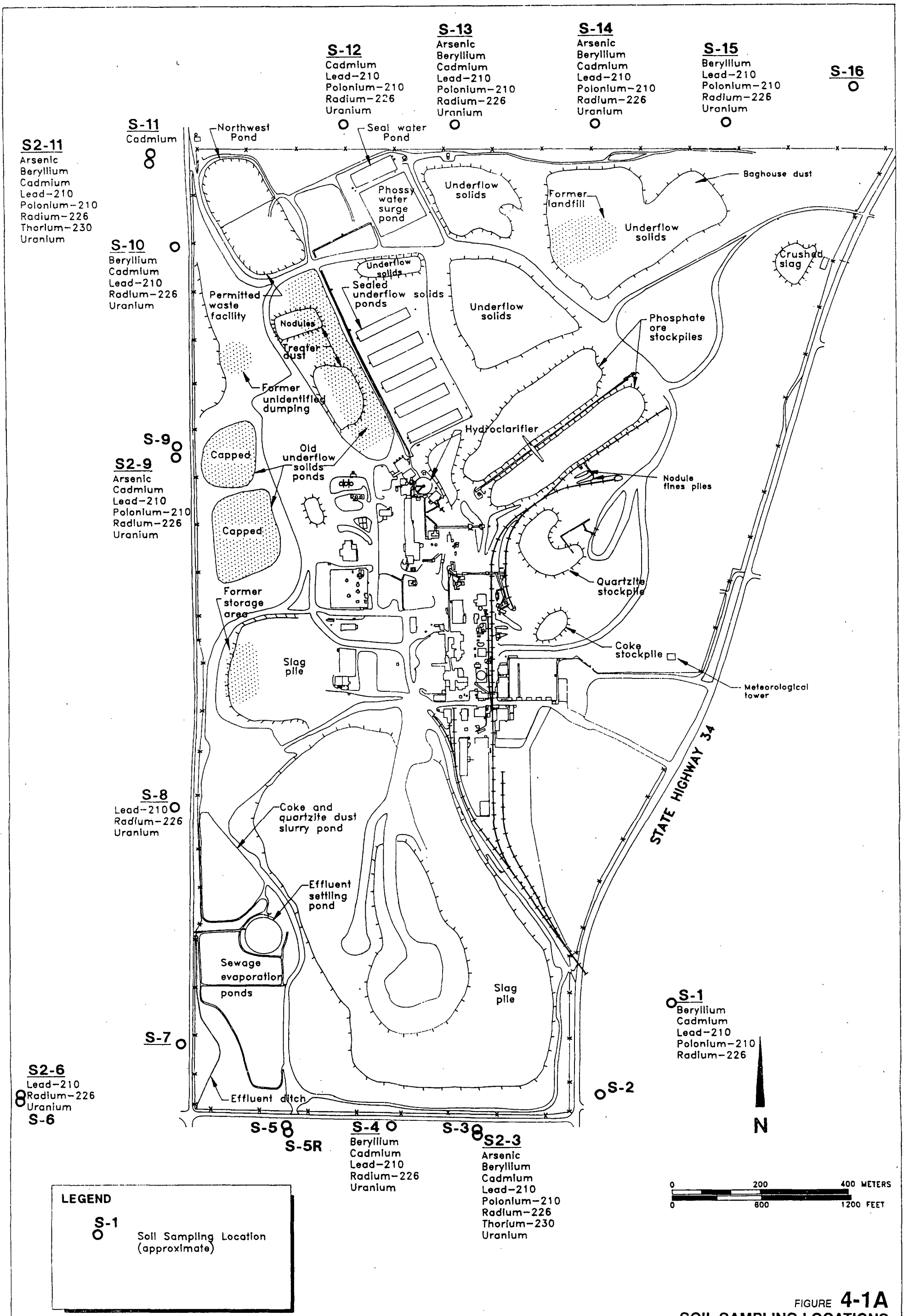


FIGURE 4-1A
SOIL SAMPLING LOCATIONS WITH CONSTITUENTS OF POTENTIAL INTEREST, A GROUP (0-1 INCH DEPTH)
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.204 DWG NO31715 DATE 4-7-92 DRAWN JRS

Golder Associates

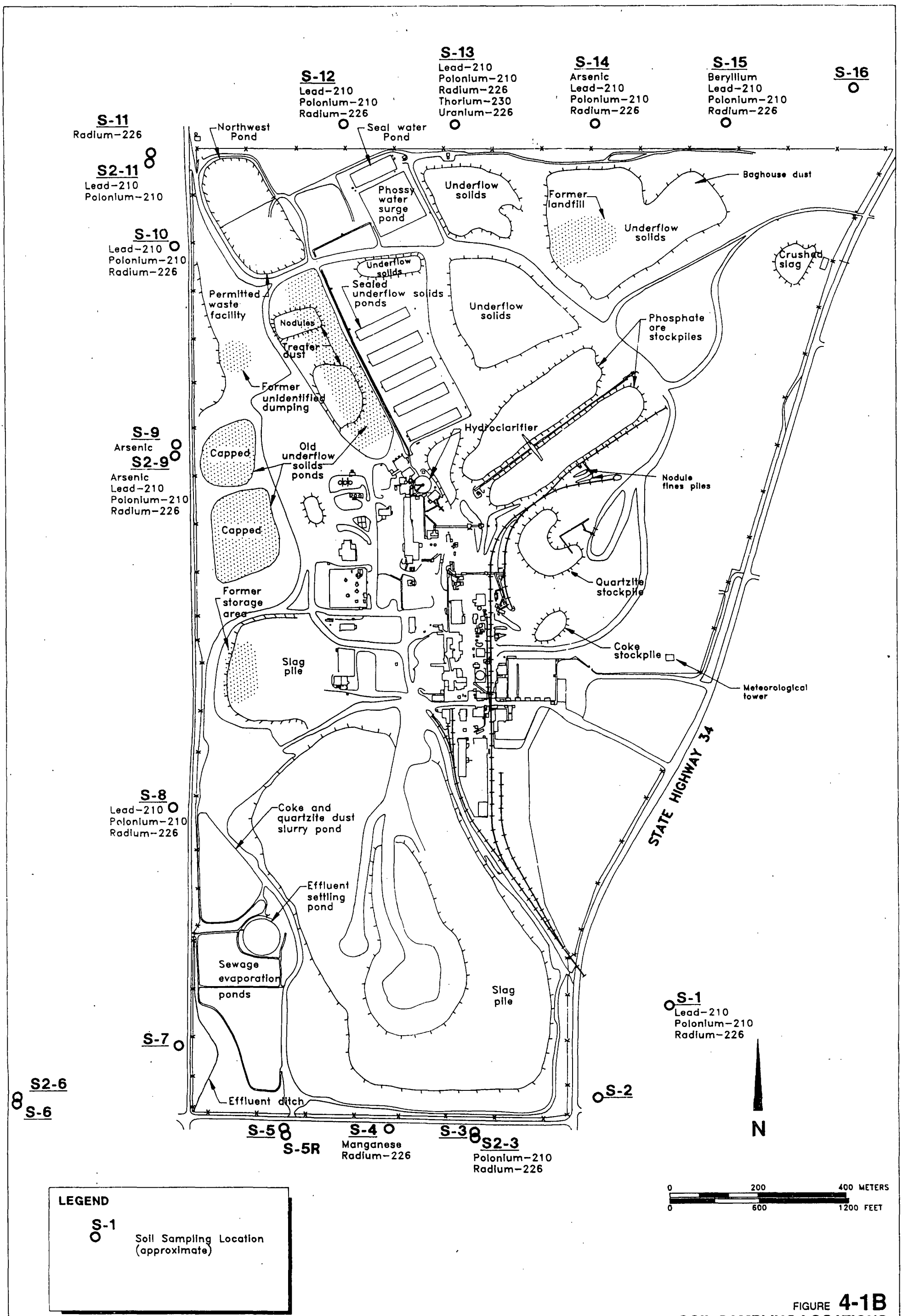


FIGURE **4-1B**

SOIL SAMPLING LOCATIONS WITH CONSTITUENTS OF POTENTIAL INTEREST, B GROUP (0-6 INCH DEPTH)

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.204 DWG NO 31714 DATE 4-7-92 DRAWN JRS

Golder Associates

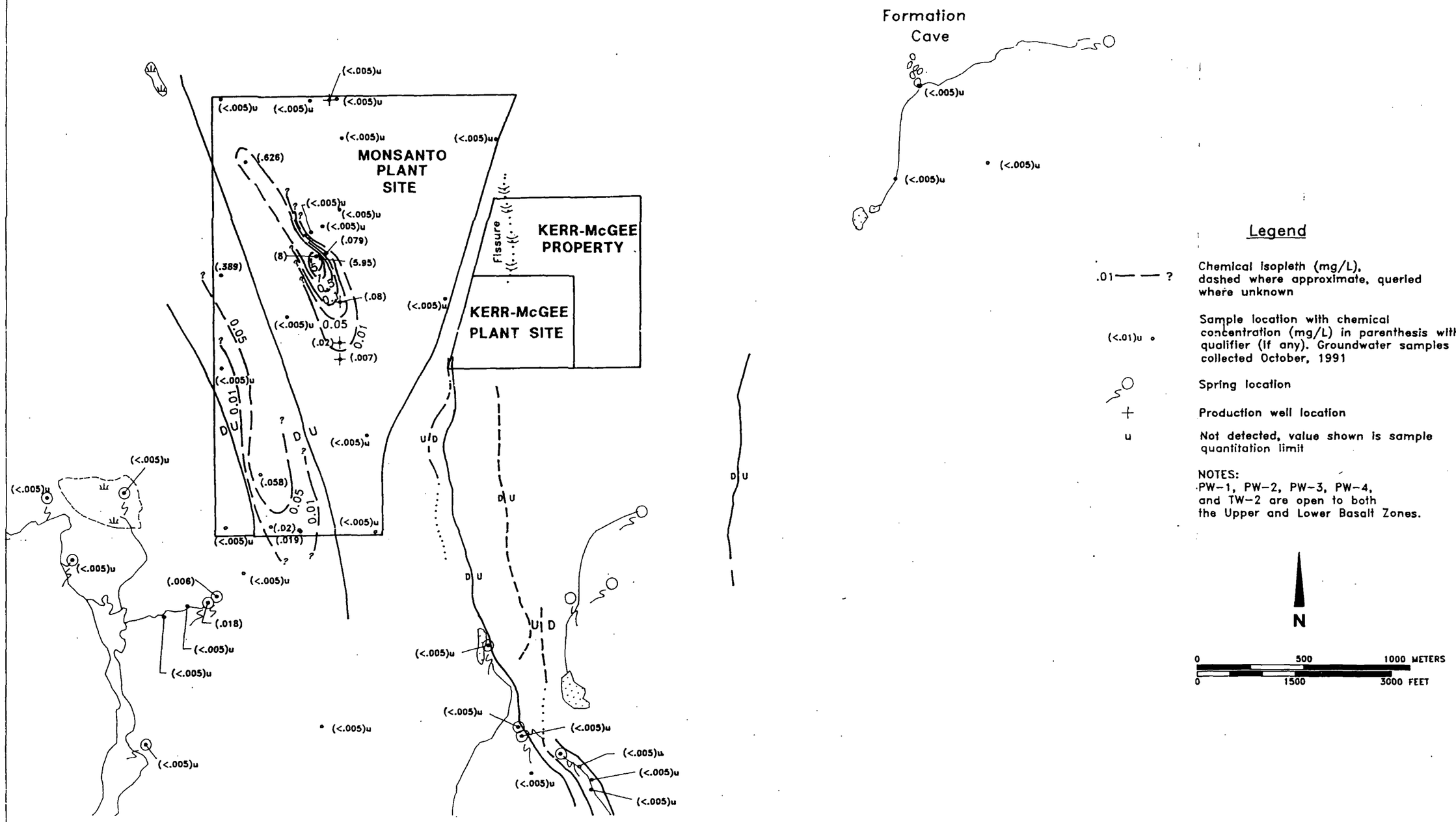


FIGURE **4-2**

UPPER BASALT ZONE CADMIUM

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101/212 DWG NO 36553 DATE 4-14-92 DRAWN PM/JSS

Golder Associates

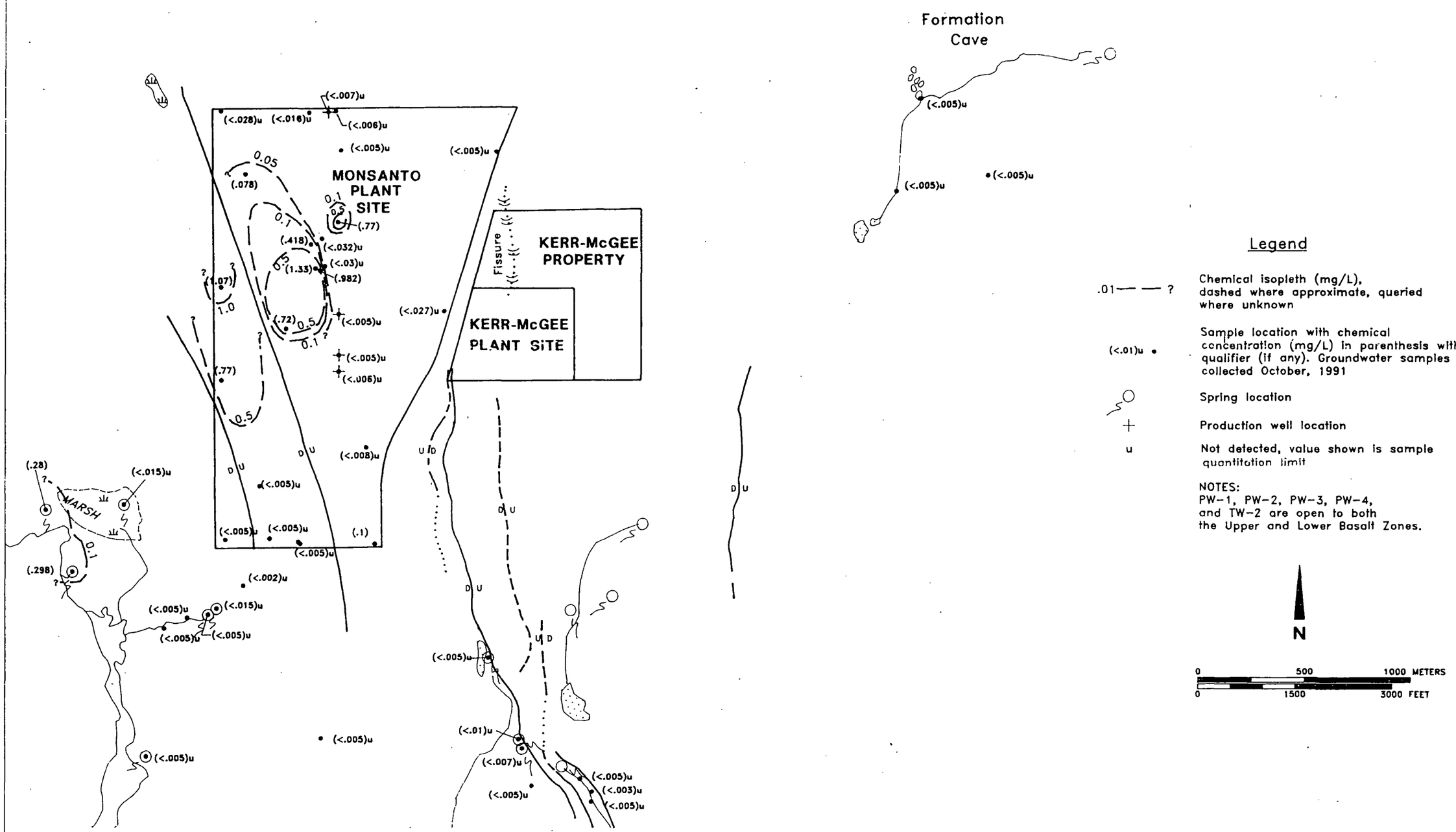


FIGURE **4-3**

UPPER BASALT ZONE MANGANESE

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101/212 DWG NO 36552 DATE 4-14-92 DRAWN PM/JSS

Golder Associates

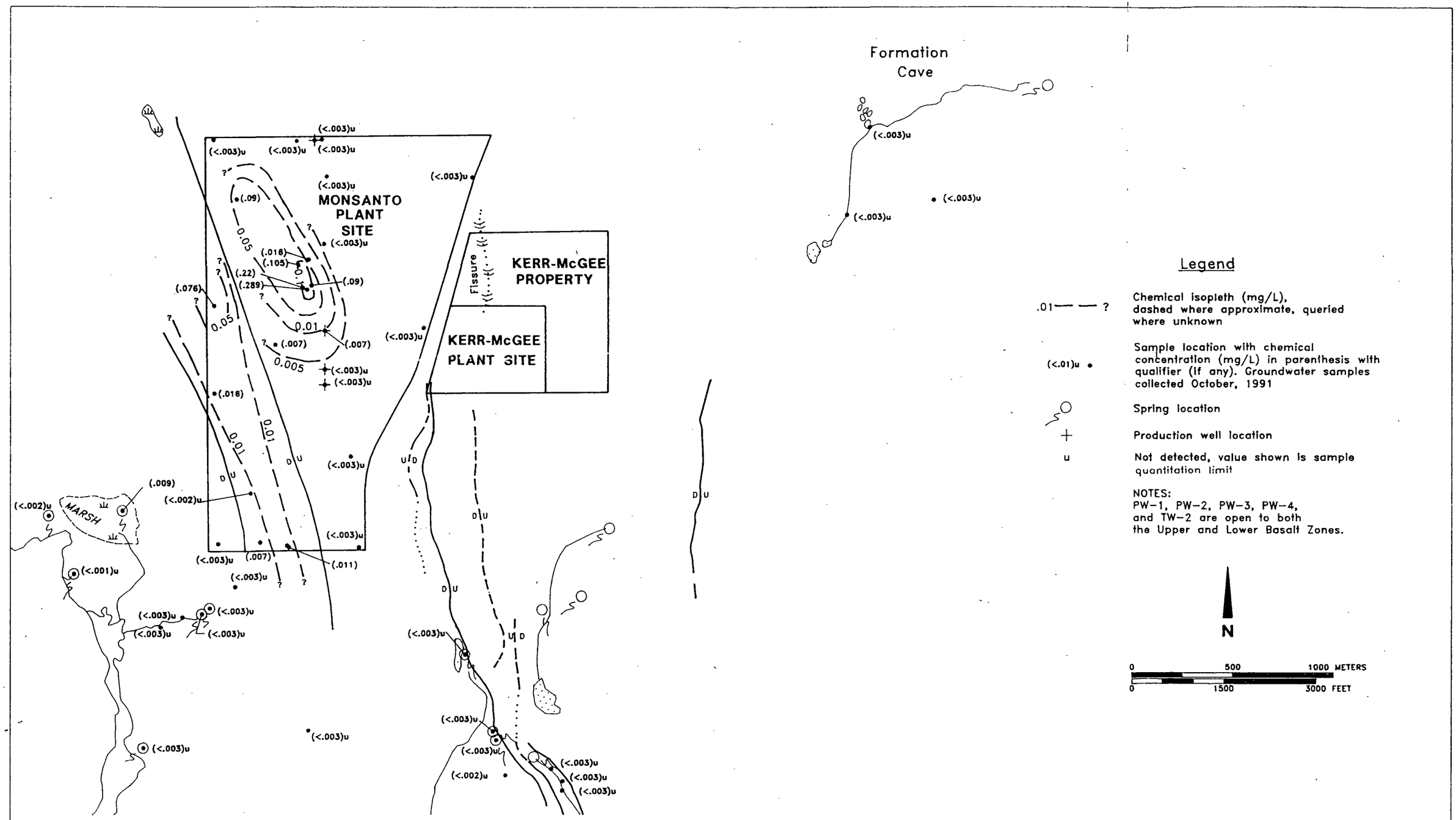


FIGURE **4-4**

UPPER BASALT ZONE SELENIUM

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101/212 DWG NO 31661 DATE 4-14-92 DRAWN PM/JSS

Golder Associates

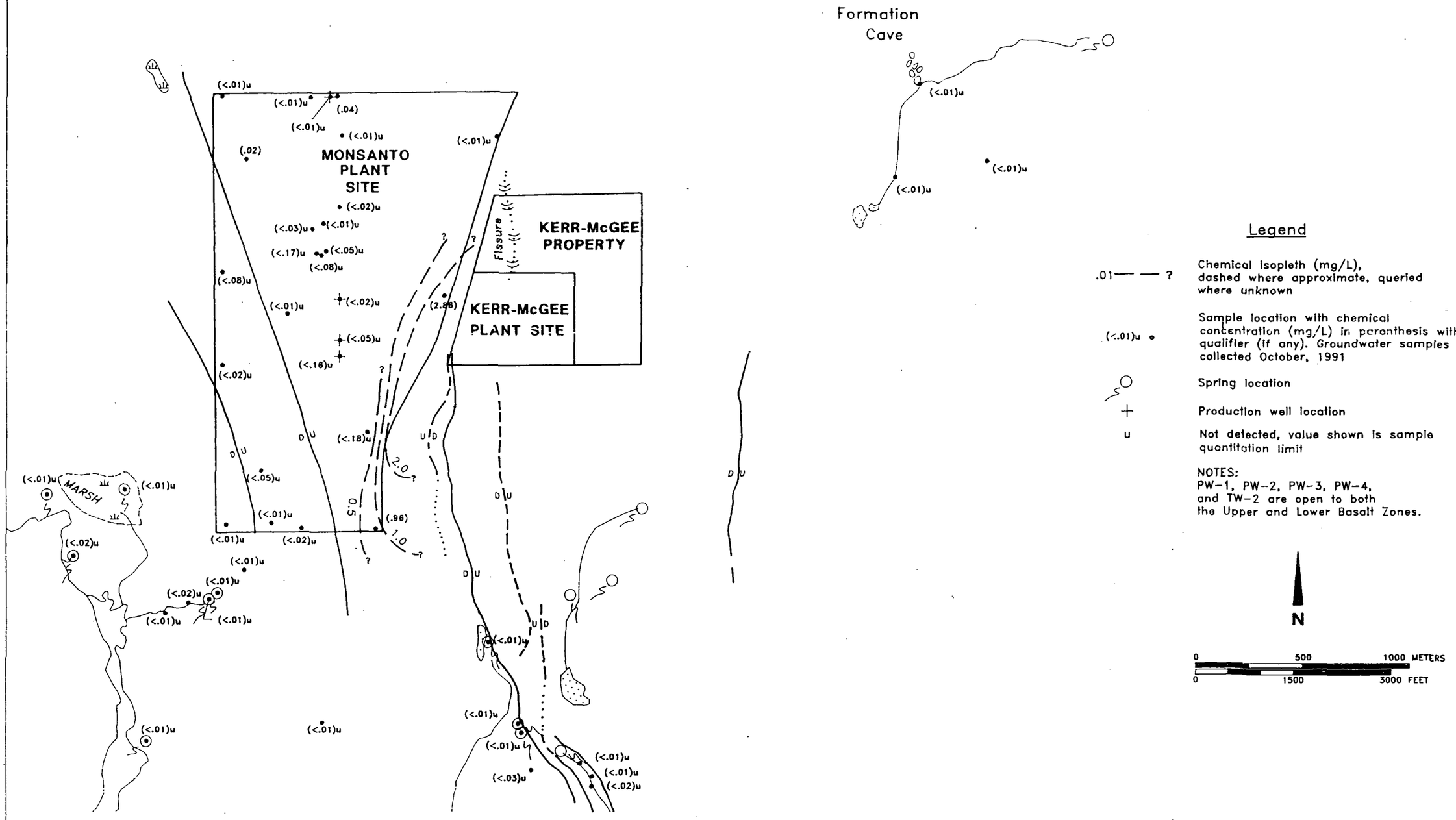


FIGURE **4-5**

UPPER BASALT ZONE VANADIUM

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101/212 DWG NO 36560 DATE 4-14-92 DRAWN PM/JSS

Golder Associates

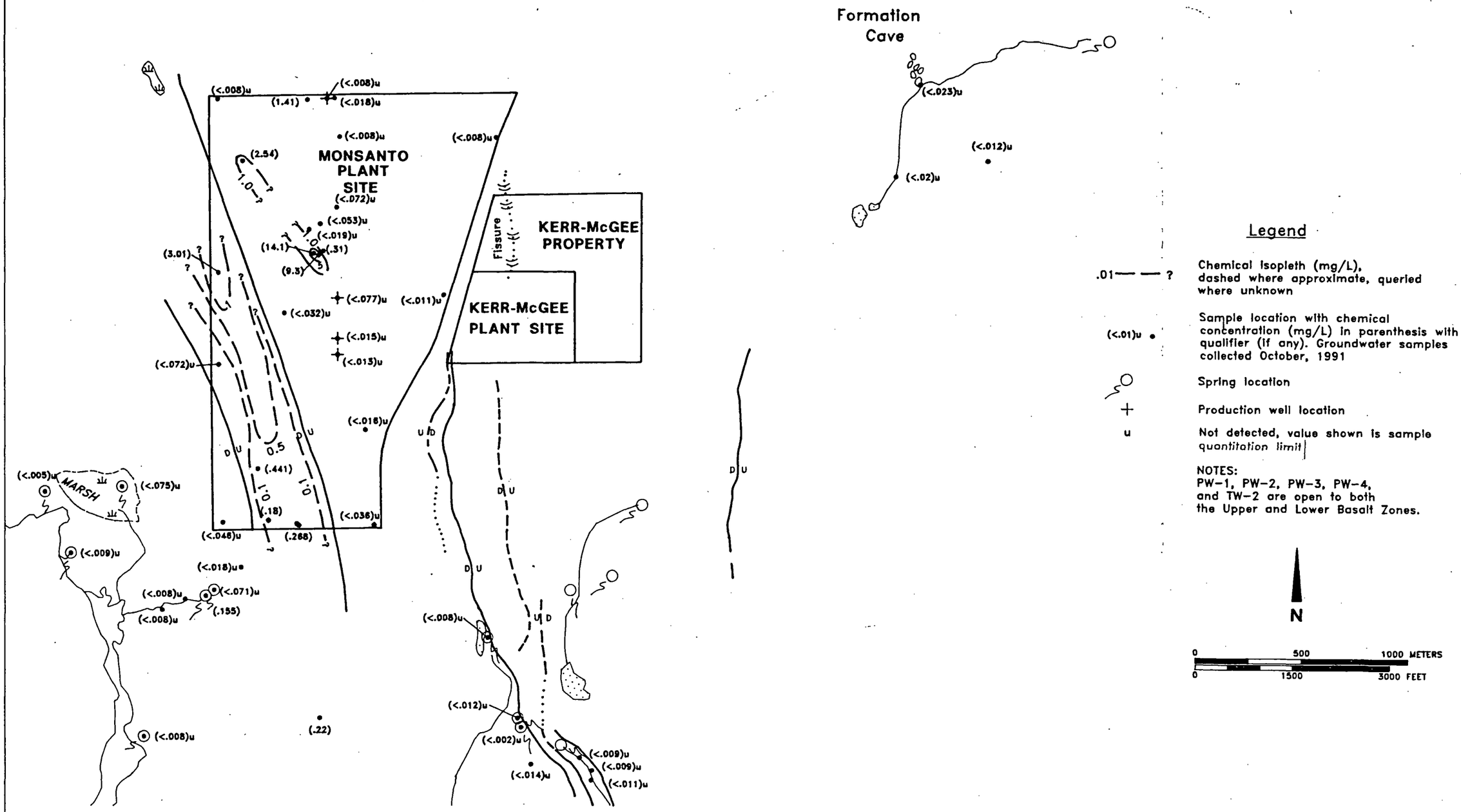


FIGURE **4-6**

UPPER BASALT ZONE ZINC

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101/212 DWG NO 36559 DATE 4-14-92 DRAWN PM/JSS

Golder Associates

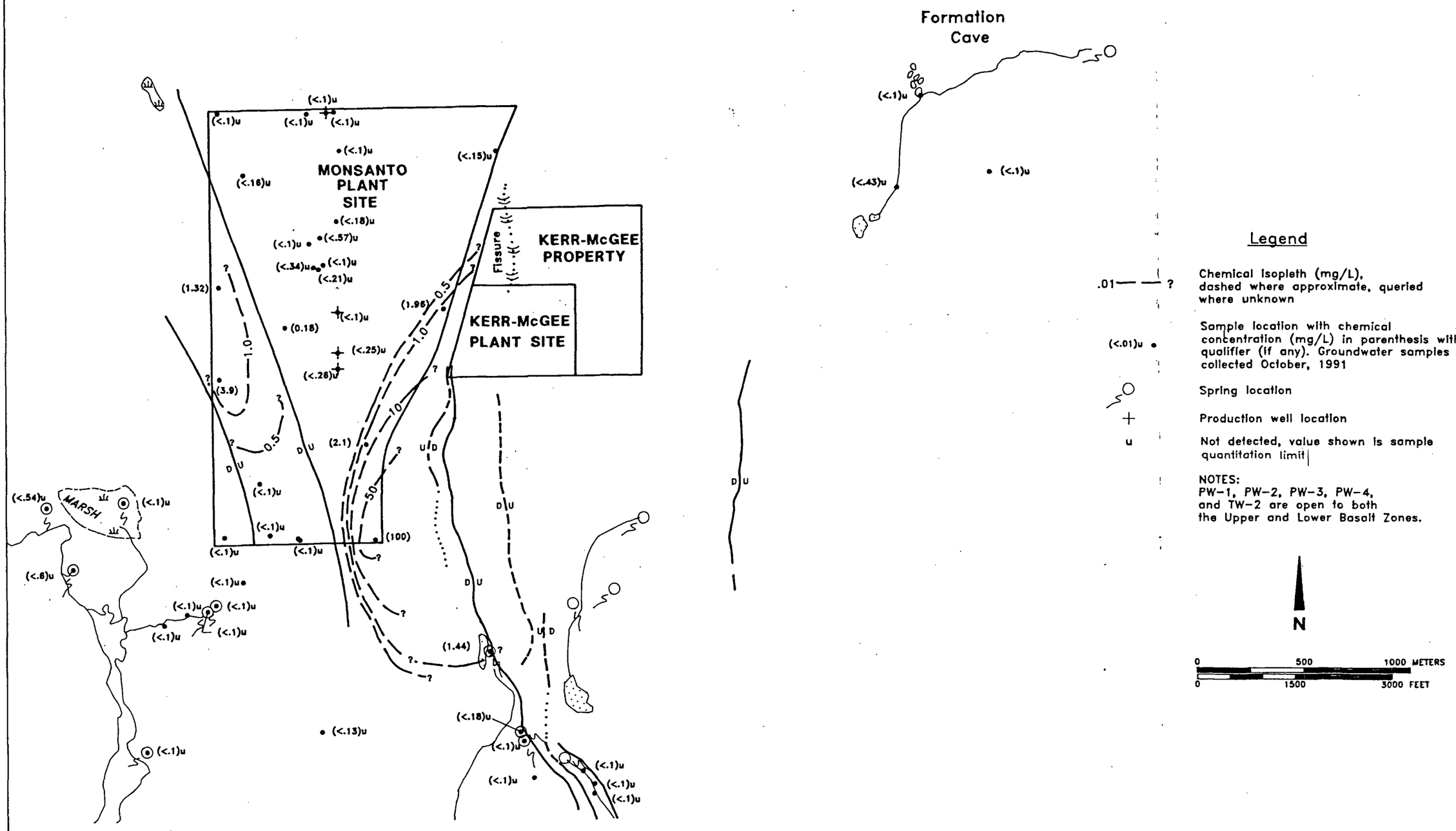


FIGURE **4-7**

UPPER BASALT ZONE AMMONIUM AS N

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101/212 DWG NO 36558 DATE 4-14-92 DRAWN PM/JSS

Golder Associates

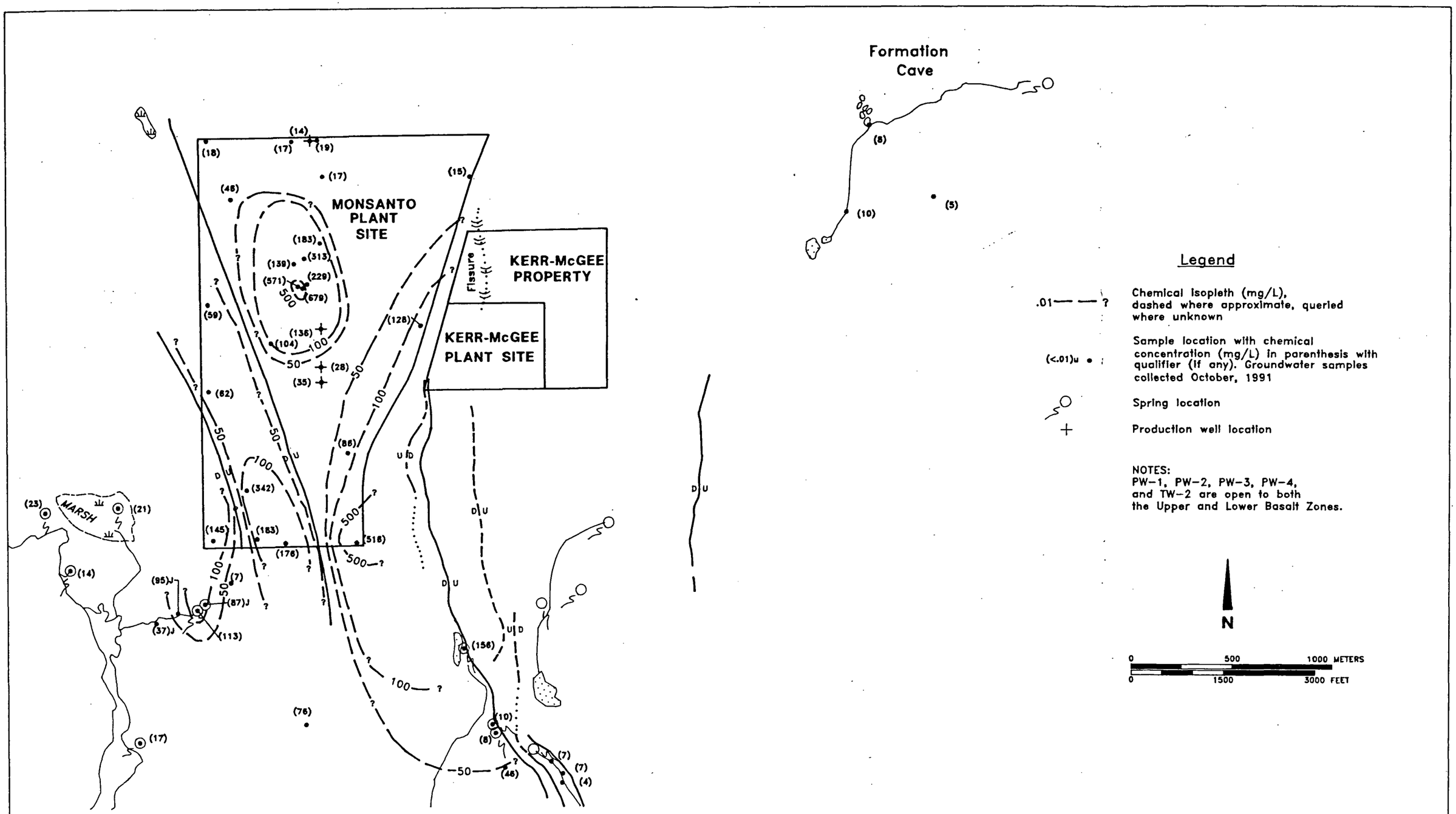


FIGURE **4-8**

UPPER BASALT ZONE CHLORIDE

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101/212 DWG NO 36557 DATE 4-14-92 DRAWN PM/JSS

Golder Associates

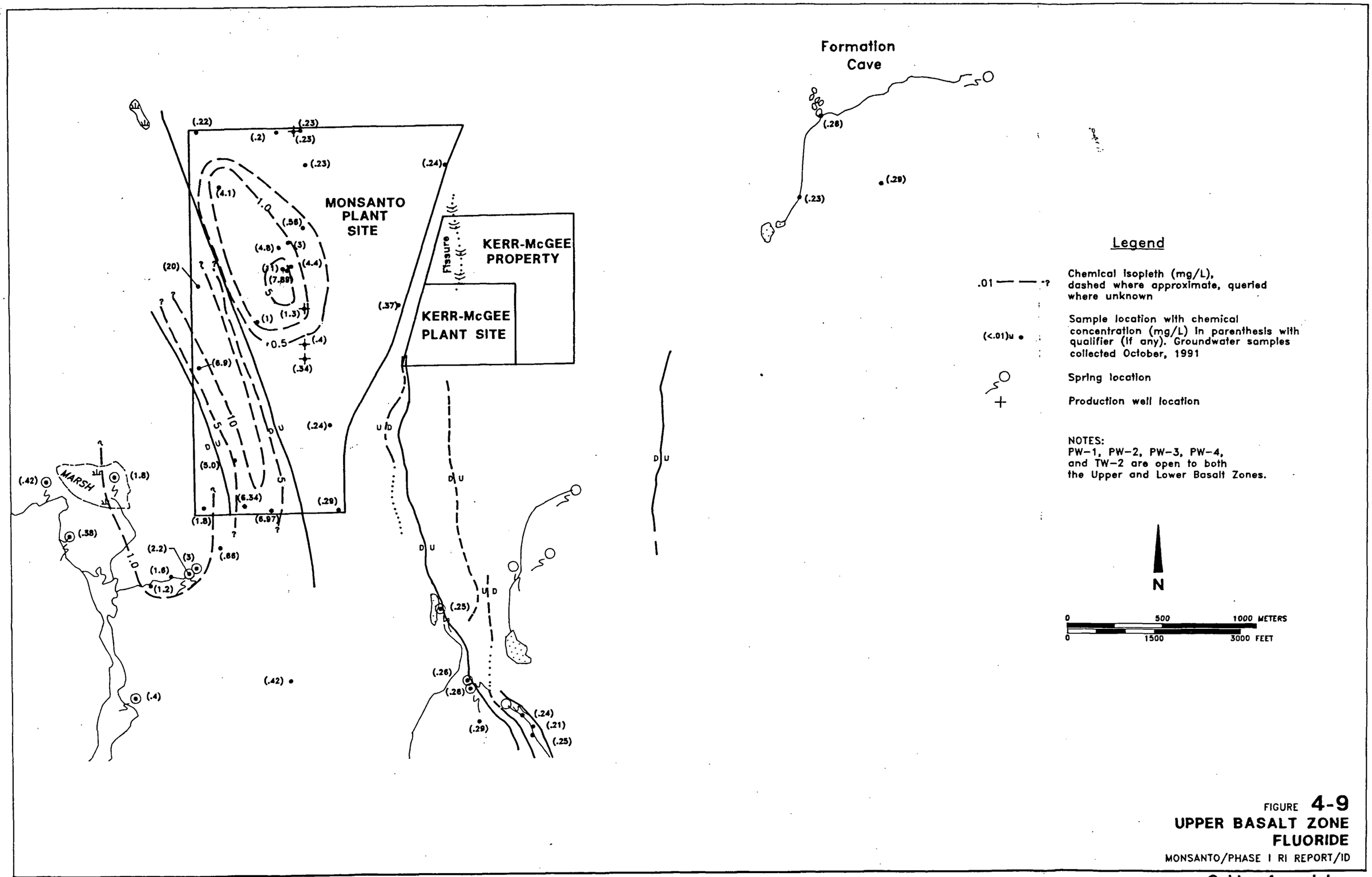


FIGURE **4-9**

UPPER BASALT ZONE FLUORIDE

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101/212 DWG NO 36556 DATE 4-14-92 DRAWN PM/JSS

Golder Associates

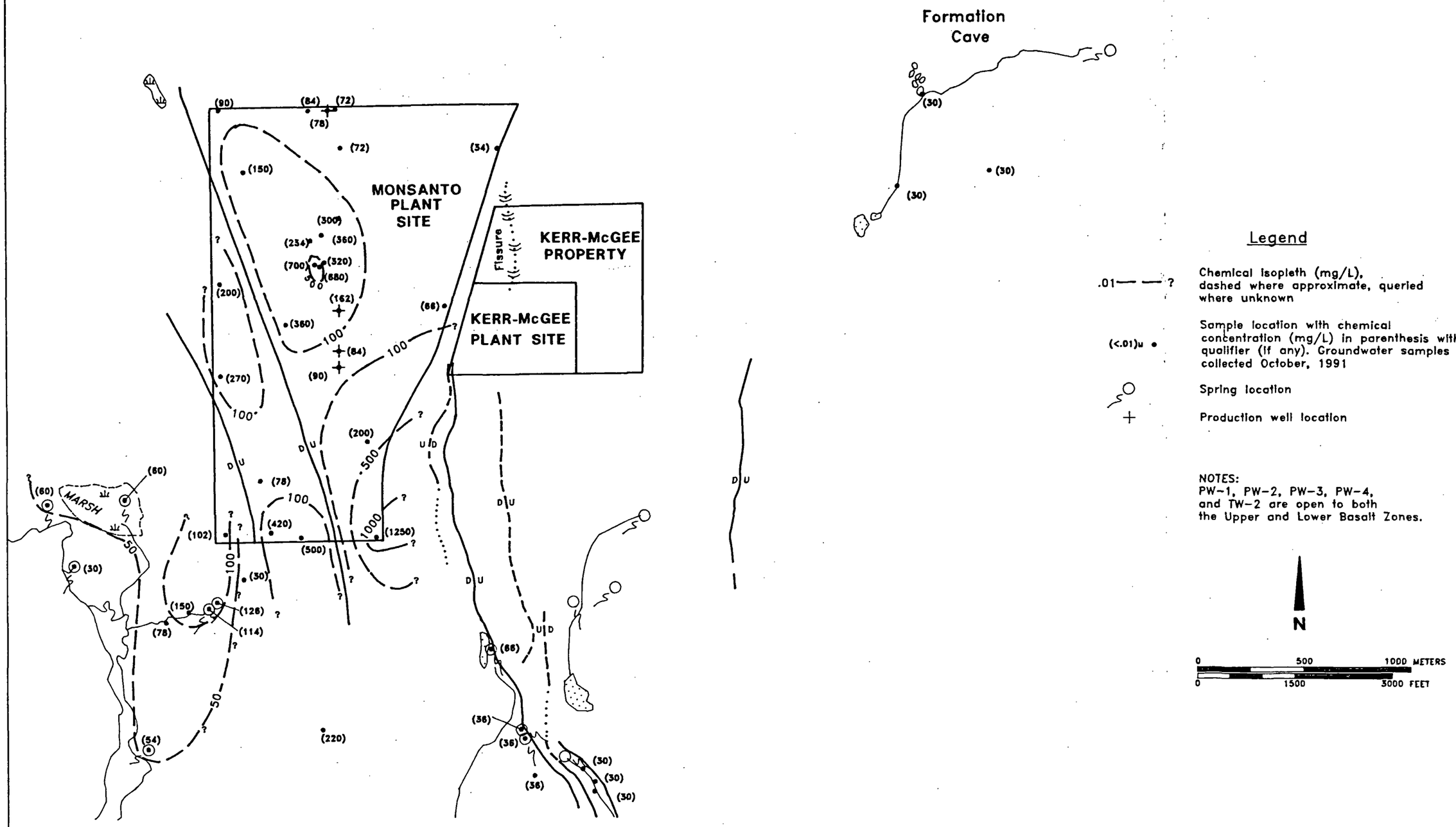


FIGURE **4-10**

UPPER BASALT ZONE SULFATE

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101/212 DWG NO 36555 DATE 4-17-92 DRAWN PM/JSS

Golder Associates

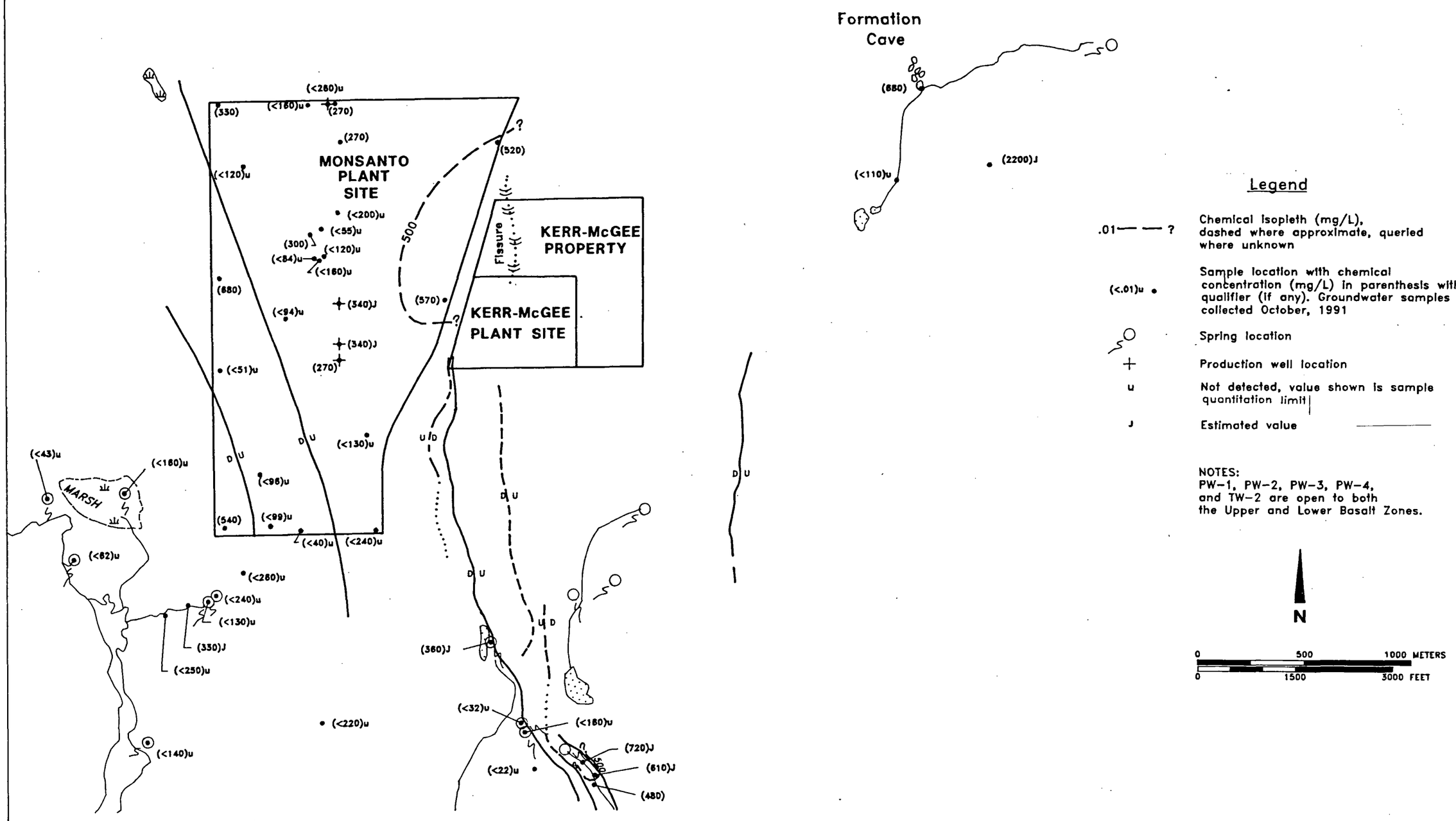


FIGURE **4-11**

UPPER BASALT ZONE RADON

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101/212 DWG NO 36554 DATE 4-15-92 DRAWN PM/JSS

Golder Associates

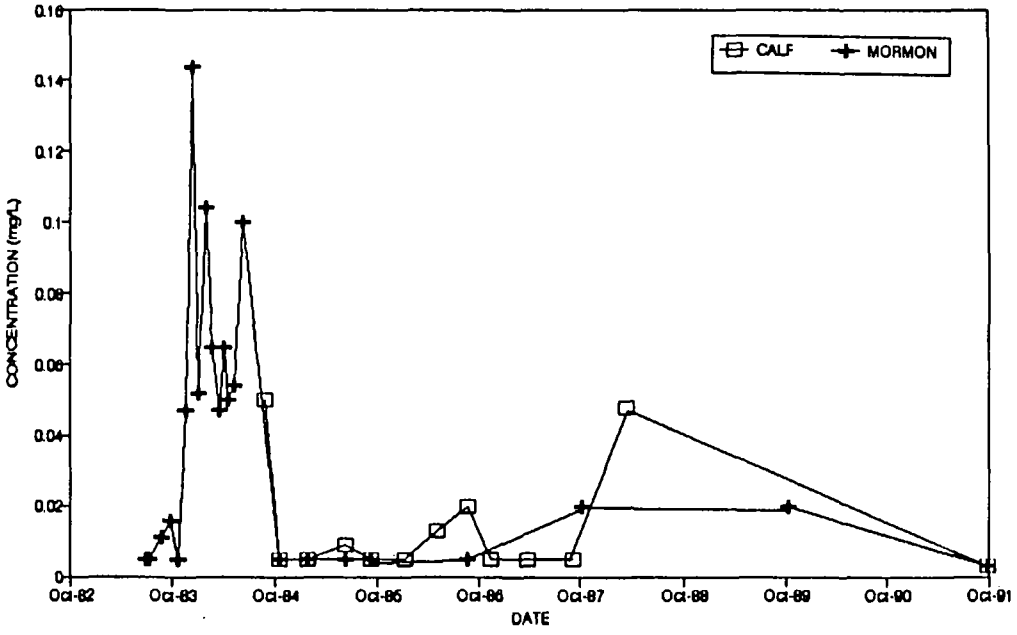


Figure 4-12. Calf Spring and Mormon Spring

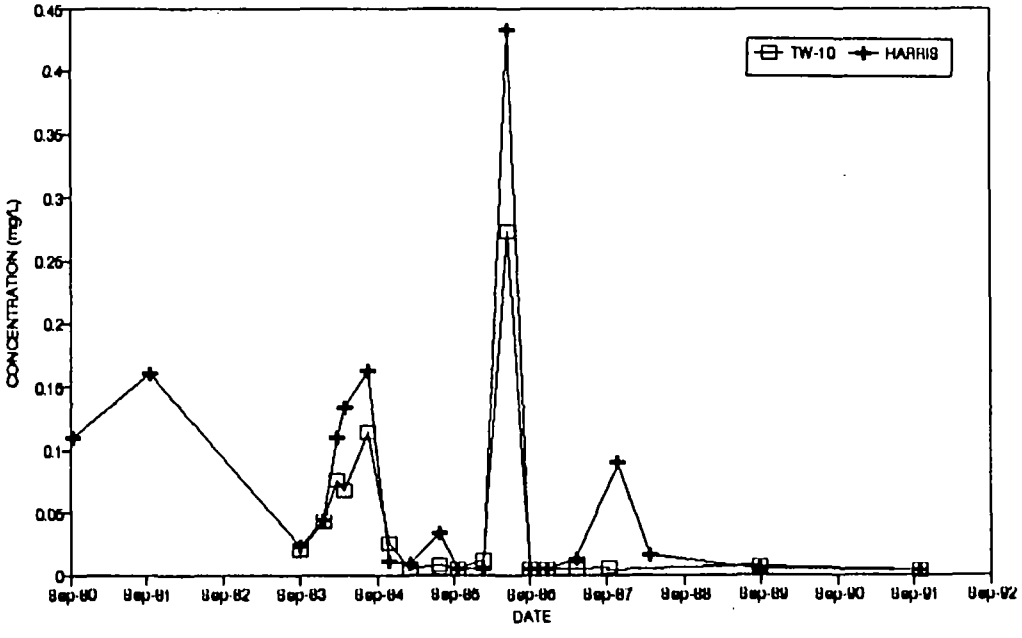


Figure 4-13. TW-10 and Harris Well

UBZ-1
SELENIUM TEMPORAL PLOT
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO. 913-1101.212 DWG. NO. 28060 DATE 4/10/92 DRAWN TK

Golder Associates

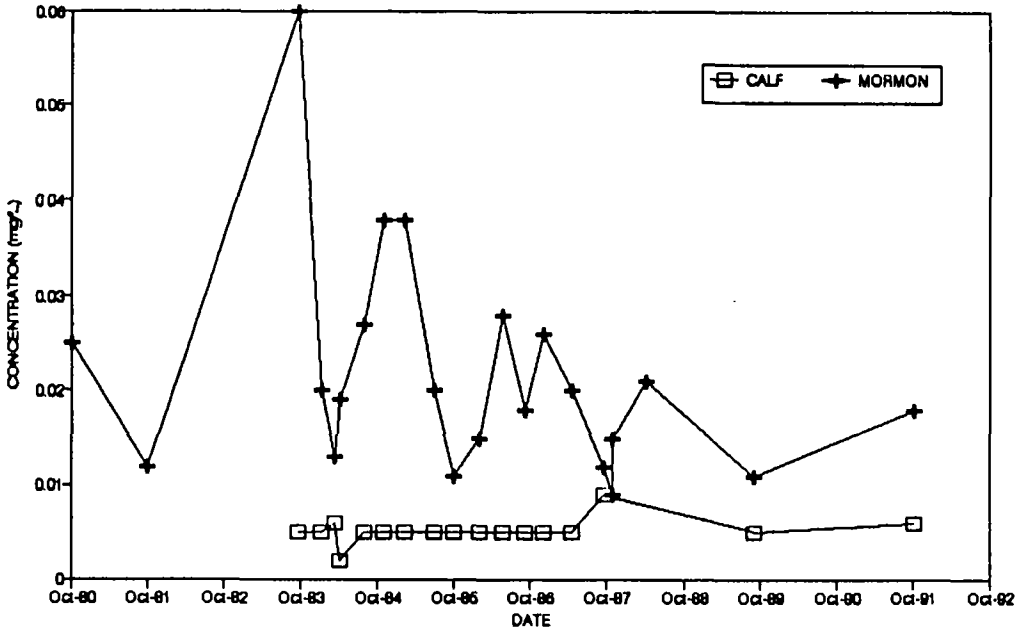


Figure 4-14. Calf Spring and Mormon Spring

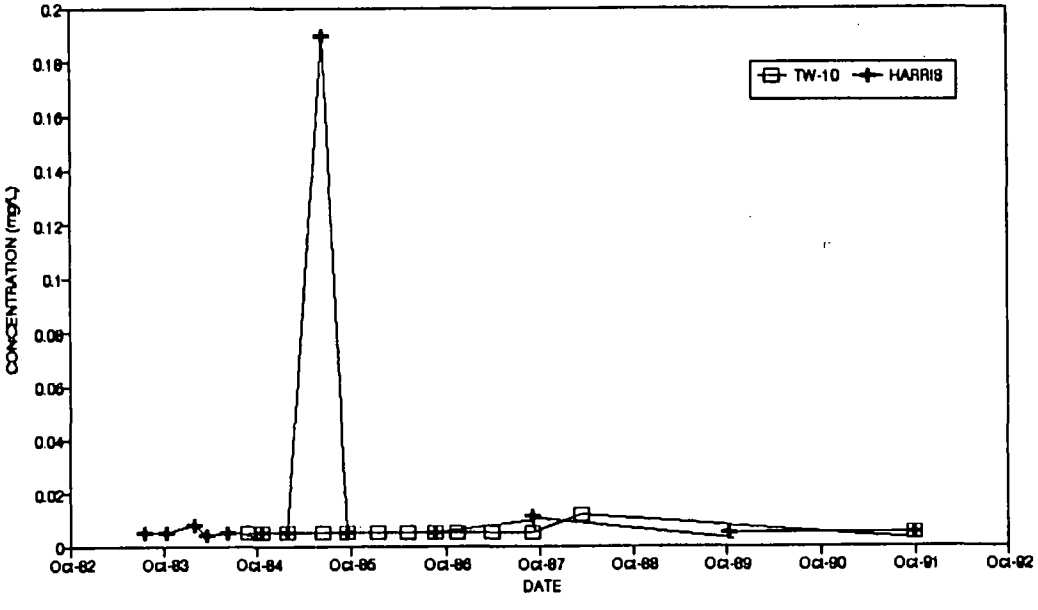


Figure 4-15. TW-10 and Harris Well

UBZ-1
CADMIUM TEMPORAL PLOT
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO. 913-1101.212 DWG. NO. 20001 DATE 4/10/92 DRAWN TK

Golder Associates

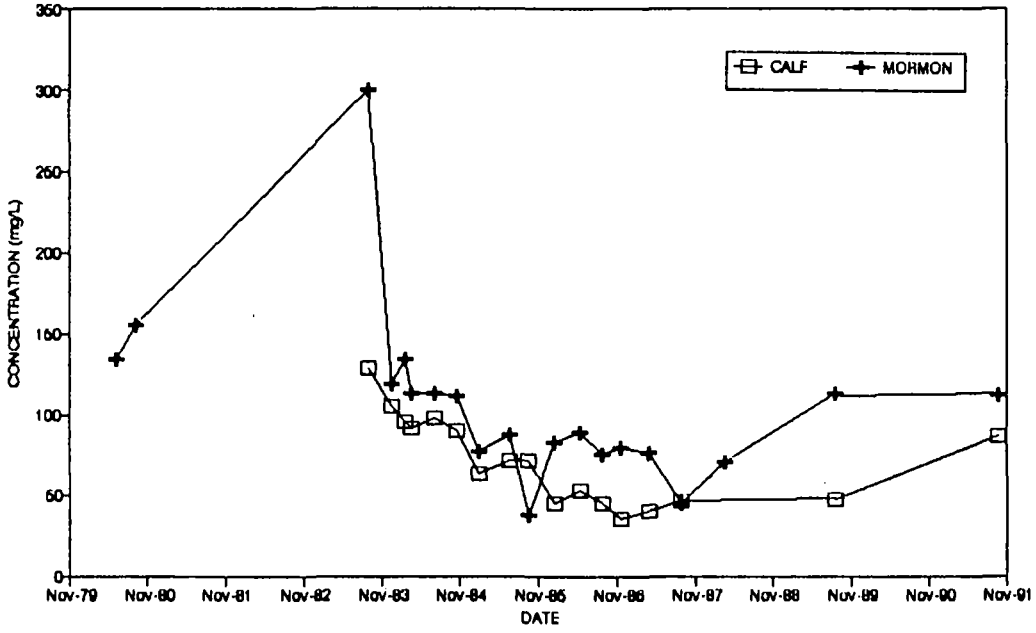


Figure 4-16. Calf Spring and Mormon Spring

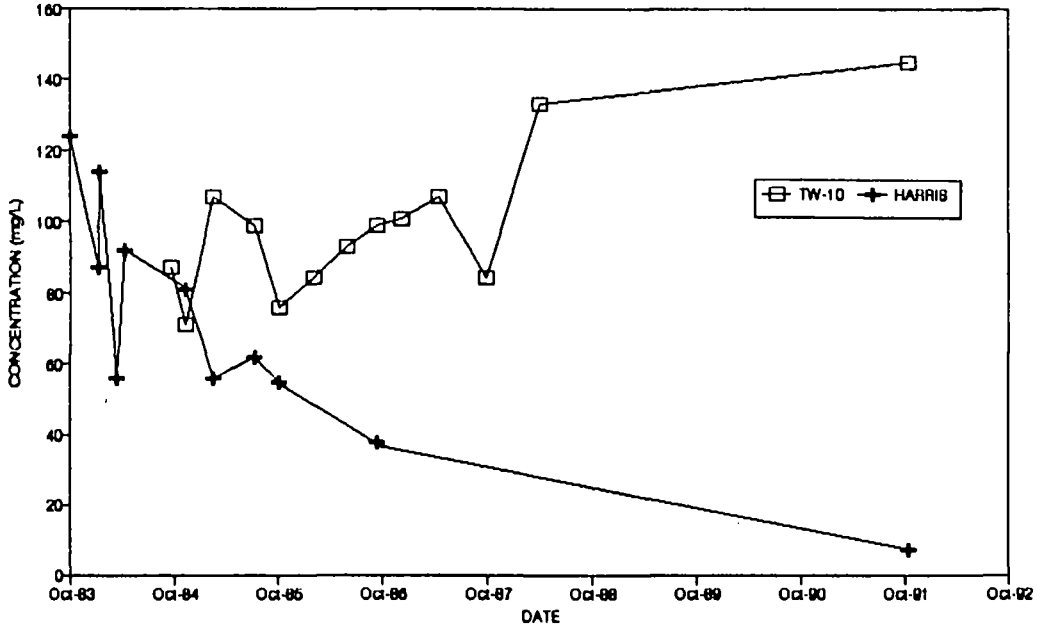


Figure 4-17. TW-10 and Harris Well

UBZ-1
CHLORIDE TEMPORAL PLOT
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO. 913-1101.212 DWG. NO. 28662 DATE 4/10/92 DRAWN TK

Golder Associates

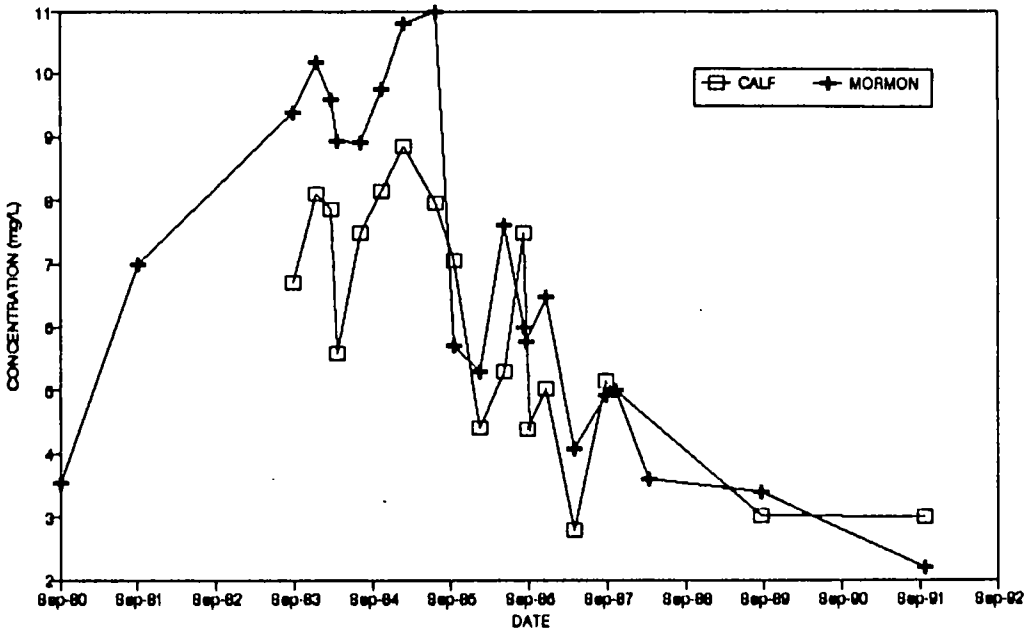


Figure 4-18. Calf Spring and Mormon Spring

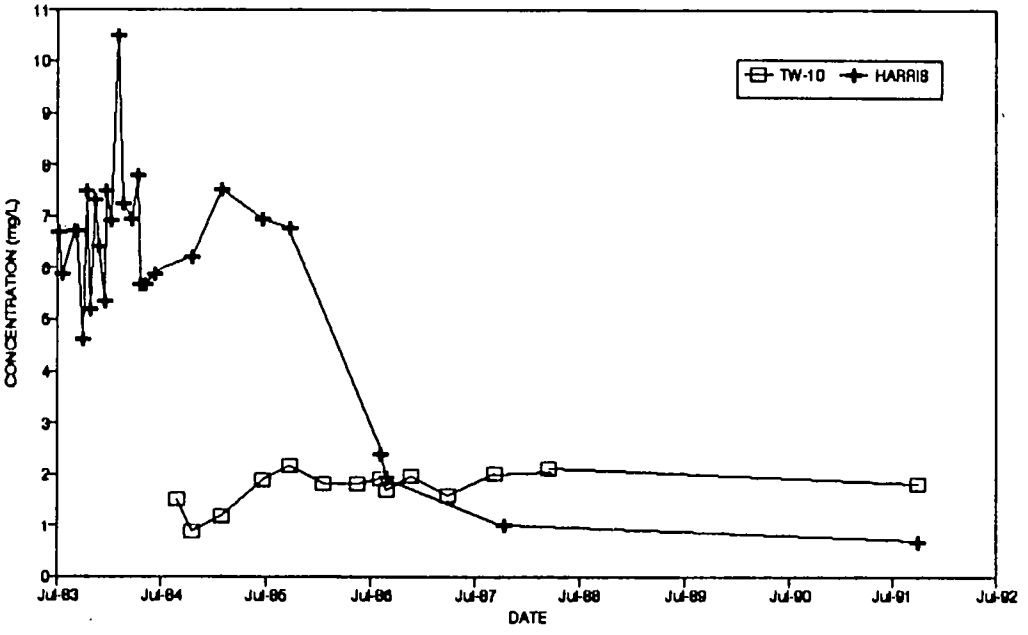


Figure 4-19. TW-10 and Harris Well

UBZ-1
FLUORIDE TEMPORAL PLOT
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO. 913-1101.212 DWG. NO. 20063 DATE 4/10/92 DRAWN TK

Golder Associates

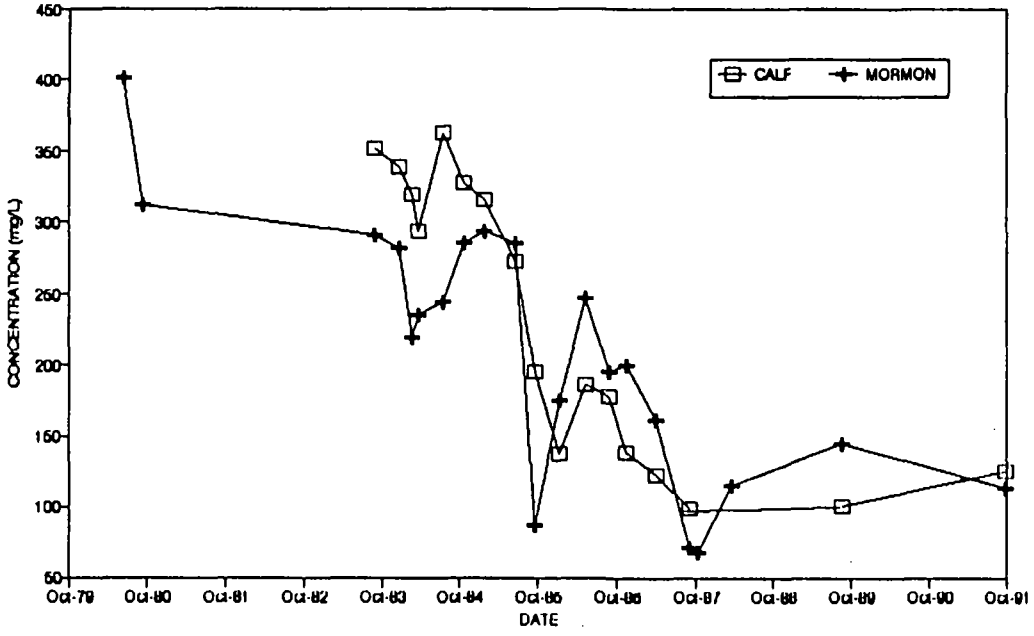


Figure 4-20. Calf Spring and Mormon Spring

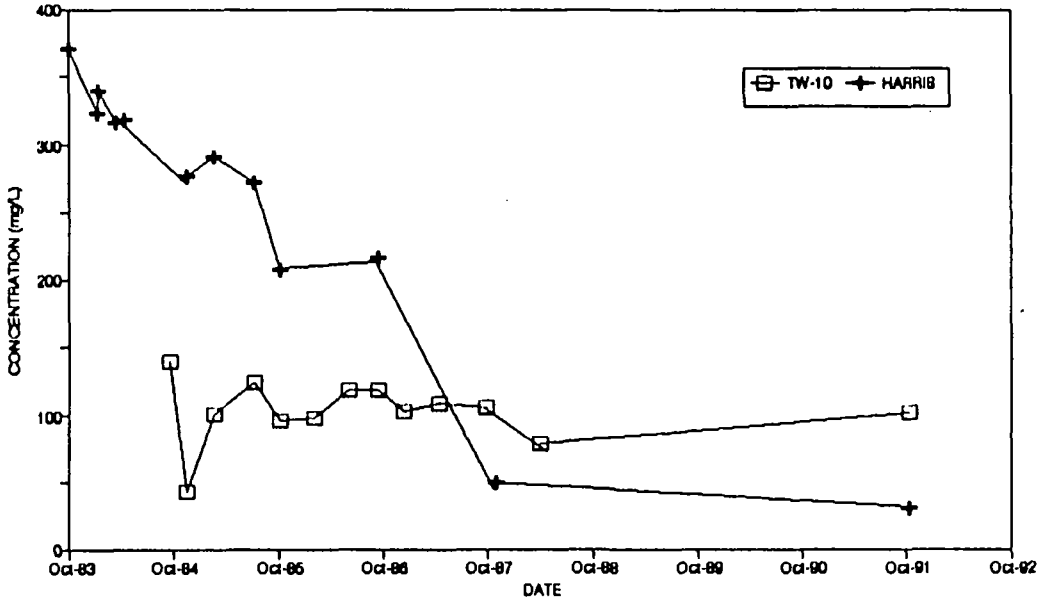


Figure 4-21 TW-10 and Harris Well

UBZ-1
SULFATE TEMPORAL PLOT
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO. 913-1101.212 DWG. NO. 28004 DATE 4/10/92 DRAWN TK

Golder Associates

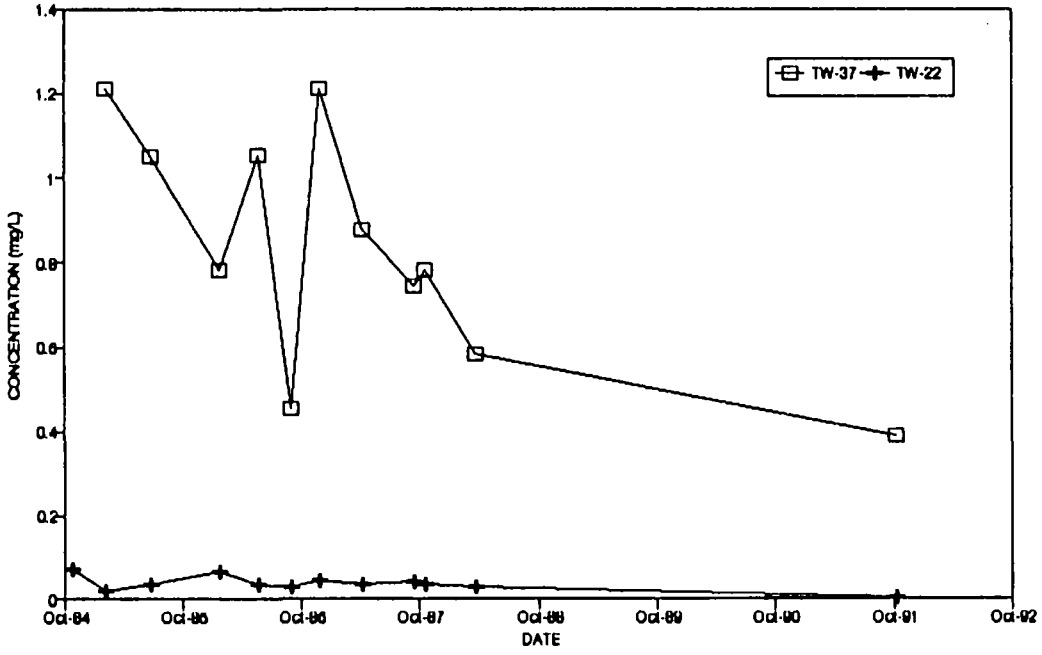


Figure 4-22. Cadmium - TW-37 and TW-22

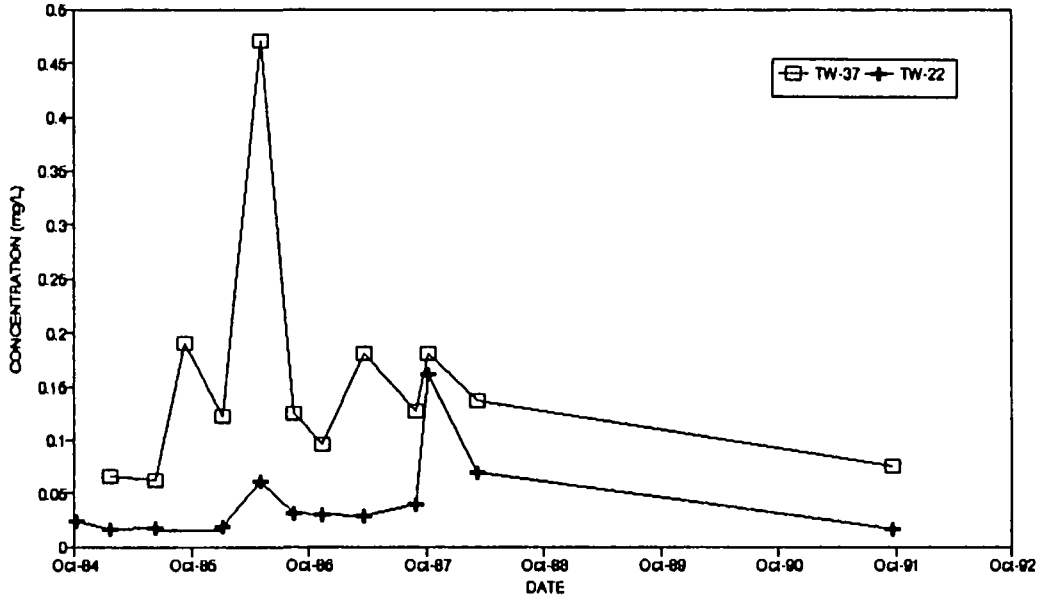


Figure 4-23. Selenium - TW-37 and TW-22

UBZ-2
TEMPORAL PLOTS
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO. 913-1101.212 DWG. NO. 28665 DATE 4/10/92 DRAWN TK

Golder Associates

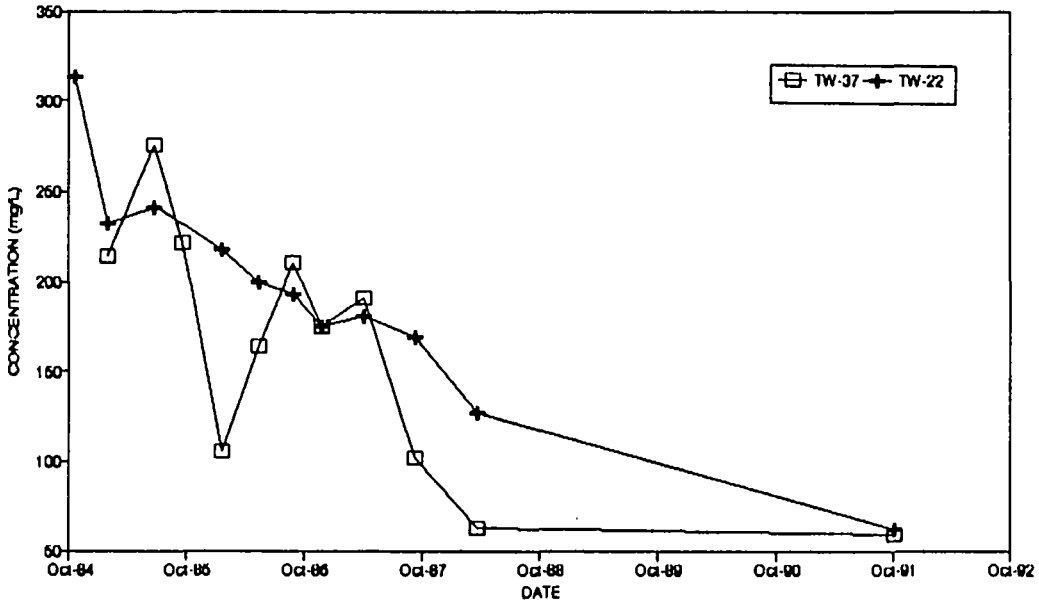


Figure 4-24. Chloride - TW-37 and TW-22

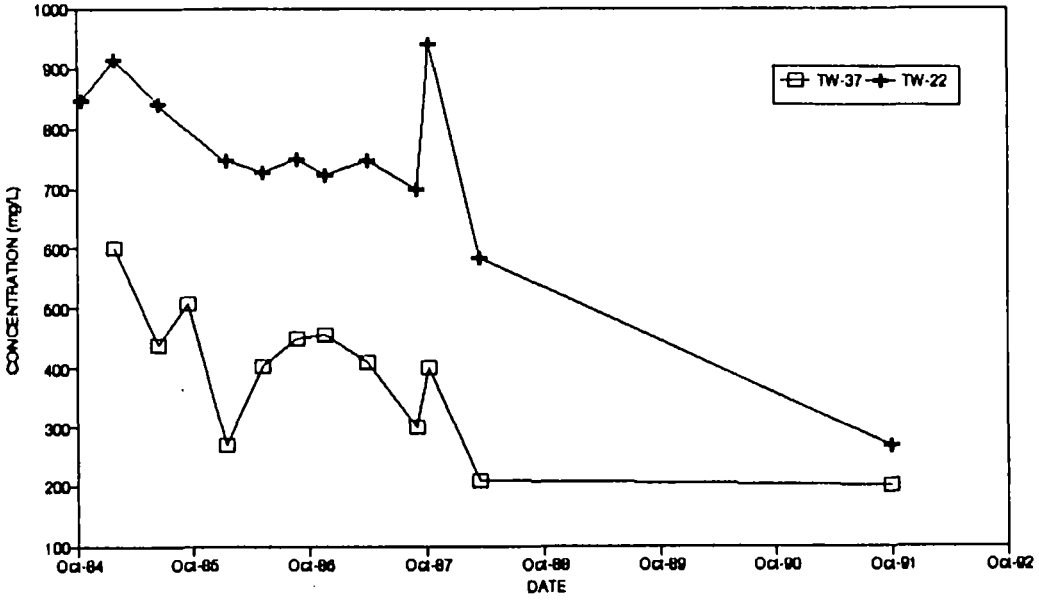


Figure 4-25. Sulfate - TW-37 and TW-22

UBZ-2
TEMPORAL PLOTS
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO. 913-1101.212 DWG. NO. 28666 DATE 4/10/92 DRAWN TK

Golder Associates

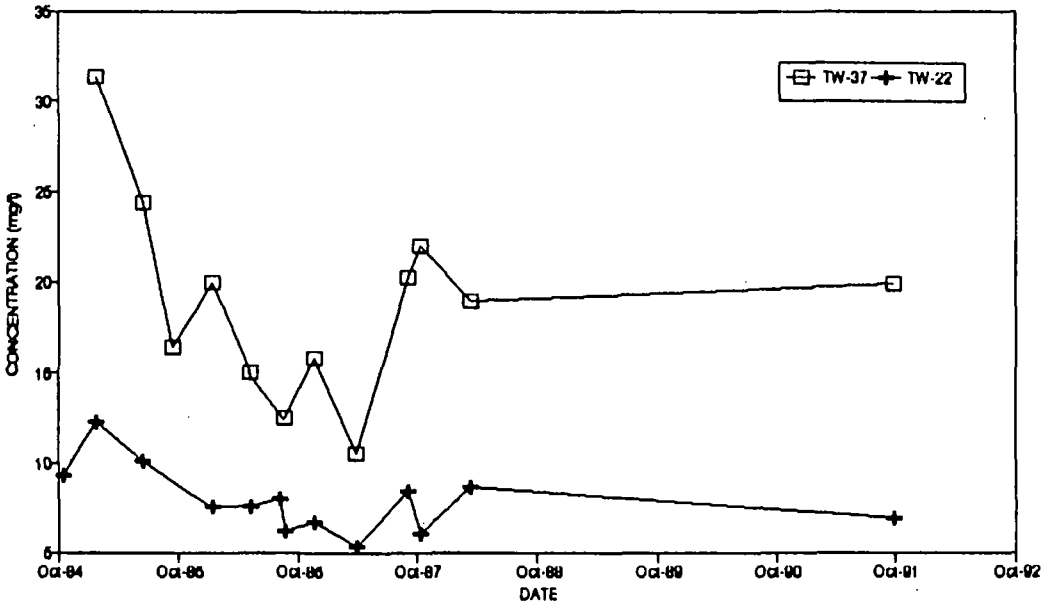


Figure 4-26. Fluoride - TW-37 and TW-22

UBZ-2
TEMPORAL PLOT
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO. 913-1101.212 DWG. NO. 28667 DATE 4/10/92 DRAWN TK

Golder Associates

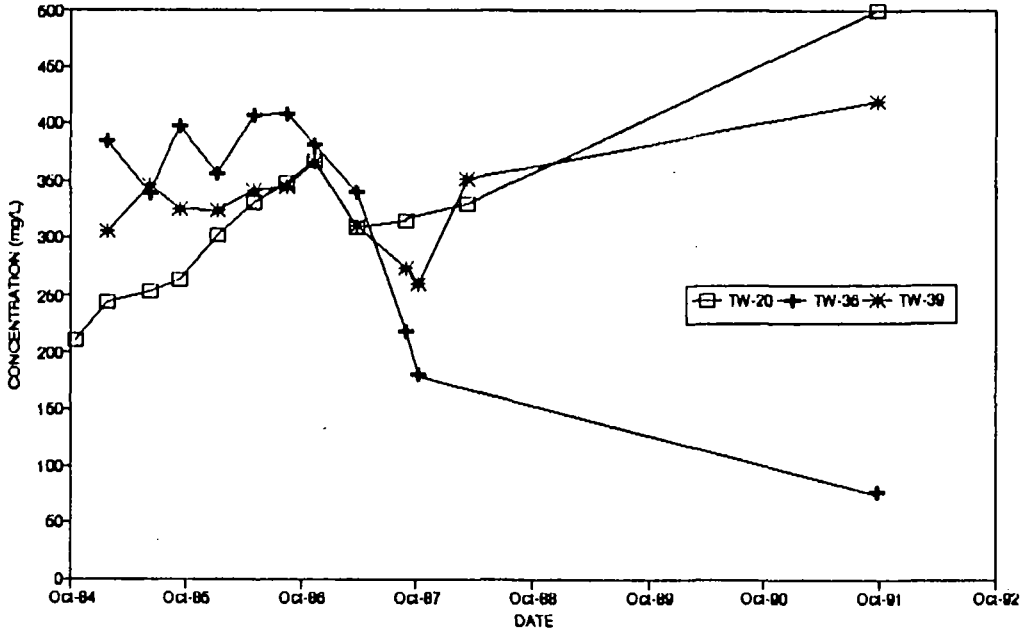


Figure 4-27. Chloride - TW-20, TW-36, and TW-39

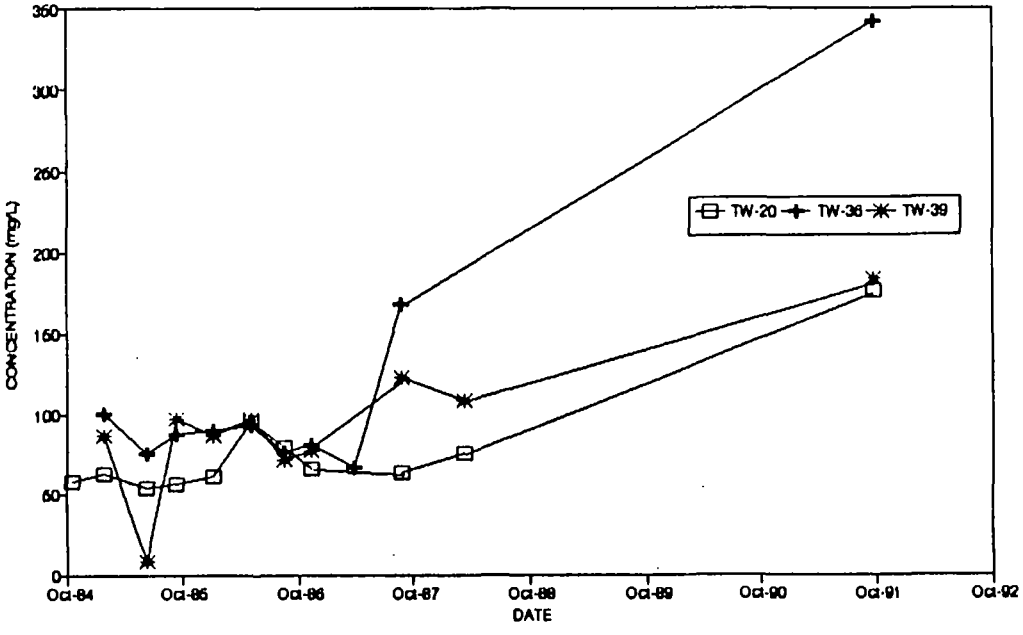


Figure 4-28. Sulfate - TW-20, TW-36, and TW-39

UBZ-2
TEMPORAL PLOTS
MONSANTO/PHASE I RI REPORT/ID

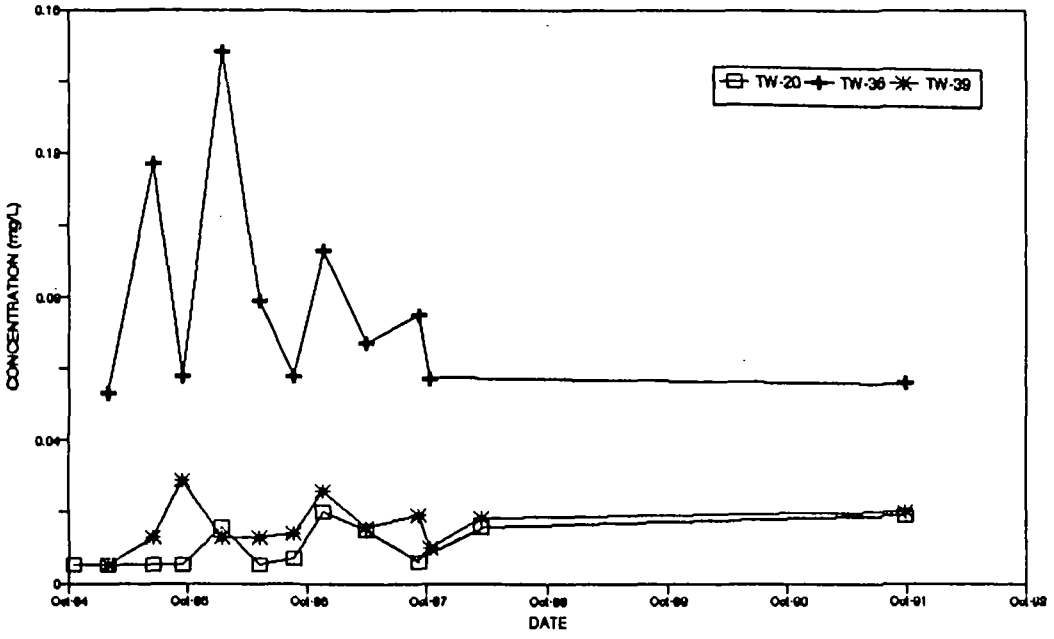


Figure 4-29. Cadmium - TW-20, TW-36, and TW-39

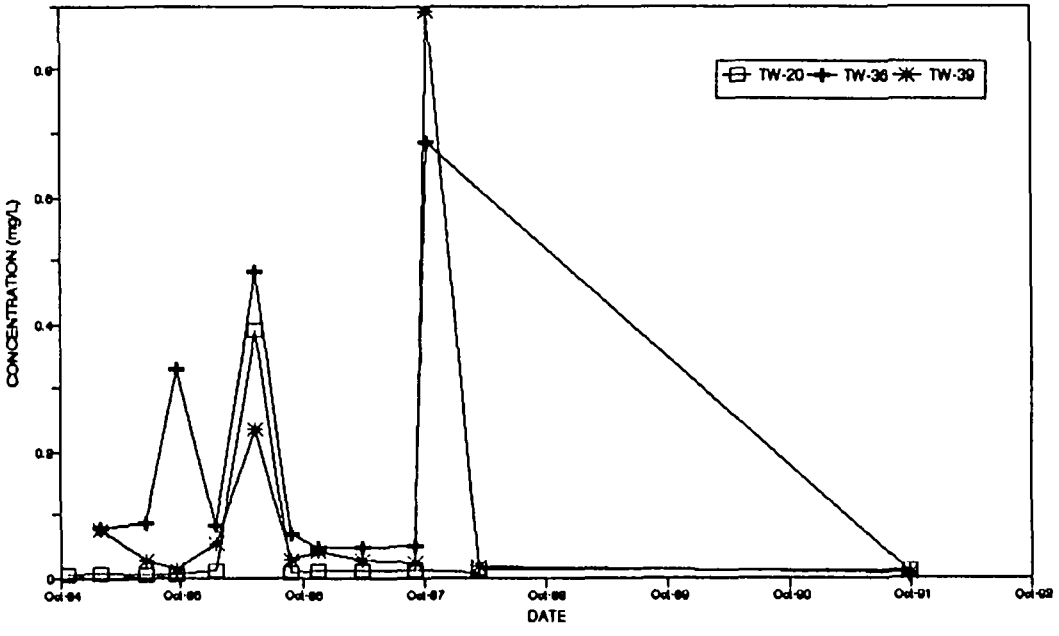


Figure 4-30. Selenium - TW-20, TW-36, and TW-39

UBZ-2
TEMPORAL PLOTS
MONSANTO/PHASE I RI REPORT/ID

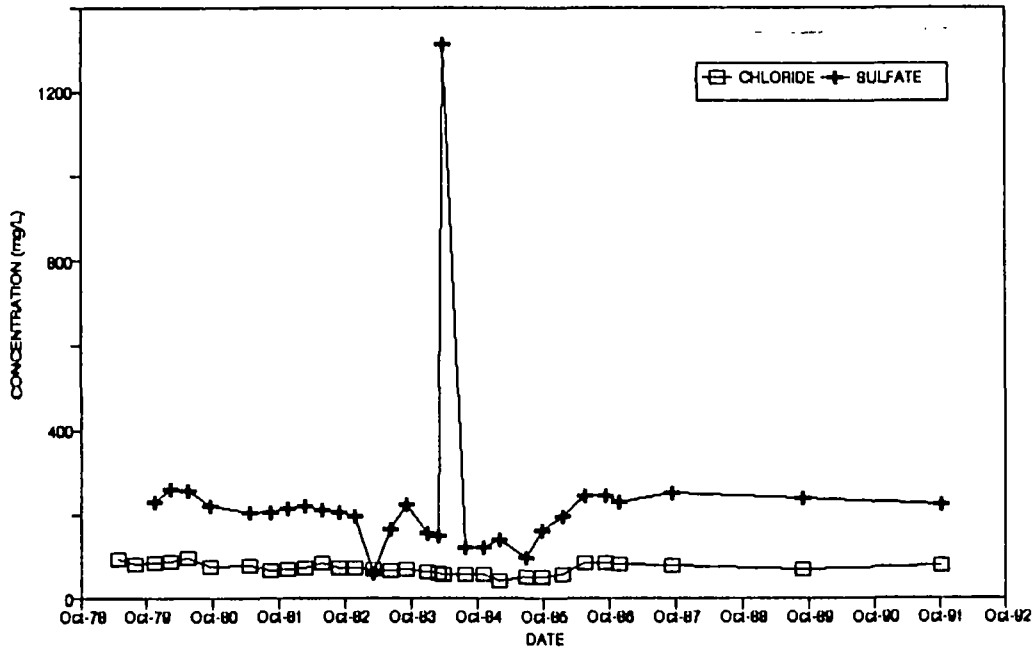


Figure 4-31. Chloride and Sulfate - Lewis Well

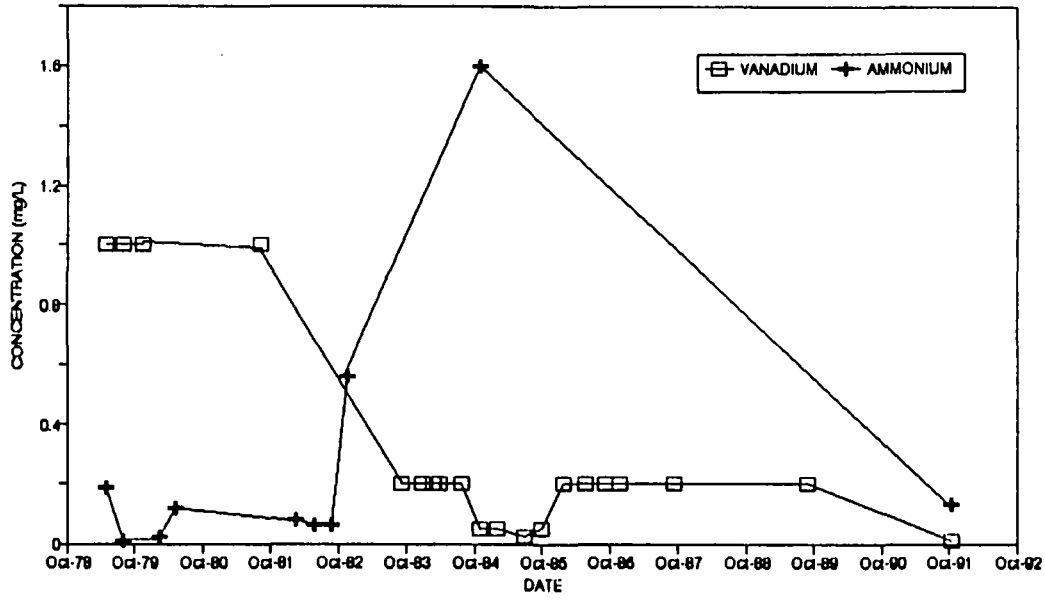


Figure 4-32. Vanadium and Ammonium - Lewis Well

UBZ-2
TEMPORAL PLOTS
MONSANTO/PHASE I RI REPORT/ID

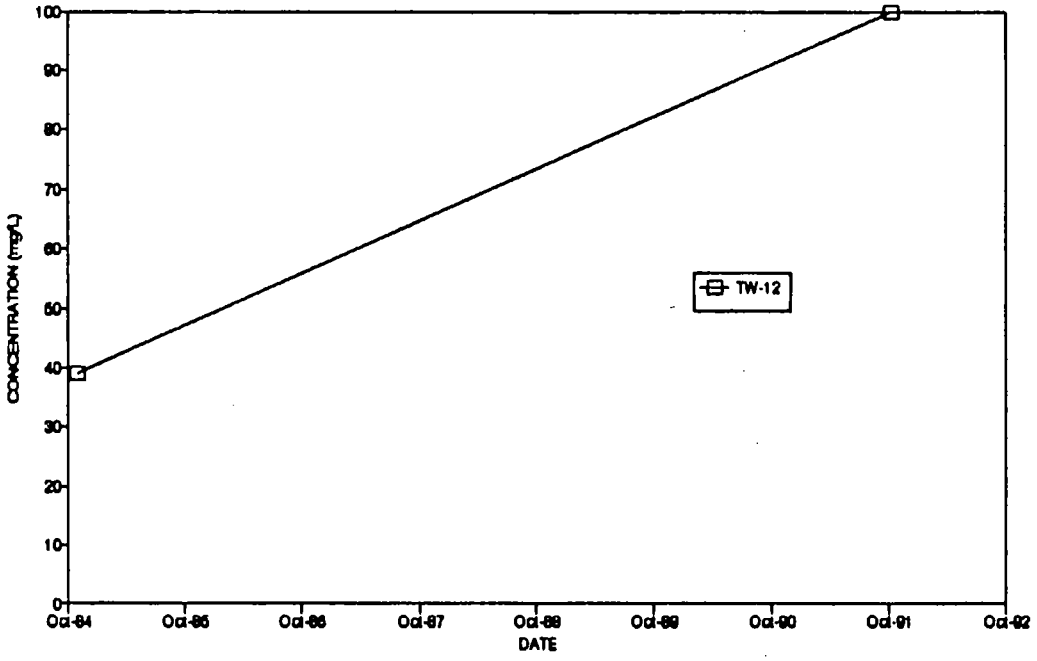


Figure 4-33. Ammonium - TW-12

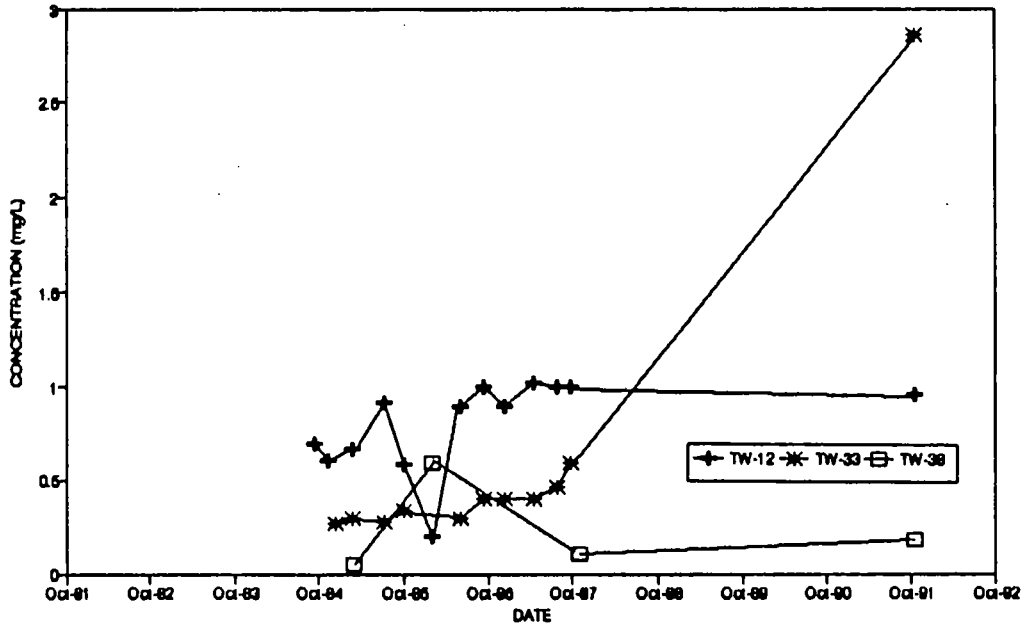


Figure 4-34. Vanadium - TW-12, TW-33, and TW-38

UBZ-3
TEMPORAL PLOTS
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO. 913-1101.212 DWG. NO. 28671 DATE 4/10/92 DRAWN TK

Golder Associates

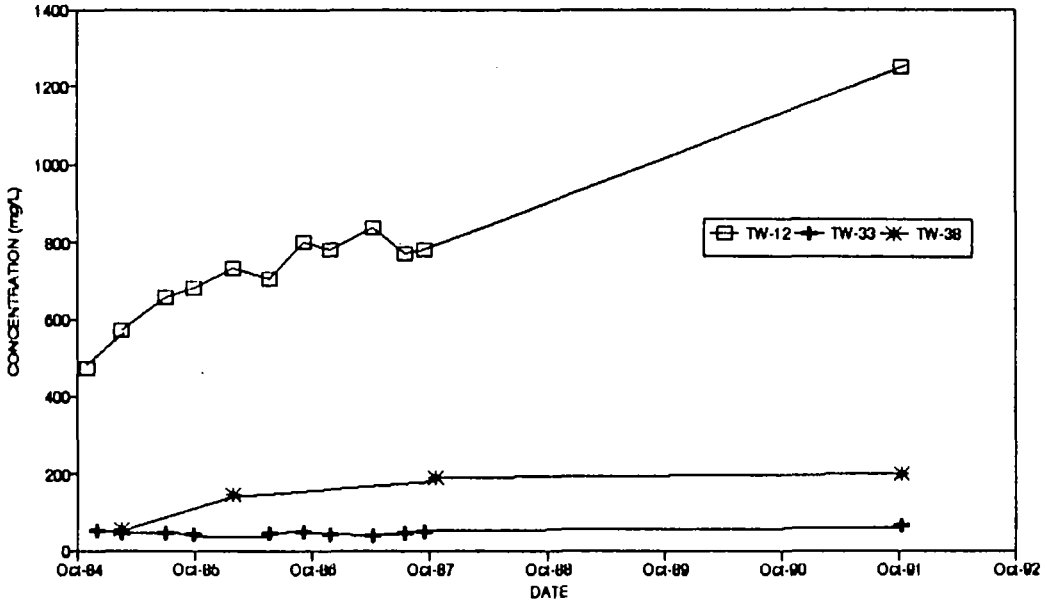


Figure 4-35. Chloride - TW-12, TW-33, and TW-38

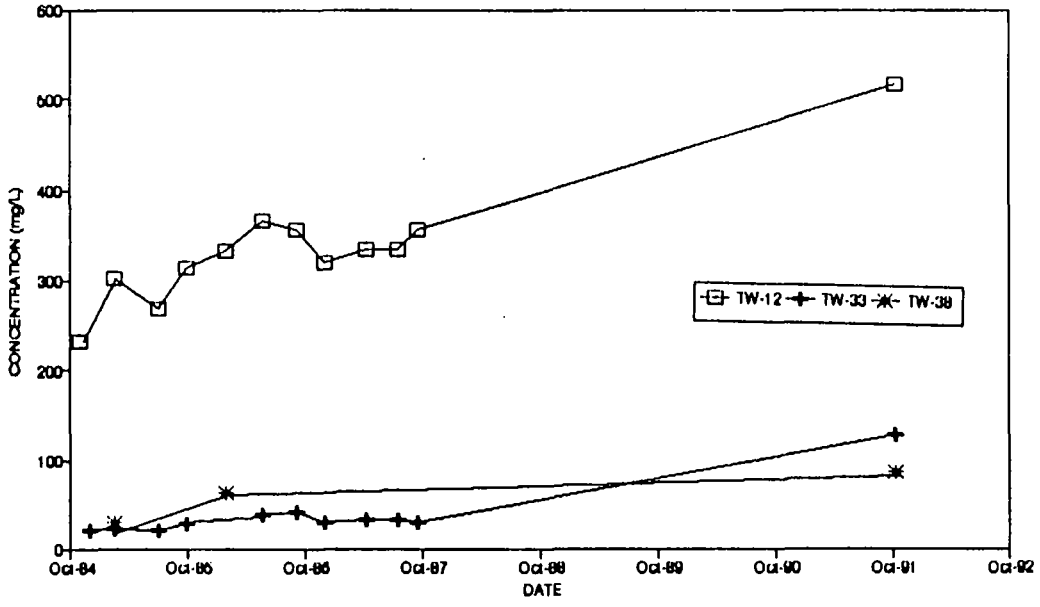


Figure 4-36. Sulfate - TW-12, TW-33, and TW-38

UBZ-3
TEMPORAL PLOTS
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO. 913-1101.212 DWG. NO. 28072 DATE 4/10/92 DRAWN TK

Golder Associates

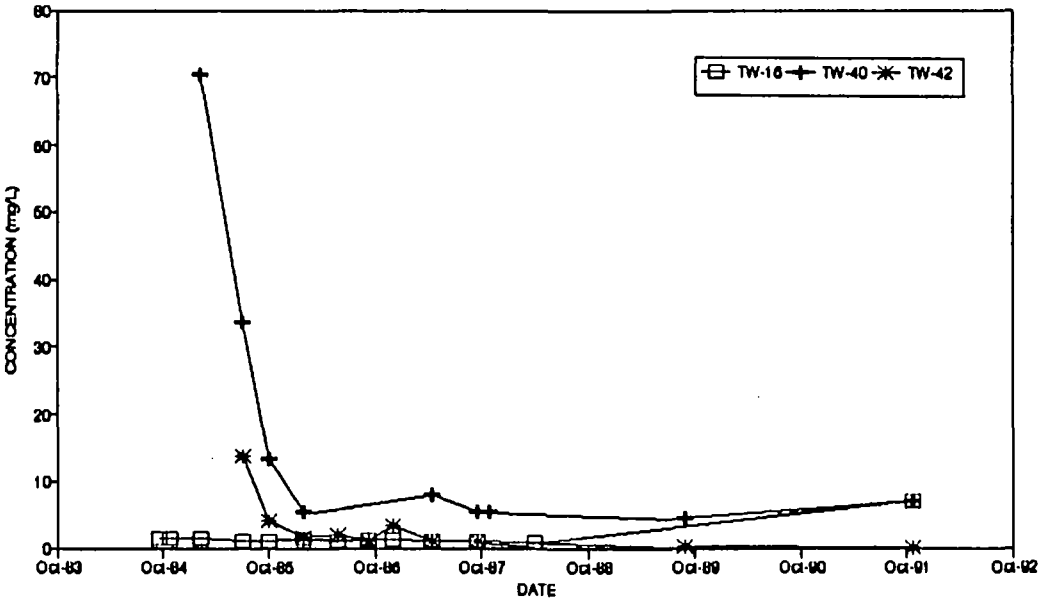


Figure 4-37. Cadmium - TW-16, TW-40, and TW-42

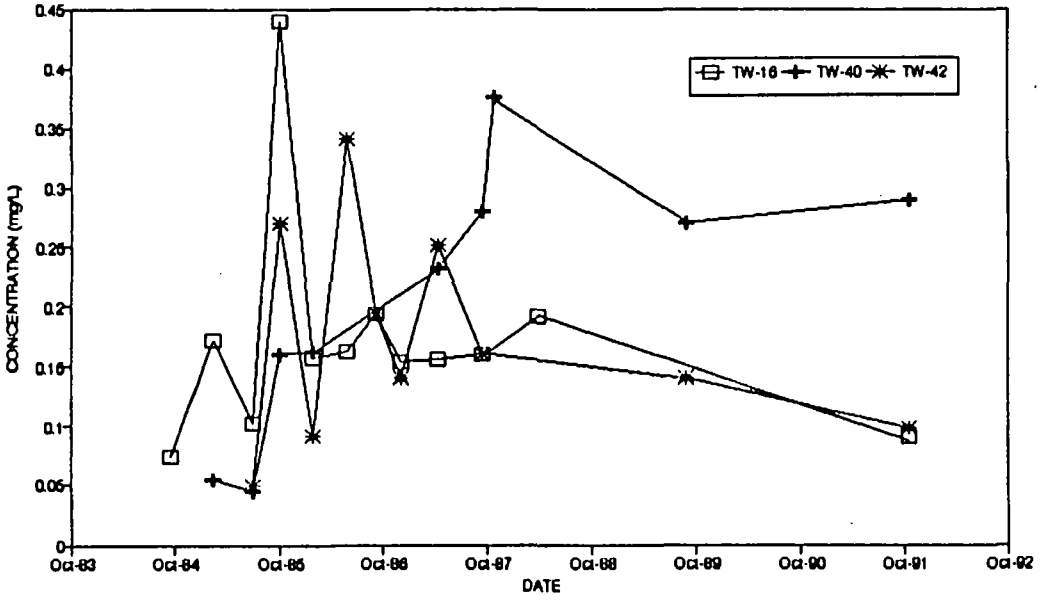


Figure 4-38. Selenium - TW-16, TW-40, and TW-42

UBZ-4
TEMPORAL PLOTS
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO. 913-1101.212 DWG. NO. 28673 DATE 4/10/92 DRAWN TK

Golder Associates

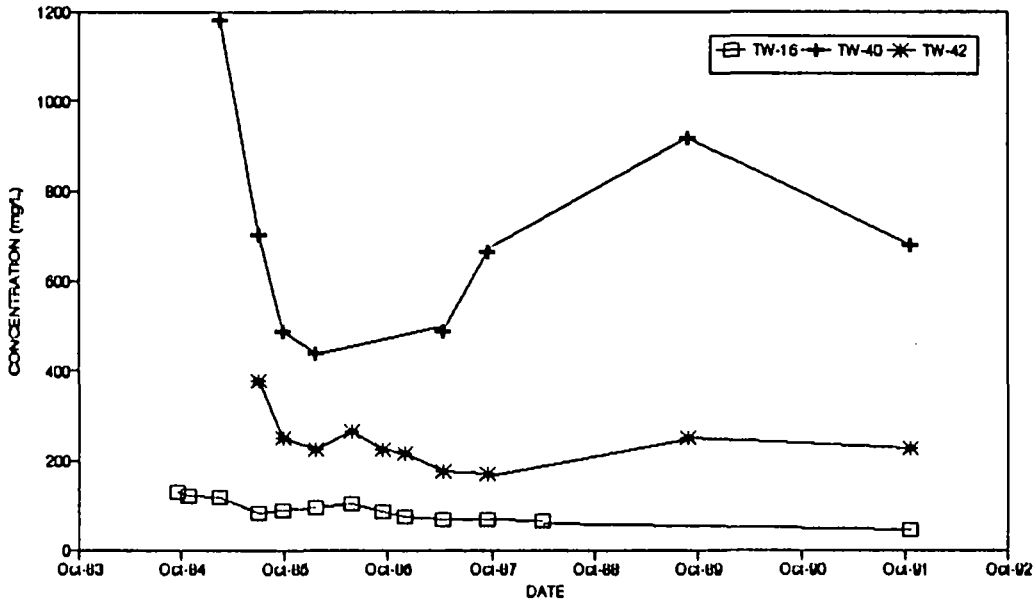


Figure 4-39. Chloride - TW-16, TW-40, and TW-42

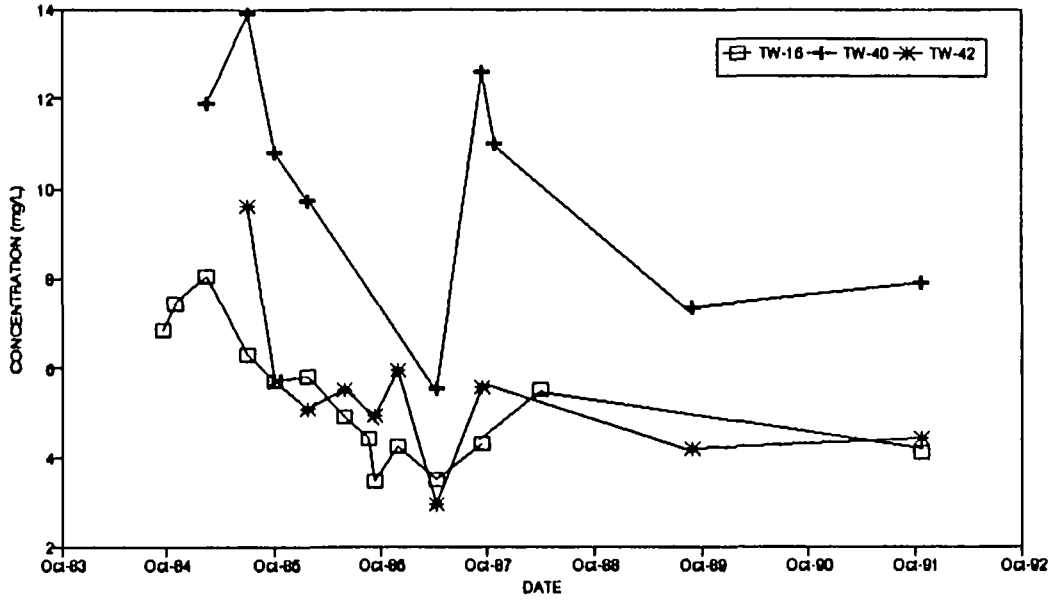


Figure 4-40. Fluoride - TW-16, TW-40, and TW-42

UBZ-4
TEMPORAL PLOTS
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO. 913-1101.212 DWG. NO. 28074 DATE 4/10/92 DRAWN TK

Golder Associates

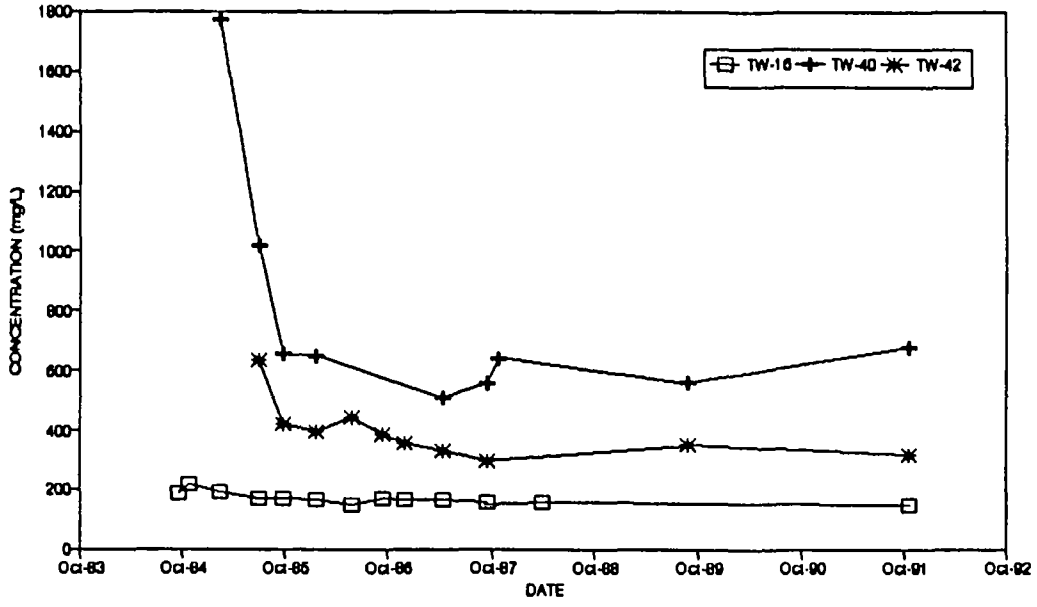


Figure 4-41. Sulfate - TW-16, TW-40, and TW-42

UBZ-4
TEMPORAL PLOT
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO. 913-1101.212 DWG. NO. 28675 DATE 4/10/92 DRAWN TK

Golder Associates

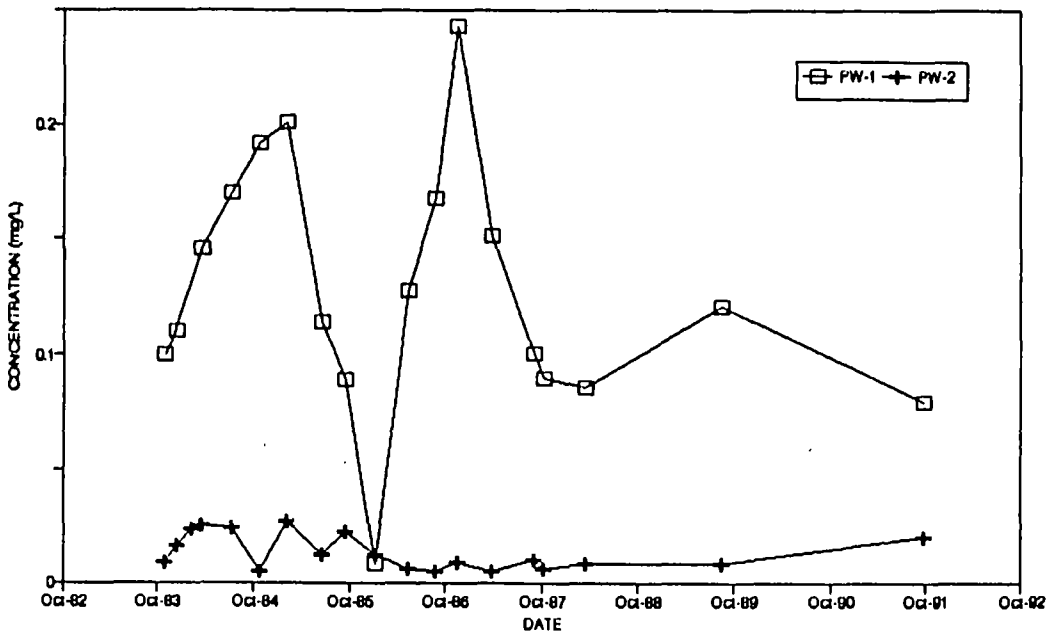


Figure 4-42. Cadmium - PW-1 and PW-2

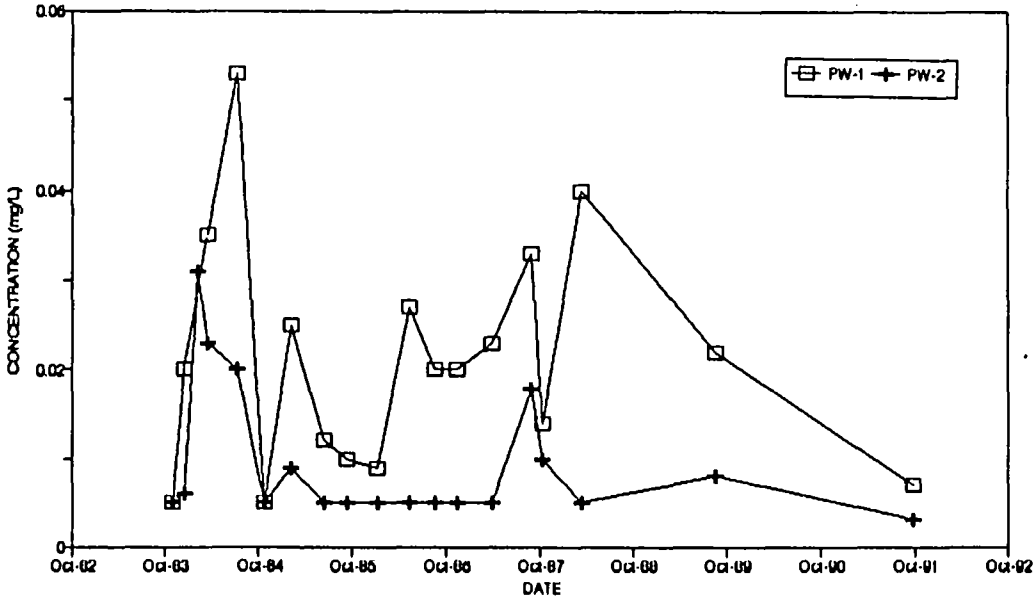


Figure 4-43. Selenium - PW-1 and PW-2

UBZ-4
TEMPORAL PLOTS
MONSANTO/PHASE I RI REPORT/ID

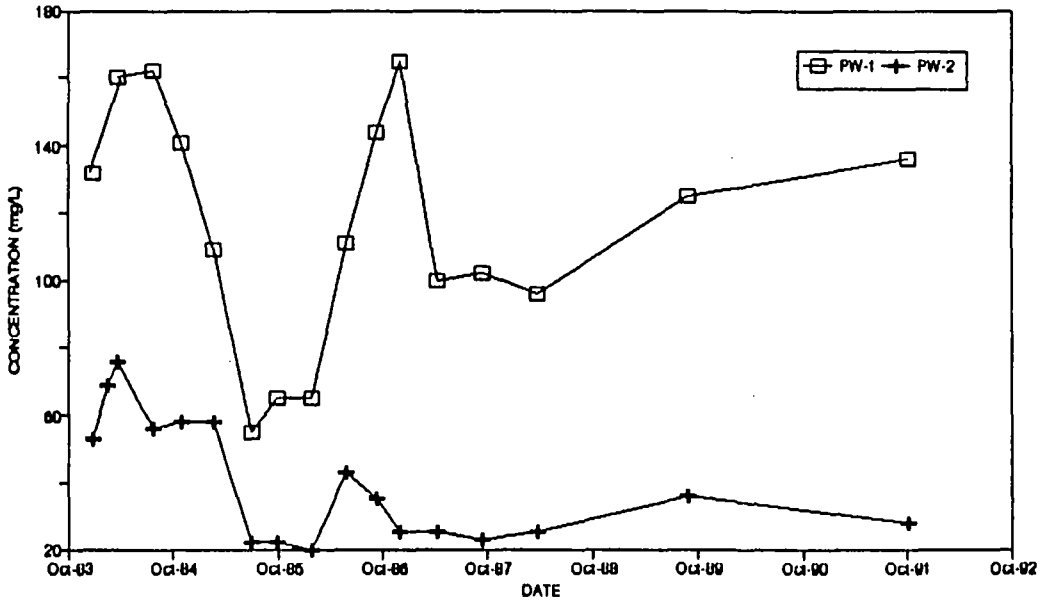


Figure 4-44. Chloride - PW-1 and PW-2

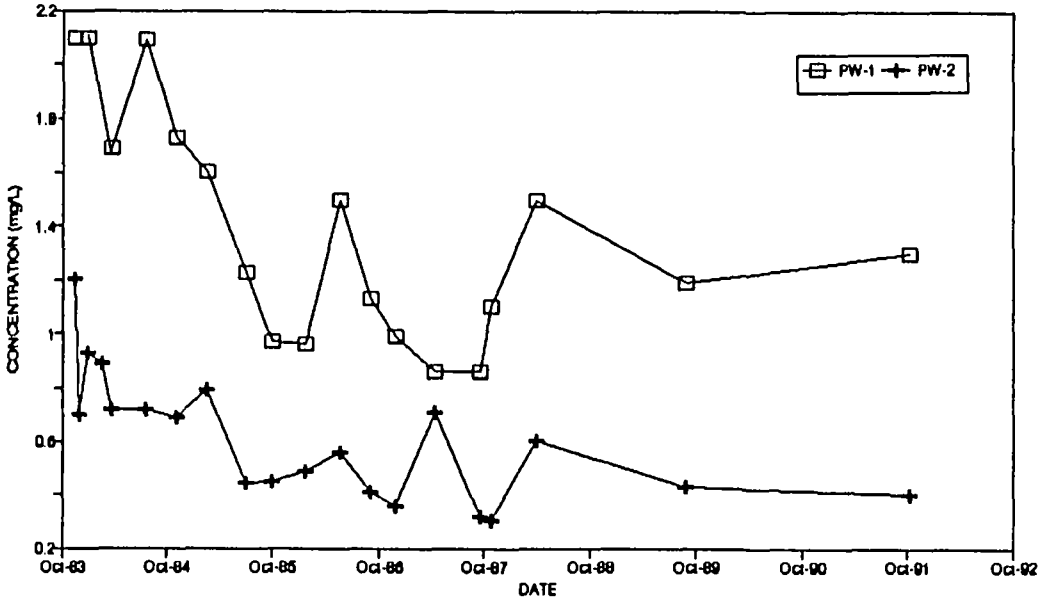


Figure 4-45. Fluoride - PW-1 and PW-2

UBZ-4
TEMPORAL PLOTS
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO. 913-1101.212 DWG. NO. 28677 DATE 4/10/92 DRAWN TK

Golder Associates

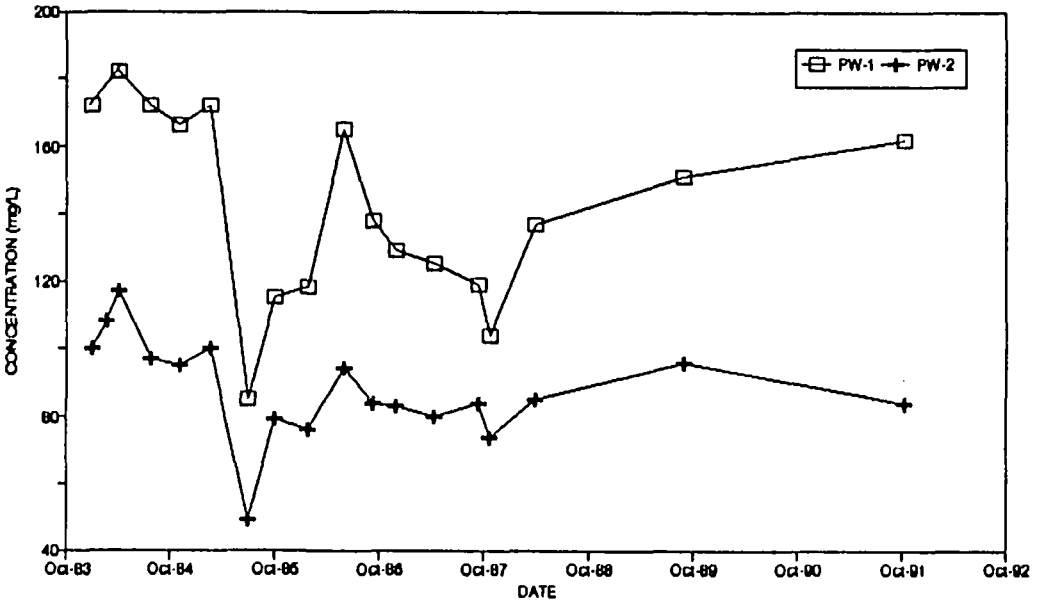


Figure 4-46. Sulfate - PW-1 and PW-2

UBZ-4
TEMPORAL PLOT
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO. 913-1101.212 DWG. NO. 28678 DATE 4/10/92 DRAWN TK

Golder Associates

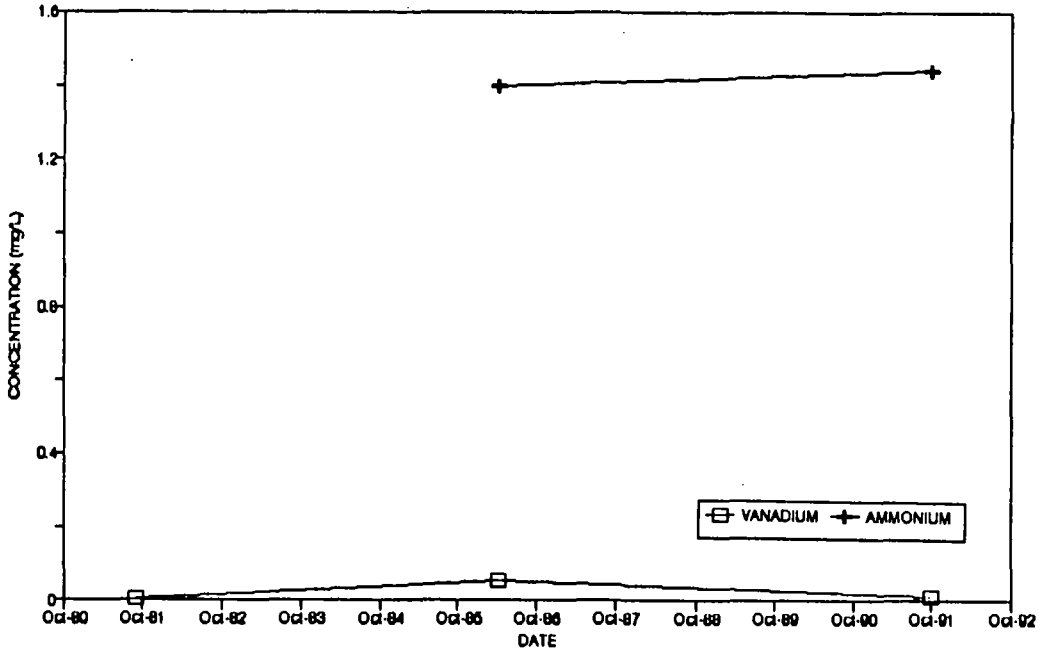


Figure 4-47. Vanadium and Ammonium - Finch Spring

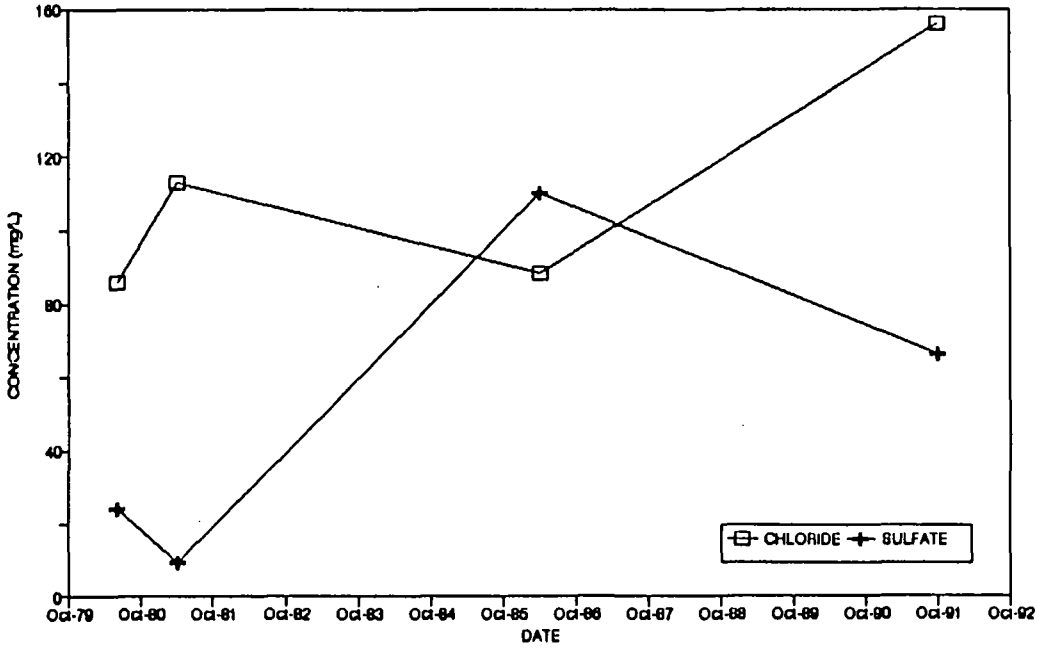


Figure 4-48. Chloride and Sulfate - Finch Spring

UBZ-5
TEMPORAL PLOTS
MONSANTO/PHASE I RI REPORT/ID

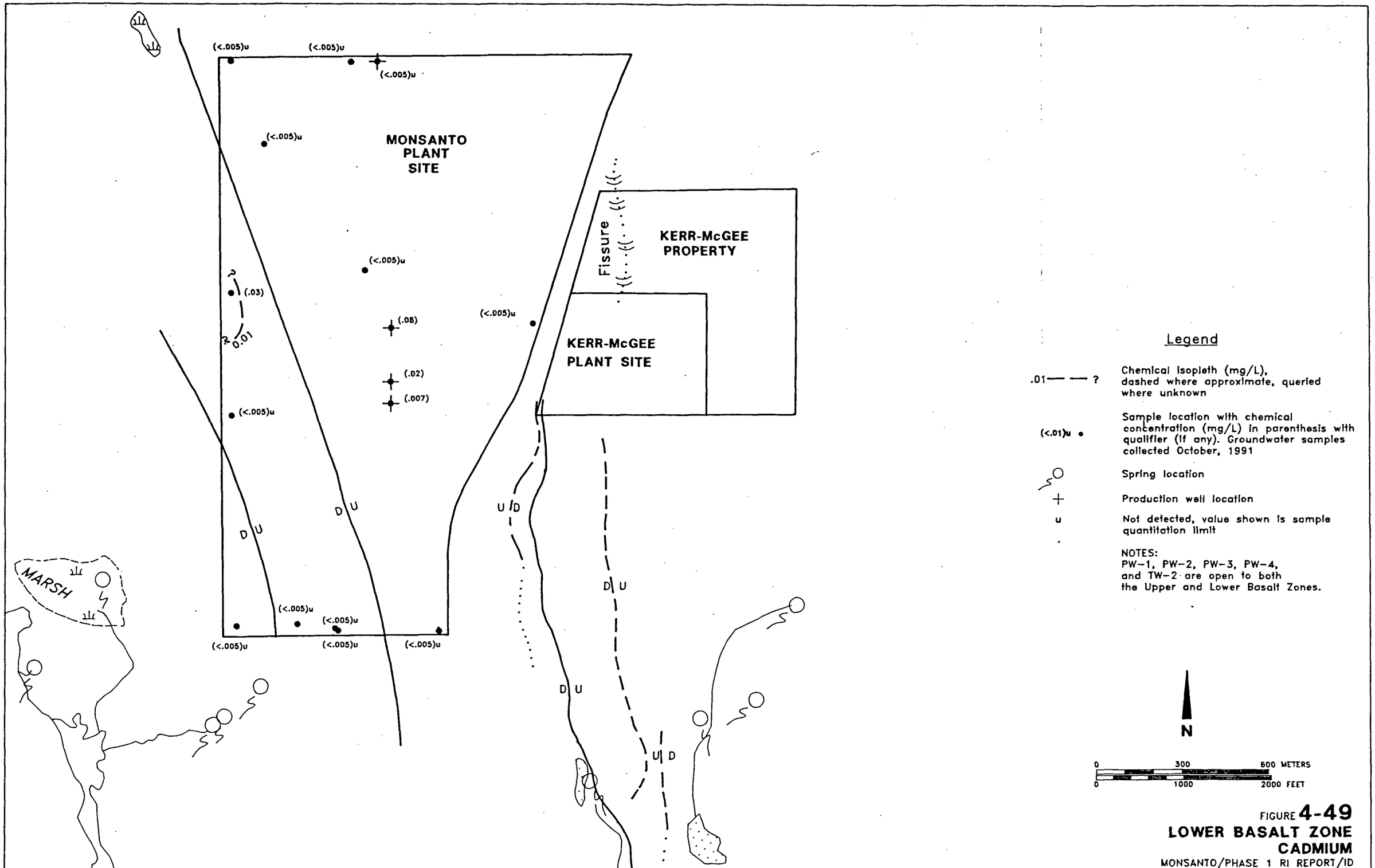


FIGURE 4-49
LOWER BASALT ZONE CADMIUM
MONSANTO/PHASE 1 RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO 36582 DATE 4-17-92 DRAWN JRS

Golder Associates

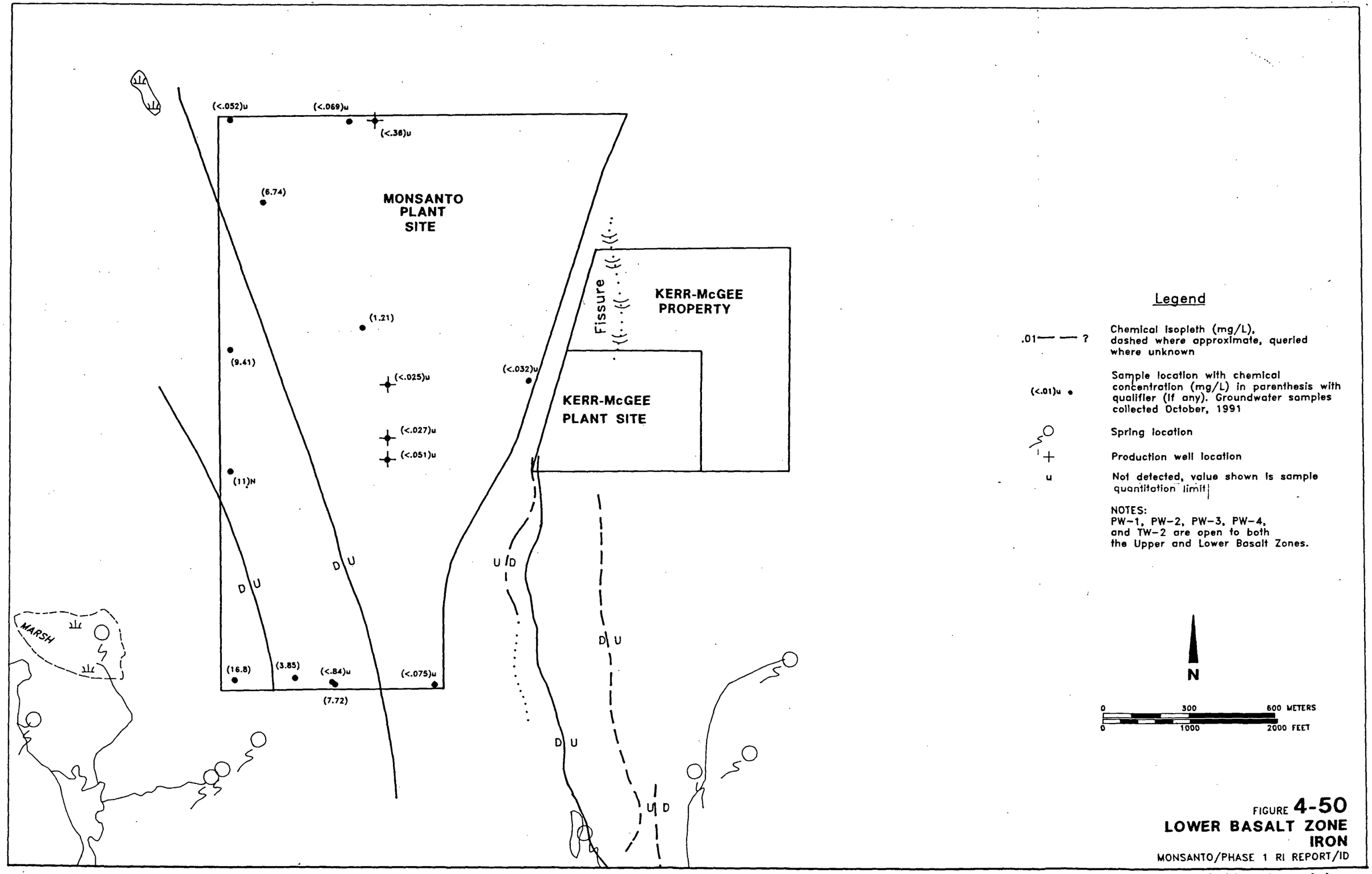
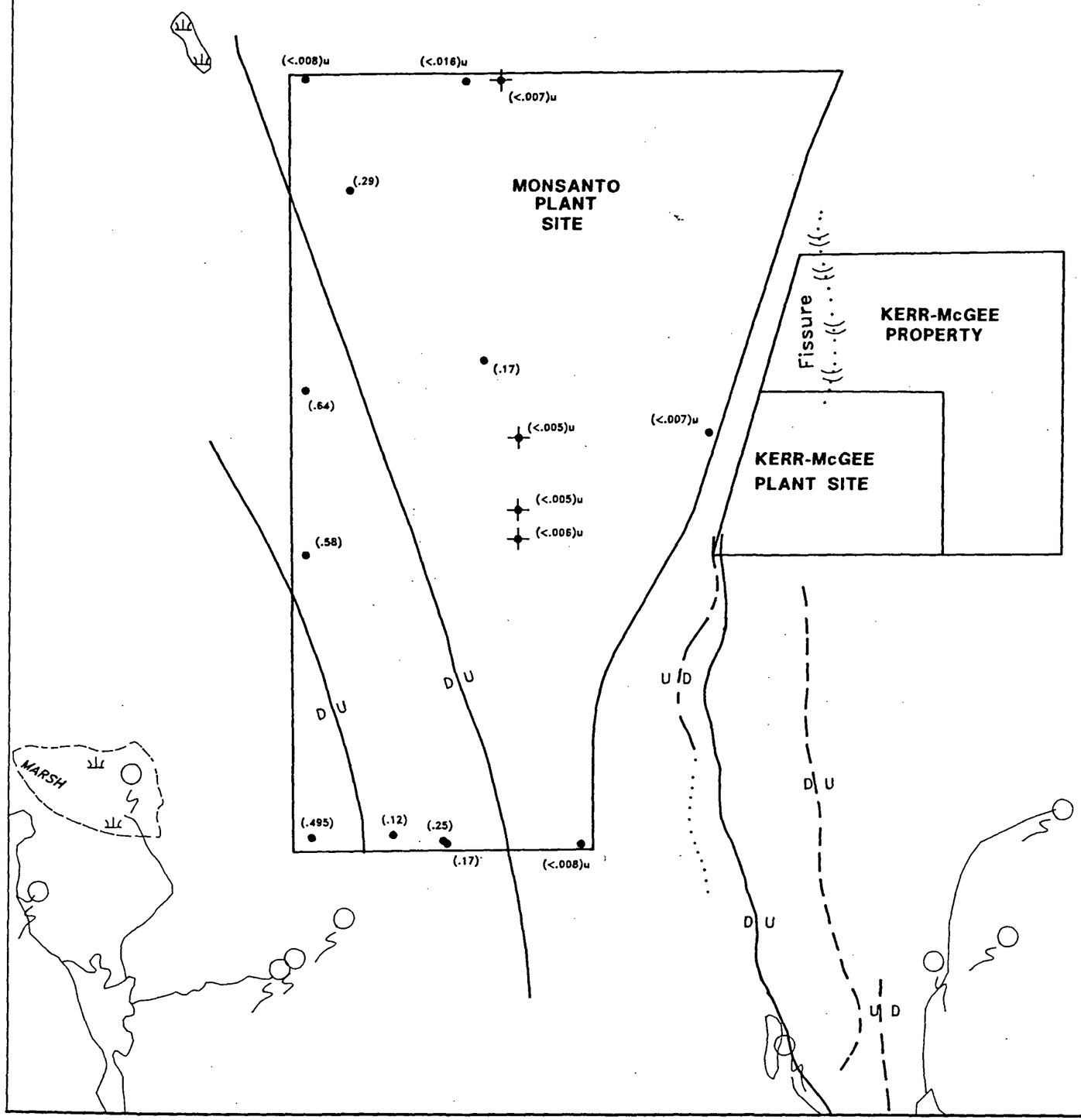


FIGURE 4-50
LOWER BASALT ZONE IRON
MONSANTO/PHASE 1 RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO36580 DATE 4-16-92 DRAWN JRS

Golder Associates



Legend

.01 — — ?	Chemical isopleth (mg/L), dashed where approximate, queried where unknown
(<.01)u •	Sample location with chemical concentration (mg/L) in parenthesis with qualifier (if any). Groundwater samples collected October, 1991
	Spring location
+	Production well location
u	Not detected, value shown is sample quantitation limit

NOTES:
PW-1, PW-2, PW-3, PW-4, and TW-2 are open to both the Upper and Lower Basalt Zones.

N

0 300 600 METERS
0 1000 2000 FEET

FIGURE **4-51**
LOWER BASALT ZONE MANGANESE
MONSANTO/PHASE 1 RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO36578 DATE 4-16-92 DRAWN JRS

Golder Associates

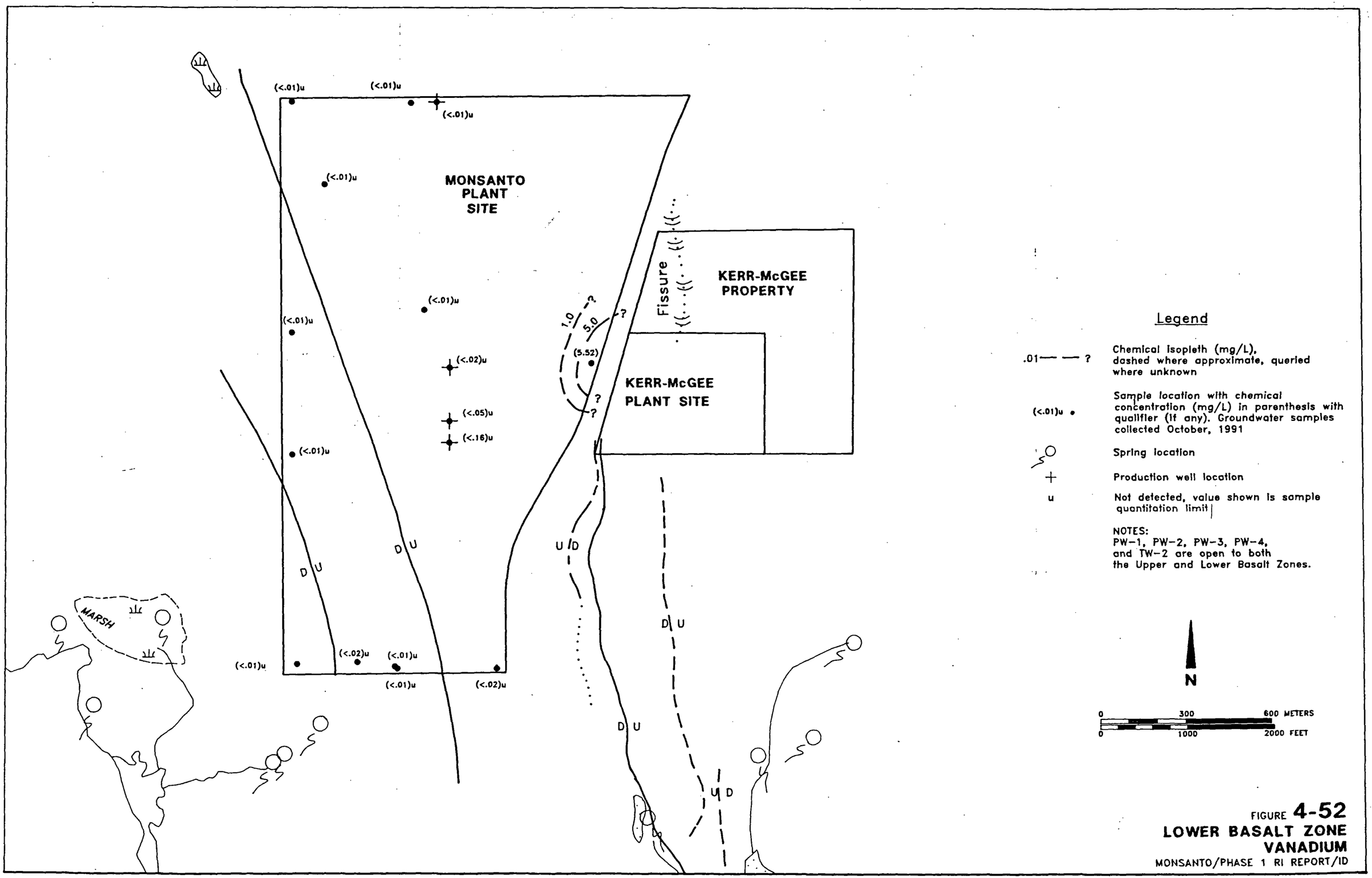


FIGURE 4-52
LOWER BASALT ZONE VANADIUM
MONSANTO/PHASE 1 RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO 36575 DATE 4-16-92 DRAWN JRS

Golder Associates

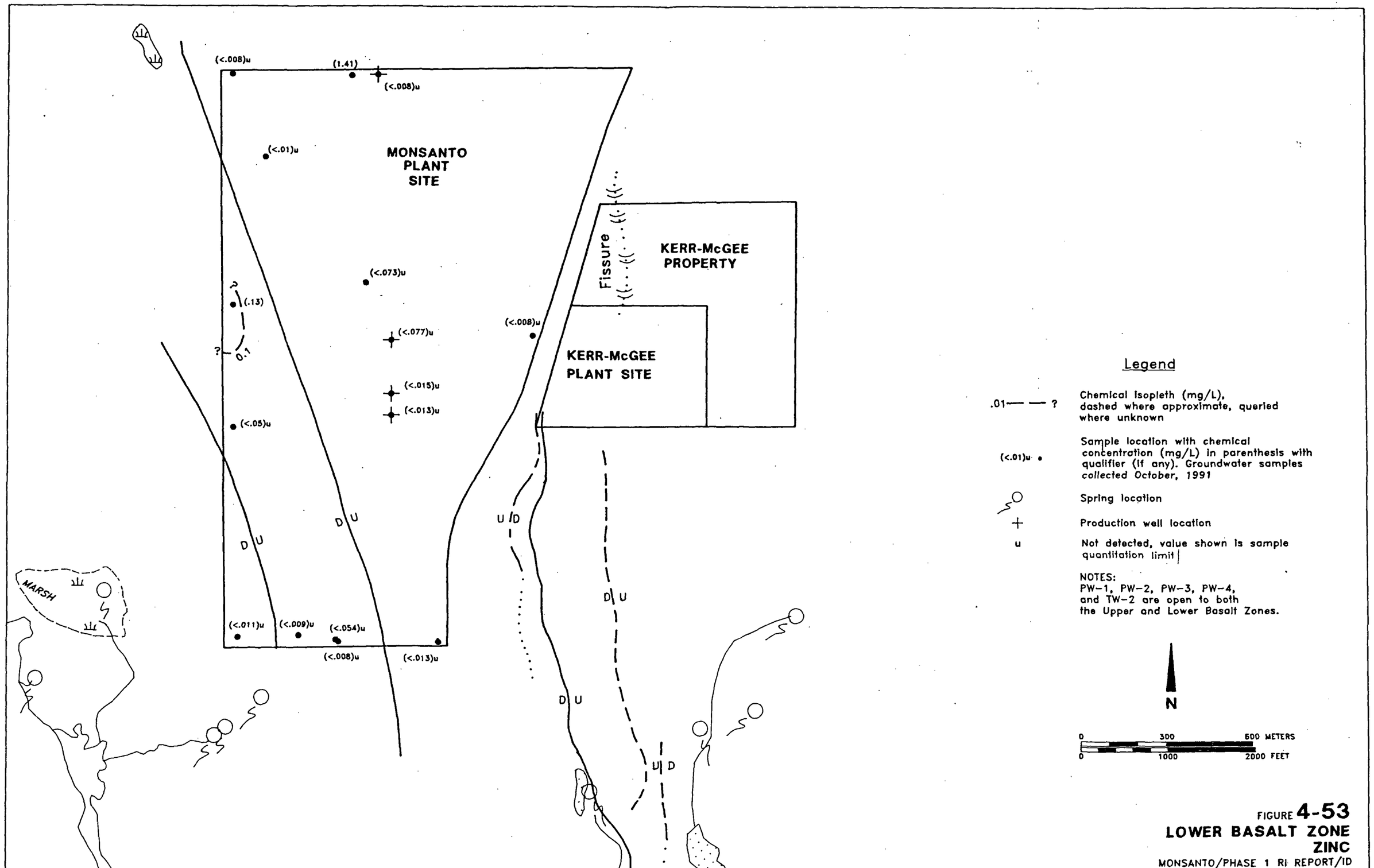
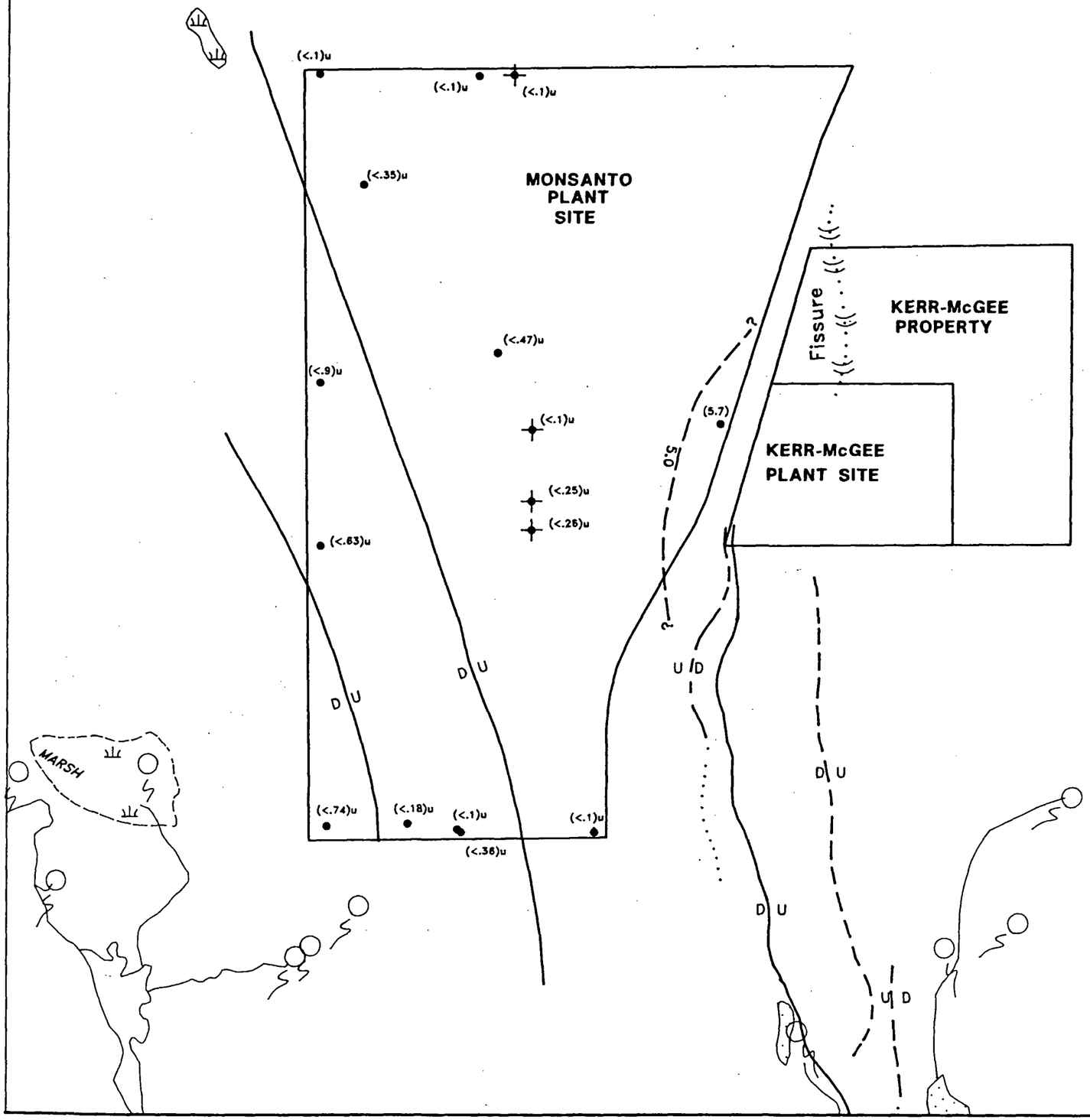


FIGURE 4-53
LOWER BASALT ZONE ZINC
MONSANTO/PHASE 1 RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO36584 DATE 4-16-92 DRAWN JRS

Golder Associates



Legend

.01 — — ? Chemical isopleth (mg/L), dashed where approximate, queried where unknown

(<.01)u • Sample location with chemical concentration (mg/L) in parenthesis with qualifier (if any). Groundwater samples collected October, 1991

Spring location

Production well location

u Not detected, value shown is sample quantitation limit

NOTES:
PW-1, PW-2, PW-3, PW-4, and TW-2 are open to both the Upper and Lower Basalt Zones.

N

0 300 600 METERS
0 1000 2000 FEET

FIGURE 4-54
LOWER BASALT ZONE AMMONUUM AS N
MONSANTO/PHASE 1 RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO 36583 DATE 4-16-92 DRAWN JRS

Golder Associates

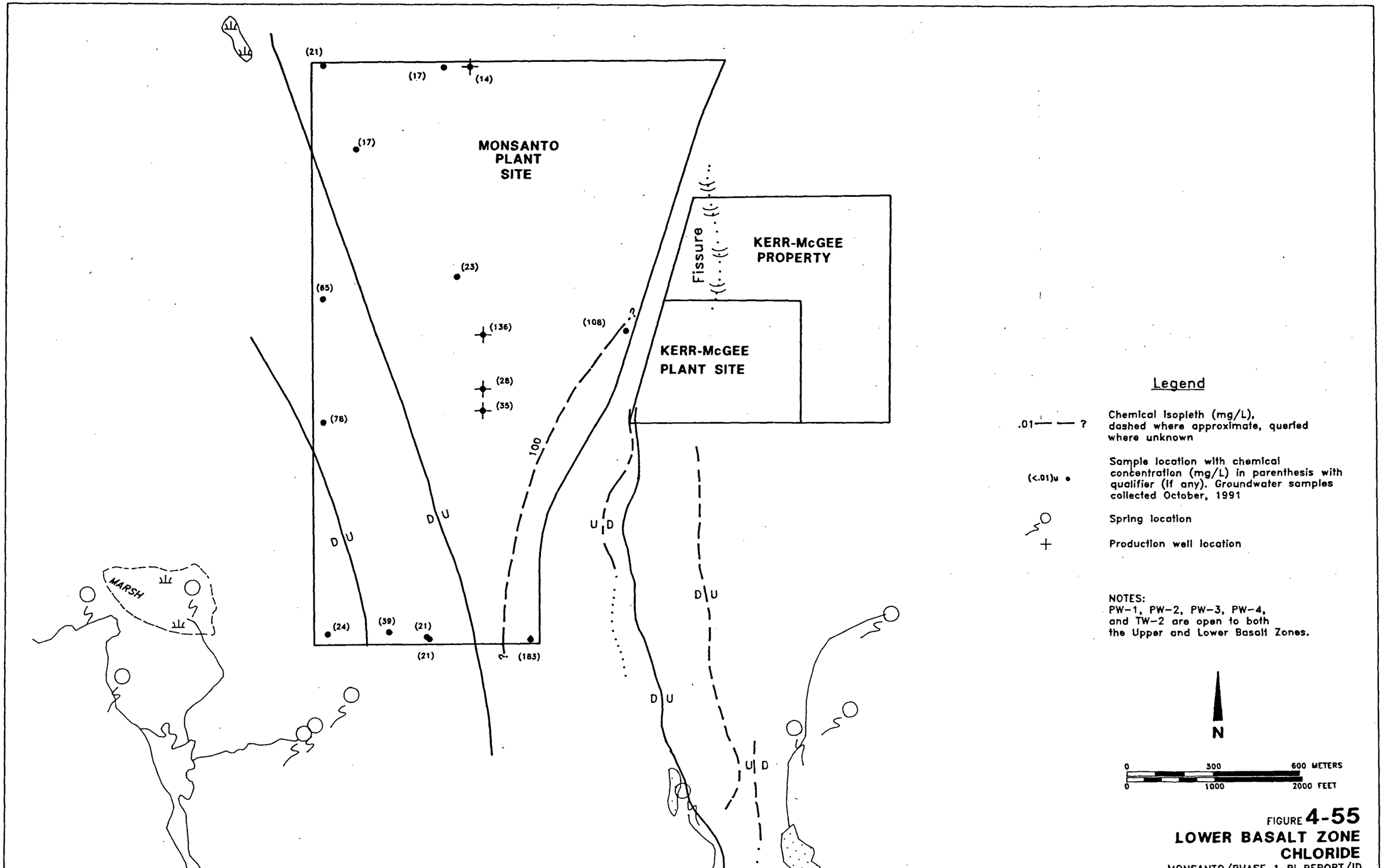
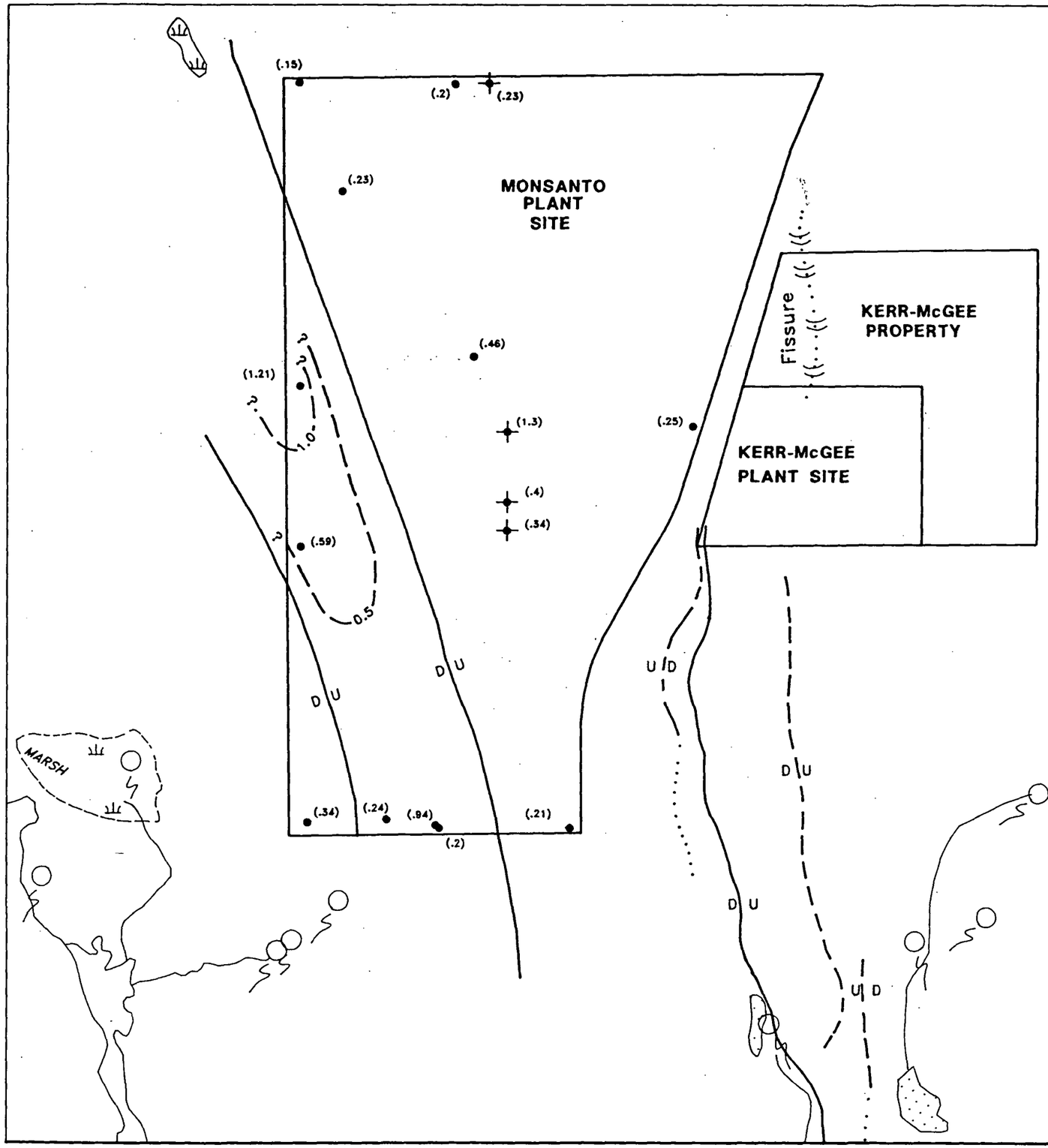


FIGURE 4-55
LOWER BASALT ZONE CHLORIDE
MONSANTO/PHASE 1 RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO 36576 DATE 4-16-92 DRAWN JRS

Golder Associates



Legend

.01 — — ?	Chemical isopleth (mg/L), dashed where approximate, queried where unknown
(<.01)u •	Sample location with chemical concentration (mg/L) in parenthesis with qualifier (if any). Groundwater samples collected October, 1991
	Spring location
+	Production well location

NOTES:
PW-1, PW-2, PW-3, PW-4, and TW-2 are open to both the Upper and Lower Basalt Zones.

N

0 300 600 METERS
0 1000 2000 FEET

FIGURE **4-56**
LOWER BASALT ZONE FLUORIDE
MONSANTO/PHASE 1 RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO 36581 DATE 4-16-92 DRAWN JRS

Golder Associates

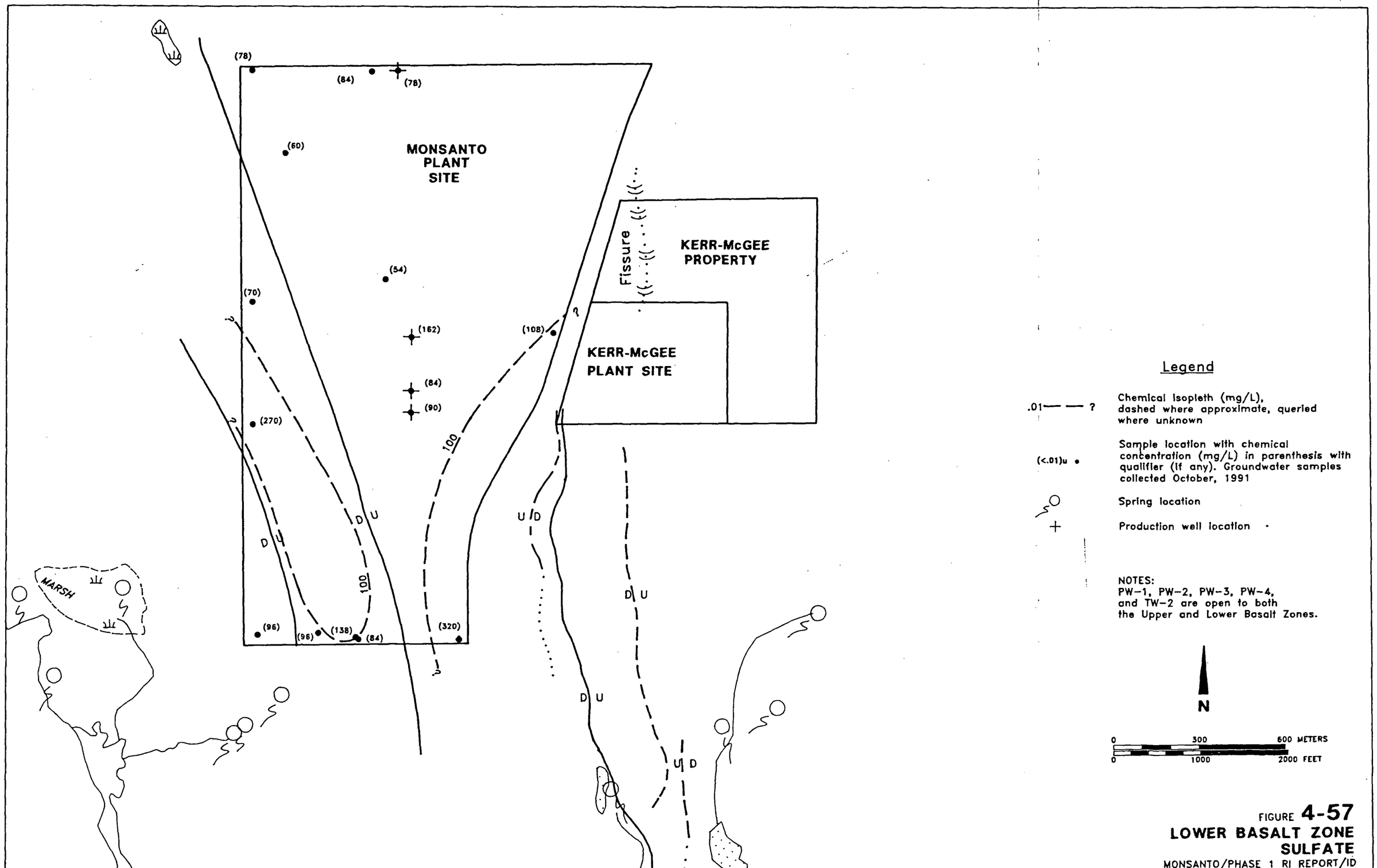


FIGURE **4-57**
LOWER BASALT ZONE SULFATE
MONSANTO/PHASE 1 RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO 36577 DATE 4-16-92 DRAWN JRS

Golder Associates

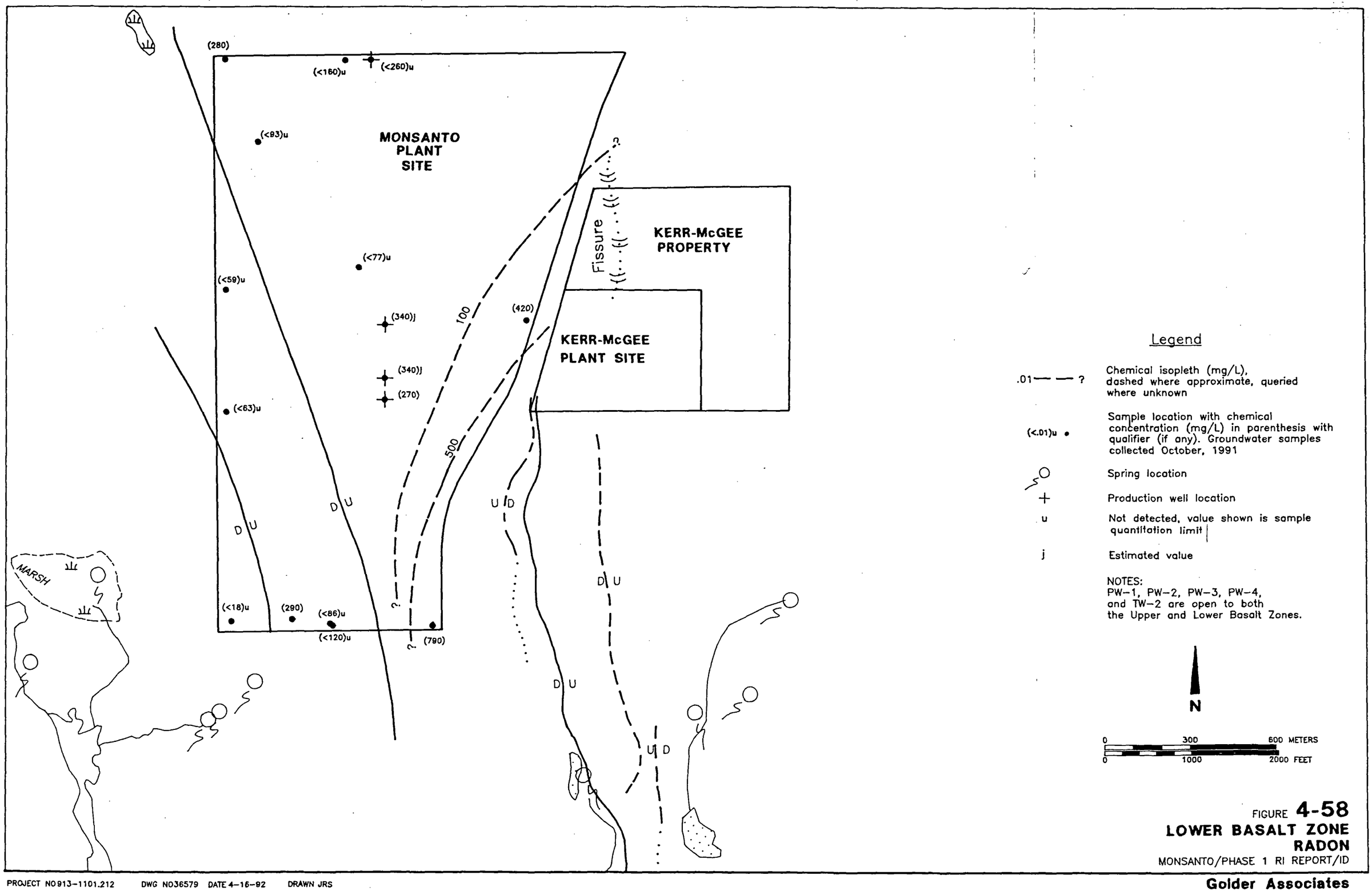


FIGURE **4-58**

LOWER BASALT ZONE RADON

MONSANTO/PHASE 1 RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO 36579 DATE 4-16-92 DRAWN JRS

Golder Associates

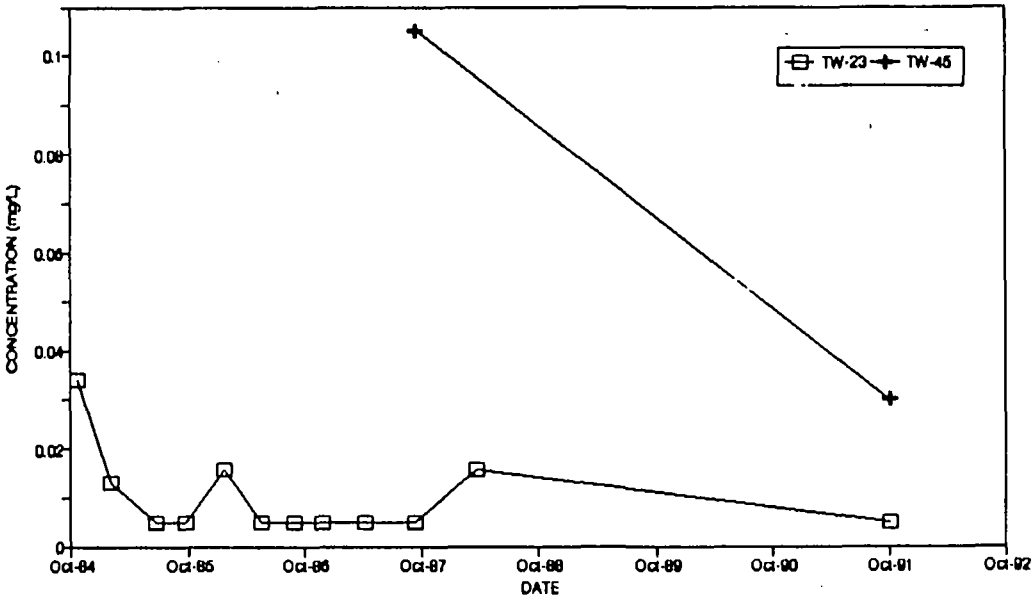


Figure 4-59. Cadmium - TW-23 and TW-45

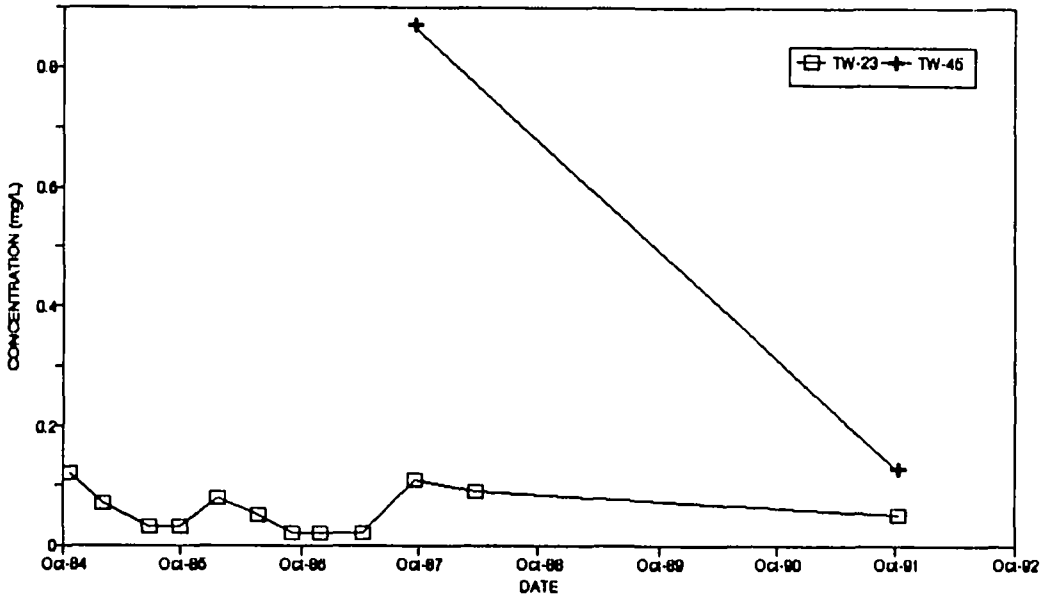


Figure 4-60. Zinc - TW-23 and TW-45

LBZ-2
TEMPORAL PLOTS
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO. 913-1101.212 DWG. NO. 20600 DATE 4/10/92 DRAWN TK

Golder Associates

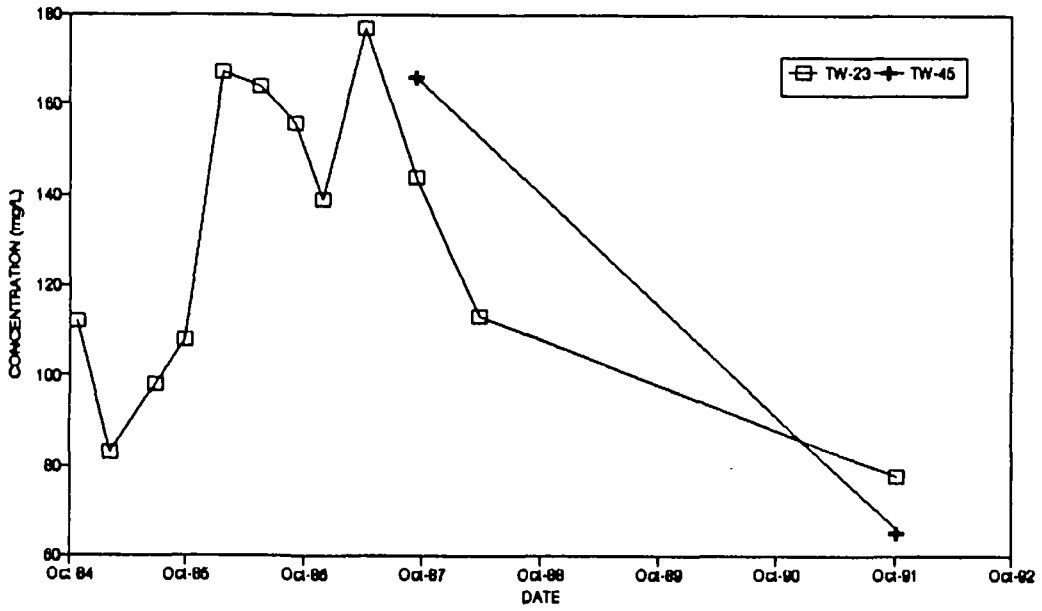


Figure 4-61. Chloride - TW-23 and TW-45

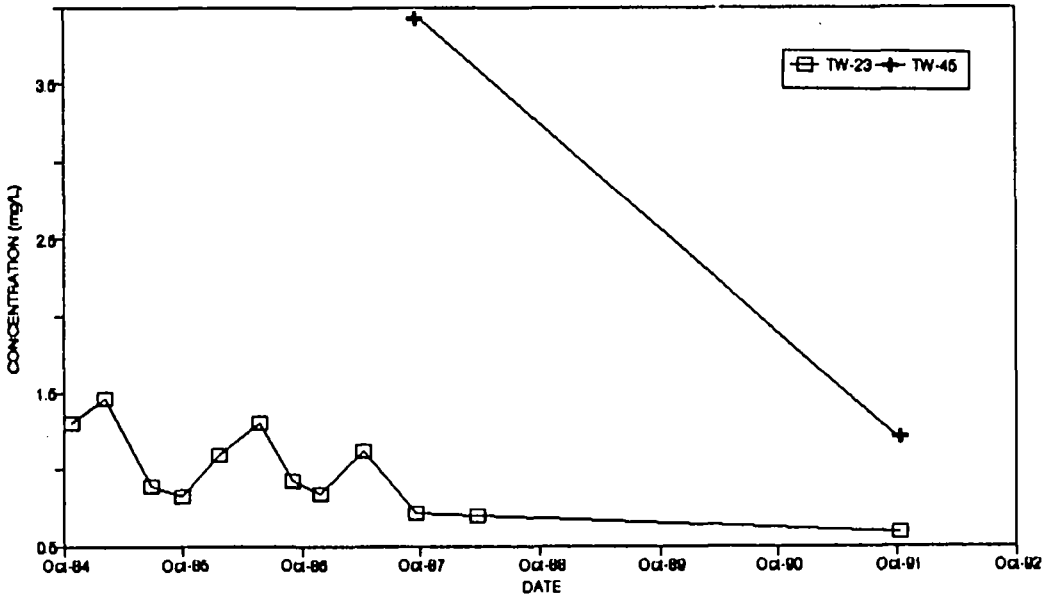


Figure 4-62. Fluoride - TW-23 and TW-45

LBZ-2
TEMPORAL PLOTS
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO. 913-1101.212 DWG. NO. 28681 DATE 4/10/92 DRAWN TK

Golder Associates

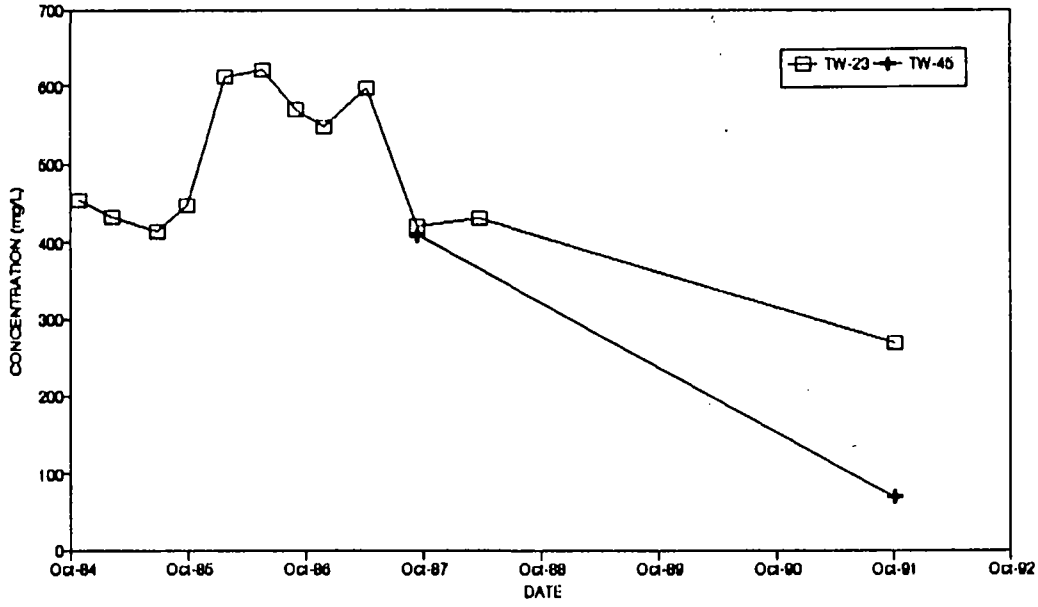


Figure 4-63. Sulfate - TW-23 and TW-45

LBZ-2
TEMPORAL PLOT
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO. 913-1101.212 DWG. NO. 28002 DATE 4/10/92 DRAWN TK

Golder Associates

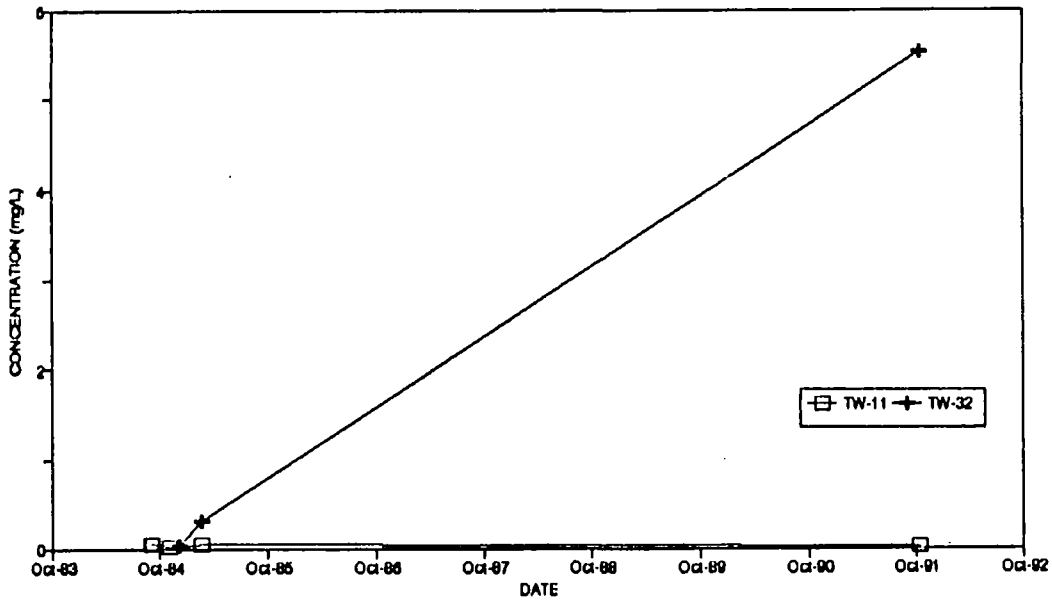


Figure 4-64. Vanadium - TW-11 and TW-32

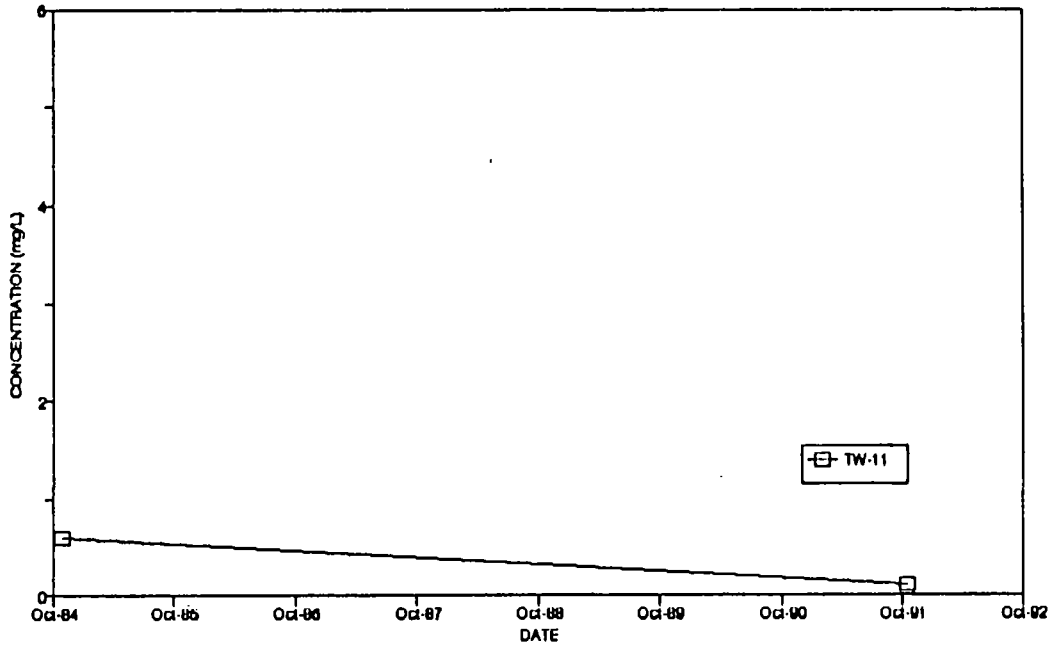


Figure 4-65. Ammonium - TW-11

LBZ-3
TEMPORAL PLOTS
MONSANTO/PHASE I RI REPORT/ID

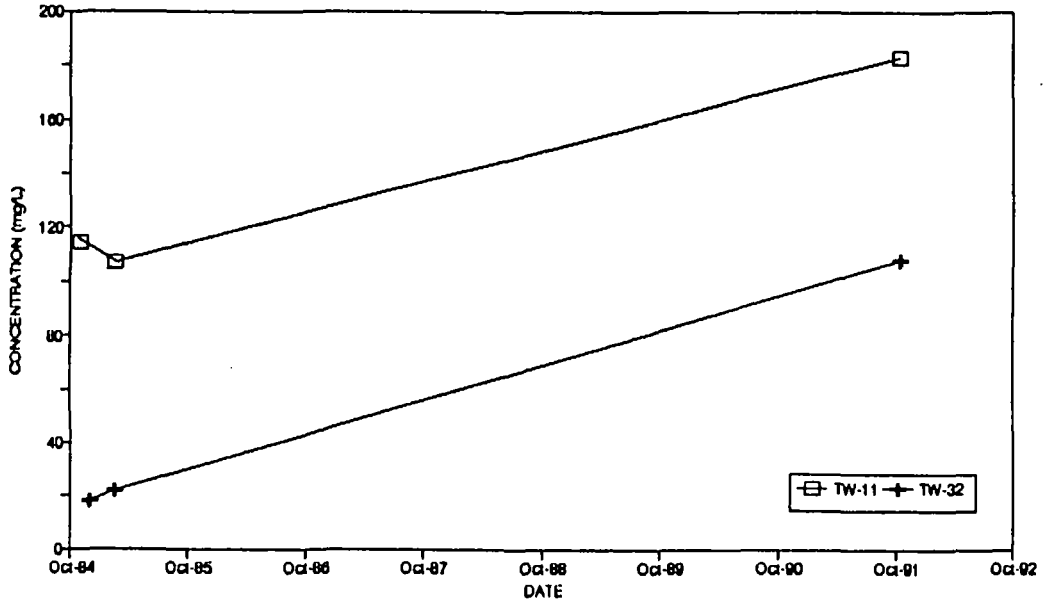


Figure 4-66. Chloride - TW-11 and TW-32

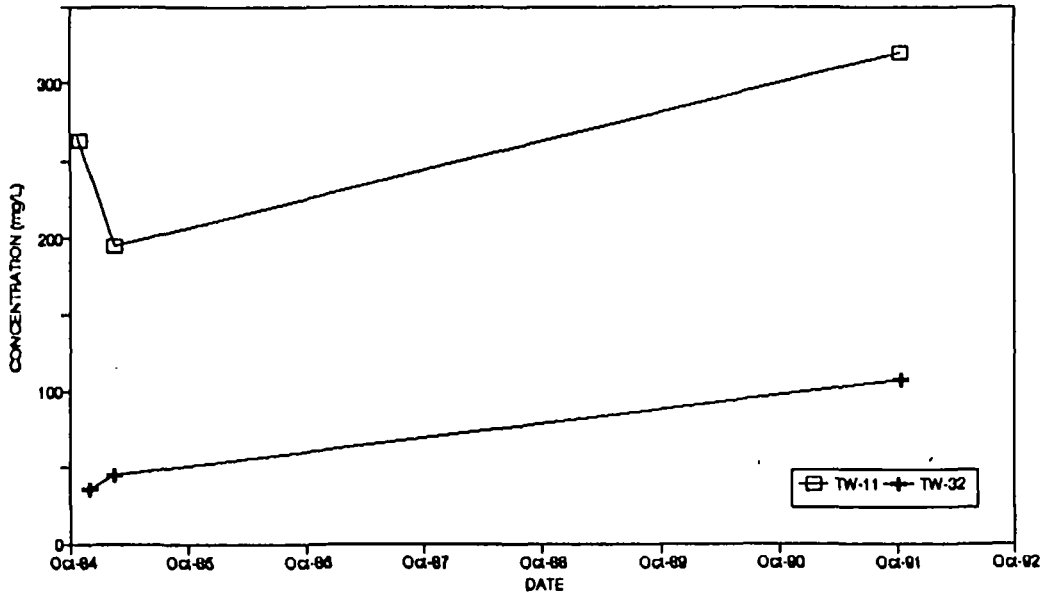


Figure 4-67. Sulfate - TW-11 and TW-32

LBZ-3
TEMPORAL PLOTS
MONSANTO/PHASE I RI REPORT/ID

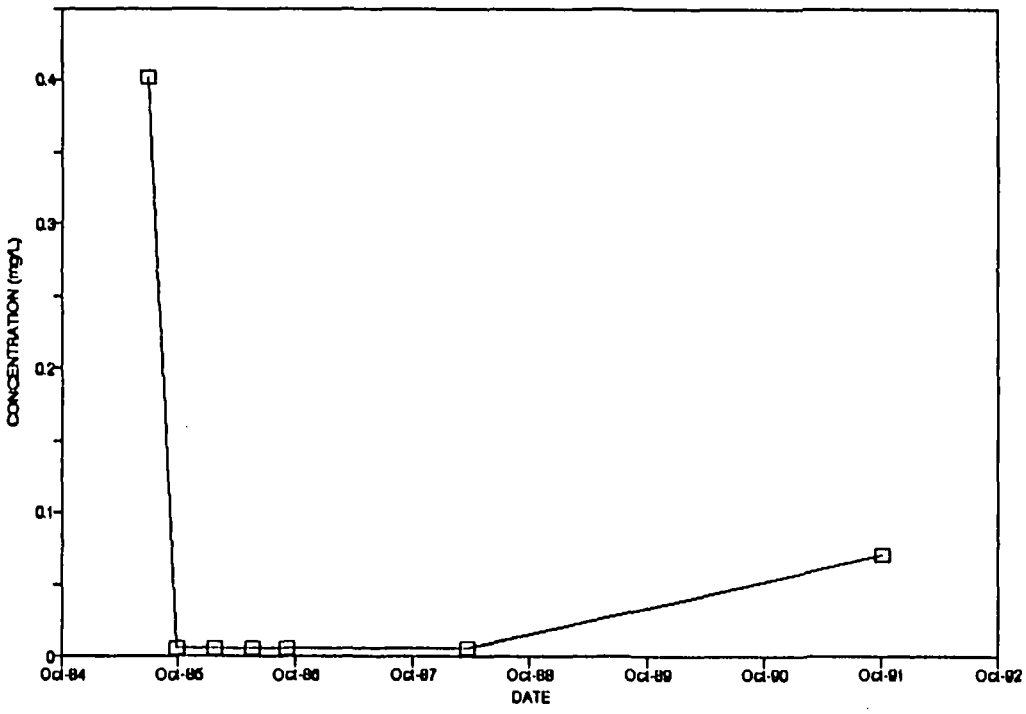


Figure 4-68. Cadmium - TW-44

LBZ-4
TEMPORAL PLOT
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO. 913-1101.212 DWG. NO. 28685 DATE 4/10/92 DRAWN TK

Golder Associates

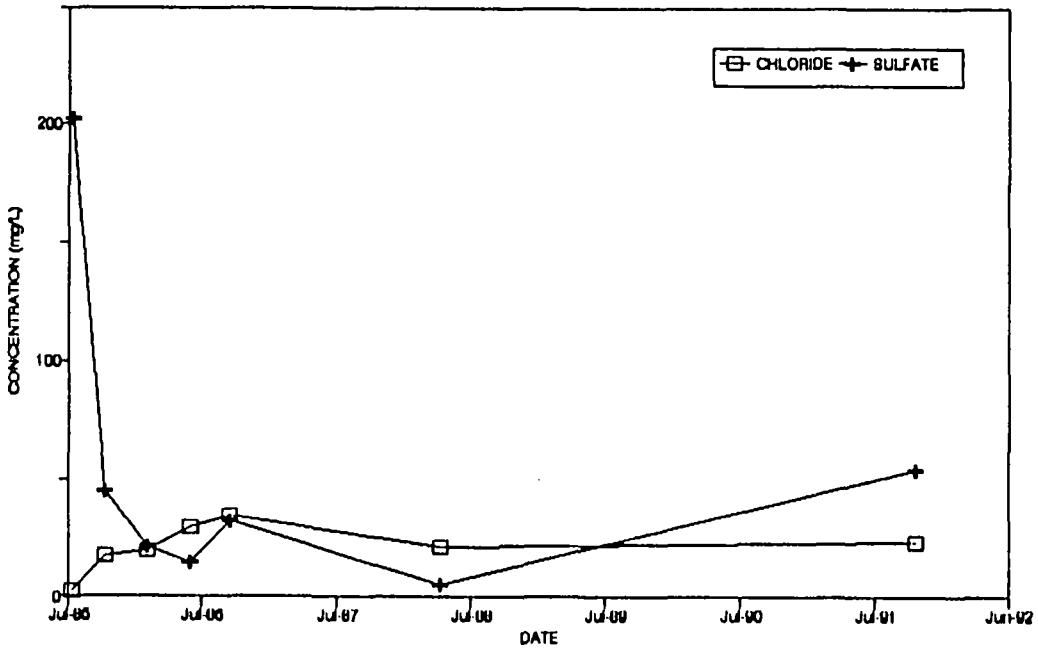


Figure 4-69. Chloride and Sulfate - TW-44

LBZ-4
TEMPORAL PLOTS
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO. 913-1101.212 DWG. NO. 28608 DATE 4/10/92 DRAWN TK

Golder Associates

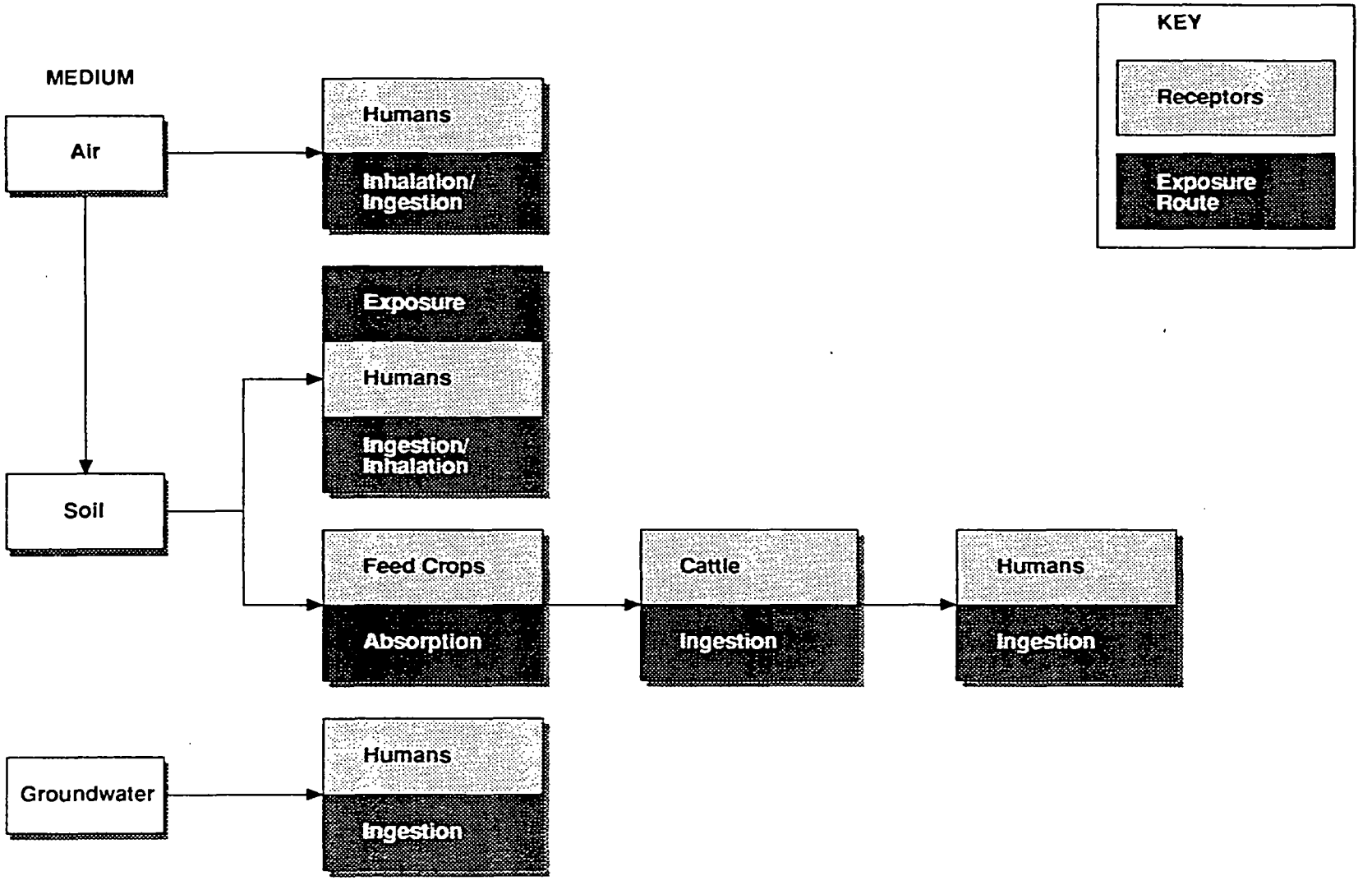
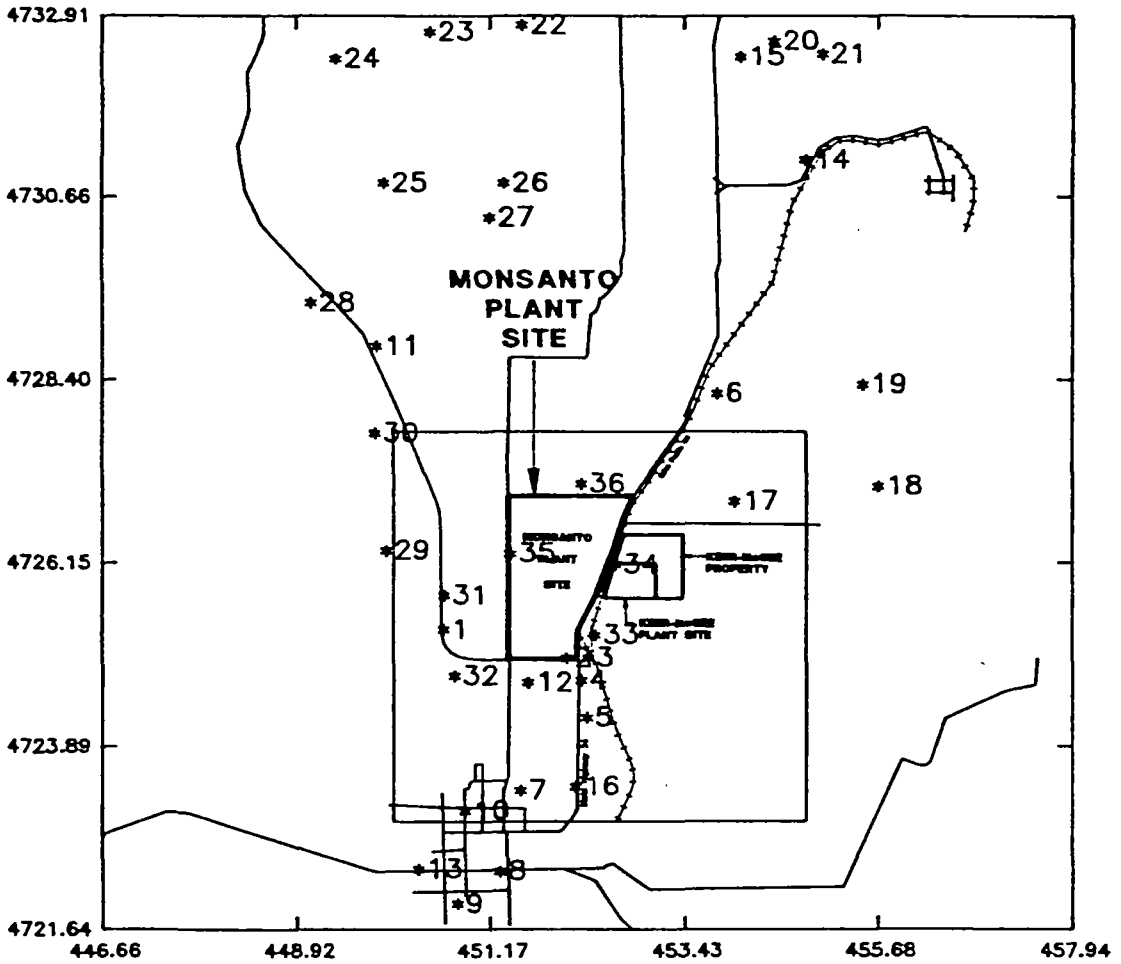


FIGURE **5-1**
POTENTIALLY SIGNIFICANT PATHWAYS FOR HUMAN AND ENVIRONMENTAL EXPOSURES
MONSANTO/PHASE I RI REPORT/ID

PROJECT NO. 913-1101.212 DRAWING NO. 28687 DATE 4/23/92 DRAWN BY TK

Golder Associates



EXPLANATION:

*18 Receptor Location

4721.64 UTM Coordinates (x1000m)

NOTE:
Inset refers to area depicted in Figures 5-3 to 5-22.

FIGURE **5-2**

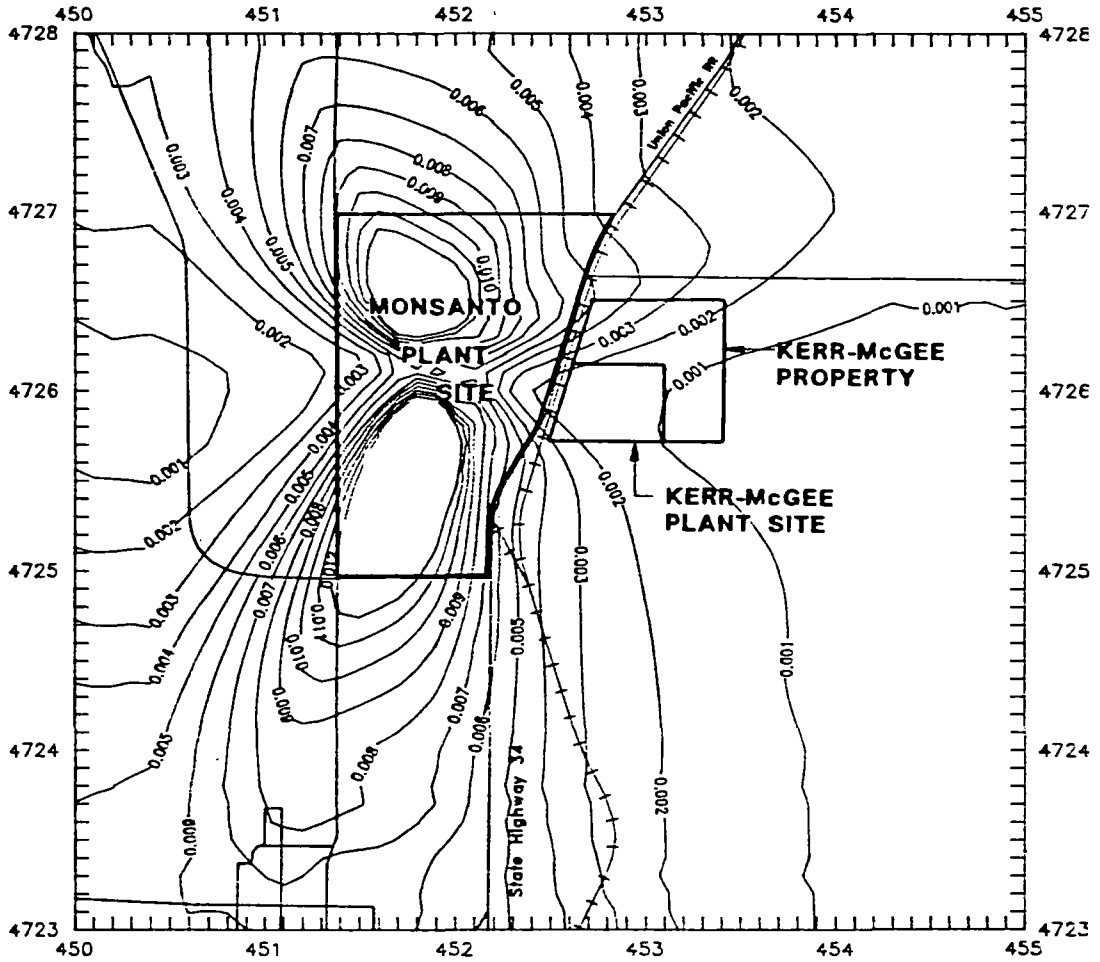
LOCATION OF DISCRETE RECEPTORS RELATIVE TO MONSANTO PLANT PROPERTY LINE

SODA SPRINGS, IDAHO

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO FIG5-1 DATE 4-18-92 DRAWN JSS

Golder Associates



EMISSION SOURCES:
- Permitted Sources
- Slag Dumping
- Baghouses
- Furnace Building Fugitives
- Nodule Reclaim Area

CONTROL CONCENTRATION: 0.025 to 0.030 (mg/m³)
CRITERIA CONCENTRATION:
- Primary 0.075 (mg/m³)
- Secondary 0.060 (mg/m³)

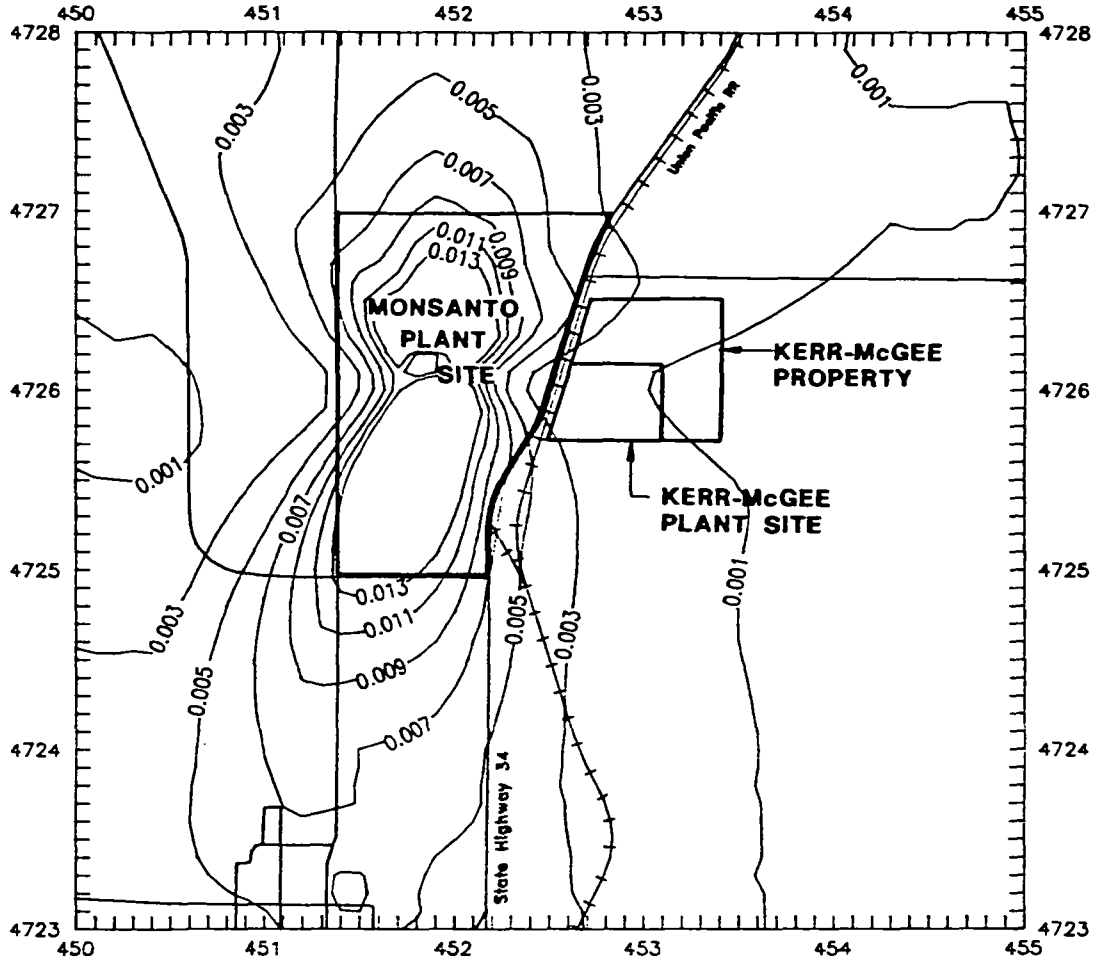
FIGURE **5-3**

PREDICTED AVERAGED ANNUAL TSP CONCENTRATIONS (mg/m3) FOR 1990 SOURCE GROUPS 1,2, AND 3 SODA SPRINGS, IDAHO

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO FIG5-2 DATE 4-22-92 DRAWN JSS

Golder Associates



EMISSION SOURCES:
- Permitted Sources
- Slag Dumping
- Baghouses
- Furnace Building Fugitives
- Nodule Reclaim Area

CONTROL CONCENTRATION: Unknown
CRITERIA CONCENTRATION: 0.050 (mg/m^3)

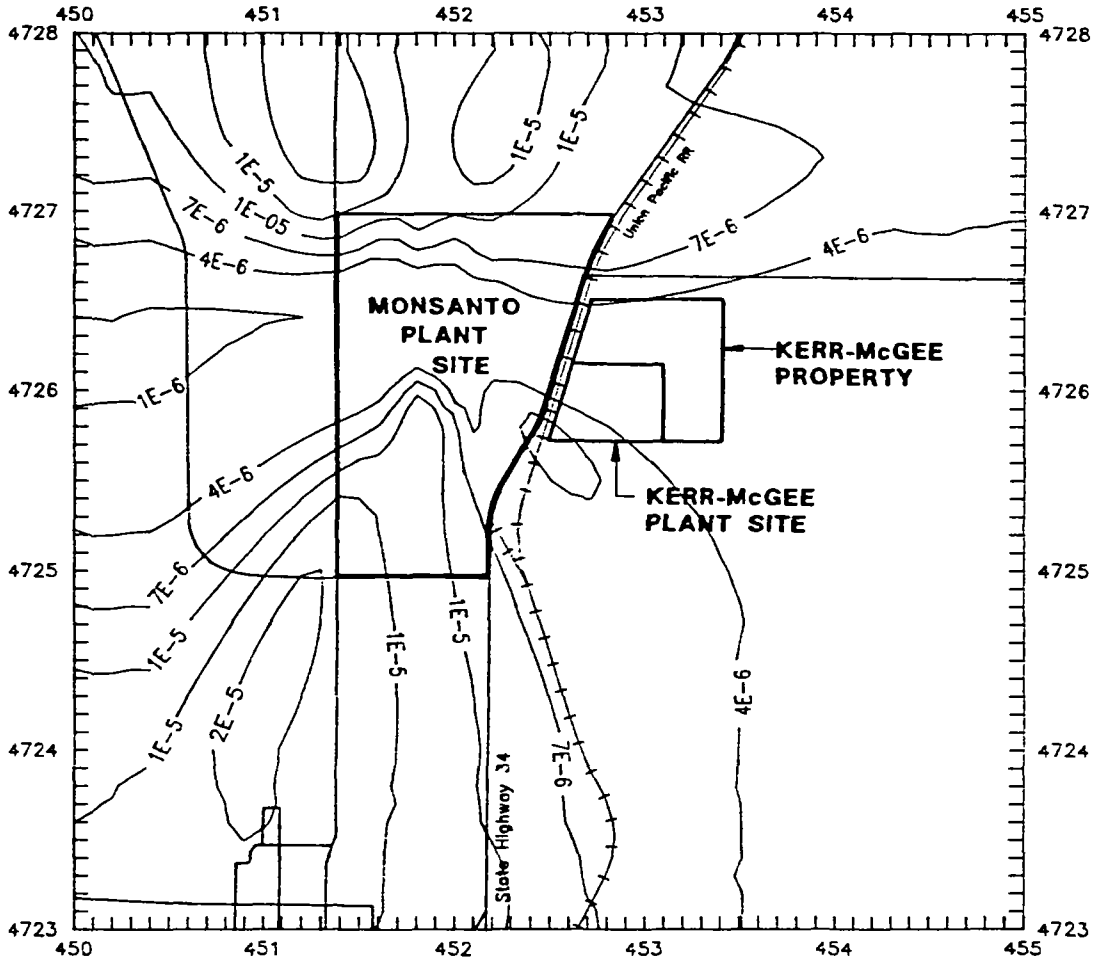
FIGURE **5-4**

PREDICTED AVERAGED ANNUAL PM10 CONCENTRATIONS (mg/m^3) FOR 1990 SOURCE GROUPS 1,2, AND 3 SODA SPRINGS, IDAHO

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO FIG5-3 DATE 4-23-92 DRAWN JSS

Golder Associates



EMISSION SOURCES:
- Permitted Sources
- Slag Dumping
- Baghouses
- Furnace Building Fugitives
- Nodule Reclaim Area

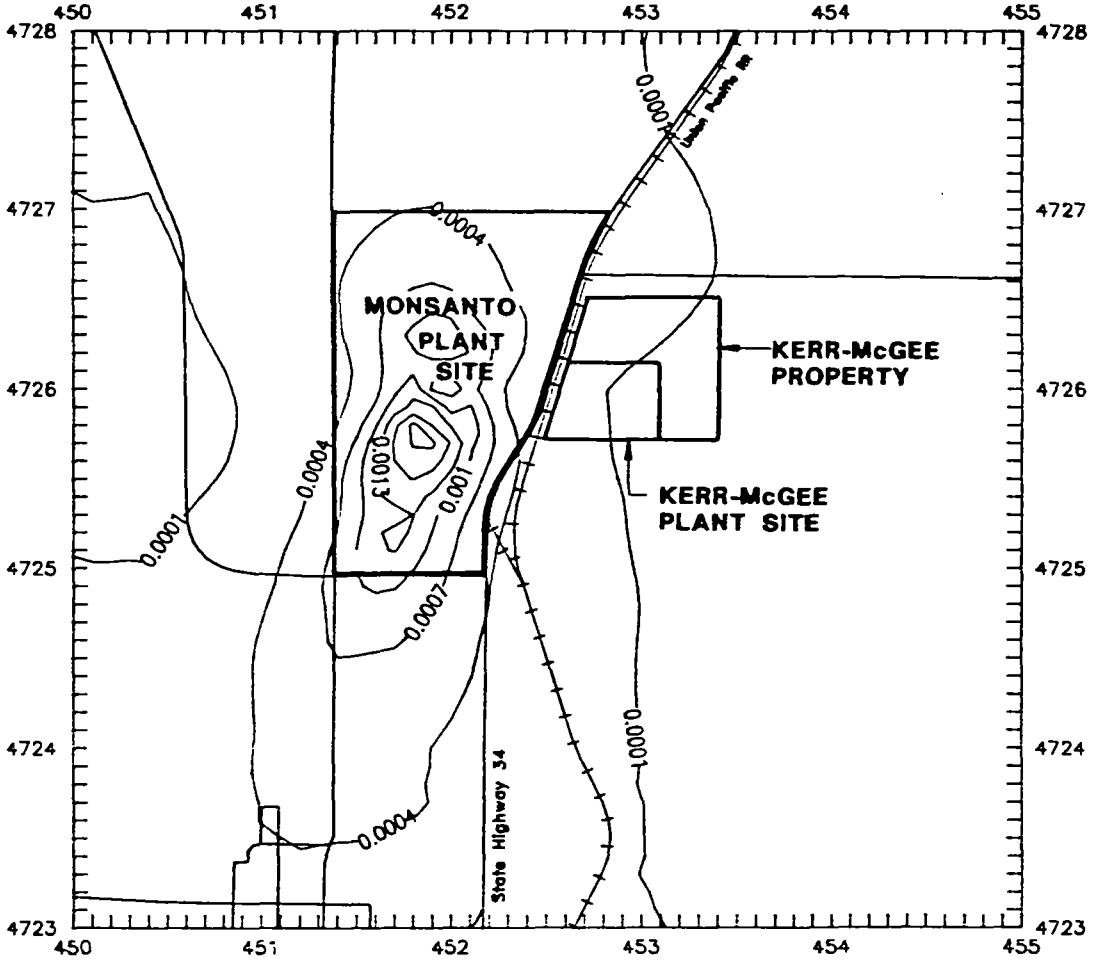
FIGURE **5-5**

PREDICTED AVERAGED ANNUAL CADMIUM CONCENTRATIONS (mg/m^3) FOR 1990 SOURCE GROUPS 1,2, AND 3 SODA SPRINGS, IDAHO

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO FIG5-4 DATE 4-22-92 DRAWN JSS

Golder Associates



EMISSION SOURCES:
- Permitted Sources
- Slag Dumping
- Baghouses
- Furnace Building Fugitives
- Nodule Reclaim Area

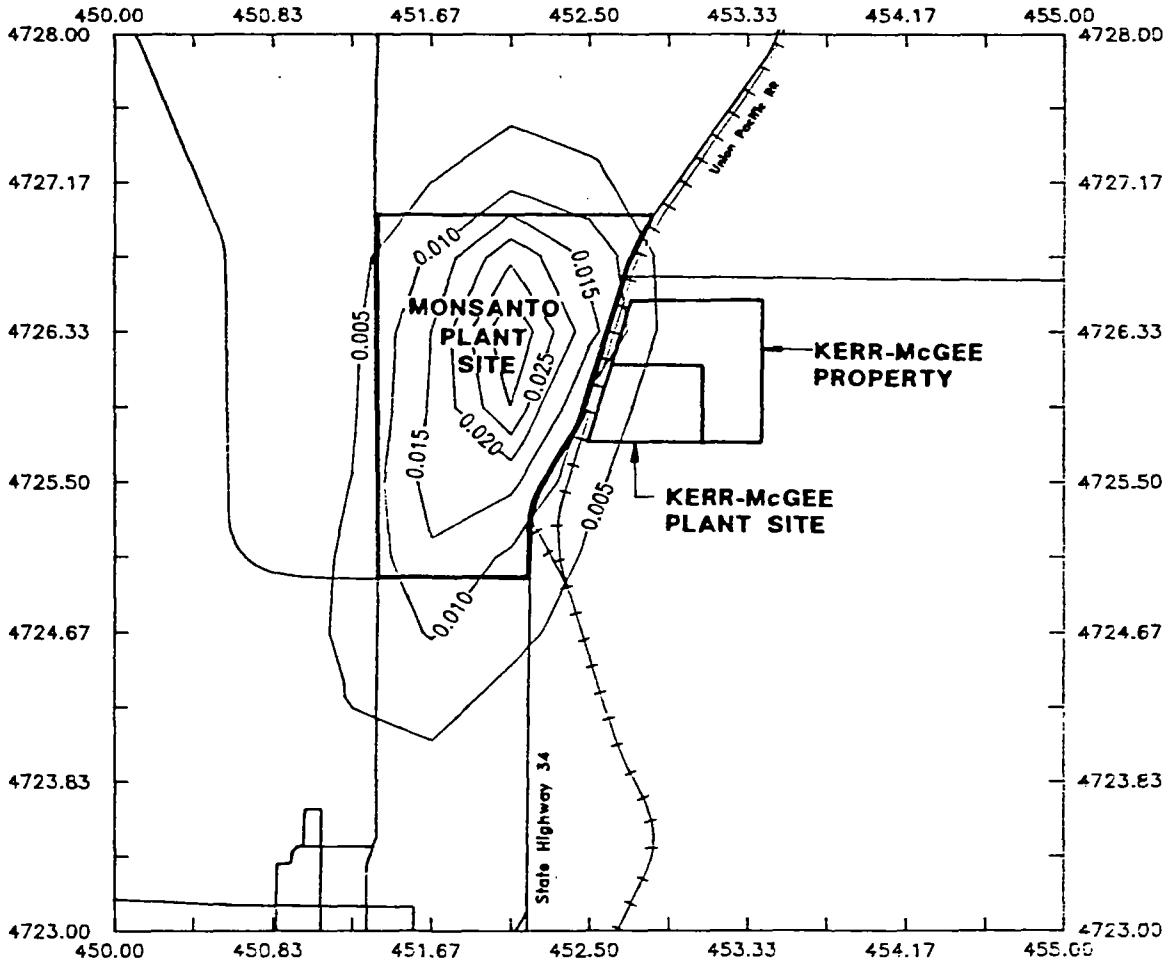
FIGURE **5-6**

PREDICTED AVERAGED ANNUAL FLUORIDE CONCENTRATIONS (mg/m3) FOR 1990 SOURCE GROUPS 1,2, AND 3 SODA SPRINGS, IDAHO

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO FIG5-5 DATE 4-23-92 DRAWN JSS

Golder Associates



EMISSION SOURCES:
- Roads
- Material Handling Operations
- Wind Erosion

CONTROL CONCENTRATION: 0.025 to 0.030 (mg/m^3)
CRITERIA CONCENTRATION:
- Primary 0.075 (mg/m^3)
- Secondary 0.060 (mg/m^3)

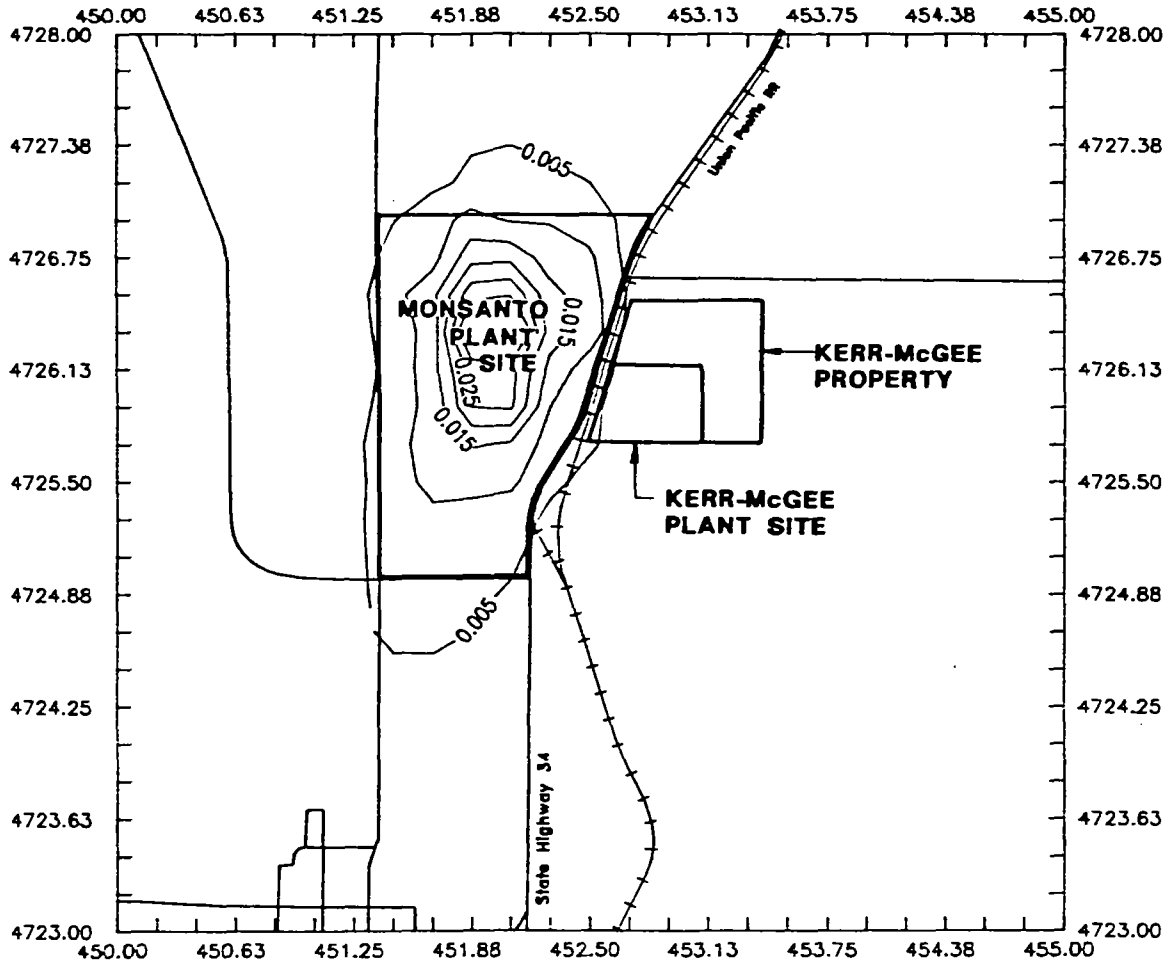
FIGURE **5-7**

PREDICTED AVERAGED ANNUAL TSP CONCENTRATIONS (mg/m3) FOR 1990 SOURCE GROUP 4 SODA SPRINGS, IDAHO

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO FIG5-6 DATE 4-22-92 DRAWN JSS

Golder Associates



EMISSION SOURCES:
- Roads
- Material Handling Operations
- Wind Erosion

CONTROL CONCENTRATION: Unknown
CRITERIA CONCENTRATION: 0.050 (mg/m³)

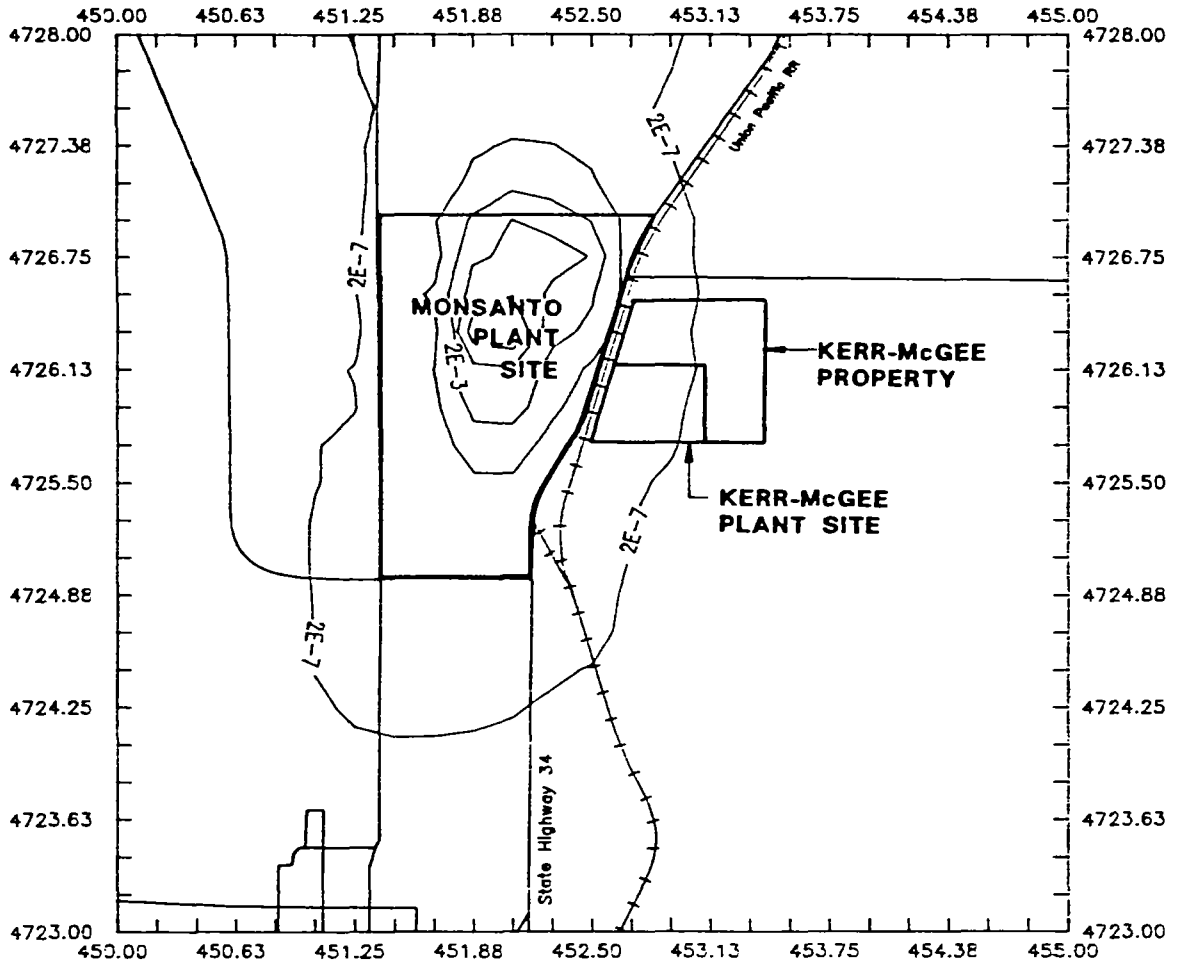
FIGURE **5-8**

PREDICTED AVERAGED ANNUAL PM10 CONCENTRATIONS (mg/m3) FOR 1990 SOURCE GROUP 4 SODA SPRINGS, IDAHO

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO FIG5-7 DATE 4-23-92 DRAWN JSS

Golder Associates



EMISSION SOURCES:
- Roads
- Material Handling Operations
- Wind Erosion

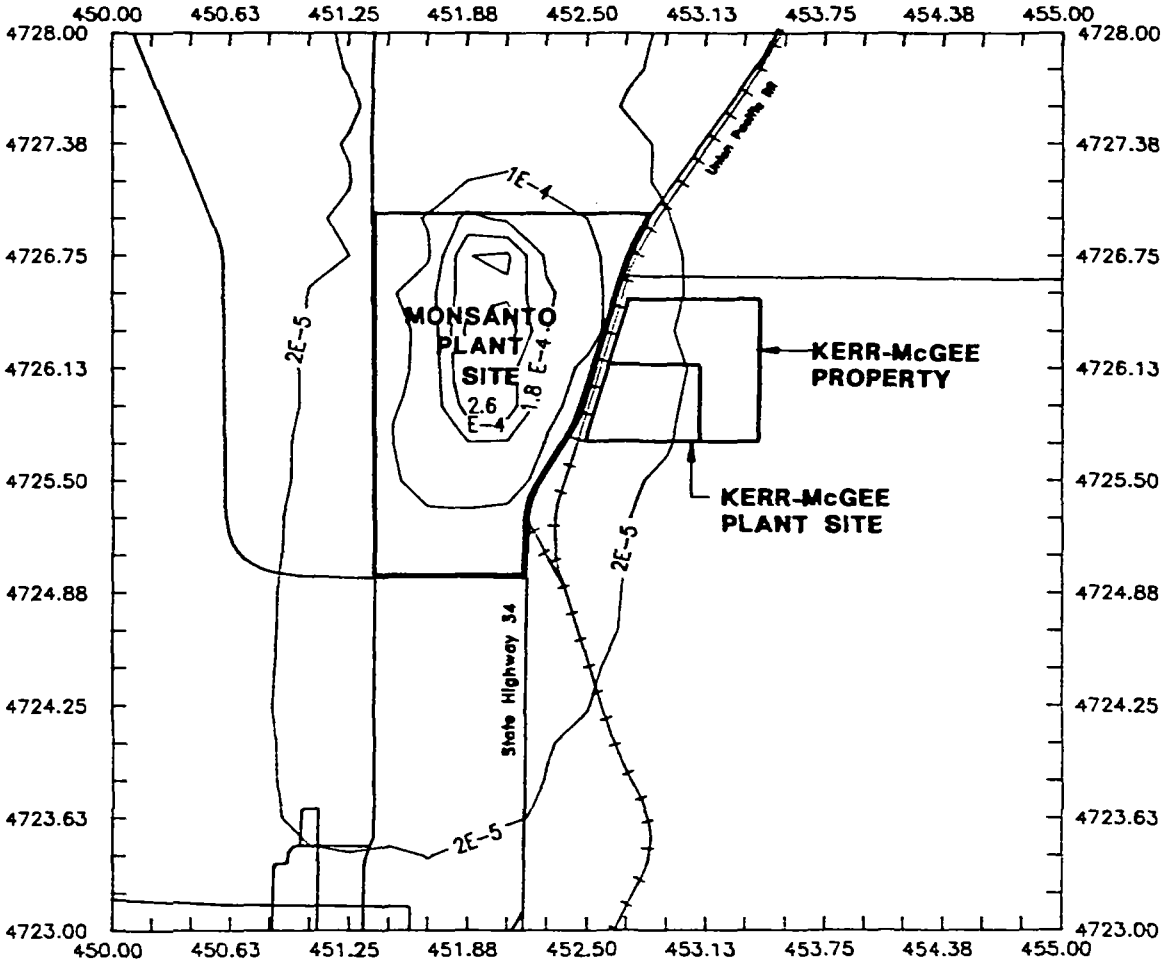
FIGURE **5-9**

PREDICTED AVERAGED ANNUAL CADMIUM CONCENTRATIONS (mg/m^3) FOR 1990 SOURCE GROUP 4 SODA SPRINGS, IDAHO

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO FIG5-8 DATE 4-22-92 DRAWN JSS

Golder Associates



EMISSION SOURCES:
- Roads
- Material Handling Operations
- Wind Erosion

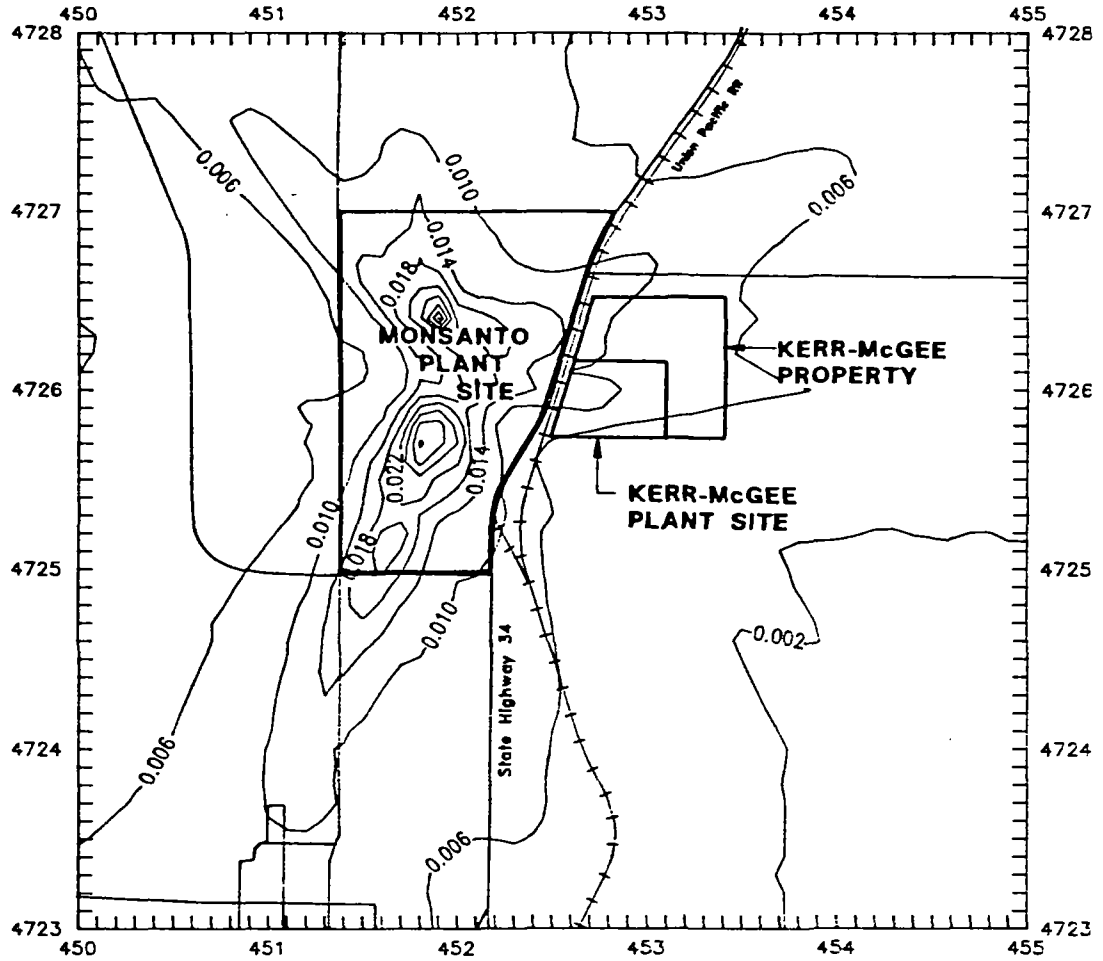
FIGURE **5-10**

PREDICTED AVERAGED ANNUAL FLUORIDE CONCENTRATIONS (mg/m3) FOR 1990 SOURCE GROUP 4 SODA SPRINGS, IDAHO

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO FIG5-9 DATE 4-23-92 DRAWN JSS

Golder Associates



EMISSION SOURCES:
- Permitted Sources
- Slag Dumping
- Baghouses
- Furnace Building Fugitives

CONTROL CONCENTRATION: 0.115 to 0.122 (mg/m³)
CRITERIA CONCENTRATION:
- Primary 0.260 (mg/m³)
- Secondary 0.150 (mg/m³)

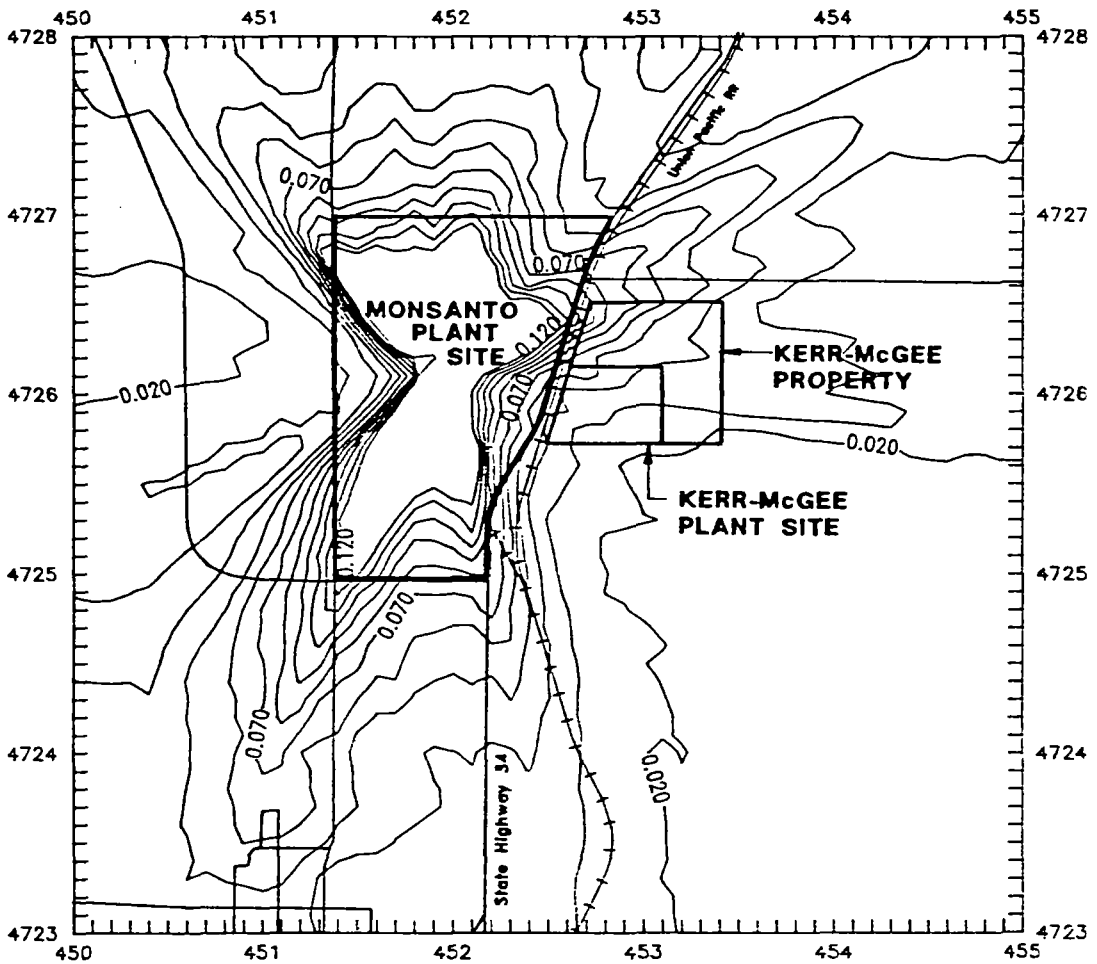
FIGURE **5-11**

PREDICTED SECOND HIGHEST 24 HOUR TSP CONCENTRATIONS (mg/m3) FOR 1990 SOURCE GROUPS 1 AND 2 SODA SPRINGS, IDAHO

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO FIG5-10 DATE 4-22-92 DRAWN JSS

Golder Associates



EMISSION SOURCES:
- Nodule Reclaim Area

CONTROL CONCENTRATION: 0.115 to 0.122 (mg/m³)
CRITERIA CONCENTRATION:
- Primary 0.260 (mg/m³)
- Secondary 0.150 (mg/m³)

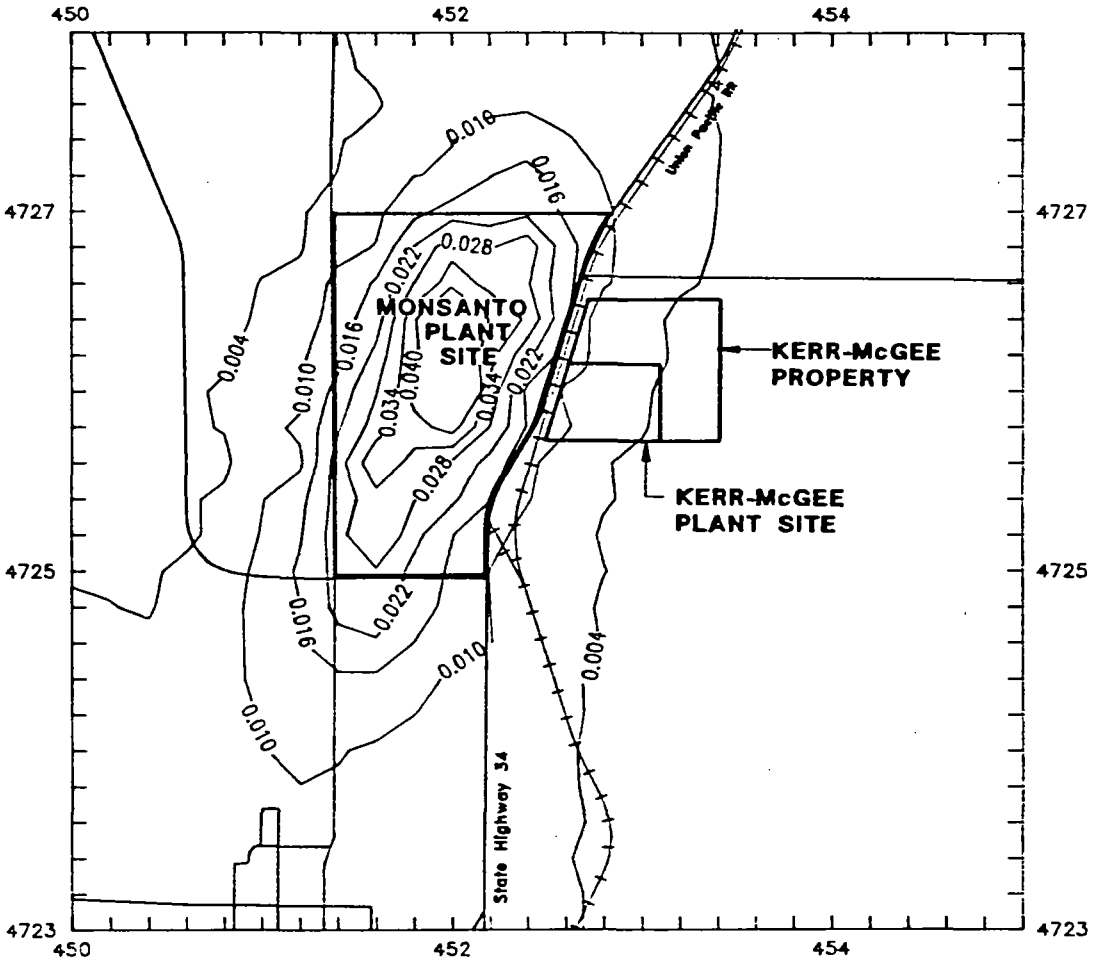
FIGURE **5-12**

PREDICTED SECOND HIGHEST 24 HOUR TSP CONCENTRATIONS (mg/m³) FOR 1990 SOURCE GROUP 3 SODA SPRINGS, IDAHO

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO FIG5-11 DATE 4-22-92 DRAWN JSS

Golder Associates



EMISSION SOURCES:
- Roads
- Material Handling Operations
- Wind Erosion

CONTROL CONCENTRATION: 0.115 to 0.122 (mg/m³)
CRITERIA CONCENTRATION:
- Primary 0.260 (mg/m³)
- Secondary 0.150 (mg/m³)

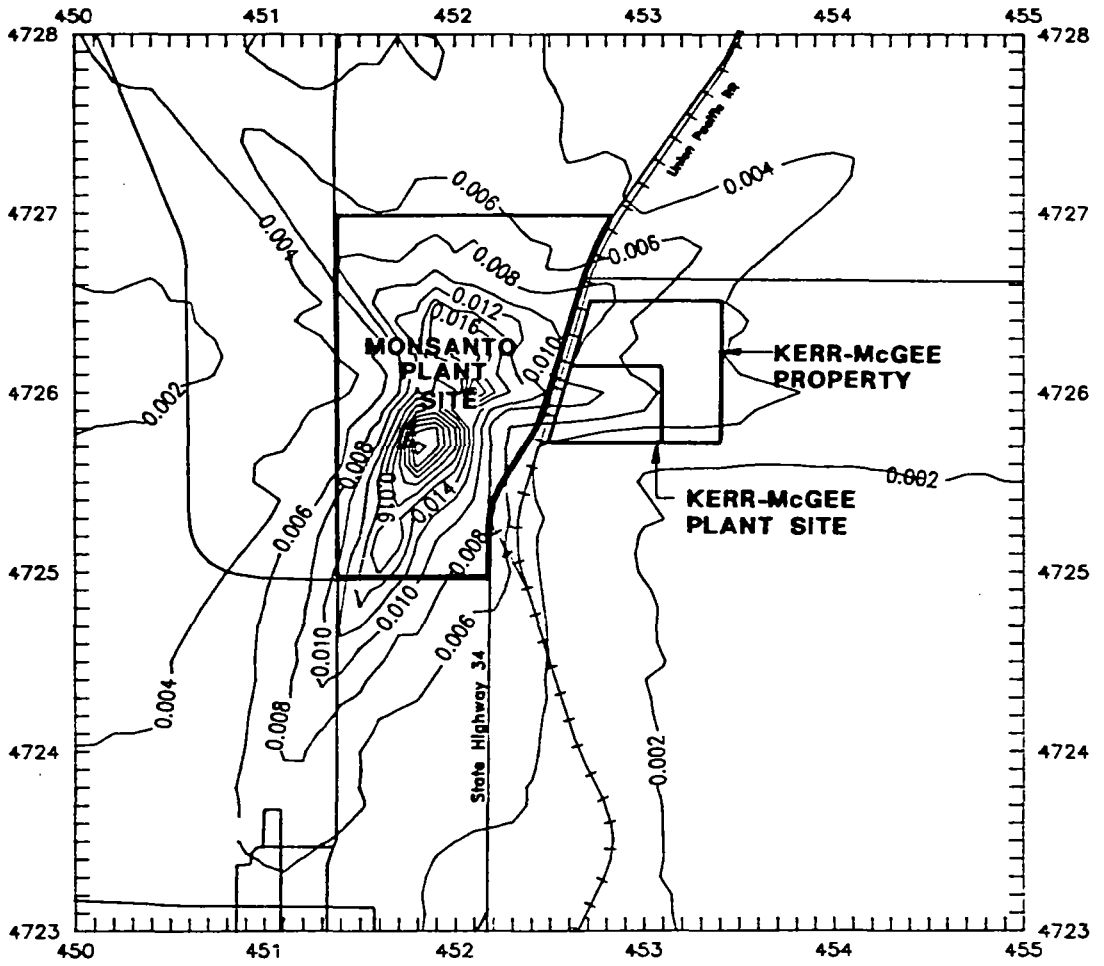
FIGURE **5-13**

PREDICTED SECOND HIGHEST 24 HOUR TSP CONCENTRATIONS (mg/m3) FOR 1990 SOURCE GROUP 4 SODA SPRINGS, IDAHO

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO FIG5-12 DATE 4-22-92 DRAWN JSS

Golder Associates



EMISSION SOURCES:
- Permitted Sources
- Slag Dumping
- Baghouses
- Furnace Building Fugitives

CONTROL CONCENTRATION: Unknown
CRITERIA CONCENTRATION: 0.150 (mg/m³)

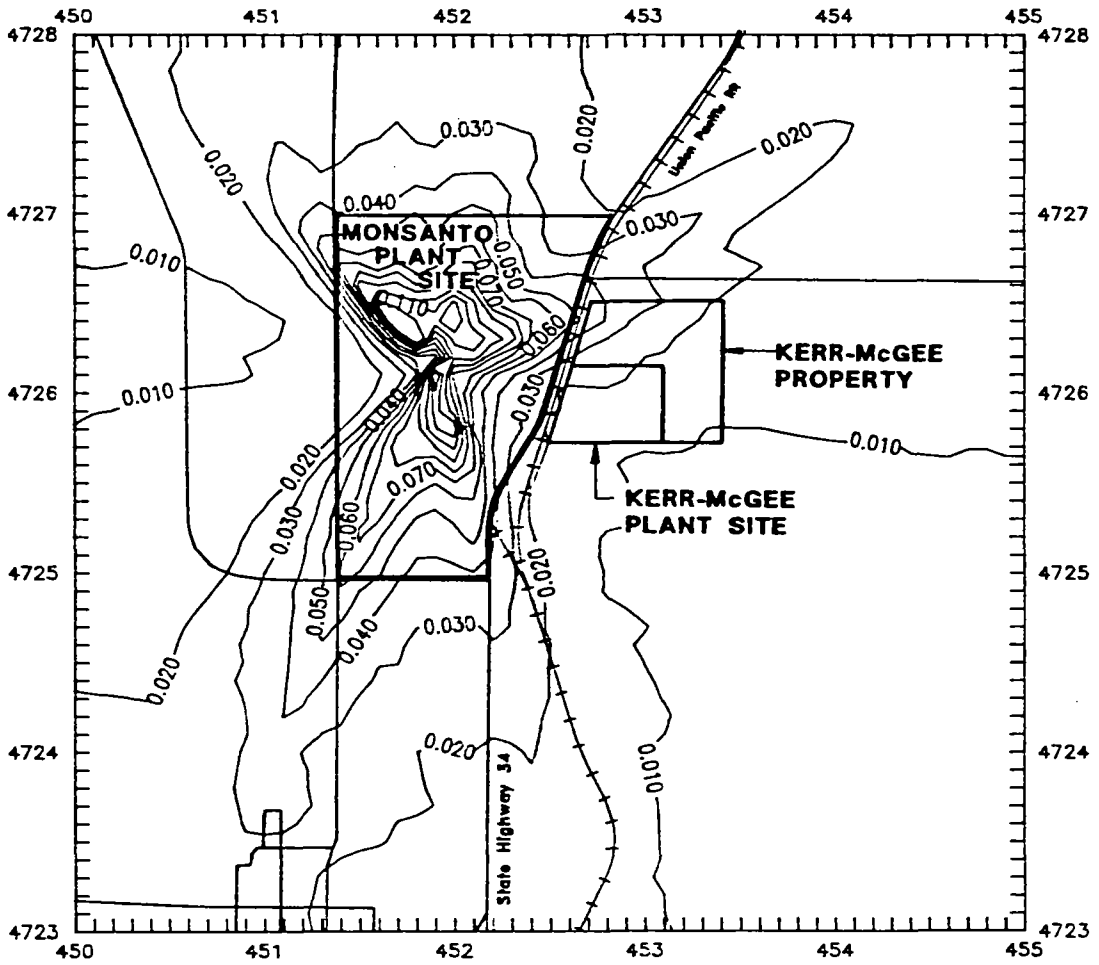
FIGURE **5-14**

PREDICTED SECOND HIGHEST 24 HOUR PM10 CONCENTRATIONS (mg/m3) FOR 1990 SOURCE GROUPS 1 AND 2 SODA SPRINGS, IDAHO

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO FIG5-13 DATE 4-23-92 DRAWN JSS

Golder Associates



EMISSION SOURCES:
– Nodule Reclaim Area

CONTROL CONCENTRATION: Unknown
CRITERIA CONCENTRATION: 0.150 (mg/m³)

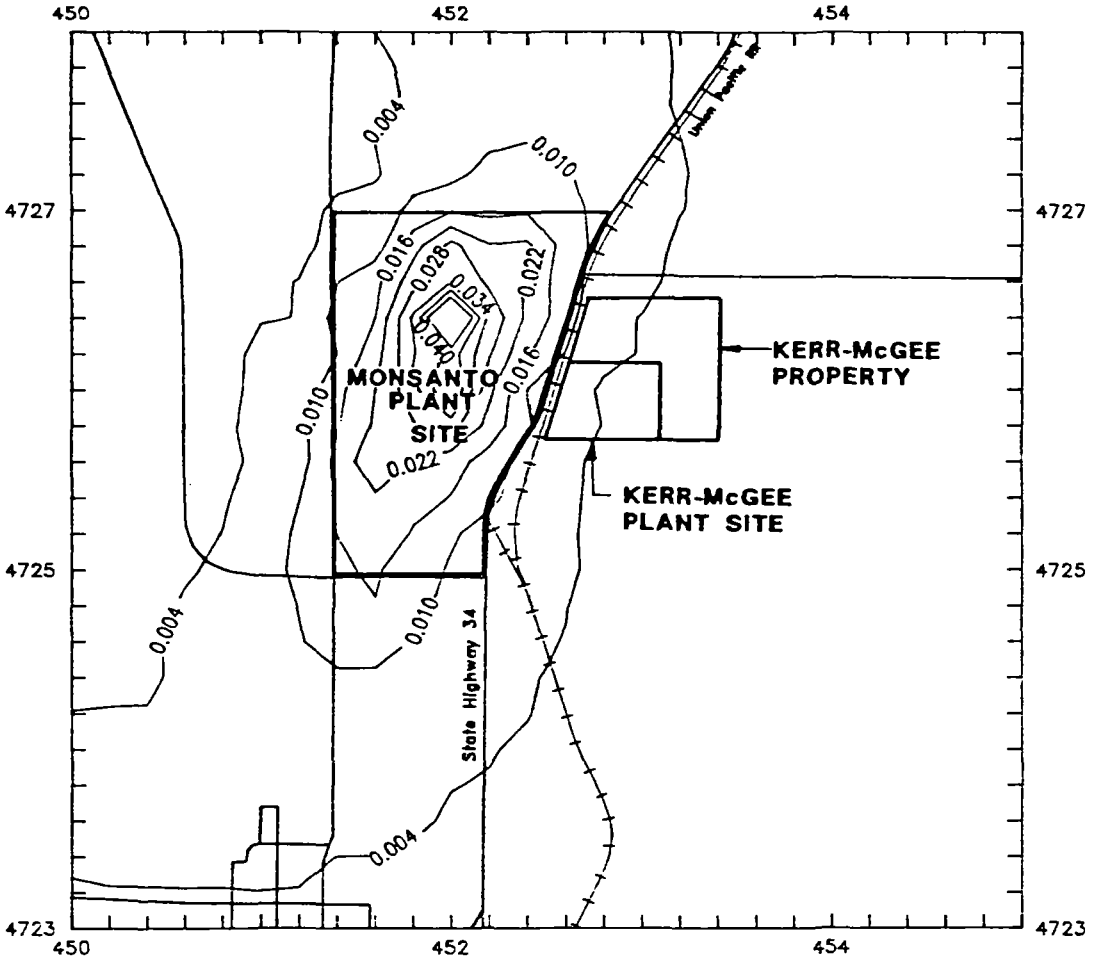
FIGURE **5-15**

PREDICTED SECOND HIGHEST 24 HOUR PM10 CONCENTRATIONS (mg/m3) FOR 1990 SOURCE GROUP 3 SODA SPRINGS, IDAHO

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO FIG5-14 DATE 4-22-92 DRAWN JSS

Golder Associates



EMISSION SOURCES:
- Roads
- Material Handling Operations
- Wind Erosion

CONTROL CONCENTRATION: Unknown
CRITERIA CONCENTRATION: 0.150 (mg/m³)

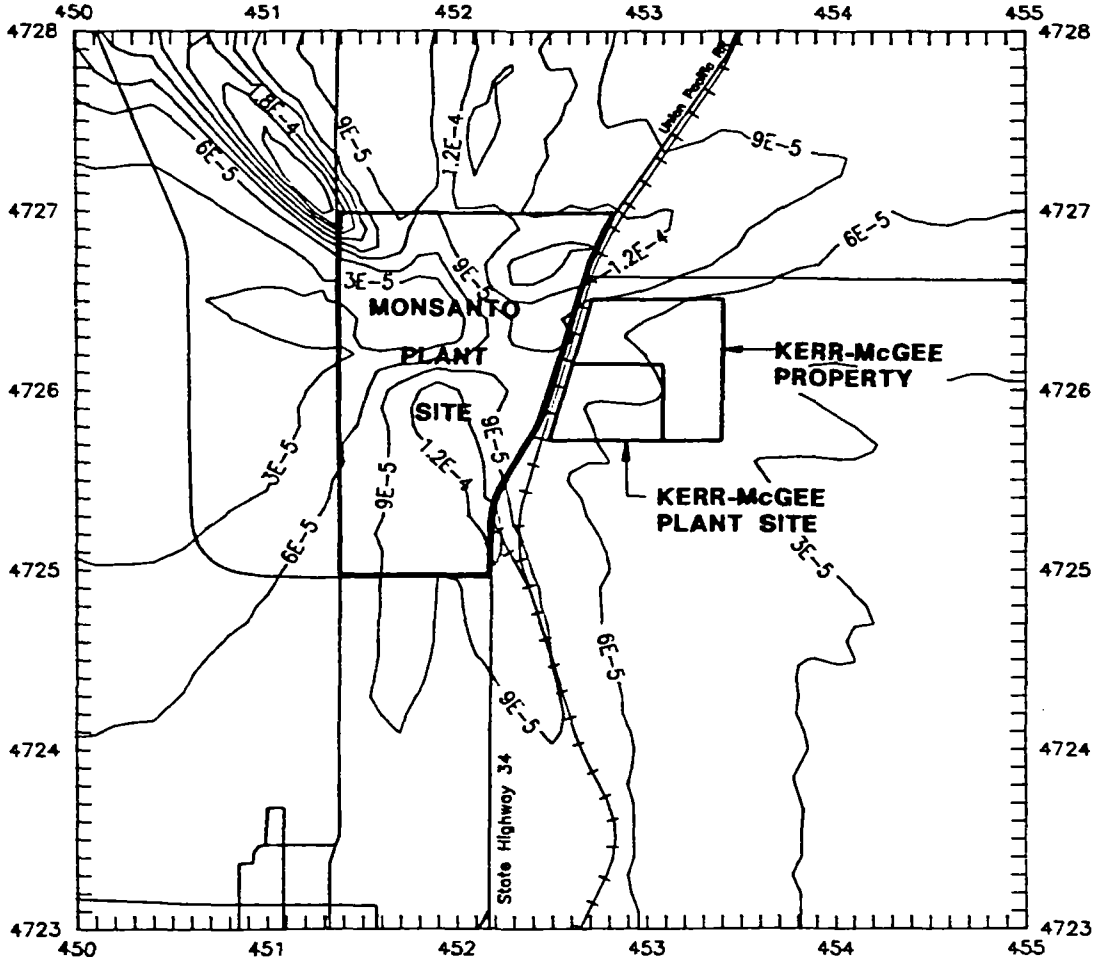
FIGURE **5-16**

PREDICTED SECOND HIGHEST 24 HOUR PM10 CONCENTRATIONS (mg/m3) FOR 1990 SOURCE GROUP 4 SODA SPRINGS, IDAHO

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO FIG5-15 DATE 4-22-92 DRAWN JSS

Golder Associates



EMISSION SOURCES:
- Permitted Sources
- Slag Dumping
- Baghouses
- Furnace Building Fugitives

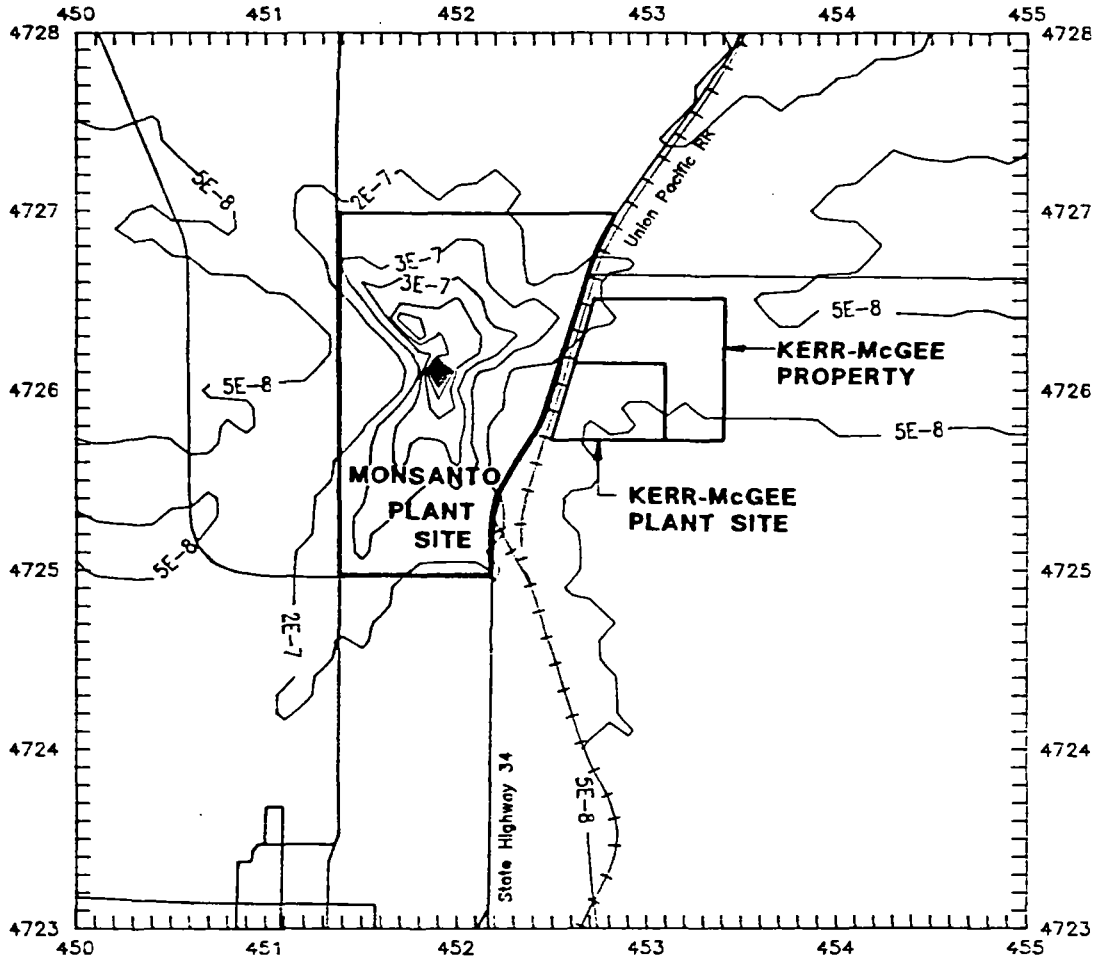
FIGURE **5-17**

PREDICTED SECOND HIGHEST 24 HOUR CADMIUM CONCENTRATIONS (mg/m3) FOR 1990 SOURCE GROUPS 1 AND 2 SODA SPRINGS, IDAHO

MONSANTO/PHASE I RI REPORT/ID

PROJECT NO 913-1101.212 DWG NO FIG5-16 DATE 4-23-92 DRAWN JSS

Golder Associates



EMISSION SOURCES:
– Nodule Reclaim Area

FIGURE **5-18**

PREDICTED SECOND HIGHEST 24 HOUR CADMIUM CONCENTRATIONS (mg/m3) FOR 1990 SOURCE GROUP 3 SODA SPRINGS, IDAHO

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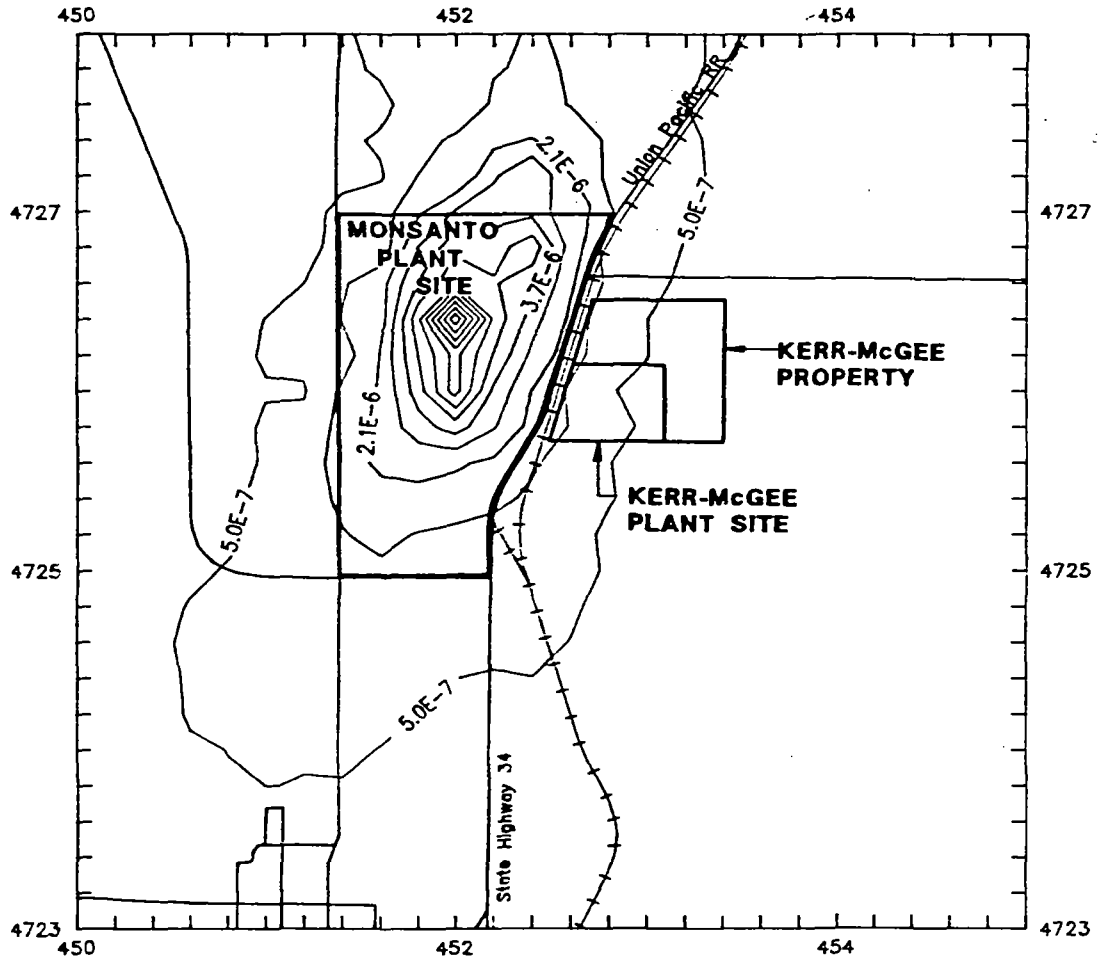
PROJECT NO 913-1101.212 DWG NO FIG5-17 DATE 4-22-92 DRAWN JSS

Golder Associates



EMISSION SOURCES:
- Roads
- Material Handling Operations
- Wind Erosion

FIGURE **5-19**

PREDICTED SECOND HIGHEST 24 HOUR CADMIUM CONCENTRATIONS (mg/m3) FOR 1990 SOURCE GROUP 4 SODA SPRINGS, IDAHO

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PROJECT NO 913-1101.212 DWG NO FIG5-18 DATE 4-22-92 DRAWN JSS

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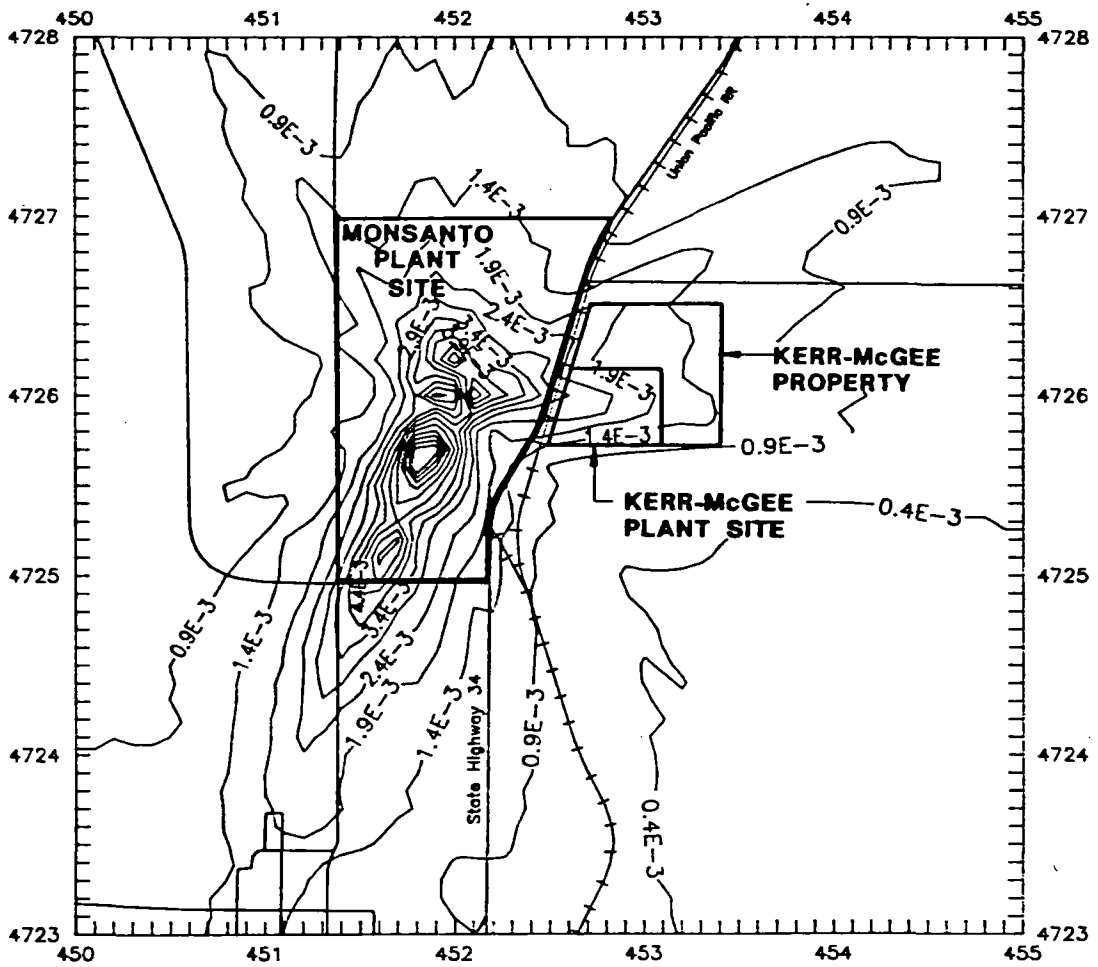

EMISSION SOURCES:
- Permitted Sources
- Slag Dumping
- Baghouses
- Furnace Building Fugitives

FIGURE **5-20**

PREDICTED SECOND HIGHEST 24 HOUR FLUORIDE CONCENTRATIONS (mg/m3) FOR 1990 SOURCE GROUPS 1 AND 2 SODA SPRINGS, IDAHO

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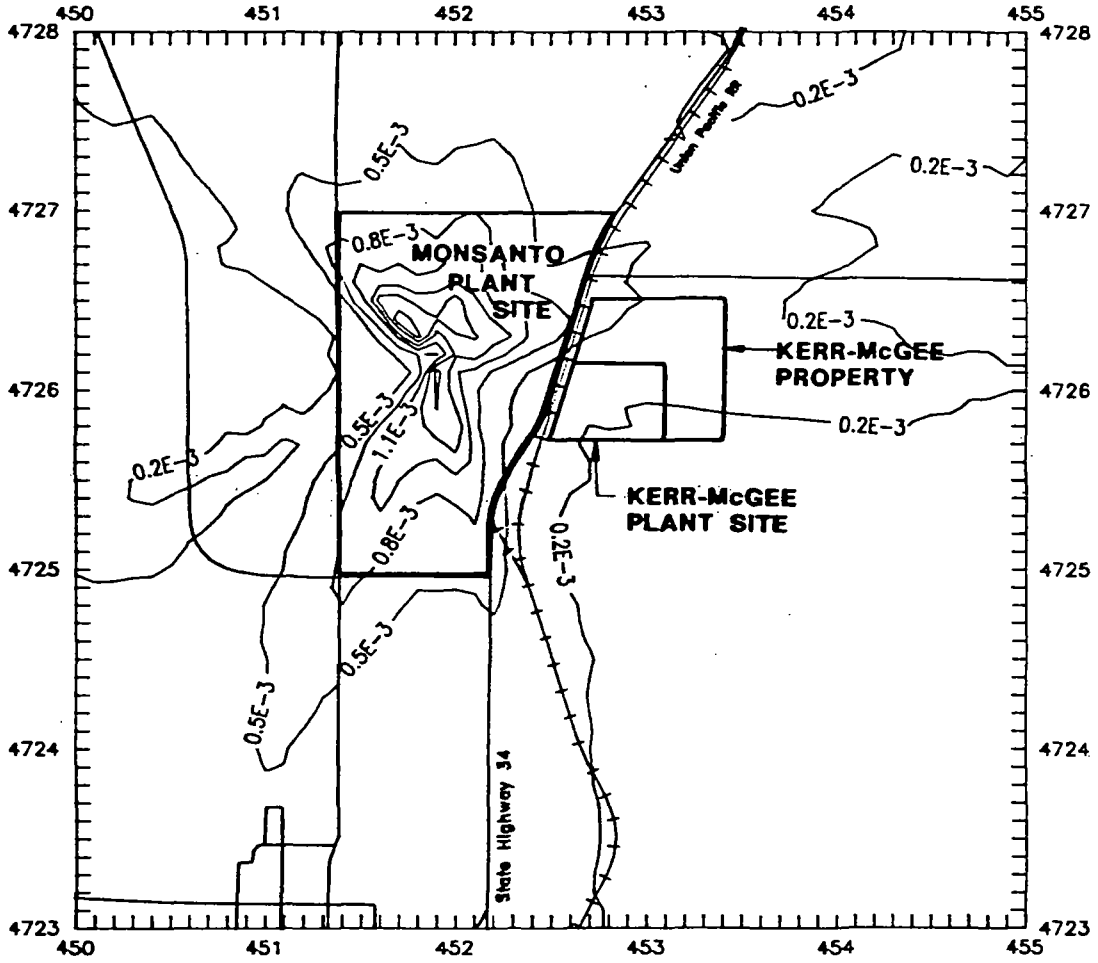

EMISSION SOURCES:
– Nodule Reclaim Area

FIGURE **5-21**

PREDICTED SECOND HIGHEST 24 HOUR FLUORIDE CONCENTRATIONS (mg/m3) FOR 1990 SOURCE GROUP 3 SODA SPRINGS, IDAHO

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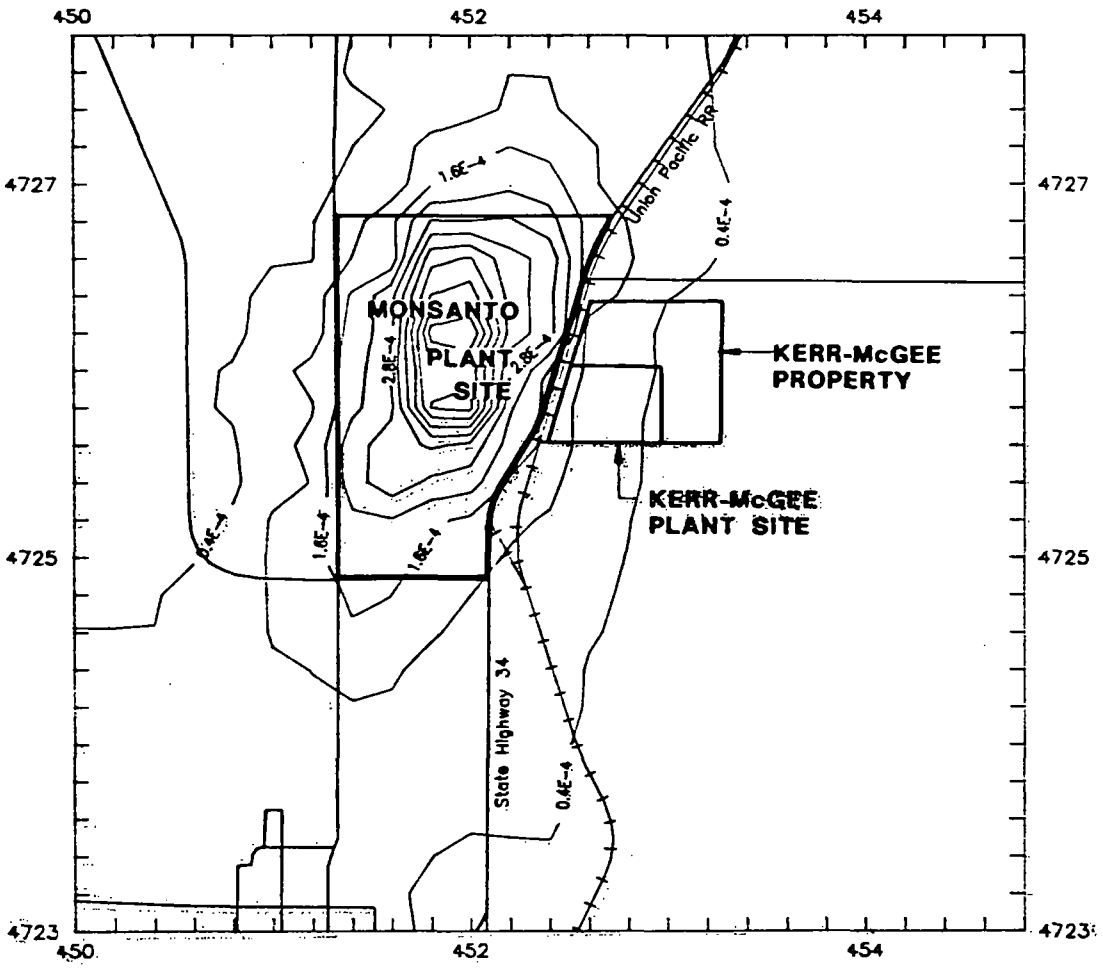

EMISSION SOURCES:
- Roads
- Material Handling Operations
- Wind Erosion

FIGURE **5-22**

PREDICTED SECOND HIGHEST 24 HOUR FLUORIDE CONCENTRATIONS (mg/m3) FOR 1990 SOURCE GROUP 4 SODA SPRINGS, IDAHO

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