Monsanto

Phase II Remedial Investigation Report
for the Soda Springs Elemental Phosphorus Plant
Volume I

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PHASE II REMEDIAL INVESTIGATION

REPORT FOR THE

MONSANTO SODA SPRINGS PLANT

Prepared by:

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November 21, 1995

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LIST OF ACRONYMS AND SYMBOLS

ACGIH	American Conference of Government Industrial Hygienists
amsl	above mean sea level
AOC	Administrative Order on Consent
atm	atmospheres
bgs	below ground surface
BLM	Bureau of Land Management
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfs	cubic feet per second
CRP	Conservation Reserve Program
EM	electromagnetic
EPA	Environmental Protection Agency
EPA-10	EPA, Region 10
FDM	fugitive dust model
FWS-BFS	Fish and Wildlife Service, Boise Field Station
Golder	Golder Associates, Inc.
gpm	gallons per minute
HQ	hazard quotient
HRS	hazard ranking system
IDHW	Idaho Department of Health and Welfare
IDHW-BAQ	Idaho Department of Health and Welfare, Bureau of Air Quality
IRIS	Integrated Risk Information System
kg	kilogram
KVS	kiln venturi scrubbers
LBZ	lower basalt zone
LICR	lifetime incremental cancer risk
m/s	meters per second
MCL	maximum contaminant limit
MGD	million gallons per day
Monsanto	Monsanto Company
mph	miles per hour
NCC	National Climate Center
NCP	National Contingency Plan
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NOAA	National Oceanic and Atmospheric Agency
NPDES	National Pollution Discharge Elimination System
NPL	National Priorities List
NTU	nephelometric turbidity unit
NWS	National Weather Service
OSHA	Occupational Safety and Health Act
PCB	polychlorinated biphenyls
PM_{10}	inhalable particulates
QAPP	quality assurance project plan
QA/QC	Quality Assurance/Quality Control
RbC	risk-based concentration
RCRA	Resource Conservation and Recovery Act

LIST OF ACRONYMS (Cont.)

RfD	reference dose
RI/FS	remedial investigation/feasibility study
SAB	Science Advisory Board
SCS	Soil Conservation Service
SDZ	surficial deposit zone
SF	slope factor
SLZ	salt lake zone
SPCC	spill prevention, control, and countermeasures
SQL	sample quantitation limit
TCLP	toxicity characteristic leaching procedure
TLV	threshold limit value
TSCA	Toxic Substances Control Act
TSP	total suspended particulates
TU	turbidity unit
UBZ	upper basalt zone
USCS	Unified Soil Classification System
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey
UTL	upper tolerance limit
WQC-FWC	water quality criteria -freshwater

1. INTRODUCTION

In August, 1990, the United States Environmental Protection Agency (EPA) placed the Monsanto Company (Monsanto) elemental phosphorus 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.).

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 Plant). Monsanto subsequently authorized Golder Associates Inc. (Golder) to prepare the RI/FS. This Phase II RI report has been prepared in a manner consistent with the statutory requirements of CERCLA and the regulatory requirements of the NCP.

The RI/FS process under CERCLA is described in detail by the EPA RI/FS guidance document (EPA 1988). The EPA expects that the RI and FS are to be conducted concurrently and that data compiled in the RI influence the development of remedial alternatives in the FS. The FS should in turn direct RI data collection toward information necessary to evaluate remedial alternatives.

Pursuant to the Administrative Order on Consent, two phases of investigation have been completed for the RI, Phases I and II. Phase I of the FS (Golder 1992a) also was completed subsequent to Phase I of the RI.

Phase I of the RI was initiated with the development of the Phase I RI Work Plan (Golder 1991), approved by EPA in September, 1991. Phase I investigations were subsequently completed and documented in the Phase I RI report, referred to as the Preliminary Site Characterization Summary Report (Golder 1992b). The Phase I report identified data gaps and made recommendations concerning additional investigations for Phase II. EPA provided comments on the Phase I report concerning data gaps and with suggestions for further investigations (Letter to Mr. R. L. Geddes, Monsanto Chemical Company, from Mr. T. H. Brincefield, EPA, June 15, 1992).

Phase II of the RI was developed to address information needs identified from Phase I. The Phase II RI was initiated with the Phase II RI Work Plan (Golder 1992c) approved by EPA in January, 1993. During the course of Phase II, many interim documents were provided to EPA for review. These documents included: results of a geophysical survey (Golder 1992d), analyses of geochemistry and hydrology of source areas and the vadose zone (Golder 1993a), details concerning hydrogeological investigations (Golder 1993b), investigations of surficial soil and stream sediments (Golder 1993c), modeling of constituent transport in groundwater (Golder 1993d), an inventory of air emissions (SENES 1993a), and air dispersion modeling (SENES 1993b).

Upon completion of Phase II RI data collection activities and preparation of interim documents, this Phase II RI report was prepared. This report presents a compilation of data and analyses conducted for both Phases I and II of the RI. Information from the interim Phase II documents listed above also is contained within this RI report.

1.1 Report Organization

The purpose of this report is to document the remedial investigation conducted for the Monsanto Plant in Soda Springs, Idaho, as required by the Administrative Order on Consent. The report has been organized to present the remedial investigation in a logical sequence. This report organization follows the recommendations in the EPA RI/FS guidance document (EPA 1988). The Phase II RI report consists of seven chapters and appendices.

Chapter 1, in addition to introductory material, provides background information for the Monsanto Plant. Previous studies performed at the Monsanto Plant and the current regulatory status of the Plant are summarized.

A description of RI data collection activities is presented in Chapter 2. This information is derived from the RI/FS work plans for Phases I and II (Golder 1991, 1992c).

Chapter 3 presents the physical characterization of the Monsanto Plant. Plant sources, geology, hydrogeology, soils, and other physical conditions related to the Plant are presented. Discussions are based on data collection activities and existing information.

Chapter 4 presents the characterization of Plant-related chemical constituents. This characterization is based on data collection activities and existing information. Chemical analyses for soil, sediment, water and air are presented. A screening analysis used to compare Plant data to background data also is described.

Fate and transport analyses for selected chemical constituents are presented in Chapter 5. Transport properties and pathways are discussed. The results of transport modeling to estimate future constituent concentrations in air and groundwater also are presented.

Chapter 6 presents a summary and conclusions of the RI report. Recommendations concerning the report and future RI/FS activities for the Monsanto Plant are also presented.

References cited within the body of the report are provided in Chapter 7. Appendices are also used to present personal correspondences, such as letters and memorandums, data validation summaries, and detailed technical documentation. The Table of Contents lists titles indicating the contents of each Appendix.

EPA Region 10 has prepared a risk assessment for the facility, which is contained in Appendix O. The risk assessment evaluates risk to human health and the environment posed by the Monsanto Plant and is based on results of the remedial investigation.

1.2 Monsanto Plant Background

This section provides an overview of the Monsanto Plant. Discussions are provided concerning the general area of the Plant, the phosphorus production process, previous environmental investigations, and the regulatory status. More information is provided concerning each of these topics throughout the remainder of the Phase II RI report.

1.2.1 General Area

The Monsanto Plant is located in southeastern Idaho, approximately one mile north of the City of Soda Springs (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 Ninety Percent Range and the Soda Springs Hills.

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

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

- Kerr-McGee Chemical Corporation (production of vanadium compounds), across State Highway 34 from the Monsanto Plant;
- Evergreen Resources (fertilizer products), 1,000 to 2,000 feet southeast of the Monsanto Plant;
- Soda Springs Phosphate Industries (fertilizer products), adjacent to Evergreen Resources;
- Nu-West Industries (phosphoric acid production and fertilizer products), four miles north of the Monsanto Plant (not shown on Figure 1-2); and

Groundwater supplies 350 people at the Monsanto Plant from an on-site upgradient well. Eighty employees at Kerr McGee are supplied with groundwater from Formation Spring. The City of Soda Springs obtains water from Formation and Ledger Springs. These springs are located within two miles of the Monsanto Plant, upgradient and across-gradient, respectively. No individuals living downgradient of the Monsanto Plant are served by groundwater from domestic wells.

1.2.2 Plant Description

Monsanto purchased agricultural land in 1952 to construct the elemental phosphorus production plant. Elemental phosphorus is obtained from phosphate ore, which is in the form of crushed rock prior to processing at the Plant. The ore is processed by a technology utilizing electric-arc furnaces. The phosphorus is shipped off site, where it is used for the production of many phosphorus and phosphate based chemicals and products. The layout of the Plant facility is shown in Figure 1-3.

The two general phases of phosphorus production are beneficiation and processing. These phases are summarized below. Further details are presented in Chapters 3 and 4.

1.2.2.1 Phosphate Ore Beneficiation

The beneficiation of the phosphate ore occurs in a rotary kiln. Phosphate ore, which is mined nearby, is fed into a kiln to drive off moisture and fuse the ore. The kiln operates in a rolling fashion that produces nodules of ore, 4-inch to 8-inch in diameter, which are crushed and sized for further processing in the furnace. The fine material that blows out of the kiln is temporarily placed in a stock pile and is partially recycled through the kiln. This material is called underflow solids. Small nodules are also separated and recycled to form larger nodules in the kiln.

1.2.2.2 Processing Elemental Phosphorus

The processing of phosphate ore nodules occurs within electric-arc furnaces. The nodules of ore from the kiln are blended with coke and quartzite materials. This blend of materials is then heated in electric-arc furnaces. Carbon (from coke) and silica (from quartzite) produce a reducing chemical environment, resulting in off gases containing carbon monoxide and elemental phosphorus. The elemental phosphorus gas is directed through an electrostatic precipitator where the gases are cleaned and a spray tower condenses the phosphorus to form a liquid. The liquid phosphorus is stored in tanks to await shipment. The phosphorus is always stored and transported under water to prevent contact with the atmosphere and spontaneous combustion.

1.2.2.3 By-Products

By-products are materials other than ore-nodules and elemental phosphorus that result from elemental phosphorus production. These materials include solids, airborne particles, and gases. Solid materials are typically collected and stored in piles for reuse or permanently disposed of on-site. Airborne particles and gases are typically passed through one or more control devices for particulate removal (dissolved and suspended). These devices include scrubbers and spray towers which incorporate particles into liquid droplets, and baghouse filters, which physically filter particles from the air. To some degree, the scrubbers used for particulate control on the kiln and furnaces also reduce emissions of SO_2. The liquids formed during the particulate removal on the kiln are currently routed to a hydroclarifier, which separates solids from liquids. The solids generated from this process are called underflow solids. These solids after being dewatered by a belt filter press are stockpiled and recycled to

the kiln for reprocessing. Controls on the pH of the hydroclarifier are used to reduce emissions of SO_2 and HF.

One of the major solid by-products from phosphorus processing is called calcium silicate slag. The slag forms primarily from the quartzite used in the ore processing. The slag is collected from the electric-arc furnaces as molten material and is poured onto a pile on-site where it solidifies, forming a solid material. Slag was previously used off-site for various construction materials.

A smaller, but similar by-product called ferrophosphorus slag, also is produced in the electric-arc furnaces. This slag forms primarily from the naturally occurring iron and other metals in the ore. The ferrophosphorus slag is collected from the furnace and sold to Kerr-McGee for vanadium extraction.

1.2.2.4 Ancillary Products

Several ancillary products are produced at the Plant as part of general plant operations and elemental phosphorus production. These products include sanitary solid wastes, sanitary wastewater, cooling water, electrode seal water and phossy water.

- Sanitary solid wastes are currently disposed of in a permitted sanitary landfill located in the northwest corner of the Plant (Northwest Pond shown on Figure 1-3).

- Sanitary wastewater is currently routed to the City of Soda Springs wastewater treatment plant. Prior to the summer of 1993, sanitary wastewater was discharged to sewage infiltration and evaporation ponds located in the southwest corner of the Plant. These ponds are being closed out.

- Cooling water is used to cool the furnaces and other equipment. This water does not contact processing materials and is referred to as non-contact cooling water. This water is discharged to Soda Creek under an NPDES permit via an outfall located southwest of the Plant. The non-contact cooling water passes through a settling pond prior to discharge to reduce the water temperature and to settle particulates.

- Electrode seal water is generated from water seals used to prevent gases from escaping from the furnace. The seals surround the electrodes where they enter the furnace. This water is recycled after storage and cooling in a bentonite-lined pond.

- "Phossy" water is that water used to cool furnace off gases, and that come into contact with elemental phosphorus. It is treated and used in a total recycle loop.

1.3 Previous Environmental Investigations

A summary of environmental investigations conducted prior to the Phase I RI is provided in this section.

1.3.1 Groundwater Quality

Monsanto installed six groundwater monitoring wells in 1978 (TW-1, 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 in 1982. Off-site spring sampling was conducted by Monsanto in 1983.

A hydrogeological and surface-water investigation was conducted by Golder during 1984 to assess the effect of past and current operations on groundwater and surface-water quality (Golder 1985). 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 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 test wells, production wells, the Plant effluent and springs on two occasions during the project (November, 1984 and February, 1985) to determine the potential effects to the subsurface- and surface-water quality from Plant practices; and

- Quality Assurance — to determine sample precision, accuracy, completeness and representativeness involving: laboratory instrument calibration to standards, internal laboratory spike and replicate analyses, equipment and travel blank sample analysis, replicate sample analysis, and spike sample analysis.

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) because they had poor seals allowing inter-aquifer communication. Monsanto also installed several additional monitoring wells and a new production well (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 Monsanto's investigations indicated 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 (Figure 1-3). 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 1987, 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) and recommended on-going monitoring of groundwater quality. Remedial action was not recommended.

1.3.2 Air Quality

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: 1) the three furnace taphole fume collectors; 2) the nodule crushing and screening venturi scrubber; 3) the kiln cooler spray tower; 4) the four nodule kiln venturi scrubbers; and 5) fugitive emissions from the slag dumping area. The modeling was conducted using the long-term version of the EPA Industrial Source Complex Model. However, it was recognized that more precise studies of emissions were required to validate the dispersion calculations.

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

- Venturi scrubbers for the kiln;
- The spray tower for the nodule cooler;
- The baghouse outlet from the scale room;
- The venturi scrubber for the nodule crushing and screening area; and
- The furnace taphole fume collectors 7, 8, and 9.

In addition, tests were conducted for fugitive dust and particulate emissions released from material piles and stacks, respectively. These tests were conducted for 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). Chemical analyses for air emissions were 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 (IDHW), Division of the Environment, Bureau of Air Quality (IDHW-BAQ) in the immediate vicinity of the Monsanto Plant. These monitoring stations are shown on Figure 1-4. The monitoring includes 24-hour measurements of total suspended particulates (TSP) using high volume air samplers at the following stations:

- Station 13-0420-026, located on the Harris Ranch, south of the Monsanto Plant, from January, 1986, to May, 1988;
- Station 13-029-0029, located 1.5 miles northwest of the Monsanto Plant, from January, 1986, to September, 1988; and
- Station 13-0420-021, located at Soda Springs Hospital, approximately two miles southwest of the Monsanto Plant, from January, 1986, to September, 1988.

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

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

- Station 13-029-0002, located at the Torgeson residence. TSP was monitored from January, 1986, to September, 1988; and
- Station 13-0420-027, located about 1 mile west of Conda. TSP was monitored from January, 1986, to September, 1988, and PM_{10} was monitored from January, 1987, to June, 1989.

1.3.3 Ecology

The IDHW has conducted evaluations of Soda Creek and tributaries in the vicinity of the Monsanto Plant. The state 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 National Pollution Discharge Elimination System (NPDES)-permitted, non-contact cooling water discharge into Soda Creek.

The IDHW study indicated that the diversity of Soda Creek benthic macroinvertebrate community is decreased due to the highly mineralized and carbonated spring water that feeds the creek. The impact due to the high carbon dioxide content has been measured from the headwaters down to and below the outfall of the plant discharge. The water quality does improve in the lower reaches of the creek after the gas concentration has decreased, allowing the macroinvertebrate population to recover.

The IDHW study also included a fish survey. No fish were noted within the upper portions of Soda Creek due to the harsh environmental conditions imposed by the naturally carbonated springs that feed the creek. Small numbers of fish (salmonids) were noted in the lower reaches of Soda Creek, about one mile above the confluence with the Bear River. The study concluded 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 ecological impacts of the permitted discharge into Soda Creek, Monsanto conducted a fathead minnow static bioassay (Grothe 1980). During the 96-hour duration of this test, no mortality was observed. Therefore, based on review of existing data (the IDHW study and the Monsanto bioassay), no adverse effects to the stream ecology have been attributed to the Monsanto discharge to Soda Creek.

Terrestrial ecological data are available from a report by Severson and Gough (1979) who sampled and analyzed soils and vegetation. Vegetation sampling included big sagebrush and bluebunch wheatgrass in the vicinity of the Monsanto Plant. This study made the following conclusions:

- 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, intermittently and under certain conditions, to be harmful 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 the elements considered than did grass; and

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

It should be noted that since publication of the findings of Severson and Gough considerable changes in process and pollution controls have been implemented. The same conditions that existed in 1979 are not reflected in the current operation.

The Utah State University Foundation conducted a series of studies of fluoride concentrations in vegetation samples collected within a five-mile radius of the Monsanto Plant from 1985 to 1988 (Miller and Pushnik 1985, Miller 1986, Miller 1987, Miller 1990). The two most recent studies are summarized below.

A vegetation sampling study was conducted during the months of June through October of 1987 (Miller 1987). Alfalfa, pasture grasses, and range grasses were sampled at twenty locations. At each location one vegetation type was sampled and mean fluoride concentration was determined by type. The results showed that one location had a mean value of 45 ppm; three locations had mean values between 30 and 40 ppm; thirteen had mean values between 20 and 30 ppm; and the remaining locations had mean values less than 20 ppm.

A second vegetation sampling study was conducted during the months of June through September of 1988 at the same twenty locations (Miller 1990). The results showed that two locations had higher mean values of 74 ppm and 82 ppm than in the previous study. Seven locations had mean values between 30 and 40 ppm; six had mean values between 20 and 30 ppm; and the remaining locations had mean values less than 20 ppm.

It is important to note that in both studies fluoride concentrations were not measured in the soil medium. There was also no description of vegetation washing included in the analysis method. Considering these aspects of the analysis, it is not conclusive as to whether all fluoride measured was actually assimilated by the vegetation. An unknown proportion of the measured fluoride may have existed in dust settled onto the vegetation. This proportion is anticipated to be highly variable due to dependencies on climatic variables, e.g., wind speed and precipitation.

1.4 Previous Remedial Measures

During and subsequent to environmental investigations, Monsanto independently carried out several 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 of 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.

- Four underground fuel storage tanks were replaced with above-ground tanks with concrete sumps in 1986. These tanks were removed to comply with new regulations. There was no indication either in the inventory control process or during the inspection of the tanks that leaking had occurred.

- A pollution control project was installed in September, 1987, to provide additional scrubbing of kiln exhaust. 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. Much of 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. Solids that remained in the pond are below the cap, but well above the water table.

- The northwest pond, which was also suspected to be affecting groundwater, was excavated to remove affected soils. Discolored soils were removed from the northwest pond 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 known and suspected source areas to prevent degradation of the 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 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.

- The sewage evaporation ponds were taken out of service in the summer of 1993. The Plant was connected to the City of Soda Springs wastewater collection system.

- Emission controls were implemented during 1992 in the nodule reclaim area. These controls included a stationary stacking tube and dust collectors at material transfer points to reduce fugitive dust emissions.

Because of the high electricity demand of the Monsanto Plant, transformers and other electrical equipment containing insulating fluids have been used extensively. A complete file dating back to 1978 is maintained at the Plant concerning this equipment. 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 services were contracted to reputable companies who specialize in PCB and 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 these materials are not leaking and timely disposal is accomplished.

During the summer of 1991, EPA-10 completed a PCB inspection at the Plant. 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 there were no apparent violations of the PCB regulations, and the Plant case was closed. The plant is now free of regulated PCB containing equipment.

1.5 Regulatory Status

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

1.5.1 Hazardous Substance Response

The Monsanto Plant was placed on the CERCLA National Priority List in August, 1990, primarily due to the potential effects on groundwater of the Plant. The AOC issued in March, 1991, detailed the agreement between EPA-10 and Monsanto to perform the RI/FS for the Plant. This Phase II RI report was prepared in compliance with the AOC.

1.5.2 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 generated from the extraction, beneficiation, and processing of ores are excluded from this listing (40 CFR 261.4). Monsanto has evaluated process 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 unnecessary, 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 safety-clean solvents, fluorescent light bulbs, aerosol cans, and nicad batteries. This status allows the Plant to generate hazardous wastes at a rate of 100 to 1,000 kilograms per month and store these wastes on-site (for subsequent recycling off-site) for up to 180 days without a permit.

A sanitary landfill was created at the old northwest pond area for disposal of Plant refuse, including office trash, lunchroom waste, shipping and packaging materials, and construction debris. Monthly inspections of the sanitary landfill are conducted by the Southeastern Idaho Health District. No violations have been recorded during the operation of this facility. The sanitary landfill is also permitted by EPA-10 to allow disposal of asbestos materials from Plant operations.

Calcium silicate slag is being studied 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 that concluded the population is at a significant risk from the low-level gamma radiation resulting from the use of slag as aggregate for construction purposes (EPA 1990a). The issue was reviewed by the EPA Science Advisory Board (SAB) which determined the study did not provide the necessary data to evaluate risk-based exposures to gamma radiation. The SAB recommended EPA prepare a plan for obtaining reliable exposure determinations, and provide the plan for technical review (EPA 1991a). EPA and Monsanto are addressing these recommendations through a separate AOC.

1.5.3 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.

The nodule screening and crushing area was 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 (NESHAP) (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. The standard of 2.0 curies per year was based on the performance standard demonstrated by the scrubbing systems at the Monsanto Soda Springs plant. Radionuclide emissions from the kiln spray tower and venturi scrubbers have been tested since 1985. Recent testing results indicate emissions from this tower are 0.6 Curies per year, which is below the standard.

1.5.4 Water Quality

There is a National Pollution Discharge Elimination System (NPDES)-permitted discharge of non-contact cooling water to Soda Creek. Process waters are recycled within the Plant. Unlined ponds at the Plant have been retired, and the only ponds currently in use are lined using synthetic and/or bentonite liners. Sanitary wastewaters are discharged to the City of Soda Springs wastewater collection system, a publicly owned treatment works.

1.5.5 Occupational Health

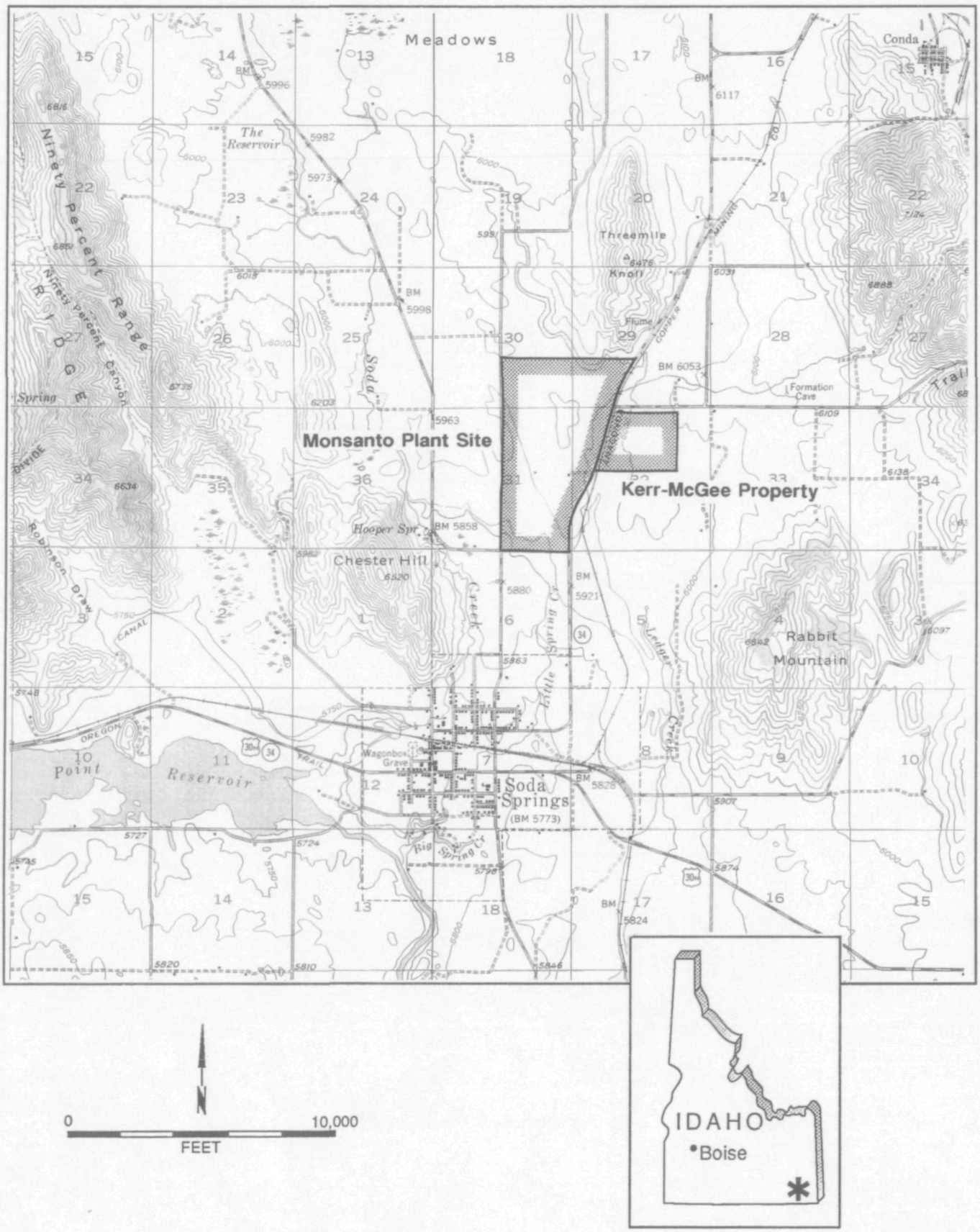
Significant steps have been taken to protect Plant employees and to comply with the Occupational Safety and Health Act (OSHA) regulations. Programs have been implemented and employees trained in hazard communication, respiratory protection, hearing conservation, personal protective equipment, confined space entry, asbestos removal, and radiation protection monitoring. Respiratory protection is currently required in the furnace area pending the placement of engineering controls. The Plant also meets all OSHA radiation protection standards. The Plant was recently awarded OSHA Star Status demonstrating that the facility has a proven compliance record in complying with OSHA regulations.

1.5.6 Toxic Substances

The Plant has instituted an aggressive program to eliminate the use of PCB-regulated equipment. EPA-10 conducted an inspection under the Toxic Substances Control Act (TSCA) in

June, 1991, and confirmed there were no PCB violations, and that Plant operations were in compliance with TSCA. The Plant has eliminated all PCB-regulated equipment.

1116mcl.ch1



SOURCE: Topographic map of the USGS Soda Springs Quadrangle (1:62,500) 1948.

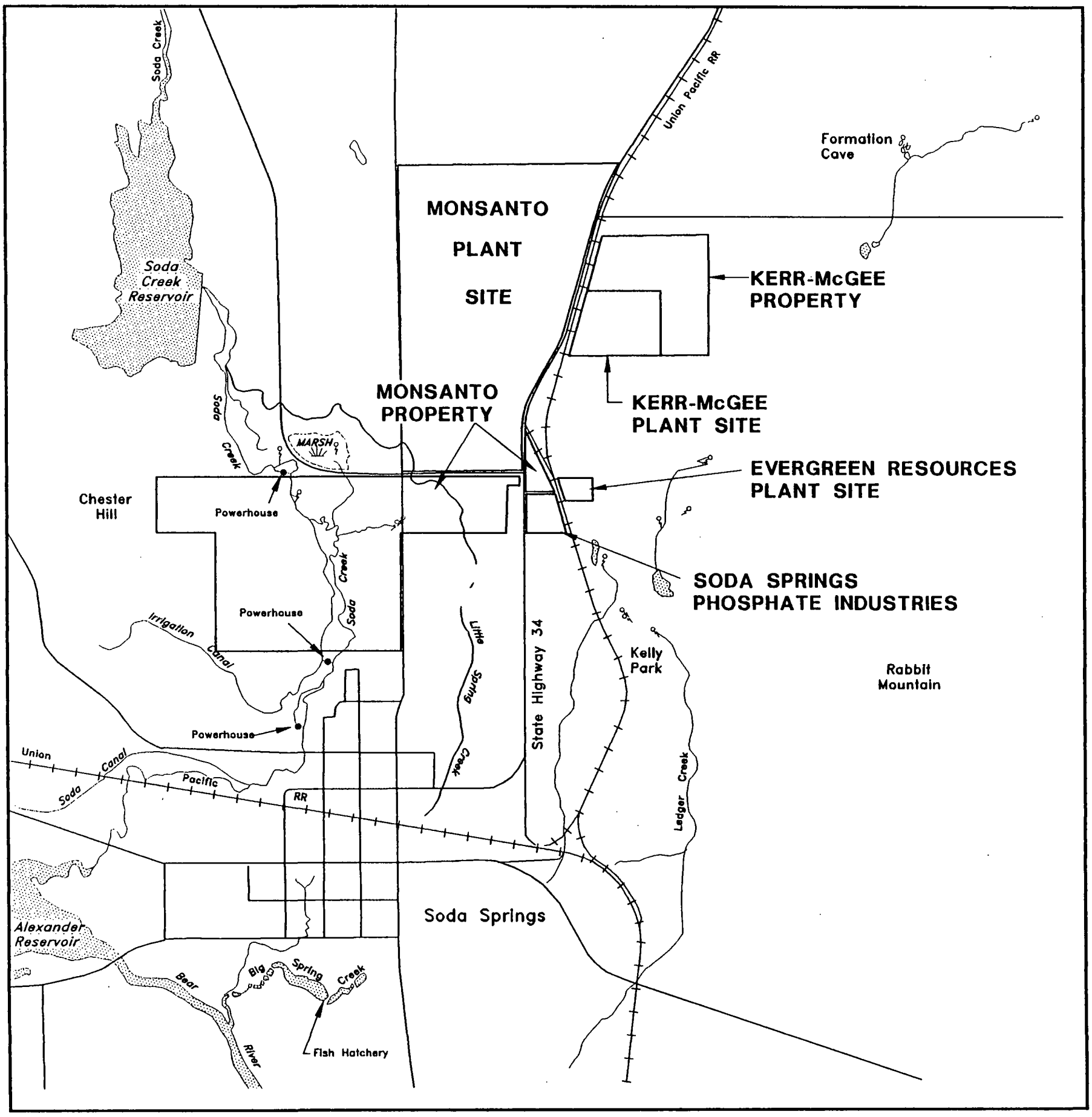
FIGURE **1-1**

LOCATION MAP

MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913 1101.608 DRAWING NO. 46005 DATE 6/3/94 DRAWN BY EA

Golder Associates



N

0 750 1500 METERS
0 2500 5000 FEET

NOTE:
Plant and property boundaries are approximate.

FIGURE 1-2
MONSANTO PLANT VICINITY
MONSANTO/PHASE II RI REPORT/ID

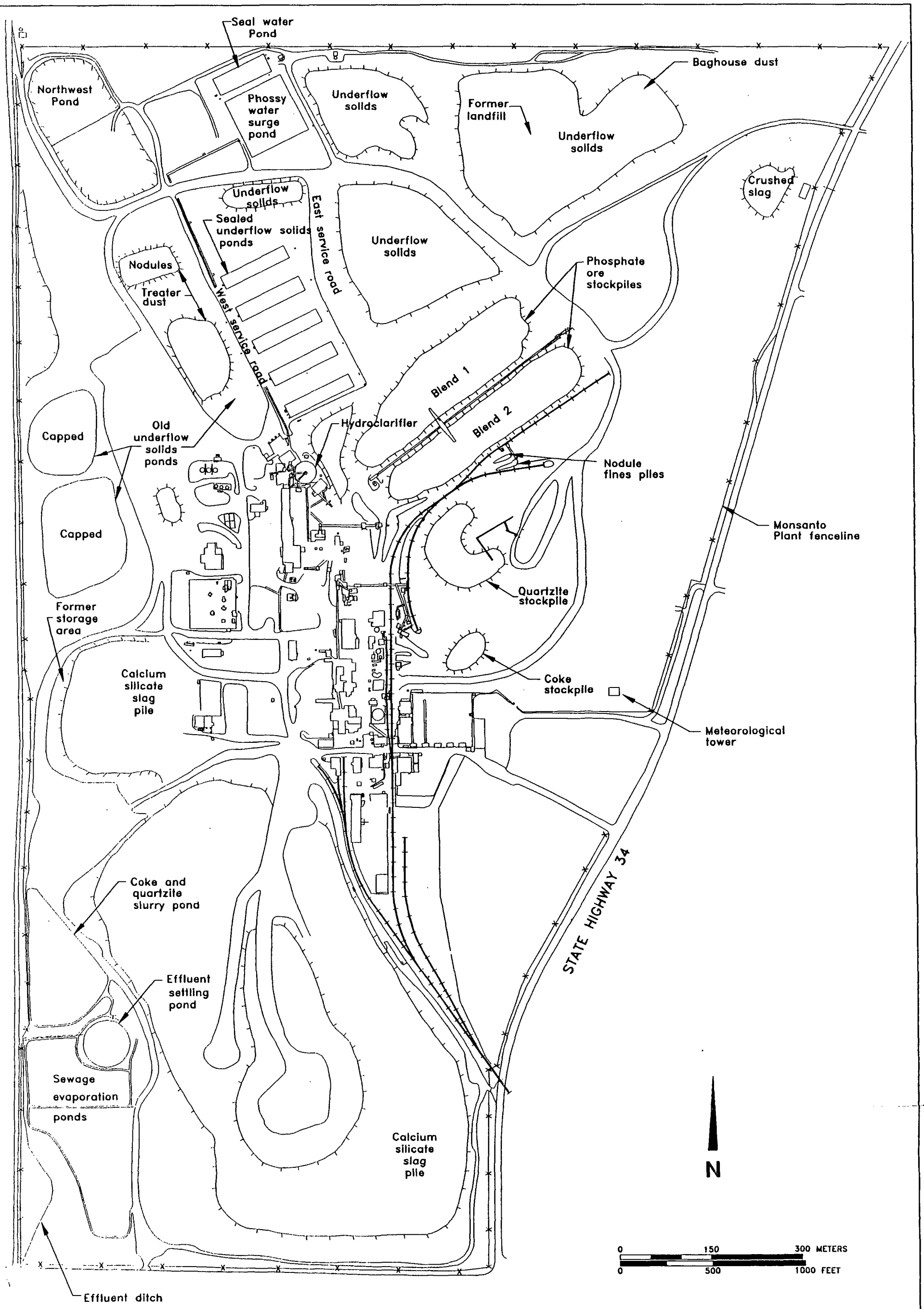


FIGURE **1-3**

MONSANTO FACILITY MAP

MONSANTO/PHASE II RI REPORT/ID

DWG ID: \JPM\9131101\608\51165 2-5-95 8:12

Golder Associates

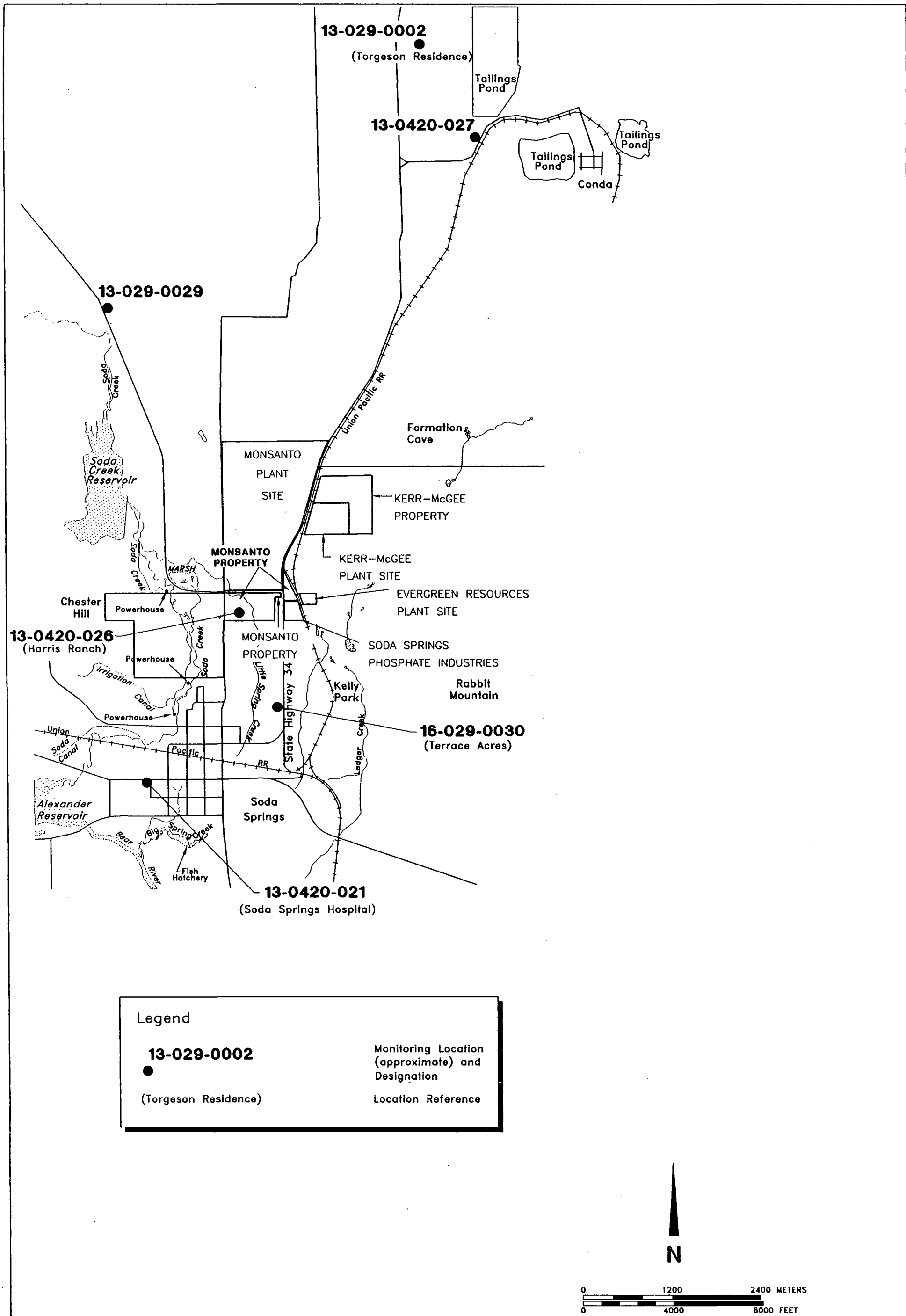


FIGURE **1-4**

AIR MONITORING LOCATIONS

MONSANTO/PHASE II RI REPORT/ID

\JPM\9131101\608\43333 6-3-94 11:06 DRAWN AG/JSS

Golder Associates

Section 2

2. DATA COLLECTION ACTIVITIES

An RI consists of numerous data collection and data evaluation activities. Necessary data can be collected by compiling existing information, conducting interviews, and through field investigations.

Phase I and II of the Monsanto Soda Springs Plant RI were conducted in accordance with the RI/FS Work Plans (Golder 1991, Golder 1992*c*). The purpose of this chapter is to provide the reader with an understanding of the data collection activities that were undertaken during the course of this RI. Interpretations of these data are provided in subsequent chapters.

Phase I and II RI data collection activities are presented in subsequent sections by the following categories:

- Potential Sources (Section 2.1);
- Meteorology and atmospheric characteristics (Section 2.2);
- Surface-water and sediments (Section 2.3);
- Geology (Section 2.4);
- Soils (Section 2.5);
- Hydrogeology (Section 2.6); and
- Ecology (Section 2.7).

These categories, with the exception of geology, represent environmental compartments within which constituents can potentially reside or be transported. There are no absolute boundaries between any given environmental media discussed in this report. They are recommended by EPA (1988) 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 Plant and the nature and extent of chemical constituents, respectively.

Data collection activities were conducted under a quality assurance project plan (QAPP) approved by EPA and Monsanto. Additional details on methods used during the RI appear in the QAPP, which is appended to the Phase I and Phase II RI/FS Work Plans (Golder 1991, Golder 1992*c*). 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.

Letters and memoranda cited are located in Appendix A.

2.1 Potential Sources

The objective of this task was to collect data in order to evaluate potential sources that could possibly release constituents to air, water, and soil. The potential sources occur within the Monsanto Plant. The source investigation consisted of the following data collection activities:

- Compilation of existing source information;
- Sampling and analysis of source materials; and
- A gamma radiation survey.

These data collection activities are summarized below. Physical characteristics of potential sources are presented in Chapter 3. Analytical results of source sampling are discussed in Chapter 4.

2.1.1 Compilation of Existing Source Information

Existing source information was compiled to supplement data gathered during Phase I and II of the RI. This information includes the following:

- Previous Monsanto Plant investigation reports (Golder 1985, 1987, 1988a, and 1988b; Ecology and Environment 1988a);
- An aerial photographic analysis (consisting of photographs covering a 46-year period from 1945 to 1990) used in monitoring physical conditions and activities at the Monsanto Plant (EPA 1990b);
- Raw material analytical data (Geddes, R.L., Monsanto [Memo to C. Yates, Golder] March 20, 1992);
- Plant records and archived photographs; and
- Employee interviews.

Existing information on fugitive dusts and stack emissions is provided in SENES (1992) and includes the following:

- Summaries of test results for particulate emissions from permitted point sources;
- Summaries of test results for particulate emissions and particle size distributions from the scaleroom baghouse collector;
- Fluoride emission test results from the cooler spray tower and the four kiln venturi scrubbers;
- Monitoring results for fugitive emissions testing in the nodule reclaim area;

- Trace metal analyses conducted by Monsanto in 1987 for the furnace taphole fume collectors, kiln venturi scrubbers, and the nodule screening and crushing scrubber;
- Trace metal analyses for baghouse dust samples collected by Monsanto in 1991;
- Fluoride emission rates from slag operations;
- Grain-size and moisture content of bulk materials from material handling operations;
- Air dispersion modeling results for cadmium and fluoride emissions from the permitted stacks and calcium silicate slag dumping operations; and
- Ambient particulate monitoring data for the period from 1986 to 1988 from the State of Idaho.

2.1.2 Sampling and Analysis of Source Materials

Potential sources at the Monsanto Plant include:

- Material stockpiles;
- By-products (solids and liquids);
- Point-source air emissions;
- Sewage evaporation ponds;
- Material handling operation areas; and
- Unpaved roads.

Physical characteristics of these potential sources are described in detail in Chapter 3. Air emissions from point sources and material handling operation areas were not sampled during this RI, but are discussed in Chapters 3 and 4. Sample collection activities of the potential sources which were sampled are discussed below.

Phase I activities consisted of analyzing material stockpiles and by-products for a limited suite of chemical constituents but primarily for physical analyses. Phase II activities included sampling of unpaved roads, the sewage evaporation ponds, and re-sampling of material stockpiles and by-products for additional analyses. Sample locations for both Phase I and Phase II samples are shown on Figure 2-1.

Samples were analyzed for physical, radiological, and/or chemical parameters. Physical analyses were carried out to estimate fugitive dust emissions from material handling operations, vehicle use on unpaved roads, and wind erosion of stockpiles and by-products. Chemical and radiological analyses were conducted on two sample types: 1) samples including the total grain-size distribution to provide data for use in mass balance calculations; and 2) samples consisting of only the sub-200 mesh (grain sizes less 74 μm, or sub-200 mesh) grain-sizes. The sub-200 mesh samples were collected from various materials at the Plant that were

considered representative of all the materials that could possibly be sources of fugitive dusts. The total samples were only collected from new materials, because these data were used in computing a current mass balance for the Plant, which is based on current emissions data.

Sampling procedures are discussed in detail in Golder (1991, 1992c). Physical characteristics of potential sources are presented in Chapter 3. Analytical results of source sampling are be discussed in Chapter 4.

2.1.2.1 Material Stockpiles

The following raw materials used in the elemental phosphorus production process are potential sources of constituent release:

- Phosphate ore stockpile - Blend 1;
- Phosphate ore stockpile - Blend 2;
- Coke stockpile; and
- Quartzite stockpile.

Material stockpile sample locations are shown on Figure 2-1. Samples were collected during Phases I and II of the RI as indicated in Table 2-1 and were analyzed for physical and chemical parameters. Chemical analyses included total and sub-200 mesh fraction analyses. Material stockpiles were analyzed for the constituents indicated in Table 2-1.

2.1.2.2 By-Products

The by-products of the elemental phosphorus production process are stored in piles or ponds. The potential sources associated with the by-products sampled during this RI have been divided into several categories based on physical form: solids or liquids. These potential sources are shown on Figure 2-1 and are listed below.

Solids

Solid by-products include the following:

- Baghouse dust;
- Calcium silicate slag;
- Coke and quartzite dust;
- Ferrophosphorus slag;
- Nodule fines;
- Treater dust; and
- Underflow solids.

Samples were collected during RI Phases I and/or II. Coke and quartzite dust were sampled as a Phase I activity; however the dust is no longer generated during the process. Calcium silicate slag, nodule fines, and treater dust samples were collected from representative materials and from relatively new materials. The samples were analyzed for the physical and chemical

parameters indicated in Table 2-1. Chemical analyses generally included both sub-200 mesh and total analyses.

Solid materials remaining in the northwest pond and the old underflow solids ponds were not sampled during the RI. The northwest pond was taken out of service in 1983. At this time affected soils were excavated and placed in the old underflow solids pond. The pond was converted to a permitted sanitary landfill in 1988, which included the installation of a bentonite liner. Operations of the old underflow solids ponds were discontinued in 1983 and the ponds were filled with molten slag and capped with bentonite in 1987.

Liquids

Liquid by-products include the following:

- Non-contact cooling water;
- Hydroclarifier process water;
- Phossy water; and
- Electrode seal water.

The non-contact cooling water was sampled during the Phase I RI. Three samples were collected directly above the weir in the non-contact cooling water effluent ditch, which is approximately 3-feet wide and 1-foot deep and is located in the southwest corner of the Plant as shown on Figure 2-1. The samples were analyzed for the constituents indicated in Table 2-1. Non-contact cooling water was re-sampled during Phase II for selenium.

Samples were not collected from the hydroclarifier, the phossy water pond, and the seal water pond during the RI. The hydroclarifier was replaced with a new unit in 1985 which is equipped with a steel liner and a leachate collection system and is not a current source for constituent release. The phossy water pond and electrode seal water pond are both lined with bentonite and are not considered potential sources.

2.1.2.3 Sewage Evaporation Ponds

One sanitary wastewater sample was collected from the sewage evaporation pond shown on Figure 2-1. The sample was collected during Phase II activities for the constituents indicated in Table 2-1.

2.1.2.4 Unpaved Road Materials

Unpaved roads within the Monsanto Plant fenceline consist of soil and gravel surfaces. The unpaved roads sampled during this RI include the following:

- ore haul road;
- quartzite haul road;
- calcium silicate slag haul road;
- east service road; and

- west service road.

Unpaved road locations are shown on Figure 2-1. Five samples were collected from evenly spaced locations along each road and were combined to form a single, composite sample. Per the approved project workplan, samples were collected from the surface of the roads. Many of the samples were collected during winter while the ground surface was frozen. Samples were analyzed for both physical and chemical analyses as indicated in Table 2-1.

2.1.3 Gamma Radiation Survey

A gamma radiation survey was conducted during the Phase II RI as part of the source investigation. The purpose of this activity was as a screening tool to evaluate potential gamma radiation emissions from selected by-product piles at the Plant and from surface soils around the perimeter of the Plant. The survey was not intended to provide tissue-equivalent data for use in a risk assessment.

Gamma radiation levels were recorded using an Eberline ESP-1 gamma meter with an HP-260 Geiger-Muller probe. The probe was held parallel to the measured material at a distance of approximately three feet. Three readings were collected from each location in counts per minute. These measurements were converted to m-Roentgens per hour and averaged. Gamma survey locations are shown on Figure 2-2. In addition, gamma radiation readings were collected at Phase II source sample locations (Figure 2-1) prior to sampling. The results of the gamma survey are presented in Chapter 4.

2.2 Meteorology and Atmospheric Characteristics

The objective of this task was to collect data in order to evaluate the air quality associated with the Monsanto Plant. The meteorological and atmospheric investigation consisted of a compilation of existing data. This activity is summarized below. Meteorological information is presented in Chapter 3. Air quality data are discussed in Chapter 4.

2.2.1 Compilation of Existing Meteorological and Air Quality Data

Existing meteorology information compiled included the following:

- Temperature, wind speed, and wind direction data from the Monsanto meteorological monitoring station;
- Mixing height data from the National Climate Center (NCC) for Boise, Idaho, and Salt Lake City, Utah;
- Wind speed data from Pocatello, Idaho;

An additional gamma radiation survey was conducted at the plant to evaluate worker exposure to naturally occurring radioactivity found in materials used and generated during phosphorus production. (Memo from Dr. J. Alvarez, IT Corporation, September 13, 1994.)

- Barometric, temperature, and precipitation data from a National Oceanic and Atmospheric Agency (NOAA) at the airport in Soda Springs, Idaho (Hydrosphere 1993); and

- Precipitation data from a National Weather Service (NWS) station located in Conda, Idaho.

Existing ambient air quality data are available from the Idaho Department of Health and Welfare, Division of the Environment, Bureau of Air Quality (IDHW-BAQ) and include data from air monitoring stations in the immediate vicinity of the Monsanto Plant and in the southeastern Idaho region (SENES 1992). Data include ambient TSP and PM_{10} concentrations. Air quality data are provided in Appendix D. Chapter 1 includes a discussion of existing air quality information.

2.3 Surface-Water and Sediments

The objective of this task was to collect data in order to evaluate the surface-water and sediment quality in Soda Creek. The surface-water and sediment investigation consisted of the following data collection activities:

- Compilation of existing surface-water and sediment information; and

- Sampling and analysis of surface water and sediments.

These activities are summarized below. Physical characteristics of the sediments are presented in Chapter 3. Analytical results of surface water and sediment sampling are discussed in Chapter 4.

2.3.1 Compilation of Existing Surface-Water and Sediment Information

Existing regional and local surface-water and sediment information was compiled to supplement new data gathered during this investigation. This information includes the following:

- The 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 of hydrologic data and water supply information of the Great Basin region of Idaho, Nevada, Utah, and Wyoming (Price and Eakin 1974);

- A publication 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);
- A survey of water quality 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);
- The 7.5-minute United States Geological Survey (USGS) topographic map of Soda Springs (USGS 1982);
- USGS stream gaging station data for Soda Creek and Bear River (Hydrosphere 1993);
- Monsanto internal memoranda on local surface hydrology (Soda Creek Reservoir, Soda Creek, irrigation, weirs, and the fish hatchery); and
- A hydrologic budget analysis of the Blackfoot River, Soda Creek, and Bear River (Dion 1974).

2.3.2 Sampling and Analysis of Surface-Water and Sediments

The purpose of this activity was to sample and analyze water and sediment from Soda Creek downstream and upstream from the non-contact cooling water effluent discharge. Sampling and analysis of surface water and sediments took place during both Phase I and II of the RI.

During the summer of 1994 which coincided with the Phase II RI review period, additional sampling and analysis was conducted for the surface water and sediment media. The need for these additional data was identified in the Phase II RI. A report has been prepared documenting this work and is included in Appendix G-4.

2.3.2.1 Surface-Water

A total of six surface-water samples were collected. Sample locations are shown on Figure 2-3. Three control surface-water samples were collected from Soda Creek approximately 400 feet upstream from the effluent discharge: one along the east bank (UP-NEAR); one in the middle of the creek (UP-MIDDLE); and one along the west bank (UP-FAR). At the upstream sampling location, Soda Creek 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.

Surface-water samples were collected by submerging the 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). Sampling proceeded from downstream to upstream locations to avoid contaminating downstream samples with disturbed upstream sediments. Surface-water sampling took place during the Phase I RI.

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

2.3.2.2 Sediment

Sediment samples were collected during Phases I and II of the RI. Samples were collected in Soda Creek upstream and downstream relative to the non-contact cooling water effluent discharge; and in several spring-fed creeks, upstream from their confluence with Soda Creek. Sample locations are shown on Figure 2-4. Sediment samples were analyzed for the constituents indicated in Table 2-2. Sediment sampling procedures are described in detail in Golder (1991, 1992c, 1993c).

Upstream sediment samples were analyzed as controls. These samples include three samples collected approximately 400 feet upstream from the effluent discharge. One additional sample was collected 100 feet upstream from the effluent discharge as a control for molybdenum. Downstream sediment samples were collected from Soda Creek at the locations shown on Figure 2-4. Spring-fed tributaries to Soda Creek downstream of the effluent discharge (Southwest Spring, Mormon Spring, and Homestead Spring) were sampled approximately 100 feet above their confluence with Soda Creek, as shown on Figure 2-4 by sample locations SWSS3-100, MSSS-100, and HSS3-100, respectively.

Additional sediment samples were collected for biological toxicity testing in Phase II of the RI. Sample locations were located 100 feet upstream of the effluent discharge, and 100 feet and 2,400 feet downstream of the effluent discharge. Biological toxicity testing of sediments was conducted using differences in algal growth and bacterial growth (enzyme activity) relative to controls as indicators of toxicity. Results of biological toxicity testing are presented in Chapter 4.

2.4 Geology

The objective of this task was to collect data in order to evaluate the geological features of the Monsanto Plant on a local and regional scale. The geological investigation consisted of the following data collection activities:

- Compilation of existing geological information;
- Geological reconnaissance;
- A geophysical survey; and
- Drilling and installation of monitoring and test wells.

The information compilation and geological reconnaissance are summarized below. The geophysical survey and drilling data collection activities were conducted as part of the hydrogeological investigation and are summarized in Section 2.6 (Hydrogeology). Geological interpretations are presented in Chapter 3 (Physical Characteristics).

2.4.1 Compilation of Existing Geological Information

Existing geological information was compiled to supplement data gathered during Phases I and II of the RI. Existing information of the regional geology included the following:

- 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, 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);

- 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);

- 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, Oriel and Armstrong 1966);

- Discussion concerning 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, Perkins and Fiesinger 1979).

Information on local geology, which was generally specific to the Soda Springs area and the Blackfoot Lava Field included the following:

- Reports on the geology and structure of the Soda Springs area (Richards and Mansfield 1910, Armstrong 1969);

- An investigation of the Blackfoot Lava Field 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 (Gulbrendsen 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); and

- An aerial photographic and fracture trace analysis of the Soda Springs area (EPA 1990b).

Other geologic information was available that was specific to the Monsanto and Kerr-McGee Plants. This information includes the following:

- Geologic and aerial reconnaissance in the vicinity of the Monsanto Plant (Golder 1985);

- Drilling and geophysical logs from previously installed monitoring wells, production wells, and domestic wells at the Monsanto Plant and vicinity (Golder 1985, Golder 1988a);

- Geophysical survey results for the Kerr-McGee plant (Ecology and Environment 1988b); and

- RI geological and geophysical logging results for the Kerr-McGee Plant (Dames and Moore 1993).

2.4.2 Geologic Mapping

The purpose of this activity was to locate and identify surficial geologic features that may influence groundwater flow, especially in the area to the east and south of the Plant.

Prior to field investigations, an air-photo analysis of the area was conducted using existing United States Department of Agriculture (USDA) black-and-white aerial photographs. The photographs were 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 verification.

Field mapping was conducted during the Phase I RI. 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). Prominent faults and associated structures in the vicinity of the Monsanto Plant were visited as part of the reconnaissance, as well as springs and drainage features near the Plant and to the south of Soda Springs. In addition, 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 also investigated.

2.5 Soils

The objective of this task was to collect data in order to evaluate the properties of off-site soils in the vicinity of the Monsanto Plant. The soil investigation consisted of the following data collection activities:

- Compilation of existing soil information;
- Sampling and analysis of soil; and
- A gamma radiation survey of soils.

These activities are summarized below. Physical characteristics of the soils are presented in Chapter 3. Analytical results are discussed in Chapter 4.

2.5.1 Compilation of Existing Soil Information

Existing regional and local soil information was compiled to supplement new data gathered during this RI. This information included the following references:

- 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);

- Information on soil moisture depletion at three sites in the Bear River basin (Allen and Brockway 1982);
- The impact of elemental emissions from industrial processing of phosphatic shale on the chemistry of vegetation and soil near Soda Springs and Pocatello (Gough and Severson 1976, Hutchison et al. 1979, Severson and Gough 1979, Johnson et al. 1980);
- The elemental composition of regional soils (Shacklette et. al., 1971, 1984);
- Information obtained from RI activities conducted at the Kerr-McGee plant (Dames and Moore 1992 and 1993); and
- Regional and local soil maps 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

Soils surrounding the Monsanto Plant were sampled during Phases I and II of the RI. One or more samples were collected from each sample location at varying depths. Sample depth intervals consist of 0-to-1 inch, 0-to-6 inch, 6-to-12 inch, and 12-to-24 inch depth intervals. Soil sampling depth intervals were informally assigned an identification letter as follows:

Identification	Depth Interval (inches)
A	0-to-1
B	0-to-6
C	6-to-12
D	12-to-24

Soil samples were collected from a total of 72 locations, as shown on Figures 2-5 and 2-6. Locations were selected in order to ensure relatively undisturbed land was sampled and a variety of land uses were represented (e.g., plowed field, range land, and grass land). Soil sample locations have been divided into four categories as described above. Sampling procedures are described in Golder (1991, 1992c, 1993c).

During both phases of this RI, chemical analyses of soil samples have been for total content except for fluoride which was analyzed for soluble content. The soluble fluoride was judged more relevant for evaluating crop uptake of fluoride from soil. EPA requested additional information on the feasibility of using soluble fluoride to predict total fluoride concentrations in soils for exposure pathways other than crop uptake. Therefore, a subset of Phase I and II samples was analyzed for total fluoride and used to develop a regression equation to predict total fluoride using soluble fluoride. This regression equation is

$$\log_e(\text{Total Fluoride}) = 5.44 + 0.867 * \log_e(\text{Soluble Fluoride})$$

The development of this equation is detailed in a letter to EPA (Letter to Mr. T.H. Brincefield, EPA, from Mr. C.R. Hunter, Golder Associates, February 23, 1994).

2.5.2.1 Surface-Soil Sample Locations

Surface-soil samples were collected from a total of 34 locations during the RI (16 locations were sampled during Phase I and 18 locations were sampled during Phase II). Samples were collected at each location from the A and B depth intervals. Samples were analyzed for the chemical constituents indicated in Table 2-3; only samples collected from the B interval during Phase II were analyzed for physical parameters. Sample locations are shown on Figure 2-5.

2.5.2.2 Soil-Profile Sample Locations

Soil-profile samples were collected from a total of eight locations during the RI (soil-profile samples were collected during Phase II). Samples were collected from the four depth intervals (A, B, C, and D) at each location. Samples were analyzed for the constituents listed in Table 2-3; however, only samples collected from the B interval were analyzed for the physical parameters listed in Table 2-3. Sample locations are shown on Figure 2-5.

2.5.2.3 Contingent Surface-Soil Sample Locations

Contingent surface-soil samples were collected from a total of 10 locations during the RI (contingent soil samples were collected during Phase II). Samples were collected from the B depth intervals at each location. Contingent samples were only analyzed if adjacent sample locations (surface-soil or soil-profile sample locations) showed results that exceeded screening concentrations (maximum background concentrations and risk-based concentrations). If analyzed, contingent samples were only analyzed for the constituents which exceeded the screening values. Sample locations are shown on Figure 2-5.

2.5.2.4 Control Soil Sample Locations

Control soil samples were collected from a total of 20 locations during the RI. Six locations were sampled during Phase I activities (three of these locations were sampled by Dames and Moore (1993) for Kerr-McGee) from the A and B depth intervals, and re-sampled during Phase II for the C and D intervals. An additional 14 control locations were sampled during Phase II from the A depth interval only. Control samples collected during Phase I and II were analyzed for the same constituents as Phase I and II surface-soil samples, respectively (Table 2-3). However, only samples collected from the B interval were analyzed for the physical parameters listed in Table 2-3. Control sample locations are shown on Figure 2-6.

2.5.3 Gamma Radiation Survey of Perimeter Soils

A gamma radiation survey of perimeter soils was conducted during the Phase II RI as part of the source investigation. The purpose of this activity was as a screening tool to evaluate potential gamma radiation emissions from selected by-product piles at the Plant and from

surface soils around the perimeter of the Plant. The data were not planned to be used for risk assessment purposes.

Gamma radiation levels were recorded using an Eberline ESP-1 gamma meter with an HP-260 Geiger-Mueller probe. The meter was held parallel to the measured material at a distance of approximately three feet. Three readings were collected from each location in counts per minute. These readings were converted to m-Roentgens per hour and averaged. Gamma survey locations are shown on Figure 2-2. In addition, gamma radiation levels were measured at each Phase II soil control and sample location. The results of the survey are discussed in detail in Chapter 4.

2.6 Hydrogeology

The objective of this task was to collect data in order to evaluate the groundwater conditions in the vicinity of the Monsanto Plant. The hydrogeological investigation consisted of the following data collection activities:

- Compilation of existing information;
- A geophysical survey;
- Installation of monitoring and test wells;
- Aquifer testing;
- Sampling and analysis of groundwater;
- A geodetic survey; and
- Water-level monitoring.

These activities are summarized below. Interpretation of the hydrogeological data is presented in Chapter 3. Groundwater quality results and interpretations are presented in Chapter 4. Results of constituent fate and transport modeling are presented in Chapter 5.

2.6.1 Compilation of Existing Information

Existing hydrogeological and groundwater-quality information was compiled to supplement newly collected data. The information includes the published documents summarized below.

- A hydrological investigation in the Great Basin region of Idaho, Nevada, Utah, and Wyoming (Price and Eakin 1974);

- A water-quality study providing representative data of several different regional aquifers and relating the data to natural and man-made 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 hydrogeological/hydrochemical data interpretation of several springs in the Soda Springs area (Ralston et al. 1983);

- A discussion of water resources for the entire Bear River drainage in Idaho (Barnett 1967);
- An evaluation of groundwater resources in Lower Dry Valley (10 miles east of Soda Springs) for a potential open pit mine (Robinette and Ralston 1976);
- An investigation of groundwater flow patterns in the Meade thrust allochthon, southeastern Idaho (includes analyses of 38 spring and well samples) (Mayo et al. 1985);
- A study of spring-water geochemistry in the Blackfoot Reservoir region of southeastern Idaho (includes Soda Springs area) (Mitchell 1976, Hutsinpiller 1979, Hutsinpiller and Parry 1985);
- A discussion of groundwater resources and movement in the area between Soda Springs and Conda, Idaho (Anderson and Kelley 1967); and
- A study of leakage from the Blackfoot Reservoir (Dion 1974).

Hydrogeological information specific to the Monsanto and Kerr-McGee plants was also available from previous studies. These information sources include the following:

- Reports documenting well abandonments and installations at the Monsanto Plant (Golder 1987, 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 hydrostratigraphic information, geophysical borehole logs, well pump testing data, and water quality sampling results (Golder 1985, 1988b);
- An EPA site inspection report for the Monsanto Plant (Ecology and Environment 1988a);
- An EPA site inspection report of the Kerr-McGee Plant (Ecology and Environment 1988b); and
- Hydrostratigraphic information, geophysical borehole logs, and water quality sampling results from Phase RI activities at the Kerr-McGee plant (Dames and Moore 1993).

2.6.2 Geophysical Survey

Geophysical survey activities took place during the Phase II RI and were conducted using electromagnetic (EM) induction methods. The purpose of the activities were the following:

- Delineate constituent plumes originating from the Monsanto Plant;
- Identify the presence of faults south of the Monsanto Plant; and
- Assist in the selection of locations for monitoring wells south of the Monsanto Plant.

The survey was conducted along four east-west transects shown on Figure 2-7. Two different EM instruments were used, the Geonics EM-31 and EM-34. Geophysical survey procedures are described in detail in Appendix L. Interpretation of the geophysical survey is discussed in Chapter 3.

2.6.3 Installation of Monitoring and Test Wells

Six wells were installed during the Phase II RI as part of the hydrogeological investigation. This activity took place in the fall of 1992 and involved the completion of five new monitoring wells and one new test well. The new wells were designated Test Wells 53 through 58 (TW-53 through TW-58) and are located as shown on Figure 2-8.

Also shown on Figure 2-8 are the locations of wells previously drilled at the Monsanto Plant. Test wells TW-01 through TW-08 and production wells PW-01 through PW-03 existed prior to the hydrogeological investigation conducted by Golder in 1984 (Golder 1985). Subsequent to that investigation, wells TW-09 through TW-52 were installed under the supervision of a Golder hydrogeologist between the years 1984 and 1988.

Not all of the wells are presently available for water quality sampling due to the following reasons: TW-1, TW-3, TW-4, TW-5, TW-6, TW-25, and TW-27 have been grouted up and abandoned; TW-46 and TW-47 were never drilled; TW-51 was drilled as a test well for groundwater supply; TW-52 was renamed PW-4 and completed with a permanent pump for production purposes; and TW-58 was completed for pumping-test purposes.

Monitoring wells at the Monsanto Plant comply with the Idaho Department of Water Resources (IDWR) well construction standards for monitoring wells (IDWR 1989). The monitoring wells are completed with 4-inch PVC casing and bentonite-pellet seals. The production wells at the Plant (PW-1 through PW-4) are completed with steel casing and/or completed as open holes. TW-2 is completed as an open hole. Borehole logs and well construction drawings are provided in Appendix H.

Drilling and well installation procedures are described in Appendix H. Information obtained from well drilling activities is discussed pertaining to the Plant geology and hydrogeology in Chapter 3.

2.6.4 Aquifer Testing

Hydraulic testing was conducted during Phase II of the RI. Previous well hydraulics testing was conducted in 1984 (Golder 1985). The tests were conducted to provide estimates of the hydraulic parameters of the material surrounding the new monitoring wells, to determine the boundary effects of two faults crossing the Plant, and to determine the hydraulic properties of the material underlying the southern Plant area.

Aquifer test procedures are described in detail in Appendix H. Analyses and interpretations are provided in Chapter 3.

2.6.4.1 Single-Well Hydraulics Testing

Single-well hydraulics testing was performed on the five new monitoring wells, TW-53 through TW-57. The type of single-well hydraulics test performed (slug test or short-term pumping test) was based on the well response during development. Slug tests were performed in the wells which could not sustain production over a short time period; whereas, short-term pumping tests were performed in wells which produced larger quantities of water over a longer period of time. Slug tests were performed in wells TW-53, TW-54, and TW-56 and short-term pumping tests were performed in wells TW-55 and TW-57.

Slug tests involve the rapid removal or addition of a small volume of water from a well, after which the water-level recovery is measured. Slug tests at the Monsanto Plant were performed by pumping a well at a rate of 25 gpm, rapidly drawing down the water in the well to the pump intake. The flowrate was measured using a bucket and stop-watch. After removing the water from the well, the pump was turned off and water-level recovery was measured using an electric water-level probe and watch.

Short-term pumping tests involve pumping a well at a constant rate for a set amount of time, after which the water-level in the well is allowed to recover. The water level during both pumping and recovery is measured. The wells at the Monsanto Plant in which short-term pumping tests were conducted were pumped for approximately two hours. Water levels were measured using an electric water-level probe. A totalizing flow meter was used, along with a bucket and stop-watch to measure the pumping rate.

2.6.4.2 Long-term Pumping Test

In addition to the single-well hydraulics testing, a pumping test was conducted involving multiple wells. The pumping test consisted of an initial step test, followed by a three-day constant-rate test.

TW-58 was used as the pumping well. Water levels were recorded in 24 observation wells (including the test well). Water levels in 12 of the 24 observation wells were measured using pressure transducers and automatic datalogging equipment. Water levels in the remaining observation wells and the test well (TW-58) were measured manually with an electric water-level probe. A totalizing flow meter was used to measure the pumping rate.

The step test consisted of six one-hour steps, with a pumping-rate increase after each step. The initial pumping rate was approximately 100 gpm and proceeded to increase by 100 gpm for each step (with the exception of the last step for which the pumping rate increased by about 40 gpm). After the pump was turned off, the water levels in the wells were allowed to recover.

The constant-rate test consisted of pumping the test well for three days, after which the water level was allowed to recover. The well was pumped at a constant rate of 500 gpm. After the pump was turned off, water-level recovery was monitored for four to eight days, with the exception of TW-34 which was monitored for 24 days.

2.6.5 Groundwater Sampling and Analysis

The purpose of this activity was to collect data in order to determine groundwater quality and to characterize groundwater flow patterns. A total of four groundwater-sampling rounds have been completed as part of this report. Samples were collected from approximately 50 to 60 locations during each sampling round. Sample locations consisted of monitoring wells, production wells, and springs (or other groundwater-fed surface-water bodies) and are shown on Figures 2-8 and 2-9. Wells and springs located upgradient from potential source areas were used as control locations to examine background groundwater quality.

Sample locations and analysis parameters were modified between sampling rounds depending on the results of the previous round. Table 2-4 lists the wells and springs sampled during each of the sampling rounds. Constituents analyzed for each sampling round are listed in Table 2-5. Samples were analyzed for trace metals, ions, and water-quality parameters. Selected wells and springs were also analyzed for radiochemicals, environmental isotopes, biological oxygen demand, chemical oxygen demand, and total petroleum hydrocarbons. It should be noted that groundwater samples collected in May and November 1992 were analyzed for nitrate-nitrogen and nitrite-nitrogen as separate species. Results for these sampling rounds showed nitrite-nitrogen was undetected. Although subsequent groundwater samples were analyzed for nitrate/nitrite-nitrogen, the results are considered to be comprised only of nitrate-nitrogen.

Groundwater sampling procedures are described in Appendix H. Results for chemical analyses of groundwater are presented in Chapter 4 (Nature and Extent of Chemical Constituents).

2.6.6 Water-Level Monitoring

Groundwater elevations were monitored during the RI as part of the hydrogeological investigation. Water-level measurements were collected from production and monitoring wells prior to water-quality sampling activities and pumping test activities. Groundwater elevations of springs and surface-water bodies were geodetically surveyed, as discussed below. Groundwater elevation data were used to construct potentiometric-surface maps used to determine directions and gradients of groundwater flow. Water-level measurements were collected using an electric water-level probe. The data are considered accurate to within 0.01 feet. Water level data are presented in Chapter 3.

2.6.7 Geodetic Survey

Monitoring wells, production wells, and springs selected for use in the RI 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 H [Well Information]. 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; horizontal 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.

2.7 Ecology

The objective of this task was to collect data in order to evaluate potential receptor populations (human and wildlife) of constituents of potential interest associated with the Monsanto Plant. In this report, the term wildlife refers to non-domesticated populations of both plants and animals, inhabiting both terrestrial and aquatic habitats. Human and wildlife investigation activities are described in further detail below. Interpretations of the ecology of the Plant can be found in Chapter 3 (Physical Characteristics).

2.7.1 Human Ecological Investigation

The human ecological investigation consisted of the following data collection activities:

- Compilation of existing land-use information;
- Compilation of existing water-use information;
- Compilation of existing cultural information (i.e., archeological and historical);
- A land-use survey; and
- A well inventory.

These data collection activities are described below.

2.7.1.1 Compilation of Existing Land-Use Information

Existing land-use information was compiled during Phases I and II of the RI. Published documents were reviewed and state, regional, county, city, and Monsanto Plant employees were interviewed. The City of Soda Springs zoning ordinance (Title 17, Soda Springs 1990) 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).

The following city and county officials were interviewed to gather information pertaining to current and 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. Plant visits also provided land-use information.

2.7.1.2 Compilation of Existing Water-Use Information

Water use can be divided into groundwater and surface water uses. A compilation of existing wells and groundwater withdrawal points within approximately 24 square miles of the Monsanto Plant was prepared from the following sources: well logs and a listing of water rights on file with the IDWR (obtained from the Idaho Falls and Boise offices); well information obtained from the USGS Water Resources Division in Boise; City of Soda Springs drinking-water database; and a review of published literature.

Existing surface water use information compiled includes topographic maps and City of Soda Springs water-use records. This information provided locations of water intake, recreational areas, and other relevant facilities.

In addition to the city and county officials interviewed regarding land use, the following officials were interviewed to obtain information regarding water use and related 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 [Letters and Memo Cited] (Wright, B., Golder [Memo to Monsanto Soda Springs Plant Phase I RI File] November 12, 1991).

2.7.1.3 Compilation of Existing Cultural Information

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 the RI/FS. Findings on this issue are presented in Chapter 3 (Physical Characteristics).

2.7.1.4 Land-Use Survey

A land-use survey was conducted as part of the ecological investigation. The objective of the survey was to determine which lands within 1.6 miles (2 kilometers) of the Monsanto Plant are being used for agricultural/consumable-products purposes. Property maps were obtained from the Caribou County Assessor's Office in Soda Springs. A drive-by field survey was conducted (each property was photographed) and the property owners or tenants were contacted and interviewed.

In addition to the land-use assessment, an informal evaluation of residential garden production was conducted. The University of Idaho Cooperative Extension System in Soda Springs was contacted and information was provided by Ms. Darlene Moss, Extension Home Economist for Caribou County.

2.7.1.5 Well-Inventory

A well inventory was conducted as part of Phase II activities to update and verify groundwater-use information compiled during Phase I activities. The well inventory included known wells located within 2.5 miles downgradient (south) of the Monsanto Plant and was conducted to verify locations and uses. This downgradient area represents the area that could potentially be affected by groundwater flowing south from the Monsanto Plant before discharging into Soda Creek, Bear River, and Alexander Reservoir. Well owners were contacted and interviewed and each well was photographed.

2.7.2 Wildlife Ecological Investigation

The wildlife ecological investigation consisted of the following data collection activities:

- Compilation of existing wildlife information; and
- Field habitat reconnaissance.

2.7.2.1 Compilation of Existing Wildlife Information

Existing 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 included: a State environmental overview (Montgomery 1975); an assessment of special mineral processing wastes (EPA 1990c); 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, Severson and Gough 1976, Severson and Gough 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 above) were interviewed as part of the biological data compilation effort:

- Mr. Bob Kukachka, Soil Survey Project Leader, Soil Conservation Service (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 are provided in a project memorandum contained in Appendix A (Wright, B., Golder [Memo to Monsanto Soda Springs Plant Phase I RI File] November 12, 1991).

2.7.2.2 Field Habitat Reconnaissance

A field habitat reconnaissance of sensitive or critical habitats was completed within a 1.6-mile (2-kilometer) radius of the Monsanto Plant during the Phase II RI. As the data compilation effort identified Soda Creek as the only sensitive habitat within this area, and no critical habitats were identified (see Chapter 3), the field reconnaissance was restricted to Soda Creek. Chapter 3 incorporates the observations noted during the reconnaissance.

TABLE 2-1

SOURCE SAMPLING ANALYSIS PARAMETERS

PARAMETER GROUP	CONSTITUENT	MATERIAL STOCKPILES		PROCESS BY-PRODUCTS (solids)		NON-CONTACT COOLING WATER		SANITARY WASTE-WATER		UNPAVED ROADS	
		PHASE		PHASE		PHASE		PHASE		PHASE	
		I	II	I[1]	II	I	II	I	II	I	II
Metals	Aluminum		x	x	x	x			x		x
	Arsenic		x	x	x	x			x		x
	Beryllium		x	x	x	x					x
	Cadmium		x	x	x	x			x		x
	Chromium		x	x	x	x					x
	Iron			x		x					x
	Lead			x		x			x		x
	Manganese		x	x	x	x					x
	Molybdenum		x		x				x		x
	Nickel			x		x			x		x
	Potassium			x		x			x		x
	Selenium		x	x	x	x	x				x
	Silver		x	x	x	x			x		x
	Sodium			x		x					
	Vanadium		x	x	x	x			x		x
	Zinc		x	x	x	x			x		x
Ions	Ammonium[2]					x			x		
	Bicarbonate					x					
	Calcium					x					
	Carbonate					x					
	Chloride					x			x		
	Fluoride		x	x	x	x			x		x
	Hydroxide					x					
	Magnesium					x					
	Nitrate/Nitrite as N				x	x			x		
	Sulfate					x			x		x
	Total Phosphorus					x					
Radionuclides	Gross Alpha					x					
	Lead-210		x	x	x						x
	Polonium-210		x	x	x						x

TABLE 2-1

SOURCE SAMPLING ANALYSIS PARAMETERS

PARAMETER GROUP	CONSTITUENT	MATERIAL STOCKPILES		PROCESS BY-PRODUCTS (solids)		NON-CONTACT COOLING WATER		SANITARY WASTE-WATER		UNPAVED ROADS	
		PHASE		PHASE		PHASE		PHASE		PHASE	
		I	II	I[1]	II	I	II	I	II	I	II
Radionuclides (cont.)	Potassium-40			x							
	Radon					x					
	Radium-226		x	x	x	x					x
	Radium-228			x		x					
	Thorium-228		x	x	x						x
	Thorium-230		x	x	x						x
	Thorium-232		x	x	x						x
	Uranium			x		x					
	Uranium-234		x		x						x
	Uranium-238		x		x						x
Physical	Hydrometer	x		x							x
	Moisture Content	x		x							x
	Specific Gravity	x		x							x
	Wet Sieve	x		x							
Water Quality	Eh[4]					x					
	pH[4]					x					
	Specific Conductance[3]					x					
	Temperature[4]					x					
	Total Dissolved Solids					x					
	Turbidity[4]					x					
Others	Cation Exchange Capacity			x							
	pH (of soils)			x							

[1]Chemical analyses performed on sub-200 sieve fraction only (particles < 0.074 mm).
[2]The actual constituent analyzed is ammonia, which can be used with pH and temperature to calculate ammonium concentration.
[3]Analyzed in field and laboratory.
[4]Analyzed in field only.

Golder Associates

TABLE 2-2

SURFACE WATER AND SEDIMENT SAMPLING ANALYSIS PARAMETERS

PARAMETER GROUP	CONSTITUENT	SURFACE WATER		STREAM SEDIMENTS	
		PHASE		PHASE	
		I	II	I	II
Metals	Aluminum	x		x	
	Arsenic	x		x	x
	Beryllium	x		x	
	Cadmium	x		x	x
	Chromium	x		x	
	Copper	x		x	x
	Iron	x		x	
	Lead	x		x	
	Manganese	x		x	
	Molybdenum				x
	Nickel	x		x	x
	Potassium	x		x	
	Selenium	x		x	x
	Silver	x		x	x
	Sodium	x		x	
	Vanadium	x		x	x
	Zinc	x		x	
Ions	Ammonium[1]	x			
	Bicarbonate	x			
	Calcium	x			
	Carbonate	x			
	Chloride	x			
	Fluoride	x		x	
	Hydroxide	x			
	Magnesium	x			
	Nitrate/Nitrite as N	x			
	Sulfate	x			
	Total Phosphorus	x			
Radionuclides	Gross Alpha	x			
	Lead-210			x	
	Polonium-210			x	x
	Potassium-40			x	
	Radon	x			

TABLE 2-2

SURFACE WATER AND SEDIMENT SAMPLING ANALYSIS PARAMETERS

PARAMETER GROUP	CONSTITUENT	SURFACE WATER		STREAM SEDIMENTS	
		PHASE		PHASE	
		I	II	I	II
Radionuclides (Cont.)	Radium-226	x		x	
	Radium-228	x		x	
	Thorium-228			x	
	Thorium-230			x	
	Thorium-232			x	
	Uranium	x		x	
	Uranium-234				
	Uranium-238				
Physical	Hydrometer			x	x
	Moisture Content			x	x
	Specific Gravity			x	x
	Wet Sieve			x	
Water Quality	Eh[3]	x			
	pH[2]	x			
	Specific Conductance[2]	x			
	Temperature[3]	x			
	Total Dissolved Solids	x			
	Turbidity[3]	x			
Others	Cation Exchange Capacity			x	
	pH (of soils)			x	x

[1]The actual constituent analyzed is ammonia, which can be used with pH and temperature to calculate ammonium concentration.
[2]Analyzed in field and laboratory.
[3]Analyzed in field only.

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TABLE 2-3

SOIL SAMPLING ANALYSIS PARAMETERS

Parameter Group	Constituent	Surface Soils		Soil Profile	
		Phase		Phase	
		I	II	I	II
Metals	Aluminum	x	x		x
	Arsenic	x	x		x
	Beryllium	x	x		x
	Cadmium	x	x		x
	Chromium	x	x		x
	Copper	x			
	Iron	x			
	Lead	x			
	Manganese	x	x		x
	Molybdenum		x		x
	Nickel	x			
	Potassium	x			
	Selenium	x			
	Silver	x	x		x
	Sodium	x			
	Vanadium	x	x		x
	Zinc	x	x		x
Ions	Ammonium[1]				
	Bicarbonate				
	Calcium				
	Carbonate				
	Chloride				
	Fluoride	x	x		x
	Hydroxide				
	Magnesium				
	Nitrate/Nitrite as N	x			
	Sulfate				
	Total Phosphorus				

TABLE 2-3

SOIL SAMPLING ANALYSIS PARAMETERS

Parameter Group	Constituent	Surface Soils		Soil Profile	
		Phase		Phase	
		I	II	I	II
Radionuclides	Gross Alpha				
	Lead-210	x	x		x
	Polonium-210	x	x		x
	Potassium-40	x			
	Radon				
	Radium-226	x	x		x
	Radium-228	x			
	Thorium-228	x	x		x
	Thorium-230	x	x		x
	Thorium-232	x			
	Uranium				
	Uranium-234				
	Uranium-238	x	x		x
Physical	Hydrometer	x	x		x
	Moisture Content	x	x		x
	Specific Gravity	x	x		x
	Wet Sieve	x			
Others	Cation Exchange Capacity	x	x		x
	pH (of soils)	x			

[1]The actual constituent analyzed is ammonia, which can be used with pH and temperature to calculate ammonium concentration.

1219crtbl.2-3

TABLE 2-4

WELLS AND SPRINGS SAMPLED DURING RI

Groundwater Source	Sample Location	Sampled Oct. 1991	Sampled May 1992	Sampled Nov. 1992	Sampled May 1993	Comments
Monsanto Wells	TW-01	no	no	no	no	abandoned
	TW-02	yes	no	no	no	
	TW-03	no	no	no	no	abandoned
	TW-04	no	no	no	no	abandoned
	TW-05	no	no	no	no	abandoned
	TW-06	no	no	no	no	abandoned
	TW-07	no	no	yes	yes	
	TW-08	no	no	no	no	
	TW-09	yes	no	yes[4]	yes	
	TW-10	yes[1]	yes	yes	yes	
	TW-11	yes	yes	yes	yes	
	TW-12	yes[1]	yes	yes	yes	
	TW-13	yes	no	no	no	Salt Lake Zone
	TW-14	no	no	no	no	Surficial Deposit Zone
	TW-15	yes[1]	yes	yes	yes	
	TW-16	yes[2,3]	yes	yes	yes	
	TW-17	no	yes	yes	yes	
	TW-18	yes[3]	yes	yes	yes	
	TW-19	no	no	no	no	
	TW-20	yes[1,2]	yes	yes	yes	
	TW-21	yes	yes	yes	yes	
	TW-22	yes[2,3]	yes	yes	yes	
	TW-23	yes[3]	yes	yes	yes	
	TW-24	no	no	yes	yes	
	TW-25	no	no	no	no	abandoned
	TW-26	yes[2]	yes	yes	yes	
	TW-27	no	no	no	no	abandoned
	TW-28	yes	yes	yes	yes	
	TW-29	yes	yes	yes	yes	
	TW-30	yes	yes	yes	yes	
	TW-31	no	yes	no	yes	

TABLE 2-4 (Cont'd.)

WELLS AND SPRINGS SAMPLED DURING RI

Groundwater Source	Sample Location	Sampled Oct. 1991	Sampled May 1992	Sampled Nov. 1992	Sampled May 1993	Comments
Monsanto Wells	TW-32	yes	yes	yes	yes	
	TW-33	yes	yes	yes	yes	
	TW-34	yes	yes	yes	yes	
	TW-35	yes	yes	yes	yes	
	TW-36	yes	yes	yes	yes	
	TW-37	yes[3]	yes	yes	yes	
	TW-38	yes	yes	yes	yes	
	TW-39	yes[2]	yes	yes	yes	
	TW-40	yes[2]	yes	yes	yes	
	TW-41	yes[2]	yes	yes	yes	
	TW-42	yes	yes	yes	yes	
	TW-43	yes	yes	yes	yes	
	TW-44	yes	yes	yes	yes	
	TW-45	yes[3]	yes	yes	yes	
	TW-48	yes[3]	yes	yes	yes	
	TW-49	yes[3]	yes	yes	yes	
	TW-50	yes[2,3]	yes	yes	yes	
	TW-51	no	no	no	no	
	TW-53	NA	NA	yes	yes	well installed Oct. 1992
	TW-54	NA	NA	yes	yes	well installed Oct. 1992
	TW-55	NA	NA	yes	yes	well installed Oct. 1992
	TW-56	NA	NA	yes	yes	well installed Oct. 1992
	TW-57	NA	NA	yes	yes	well installed Oct. 1992
	TW-58	NA	NA	no[6]	no	well installed Nov. 1992
	PW-01	yes[2]	yes	yes	yes	open over full depth
	PW-02	yes	yes	yes	yes	open over full depth
	PW-03	yes	yes	yes	yes	
	PW-04	yes	yes	yes	yes	
	Harris Well (SWG)	yes	yes	yes	yes	

TABLE 2-4 (Cont'd.)

WELLS AND SPRINGS SAMPLED DURING RI

Groundwater Source	Sample Location	Sampled Oct. 1991	Sampled May 1992	Sampled Nov. 1992	Sampled May 1993	Comments
Springs	Big Spring	no	yes	yes	yes	
	Boy Scout Spring	yes[1]	no	no	no	
	Calf Spring	yes	yes	yes	yes	
	City Park Spring	no	yes	yes	yes	
	Doc Kackley Spring	yes[1]	yes	yes	yes	
	Finch Spring	yes[1]	no	no	no	
	Formation Spring	no[6]	no	no	no	
	Formation Spring A	yes[1]	no	yes[4]	no	
	Formation Spring B	yes[1]	no	no	no	
	Formation Spring C	yes[1]	no	no	no	
	Homestead Spring	yes	yes	yes	yes	
	Hooper Spring	yes[1]	yes	yes	yes	
	Kelly Park Spring	yes[1]	no	no	no	
	Ledger Creek	no[6]	no	no	no	
	Ledger Spring A	yes[1]	no	no	no	
	Ledger Spring B	yes[1]	no	no	no	
	Ledger Spring C	yes[1]	yes	yes	yes	
	Mormon Spring A	yes	yes	yes	yes	
	Mormon Spring B	yes	yes	yes	yes	
	Mormon Spring C	yes	yes	yes	yes	
	Southwest Spring	yes	yes	yes	yes	
	Spring Box Spring	yes[1]	no	no	no	
Public and private water supplies	Brown Well	no	no	no	no[8]	
	City Hall	no	no	yes	no	city water
	Hart Residence	no	no	yes[4]	no	city water
	Jensen Residence	no	no	yes	no	city water
	Jorgensen Residence	no	no	yes	no	city water
	Lewis Well	yes[1]	yes	yes	yes	
	Nelson Well (shallow)	no	no	no	no[8]	
	Nelson Well (deep)	no	no	no	no[8]	
	Stanford Steele Well	no	no	no	no[8]	

TABLE 2-4 (Cont'd.)

WELLS AND SPRINGS SAMPLED DURING RI

Groundwater Source	Sample Location	Sampled Oct. 1991	Sampled May 1992	Sampled Nov. 1992	Sampled May 1993	Comments
Public and private water supplies	Mark Steele Well	no	no	no	no[8]	
	Ref-Chem (SWC)[2]	no	no	no	no	abandoned

Notes:
NA - Not applicable
* - Formation A is the inlet to the City of Soda Springs chlorination building.
[1] - sample also analyzed for environmental isotopes
[2] - sample also analyzed for total petroleum hydrocarbons (TPH)
[3] - sample also analyzed for biological oxygen demand (BOD) and chemical oxygen demand (COD)
[4] - sample analyzed for radon and field parameters only
[5] - sampled in Jan. 1992 (not included in sampling round)
[6] - sampled in Dec. 1992 during pump test (not included in sampling round)
[7] - also known as Washington Construction and Wood well
[8] - sampled in June 1993 during well inventory survey (not included in sampling round)

1219crh1.2-4

TABLE 2-5

GROUNDWATER SAMPLING ANALYSIS PARAMETERS

PARAMETER GROUP	CONSTITUENT	OCT. 1991	MAY 1992	NOV. 1992	MAY 1993
Metals	Aluminum	x	x	x	x
	Arsenic	x	x	x	x
	Beryllium	x	x	x	
	Cadmium	x	x	x	x
	Chromium	x	x		
	Copper	x	x		
	Iron	x	x	x	x
	Lead	x	x		
	Manganese	x	x	x	x
	Molybdenum		x	x	x
	Nickel	x	x	x	x
	Potassium	x	x	x	
	Selenium	x	x	x	x
	Silicon (total)		x	x	
	Silver	x	x		
	Sodium	x	x	x	
	Vanadium	x	x	x	x
	Zinc	x	x	x	x
Ions	Alkalinity (total)			x	
	Ammonium[1]	x	x	x	x
	Bicarbonate	x	x	x	
	Calcium	x	x	x	
	Carbonate	x	x	x	
	Chloride	x	x	x	x
	Fluoride	x	x	x	x
	Hydroxide	x	x		
	Magnesium	x	x	x	
	Nitrate/Nitrite as N	x	x*	x*	x
	Nitrite		x	x	
	Orthophosphate as P		x		
	Sulfate	x	x	x	x
	Sulfide		x		
	Total Phosphorus	x	x	x	

TABLE 2-5

GROUNDWATER SAMPLING ANALYSIS PARAMETERS

PARAMETER GROUP	CONSTITUENT	OCT. 1991	MAY 1992	NOV. 1992	MAY 1993
Metals	Aluminum	x	x	x	x
	Arsenic	x	x	x	x
Radionuclides	Gross Alpha	x			
	Radon	x		x*	
	Radium-226	x	x	x	
	Radium-228	x			
	Uranium	x			
Environmental Isotopes[4]	Deuterium	x			
	Carbon-14	x			
	Oxygen-18	x			
	Tritium	x			
Water Quality	Eh[3]	x			x
	Dissolved Oxygen[3]		x	x	x
	pH[2]	x	x	x	x
	Specific Conductance[2]	x	x	x	x
	Temperature[3]	x	x	x	x
	Total Dissolved Solids	x	x	x	x
	Turbidity[3]	x	x	x	x
Others[4]	Biological Oxygen Demand	x			
	Chemical Oxygen Demand	x			
	Total Petroleum Hydrocarbons	x			

[1]The actual constituent analyzed is ammonia, which can be used with pH and temperature to calculate ammonium concentration.
[2]Analyzed in field and laboratory.
[3]Analyzed in field only.
[4]Analyzed at selected locations only.
*Analyzed as nitrate-nitrogen only.

1220crh1.2-5

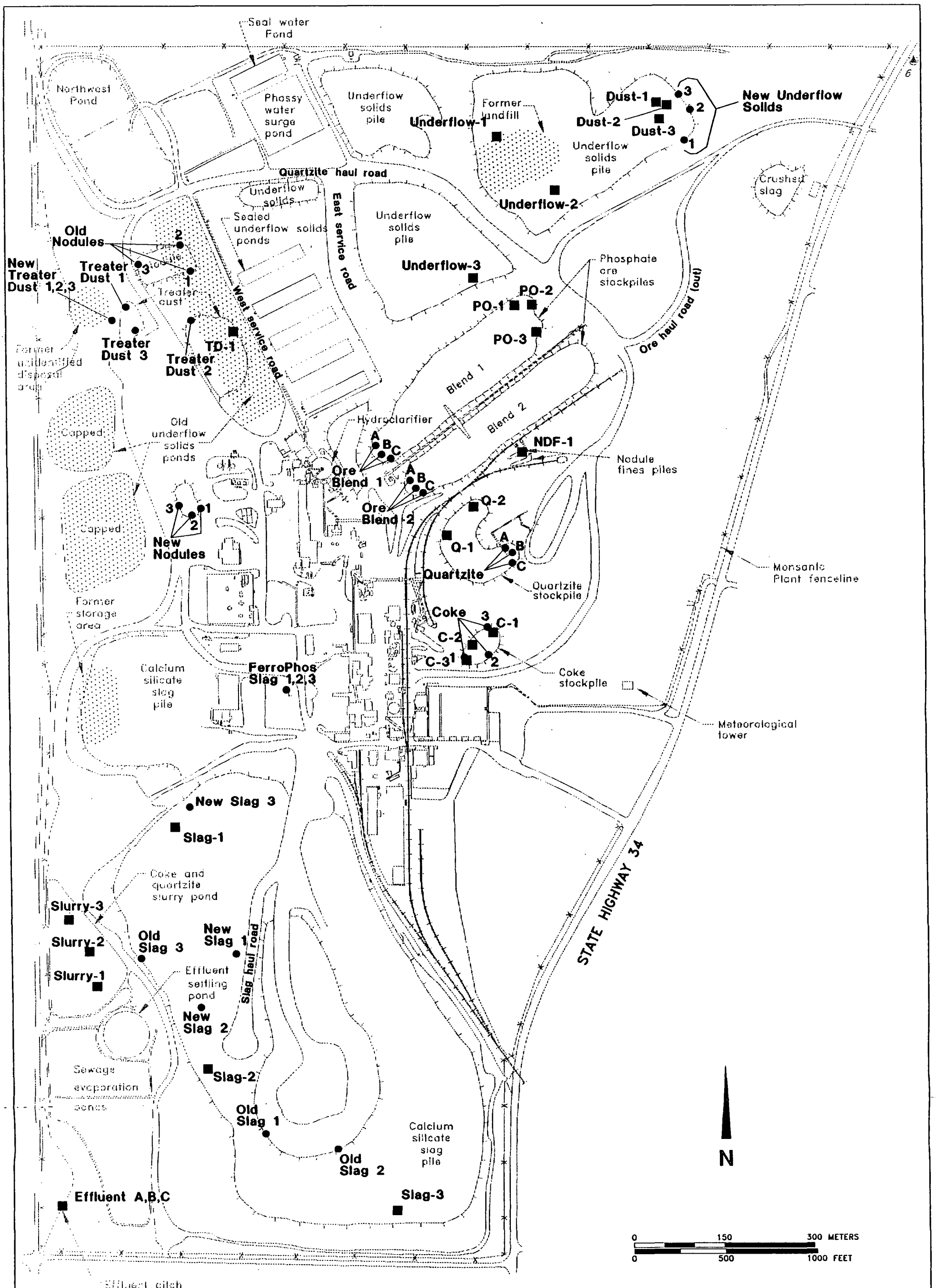
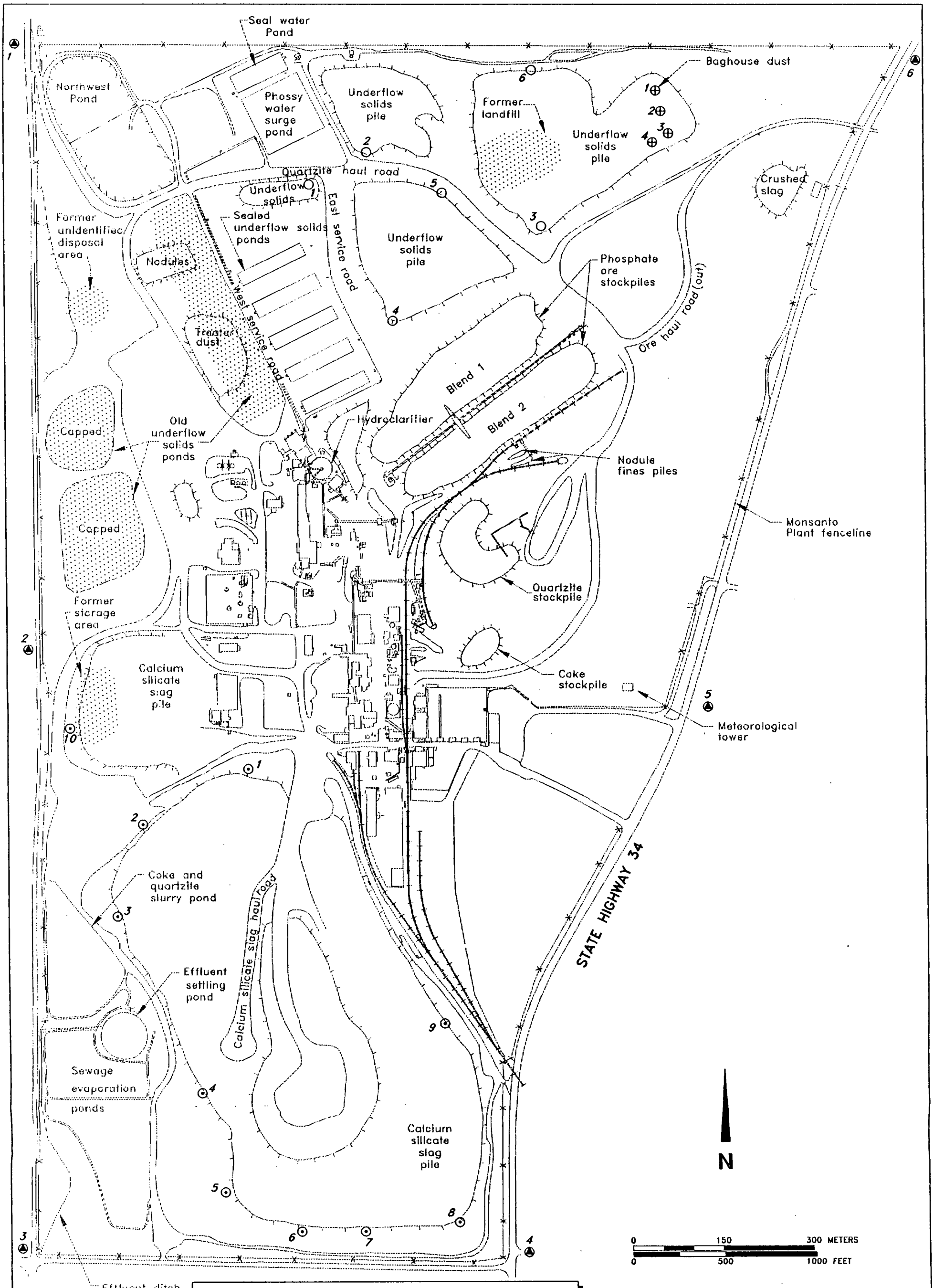


FIGURE 2-1
MATERIAL STOCKPILE AND PROCESS BY-PRODUCT SAMPLING LOCATIONS
MONSANTO/PHASE II RI REPORT/ID

DWG ID: \JPM\9131101\608\42442 6-3-94 10:29

Golder Associates



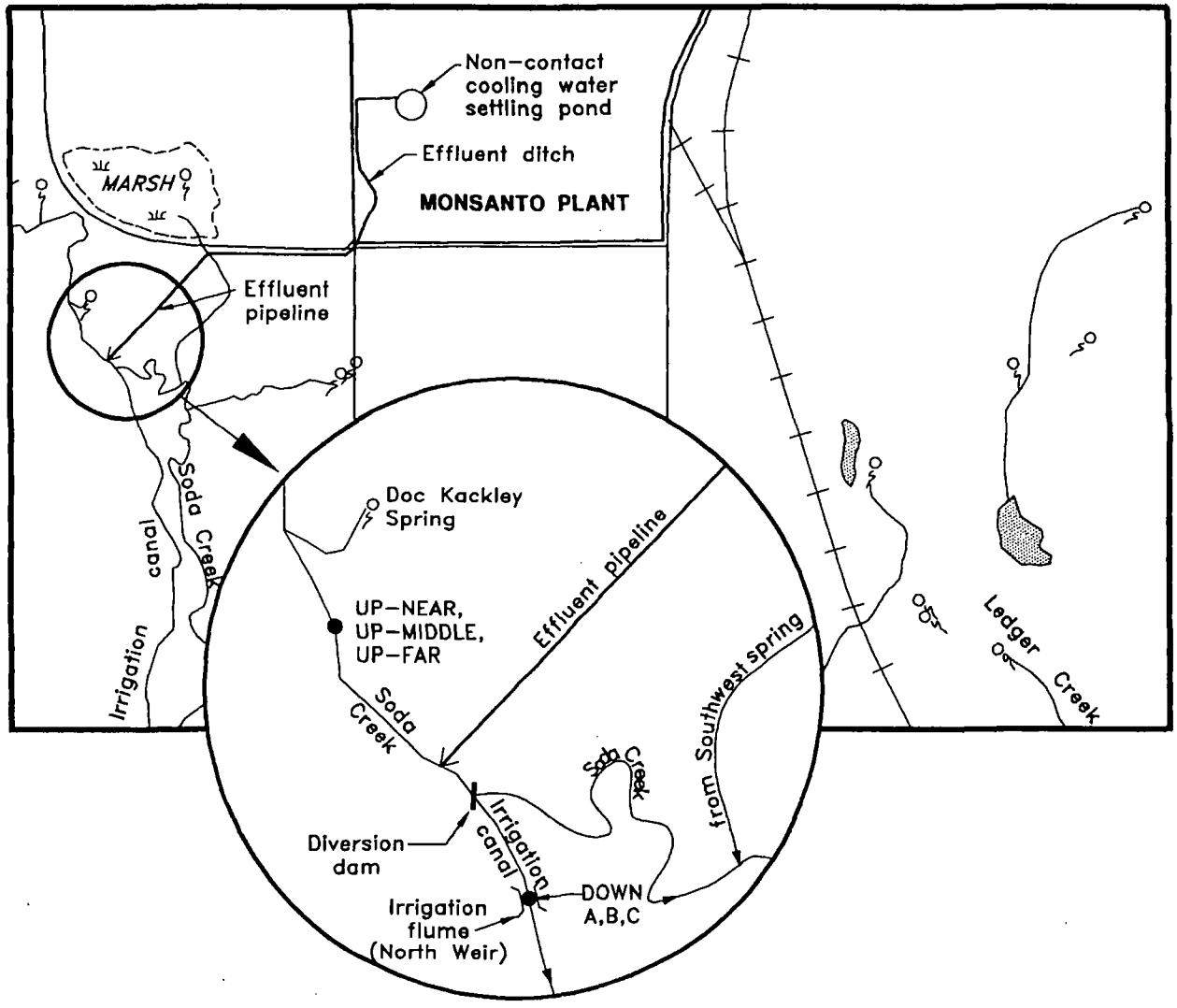
LEGEND

- 1 ⊕ Baghouse dust survey location and designation
- 1 ▲ Perimeter soil survey location and designation
- 1 ⊙ Calcium silicate slag survey location and designation
- 1 ○ Underflow solids survey location and designation

FIGURE 2-2
GAMMA RADIATION SURVEY LOCATIONS
MONSANTO/PHASE II RI REPORT/ID

DWG ID: \JPM\9131101\608\42441 6-3-94 10:39

Golder Associates



N

0 500 1000 METERS
0 1500 3000 FEET

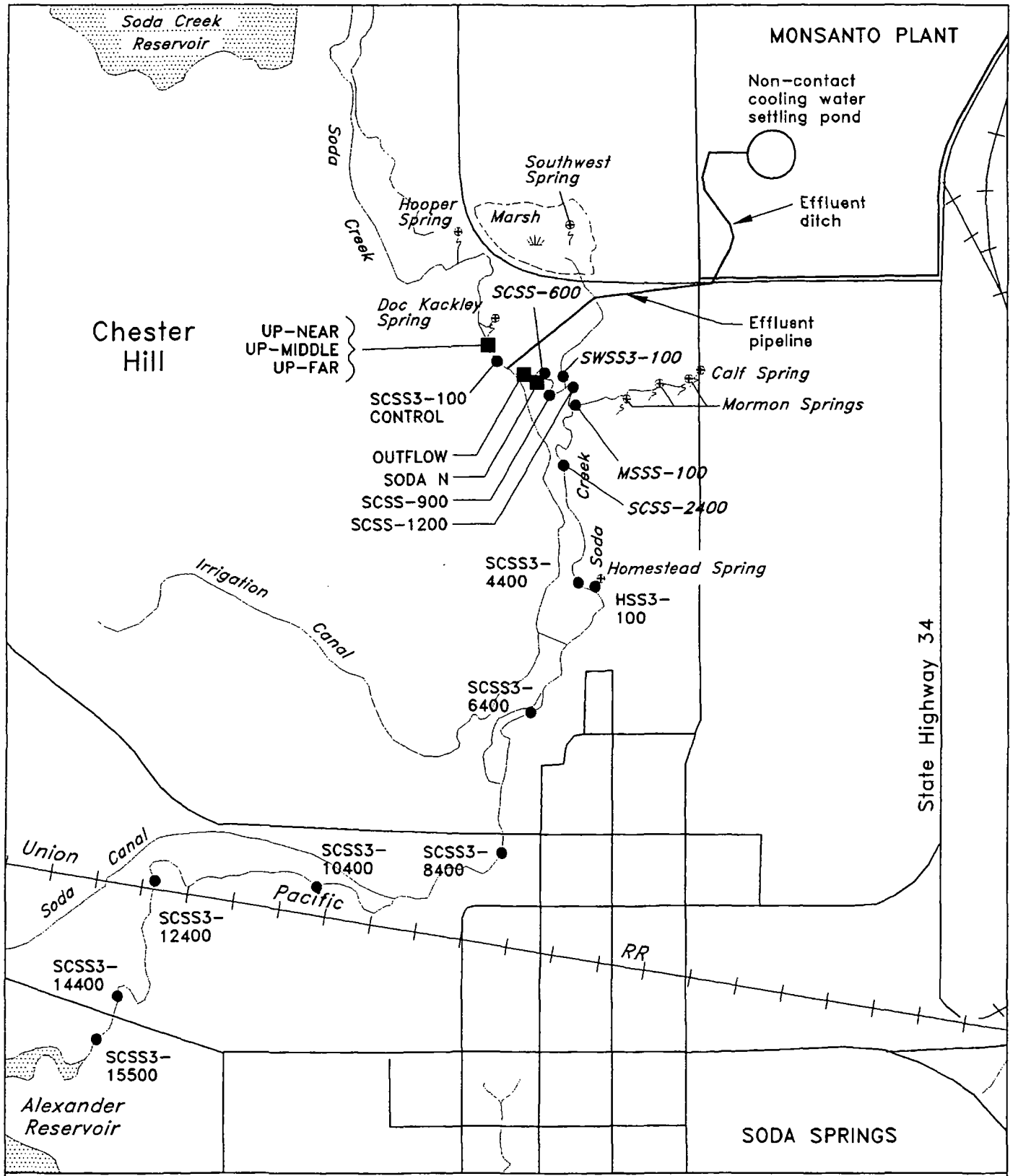
LEGEND
DOWN A
● Sample location (and designation)

Note: Locations are approximate.

FIGURE 2-3
SURFACE-WATER SAMPLING LOCATIONS
MONSANTO/PHASE II RI REPORT/ID

DWG ID: \JPM\9131101\608\42447 DATE 1-28-94 11:35

Golder Associates

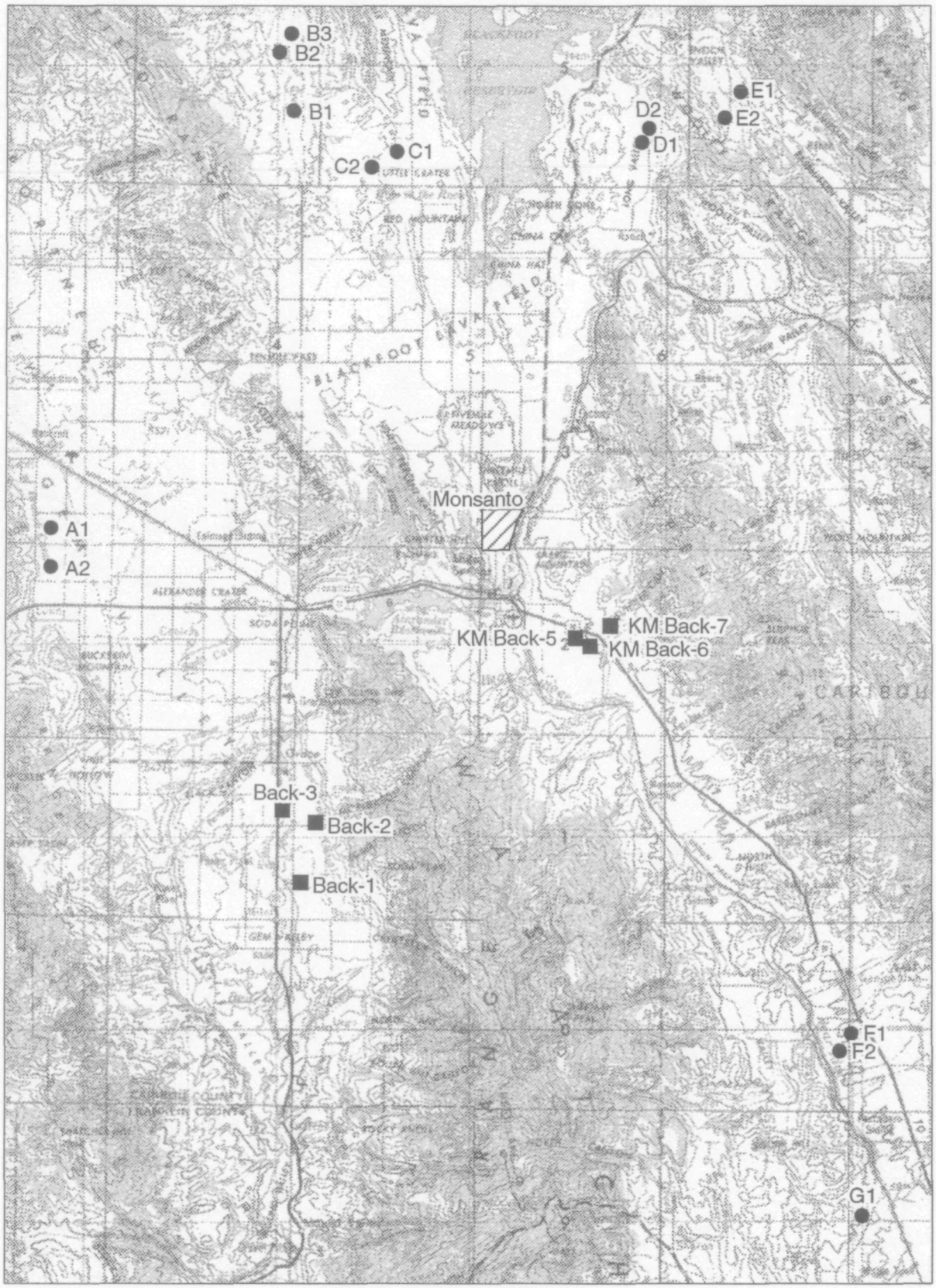


Note: Locations are approximate.

FIGURE 2-4
STREAM SEDIMENT SAMPLING LOCATIONS
MONSANTO/PHASE II RI/ID

DWG ID: \CAD\9131101\608\42443 DATE 4-4-94 11:02 DRAWN JSS

Golder Associates



Statute Miles
5 0 5
5 0 5
Kilometers

■ Back-1 Phase I Control Soil Sampling Locations

● A1 Phase II Control Soil Sampling Locations

FIGURE **2-6**
CONTROL SOIL SAMPLING LOCATIONS
MONSANTO/PHASEII RI REPORT/ID

PROJECT NO. 913-1101.608 DRAWING NO. 48872 DATE 6/2/94 DRAWN BY TB

Golder Associates

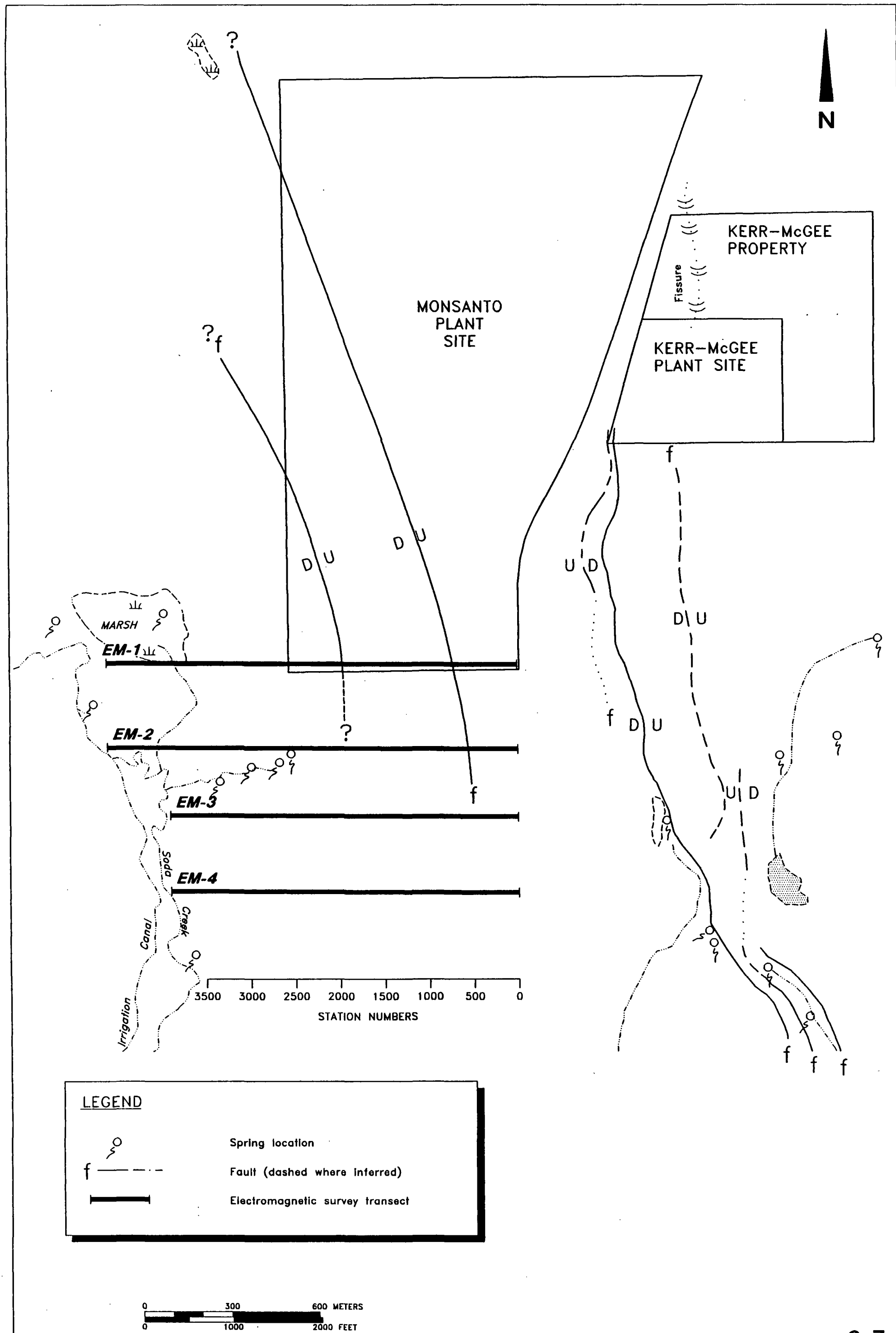


FIGURE 2-7
ELECTROMAGNETIC SURVEY TRANSECTS
MONSANTO/PHASE II RI REPORT/ID

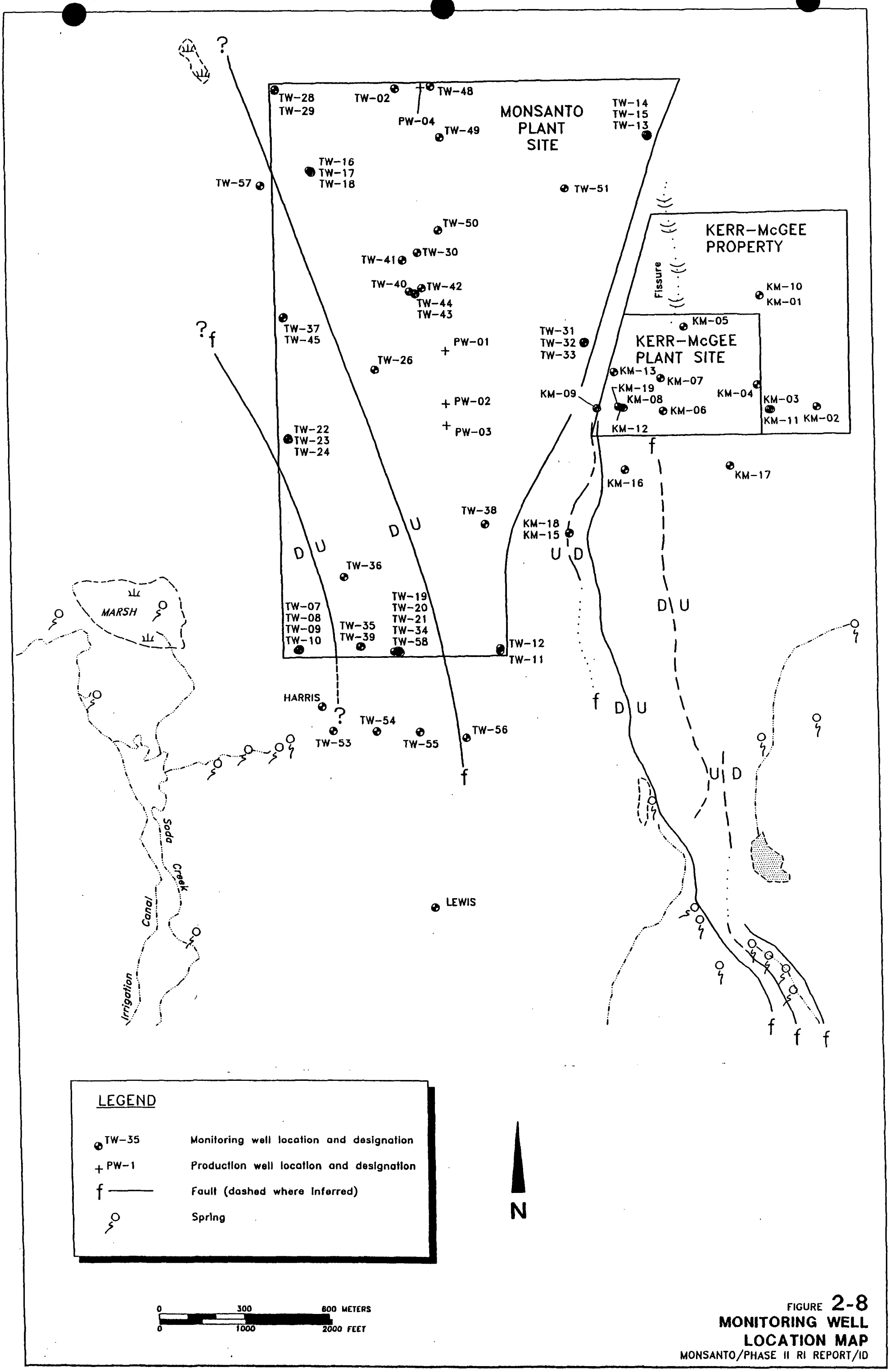
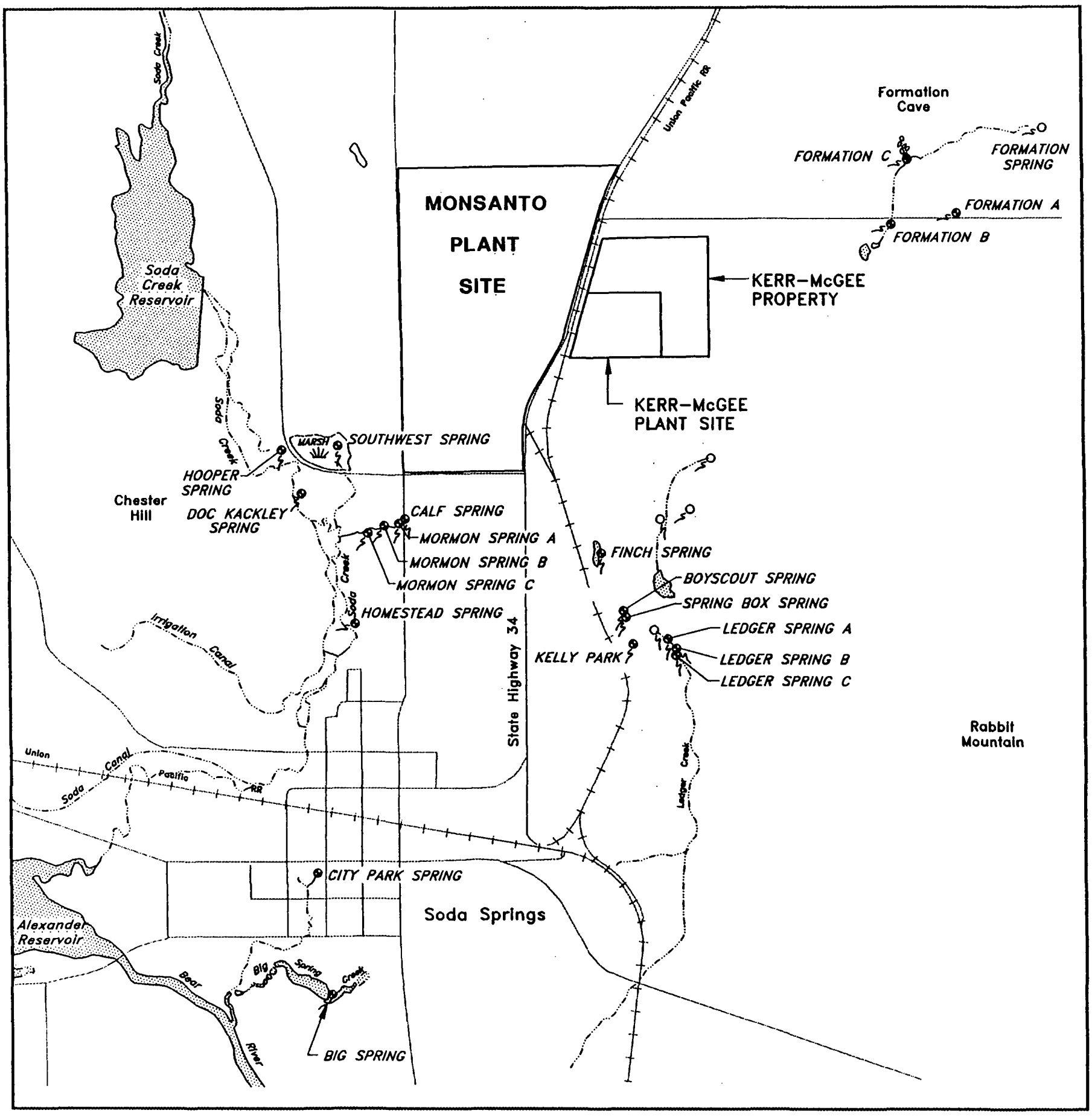


FIGURE 2-8
MONITORING WELL LOCATION MAP
MONSANTO/PHASE II RI REPORT/ID

\CAD\9131101\608\42445 4-4-94 11:23

Golder Associates



LEGEND

Formation A	Spring or spring related surface-water location and designation (sampled during RI)
	Other springs

N

0 750 1500 METERS
0 2500 5000 FEET

FIGURE 2-9
SPRINGS LOCATED IN THE VICINITY OF THE MONSANTO PLANT
MONSANTO/PHASE II RI REPORT/ID

DWG ID: \JPM\9131101\608\42444 1-28-94 11:39 DRAWN DH

Golder Associates

Section 3

3. PHYSICAL CHARACTERISTICS

This chapter provides a description of the physical characteristics of the Monsanto Plant. Included in this chapter are discussions of the Plant, the area surrounding the Plant, and the physical characteristics, such as the geology, hydrogeology, and meteorology. Information on land-use in the area is also presented. The nature and extent of constituents related to the Plant is described in Chapter 4.

3.1 Monsanto Plant and Vicinity

The Monsanto Plant is located in southeastern Idaho, approximately one mile north of the City of Soda Springs, Idaho (Figure 1-1). The valley in which the Plant is located is broad and rural, bordered by Soda Springs Hills and Ninety Percent Range on the west, by the Blackfoot Reservoir on the north, by the Aspen Range on the east, and by the Bear River on the south. The elevation of the valley ranges from 5,800 feet to 6,100 feet amsl. The mountain ranges rise 700 to 1,300 feet above the valley floor. Surface-water features in the valley include rivers, streams, reservoirs, ponds, and wetlands. 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.

3.1.1 Monsanto Plant

The Monsanto Plant encompasses approximately 540 acres and occupies portions of Sections 29, 30, 31, and 32 of Township 8 South, Range 42 East. State Highway 34 runs roughly north-south forming the eastern boundary of the Plant, and is the primary access road to the Plant. The western boundary is formed by Third East Street (Government Dam Road). Hooper Road forms the southern Plant boundary. The northern boundary borders agricultural land. Monsanto also owns the Kackley property to the southwest of the Plant and the Harris, Jorgensen, and Ponderosa properties to the south of the Plant as indicated on Figure 1-2. These properties have not been further developed.

The 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. Selected gates are opened during certain times of the year for deer migration. Plant access is possible via a railspur from the Union Pacific Railroad, which roughly parallels State Highway 34. The Plant facilities include buildings, paved and unpaved areas and roads, railroad tracks, various utilities, ore stockpiles, by-product piles, and man-made ponds (Figure 1-3).

Water for Plant process operations is provided from on-site production wells referred to as PW-01, PW-02, and PW-03 and located as shown on Figure 2-8. PW-03 is the primary production well and is pumped continuously at a rate of approximately 1,000 gpm, as shown in Table 3-1. PW-01 is pumped intermittently at a rate of less than 900 gpm and PW-02 is seldom used. Prior to use, the water from these three wells is stored in a shared water tower. The water is used for non-contact cooling purposes and as process water.

The drinking water supply for the Plant was provided by production well PW-03 until 1989. In response to water-quality issues, use of PW-03 for drinking water purposes was discontinued and a new well, PW-04, was installed at the northern edge of the Plant. PW-04 is pumped continuously at a rate of approximately 300 gpm as shown in Table 3-1. This well provides drinking water to approximately 350 individuals working at the Plant through a dedicated distribution system.

3.1.2 Neighboring Facilities

There are several other industrial facilities near the Monsanto Plant that may be potential sources of constituents, as shown on Figure 1-2. In addition to these facilities, which are described below, nearby transportation corridors and agricultural activities serve as potential sources that may affect the environment.

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 Kerr-McGee Plant is discharged into on-site surface impoundments (lined ponds or ponds excavated in native clays). Releases to the shallow groundwater system from the impoundments have been documented in a CERCLA site inspection report (Ecology and Environment 1988b) and in a remedial investigation conducted by Kerr-McGee (Dames and Moore 1993).

Evergreen Resources Evergreen Resources is located about 1,000 to 2,000 feet southeast of the Monsanto Plant. This facility produces fertilizer products.

Soda Springs Phosphate Industries Soda Springs Phosphate Industries is located adjacent to Evergreen Resources and also produces fertilizer products.

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 phospho-gypsum. The products from this industry include di-ammonium and mono-ammonium phosphate fertilizer, phosphoric acid, and super-phosphoric acid.

3.2 Potential Sources

The elemental phosphorus production process at the Monsanto Plant was summarized in Chapter 1, outlining the raw materials used, the resulting by-products and air emissions. Raw material, by-product storage and disposal areas, and air emissions were identified in the RI as potential sources of constituent releases at the Plant. Also identified as potential sources were unpaved roads, material handling areas, and sewage evaporation ponds.

Details regarding potential sources at the Monsanto Plant are discussed below. Selected potential sources were sampled for physical and chemical analyses as part of the RI. Physical descriptions of the potential sources sampled are included below with Unified Soil

Classification System (USCS) designations given in parentheses. Grain-size analysis, moisture content results, and specific gravity results are given in Appendix B. Chemical results are discussed in Chapter 4.

3.2.1 Material Stockpiles

Phosphate ore, coke, and quartzite comprise the raw materials used in the production of elemental phosphorus. These material stockpiles are primarily potential sources for fugitive dust due to wind erosion. Wind erosion emission estimates are discussed in detail in SENES (1993b).

Phosphate ore Phosphate ore is stockpiled in the northeast portion of the Plant and is sorted into two piles based on blend, as shown on Figure 1-3. Blend 1 accounts for about 67% of the stockpiled material, whereas Blend 2, which is a lower grade 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, and comprise approximately 500,000 to 1,000,000 tons of ore. The phosphate ore is brown to dark brown, coarse-to-fine sand with some silt and some gravel (SM).

Coke Coke stockpiles are located in the eastern portion of the Plant, south of the phosphate ore stockpiles, as shown on Figure 1-3. The coke stockpiles consist of approximately 22,000 tons of material. The coke is black, fine gravel with some sand (GW and GP).

Quartzite The quartzite stockpile is located next to the coke stockpile in the eastern portion of the Plant (Figure 1-3). The stockpile consists of approximately 150,000 to 250,000 tons of material. The quartzite is pinkish gray, coarse-to-fine gravel (GP).

3.2.2 By-Products

By-products are generally stored in piles or ponds at various locations within the Plant or are emitted from stacks. These storage or disposal locations are described below according to material type - solids or liquids.

3.2.2.1 Solids

Solid by-products are generally stored or disposed of in piles or as residual pond sediments. These by-product storage or disposal areas are primarily potential sources for fugitive dust due to wind erosion. Wind erosion emission estimates are discussed in detail in SENES (1993b).

Baghouse dust pile Baghouse dust is the name given to dust collected by air-emission control units called baghouses. Baghouse dust consists primarily of small-size fractions of phosphate ore, nodules, coke, and quartzite. Baghouse dust is generally dark yellowish brown, coarse-to-fine sand and silt, or silt with some fine sand (SM or ML). Baghouse dust is currently mixed with underflow solids at the stockpile location (Figure 1-3), which reduces fugitive dust emissions from this material.

Calcium silicate slag piles Calcium silicate slag is produced as a by-product of furnace operations and constitutes the greatest quantity of waste material at the Plant. An estimated 23 million tons of slag are stockpiled at the Plant at locations shown on Figure 1-3. The slag is poured as a molten material and cools to a medium gray, solid mass, massive in the centers and vesicular at the surface. Particle-size distributions for slag samples are not representative of the hardened slag, as the samples were collected by pulverizing the slag with a hammer. Prior to 1990, slag was sold for use in road construction, as railroad ballast, and as fill material.

Coke and quartzite slurry pond The coke and quartzite slurry pond is located in the southwest corner of the Plant as shown on Figure 1-3. Coke and quartzite dust was originally collected by a wet scrubber system and directed to the coke and quartzite slurry pond for dewatering. This pond was taken out of service in 1987 when a new coke and quartzite dryer was installed, eliminating the need for a slurry dewatering pond. The coke and quartzite slurry pond contained sediments composed of olive gray to grayish black, fine sand and silt or clayey silt (SM or CL). The pond is now filled with calcium silicate slag eliminating this source from groundwater recharge and as a fugitive dust source.

Ferrophosphorus slag Ferrophosphorus slag is a by-product generated in the furnace as a result of iron and other metals present in the ore. It is sold to Kerr-McGee for vanadium extraction and is temporarily stored at the Monsanto Plant.

Nodule fines piles Nodule fines are a by-product of the nodulizing of the phosphate ore in the kilns and are stockpiled in the northeast corner of the Plant, south of the phosphate ore stockpiles (Figure 1-3). These materials are recycled through the kilns with the phosphate ore during the beneficiation process. The nodule fines are light olive gray, coarse-to-fine sand (SP).

Northwest Pond The northwest pond, located in the northwest corner of the Plant (Figure 2-1), was created between 1956 and 1964 (EPA 1990b). 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. Affected soils in the pond were excavated in 1988 and placed in the old underflow solids ponds prior to their closure. The northwest pond was converted to a sanitary landfill in 1988. This conversion included the installation of a bentonite liner. The facility is permitted by the IDHW and currently accepts sanitary solid wastes from the Plant, office debris, lunchroom scraps, construction debris, and asbestos-containing insulation (Geddes, R.L., Monsanto [Memo to D. Banton, Golder] March 23, 1992).

Treater dust Treater dust is generated by removing dust from the phosphorus gas in the electrostatic precipitator. Any residual phosphorus is oxidized from the dust in a burning chamber prior to stockpiling in the northern portion of the plant (Figure 1-3). Treater dust is composed of dark gray to grayish black, coarse-to-fine sand and silt (SM).

Underflow solids piles Fine-grained particulate matter is removed from rotary-kiln exhaust gas by a spray-tower scrubber followed by high-energy venturi scrubbers. The resulting wet slurry (off-gas slurry) is settled in the hydroclarifier and dewatered in a filter press, resulting in underflow solids. The underflow solids are stored in piles in the north central part of the Plant

as shown on Figure 1-3. The underflow solids are later recycled to recover their phosphate ore value. The underflow solids are light olive gray to dark gray, clayey silt with some coarse-to-fine sand (ML).

Underflow solids ponds The underflow solids ponds were located in the west central part of the Plant as shown on Figure 1-3. Prior to 1983, the underflow solids ponds were used to dewater underflow solids obtained from the hydroclarifier. Dewatering occurred by directing a slurry into the ponds and allowing infiltration of the fluid portion. The remaining solids, having phosphate ore value, were excavated from the ponds for further processing. The ponds were used until 1983. In 1987, the ponds were filled with molten slag and capped with bentonite. A protective cover of crushed gravel was emplaced over the bentonite cap.

3.2.2.2 Liquids

Liquid by-products are generally stored or disposed of in ponds. The storage or disposal areas are potential sources of constituent releases to soils, the vadose zone, and groundwater.

Hydroclarifier The hydroclarifier is located in the center of the Plant as shown on Figure 1-3. The hydroclarifier receives scrubber slurry for treatment and solids settling. Investigations conducted in 1984 identified the hydroclarifier in use was leaking (Golder 1985). At that time Monsanto replaced the hydroclarifier, installing a completely new facility with a steel liner and a leachate collection system. Subsequent monitoring has shown the new hydroclarifier is not leaking, and consequently, this facility is no longer considered a source of constituents to the subsurface.

Non-contact cooling water settling pond and effluent ditch Non-contact cooling water is used to cool the furnace shell and other equipment. The water is obtained from production wells at the Plant. The water passes over the outer furnace shell to maintain proper temperature and does not contact any process material. After leaving the furnace, the water passes through a settling pond for cooling and particulate removal prior to being discharged, under a NPDES permit, via an effluent ditch and subsurface pipeline to Soda Creek. The non-contact cooling water effluent settling pond and the effluent ditch are located in the southwest corner of the Plant as shown on Figure 1-3.

Phossy water surge pond Phosphorus-contacting water (phossy water) is routed to the hydroclarifier for lime treatment to remove any residual elemental phosphorus prior to recycling. The phossy water surge pond is a bentonite-lined pond located in the north-central portion of the Plant (Figure 1-3). The pond is used for surge capacity when the hydroclarifier capacity is exceeded.

Electrode seal water pond Water is used to provide a seal between furnace gases and the atmosphere and is referred to as seal water. This water is cooled in the bentonite-lined electrode seal water pond located in the north central part of the Plant, as shown on Figure 1-3. The electrode seal water is completely reused. Water balance in the electrode seal water pond is maintained by evaporation.

Sealed underflow solids ponds Five rectangular sealed underflow solids ponds are located in the north central part of the Plant as shown on Figure 1-3. These ponds are used to temporarily store the underflow solids slurry whenever the underflow solids filter press is taken off-line. The sealed underflow solids ponds were constructed with bentonite liners and a leachate collection system to prevent percolation of fluids into the surrounding soils. The leachate collection system consists of coarse materials with collector pipes that drain to a collection sump. The bentonite liner underlies the leachate collection system.

3.2.3 Air Emissions

Air emissions from point-sources form another by-product of the elemental phosphorus production process. The point sources consist of permitted stack emissions and baghouse exhaust. These emissions are potential sources to the atmosphere and to off-site soils. Air emissions are discussed in detail in SENES (1993a) and are listed below.

Permitted stacks

- Kiln venturi scrubber stacks (A, B, C, & D);
- Kiln cooler spray tower;
- Nodule crushing/screening scrubber stack; and
- Taphole fume collectors (#7, #8, & #9).

Baghouses

- Coke fines air conveyor baghouse;
- Coke handling baghouse;
- Coke/quartzite dryer baghouse;
- Coke/quartzite satellite baghouse;
- Carbon monoxide dust collectors (one for each furnace);
- Furnace stocking system baghouse;
- Ore satellite baghouse; and
- Scaleroom baghouse.

3.2.4 Sewage Evaporation Ponds

Two sewage evaporation ponds were located in the southwest corner of the Plant, as shown on Figure 1-3. The ponds were used to treat sanitary wastewater from the Plant until the fall of 1993. Sanitary wastewater from the Plant is now routed to the City of Soda Springs wastewater treatment plant. While in operation, sanitary wastewater routed to the ponds was treated by solids settling and biodegredation. Wastewater in the ponds eventually infiltrated the subsurface, evaporated, or was applied to nearby fields as fertilizer.

3.2.5 Unpaved Road Materials

Unpaved road materials are a potential source for fugitive dust due to vehicle traffic. The unpaved roads at the Monsanto Plant which are considered potential sources are located primarily in the north central Plant area as shown on Figure 1-3. Fugitive emissions from unpaved roads are discussed in detail in SENES (1993a). The unpaved roads are summarized below.

Ore haul road The ore haul road is used to transport ore from the mine to a hopper on-site. The incoming road is paved, however, the outgoing road is unpaved. The outgoing ore haul road is traveled approximately 76 trips per day (summer only) at an average speed of eight miles per hour (mph) by 75 ton trucks. The outgoing ore haul road surface consists of grayish brown, coarse-to-fine sand with some silt and some coarse-to-fine gravel (SM).

Quartzite haul road The quartzite haul road is used to transport quartzite from a nearby quarry to stockpiles at the Plant. The quartzite haul road is traveled approximately 12 round trips per day (summer only) at an average speed of 15 mph by 58 ton trucks. The quartzite haul road surface consists of dusky yellowish brown, coarse-to-fine sand with some silt and some fine gravel (SM).

Calcium silicate slag haul road The slag haul road is used to transport molten slag to the dumping areas. The road is traveled approximately 121 round trips per day at an average speed of 10 mph by 73 ton pot-carrier trucks. The slag haul road surface consists of coarse-to-fine sand and fine gravel, with little silt (SP-SM).

East service road The east service road is traveled approximately 44 round trips per day at an average speed of 6 mph by 55 ton trucks. The east service road surface consists of grayish brown, coarse-to-fine sand with some silt and some fine gravel (SM).

West service road The west service road is traveled approximately 44 trips per day at an average speed of 6 mph by 55 ton trucks. The west service road surface consists of olive gray, coarse-to-fine sand with some coarse-to-fine gravel and some silt (SM).

3.2.6 Material Handling Operation Areas

Material handling operations are potential sources for fugitive dusts. Fugitive dust emissions from material handling operations are discussed in detail in Appendix D. Material handling operations are listed below.

- Baghouse dust handling operations;
- Furnace tapping operations;
- Material stockpile handling operations;
- Nodule reclaim operations;
- Underflow solids pile handling operations;
- Slag pouring operations; and
- Treater dust pile handling operations.

3.3 Meteorology

Meteorological characteristics for the Monsanto Plant were determined using regional and site-specific data. The meteorological characteristics are also discussed in detail in SENES (1992).

3.3.1 Regional

Regional data from southern Idaho were used to evaluate general meteorological conditions for the Monsanto Plant. NOAA operates a weather station at the Soda Springs airport, approximately 4 miles south of the Monsanto Plant. Data were obtained for the NOAA station for the period from 1978 to 1991 (Hydrosphere 1993).

3.3.1.1 Precipitation

Annual precipitation averages 16 inches per year for the period of record at the NOAA station. The monthly average precipitation ranges from 0.9 to 2.1 inches and is fairly uniform throughout the year. The peak monthly average of 2.1 inches occurs during May. The minimum monthly average of 0.9 occurs during December. During spring and summer, precipitation occurs primarily during thunder storms, which are high-intensity, short duration events. Precipitation during the winter months is primarily snow.

3.3.1.2 Temperature

Temperature measurements at the NOAA station average 12.8°C on a daily basis for the period of record. The monthly average temperatures are indicative of the hot summers and cold winters characteristic of the Soda Springs area. Average monthly temperatures in mid-summer exceed 15.6°C, whereas winter monthly averages are below -6.7°C (determined by taking the average of the monthly minimum and maximum). It is not uncommon for daily temperatures in winter to fall below -17.8°C and in summer to exceed 32°C.

3.3.1.3 Evaporation

Data for evaporation were available from the Lifton Pumping Station in Bear Lake County, Idaho for the period from 1948 to 1990 (Hydrosphere 1993). This station is located at elevation 5,930 feet above mean sea level and is southeast of the Monsanto Plant approximately 40 miles. Pan evaporation data were available for April through October. Data are not available from November through March due to freezing conditions. The monthly average pan evaporation ranged from a low of 2.96 inches in October to a high of 8.81 inches during July. Assuming a pan coefficient of 0.7, the free-waterbody evaporation is estimated as 2.1 inches in October to a high of 6.2 inches in July. The free waterbody evaporation exceeded precipitation at the Soda Springs NOAA station by a factor of 2 to 4.

3.3.2 Local

Local meteorological data were collected from a meteorological tower at the Monsanto Plant (Figure 1-3). Data have been collected from sensors at the 33-foot and 120-foot levels since the tower was installed in 1987. These sensors continually measure wind speed, wind direction, and temperature. Data are available from late 1987 to present with some data gaps present due to temporary equipment failure; data collected after 1989 are complete. A review of the quality assurance/quality control (QA/QC) program for the Monsanto meteorological station is presented in Appendix C. The remainder of this section summarizes the meteorological data collected from the tower.

3.3.2.1 Wind Speed and Direction

The average annual wind speed at the Plant and frequency of occurrence by direction for 1990 and 1991 is presented in Tables 3-2 and 3-3 (recorded from the 33-foot level of the meteorological tower). A wind rose for the 1990 data is presented on Figure 3-1. The most frequent winds recorded in both years were from the north and from the south. Northerly winds occur primarily in the summer months due to high pressure conditions. Southerly winds occur primarily in the winter months due to the passage of low pressure systems from west to east across southern Idaho.

Mean wind speed ranges from calm to about 6 meters per second (m/s), as measured at the Monsanto Plant. The strongest average wind speed occurs during the period of southerly winds, which are typically in the winter. These winds average from 3.5 m/s to about 6 m/s. The northerly winds, which are the second most dominant wind direction, are much lighter, averaging from 2 m/s to 3 m/s. Westerly winds of significant speed also occur at the Plant, but at a much lower frequency than the northerly or southerly winds. The westerly winds average from 3 m/s to 4 m/s. The lightest winds observed at the Plant are easterly and range from 1.5 m/s to 2 m/s.

3.3.2.2 Temperature

The minimum and maximum daily temperatures recorded for 1990 and 1991 are listed in Table 3-4. The lowest daily temperature recorded for 1990 and 1991 was -33.9°C in December 1990 and the highest daily temperature was 31.7°C in August 1990. Average daily temperatures ranged from -10.9°C in December 1990 to 18.9°C in July 1990.

3.4 Hydrology

The Blackfoot Lava Field occupies a northerly trending valley that is approximately three to six miles wide in the Plant area. This valley is bordered by Soda Springs Hills and Ninety Percent Range on the west, by the Blackfoot Reservoir on the north, by the Aspen Range on the east, and by the Bear River on the south as shown on Figure 3-2. The valley slopes gradually toward the south to the Bear River.

The Blackfoot Lava Field is within the Bear River (Great Basin) drainage as shown on Figure 3-2. The Bear River/Portneuf River drainage divide trends north-south and runs between Ninety Percent Range and Soda Springs Hills. The Bear River/Snake River drainage divide is located between Blackfoot Reservoir and Fivemile Meadows to the north and is formed by the Aspen Range crest to the east.

Surface-water features in the region are shown on Figure 3-2 and include the following:

- Bear River;
- Alexander Reservoir;
- Soda Creek Reservoir;
- Blackfoot Reservoir;
- Fivemile Meadows;
- Soda Creek;
- Ledger Creek;
- Big Spring Creek;
- Natural ponds; and
- Wetlands.

These surface-water features are discussed below.

3.4.1 Bear River

The southern edge of the Blackfoot Lava Field is bordered by the Bear River (Figure 3-2). The Bear River flows from its source in the Uinta Mountains of Utah, through Wyoming, and into Idaho where it flows northwestward from Bear Lake past Soda Springs to the town of Alexander. It bends southward at Alexander towards the Great Salt Lake in Utah.

Flow data for the Bear River were collected by the USGS from 1954 to 1989 at the Bear River at Soda Springs gaging station (#10075000), located approximately five miles upstream from Alexander Reservoir, as shown on Figure 3-2. The annual average flow in the Bear River, as measured at this station, ranged from 390 to 1,900 cubic feet per second (cfs) (Hydrosphere 1993). The monthly average flow, considering all months for the period of record, ranged from 510 to 1,340 cfs.

3.4.2 Alexander Reservoir

The Bear River flows northwest to Soda Springs and into Alexander Reservoir. Alexander Reservoir (also known as Soda Point Reservoir) is located immediately west of the City of Soda Springs, as shown on Figure 3-2.

Water storage data for Alexander Reservoir were obtained from the Alexander Reservoir gaging station (#10079000), located downstream of the spillway approximately one mile from the town of Alexander, as shown on Figure 3-2. Annual average storage capacities of Alexander Reservoir for 1986 and 1988 were 12,410 and 12,607 acre-feet, respectively (Hydrosphere 1993). Monthly average storage capacities for the same years ranged from approximately 11,180 to 13,220 acre-feet. The reservoir is used for recreation, irrigation, and hydroelectric power.

3.4.3 Blackfoot Reservoir

Blackfoot Reservoir was constructed in 1910 and is located approximately 12 miles north of the Monsanto Plant as shown on Figure 3-2. The reservoir is used primarily for irrigation purposes and receives water from the Blackfoot River, which originates in the mountain ranges near the Idaho-Wyoming border and flows northwestward to the Snake River. Although contained within the Snake River drainage basin, water from the Blackfoot Reservoir apparently leaks to the south, via fractured basalts, into the Blackfoot Lava Field of the Bear River drainage basin (Dion 1974). According to the study conducted by Dion, about 12 cfs of water leaks from Blackfoot Reservoir to the Blackfoot Lava Field groundwater flow system.

3.4.4 Soda Creek Reservoir

Soda Creek Reservoir is located about one mile west of the Monsanto Plant as shown on Figure 3-2. The primary purpose of the reservoir is to store water for irrigation. In the process, a supply of water is maintained to supply power to the City of Soda Springs. Three 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.

3.4.5 Fivemile Meadows

Fivemile Meadows is located northwest of the Monsanto Plant in the center of the Blackfoot Lava Field as shown on Figure 3-2. Fivemile Meadows comprises an area of approximately 800 acres and consists of marshland and several springs. This area forms the headwaters of Soda Creek (discussed below). Seepage from Fivemile Meadows was noted to increase substantially shortly after construction of Blackfoot Reservoir around 1910 (Dion 1974). Prior to the construction of Blackfoot Reservoir, this area was primarily agricultural land. The response of the meadows to the construction of the reservoir indicates hydraulic connection between the two features.

3.4.6 Soda Creek

Soda Creek is a tributary to the Bear River and forms the main surface water drainage feature of the Blackfoot Lava Field near to the Monsanto Plant. Soda Creek originates at Fivemile

Meadows, flows south to Soda Creek Reservoir and eventually to Alexander Reservoir (Figure 3-2). The creek discharges into Alexander Reservoir at a point immediately west of the City of Soda Springs. Soda Creek passes within 2,000 feet of the Monsanto Plant.

The USGS operated a stream gaging station in Soda Creek near Fivemile Meadows from 1913 to 1926 and from 1965 to 1986 (Figure 3-2). The new stream gage installed in 1965 apparently replaces the stream gage used during the earlier monitoring period, as it is nearly in the same location and is noted to have an equal drainage area. Data for both gaging stations are presented in Hydrosphere (1993), however, only the more recent data are used here.

The annual average flow rate for Soda Creek at the Fivemile Meadows gage for the period 1965 to 1986 is 18 cfs. The daily average by month ranges from 11 cfs to 18 cfs. Over the 21 years of record, the annual average flow rate has ranged from 6 to 35 cfs as shown on Figure 3-3. The monthly average for the period of record, considering all years combined, ranges from 11 to 28 cfs, as shown on Figure 3-4. The flow rate in Soda Creek increases downstream due to additional recharge from overland flow and discharge of groundwater to the creek. Several springs nearby the Monsanto Plant discharge to Soda Creek. Hooper Spring appears to provide the most significant recharge to the creek, estimated at 1 cfs to 2 cfs. Other springs appear to provide small quantities of water to the creek, such as Doc Kackley, Mormon, Calf, and Homestead Springs.

Soda Creek is used for power generation and irrigation. 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 dams are located on Soda Creek. One dam is located approximately 100 feet downstream of the Monsanto effluent outfall. This dam diverts the majority of water from Soda Creek into an irrigation canal year-round. Most of this water is channeled back into the lower reaches of Soda Creek through the second and third powerhouses. The second diversion dam on Soda Creek is located approximately 2,000 feet below the third powerhouse and diverts water from Soda Creek into the Soda Canal irrigation system during the summer months. The remaining water in Soda Creek continues to flow southwest into Alexander Reservoir.

Upstream of the Monsanto effluent outfall, Soda Creek is a relatively swift-moving stream in a well-defined channel. Due to the diversion of the majority of water in Soda Creek to an irrigation canal as mentioned above, Soda Creek becomes very slow moving downstream of the outfall, with a gently meandering channel, in many places choked with vegetation.

Sediment samples were collected from Soda Creek as part of the RI field investigations, as shown on Figure 2-4. The samples ranged from dusky yellowish brown clayey silt, some fine sand, and some organics (ML) to coarse-to-fine gravel, some coarse-to-fine sand, and trace silt (GP). Grain size distribution, moisture content, and specific gravity results are provided in Appendix F.

3.4.7 Ledger Creek

Ledger Creek originates from Ledger Spring and several related springs located less than one mile southeast of the Monsanto Plant and immediately east of the City of Soda Springs (Figure 3-2). Ledger Creek flows south into Bear River. The estimated flow rate of Ledger Creek at Ledger Spring ranges from approximately 4 to 8 cfs.

3.4.8 Big Spring Creek

Big Spring Creek discharges into the Bear River on the south side of Soda Springs as shown on Figure 3-2. The creek is fed by Big Spring, south of Soda Springs. The flow in Big Spring Creek averages 14 cfs, as measured at the Clear Springs Trout Company weir by hatchery personnel. Flow in the creek has declined during the past few years, due to the drought conditions in the area.

3.4.9 Little Spring Creek

Little Spring Creek is located south of the Monsanto Plant and is a small, man-made drainage once used for diverting irrigation water from Soda Creek. The drainage is no longer used and does not contain surface water.

3.4.10 Natural Ponds

Formation Cave Ponds Formation Cave ponds are located approximately one mile east of the Monsanto Plant as shown on Figure 3-2 and consist of about eight natural ponds filled by the discharge from Formation Spring. Formation Spring is the largest of the springs in the Blackfoot Lava Field and is estimated to discharge on the order of 20 cfs, although a gaging station does not exist to accurately measure the Spring's discharge. A small stream serves as an outlet for the ponds and flows west for approximately 800 feet before infiltrating entirely to the subsurface. Water from the ponds appears to evaporate or discharge to groundwater, as there are no continuous streams to convey water away from the ponds to other surface water features.

Other Ponds Other ponds in the region consist of several small ponds near Kelly Park in Soda Springs, which are fed by Finch, Boyscout, and Spring Box Springs. An additional pond in the vicinity is situated north of Ledger Creek on an upthrown basalt block.

3.4.11 Wetlands

Immediately northwest and 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. In the past, this area has extended onto the

Monsanto Plant. The area to the southwest is much larger, covering approximately 16 acres, and is marshy year-round. Southwest Spring originates in this area.

3.5 Geology

This section provides a description of the regional and local geological characteristics of the Monsanto Plant and vicinity. Pertinent geologic information presented includes geomorphology, stratigraphy, lithology, and structure of the bedrock units.

3.5.1 Regional Geology

3.5.1.1 Geomorphology

The geomorphology and physiography of the area surrounding the Monsanto Plant 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 and subsequent intrusion of rhyolite domes have also been important processes in shaping the present land surface.

The Blackfoot Lava Field occupies a northerly trending valley that is approximately three to six miles wide in the Plant area. This valley is bordered by Soda Springs Hills and Ninety Percent Range on the west, by the Blackfoot Reservoir on the north, by the Aspen Range on the east, and by the Bear River on the south. The broad valley floor is at an elevation of approximately 6,150 feet; sloping gradually to the south at approximately 50 feet per mile to the Bear River at an elevation of about 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 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.

3.5.1.2 Regional Stratigraphy

The Blackfoot Lava Field 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, Oriel and Platt 1980). The oldest rocks in the area are 300 to 600 million years old and consist of sedimentary rocks exposed in the mountains of the Chesterfield Range and Soda Springs Hills on the west side of the valley. These rock units are primarily limestone, dolomite, shale, sandstone, and quartzite (Armstrong 1969, Oriel and Platt 1980). A generalized stratigraphic

column for the area is shown in Table 3-5. A regional geologic map is provided on Figure 3-5 and a regional geologic cross-section is provided on Figure 3-6.

The mountains of the Aspen Range on the east side of the valley expose younger (less than 300 million years old) sedimentary rocks, which include the Chesterfield Range Group, the Wells Formation, the Phosphoria Formation, and the Dinwoody Formation. These rock units are primarily limestone, sandstone, and shale. A few olivine basalt dikes (Tertiary age) intrude these sedimentary rocks (Armstrong 1969, Oriel and Platt 1980). The Phosphoria Formation contains phosphate-bearing beds that produce the ore which is being processed at the Monsanto Plant.

The Thaynes Limestone (Triassic age) is exposed within the valley in Threemile Knoll, an upthrown block which is located adjacent to the northeast corner of the Plant (Figure 3-5). The valley is partly filled by the Salt Lake Formation (Pliocene age), 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 olivine basalt flows (Quaternary age) of the Blackfoot Lava Field, which unconformably overlie the Salt Lake Formation (Armstrong 1969) (Figures 3-5 and 3-6). Well logs indicate the basalts are at least several hundred feet thick in the center of the valley, but thin toward the edges where they lap onto older rocks. Armstrong (1969) and Mabey and Oriel (1970) indicate the basalts may locally be 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).

Spring deposits composed of tufa and travertine (Holocene age) overlie parts of the Blackfoot Lava Field (Armstrong 1969) (Figures 3-5 and 3-6). These deposits are well developed at springs along the eastern and western margins of the valley adjacent to the bounding normal faults (Armstrong 1969).

Other geologic formations include alluvial fan deposits adjacent to the mountain ranges, alluvium in creeks and drainages (Armstrong 1969), and a thin surficial soil layer composed of windblown loess and weathered bedrock.

3.5.1.3 Regional Structure

The Monsanto Plant is situated in the transition zone between two geologic provinces, each having distinctive geologic structures (Oriel and Platt 1980, 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, Nevada, and eastern California. The Basin and Range province is characterized by extension of the earth's crust. The extension has resulted in many northerly-striking, high-angle, normal faults which have produced mountain ranges separated by valleys.

The Monsanto Plant is located within a Basin and Range-like valley, bordered on the west by the Soda Springs Hills and on the east by the Aspen Range (Armstrong 1969). A series of north-northwest-trending normal faults extend from southeast of the Plant northward to the Blackfoot Reservoir (Armstrong 1969, Oriel and Platt 1980). These normal faults exhibit both west-side-down and east-side-down displacements, with primary displacement west-side-down, as shown in the regional cross-section (Figure 3-6).

The Plant is underlain at a depth of approximately 4,000 feet by an extension of the Paris Thrust fault, a structural feature of the Rocky Mountain system. This fault was apparently active during formation of the overthrust belt and does not displace the Pliocene Salt Lake Formation or the Quaternary Blackfoot Lava Field basalts (Armstrong 1969) (Figures 3-5 and 3-6). The thrust fault is presumably off-set in many locations by the younger normal faults.

3.5.2 Local Geology

A summary of the local geology is presented below and includes a discussion of the geologic units, stratigraphy, and structure. The description of the geology of the Monsanto Plant is based on previous investigations at the Monsanto and Kerr-McGee plants and on the geologic investigations completed during this RI.

3.5.2.1 Local Stratigraphy

Field reconnaissance mapping and a review of geological and geophysical borehole logs indicate, in general, the Monsanto Plant is underlain by a thin veneer of overburden soils which, in turn, overlie basalt flows of the Blackfoot Lava Field. The basalt flows are separated by porous, fractured interflow zones and unconformably overlie the Salt Lake Formation. Other geologic units in the vicinity of the Monsanto Plant include spring deposits. These units are described below.

Overburden Soils The overburden surface soils are largely derived from windblown loess and weathered bedrock. They consist primarily of silty clay and generally range in thickness from 3 to 23 feet. 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. Soils are discussed in detail in Section 3.6.

In parts of the Plant, the overburden soils are mantled by gravel or calcium silicate slag fill. The greatest thickness of fill is 24 to 27 feet, encountered in wells TW-25, TW-26, and TW-27, located near the center of the Plant.

Blackfoot Lava Field Basalts The Blackfoot Lava Field basalts underlying the Plant are typically fine-grained and vesicular. Following the Brown (1981) rock description method, the basalt flow exposures near the Plant are described 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 were based on a rock-color chart prepared by the Rock-Color Chart Committee (1984).

The individual basalt flows vary in thickness from less than 10 feet to 80 feet. 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.

Interflow Zones Each basalt flow is separated from the overlying and underlying basalt flows by porous interflow zones ranging from 1-to-23-feet in thickness. The interflow zones generally are composed of sediments, weathered and broken basalt, and scoriaceous basalt cinders. The sediments are typically reddish brown to gray silty clay, clayey silt, sand, and gravel. The cinders are composed of sub-angular gravel-to-cobble size clasts, which range from less than 0.5 inches to greater than 6 inches in diameter. The cinder clasts are reddish brown to gray and contain numerous vesicles which are occasionally filled with zeolite. Sediments are occasionally present in the cinder zones, but typically form discrete strata.

Salt Lake Formation The Salt Lake Formation is composed of sandstone, conglomerate, and limestone, all of which may be tuffaceous (Armstrong 1969).

Spring Deposits Other local geologic units include spring deposits composed of tufa and travertine. Spring deposits are locally present within the valley at locations such as Formation Spring, Ledger Spring, and Rabbit Mountain. A description of the spring deposits near the Plant is as follows:

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

Travertine terraces indicate areas where springs surfaced along faults associated with the Aspen Range (Ralston et al. 1983).

Geologic Cross Sections Six geologic cross sections were developed for this investigation from the drilling and borehole geophysical data collected during the RI activities at the Monsanto and Kerr-McGee plants and during earlier investigations (Golder 1985, 1987, 1988a, and 1988b). The locations of the cross sections are shown on Figure 3-7. The cross sections are shown on Figures 3-8 through 3-13.

The cross sections generally show 3 to 23 feet of overburden soils overlying the basalt flows of the Blackfoot Lava Field. Five basalt flows have been identified beneath the Plant and have been designated Flows I through V, with Flow I being the oldest and flow V the youngest. The entire sequence of basalt flows can be seen on Figures 3-8 and 3-12 and is at least 250 feet thick

as recorded in boreholes TW-09, TW-18, TW-25, and PW-03. The individual flows vary in thickness from less than 10 feet to 80 feet as seen on Figure 3-10. The flows are distinguished from one another based on changes in lithology or abrupt changes in the natural gamma log response (Golder 1985, Golder 1992b).

Data from wells TW-01 (now abandoned) and TW-02 indicate the basalt sequence thins toward Threemile Knoll, an upthrown block of older sedimentary rocks located adjacent to the northeast corner of the Plant. Well TW-02 encountered 224 feet of basalt and cinders overlying "a white and yellow formation," inferred to represent the Salt Lake Formation. Well TW-01 encountered 45 feet of basalt and cinders overlying 255 feet of sandstone, shale and clay (Golder 1985). Well TW-13, shown on Figure 3-13, encountered a light brown, fairly well indurated silty conglomerate at a depth of 73 feet below ground surface (bgs) which was interpreted to be part of the Salt Lake Formation.

Each basalt flow is separated from the overlying and underlying basalt flows by porous interflow zones. The interflow zones exhibit distinctive gamma-log signatures due to the presence of clay minerals. These signatures have been used for stratigraphic correlation. The gamma-1, -2, -3, and -4 signatures are found associated with zones at the top of Basalt Flows I, II, III, and IV, respectively (Figures 3-8 through 3-13). The interflow zones range in thickness from 1-to-23-feet and are generally continuous beneath the Plant. In some areas, however, the interflow zones are discontinuous and laterally pinch out as seen on Figures 3-10 and 3-11. The interflow zones have been identified as the primary water-bearing zones beneath the Plant.

Dames and Moore (1993) have also identified five primary basalt flows underlying the Kerr-McGee Plant and refer to them as Basalts No. 1 through No. 5, in ascending order. Four interflow zones have been identified and are referred to as Interflow Zones No. 1 through No. 4. Correlations of geologic units between boreholes from the Monsanto and Kerr-McGee Plants indicate units underlying the Kerr-McGee Plant are equivalent to those underlying the Monsanto Plant. However, the units are offset as a result of displacement along faults.

With regards to spring deposits, field reconnaissance mapping identified two locations where basalt/travertine contacts were visible. In the east cliff of the Ledger Creek valley, calcium carbonate has been deposited in the basalt joints and fractures near the base of the cliff. In exposures at the easternmost mapped fault travertine overlies basalt and has been displaced by the fault. Open solution cavities in the travertine up to two feet in diameter are present at the basalt/travertine contact. Farther north from this fault, low outcrops of basalt and travertine consistently show travertine overlying basalt.

3.5.2.2 Local Structure

The literature review and field reconnaissance mapping indicate the Blackfoot Lava Field basalts in the vicinity of the Plant have well-developed columnar joints. The vertical columnar joints are typically spaced 2 to 10 feet apart and 0.5-inch to 1-inch wide apertures are visible above ground surface. It is noteworthy that aperture widths likely decrease with depth due to increasing stress. Basalt exposures north of the Monsanto Plant display horizontal joints spaced 9 to 12 inches apart, with 0.5-inch to 1-inch wide apertures. Some of the horizontal joints are continuous for hundreds of feet (Golder 1985).

Aerial photograph interpretation, field reconnaissance mapping, and geophysical survey results indicate a discontinuous zone of normal faults is present near the Plant. The zone consists of north trending, en-echelon normal faults that extend from southeast of the Plant northward, towards the west side of Blackfoot Reservoir. These normal faults display both west- and east-side-down relative displacement, and commonly form fault scarps and 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 Plant vicinity are shown on Figure 3-14 and are discussed below. A local structure block diagram is shown on Figure 3-15.

A prominent northwest-trending, southwest-facing fault enters the Plant near the northwest corner and appears to die out south of the southeast corner of the Plant as shown on Figures 3-5 and 3-14. This fault is informally referred to as the Monsanto Fault. The fault strikes approximately N29°W and the fault scarp decreases in height from 40 feet in the northwest Plant area to about 20 feet at the south fenceline. The scarp slope angle was measured between 15 and 17 degrees. Most of the fault scarp within the central portion of the Plant is covered by slag and fill.

Cross-sections A-A', D-D', and E-E' (Figures 3-8, 3-11, and 3-12), located as shown on Figure 3-7, indicate the Monsanto Fault has between 2 and 90 feet of vertical displacement (west-side down) in the vicinity of the Plant. The fault is a hinge fault, with the greatest displacement to the north, decreasing to the south. The displacement of the fault along the south Plant fenceline is about 7 to 20 feet, decreasing to between 2 to 16 feet south of the Plant. The Monsanto Fault may die out to the south of TW-56. This conclusion is based on the geophysical survey conducted and the lack of pronounced topographic evidence for the fault in this area. The displacement from the Monsanto Fault has offset permeable basaltic interflow zones against less permeable, unweathered basalt flow interiors, forming barrier boundaries to groundwater flow.

A subsidiary fault runs parallel and approximately 1,500 feet west of the Monsanto Fault as shown on Figures 3-14 and 3-15. This fault, informally referred to as the Subsidiary Fault, is also considered to die out south of the southern Plant fenceline. The Subsidiary Fault was estimated to have 5 to 10 feet of vertical displacement (west-side down) based on stratigraphy observed in boreholes as shown in cross-sections A-A' and D-D' (Figures 3-8 and 3-11).

Several faults exist east and southeast of the Monsanto Plant as shown on Figures 3-14 and 3-15. The more prominent faults in this area have been informally named Fault A, the Finch Spring Fault, Fault B, and Fault C. These four normal faults trend approximately north-south and have vertical displacements ranging from about 10 feet to 70 feet, as measured at the surface. Fault A, the Finch Spring Fault, and Fault B possibly extend north, causing offset of geologic units between boreholes at the Monsanto Plant and the Kerr-McGee Plant, as shown on Figures 3-12 and 3-13. At depth, Fault A may have a displacement of 25 to 45 feet (east-side down) as estimated from the offset of basalt horizons between wells TW-25 and TW-32 and between wells TW-38 and TW-32. The Finch Spring Fault and Fault B may have a combined displacement of 20 to 25 feet (west-side down) as estimated from offset strata between well TW-32 and Kerr-McGee corehole CH-04. Along the northern projection of Fault B there is a 0.3-

mile-long lineament that in two places is an open fissure in the basalt, with a measured opening as great as 2.5 feet.

Subparallel to the southern part of the Finch Spring Fault, is the Ledger Creek graben (Figures 3-14 and 3-15). The graben is bordered by prominent fault scarps that have an estimated 40 to 60 feet of vertical displacement. The vertical displacement appears to decrease to the north. Numerous springs, including Ledger Spring, emanate from the base of the eastern fault scarp. Fault C exists about 800 feet north of the Ledger Creek graben and may be an extension of the fault forming the west side of the Ledger Creek graben. Fault C has an estimated vertical displacement of 40 feet.

3.6 Soils

3.6.1 Regional Soils

The soils of Caribou County are in the process of being mapped by the SCS. An advanced copy of the general soils map of Caribou County (Kukachka, B., SCS, [Personal communication], November 26, 1991) was used to identify major soil groups in the region. 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 on Figure 3-16. This map displays general patterns of soils with similar characteristics across the landscape. According to this map there are five major soil groups in the area around Soda Springs. These five soil groups are differentiated by topography, drainage, soil depth, and landscape position, and are summarized below.

Soil Group 1 This group contains nearly level, moderately well to very poorly drained, very deep soils that are found on floodplains and low stream terraces. Present uses include hayland, pastureland, and wildlife refuge. The principal limitations to use are flooding potential and high water table conditions.

Soil Group 2 This group contains gently sloping to steep, well drained, very deep soils that are found on lake terraces and terrace breaks. Present uses include irrigated and non-irrigated cropland, hayland, and pastureland. The principal limitations to use include slope and a water-erosion potential.

Soil Group 3 This group contains nearly level to gently rolling, well drained, moderately deep to very deep silty soils that are found on basalt plains and alluvial plains. Present uses include irrigated and non-irrigated cropland, hayland, pastureland, and rangeland. Limitations to use include water- and wind-erosion potential and rock outcrops.

Soil Group 4 This group contains nearly level to moderately steep, well drained, very deep soils that are found on fan terraces and hill slopes. Present uses include irrigated and non-irrigated cropland, hayland, pastureland, and rangeland. Limitations to use include water-erosion potential and steep slopes.

Soil Group 5 This group contains strongly sloping to very steep, well drained, shallow to very deep soils that are found on mountainsides and hillsides. Present uses include non-irrigated cropland, rangeland, and woodland. Limitations to use include steep slope, water-erosion potential, areas of low permeability, and areas with thin soil overlying bedrock.

3.6.2 Local Soils

Soil samples were collected from 52 locations surrounding the Monsanto Plant as shown on Figure 2-5. Physical analyses were conducted to determine grain-size distribution. Grain size distribution, moisture content, and specific gravity results are provided in Appendix I.

In general, most samples were classified as a moderate brown or dusky brown, clayey silt with trace or little sand and trace or little fine gravel (ML). 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.

3.6.2.1 Soil Types

Based on preliminary mapping by SCS, soils at the Monsanto Plant and in the vicinity have been categorized into a variety of soil types. The areal distribution of the soil types are shown on Figure 3-17. Many of the soils identified in the regional Caribou County survey are not distinguishable at the local scale. The most common soil types in proximity to the Plant are discussed below.

Map Unit 293A, Dumps and Mines The Monsanto Plant was mapped as a disturbed site, or as Map Unit 293A. Due to the disturbance of soils within the boundaries of the Monsanto Plant, the soils occurring inside the fenceline cannot be correlated with native soil types surrounding the Plant. Prior to Plant operations, however, the soils within the Plant fenceline were likely similar to the surrounding soils. These soils include the Rexburg-Ririe Complex, the Rin-Lantonia Complex, and the Lantonia-Crow Creek Complex. Of these, the Rexburg-Ririe Complex is the most prevalent.

Map Unit 485A, Lantonia-Chinahat Complex This map unit is composed of Lantonia soil and similar inclusions (55 percent), Chinahat soil and similar inclusions (35 percent), and contrasting inclusions (15 percent). It is found on loess covered basalt plains. The Lantonia soil is found on north- and east-facing smooth and concave slopes. The Chinahat soil is found on south- and west-facing convex slopes. Slopes range from 1 to 4 percent.

The Lantonia soil is deep, well drained and of moderate permeability. Available water-holding capacity is 10 to 12 inches and the potential rooting depth is 60 inches or more. The hazard of erosion by water or wind is slight to moderate. Typically, the surface layer 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.

The Chinahat soil is also deep, well drained, and of moderate permeability. Available water-holding capacity is 11 to 13 inches and the potential rooting depth is 60 inches or more. The hazard of erosion by water or wind is slight to moderate. Typically, the surface layer is brown silt loam about 13 inches thick. The subsoil is a light yellowish-brown silt loam about 19 inches thick. The substratum is a very pale brown and light yellowish-brown silt loam about 28 inches thick.

Map Unit 485C, Lantonia-Crow Creek Complex This map unit is composed of Lantonia soil and similar inclusions (55 percent), Crow Creek soil and similar inclusions (30 percent), and contrasting inclusions (15 percent). 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. Available water-holding capacity is 10 to 12 inches and the potential rooting depth is 60 inches or more. The hazard of erosion by water is severe and moderate by wind. 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. Available water-holding capacity is 10 to 11 inches and the potential rooting depth is 60 inches or more. The hazard of erosion by water is severe and moderate by wind. 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 This map unit is composed of Rexburg soil and similar inclusions (55 percent), Ririe soil and similar inclusions (35 percent), and contrasting inclusions (10 percent). 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. The available water-holding capacity is 11 to 13 inches and the potential rooting depth is 60 inches or more. The hazard of erosion by water or wind is slight to 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. The available water-holding capacity is 11 to 13 inches and the potential rooting depth is 60 inches or more. The hazard of erosion by water or wind 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 This map unit is composed of Rexburg soil and similar inclusions (55 percent), Ririe soil and similar inclusions (35 percent), and contrasting inclusions (10 percent). 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 with south aspects. Slopes range from 4 to 8 percent.

The Rexburg soil is very deep and well-drained. Permeability is moderate. The available water-holding capacity is 11 to 13 inches and the potential rooting depth is 60 inches or more. The hazard of erosion by water or wind is moderate to severe. Typically, the surface soil is brown silt loam about 16-inches thick. The subsoil is pale brown silt loam about 8-inches thick. The substratum is light yellowish-brown silt loam about 36-inches thick.

The Ririe soil is very deep and well drained. Permeability is moderate. The available water-holding capacity is 11 to 13 inches and the potential rooting depth is 60 inches or more. The hazard of erosion by water or wind is moderate to severe. Typically, the surface soil is 15 inches of brown silt loam. The subsoil is about 39 inches of pale-brown silt loam. The substratum is a light yellowish-brown silt loam about 16-inches thick.

Map Unit 705A, Rin-Lantonia Complex This map unit is composed of Rin soil and similar inclusions (60 percent), Lantonia soil and similar inclusion (35 percent), and contrasting inclusions (5 percent). 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. Slopes range from 1 to 4 percent.

The Rin soil is very deep and well drained. Permeability is moderate. Available water-holding capacity is 11 to 13 inches and potential rooting depth is 60 inches or more. The hazard of erosion by water or wind is slight to 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. Available water-holding capacity is 11 to 13 inches and potential rooting depth is 60 inches or more. The hazard of erosion by water or wind is slight to 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.

3.6.3 Control Soils

To provide reference concentrations for chemical constituents in soil, 20 soil samples were collected as control samples. These samples were collected at locations shown on Figure 2-6. Each location is considered to provide soil samples that are undisturbed by activities occurring at the Monsanto Plant. The soil map units corresponding to the 20 control soil samples are presented in Table 3-6.

3.7 Hydrogeology

This section presents the regional and local hydrogeology for the Monsanto Plant. The discussion on regional hydrogeology summarizes groundwater conditions in the Blackfoot Lava Field, providing a regional context for the local hydrogeology. The local hydrogeology discussion, relying on data collected during this RI and during previous investigations, addresses groundwater conditions at the Monsanto Plant.

3.7.1 Regional Hydrogeology

Hydrologic features and geologic structures and stratigraphy have major influences on groundwater flow within the Blackfoot Lava Field and have been reviewed in Sections 3.4 and 3.5, and in previous investigations (Golder 1985).

3.7.1.1 Regional Groundwater Flow

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

1) The Shallow Groundwater System, which moves locally through the upper elevations of basalt in the Blackfoot Lava Field;

2) The Mead Thrust System, which discharges along the eastern margins of the Blackfoot Lava Field; and

3) The Chesterfield Range System, which discharges along the western portions of the Blackfoot Lava Field.

The Shallow Groundwater System flows through the upper stratigraphic units of the Blackfoot Lava Field basalt sequence and through the surficial Quaternary alluvium. The basalt contains the most productive aquifers in the region. Aquifers occur primarily between individual basalt flows in sedimentary interbeds and weathered zones. Groundwater from the aquifers is used for industrial, domestic, and agricultural purposes.

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 Salt Lake Formation and pre-Tertiary rocks yield variable amounts of groundwater for domestic and stock purposes, and are unpredictable as a water-supply source.

Recharge to the Shallow Groundwater System occurs by infiltration of precipitation and irrigation, leakage from the Blackfoot Reservoir, and possibly from deeper within the groundwater system. Dion (1974) estimated that approximately 12 cfs of Blackfoot Reservoir water was leaking into the underlying basalt aquifer and moving toward Soda Springs.

Groundwater elevations and general groundwater flow directions for the Shallow Groundwater System are shown on Figure 3-18.

Recharge to the Shallow Groundwater System from depth possibly occurs along deep, high-angle, normal faults forming the eastern and western margins of the Blackfoot Lava Field. Recharge along the eastern margin of the Blackfoot Lava Field is assumed to originate from the Mead Thrust Aquifer System. Recharge along the western margin is uncertain but may originate from the Chesterfield Range Aquifer System. Little recharge appears to occur along the western margin.

The Mead Thrust Aquifer System is recharged by precipitation over the mountains to the east of the Monsanto Plant, which include the Aspen Range, Schmid Ridge, Dry Ridge, and the Webster Range (Ralston et al. 1983). Groundwater flow in the Mead Thrust Aquifer System is apparently westward along permeable sedimentary beds, with the Mead Thrust Fault possibly acting as a conduit for groundwater flow. The numerous springs located along normal faults along the eastern margin of the Blackfoot Lava Field are assumed to be discharge points for the Mead Thrust Aquifer System. Formation Spring is an example of such a spring.

The numerous springs along the western margin of the Blackfoot Lava Field may possibly be discharge points of the Chesterfield Range Aquifer System. However, this relation is uncertain. Hooper Spring is an example of the springs located along the western margin of the valley.

The regional direction of groundwater movement in the Shallow Groundwater System is to the southwest as shown on Figure 3-18, although this pattern is locally affected by faults and by production wells at the Monsanto and Kerr-McGee plants. Discharge from the Shallow Groundwater System is to Soda Creek, Alexander Reservoir, and Bear River.

3.7.1.2 Regional Hydrologic Features

Hydrologic features which can influence groundwater flow consist of recharge and discharge locations. The main hydrologic features which influence groundwater flow in the Blackfoot Lava Field are shown on Figure 3-2. These features are discussed below.

Aspen Range

The Aspen Range borders the entire eastern edge of the Blackfoot Lava Field, with the exception of a short segment on the northeast edge. The eastern half of the Blackfoot Lava Field receives recharge from the Aspen Range. The watershed area of the Aspen Range increases in size toward the south, thus greater recharge is anticipated to occur in this area in comparison to the northern part of the range.

Ninety Percent Range

The Ninety Percent Range lines the southwestern edge of the Blackfoot Lava Field. The range is much smaller and generally drier than the Aspen Range. A small quantity of recharge to groundwater is likely from rainfall and snowmelt in this area.

Blackfoot Reservoir

The Blackfoot Reservoir is located on the northern boundary of the Blackfoot Lava Field. Although contained within the Snake River basin, the Blackfoot Reservoir has some leakage to the south, into the shallow aquifer underlying the Blackfoot Lava Field. The Blackfoot Reservoir is a source of recharge to groundwater in the western half of the Blackfoot Lava Field (Dion 1974).

Bear River

The Bear River is located on the southern edge of the Blackfoot Lava Field. In this area of the Blackfoot Lava Field, groundwater discharge occurs to the Bear River, as shown by hydraulic gradients (Dion 1974). Discharge into the Bear River and Alexander Reservoir comprises the majority of the groundwater discharge from the Blackfoot Lava Field. The mean annual flow in the Bear River, measured at a gaging station upstream from Alexander Reservoir for the period from 1954 to 1970, was 530 cfs (Dion 1974).

Alexander Reservoir

Alexander Reservoir (also known as Soda Point Reservoir) is located along the southwestern edge of the Blackfoot Lava Field, just west of the City of Soda Springs, and receives water from the Bear River. This reservoir and the Bear River forms the primary discharge location of groundwater from the Blackfoot Lava Field.

Fivemile Meadows

Fivemile Meadows is located northwest of the Monsanto Plant in the center of the Blackfoot Lava Field. The meadow is an area of groundwater discharge from the Blackfoot Lava Field and forms the headwaters of Soda Creek. Seepage from Fivemile Meadows was noted to increase substantially shortly after construction of Blackfoot Reservoir around 1910 (Dion 1974). The response of the meadows to the reservoir indicates hydraulic connection exits between the two features.

Soda Creek

Soda Creek is the primary stream in the Blackfoot Lava Field. Precipitation and groundwater discharge from Fivemile Meadows and tributary springs provide water to Soda Creek. Soda Creek is likely in hydraulic connection with groundwater throughout its entire length, however, flow between Soda Creek and the Blackfoot Lava Field is considered to be negligible away from the stream's headwaters. Soda Creek ultimately discharges to Alexander Reservoir. A more detailed discussion of Soda Creek is provided in Section 3.4.

Hooper Spring

Hooper Spring is located west of the southern portion of the Monsanto Plant and discharges about 1 to 2 cfs to Soda Creek. Discharge from the spring is noted for its high iron content,

which causes the water to have substantial color, and also its effervescence, which is a result of high concentrations of dissolved carbon dioxide.

Formation Spring

Formation Spring occurs along the eastern edge of the Blackfoot Lava Field, about due east of the Monsanto Plant. The groundwater discharged from Formation Spring is believed to rise from depth along a normal fault that borders the east edge of the Blackfoot Lava Field. The source water for Formation Spring is likely further to the east beyond the Aspen Range (Mayo et al. 1985). Formation Spring is a drinking water source for the City of Soda Springs.

Formation Spring discharges approximately 20 cfs (field estimate by a Golder hydrogeologist) of groundwater into streams directed towards the Blackfoot Lava Field. Formation Cave receives most of this water and provides recharge to the Blackfoot Lava Field. Thus, Formation Spring is a recharge source to the basalts, rather than a point of discharge.

Ledger Spring

Ledger Spring and several other springs exist southeast of the Monsanto Plant, in the southeast part of the Blackfoot Lava Field. Ledger Spring is a drinking water source for the City of Soda Springs which draws approximately 4 cfs (2.5 MGD) from the spring year round. This amount is about one-half to one-third the total flow from the spring. The remaining water enters a creek that flows southerly to the Bear River. The absence of travertine deposits and the fresh water quality of Ledger Spring indicate the source for the spring is likely the Blackfoot Lava Field. Because the discharge feeds a stream and does not percolate back into the shallow groundwater system, the spring represents a point of groundwater discharge.

Big Spring

Big Spring is located immediately south of Soda Springs. The spring is assumed to be a discharge point for the Blackfoot Lava Field. Big Spring discharges to Big Spring Creek, which in turn flows into Bear River. The flow in Big Spring Creek averages 14 cfs, as measured at the Clear Springs Trout Company weir by hatchery personnel. Discharge from Big Spring is considered to make up a significant component of groundwater discharge from the shallow groundwater system to Bear River/Alexander Reservoir.

3.7.2 Local Hydrogeology

The hydrogeologic system underlying the Monsanto Plant is consistent with the regional hydrogeologic model of the Blackfoot Lava Field. Information on the local hydrogeology is available from previous investigations and from Phase I and II RI activities conducted at the Monsanto and Kerr-McGee plants. The Phase I RI hydrogeological investigation evaluated the groundwater-quality data previously collected by Monsanto (since the mid-1980s), plus one sample round as part of the RI. The Phase II investigation evaluated and incorporated data and information from geophysical survey activities, well drilling activities, pumping test activities,

three additional sampling rounds, and physical and chemical data generated by Kerr-McGee (Dames and Moore 1993).

This section discusses the local hydrostratigraphy, well drilling and installation activities, groundwater flow regions and directions, groundwater quality characteristics (as pertaining to the differentiation of local flow systems), and the results of pumping test activities. Groundwater quality, as pertaining to constituent releases, is discussed in Chapter 4.

3.7.2.1 Hydrostratigraphy

Four local hydrostratigraphic zones have been identified beneath the Monsanto Plant:

- The Surficial Deposit Zone (SDZ);
- The Upper Basalt Zone (UBZ);
- The Lower Basalt Zone (LBZ); and
- The Salt Lake Zone (SLZ).

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 may also be present at depth beneath the Lower Basalt Zone. Neither the Surficial Deposit Zone nor the Salt Lake Zone produce large amounts of groundwater. The Upper Basalt Zone and the Lower Basalt Zone are discussed below. The hydrostratigraphy of the Plant is shown in cross sections on Figures 3-8 through 3-13. Cross section locations are shown on Figure 3-7.

Upper Basalt Zone

As discussed earlier in Section 3.5, basalts underlying the Plant consist of five lava flows. These flows have been designated Flow I, II, III, IV, and V in ascending order and are separated by porous interflow zones. The interflow zones are delineated on the basis of changes in lithology or abrupt changes in the natural gamma-log response and have been informally designated gamma-1 through gamma-5, in ascending order, with the gamma-1 interflow zone overlying Basalt Flow I and the gamma-2 interflow zone overlying Basalt Flow II, and so on.

The UBZ is the principal aquifer underlying the Plant and consists of two, and at some locations three, interflow zones. Descending from the top of the Blackfoot Lava Field basalt sequence, the UBZ is in general composed of:

- Basalt Flow V (20 - 40 ft thick);
- The gamma-4 interflow zone (1 - 20 ft thick);
- Basalt Flow IV (10 - 25 ft thick); and
- The gamma-3 interflow zone (1 - 10 ft thick).

The UBZ is found in 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 to about

100 feet bgs in the center of the Plant. Wells completed in the UBZ, and springs which are believed to discharge groundwater from the UBZ, are shown on Figure 3-19.

Lower Basalt Zone

The LBZ underlies the UBZ to depths of at least 250 feet bgs and is the secondary aquifer underlying the Plant. The LBZ is composed of several moderately permeable interflow zones and is composed of:

- Basalt Flow III (25 - 45 ft thick);
- The gamma-2 interflow zone (2 - 20 ft thick);
- Basalt Flow II (20 - 60 ft thick); and
- Underlying basalt.

Wells completed in the LBZ are shown on Figure 3-20.

3.7.2.2 Groundwater Flow Regions

Groundwater flow in the UBZ and LBZ is influenced by faulting and pumping of the Plant production wells. As a consequence of the faulting and pumping, it is possible to identify up to five separate groundwater flow regions. The groundwater flow regions for the UBZ are shown on Figure 3-21. In plan view, the four LBZ regions correspond to the first four regions of the UBZ. The fifth UBZ region does not have a corresponding region in the LBZ. Table 3-7 lists the groundwater flow region for each Monsanto well and other wells sampled during the RI. The groundwater flow regions are defined as follows:

UBZ-1 & LBZ-1

These regions are located in the immediate southwestern corner of the Plant and are bounded by the Subsidiary Fault to the northeast. Plant facilities above these regions include the former coke and quartzite dust slurry pond, the non-contact cooling water settling pond and non-contact cooling water ditch, and the former sewage evaporation ponds.

UBZ-2 & LBZ-2

These regions are located in the western part of the Plant and are bounded by the Monsanto Fault and the Subsidiary Fault. UBZ-2 is assumed to include the Lewis well, TW-54, and TW-55, located south of the Plant, TW-57, located northwest of the Plant, and other wells installed between the faults. The old underflow solids ponds are located above these regions.

UBZ-3 & LBZ-3

These regions are located in the southeastern part of the Plant and are bounded by the Monsanto Fault to the west. UBZ-3 includes TW-56, located south of the Plant. These regions are downgradient of the Kerr-McGee Plant.

UBZ-4 & LBZ-4

These regions primarily underlie the northern and central parts of the Plant. Plant facilities located above these regions include the northwest pond and the hydroclarifier. Groundwater in these regions appears to be withdrawn through production wells PW-01, PW-02, PW-03 and PW-04.

UBZ-5

This region includes the springs and ponds located to the east of the Plant near Formation Cave and southeast of the Plant near Ledger Creek and Kelly Park. Groundwater recharge to this region appears to occur from the east.

3.7.2.3 Groundwater Hydraulics

Hydraulics testing was carried out in test wells at the Monsanto Plant to determine aquifer transmissivity and storativity, and to provide information on hydraulic boundaries.

Activities conducted for this RI involved single-well hydraulics testing (slug tests and short-term pumping tests) of the new monitoring wells, TW-53 through TW-57, and a longer term pumping test using test well TW-58 as the pumping well. Results and interpretations of this testing are discussed below and in Appendix H.

Single-Well Hydraulics Testing

Single-well hydraulics testing consisted of either slug tests or short-term pumping tests. Slug tests involve the rapid removal or addition of a volume of water from a well, after which the water-level recovery is measured (Freeze and Cherry 1979). Short-term pumping tests involve pumping a well at a constant rate for a set amount of time, after which the water-level in the well is allowed to recover. The water level during both pumping and recovery is measured.

The choice to conduct a slug test or a short-term pumping test was dependent on the ability of the monitoring well to produce water. If the well was installed into low permeability materials and could not provide water at a constant pumping rate, a slug test was conducted. If the well was installed into materials of greater permeability and a pumping rate could be sustained, a short-term pumping test was conducted. The sustained pumping rate required from the well ranged from 7 to 15 gpm. Note that this basis for conducting either a slug test or a short-term pumping test results in lower transmissivity determinations from the slug test data. This occurrence is related to the test selection method rather than the test analysis method.

Results of single-well hydraulics testing are summarized below in this section. Appendix H-7 and H-8 contains additional information documenting the calculations and well response curves for the individual tests.

Previous Single-Well Hydraulics Testing Single-well hydraulics testing conducted in 1984 (Golder 1985) involved wells TW-03 through TW-10, TW-25, and TW-34. Slug tests were performed by either pumping the wells using a submersible pump (TW-04, TW-08, and TW-09)

or by airlifting water from the wells (TW-25 and TW-35). Water-level recovery was measured using an electric probe and recovery data were analyzed using a modified Hvorslev method.

Short-term pumping tests in 1984 involved wells TW-03, TW-05, TW-06, TW-07, and TW-10 and were performed by pumping each well using a submersible pump for one hour. Flowrates ranged from about 7 to 15 gpm and were measured using an in-line totalizing flow meter. Water-level drawdown and recovery measurements were collected using an electric probe. Drawdown data were analyzed using the Cooper-Jacob method and recovery data were analyzed using the Theis recovery method (Freeze and Cherry 1979).

Results from the slug tests and short-term pumping tests from 1984 are presented in Table 3-8. Transmissivities (T) for the UBZ were found to range from 2 to 9,700 ft^2/d, resulting in hydraulic conductivities (K) ranging from 0.3 to 530 ft/d. The interflow zones of the LBZ were found to be less permeable, with transmissivities ranging from 0.5 to 2,400 ft^2/d.

Present Investigation Single-well hydraulics testing was conducted during this RI in the fall of 1992 and involved wells TW-53 through TW-57. Slug tests were performed in wells TW-53, TW-54, and TW-56 and short-term pumping tests were performed in wells TW-55 and TW-57. Submersible pumps were used to perform both types of tests and water-level measurements were collected using an electric probe.

Slug tests were performed by pumping a well at a rate of 25 gpm, rapidly drawing down the water in the well to the pump intake over a period of about 30 to 45 seconds and, hence, removing about one well volume of water. The pump intake was set a few inches off the bottom of the well and the pump was equipped with a check valve to prevent water returning to the well after the pump was turned off. After the well was evacuated, water-level recovery was measured to within 5% of the original static water level. Recovery took approximately 0.7, 3.5, and 75 minutes, respectively, for TW-53, TW-54, and TW-56. Purged water from the slug tests was discharged into a container for later disposal to the seal water pond, located in the northern portion of the Monsanto Plant.

The short-term pumping tests conducted during this RI were performed in wells TW-55 and TW-57. A totalizing flow meter was used to measure the pumping rate. TW-55 was pumped for 124 minutes at a constant rate of 25 gpm. The water level in TW-55 drew down 11.3 feet during pumping. There was no discernible drawdown in neighboring wells TW-53, TW-54, or TW-56 during this test. TW-57 was pumped for 120 minutes at a constant rate of 26 gpm. The water level in TW-57 drew down 5.2 feet during pumping. Purged water from the short-term pumping tests was discharged onto the ground.

Slug test data were analyzed using the Hvorslev method and the Theis recovery method (Freeze and Cherry 1979). The Hvorslev method assumes instantaneous removal of water from the well, while the Theis recovery method takes into account the pumping period. TW-56 was additionally analyzed using the Papadopoulos and Cooper method (Papadopoulos et al. 1973).

The assumption of instantaneous removal of water from the wells appears generally valid. The test conducted in TW-53 is an exception, however, as recovery occurred within 45 seconds after

purging the well. The Hvorslev method analysis for data collected from this test is likely to underestimate the aquifer transmissivity due to the rapid recovery.

Short-term pumping test data from TW-55 and TW-57 were analyzed using the Cooper-Jacob method and the Theis recovery method. The water level in TW-55 continued to draw down during pumping and did not stabilize. An increase of the drawdown data after approximately 30 minutes indicates a low permeability boundary may be affecting the data. The water level in TW-57 also continued to draw down with pumping, however, no effects of boundaries were observed. The absence of a boundary effect in the TW-57 well response indicates the zone of influence of the test did not extend to the Monsanto Fault, located to the east of TW-57 approximately 50 ft. A low pumping rate and/or short test duration may have prevented the test region from extending to the fault boundary.

The results of the slug tests and short-term pumping tests conducted during this RI are given in Table 3-9. Estimated hydraulic conductivity values from these tests vary by four orders of magnitude between well locations, ranging from about 0.04 to 676 ft/d. Wells TW-55 and TW-57 are completed in the most permeable materials while TW-56 is completed in the least permeable materials. As noted above, the Hvorslev analysis of data from TW-53 provides a lower estimate than the Theis recovery analysis of the same data. This result likely reflects the rapid recovery of this well and the violation of the analysis assumption pertaining to the instantaneous removal of water from the well.

Hydraulic conductivities obtained from this RI and from the previous investigation in 1984 (Golder 1985) are grouped by interflow zones and presented in Table 3-10. With the exception of data from TW-55, an apparent pattern of decreasing hydraulic conductivity with depth is observed. Hydraulic conductivity measurements also vary within each interflow zone, indicating heterogeneous hydraulic properties for the interflow zones.

Aquifer Testing

An aquifer test was conducted in the southern Plant area in December 1992. The aquifer test involved multiple wells, using test well TW-58 as the pumping well, and consisted of an initial step test followed by a three-day constant-rate test.

The step test and constant-rate test were conducted using a submersible pump installed in TW-58 capable of pumping between 50 and 500 gpm. A 1-inch diameter, PVC dip-tube was installed with the pump to allow use of a water-level probe. The pump intake was set in the well screen, at a depth of 45.6 feet bgs. The pump was equipped with a check valve to prevent water from returning to the well after the pump was turned off. The pumped water was routed to the non-contact cooling water ditch. An in-line totalizing flow meter was used during the test to measure pumping rates.

Twenty-four wells located in the southern Plant area were monitored prior to, during, and after the pumping test. The observation wells included: TW-07, TW-08, TW-09, TW-10, TW-53, and Harris well, located in the UBZ-1 and LBZ-1 regions; TW-22, TW-23, TW-24, and TW-37, located in the northern UBZ-2 and LBZ-2 regions; TW-19, TW-20, TW-21, TW-34, TW-35, TW-36, TW-39, TW-54, TW-55, TW-58 (the test well), located in the southern UBZ-2 and LBZ-2 regions; and

TW-11, TW-12, TW-38, and TW-56, located in the UBZ-3 and LBZ-3 regions. Water levels in the observation wells were measured using a combination of 5-pounds per square inch (psi) pressure transducers connected to automatic data loggers and an electric water-level probe.

Pre-test groundwater level monitoring, step test, and constant-rate test procedures and results are described below and in Appendix H-7.

Pre-Test Groundwater Level Monitoring For six days prior to the pumping test, water levels were monitored daily in TW-58 and in the observation wells to determine local variations in groundwater levels. Pre-testing water levels are used to identify if any trends or patterns exist in the water level data. If such features are identified, the test data can be corrected to remove extraneous effects prior to analysis.

Hydrographs for the test observation wells are presented in Appendix E of the "Phase II Remedial Investigation Revised Memorandum on Hydrogeologic Investigations" (Golder 1993b). This memorandum was prepared as an interim document for the Phase II RI and was reviewed by EPA during Spring 1993. The memorandum is included in this Phase II RI report as Appendix H-7.

In general, no trends or patterns were observed in the pre-test data to indicate that a data adjustment should be made prior to test analysis. The general absence of any trends or patterns is shown in the individual well hydrographs contained in Appendix H-7. The pre-test water level data in a few wells (e.g., TW-07, TW-11, TW-12) indicate the possible occurrence of groundwater recharge (increasing water levels) and fluctuations related to changes in atmospheric pressure. These latter fluctuations are identified by correlating atmospheric pressure data with water level measurements in monitoring wells. The correlation that occurs is inverse, i.e., increases in atmospheric pressure result in declining water levels and vice versa.

The water-level fluctuations observed in TW-07 correlate with atmospheric pressure changes, as recorded at the Soda Springs Airport. These data are shown on Figure 3-22. The magnitude of the water level changes caused by atmospheric pressure fluctuations was measured to be less than 0.3 ft, or less than 3.6 inches, in TW-07.

Based on the pre-test water level monitoring, it was concluded that data adjustments were not warranted prior to the test analysis. It was noted that a recharge effect may be present in the UBZ-3 groundwater region, which is east of the Monsanto Fault and was not affected by the test. It was also noted that although atmospheric pressure changes may have affected test data, such effects are minor in comparison to the magnitude of the drawdown observed during the test. Atmospheric pressure adjustments would result in changes to the drawdown data of generally less than 3 inches, whereas drawdown in many of the wells was measured to exceed several feet.

Analysis Assumptions In order to describe flow to a well and evaluate data obtained from pumping tests, assumptions are made about the test well and about the aquifer in which the test well is completed. The following assumptions generally apply to the analysis: the aquifer is assumed to consist of porous media; the aquifer is assumed to be confined, homogeneous, isotropic, and infinite in areal extent with a constant thickness throughout; the piezometric

surface is assumed to be horizontal over the area influenced by the test prior to the test; the pumping rate is assumed to be constant; the pumping-well diameter is assumed to be infinitesimally small; and the screened interval of the pumping well is assumed to fully penetrate the aquifer (Kruseman and de Ridder 1990).

Step Test The step test was conducted on December 8, 1992, to determine an appropriate pumping rate for the constant-rate test. The step test consisted of six one-hour steps, with a pumping rate increase after each step. The pumping rates for the steps was as follows: 98, 197, 307, 397, 510, and 543 gpm. The water-level drawdown in TW-58 during the step test is shown on Figure 3-23 along with the approximate pumping rate of each step. Three different methods of analysis were used to analyze the data from TW-58: Eden-Hazel (Eden and Hazel 1973); Theis recovery; and Cooper-Jacob (Freeze and Cherry 1979). Drawdowns of only one foot or less were observed in a few of the monitoring wells during the step test and were not analyzed.

The hydraulic conductivities obtained for the step test using the three analysis methods ranged from approximately 4,300 to 7,800 ft/d. In calculating the hydraulic conductivity, the aquifer thickness was assumed to be 10 feet, which is equal to the thickness of the gamma-4 interflow zone in the vicinity of test well TW-58.

After the pump was turned off, water levels were allowed to recover for approximately 22 hours. After 22 hours, the groundwater level in TW-58 recovered to within 14% of the original static water level and stabilized.

Constant-Rate Test The constant-rate test began on December 9, 1991, and consisted of a three-day pumping period followed by a recovery period. The pumping rate in test well TW-58 during the constant-rate test was 500 gpm. The drawdown observed in the UBZ at the end of the test (immediately before the pump was turned off) is shown on Figure 3-24. The maximum drawdown observed in each observation well is presented in Table 3-11. Drawdown and recovery in test well TW-58 is shown on Figure 3-25. The aquifer response to the constant rate test was observed primarily within the Plant boundaries. Hydrographs for the test period are provided in Appendix H for the wells monitored during the test. The well responses were analyzed to assess aquifer boundaries and aquifer hydraulic properties.

As shown by the constant-rate test data, the drawdown from the test ranged from 0 to 8 feet. The pattern was radial at early times during the test. At later times, however, the Monsanto and Subsidiary Faults acted as barrier boundaries, causing the zone of influence to become elongated between the faults. There was no drawdown due to pumping in either the UBZ-1 and LBZ-1 (west of the Subsidiary Fault), or the UBZ-3 and LBZ-3 regions (east of the Monsanto Fault) within the Plant boundaries. The drawdown responses observed in the observation wells in the southern UBZ-2 region were also indicative of no-flow boundaries. Drawdown in observation wells increased rapidly after approximately 100 to 300 minutes of pumping, indicating the presence of barrier boundaries.

South of the Plant, drawdown was observed in Harris well and TW-53. Both wells are believed to be located west of the Subsidiary Fault which, as determined from the geophysical survey, extends at least 1,300 feet south of the Plant. The pumping test results indicate the Subsidiary Fault does not fully impede groundwater flow south of the Plant. TW-56, which is located east

of the Monsanto Fault, was not affected by the test, indicating the Monsanto Fault is a barrier in this area. The Monsanto Fault was determined from geophysical survey results to extend at least 1,950 feet south of the Plant.

Also under investigation by the constant rate test was the hydraulic connection between the UBZ and LBZ regions. TW-21 is a monitoring well screened within the LBZ-2 region directly below TW-58, the test well. The drawdown response in TW-21 consisted of approximately 1.5 feet of drawdown. Thus, the constant rate test lowered the hydraulic head in the underlying LBZ-2 region, indicating a degree of hydraulic connection exists between the UBZ-2 and LBZ-2 in the vicinity of TW-58. Vertical permeability estimates were made from these data and are presented below.

Given the complex hydrogeological conditions, three analysis methods were used to analyze the constant rate test data for aquifer horizontal transmissivity and aquifer storativity. Two of these methods, Cooper-Jacob and Theis (Freeze and Cherry 1979) are conventional to pumping tests analysis. The third method, Stallman (Kruseman and DeRidder 1990), is less well known and applies to bounded aquifer conditions. Vertical hydraulic conductivity was also analyzed from the constant rate test data using a method presented by Neuman and Witherspoon (Kruseman and DeRidder 1990). These analyses and results are summarized below. Further details are provided in Appendix H.

Cooper-Jacob and Theis Analyses Both the Cooper-Jacob method and the Theis recovery method use the same assumptions as outlined above. The Cooper-Jacob method uses drawdown data obtained during pumping while the Theis recovery method uses data obtained during the recovery phase of the test. Because of boundary condition effects, the Cooper-Jacob method is most appropriate for analysis of the early-time pumping phase data, assuming other method assumptions are met. Likewise, the Theis recovery analysis is most appropriate for analysis of the late-time recovery phase data.

The Cooper-Jacob method resulted in hydraulic conductivity values ranging from 2,700 to 6,800 ft/d, assuming a 10 ft aquifer thickness. The hydraulic conductivity value obtained from TW-58 using the Theis recovery method was only 100 ft/d, which also assumed a 10 ft aquifer thickness. Recovery data for TW-58 are shown on Figure 3-26. Storativities ranged from 5.3×10^{-3} to 2.1×10^{-1} as calculated using the Cooper-Jacob method.

Stallman Analysis Given the proximity of the faults to the pumping well, a bounded aquifer solution was also considered for analysis of the pumping test data. The Stallman method is a means of analyzing aquifer tests that may be affected by one or more straight recharge or barrier boundaries (Kruseman and de Ridder 1990). The conditions for the UBZ/LBZ-2 groundwater region may be approximated by an aquifer bounded by two straight barrier boundaries (the Subsidiary and Monsanto Faults).

Pumping test data from TW-20 and TW-39 were analyzed using the Stallman method, providing an estimate of hydraulic conductivity of 1,400 ft/d (assumes 10 ft aquifer thickness) and a storativity of between 0.01 and 0.4. Type curves, pumping test data, and match points are shown for these two analyses on Figures 3-27 and 3-28. As shown on these figures, a poor match is obtained for the late-time data. There appears to be a third boundary or lower

conductivity zone intercepted by the zone of influence. Based on geologic data, it appears such a zone may occur in the vicinity of TW-36, approximately 1,000 ft north of the test well TW-58. In the vicinity of TW-36, the gamma-4 interflow zone may be discontinuous (Figure 3-10), or may become less permeable.

Vertical Hydraulic Conductivity The constant-rate test well responses for wells screened in the LBZ-2 were used in an analysis to determine vertical hydraulic conductivity between the LBZ-2 and UBZ-2 regions. Observations from TW-21 (LBZ-2) were analyzed using the Neuman and Witherspoon ratio method (Kruseman and de Ridder 1990). By this method it is assumed that TW-21 is screened within the aquitard of a leaky to very leaky aquifer and that the aquifer conforms to the Theis equation for early-times during the pumping test. The analysis resulted in an aquitard conductivity ranging from 0.014 to 1.44 ft/d and an aquitard specific storativity ranging from 10^{-7} ft^{-1} to 10^{-5} ft^{-1}.

3.7.2.4 Groundwater Infiltration

A proportion of the precipitation falling onto the land surface may percolate into the ground and migrate to groundwater. When this precipitation falls onto historic source areas at the Monsanto Plant, it has potential to transport constituents through the subsurface. This section provides an evaluation of the groundwater infiltration, or percolation rate, through the source areas. More detailed documentation of this analysis is also provided in Appendix L.

Five potential source areas were identified as being exposed to precipitation. These source areas include: 1) Old Underflow Solids Ponds; 2) Northwest Pond; 3) Coke and Quartzite Dust Slurry Pond; 4) Sealed Underflow Solids Ponds; and 5) Underflow Solids Piles. These source areas are identified on Figure 1-3.

The percolation rate through the selected source areas was determined using the HELP computer model. Details concerning the model algorithm are provided in Appendix L and in Schroeder et al. (1988). In summary, the model performs a sequential daily analysis to determine runoff, evapotranspiration, percolation, and lateral (subsurface) drainage for the desired site. The surface processes include: snowmelt, interception of rainfall by vegetation, surface runoff, and surface evaporation. The subsurface processes include: soil evaporation, plant transpiration, vertical unsaturated drainage, and lateral saturated drainage. The daily infiltration, or percolation, is determined from a surface water balance, calculated as daily rainfall plus snowmelt minus the sum of runoff and surface evaporation.

The model input data set was based on regional climatic data and the local site conditions. Precipitation and temperature data were obtained from a NOAA station which has been operated at the Soda Springs airport since 1978. These data were characterized as mean monthly values. Storm characteristics were assumed to resemble those for a monitoring station in Pocatello, Idaho. These data are included with the HELP model and of the available data, were considered the most reasonable for the Monsanto Plant. Based on these data and considering the latitude of the Monsanto Plant, daily values for temperature, precipitation, and solar radiation were simulated by the model. These simulated values are used in calculations to determine percolation over a 20 year period. This 20 year period is the maximum period handled by the HELP model, and is a reasonable approximation of the steady-state conditions.

Data for the local site conditions were used to assess the soil hydraulic properties and the configuration of each source area. Soil hydraulic data were obtained from default values for various soil classifications. Soil classifications for the source areas were determined by grain size distribution analyses and were correlated to the HELP model data set. Soil Conservation Service (SCS) runoff curve numbers were determined for each source area based on the soil type present at the surface, the slope, and the expected compaction of the surface layer.

The 20-year average for water budget parameters was determined for each of the source areas. These data are summarized in Table 3-12. As shown, over 85% of the precipitation falling onto a source area is returned to the atmosphere by evaporation. Anywhere from essentially none to about 15% may runoff the source area, possibly infiltrating to groundwater at another location. The average recharge that actually occurs directly through the source areas was estimated to range from 0.2 to 1.2 inches per year. This recharge constitutes from 1% to 8% of the annual precipitation. Considering the surface area of each source, the volumetric recharge rate was estimated to range from less than 0.1 to 2.0 gpm. Additional details concerning the modeling input and results are presented in Appendix L.

3.7.2.5 Horizontal Groundwater Flow

Groundwater flow directions and hydraulic gradients below the Monsanto Plant and general vicinity were determined from groundwater elevation data. These data, obtained primarily from monitoring wells, have been collected biannually since October 1991 and are provided in Appendix L. Groundwater elevation maps have been prepared for the UBZ and LBZ for May 1993 and are shown on Figures 3-29 and 3-30. Groundwater elevations shown on these maps are typical for the conditions at the Monsanto Plant over the past several years.

The groundwater flow direction within the Plant boundaries is generally to the south and southeast as shown on Figures 3-29 and 3-30. Both the Monsanto Fault and the Subsidiary Fault act as barriers to groundwater flow for their length beneath the Plant. The faults appear to direct groundwater in the UBZ/LBZ-2 and regions to the east toward the southeast. In the center of the Plant, the zone of influence of the Plant's production wells results in radial groundwater flow directions toward the wells. The Plant production well PW-04 located in the northwest corner also causes localized radial flow to the well.

South of the Monsanto Plant, influence of the Subsidiary and Monsanto Faults is diminished and the groundwater flow direction arcs toward the southwest. Groundwater flow ultimately discharges toward Soda Creek, the Bear River, and Alexander Reservoir.

Groundwater flow directions and hydraulic gradients are discussed below according to each of the groundwater regions.

UBZ-1 Groundwater in the UBZ-1 region flows primarily southward toward Soda Creek and Mormon and Calf springs (Figure 3-29). The hydraulic gradient in this region ranges from approximately 0.01 to 0.03. The Subsidiary Fault acts as a barrier to groundwater flow along the eastern boundary of this region.

UBZ-2 Groundwater in the UBZ-2 region flows toward the southeast and appears to be restricted by the Subsidiary Fault to the west and the Monsanto Fault to the east. The hydraulic gradient in this region ranges from approximately 0.005 to 0.008. The gradient is relativity flat in the west central area of the Monsanto Plant (near well TW-22) and in the south central area (near well TW-20). A steeper hydraulic gradient occurs in the vicinity of TW-57.

UBZ-3 Groundwater in the UBZ-3 region flows west until it encounters the Monsanto Fault and then proceeds to flow south. The hydraulic gradient in this region ranges from 0.009 to 0.07 with the steepest gradients in the vicinity of the production wells and the Finch Spring Fault. Some groundwater from the UBZ-3 region may be intercepted by Plant production wells PW-01, PW-02, and PW-03, located in the center of the Plant. The general movement of groundwater from this region, however, is off-site, toward Bear River and Alexander Reservoir.

UBZ-4 Groundwater in the UBZ-4 region flows to the southeast and the southwest, with the Monsanto Fault acting as a barrier to the west. The hydraulic gradient in this region ranges from 0.006 to 0.06. Pumping of Plant production wells PW-01, PW-02, and PW-03 creates a cone of depression in the UBZ-4 area, causing steep hydraulic gradients in the central part of the plant. The pumping wells also intercept groundwater flowing from the north, northwest, and northeast of the Plant. Operation of production well PW-04 also has created a small cone of depression in the northern portion of UBZ-4.

UBZ-5 Groundwater in the vicinity of Formation Spring and southwest of the spring forms groundwater region UBZ-5. In this region, groundwater flows in a southwesterly direction toward Bear River. Flow in the vicinity of Ledger Spring appears complicated due to the presence of several faults. Groundwater in this area also appears to generally flow to the southwest, with seepage at the base of the Finch Spring Fault scarp forming Finch, Boyscout, Spring Box, and Kelly Park springs.

LBZ-1 through LBZ-4 Groundwater flow in the LBZ is very similar to that in the UBZ, as shown on Figure 3-30. In the LBZ, groundwater flow is in a southerly direction with the horizontal hydraulic gradient ranging from 0.005 and 0.07. The hydraulic gradient is steepest in the vicinity of the production wells and near the Finch Spring Fault scarp.

Flow directions in the four LBZ regions, LBZ-1 through LBZ-4, correspond to flow in UBZ-1 through UBZ-4 regions, respectively. Groundwater flow is influenced by faulting, with both the Subsidiary Fault and the Monsanto Fault acting as barriers to flow beneath the Plant. Pumping of Plant production wells creates a cone of depression in the center of the Plant similar to that seen in the UBZ, indicating the wells intercept flow from the LBZ-4 region and, possibly, from the LBZ-3 region.

3.7.2.6 Vertical Groundwater Flow

The distribution of vertical hydraulic gradient between the LBZ and the UBZ in the vicinity of the Monsanto Plant is shown on Figure 3-31. The occurrence of a vertical hydraulic gradient indicates the potential for vertical groundwater flow. The direction and magnitude of the vertical hydraulic gradient was measured between wells at each well cluster and is also listed in

Table 3-13. The mid-points of the monitored intervals were used as measuring points for calculations of the vertical hydraulic gradients.

UBZ/LBZ-1 The vertical hydraulic gradient of this region was determined from wells in well cluster TW-09, which includes TW-07, TW-08, TW-09, and TW-10. Groundwater elevations indicate an upward hydraulic gradient ranging from 0.011 to 0.044 (Table 3-13). The upward hydraulic gradient in this region is consistent with observations of groundwater discharge, as seen by the many springs in this region.

UBZ/LBZ-2 Vertical hydraulic gradients in this region were determined using well clusters TW-45, TW-23, and TW-21. Magnitudes ranged from 0.001 to 0.11 (Table 3-13). There is a slight downward hydraulic gradient at well cluster TW-45, whereas, there is an upward component of hydraulic gradient at well cluster TW-21 (Figure 3-31). It is possible that the Plant's production wells have influenced the vertical gradient in well cluster TW-45.

UBZ/LBZ-3 Vertical hydraulic gradients in this region were determined using well clusters TW-11, TW-32, KM-10, KM-11, KM-12, KM-18, and KM-19. The KM well clusters are located on the Kerr-McGee Plant. The largest vertical gradient in this region occurred at KM-18, a downward hydraulic gradient of 0.25. There is a slight upward component of hydraulic gradient at well cluster KM-12.

UBZ/LBZ-4 Vertical hydraulic gradients in this region were determined using well clusters TW-18 and TW-44. A downward hydraulic gradient of 0.36 was estimated in the TW-44 well cluster, which occurs in the central area of the Plant and is influenced by the production wells. At well cluster TW-18, an upward hydraulic gradient of 0.007 was measured from monitoring wells TW-18 (LBZ-3) and TW-17 (UBZ-3). This latter gradient is considered to be more typical for the natural vertical gradient in the area as it was measured 2,000 feet northeast of the main production wells.

3.7.2.7 Groundwater Chemistry

As part of the RI investigation, general water quality parameters and isotopes were evaluated as a means of characterizing the hydrogeology of the Blackfoot Lava Field. Such data may be useful to determine the approximate age of groundwater and, based on other chemical signatures, to determine where groundwater recharge may have occurred and the pathways along which groundwater has traveled. Data collected in this regard are presented and interpreted in this section.

Inorganic Geochemistry Figure 3-32 is a piper diagram based on groundwater samples collected from locations which are upgradient of constituent releases at the Plant. The piper diagram characterizes the major ions in water which include: calcium, magnesium, sodium, potassium, chloride, sulfate, and carbonate. Analytical results for these major ions are also provided in Table 3-14. Concentrations in Table 3-14 represent mean values of samples collected at each location; data in some cases were available since 1979.

Sample results shown on the piper diagram indicate the proportions of the major ions in the samples are very similar. This observation indicates the samples are likely to represent

groundwater that is generally in equilibrium with the same types of minerals. The mineral contents of the groundwater, as measured by total dissolved solids, varies among the samples from about 400 mg/L to 1,000 mg/L, indicating greater mineral dissolution has occurred in different parts of the flow system (Table 3-14). Greater dissolution may occur where the pH is locally lower than other locations or if the groundwater has traveled for longer periods in the aquifer.

For this case, the high mineral contents correspond to sodic groundwater (discussed below), which is noted to have high concentrations of carbon dioxide (CO_2). The CO_2 forms carboxylic acid, a weak acid, which may enhance the dissolution of silicate minerals formed in the basalt, causing the higher total dissolved solids concentrations.

Carbon Dioxide As mentioned above, parts of the groundwater flow system in the Soda Springs area contain high concentrations of dissolved CO_2. Partial pressures of CO_2 in these waters were determined based on a nomograph method described in Standard Methods (Clesceri et al. 1989). The values obtained are reported in Table 3-14 and ranged from 10 mg/L to 2,400 mg/L free CO_2, which is equivalent to CO_2 partial pressures of 0.02 to 0.25 atmospheres (atm). This concentration range is much greater than would occur in groundwater in equilibrium with earth's atmosphere (i.e., 0.3% CO_2).

The origin of the CO_2 has not been fully explained. Biological (Hutsinpiller and Parry 1985) and geothermal (Mayo et al. 1985) origins have been proposed. Mayo, A.L. (Personal communication February 2, 1994) has recently suggested that CO_2 gas originates at depth due to geological processes (metamorphism) and migrates upward through younger water, degassing to the atmosphere.

The occurrence of CO_2 in groundwater creates both a high mineral content, as measured by total dissolved solids, and also causes the water samples to effervesce. Hooper Spring, which is a historical cultural resource is famous in part for its high CO_2 concentration. These occurrences of high-CO_2 regions have been designated as regions of "sodic" groundwater, whereas other regions where CO_2 concentrations are much lower have been designated as "fresh" groundwater. Wells and springs used for control purposes at the Monsanto Plant have been classified as either fresh or sodic based on dissolved CO_2 content as listed in Table 3-14.

Groundwater classified as fresh is characterized primarily by relatively low dissolved CO_2 concentrations less than 450 mg/L. Sodic groundwater is characterized by CO_2 concentrations greater than 700 mg/L. Sodic water also generally has a slightly lower pH (less than 6.5) than fresh water.

Bicarbonate alkalinity correlates closely with dissolved CO_2 and was used as an indicator of dissolved CO_2 in groundwater. Fresh and sodic groundwater beneath the Monsanto Plant was subsequently identified based on the bicarbonate alkalinity. This method enabled historic data to be used to compute average bicarbonate alkalinity concentrations.

The distribution of bicarbonate in the UBZ and LBZ is shown on Figures 3-33 and 3-34. A value of 700 mg/L was designated as the upper limit for fresh groundwater. As seen on Figure 3-33, fresh water is the prominent groundwater type found in the UBZ in the vicinity of the Plant.

Sodic water in the UBZ is generally found in the northwest and southwest corners of the Plant. In the LBZ, sodic water is found on the west side of the Plant (Figure 3-34) while fresh water is found to the east. The occurrences of sodic groundwater appear to be related to faulting and also increase with depth. These relations indicate that CO_2 may migrate from depth along faults and fractures to the surface.

Tritium Tritium, or H_3, is a radioactive isotope of hydrogen. It occurs naturally in the atmosphere in small amounts and decays by 50% every 12.3 years. Large amounts of man-made tritium entered the atmosphere in 1952 due to nuclear testing. Tritium from nuclear testing provides a qualitative estimate of groundwater age for groundwater younger than 1952. If tritium is found in detectable concentrations in groundwater samples, it can be assumed the age of the groundwater is less than about 42 years (1994-1952). The results of tritium data collected at the Monsanto Plant in 1991 range from 1.5 to 25.7 tritium units (TUs), as shown in Table 3-15. These results indicate the groundwater to be relatively young, with the oldest water less than 42 years old.

Carbon-14 Carbon-14 is a naturally occurring radioactive isotope of carbon. During the Phase I RI, carbon-14 data were used for groundwater age dating following the examples of previous studies in the region completed by Ralston et al. (1983) and Mayo et al. (1985). The age dating indicated that some waters (for example Hooper Springs and Formation Springs) to be very old, on the order of 10,000 years (Table 3-14). However, minor tritium concentrations were also found in these waters suggesting limited mixing with more recent recharge.

Since the Phase I investigation, it has been proposed that CO_2 gas originates at depth and while migrating to the surface is dissolving into younger groundwater (Dr. Alan Mayo, personal communication). The CO_2 is presumably very old and does not contain any carbon-14. Consequently, the newly dissolved CO_2 lowers the proportion of carbon-14 in the water, which causes the water to appear very old. Given this hypothesis, groundwater age-dating using carbon-14 may be only partially conclusive in determining representative groundwater ages.

Oxygen-18 and Deuterium Oxygen-18 and deuterium are stable, or non-radioactive, isotopes used as chemical signatures in groundwater. Results for these isotopes are presented in Table 3-15. These isotopes can be used to indicate recharge areas to groundwater systems in mountainous areas, as they are sensitive to elevation (i.e., precipitation and temperature).

Oxygen-18 and deuterium results for samples collected from Doc Kackley Spring, Hooper Spring, and TW-10 ranged from -17.0 to -17.2 per mil for oxygen-18 and from -132 to -133 per mil for deuterium. The same results for samples collected from Formation and Ledger Springs ranged from -17.6 to -18.0 per mil and -136 to -142 per mil, respectively. These data indicate there is a significant difference in the isotope concentrations of these waters, which also indicates there are differences in the source waters to these regions. It is possible the groundwater on the west side of the Monsanto Plant is recharged to the west, whereas recharge to Formation and Ledger Springs is considered to originate east of the Blackfoot Lava Field (although recharge to Ledger Springs must first flow through the Blackfoot Lava Field to reach the spring).

3.7.3 Groundwater Flow Modeling

As part of Phase II RI activities, a groundwater flow model was developed for the shallow aquifer in the Blackfoot Lava Field. This model provided input to evaluations of solute transport, which are discussed in Chapter 5. Additional details on groundwater modeling are provided in Appendix L.

The groundwater flow model applies to the regional shallow-aquifer in the Black Foot Lava Field. The model includes representation of the primary hydrologic features of the Black Foot Lava Field. It can be used to evaluate the plausibility of the conceptual model. It can also be used to provide estimates of average groundwater velocity in parts of the Lava Field and to estimate boundary conditions for a smaller site-scale model. The regional model does not include representation of faulting. Faulting is known to occur in the Black Foot Lava field and to locally influence groundwater flow direction. Because faulting is not included in the model, the model cannot be used for detailed analysis of groundwater flow within the Monsanto Plant fenceline.

The groundwater flow modeling utilized a computer program called FLOWPATH (Franz and Guiguer 1992). FLOWPATH models the flow of groundwater based on the physics of two-dimensional saturated groundwater flow in a porous medium under steady-state conditions. The procedures to construct a computer model of groundwater flow include the following:

- Development of a conceptual hydrogeologic model;
- Gathering of input data;
- Model setup and calibration; and
- Presentation of results.

The input data and the results obtained from groundwater flow modeling activities are presented below.

3.7.3.1 FLOWPATH Modeling Input Data

In modeling the groundwater flow in the vicinity of the Monsanto Plant, a conceptual hydrogeologic model of the Blackfoot Lava Field was developed. The conceptual model includes the entire Blackfoot Lava Field, extending from the Bear River north to the Blackfoot Reservoir as shown on Figure 3-35.

In the area of the Monsanto Plant, the Blackfoot Lava Field contains two aquifers, the UBZ and the LBZ. The shallow aquifer, the UBZ, dominates the flow system and consists of one to three interflow zones in close proximity to one another. The total thickness of the interflow zones in the UBZ appears to average 30 feet, although individual interbed thicknesses may be on the order of 2 to 20 feet. The deeper aquifer, the LBZ, also occurs within interflow zones but is of much lower permeability, and consequently, conducts much less water through the groundwater flow system. The two aquifers are weakly connected through the intervening dense basaltic materials. In the computer model of groundwater flow only the shallow aquifer is considered.

In constructing the computer model, the UBZ was assumed to extend throughout the Blackfoot Lava Field. The aquifer abuts sedimentary materials along the margins of the Blackfoot Lava Field and in the area of Threemile Knoll, located northeast of the Monsanto Plant (Figure 3-35). These areas were incorporated into the groundwater flow model by adjusting the hydraulic conductivity. The hydraulic conductivity of the sedimentary materials is observed to be much less than that of the interflow zones. The hydraulic conductivity of the UBZ was estimated from hydrogeological tests to average 400 ft/d, whereas, the hydraulic conductivity of the sediments along the margins of the Blackfoot Lava Field was estimated to be about 40 ft/d. These hydraulic conductivities were incorporated into the groundwater flow model as shown on Figure 3-36.

Input data for the FLOWPATH model consist of the following:

- Aquifer type;
- Aquifer thickness;
- Aquifer hydraulic conductivity;
- Aquifer porosity;
- Boundary conditions of either constant head or constant flux;
- Discharge or recharge rates to represent springs; and
- Discharge rates for pumping wells.

Because the FLOWPATH model uses a numerical method to solve the groundwater flow equation, it is necessary to locate the input data onto a grid. The grid is overlain onto the Blackfoot Lava Field and then the necessary features are located onto the grid, or to the nearest grid intersection. The grid size used in the FLOWPATH model was 2,500 feet by 2,500 feet. Detailed computer output documenting the input data is provided in Appendix L. Data input files are also contained in machine readable form on diskette.

Aquifer Type and Thickness As discussed above, only the shallow basalt aquifer was modeled using FLOWPATH. In constructing the model, the aquifer type was assumed to be confined as a simplifying assumption. By making this assumption, it was possible to specify a single aquifer thickness for the entire model area, which is an important convenience given the limited data that exist away from the Monsanto Plant. This thickness was estimated to be 30 feet based on model calibration and data for the Monsanto Plant area. One drawback to selecting the confined aquifer type is related to areal recharge to the aquifer. In the Blackfoot Lava Field, recharge to groundwater likely occurs through the valley interior. This recharge cannot be directly represented by the confined aquifer type and was indirectly added to the aquifer through the boundary conditions.

Hydraulic Conductivity The hydraulic conductivity of the shallow basalt aquifer was varied in space to represent heterogeneity of the aquifer materials. The heterogeneity occurs where the aquifer host rock changes from volcanic interflow zones to sedimentary rock along the Blackfoot Lava Field margins. The final spatial distribution of hydraulic conductivity reflects this heterogeneity and was obtained by calibration. This distribution is shown on Figure 3-36.

Porosity Aquifer porosity was estimated as a single value over the entire model area. This parameter was assigned a value of 0.30. The porosity is used to determine pore water velocity

of the groundwater, thus, it represents an effective porosity value. The value of 0.3 was obtained partly through calibration after assuming a range of porosity from 0.15 to 0.3 for the interflow zone materials. The value of 0.3 was finally used due to the high pore water velocities predicted by the computer model. The value of 0.3 resulted in the smallest velocities, given the range of porosity values. The value of porosity has no effect on the solution to the groundwater flow equation.

Boundary Conditions Boundary conditions determine the flow of groundwater across the edges of the model area. The boundary conditions, shown on Figure 3-37, include constant head boundaries at Blackfoot and Alexander Reservoirs, constant flux boundaries along the Aspen Range, Ninety Percent Range, and Bear River, and no-flow, or zero flux, boundaries along the northeast, southeast, and northwest segments. The constant head values for the reservoirs were obtained from the United States Geological Survey 1:100,000 metric topographic map for Soda Springs. Constant flux values for the Aspen Range and Ninety Percent Range were estimated based on watershed area, annual precipitation (20 inches/year), and an assumed infiltration rate (15%). These flux values were increased slightly to represent infiltration recharge occurring in the valley interior and as part of the model calibration. Constant flux values into the Bear River were developed entirely through model calibration. The gradation in the flux values from east to west along the Bear River was developed in part to represent Big Spring Creek, which was not specifically represented by the model due to its proximity to Alexander Reservoir and Bear River.

Infiltration Recharge Precipitation onto the land surface of the Blackfoot Lava Field may infiltrate the ground and become a component of groundwater recharge. In the FLOWPATH model, this component of groundwater recharge was not explicitly represented. Rather, the "equivalent" amount of recharge was added to the model *boundary conditions*, as discussed above. This amount was never determined, but was assumed to be properly defined based on calibration of the model to field measurements of hydraulic head. Infiltration recharge was not explicitly represented because the model assumed a confined aquifer condition and, as a limitation of the FLOWPATH software, vertical leakage or infiltration to a confined aquifer is not possible. This simplification to the model results in steeper hydraulic gradients along the model boundaries, as a greater rate of recharge occurs in the model than in the actual groundwater flow system. In the area of the Monsanto Plant, however, this effect is considered to be negligible, as the Plant is located centrally in the valley.

Wells and Springs Also shown on Figure 3-37 are wells and springs represented in the computer model. These features are represented by one or more pumping or injection wells in the computer model. Fivemile Meadows is represented by five pumping wells that withdraw an estimated 15.5 cfs from the UBZ. This flow rate was partially established through calibrating the model. Formation Spring is represented by four injection wells that recharge 20 cfs into the aquifer. This flow rate is an estimate made in the field by Golder, as no gaging of the Spring exists, and is also partially based on model calibration. Ledger Spring was represented by a single pumping well withdrawing 5 cfs from the aquifer, a rate approximately 1.5 times greater than the City of Soda Springs demand from the Spring. The City of Soda Springs withdraws about 2 MGD from both Ledger Spring and from Formation Spring. Aquifer withdrawal from pumping wells is only known to occur at the Monsanto Plant (besides possibly other small

domestic users to the south). The four production wells at the Monsanto Plant were represented by a single well, pumping at an equivalent rate of 3.1 cfs.

3.7.3.2 Groundwater Flow Modeling Results

Results from the FLOWPATH modeling of the regional groundwater flow system are summarized here. A detailed discussion is provided in Appendix M. A groundwater elevation contour map of the Blackfoot Lava Field produced by FLOWPATH is shown on Figure 3-38. This map was obtained in part by matching the model output to a groundwater elevation map produced by Dion (1974) based on water levels in wells (Figure 3-18). The main departures between the contouring shown on Figures 3-38 and 3-18 occurs along the west side of the Blackfoot Lava Field. It appears field data are limited in this area. The FLOWPATH results along the west side of the model are strongly influenced by the no-flow boundary segment in the northwest, which was added to the model based on interpretation of the watershed.

Figure 3-39 shows groundwater velocity vectors throughout the model area as determined by FLOWPATH. The highest groundwater velocity occurs in the vicinity of the Monsanto Plant and is estimated as 26 ft/d. This calculated velocity appears higher than actual. Based on Phase II RI field data from the Monsanto Plant area (discussed above in Section 3.7.2.3), the linear groundwater velocity in the UBZ is about 5 ft/d. The high calculated velocity may be due to an overestimation of the flow rate from Formation Spring, as this flow rate was based on visual estimation. The relatively large groundwater velocity in the vicinity of the Monsanto Plant, and to the south of the Plant, was expected. Relatively low-permeable sedimentary materials reduce the extent of the UBZ in this area and constrict the flow of groundwater as shown on Figure 3-36, causing increased velocities.

Figure 3-40 presents groundwater pathlines generated from the FLOWPATH model. This output was generated by simulating the release of particles near the Monsanto Plant and allowing the computer model to track their progress through the aquifer. Ultimately, the particles discharge from the aquifer to Bear River and Alexander Reservoir. The average groundwater velocity along the pathlines was estimated as 10 ft/d. Based on this velocity, the average travel time for groundwater to reach the discharge locations from the Plant's southern fence-line is about four years.

As discussed in earlier hydrogeologic investigations of the Monsanto Plant (Golder 1985) and in this RI, faulting influences the groundwater flow direction in the area of the Monsanto Plant, and likely at other locations within the Blackfoot Lava Field. Faulting was not represented in the computer model for simplification. The addition of faults to the computer model may affect the pathline predictions. Thus, pathlines shown on Figure 3-40 in the vicinity of the Monsanto Plant are not representative of the actual groundwater flow directions. To the south, however, the computer-generated pathlines may be representative of the overall off-site flow system and discharge locations, as the displacement of the faults underlying the Plant decrease to the south.

3.8 Ecology

This section provides a description of the potential receptors, both humans and wildlife, that exist in and around the Monsanto Plant.

3.8.1 Population

Caribou County is largely rural, with a population density of approximately four people per square mile. 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).

The City of Soda Springs 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 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).

The Monsanto Plant is located less than one mile north of the City of Soda Springs and employs approximately 400 people. The Kerr-McGee plant employs approximately 80 people. 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

3.8.2 Land Use

3.8.2.1 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-zoning map for Caribou County designates the area surrounding the Monsanto Plant, and other areas north of the City of Soda Springs, as heavy industrial as shown on Figure 3-41. 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 designated as unallocated by the County Planning Board (Wright, B., Golder [Memo to Monsanto Soda Springs Phase I RI file] November 12, 1991).

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.

3.8.2.2 Local Land Use

Land zoning within the City of Soda Springs 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 as shown on Figure 3-42. 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 (Title 17, Soda Springs 1990):

- Agricultural Use, designated A-1, includes agriculture, golf courses, single-family residential areas on the fringe of the community; and areas important for the preservation of rural standards;

- Single-Family Residential Use, designated R-1, includes low-density, single-family dwellings;

- Combined Residential Use, designated R-2, includes medium-density, single-family and multiple-family dwellings, limited to not more than four units;

- Multiple-Family Residential Use, designated R-3, includes medium-to-high-density residential developments, limited to not more than six units, and includes hospitals, boarding houses, convalescent homes, etc.;

- Neighborhood Commercial, designated C-1, includes local commercial services, restricts incompatible uses or highway-oriented shopping areas from residential neighborhoods;

- Community Commercial, designated C-2, includes general shopping center retail services and travel- or highway-related services;

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

- Heavy Industrial, designated M-2, includes heavy industrial uses substantially free from residential or retail commercial activities.

The Monsanto Plant is located outside Soda Springs City limits. Before Monsanto purchased the land in 1952, the area where the Monsanto Plant is located was primarily agricultural, with crops of wheat and hay. 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 put into operation by Monsanto 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 present land use within the boundaries of the Monsanto Plant is industrial. In addition, Monsanto owns the agricultural land to the south and southwest of the Plant.

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 Kerr-McGee Plant.

Land within 1.6 miles (2 kilometers) around the Monsanto Plant was assessed to determine which properties were presently being used for agricultural (crop and livestock) purposes. The owners or tenants of agricultural properties were interviewed. Land uses were broken down into several categories including: crop use; livestock use; Conservation Reserve Program (CRP) - a federally funded program which allows land to be non-productive for 10 years; non-agricultural use; and uncertain use (a drive-by survey was conducted but the owner or tenant was not available for an interview). Results of this survey are shown on Figure 3-43 and are summarized in Table 3-16. The Monsanto and Kerr-McGee Plants are surrounded by open agricultural land, primarily crop land. The primary crops are barley and wheat. The land-use survey is presented in greater detail in Appendix M.

In addition to the land-use assessment, an informal evaluation of residential garden production was conducted for the region. The University of Idaho Cooperative Extension System in Soda Springs was contacted and information was provided by Darlene Moss - Extension Home Economist for Caribou County. The types of crops typically grown in residential gardens include beans, lettuce, spinach, beets, carrots, peppers, some corn, peas, squash, pumpkins, potatoes, tomatoes, apples, raspberries, strawberries, and cucumbers. The growing season is from late May and early June to late August, a growing season length of 75 to 95 days.

3.8.3 Water Use

3.8.3.1 Surface-Water Use

Regional water use includes water storage, irrigation and hydroelectric power. 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 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).

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. A weir is located approximately 100 feet downstream of this discharge point and 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 (Table 3-17) (Ecology and Environment 1988a).

3.8.3.2 Groundwater Use

Groundwater uses in the vicinity of the Monsanto Plant include drinking water, irrigation, heating, industrial, and stock watering. Groundwater is obtained from both wells and springs.

The Monsanto Plant drinking water is supplied by production well PW-04, located on the northern boundary of the Plant. Three other production wells (PW-01, PW-02, and PW-03) are located at the Plant and are used to supply process water through a separate, dedicated, distribution system.

Kerr-McGee previously used an on-site well for drinking-water purposes, serving 80 employees. The Kerr-McGee plant is now supplied by the City of Soda Springs.

The sources of drinking water for the City of Soda Springs are Ledger Spring and Formation Spring. Ledger Spring consists of several springs, each contained within a spring house, located one-half mile northeast of Soda Springs as shown on Figure 2-9. These springs are located hydraulically across-gradient from the Monsanto Plant and, based on hydrogeological interpretation are not threatened from potential sources of constituent releases from the Monsanto Plant. Formation Spring is located four miles northeast of the city and is hydraulically upgradient of any known potential sources of constituent release from the Monsanto Plant. An estimated 3,000 people are served by these sources (Ecology and Environment 1988a).

Big Spring, located south of the City of Soda Springs, supplies drinking water and industrial-use water to the Clear Springs Trout Company fish hatchery before discharging into Big Spring Creek.

Several other springs exist in the vicinity of the Plant. Hooper, Southwest, Doc Kackley, Calf, Mormon (A, B, and C), and Homestead Springs are located to the west and southwest of the Plant. Finch, Boyscout, and Spring Box Springs are located to the southeast. Of these springs, Hooper is used for cultural purposes and is discussed below; Southwest, Doc Kackley, Mormon (A, B, and C), Calf and Homestead springs may have been used in the past for stock watering but are not presently used; and Finch, Boyscout and Spring Box are not used for any specific purposes.

As part of Phase I and II RI activities, a well inventory of the Soda Springs area (covering 24 square miles) was conducted to determine the number, location, and use of wells located in the vicinity of the Monsanto Plant. The area covered in this inventory includes wells that withdraw groundwater downgradient of the Plant, and upgradient wells that may potentially be used to obtain background groundwater quality data. The owners of downgradient wells within approximately 2.5 miles of the Plant were interviewed and the wells were field-checked to verify location and use. This downgradient area represents the area that could potentially be affected by groundwater flowing south from the Monsanto Plant before discharging into Soda Creek, Bear River, and Alexander Reservoir. The inventory does not include monitoring wells owned by Monsanto or Kerr-McGee. The information from this inventory will determine areas of future groundwater monitoring.

Well uses were broken down into several categories including: domestic, heating, industrial, stock watering, testing, de-watering, and irrigation. The results of this survey are summarized in Table 3-18. The well ID numbers in Table 3-18 correspond to well locations shown on Figure 3-44. Results of the survey indicate the majority of wells considered in the well inventory are for domestic use. Secondary uses include irrigation and stock watering. The well inventory is discussed in detail in Appendix P.

As shown on Figure 3-44, the nearest well located downgradient of the Monsanto Plant is Lewis well. The Lewis well, located approximately 2,000 feet downgradient of the Monsanto Plant, is currently only used for livestock watering and irrigation purposes.

3.8.4 Cultural Resources

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.

3.8.5 Wildlife

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 Sections 3.8.5.1 and 3.8.5.2, 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 Section 3.8.5.3.

3.8.5.1 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 a 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.

3.8.5.2 Fauna

The Idaho Fish and Game Department identifies several big-game species in the vicinity of the Monsanto Plant, 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 12, 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 and 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 and Alexander Reservoir area south of the City of Soda Springs. White pelicans feed in Alexander Reservoir in the summer months only. Waterfowl are know to use the 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 and Bear River area for a wintering ground. (Lobdell, C. FWS-BFS, [Letter to W. Wright, Golder] December 2, 1991).

3.8.5.3 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, and 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 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.

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TABLE 3-1

MONSANTO PRODUCTION WELL INFORMATION

Well	Flow Rate (gpm)	Pumping Duration (hr/day)	Pumping Status	Water Storage Prior to Use	Well Uses	Point of Discharge
PW-1	900	12	intermittent	water tower[1]	process water and non-contact cooling water	seal water pond (recycled) and Soda Creek
PW-2	660	varies	seldom	water tower[1]	process water and non-contact cooling water	seal water pond (recycled) and Soda Creek
PW-3	1000	24	continuous	water tower[1]	process water and non-contact cooling water	seal water pond (recycled) and Soda Creek
PW-4	300	24	continuous	none	drinking water, showers, and washing	City of Soda Springs Sanitary Sewer (on-site sewage evaporation ponds prior to Oct. 13, 1993)

[1] Water from PW-1, PW-2, and PW-3 is pumped to a shared water tower prior to use.

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TABLE 3-2

SUMMARY OF 1990 WIND DATA COLLECTED AT THE MONSANTO PLANT

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

1216crh1.3-2

TABLE 3-3

SUMMARY OF 1991 WIND DATA COLLECTED AT THE MONSANTO PLANT

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

1216crh1.3-3

TABLE 3-4

SUMMARY OF AIR TEMPERATURE DATA FOR THE MONSANTO PLANT

1990	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Tmin(°C)	-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
Tmax(°C)	7.9	4.3	11.4	20.6	21.1	30.8	30.3	30.3	29.6	21.8	14.7	9.8	31.7
Tavg(°C)	-4.7	-6.8	0.9	7.0	8.4	14.5	18.9	18.9	15.8	4.1	0.5	-10.9	5.5
1991	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Tmin(°C)	-25.4	-14.4	-15.1	-5.3	-2.5	1.3	3.2	5.5	-2.7	-15.4	-24.2	-25.5	-25.5
Tmax(°C)	2.8	8 6	12.2	17.8	20.3	24.8	29.9	29.7	26.6	23.3	9.5	7.6	29.9
Tavg(°C)	-7.6	-2.1	-0.3	2.9	7.6	14.1	18.5	18.5	12.0	5.9	-2.3	-7.4	5.0

1216erh1.3-4

TABLE 3-5

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 3-5 (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			

1216cth1.3-5

TABLE 3-6

CONTROL SOIL SAMPLE LOCATIONS AND CORRESPONDING SOIL MAP UNITS

Sample Station Identification (Figure 2-6)	Soil Map Unit
D-2	485A: Lantonia-China Hat Complex, 1 to 4 percent slopes
B-2, D-1	485C: Lantonia-Crow Creek Complex, 4 to 12 percent slopes
A-1, F-1	700A: Rexburg-Ririe Complex, 1 to 4 percent slopes
A-2, F-2	700B: Rexburg-Ririe Complex, 4 to 8 percent slopes
G-1	700P: Rexburg silt loam, 1 to 4 percent slopes
Back-1, Back-2, Back-3, KM Back-5, KM Back-6, KM Back-7 B-1, B-2, C-1, C-2, E-1, E-2	705A: Rin-Lantonia Complex 1 to 4 percent slopes

1216cth1.3-6

TABLE 3-7

BREAKDOWN OF WELLS BY GROUNDWATER REGION

WELL	MONITORED INTERVAL (ft bgs)	GROUNDWATER REGION	REGION	COMMENTS
TW-1	120-300	LBZ	-	well abandoned
TW-2	75-260	UBZ, LBZ	4	well open over full depth
TW-3	178-250	LBZ	-	well abandoned
TW-4	104-126	LBZ	-	well abandoned
TW-5	194-221	LBZ	-	well abandoned
TW-6	104-126	UBZ	-	well abandoned
TW-7	40-60	UBZ	1	
TW-8	74-90	UBZ	1	
TW-9	236-251	LBZ	1	
TW-10	19-24	UBZ	1	
TW-11	127-137	LBZ	3	
TW-12	84-102	UBZ	3	
TW-13	79-96	SLZ	-	
TW-14	12-25	SDZ	-	
TW-15	48-60	UBZ	4	
TW-16	67-76	UBZ	4	
TW-17	96-115	UBZ	4	
TW-18	219-238	LBZ	4	
TW-19	23-30	UBZ	2	
TW-20	35-44	UBZ	2	
TW-21	105-122	LBZ	2	
TW-22	104-112	UBZ	2	
TW-23	170-190	LBZ	2	
TW-24	73-92	UBZ	2	well affected by grout
TW-25	178-191	LBZ	-	well abandoned
TW-26	136-142	UBZ	4	
TW-27	88-95	UBZ	-	well abandoned
TW-28	76-89	UBZ	4	
TW-29	40-47	UBZ	4	
TW-30	62-69	UBZ	4	
TW-31	23-31	UBZ	3	
TW-32	151-181	LBZ	3	
TW-33	67-75	UBZ	3	
TW-34	68-74	UBZ	2	
TW-35	71-89	UBZ	2	
TW-36	48-54	UBZ	2	
TW-37	93-100	UBZ	2	

TABLE 3-7 (Cont.)

BREAKDOWN OF WELLS BY GROUNDWATER REGION

WELL	MONITORED INTERVAL (ft bgs)	GROUNDWATER REGION	REGION	COMMENTS
TW-38	90-102	UBZ	3	
TW-39	48-56	UBZ	2	
TW-40	82-89	UBZ	4	
TW-41	55-68	UBZ	4	
TW-42	76-89	UBZ	4	
TW-43	80-89	UBZ	4	
TW-44	129-148	LBZ	4	replaced TW-44
TW-45	214-228	LBZ	2	
TW-48	65-71	UBZ	4	
TW-49	73-82	UBZ	4	
TW-50	73-89	UBZ	4	
TW-51	37-51, 90-158	UBZ, LBZ	4	no well casing installed
TW-53	18-32	UBZ	1	
TW-54	37-52	UBZ	2	
TW-55	52-67	UBZ	2	
TW-56	85-98	UBZ	3	
TW-57	21-35	UBZ	2	
TW-58	37-52	UBZ	2	
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

1216crh1.3-7

TABLE 3-8

RESULTS OF 1984 SINGLE-WELL HYDRAULICS TESTING[a]

Test Well Number	Analysis Method	Transmissivity (ft^2/d)	Hydraulic Conductivity (ft/d)	Monitored Interval Thickness (ft)	Hydro-stratigraphic Zone
TW-3	Jacob Jacob Theis Recovery	2,350 1,630 1,730	33 23 24	72	LBZ
TW-4	Hvorslev	11.1	0.5	22	LBZ
TW-5	Jacob Theis Recovery	14.3 10.7	0.5 0.4	27	LBZ
TW-6	Jacob Theis Recovery	8,670 9,690	394 440	22	UBZ
TW-7	Jacob Theis Recovery	477 538	24 27	20	UBZ
TW-8	Hvorslev		0.7	16	UBZ
TW-9	Hvorslev	6.9	0.5	15	LBZ
TW-10	Jacob Theis Recovery	2,650 2,250	530 450	5	UBZ
TW-25	Hvorslev	0.46	0.04	13	LBZ
TW-34	Hvorslev	1.76	0.3	6	UBZ

[a]Modified from Golder (1985)

NOTES:

Jacob = Jacob Semi-Log Analysis
Theis Recovery = Theis Recovery Method
Hvorslev = Modified Hvorslev Method
LBZ = Lower Basalt Zone
UBZ = Upper Basalt Zone

1216crhl.3-8

TABLE 3-9

SLUG TEST AND SHORT-TERM PUMPING TEST RESULTS

WELL	TYPE OF TEST AND METHOD OF ANALYSIS	GROUND-WATER REGION	T (ft^2/d)	K (ft/d)	AVERAGE K (ft/d)	MONITORED INTERVAL THICKNESS (ft)
TW-53	Slug Test - Hvorslev	UBZ-1	220	18.5	42	11.9[a]
TW-53	Slug Test - Theis (recovery) (30 sec. pump duration)		587	49		11.9[a]
TW-53	Slug Test - Theis (recovery) (45 sec. pump duration)		692	58		11.9[a]
TW-54	Slug Test - Hvorslev	UBZ-2	33	2.2	5.4	15.0
TW-54	Slug Test - Theis (recovery) (30 sec. pump duration)		83	5.5		15.0
TW-54	Slug Test - Theis (recovery) (45 sec. pump duration)		129	8.6		15.0
TW-55	Short-Term Test - Jacob (drawdown)	UBZ-2	5,875	379	448	15.5
TW-55	Short-Term Test - Theis (recovery)		8,006	516		15.5
TW-56	Slug Test - Hvorslev	UBZ-3	3	0.2	0.28	13.5
TW-56	Slug Test - Papadopoulos & Cooper		10	0.8		13.5
TW-56	Slug Test - Theis (recovery) (30 sec. pump duration)		0.53	0.04		13.5
TW-56	Slug Test - Theis (recovery) (45 sec. pump duration)		0.77	0.06		13.5
TW-57	Short-Term Test - Jacob (drawdown)	UBZ-2	4,824	341	509	14.1
TW-57	Short-Term Test - Theis (recovery)		9,547	676		14.1

[a]Saturated thickness at time of test (Nov. 10, 1992). Actual filter-pack thickness is 14.5 feet.

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TABLE 3-10

SUMMARY OF HYDRAULIC CONDUCTIVITY BY INTERFLOW ZONE
AS DETERMINED FROM SINGLE-WELL HYDRAULICS TESTING

Well	Gamma Interflow Zone	K Measured Range (ft/d)	K Average (ft/d)
TW-10	5	2,250 to 2,650	2,450
TW-57		341 to 676	509
TW-53		18.5 to 58	42
TW-07	4	447 to 538	493
TW-54		2.2 to 8.6	5.4
TW-08	3	11.1	11.1
TW-34		1.76	1.76
TW-56		0.04 to 0.8	0.28
TW-55		379 to 516	448

[a] Estimated range considering method assumptions.

1216cth1.310

TABLE 3-11

CONSTANT RATE AQUIFER TEST WATER-LEVEL INFORMATION

Well	Water Level Below MP Prior to Pump Test[a] (ft)	Water Level Below MP at End of Pumping[b] Period (ft)	Drawdown at End of Pump Test (ft)
UBZ-1 AND LBZ-1 REGIONS			
TW-7	15.63	15.49	-0.14
TW-8	15.08	14.96	-0.12
TW-9	9.62	9.80	0.18
TW-10	16.24	16.08	-0.16
TW-53	22.41	22.45	0.04
HARRIS WELL	17.69	18.51	0.82
NORTHERN UBZ-2 AND LBZ-2 REGIONS			
TW-22	73.57	73.54	-0.03
TW-23	73.98	74.03	0.05
TW-24	73.22	73.20	-0.02
TW-37	71.84	71.86	0.02
SOUTHERN UBZ-2 AND LBZ-2 REGIONS			
TW-19	DRY	DRY	na
TW-20	32.30	DRY	>2.3[c]
TW-21	26.64	27.90	1.26
TW-34	32.30	40.95	8.65

TABLE 3-11 (Cont.)

CONSTANT RATE AQUIFER TEST WATER-LEVEL INFORMATION

Well	Water Level Below MP Prior to Pump Test[a] (ft)	Water Level Below MP at End of Pumping[b] Period (ft)	Drawdown at End of Pump Test (ft)
TW-35	35.39	41.84	6.45
TW-36	32.20	32.28	0.08
TW-39	36.04	44.50	8.46
TW-54	31.96	33.36	1.40
TW-55	31.86	32.63	0.77
TW-58 (TEST WELL)	33.15	42.82	9.67
UBZ-3 AND LBZ-3 REGIONS			
TW-11	74.30	73.64	-0.66
TW-12	75.90	75.26	-0.64
TW-38	97.40	94.80	2.60
TW-56	60.94	60.90	0.02

NOTES:

[a]Water levels and elevations measured within 2 hours prior to step test (between 7:45 and 9:45 a.m. on December 8, 1992).
[b]Water levels and elevations measured within 4 hours prior to end of constant-rate test (between 9:30 and 13:30 on December 12, 1992).
[c]Water level dropped below bottom of well and was no longer measurable after 2.30 ft of drawdown.

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TABLE 3-12

HELP MODEL CALCULATIONS OF RECHARGE THROUGH SOURCE AREAS

Site No.	Site Description	Runoff[a] (%)	Evapotranspiration[a] (%)	Recharge[a] (%)	Recharge (in/yr)
1	Old Underflow Solids Ponds	15	84	1	0.2
2	Northwest Pond (waste absent)	8.8	89	2	0.3
	Northwest Pond (waste present)	0.0	93	7	1.1
3	Coke and Quartzite Dust Slurry Pond	0.1	93	<7	<1.2
5	Sealed Underflow Solids Ponds	8.8	89	<2	<0.3
6	Underflow Solids Piles	0.0	92	8	1.2

[a] Values expressed as percentage of annual precipitation equal to 16.07 inches.

1116mcl.3-1

TABLE 3-13

DIRECTION AND MAGNITUDE OF VERTICAL HYDRAULIC GRADIENTS

Well Cluster	Well	Monitored Interval Mid-Point (ft)	Water Elevation (ft)	Date	Change in Head (dH) (ft)	Distance Between Mid-Points (dL) (ft)	Components of Hydraulic Gradient		Comments
							Direction	Magnitude	
	PW-01*	open	5,885.72	23-May-93					
	PW-02*	open	ND						
	PW-03*	open	5,871.36	23-May-93					
	PW-04*	5,823.8	ND						
	PW-04*	5,923.3	ND						
	TW-01	ND	-						ABANDONED
	TW-02*	open	5,935.53	23-May-93					
	TW-03	5,666.3	-						ABANDONED
	TW-04	5,765.1	-						ABANDONED
TW-09	TW-10	5,862.9	5,870.24	27-May-93					
	TW-07	5,834.5	5,870.81	27-May-93	0.57	28.40	↑	0.020	
	TW-08	5,802.7	5,871.16	27-May-93	0.35	31.80	↑	0.011	
	TW-09	5,640.4	5,878.24	27-May-93	7.08	162.30	↑	0.044	
TW-11	TW-12	5,844.6	5,868.87	26-May-93					
	TW-11	5,804.6	5,869.18	26-May-93	0.31	40.00	↑	0.008	
TW-13	TW-14	5,968.0	5,975.85	29-May-93			↓	0.071	
	TW-15	5,932.5	5,973.34	29-May-93	-2.51	35.50			
	TW-13	5,898.9	5,974.23	29-May-93	0.89	33.60	↑	0.026	
TW-18	TW-16	5,925.4	5,935.32	27-May-93					
	TW-17	5,891.9	5,935.33	27-May-93	0.01	33.50	N	0.000	
	TW-18	5,766.1	5,936.23	27-May-93	0.90	125.80	↑	0.007	
TW-21	TW-19	5,864.7	5,866.75	26-May-93			N	0.000	
	TW-20	5,852.3	5,866.74	26-May-93	-0.01	12.40			
	TW-34	5,820.6	5,866.76	26-May-93	0.02	31.70	N	0.000	
	TW-21	5,778.0	5,871.46	26-May-93	4.70	42.60	↑	0.110	
TW-23	TW-24	5,870.0	5,883.40	28-May-93			N	0.003	
	TW-22	5,844.4	5,883.32	28-May-93	-0.08	25.60			
	TW-23	5,772.4	5,883.35	28-May-93	0.03	72.00	N	0.000	
TW-25	TW-27	5,904.1	-						ABANDONED
	TW-26	5,856.6	5,906.26	28-May-93					
	TW-25	5,811.3	-						ABANDONED
TW-28	TW-29	5,944.2	5,949.09	27-May-93			N	0.001	
	TW-28	5,904.5	5,949.05	27-May-93	-0.04	39.70			
	TW-30	5,925.5	5,930.44	30-May-93					
TW-32	TW-31	5,946.9	5,952.67	1-Jun-93			↓	0.018	
	TW-33	5,903.0	5,951.88	1-Jun-93	-0.79	43.90	↓	0.011	
	TW-32	5,815.6	5,950.89	1-Jun-93	-0.99	87.40			
TW-35	TW-39	5,843.0	5,866.74	26-May-93					

TABLE 3-13 (Cont.)

DIRECTION AND MAGNITUDE OF VERTICAL HYDRAULIC GRADIENTS

Well Cluster	Well	Monitored Interval Mid-Point (ft)	Water Elevation (ft)	Date	Change in Head (dH) (ft)	Distance Between Mid-Points (dL) (ft)	Components of Hydraulic Gradient		Comments
							Direction	Magnitude	
	TW-35	5,817.5	5,867.50	26-May-93	0.76	25.50	↑	0.030	
	TW-36	5,853.7	5,877.90	27-May-93					
TW-45	TW-37	5,860.6	5,892.42	1-Jun-93			↓	0.039	
	TW-06	5,842.1	-						ABANDONED
	TW-05	5,749.5	-						ABANDONED
	TW-45	5,736.3	5,887.60	1-Jun-93	-4.82	124.30			
	TW-38	5,874.9	5,883.47	31-May-93					
TW-44A	TW-40	5,902.8	5,916.73	31-May-93			↓	0.356	
	TW-44A	5,848.9	5,897.56	31-May-93	-19.17	53.90			
	TW-41	5,930.0	5,934.65	31-May-93					
	TW-42	5,905.4	5,910.70	31-May-93					
	TW-43	5,902.2	5,917.68	31-May-93					
	TW-44	-	-						ABANDONED
	TW-48	5,919.8	5,926.86	2-Jun-93					
	TW-49	5,918.4	5,924.45	29-May-93					
	TW-50	5,911.0	5,934.65	29-May-93					
	TW-51*	5,947.1	5,951.25	2-Jun-93					
	TW-51*	5,870.6	5,951.25	2-Jun-93					
	TW-53	5,853.4	5,862.54	20-May-93					
	TW-54	5,842.2	5,862.78	20-May-93					
	TW-55	5,824.8	5,859.93	20-May-93					
	TW-56	5,816.2	5,857.49	20-May-93					
	TW-57	5,922.4	5,943.53	20-May-93					
	TW-58	5,845.3	5,866.78	26-May-93					
	HARRIS	5,818.8	5,863.54	28-May-93					
	LEWIS	5,768.4	5,837.77	26-May-93					
KM-10	KM-01	5,977.0	5,987.22	17-May-93					
	KM-10	5,920.6	5,987.33	17-May-93	0.11	56.40	N	0.002	
	KM-02	5,971.8	5,990.52	18-May-93					
KM-11	KM-03	5,969.1	5,988.73	18-May-93			↓	0.012	
	KM-11	5,920.6	5,988.14	18-May-93	-0.59	48.50			
	KM-04	5,973.9	5,987.55	18-May-93					
	KM-05	5,958.9	5,970.84	18-May-93					
	KM-06	5,947.8	5,963.58	18-May-93					
	KM-07	5,949.4	5,966.56	17-May-93					
KM-12	KM-08	5,935.2	5,946.26	19-May-93					
	KM-12	5,832.9	5,948.74	19-May-93	2.48	102.30	↑	0.024	

TABLE 3-13 (Cont.)

DIRECTION AND MAGNITUDE OF VERTICAL HYDRAULIC GRADIENTS

Well Cluster	Well	Monitored Interval Mid-Point (ft)	Water Elevation (ft)	Date	Change in Head (dH) (ft)	Distance Between Mid-Points (dL) (ft)	Components of Hydraulic Gradient		Comments
							Direction	Magnitude	
	KM-09	5,919.6	5,943.79	18-May-93					
	KM-13	5,925.0	5,949.67	19-May-93					
KM-18	KM-15	5,906.3	5,920.57	19-May-93			↓	0.224	
	KM-18	5,795.3	5,895.67	19-May-93	-24.90	111.00			
	KM-16	5,929.5	5,944.00	19-May-93					
	KM-17	5,956.9	5,976.64	19-May-93					
	KM-19	5,771.4	5,948.43	20-May-93					

NOTES:
1) Monitoring wells listed in numerical order unless grouped by well cluster. Wells within a well cluster listed by increasing depth.
2) Water levels measured in May and June of 1993.
3) Vertical hydaulic gradient is measured between sequential wells at each well nest. Magnitude is calculated as the change in hydraulic head (dH) over the distance between measuring points (dL). The mid-points of the monitored intervals were used as measuring points. Direction indicates:
   ↑ - upward component
   ↓ - downward component
   N - negligible upward or downward component
4) ND - no data
5) * - These wells are screened over more than one interflow zone or are open holes; the groundwater elevation therefore represents a combination of potentiometric levels from various zones.

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TABLE 3-14

COMPARISON OF WATER CHEMISTRY IN BACKGROUND WELLS AND SPRINGS

Location	Free Carbon Dioxide[1] (mg/L)	Alkalinity Bicarbonate (mg/L as $CaCO_3$)	Calcium (mg/L)	Chloride (mg/L)	Specific Conductance (field) (uS\cm)	Fluoride (mg/L)	Hardness (mg/L as $CaCO_3$)	Iron (mg/L)	Magnesium (mg/L)	Nitrate plus Nitrite (mg/L as N)
MEAN VALUE										
FRESH GROUNDWATER										
Formation Spring	55[2]	486	191	29	ND	0.287	507	0.093	49	0.144
Formation A	220	599	162	5	1037	0.290	ND	0.018	43	0.250
Formation B	10	527	157	10	897	0.230	ND	0.021	44	0.250
Formation C	55	617	164	8	920	0.260	ND	0.013	44	0.250
PW-04	135	472	116	15	986	0.173	ND	0.077	55	3.784
TW-13	70	498	109	13	857	0.293	452	0.036	44	3.553
TW-15	50	454	93	10	821	0.313	416	0.042	40	2.635
TW-29	450	670	141	19	1227	0.226	690	0.039	72	4.726
TW-48	120	453	109	17	943	0.202	494	0.135	51	4.370
Mean	129	531	138	14	961	0.253	512	0.052	49	2.218
Standard Deviation	135	79	33	7	127	0.047	106	0.041	10	1.976
SODIC GROUNDWATER										
Doc Kackley Spring	700[3]	935	104	21	1531	0.433	766	6.439	125	0.147
Hooper Spring	2400[3]	943	105	28	1454	0.431	754	5.485	115	0.104
TW-28	1500[3]	926	159	25	1776	0.210	760	0.065	95	2.938
TW-57	700[3]	782	178	19	1512	0.189	ND	0.148	106	1.117
Mean	1325	896	137	23	1568	0.316	760	3.034	110	1.077
Standard Deviation	810	77	38	4	142	0.135	6	3.403	12	1.326

TABLE 3-14 (Cont.)

COMPARISON OF WATER CHEMISTRY IN BACKGROUND WELLS AND SPRINGS

Location	Field pH (Std. Units)	Potassium (mg/L)	Silicon (mg/L)	Sodium (mg/L)	Sulfate (mg/L)	Field Temperature (°C)	Total Dissolved Solids (mg/L)	Ca/Mg (mg/L)/(mg/L)	Na/Cl (mg/L)/(mg/L)	Silicon/TDS (mg/L)/(mg/L)
MEAN VALUE										
FRESH										
Formation Spring	7.3	10.5	ND	11.3	35.6	ND	512	3.89	0.39	ND
Formation A	6.8	1.7	ND	4.3	30.0	11.8	546	3.77	0.86	ND
Formation B	8.1	1.6	ND	4.6	30.0	10.0	412	3.60	0.46	ND
Formation C	7.4	1.3	ND	4.6	30.0	11.0	488	3.69	0.58	ND
PW-04	6.9	4.0	15.0	15.1	78.8	9.2	588	2.13	1.03	0.03
TW-13	7.2	3.4	ND	10.4	37.5	10.5	486	2.46	0.78	ND
TW-15	7.3	2.4	8.5	9.4	37.1	10.1	496	2.34	0.90	0.02
TW-29	6.6	4.9	16.6	21.3	82.6	9.5	749	1.95	1.12	0.02
TW-48	7.0	3.8	16.8	12.6	76.3	8.9	564	2.14	0.72	0.03
Mean	7.2	3.7	14.2	10.4	48.7	10.1	538	2.89	0.76	0.02
Standard Deviation	0.4	2.8	3.9	5.6	23.2	1.0	94	0.82	0.25	0.00
SODIC										
Doc Kackley Spring	6.5	13.2	38.6	32.6	55.7	10.6	899	0.84	1.54	0.04
Hooper Spring	6.0	12.4	33.9	31.2	55.0	11.5	911	0.92	1.12	0.04
TW-28	6.2	6.9	23.9	26.7	69.7	9.0	959	1.67	1.08	0.02
TW-57	6.4	5.9	18.8	26.4	88.1	7.5	923	1.68	1.40	0.02
Mean	6.3	9.6	28.8	29.2	67.1	9.7	923	1.28	1.29	0.03
Standard Deviation	0.2	3.8	9.0	3.1	15.5	1.8	26	0.46	0.22	0.01

TABLE 3-14 (Cont.)

COMPARISON OF WATER CHEMISTRY IN BACKGROUND WELLS AND SPRINGS

Location	Carbon-14 Age (years)	Oxygen-18 (δ‰)	Deuterium (δ‰)	Tritium (TU)
MEAN VALUE				
FRESH GROUNDWATER				
Formation Spring	ND	ND	ND	ND
Formation A	17,620	-18.0	-136	6.5
Formation B	16,415	-18.0	-142	4.6
Formation C	16,100	-18.0	-138	1.5
PW-04	ND	ND	ND	ND
TW-13	ND	ND	ND	ND
TW-15	12,775	-17.8	-137	7.2
TW-29	ND	ND	ND	ND
TW-48	ND	ND	ND	ND
Mean	15,728	-18.0	-138	5.0
Standard Deviation	2,074	0.1	3	2.5
SODIC GROUNDWATER				
Doc Kackley Spring	19,705	-17.2	-133	11.6
Hooper Spring	>25,000	-17.0	-132	11.5
TW-28	ND	ND	ND	ND
TW-57	ND	ND	ND	ND
Mean	>22,352	-17.1	-133	11.6
Standard Deviation	NA	0.1	0	0.0

Notes:

Mean values derived from available data.
[1]Free carbon dioxide content evaluated using Standard Methods (Clesceri et al. 1989).
[2]Estimated value. In determining value, temperature was unknown but was estimated as 10°C.
[3]Estimated value. In determining value, TDS and bicarbonate values were higher than limits of nomograph.
TDS - Total Dissolved Solids.
TU - Tritium Units
δ ‰ Delta Units - parts per thousand (see also Table 3-14).
NA - Not applicable
ND - No data

TABLE 3-15

ENVIRONMENTAL ISOTOPE RESULTS FOR GROUNDWATER AND SPRINGS

Sample Location Name	Local Flow Region	Oxygen-18 (δ ‰)	Deuterium (δ ‰)	Tritium (TU)
TW-10	UBZ-1	-17.1	-132	17.9
Doc Kackley Spring	UBZ-1	-17.2	-133	11.6
Hooper Spring	UBZ-1	-17.0	-132	11.5
TW-20	UBZ-2	-15.8	-124	22.5
Lewis Well	UBZ-2	-17.6	-136	17.0
TW-12	UBZ-3	-17.8	-137	6.2
TW-15	UBZ-4	-17.8	-137	7.2
Boy Scout Spring	UBZ-5	-17.6	-137	2.4
Finch Spring	UBZ-5	-17.9	-136	6.5
Formation A Spring	UBZ-5	-18.0	-136	6.5
Formation B Spring	UBZ-5	-18.0	-142	4.6
Formation C Spring	UBZ-5	-18.0	-138	1.5
Kelly Park Spring	UBZ-5	-17.7	-137	8.6
Ledger A Spring	UBZ-5	-18.0	-138	<2.1
Ledger B Spring	UBZ-5	-17.8	-138	5.2
Ledger C Spring	UBZ-5	-17.9	-139	11.2
Spring Box Spring	UBZ-5	-17.6	-136	8.7
TW-18	LBZ-4	-15.8	-125	25.7

TU = Tritium units
δ ‰ (Delta units - parts per thousand) = [(R - Rstandard)/Rstandard] * 1000, where
R = $^{2}H/^{1}H$ or $^{18}O/^{16}O$ and
Rstandard = $^{2}H/^{1}H$ or $^{18}O/^{16}O$ in standard mean ocean water.

1216cxh1.314

TABLE 3-16

SUMMARY OF AGRICULTURAL LAND USE WITHIN 2-KM OF THE MONSANTO PLANT

Property ID.	Property Owner	Person Surveyed	Property Location	Property Area (acres)	Agricultural Area (acres)	Wheat (acres)	Barley (acres)	Alfalfa (acres)	CRP (acres)	Livestock (acres)	Comments
1	Cellan, Merle	Cellan, Merle	T8S R42E 31&32, T8S R41E 25&26	560	440	440	0	0	0	0	rotates with barley and summer fallow every 3 years
2A	LDS Church	Cole, Tammy	T8S R42E 30, T8S R41E 25	160	160	60	100	0			
2B	LDS Church	Cellan, Sid	T8S R42E 30, 29, 19	160	145	45	100	0	0	0	rotates barley and wheat every 3 years
3	Gunnel, Charlotte	Clegg, David	T8S R42E 30	200	200	0	0	0	200	0	
4A	Wells, Myrl	Wells, Myrl	T8S R42E 19	360	360	0	360	0	0	0	rotates with summer fallow
4B	Wells, Myrl	Wells, Myrl	T8S R42E 33, T9S R42E 4	60	60	0	0	0	60	0	
5A	Brown, Clarke	Brown, Clarke	T8S R42E 20	90	15	0	10	0	0	5	rotates with summer fallow and wheat every 3 - 4 years

TABLE 3-16 (Cont.)

SUMMARY OF AGRICULTURAL LAND USE WITHIN 2-KM OF THE MONSANTO PLANT

Property ID.	Property Owner	Person Surveyed	Property Location	Property Area (acres)	Agricultural Area (acres)	Wheat (acres)	Barley (acres)	Alfalfa (acres)	CRP (acres)	Livestock (acres)	Comments
5B	Brown, Clarke	Brown, Clarke	T8S R42E 29 & 32	280	240	0	240	0	0	0	rotates with summer fallow and wheat every 3 - 4 years
6	Ellis, Lilly	Ellis, Lilly	T8S R42E 20 & 29	220	220	0	0	0	220	0	
7	Cellan, Thomas	Cellan, Lonnie	T8S R42E 20 & 29	80	44	0	44	0	0	0	rotates with wheat and summer fallow
8	Wheeler, Kelly	Wheeler, Kelly	T8S R42E 29 SW of NE	6	3	0	0	0	0	3	
9	Hopkins, Larry	Hopkins, Larry	T8S R42E 32, T9S R42E 5	220	180	180	0	0	0	0	rotates with summer fallow
10	Lish, Laurie & Curtis	Lish, Laurie	T8S R42E 29 NE of NE	13	10	0	0	5	0	5	rotates farmland with pasture every year
11	Garner, Owen J.	Garner, Owen J.	T8S R42E 29 NE of NE	12.5	12	0	0	0	0	12	

TABLE 3-16 (Cont.)

SUMMARY OF AGRICULTURAL LAND USE WITHIN 2-KM OF THE MONSANTO PLANT

Property ID.	Property Owner	Person Surveyed	Property Location	Property Area (acres)	Agricultural Area (acres)	Wheat (acres)	Barley (acres)	Alfalfa (acres)	CRP (acres)	Livestock (acres)	Comments
12	Christensen, Jack	Christensen, Jack	T8S R42E 21, 28, & 29	90	90	20	50	15	0	5	rotates crops every 5 - 7 years
13	Kerr-McGee	Hopkins, Larry	T8S R42E 32 & 33	320	230	0	70	0	160	0	rotates with summer fallow
14	Monsanto (On-site)	Hopkins, Larry	T8S R42E 30, 31, & 32	560	30	0	30	0	0	0	rotates with summer fallow
15	Christman & Hopkins		T8S R42E 33, 9S 42E 4 NW	280	0						
16	Mark III Inc.	Ozburn, Harry Dean	T9S R42E 6 SE of NE	15	15	0	15	0	0	0	rotates with wheat and summer fallow
17	Monsanto (Off-site)	Hopkins, Larry	T9S R42E 6 NW	400	120	0	115	0	0	5	rotates with summer fallow
18	Cole, Tammy & Morris	Cole, Tammy & Morris	T8S R42E 31 SW	75	75	0	0	0	0	75	
19	Humble, Delvin	Humble, Delvin	T9S R42E 6 NE of SE	10	8	0	0	0	0	8	
20	Lewis, Diggs Sr.		T9S R42E 6	20	0						

TABLE 3-16 (Cont.)

SUMMARY OF AGRICULTURAL LAND USE WITHIN 2-KM OF THE MONSANTO PLANT

Property ID.	Property Owner	Person Surveyed	Property Location	Property Area (acres)	Agricultural Area (acres)	Wheat (acres)	Barley (acres)	Alfalfa (acres)	CRP (acres)	Livestock (acres)	Comments
21	Grigg, Roger	Grigg, Roger	T9S R42E 6 SE of SE	9.25	9.25	0	0	0	0	9.25	
22	Torgensen, Robert		T8S R41E 36 NE of SE, T9S R41E 1	140	0						
23	Cellan, Sid	Cellan, Sid	T8S R41E 25 SE of NW	30	25	0	25	0	0	0	rotates with wheat and summer fallow every 3 years
24	Lau, Elwin	Ozburn, Harry Dean	T9S 42E 6	130	125	0	125	0	0	0	rotates with wheat and summer fallow

Note:

Survey conducted June 1993.
Property Location described according to township, range, and section (e.g. T9S R42E 6) and also to nearest quarter-section and quarter-quarter section.

1216crh1.315

Golder Associates

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 Location
				Irrigation	Stock	Domestic	Total	
Steele, Val	Groundwater		165	3.3	0.09	0.08	3.47	T9S R42E S18 NW, NE
Moore, James	Big Spring Creek	Soda Creek	57	1.4	-	-	1.4	T9S R42E S18 NW, NW
Moore, Jesse	Big Spring Creek	Soda Creek	110	2.5	-	-	2.5	T9S R42E S18 NW, NW
Anderson, Abr	Soda Creek	Bear River	32	0.3	-	-	0.3	T9S R41E S12 NW, NE
Farmers Land & Irrig Corp	Soda Creek	Soda Creek	4,040	2.84	-	-	2.84	T9S R42E S6 NW, NW[a] 9S R41E S12 SE, NE
Anderson, Abr	Big Spring Creek	Bear River	77	1.5	-	-	1.5 0	T9S R41E S13 NE, NE 9S R41E S12 SE, NE

From Ecology and Environment (1988a)
[a]Diversion to irrigation ditch
[b]Diversion to irrigation canal

1216crh1.316

TABLE 3-18

SODA SPRINGS AREA WELL INVENTORY

Well ID.	Well Name (If any)	Well Location	Owner's Name and Address	Depth (ft)	Year Drilled	Water Use	Source of Information
1		8S 41E 24ba	Mrs. Hilda Thompson	19	1965	D	WL
2		8S 41E 25bd	Monsanto Co. (off-site) Box 816 Soda Springs, ID 83276	195	1989	IR [M]	WL, [WR]
3		8S 41E 25bd	Wells Cargo, Inc. Soda Springs, ID 83276	69	1966	IR	WL
4		8S 41E 36cc	David Clegg 399 N 2nd E Soda Springs, ID 83276	212	1981	D	WL
5		8S 42E 19bab1	Lav Heber	25	1967	S	USGS
6		8S 42E 20aa	Carl E. and Carolyn Lowry	?	?	D	WR
7		8S 42E 20aa [8S 42E 20da]	Brent Maughan [William B. Maughan] Soda Springs, ID 83276	127	1974 (1975)	D [IR,S,D]	WL, (USGS), [WR]
8		8S 42E 20ad (8S 42E 20aaa1)	Ray Nelson Box 344 Soda Springs, ID 83276	147	1975	D	WL, (USGS), WR
9		8S 42E 20bcc1	Ira Ellis	50	1927	D	USGS
10		8S 42E 20da (8S 42E 20dab1)	Wayne Porter (Cove Construction) Soda Springs, ID 83276	125	1964	(IN)	WL, (USGS)
11		8S 42E 20dad1	Myrtle Campbell	80	1937	D	USGS
12		8S 42E 21bcc	N.A. Degerstrom, Inc.	?	?	IN	WR

TABLE 3-18 (Cont.)

SODA SPRINGS AREA WELL INVENTORY

Well ID.	Well Name (If any)	Well Location	Owner's Name and Address	Depth (ft)	Year Drilled	Water Use	Source of Information
13		8S 42E 28bc	Don C. Panting	?	?	S,D	WR
14		8S 42E 28dc	Bill Vandegriff Soda Springs, ID 83276	115	1978	D	WL
15		8S 42E 28dc (8S 42E 28cdc1)	Archie Vonberg Soda Springs, ID 83276	90	1966	(D)	WL, (USGS)
16		8S 42E 29aa	A. J. Garn Soda Springs, ID 83276	74	1976	D	WL
17		8S 42E 29aba1	Tom Cellan	?	1949	D	USGS
18		8S 42E 29ac	Eugene A. & Opal M. Anderson Soda Springs, ID 83276	65	1980	D	WL
19		8S 42E 29dd	Van Garner P.O. Box 305 Soda Springs, ID 83276	78	1983	D,S	WL
20		8S 42E 30dd	Monsanto Chemical Co.	?	?	IN	WR
21		8S 42E 31ad	Monsanto Chemical Co.	?	?	IN	WR
22		8S 42E 31ad	Monsanto Chemical Co.	?	?	IN	WR
23		8S 42E 31ad	Monsanto Chemical Co.	?	?	IN	WR
24		8S 42E 31da	Monsanto Chemical Co.	?	?	IN	WR
25		8S 42E 31ad	Wells Cargo, Inc. P.O. Box 11511 Reno, Nevada	390	1966	IN	WL

TABLE 3-18 (Cont.)

SODA SPRINGS AREA WELL INVENTORY

Well ID.	Well Name (If any)	Well Location	Owner's Name and Address	Depth (ft)	Year Drilled	Water Use	Source of Information
26		8S 42E 32ad (8S 42E 30bdd1)	Wells Cargo, Inc. P.O. Box 11511 Reno, Nevada	120	1966 (1967)	IN	WL, (USGS)
27		8S 42E 32bd	Kerr-McGee Chemical Corp.	?	?	IN	WR
28		9S 41E 1cbd1	William Corbett	?	1966	IR	USGS
29		9S 41E 12bc	Boyd Mason 120 E 2nd St. Soda Springs, ID 83276	88	1975	T	WL
30	Gyser	9S 41E 12add1		315	1937	Gyser	USGS
31		9S 41E 13bb (9S 41E 13bbb1)	Howard Hahn (Howard Hand) Soda Springs, ID 83276	77	1966	D	WL, (USGS)
32		9S 41E 13bb	Dennis Hansen 376 N 2nd E Soda Springs, ID 83276	65	1977	D	WL
33		9S 41E 13bc	Steve Corder (SW of city) Soda Springs, ID 83276	122	1983	D	WL
34		9S 41E 13bc	Charles Schwartz 356 S 2nd E Soda Springs, ID 83276	135	1978	D	WL
35		9S 41E 13cb	Randy Corder 159 W 2nd S Soda Springs, ID 83276	130	1978	D	WL

TABLE 3-18 (Cont.)

SODA SPRINGS AREA WELL INVENTORY

	Well Name (If any)	Well Location	Owner's Name and Address	Depth (ft)	Year Drilled	Water Use	Source of Information
36		9S 41E 13cb	Charles Stewart Soda Springs, ID 83276	122	1985	D	WL
37		9S 41E 13cc (9S 41E 13ccc1)	Fred Larsen Soda Springs, ID 83276	138	1974	D	WL, (USGS)
38		9S 41E 13cc	Merlin McCulloch 348 S. Main Soda Springs, ID 83276	140	1981	D	WL
39		9S 41E 13cc	Max Shell Soda Springs, ID 83276	165	1978	D	WL
40		9S 41E 13db (9S 41E 13bcc1)	William Corder Soda Springs, ID 83276	102	1967	D	WL, (USGS)
41		9S 42E 5db	Leroy Stevens 340 Rose Ave. Soda Springs, ID 83276	78	1974	D	WL
42		9S 42E 6aa	Fan Corporation - Gene Nicholas Soda Springs, ID 83276	86	1966	A	WL
43	Ref. Chem.	9S 42E 6aa	Advantage Electic 701 N. Hooper Avenue Soda Springs, ID 83276	135	1967	A	WL, FV
44	Harris	9S 42E 6ab	Monsanto Chemical Co. PO Box 816, Hwy 34 Soda Springs, ID 83276	64	1969	T	WL, WR, FV
45	Lewis	9S 42E 6da	Delvin Humble 540 E. 480 N. Soda Springs, ID 83276	105	1974	S, IR, T	WL, (USGS), WR, FV

Well ID.

TABLE 3-18 (Cont.)

SODA SPRINGS AREA WELL INVENTORY

Well ID.	Well Name (If any)	Well Location	Owner's Name and Address	Depth (ft)	Year Drilled	Water Use	Source of Information
46	Hooper School	9S 42E 7bb	Hooper Elementary 95 East Hooper Avenue Soda Springs, ID 83276	800	1982	H [T]	WR, [WL], FV
47	Marriott	9S 42E 8bb	Jay Lish 160 N. Hooper Avenue Soda Springs, ID 83276	40	1968	D(yard),S	WL, FV
48		9S 42E 8ca	Steve Butikofer (East of city) Soda Springs, ID 83276	240	1981	D	WL
49		9S 42E 8cd	Richard Hendricks 161 E. Oneida Preston, ID	135	1978	D	WL
50		9S 42E 9ac	Albert Christman 80 N. Hooper Avenue (Wood Canyon #3) Soda Springs, ID 83276	305	1978	D	WL
51		9S 42E 9bb	Dean Martinsen (East of city) Soda Springs, ID 83276	415	1977	D	WL
52		9S 42E 9bc	Leonard D. Owens Jr. 160 N. Main Soda Springs, ID 83276	426	1976	D	WL
53		9S 42E 9bc	Stephen Penn (East of city) Soda Springs, ID 83276	420	1981	D	WL

TABLE 3-18 (Cont.)

SODA SPRINGS AREA WELL INVENTORY

Well ID.	Well Name (If any)	Well Location	Owner's Name and Address	Depth (ft)	Year Drilled	Water Use	Source of Information
54		9S 42E 9ca	Ron Bullock (Wood Canyon #2, lot #5, block #2) Soda Springs, ID 83276	267	1978	D	WL
55		9S 42E 9ca	Mike E. McCabe (Wood Canyon #1, Lot #5, Block 1) Soda Springs, ID 83276	365	1978	D	WL
56		9S 42E 9ca	Douglas R. Moore Soda Springs, ID 83276	293	1976	D	WL
57		9S 42E 9cad1	Encil Hines	365	1955	S, DW	USGS
58		9S 42E 9cb (9S 42E 9cbc1)	Eddie Lee [Eddie and Donna Lee] Soda Springs, ID 83276	219	1969	D [IR,D]	WL, (USGS), [WR]
59		9S 42E 9cb	C. E. Lundin	?	?	D	WR
60		9S 42E 9cb	Norman Sparrow Soda Springs, ID 83276	285	1979	D	WL
61		9S 42E 9db (9S 42E 9dac1)	Dale Dunn Soda Springs, ID 83276	175	1967 (1965)	D, S	WL, (USGS)
62		9S 42E 9db	Byron Seeley Soda Springs, ID 83276	247	1980	D [IR,D]	WL, [WR]
63		9S 42E 9dc (9S 42E 9dca1)	Lowel Thomas Soda Springs, ID 83276	150	1963	D	WL, (USGS)

TABLE 3-18 (Cont.)

SODA SPRINGS AREA WELL INVENTORY

Well ID.	Well Name (If any)	Well Location	Owner's Name and Address	Depth (ft)	Year Drilled	Water Use	Source of Information
64		9S 42E 9dd	Dorsie (Bill) Hines Soda Springs, ID 83276	80	1968	D	WL
65	Gibson	9S 42E 18aa	Val Gibson 261 S. 3rd Soda Springs, ID 83276	135	1984	IR	WL, FV
66	Hildreth	9S 42E 18ab	Larry Hildreth 630 E. 490 South Soda Springs, ID 83276	70	1983, 1991	D	WL, SS, FV
67	Val Steele	9S 42E 18ba	Dean J. Beckstead 541 S. 3rd E. Soda Springs, ID 83276	17	~1979	D,S	WR, SS, FV
68	SteeleS	9S 42E 18bd	Stanford Steele 700 S. 3rd E. Soda Springs, ID 83276	72	1966	D,S	WL, (USGS), SS, FV
69	SteeleM	9S 42E 18bd	Mark Steele 780 S. 3rd E. Soda Springs, ID 83276	104	1975	D	WL, (USGS), SS, FV
70		9S 42E 18dc	LaDell Porter Soda Springs, ID 83276	165	1975	D, IR	WL, WR
71		9S 42E 18dc	Robert Ringel	160	1973	D [IR,S,D]	WL, [WR]
72	NelsonD	9S 42E 8ba	Ray Nelson 960 E. 2nd N. Soda Springs, ID 83276	545	1992	D	WL, FV

TABLE 3-18 (Cont.)

SODA SPRINGS AREA WELL INVENTORY

Well ID.	Well Name (If any)	Well Location	Owner's Name and Address	Depth (ft)	Year Drilled	Water Use	Source of Information
73	NelsonS	9S 42E 8ba	Ray Nelson 960 E. 2nd N. Soda Springs, ID 83276	40	1991	D	SS, FV
74	Brown	9S 42E 8ba	William H. Brown 145 N. Hooper Avenue Soda Springs, ID 83276	135	~1982	D (washing)	SS, FV
75	Dunn	9S 41E 13aa	Alvin Dunn 750 Big Springs Road Soda Springs, ID 83276	90	1978	D	SS, FV
76	Nell	9S 42E 8cb	Clinton Nell 2812 Highway 30 Soda Springs, ID 83276	58	~1946	D	SS, FV

Note:

Well ID is used on Figure 3-50 to show well locations.

Water Use Codes:
A - Abandoned
D - Domestic
DW - De-watering
H - Heating
IN - Industrial
IR - Irrigation
M - Mining
S - Stock
T - Testing

Source Codes:
FV - field verification (May 1993)
SS - City of Soda Springs drinking-water data base
WL - Driller's well logs
USGS - United States Geological Survey - Water Resources Division
WR - Listing of water rights

1216cnl.317

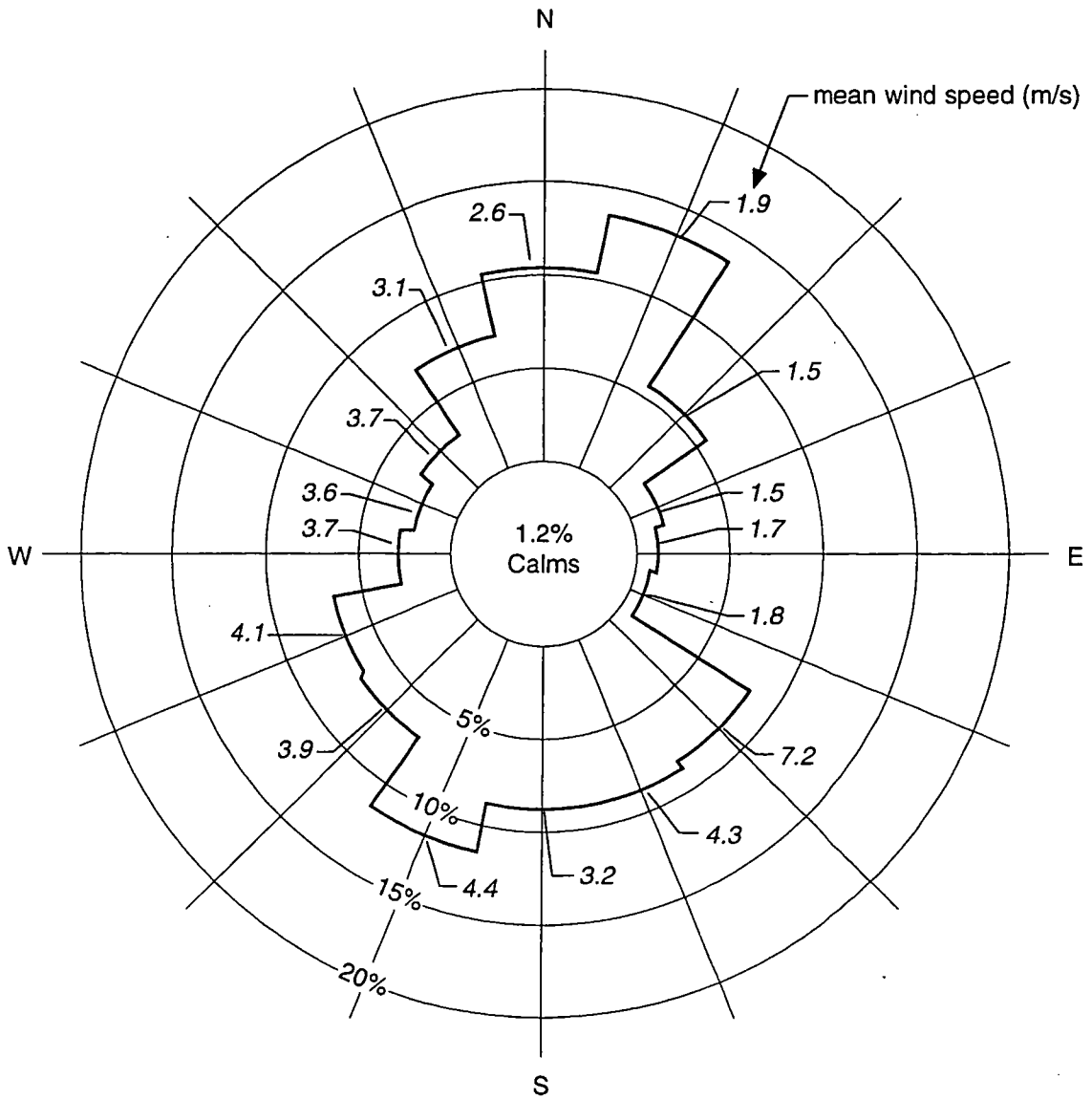


FIGURE **3-1**

1990 ANNUAL WIND ROSE FOR THE MONSANTO PLANT

MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913-1101.608 DRAWING NO. 48710 DATE 6/8/94 DRAWN BY CB

Golder Associates

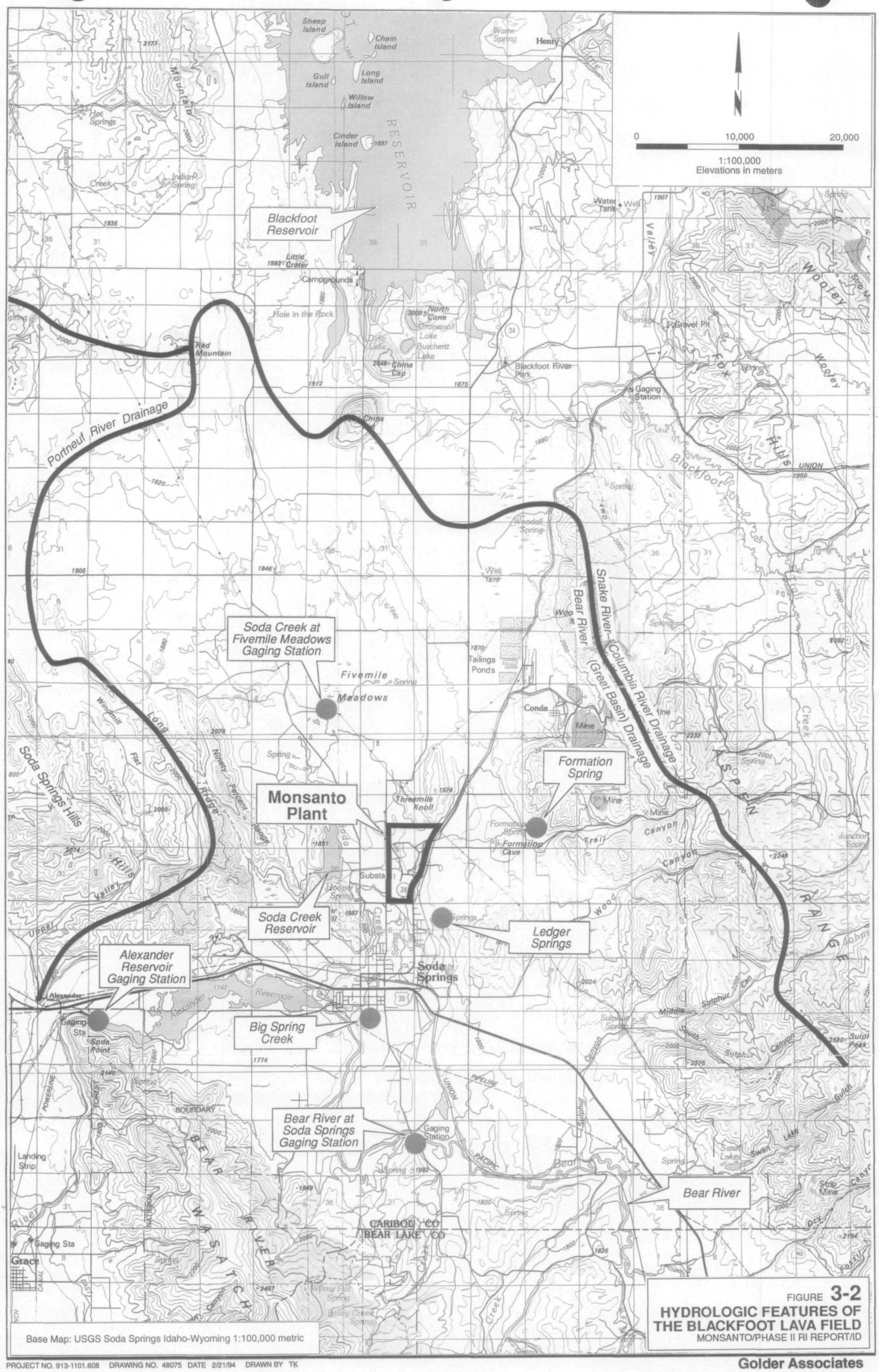
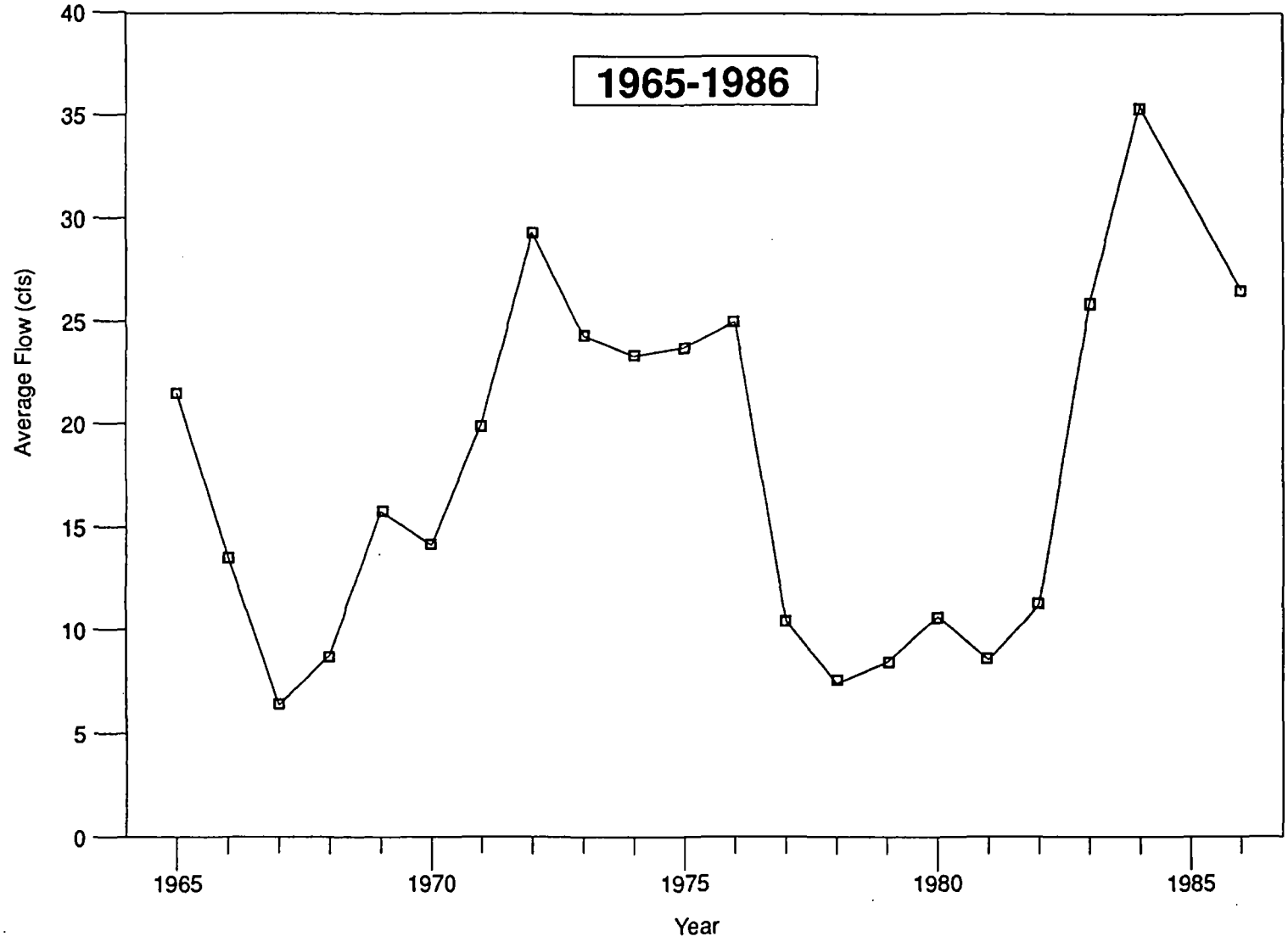


FIGURE 3-2
HYDROLOGIC FEATURES OF THE BLACKFOOT LAVA FIELD
MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913-1101.608 DRAWING NO. 48075 DATE 2/21/94 DRAWN BY TK

Golder Associates

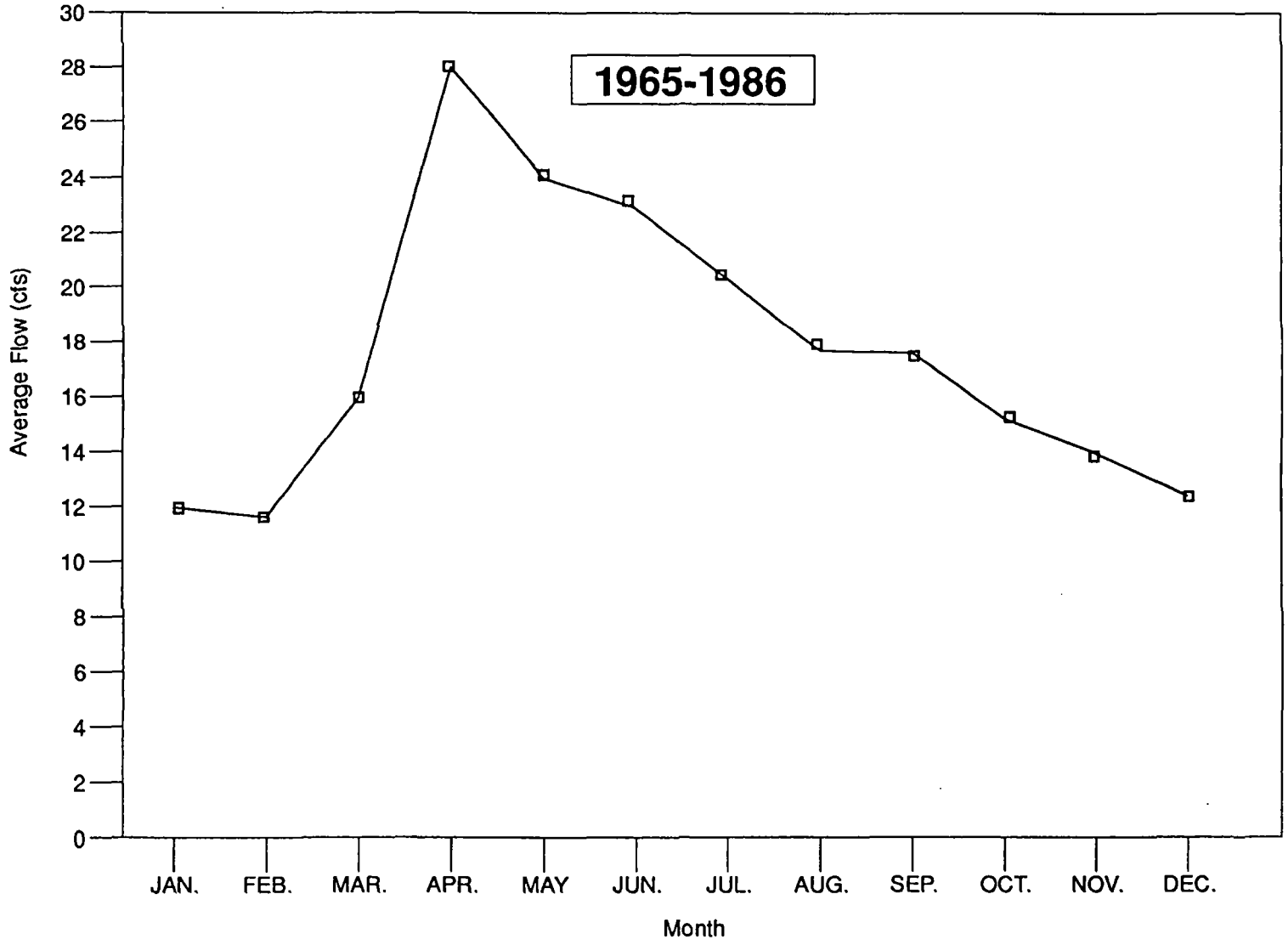


SOURCE: USGS data as presented by Hydrosphere (1993).

FIGURE **3-3**
ANNUAL AVERAGE FLOW IN SODA CREEK AT FIVEMILE MEADOWS
MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913 1101.608 DRAWING NO. 48715 DATE 6/8/94 DRAWN BY TB

Golder Associates

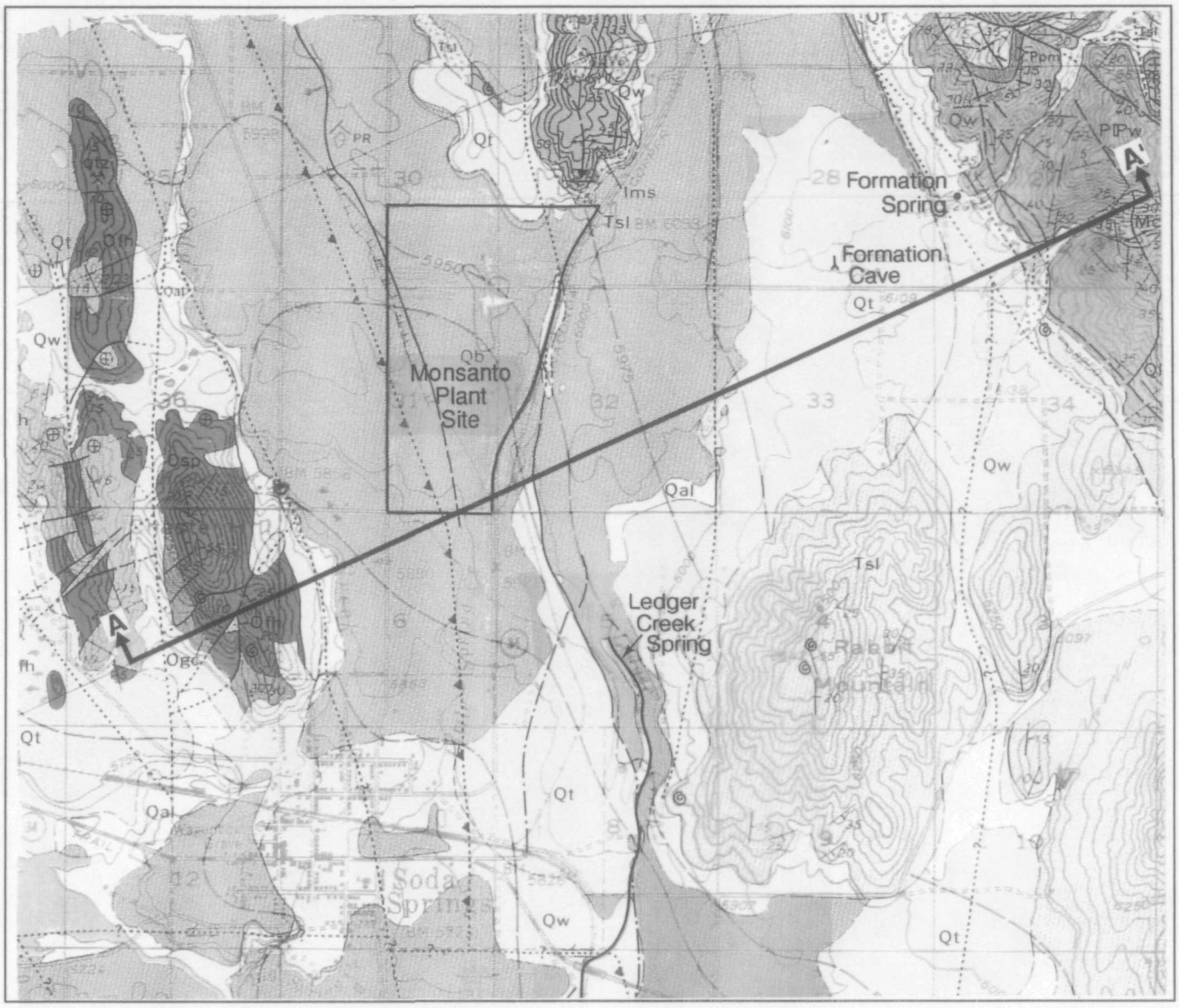


SOURCE: USGS data as presented by Hydrosphere (1993).

FIGURE **3-4**
MONTHLY AVERAGE FLOW IN SODA CREEK AT FIVEMILE MEADOWS
MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913 1101.608 DRAWING NO. 48716 DATE 6/7/94 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

A A' — Geologic Cross Section line and designation

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

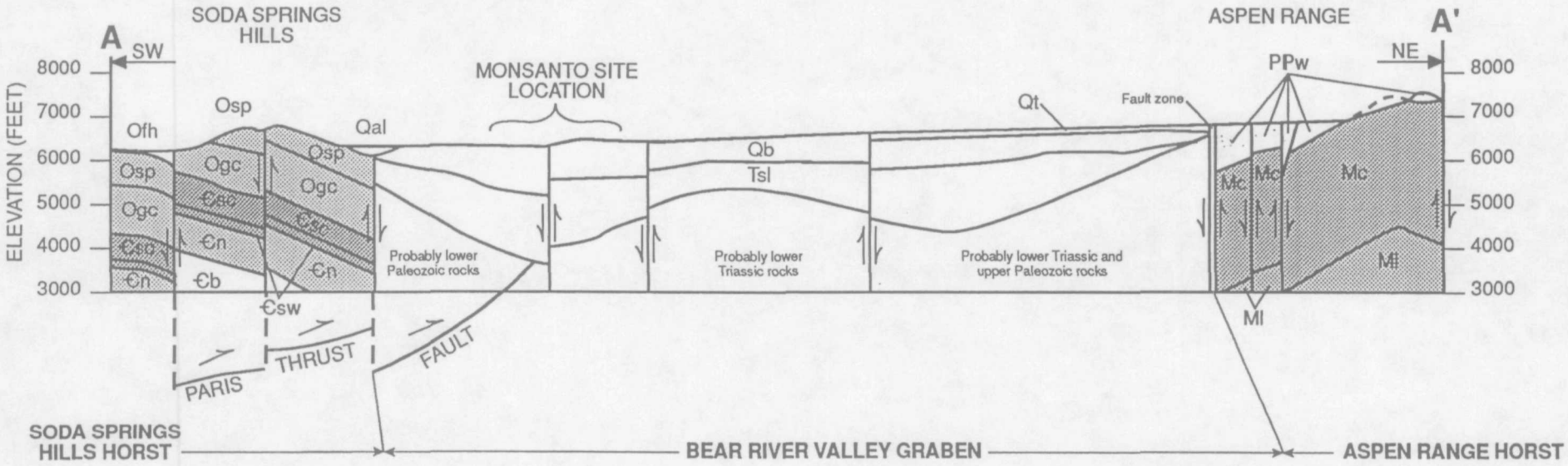
0 1
MILE

SOURCE: Modified from Geologic Map of the Soda Springs Quadrangle, Armstrong (1969).

FIGURE **3-5**
REGIONAL GEOLOGIC MAP
MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913 1101.608 DRAWING NO. 48120 DATE 6/8/94 DRAWN BY CB

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

0 1
MILES

Note: Modified from Armstrong (1969).

FIGURE **3-6**
REGIONAL GEOLOGIC CROSS SECTION ALONG LINE A-A'
MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913-1101.608 DRAWING NO. 48717 DATE 6/8/94 DRAWN BY TB

Golder Associates

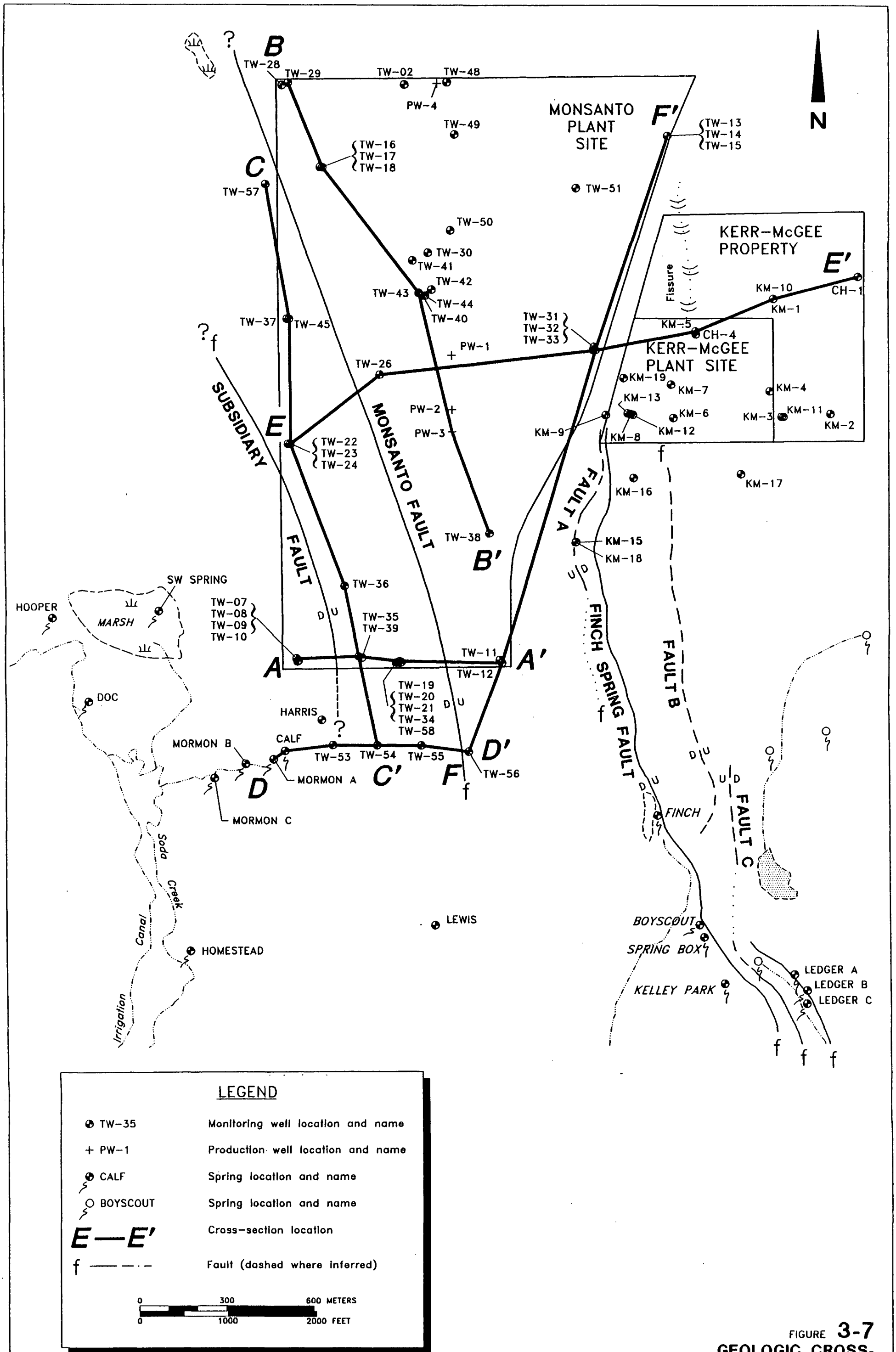
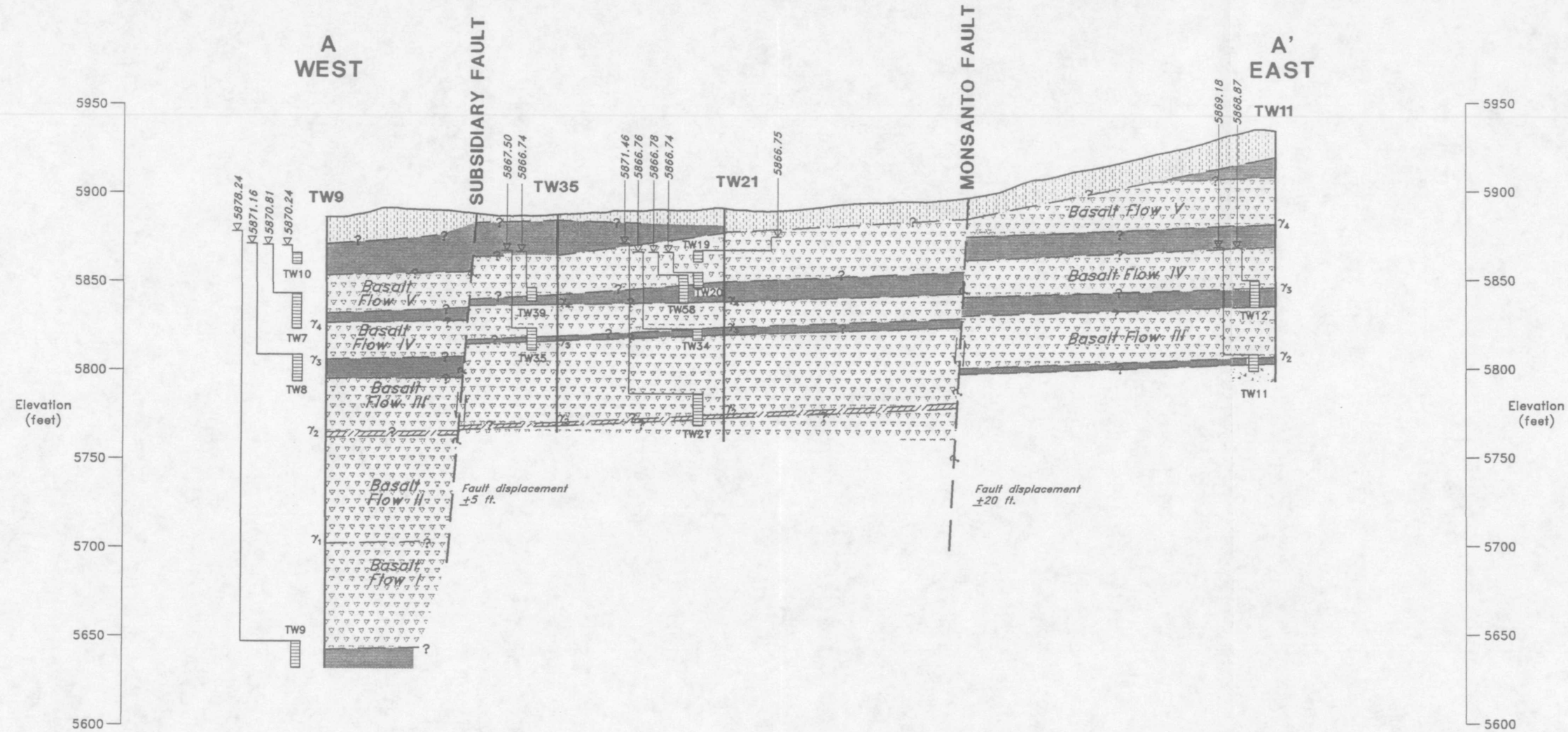


FIGURE 3-7
GEOLOGIC CROSS-SECTION LOCATIONS
MONSANTO/PHASE II RI REPORT/ID



0 240 480
FEET

Vertical scale: 1 in. = 60 ft.

Vertical exaggeration 4 x horizontal

Note:
Geologic units were inferred based on borehole information only. Actual conditions between boreholes may differ significantly from information shown on this cross section.

5875.3 Potentiometric surface and water elevation (ft) (May 1993).
Location of monitored zone for each well

Abandoned well (TW5 and TW6)

Undifferentiated unconsolidated materials

Unweathered basalt

Weathered or fractured basalt, cinders, sandy silt, silty sand

Clay

Sand and gravel

γ2 Gamma signature indicating interbed horizon, overlying corresponding basalt flow

FIGURE 3-8
GEOLOGIC
CROSS-SECTION A-A'
MONSANTO/PHASE II RI REPORT/ID

PROJECT NO \DJH\9131101\608\31955 DATE 6-8-94 11:21 DRAWN JRS\PM

Golder Associates

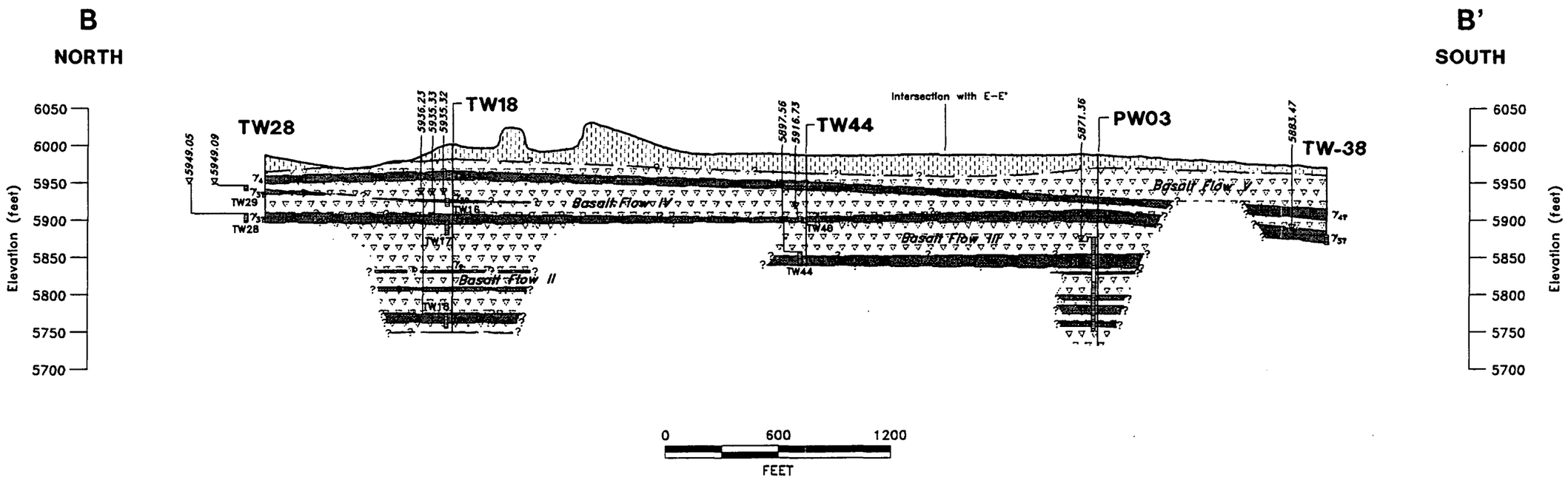
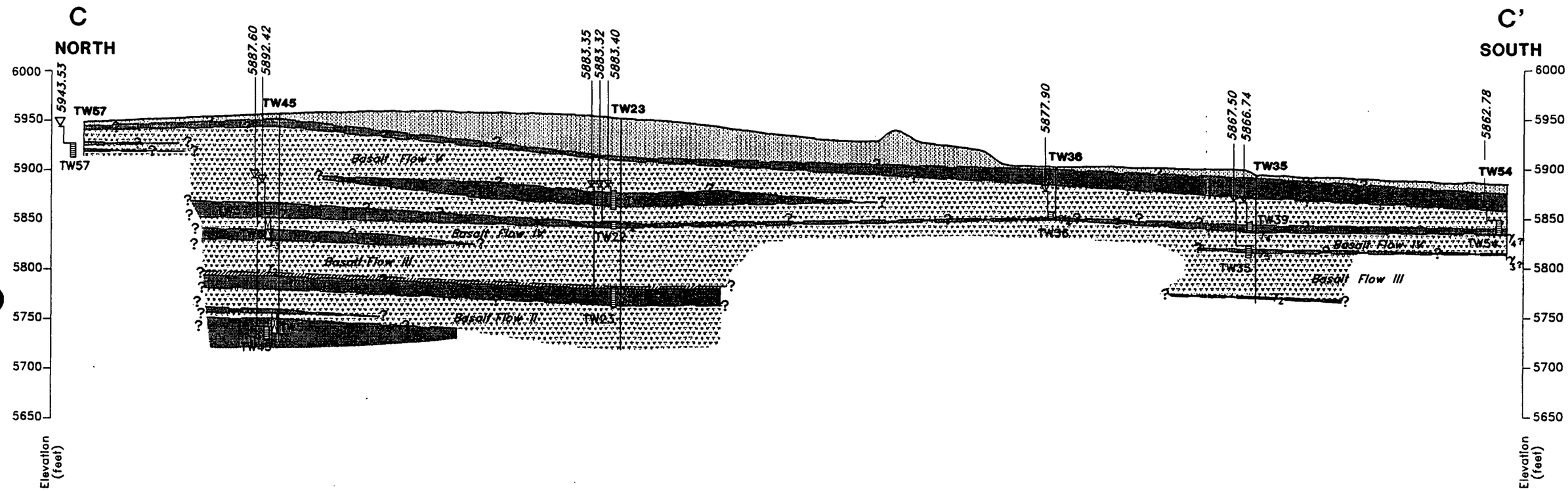


FIGURE 3-9
GEOLOGIC CROSS-SECTION B-B'
MONSANTO/PHASE II RI REPORT/ID

DWG ID: \DJH\9131101\608\42339 DATE 6-8-94 11:27

Golder Associates



0 400 800
FEET

Vertical scale: 1 in. = 100 ft.
Vertical exaggeration 4 x horizontal

Note:
Geologic units were inferred based on borehole information only. Actual conditions between boreholes may differ significantly from information shown on this cross section.

5875.3 Potentiometric surface and water elevation (ft) (May 1993).
Location of monitored zone for each well

Abandoned well (TW5 and TW6)

Undifferentiated unconsolidated materials

Unweathered basalt

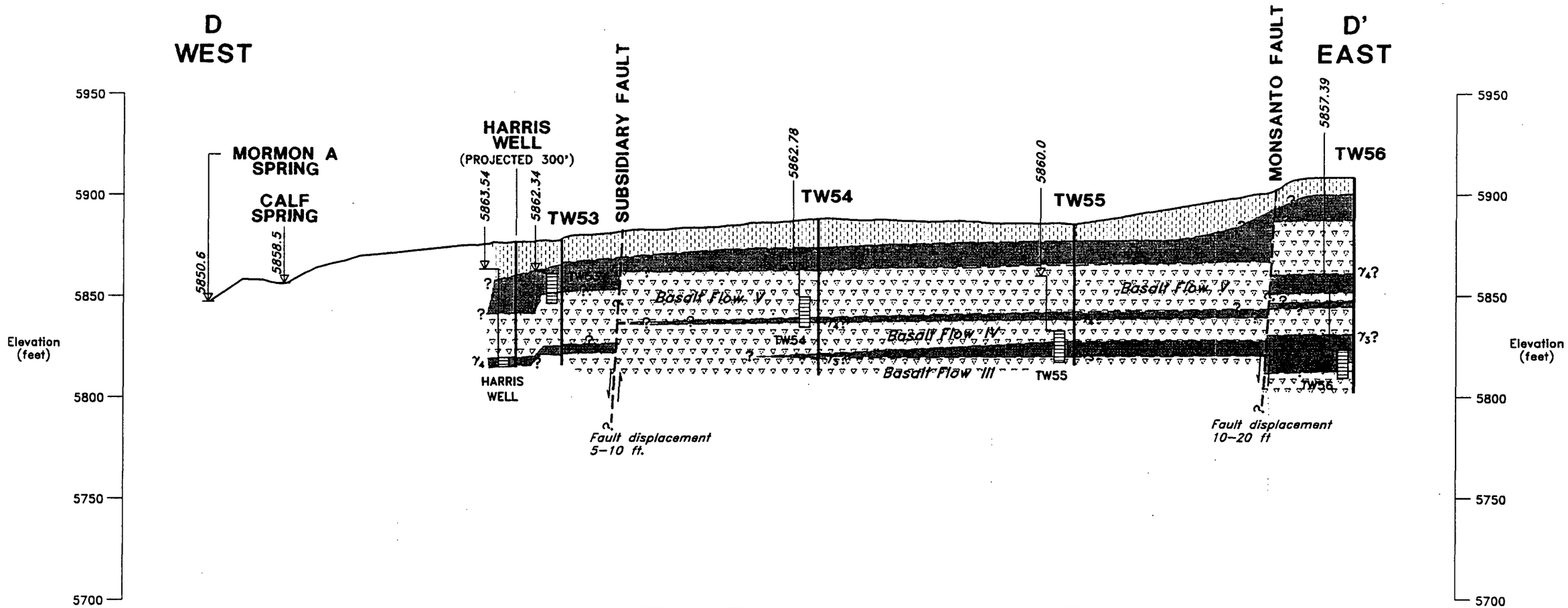
Weathered or fractured basalt, cinders, sandy silt, silty sand

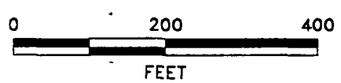
Clay

Sand and gravel

γ_4 Gamma signature indicating interbed horizon overlying corresponding basalt flow

FIGURE 3-10
GEOLOGIC CROSS-SECTION C-C'
MONSANTO/PHASE II RI REPORT/ID





Vertical scale: 1 in. = 50 ft.

Vertical exaggeration 4 x horizontal

5875.3 — Potentiometric surface and water elevation (ft) (May 1993).

Location of monitored zone for each well

Notes:

1. Geologic units were inferred based on borehole information only. Actual conditions between boreholes may differ significantly from information shown on this cross section.
2. The groundwater elevation of Harris Well is approximate.

Undifferentiated unconsolidated materials

Unweathered basalt

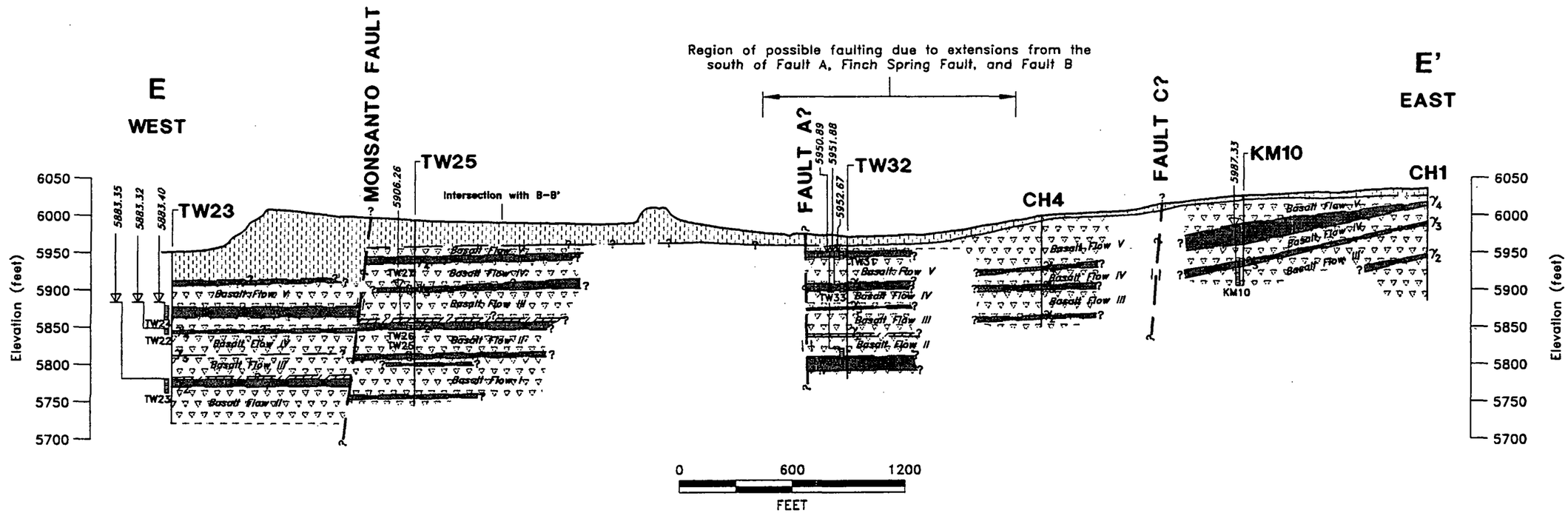
Weathered or fractured basalt, cinders, sandy silt, silty sand

Clay

Sand and gravel

γ_5 — Gama signature indicating interbed horizon, overlying corresponding basalt flow

FIGURE **3-11**
GEOLOGIC CROSS-SECTION D-D'
MONSANTO/PHASE II RI REPORT/ID



5875.3 — Potentiometric surface and water elevation (ft) (May 1993).

Location of monitored zone for each well.

Abandoned well (TW–25 and TW–27)

Undifferentiated unconsolidated materials

Unweathered basalt

Weathered or fractured basalt, cinders, sandy silt, silty sand

Clay

Sand and gravel

γ_2 — Gamma signature indicating interbed horizon, overlying corresponding basalt flow.

Note: Geologic units were inferred based on borehole information only. Actual conditions between boreholes may differ significantly from information shown on this cross section.

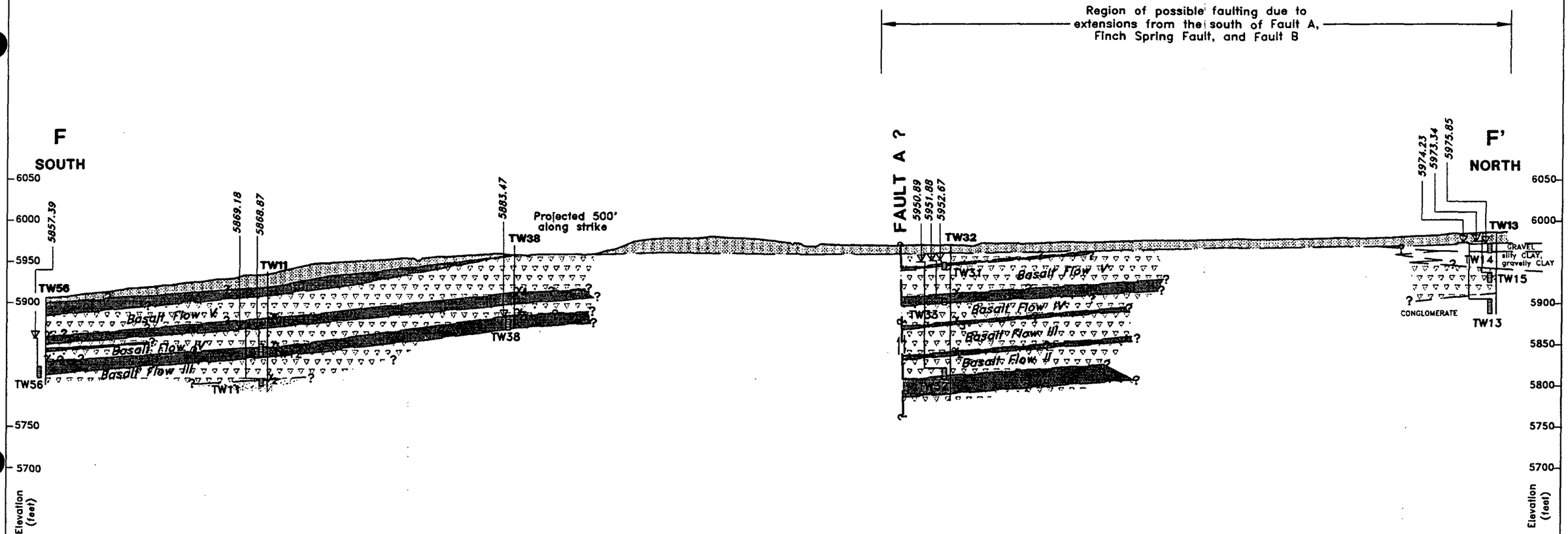
FIGURE **3-12**

GEOLOGIC CROSS-SECTION E-E'

MONSANTO/PHASE II RI REPORT/ID

DWG ID: \DJH\9131101\608\42377 DATE 6-8-94 11:42

Golder Associates



0 480 960
FEET

Vertical scale: 1 in. = 120 ft.

Vertical exaggeration 4 x horizontal

Note:
Geologic units were inferred based on borehole information only. Actual conditions between boreholes may differ significantly from information shown on this cross section.

5875.3 — Potentiometric surface and water elevation (ft) (May 1993).

Location of monitored zone for each well

γ3 — Gamma signature interbed horizon, overlying corresponding basalt flow

Undifferentiated unconsolidated materials

Unweathered basalt

Weathered or fractured basalt, cinders, sandy silt, silty sand

Clay

Sand and gravel

Abandoned well (TW5 and TW6)

FIGURE 3-13
GEOLOGIC CROSS-SECTION F-F'
MONSANTO/PHASE II RI REPORT/ID

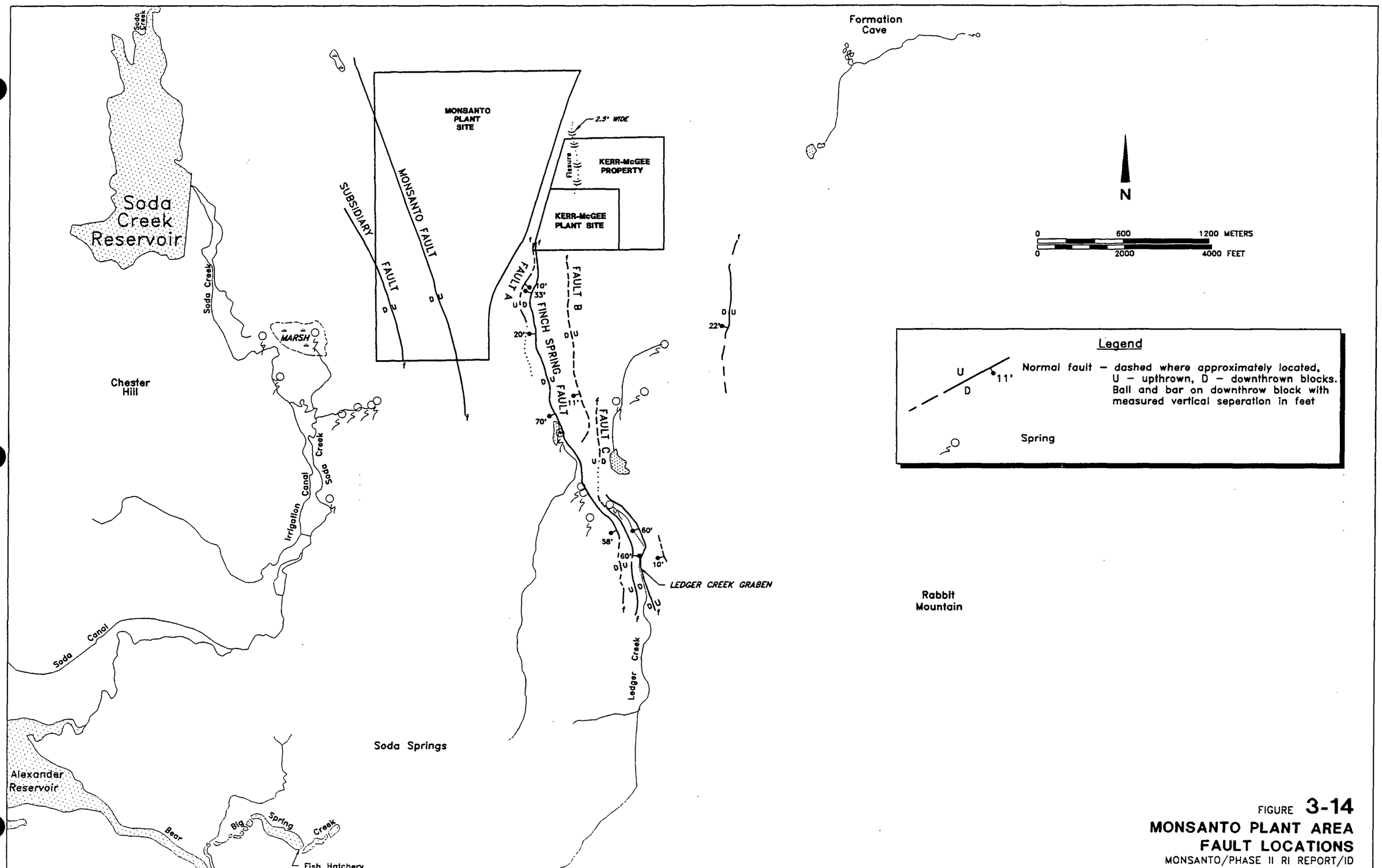
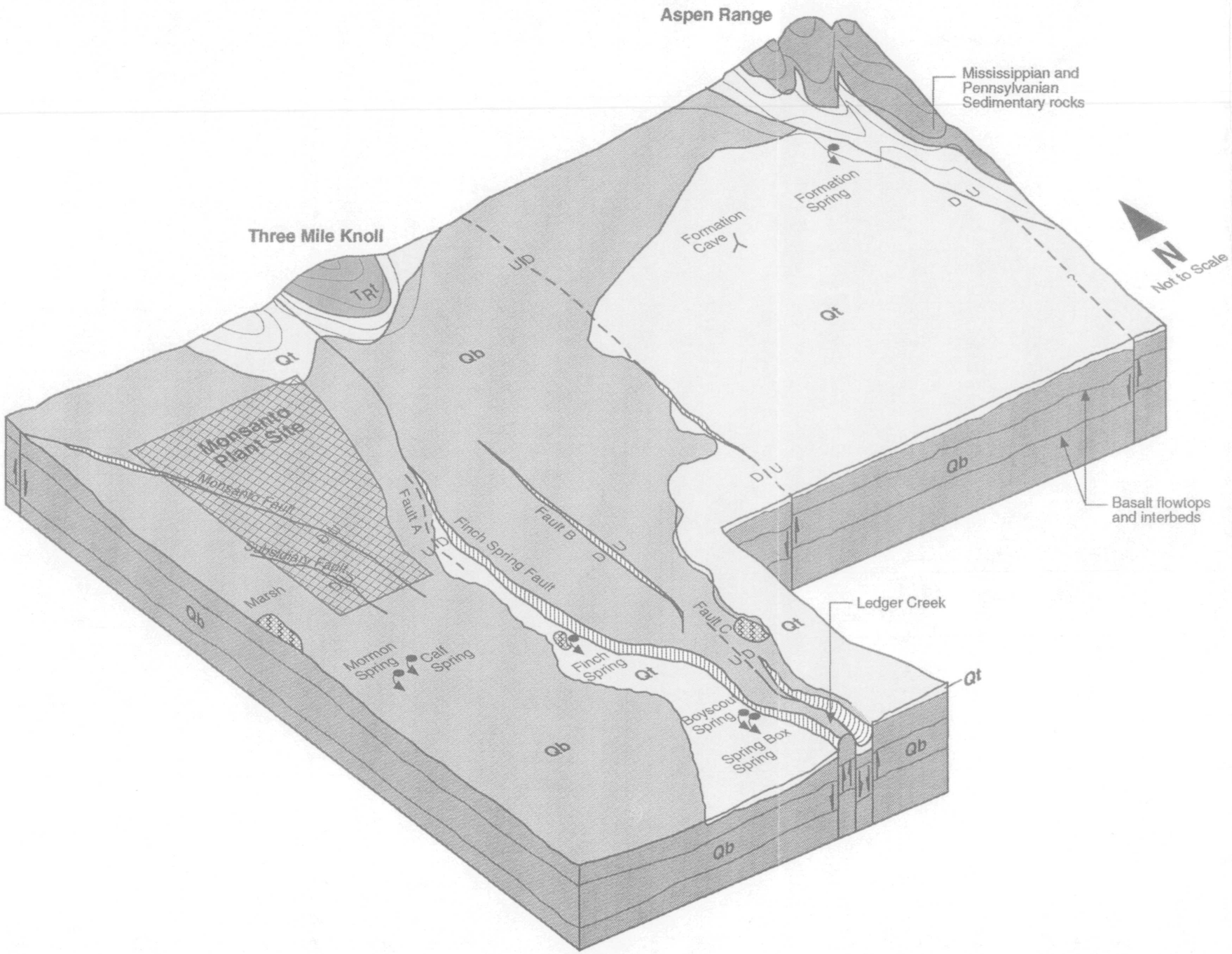


FIGURE 3-14
MONSANTO PLANT AREA FAULT LOCATIONS
MONSANTO/PHASE II RI REPORT/ID

\DJH\9131101\608\40380 6-8-94 11:48

Golder Associates



Explanation

Qt	Tufa and Travertine
Qb	Blackfoot Lava Field Basalts
$T_R t$	Thaynes Limestone

Source: Geology modified from Armstrong (1969) based on field reconnaissance.

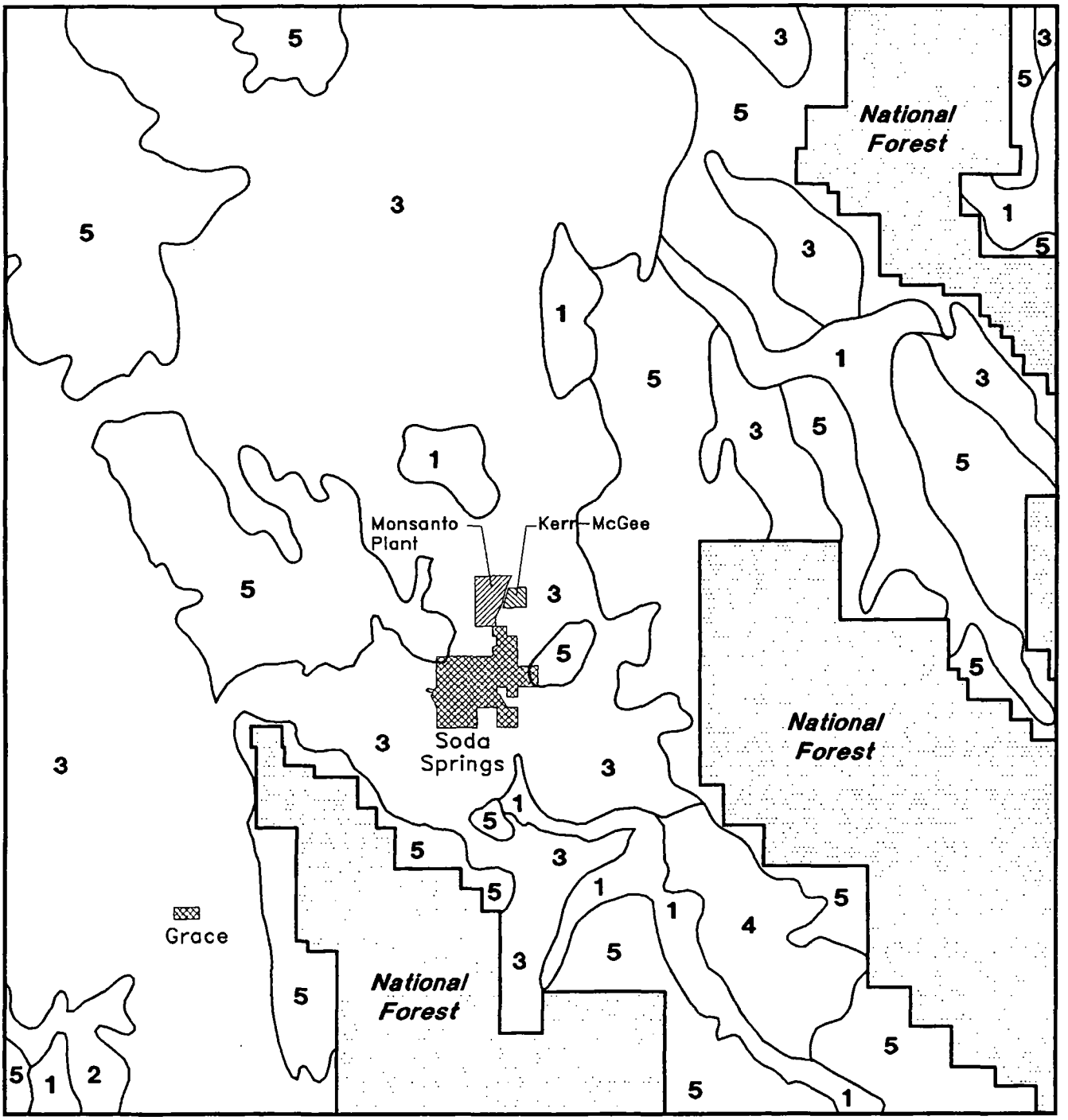
FIGURE **3-15**

LOCAL STRUCTURE BLOCK DIAGRAM

MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913 1101.608 DRAWING NO. 48121 DATE 6/8/94 DRAWN BY CB

Golder Associates



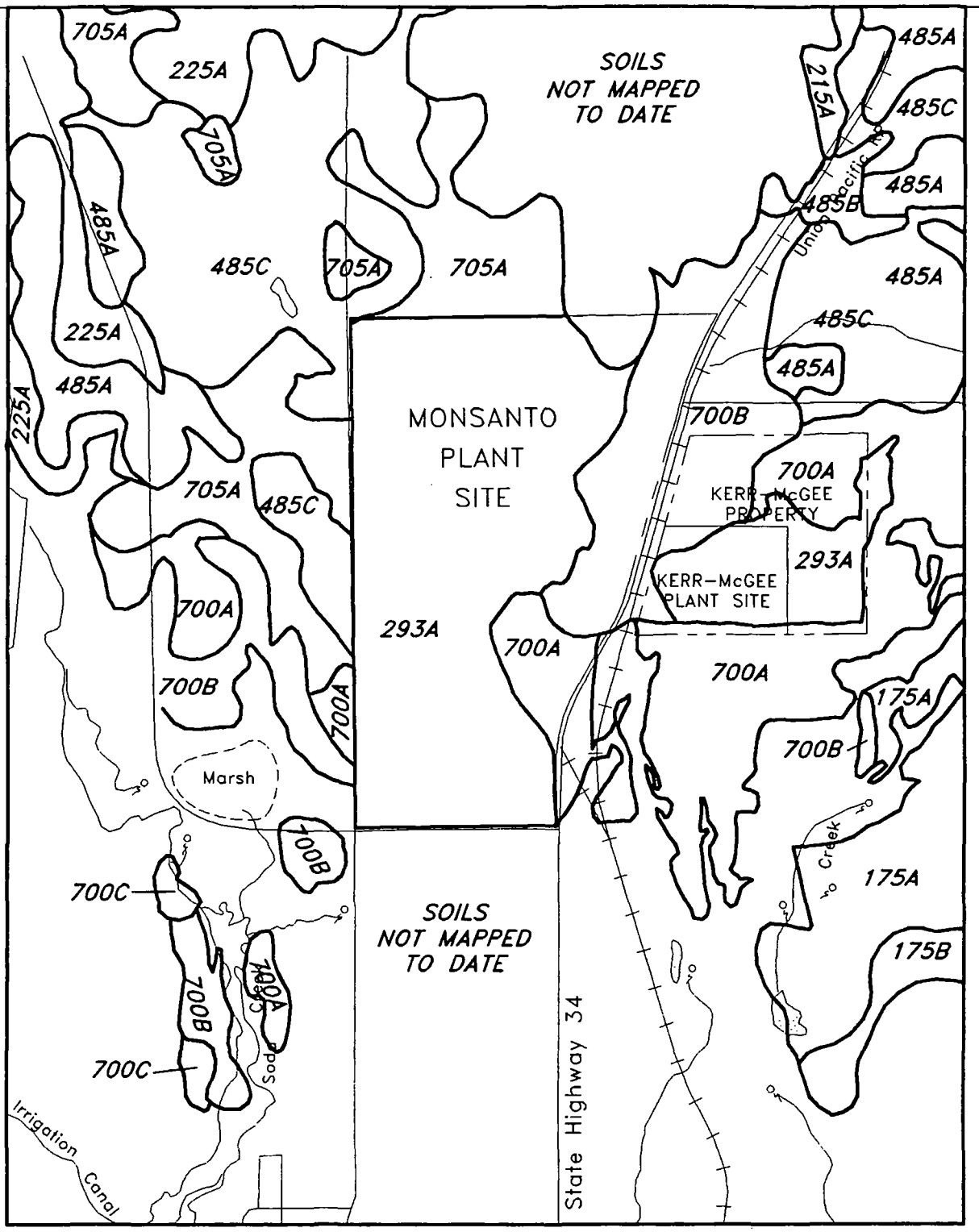
Soil Group	Description
1	Nearly level soils on flood plains and low stream terraces
2	Gently sloping to steep soils on lake terraces and terrace breaks
3	Nearly level to gently rolling soils on basalt plains and alluvial plains
4	Nearly level to moderately steep soils on fan terraces and hill slopes
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 **3-16**
REGIONAL SOIL GROUPS
MONSANTO/PHASE II RI REPORT/ID



Type	Description
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 Comples, 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 **3-17**
LOCAL SOIL TYPES
MONSANTO/PHASE II RI REPORT/ID

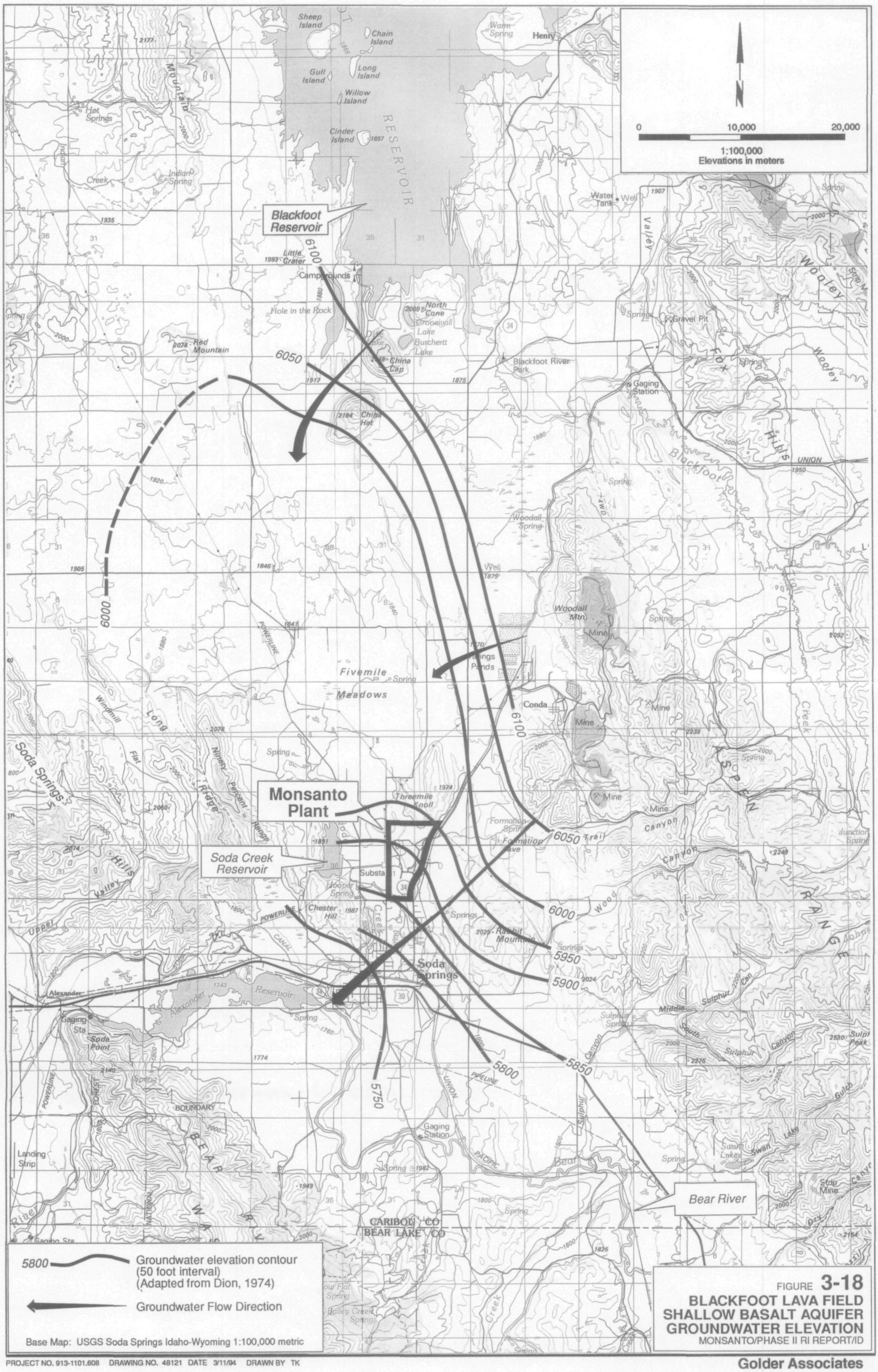


FIGURE **3-18**

BLACKFOOT LAVA FIELD SHALLOW BASALT AQUIFER GROUNDWATER ELEVATION

MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913-1101.608 DRAWING NO. 48121 DATE 3/11/94 DRAWN BY TK

Golder Associates

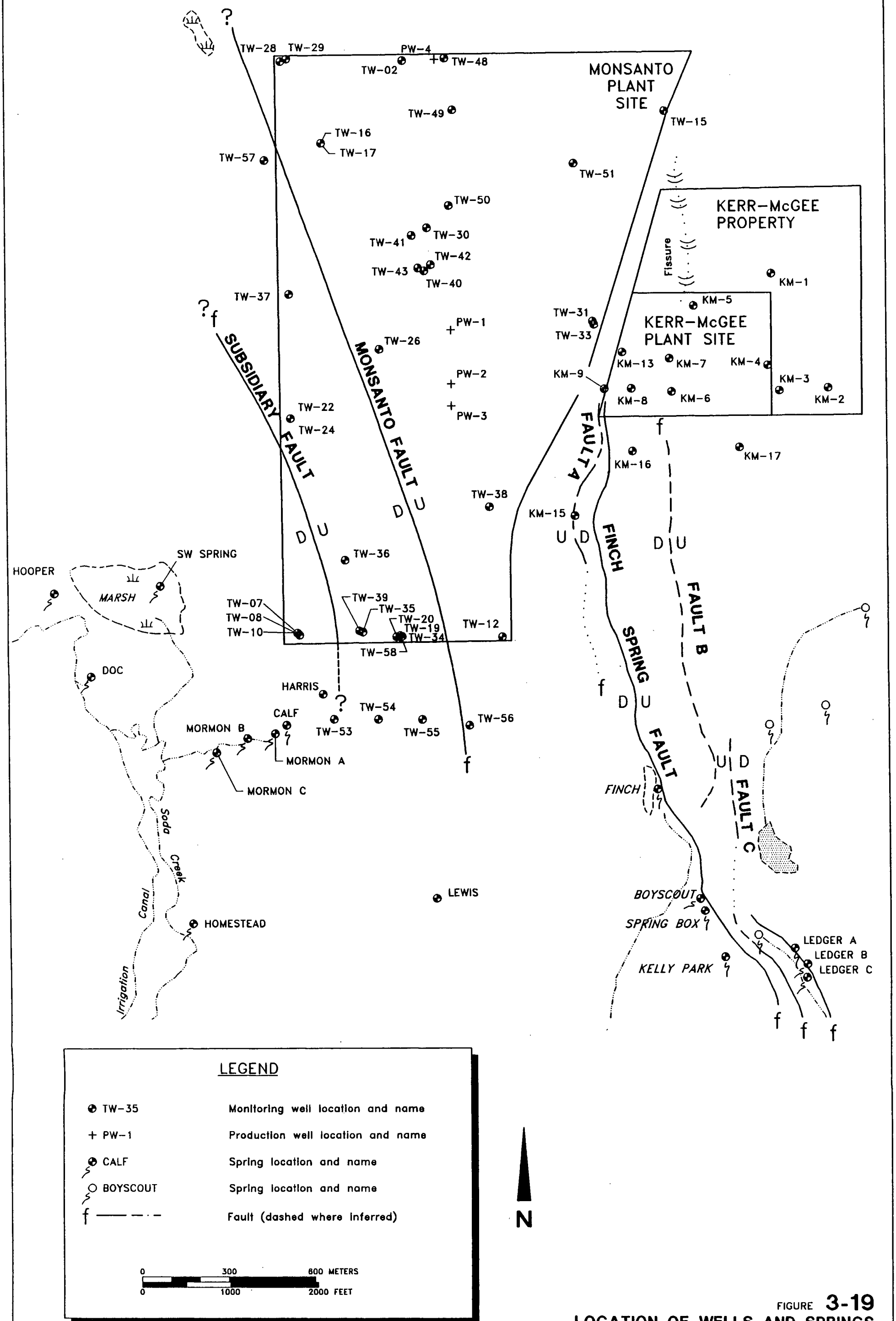


FIGURE 3-19
LOCATION OF WELLS AND SPRINGS IN THE UPPER BASALT ZONE
MONSANTO/PHASE II RI REPORT/ID

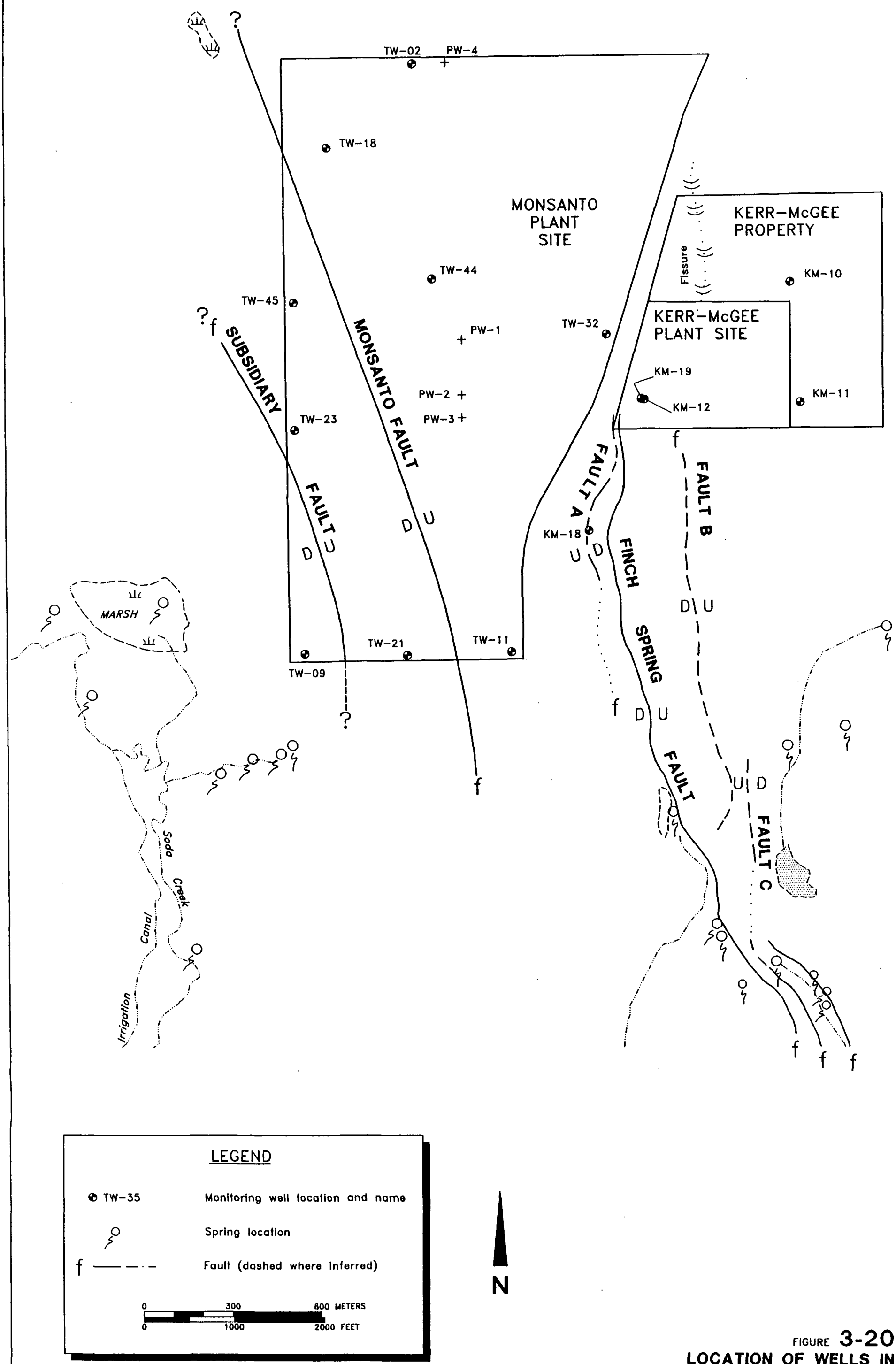
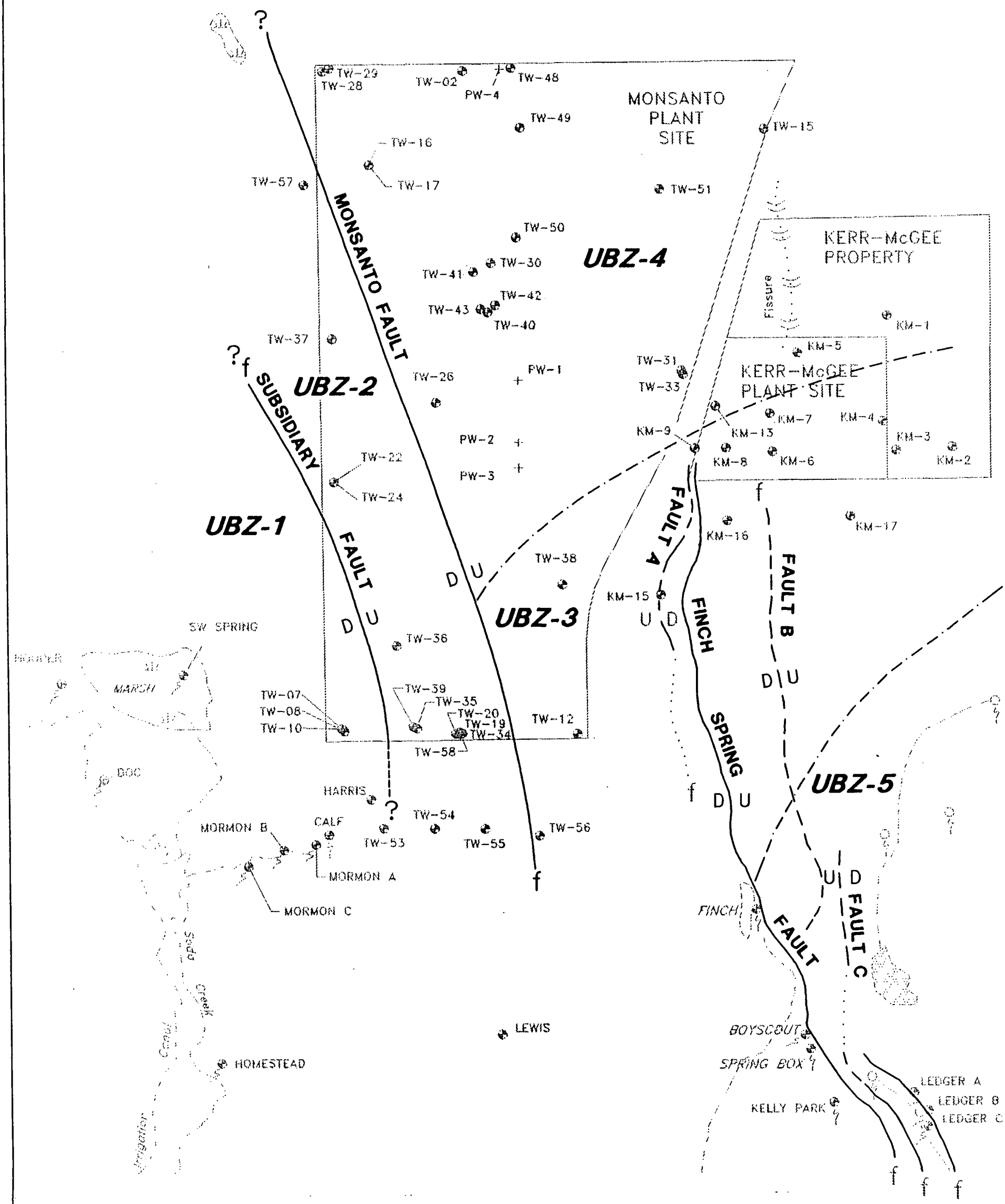


FIGURE 3-20
LOCATION OF WELLS IN THE LOWER BASALT ZONE
MONSANTO/PHASE II RI REPORT/ID



LEGEND

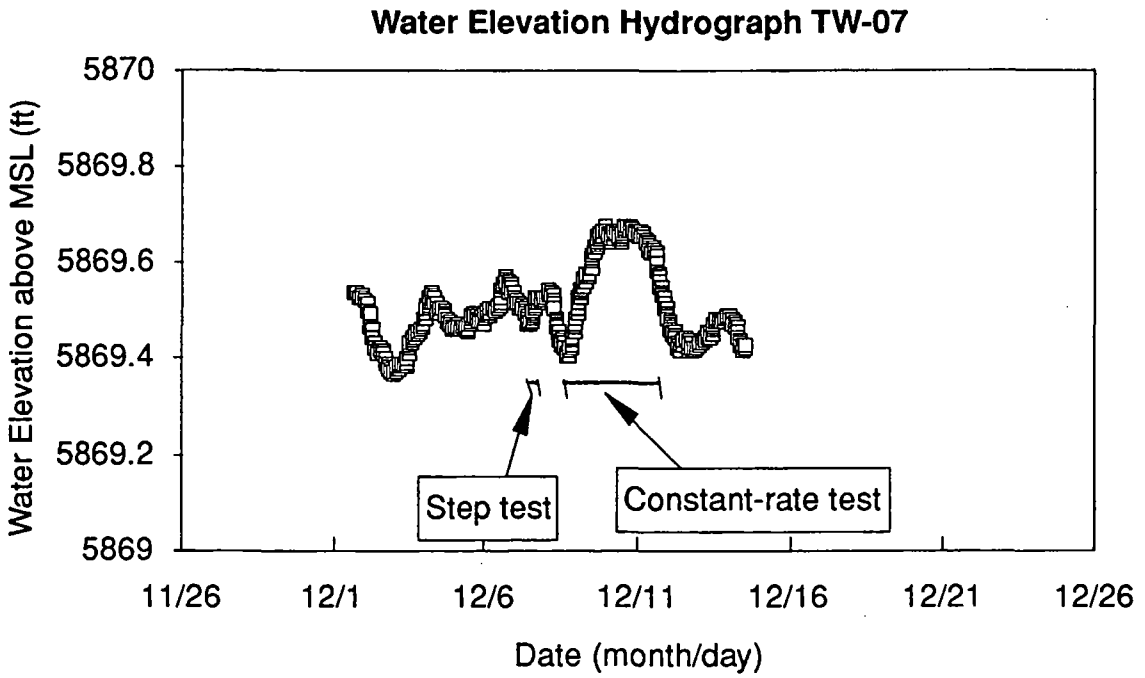
TW-35	Monitoring well location and name (UBZ only)
PW-1	Production well location and name
CALF	Spring location and name
BOYSCOUT	Spring location and name
—·—·—	Hydrostratigraphic region boundary
f —— — · —	Fault (dashed where inferred)

0 300 600 METERS
0 1000 2000 FEET

FIGURE 3-21
GROUNDWATER FLOW REGIONS IN THE UPPER BASALT ZONE
MONSANTO/PHASE II RI REPORT/ID

DWG ID: \DJH\9131101\608\42521 DATE 6-8-94 12:06 DRAWN JSS

Golder Associates



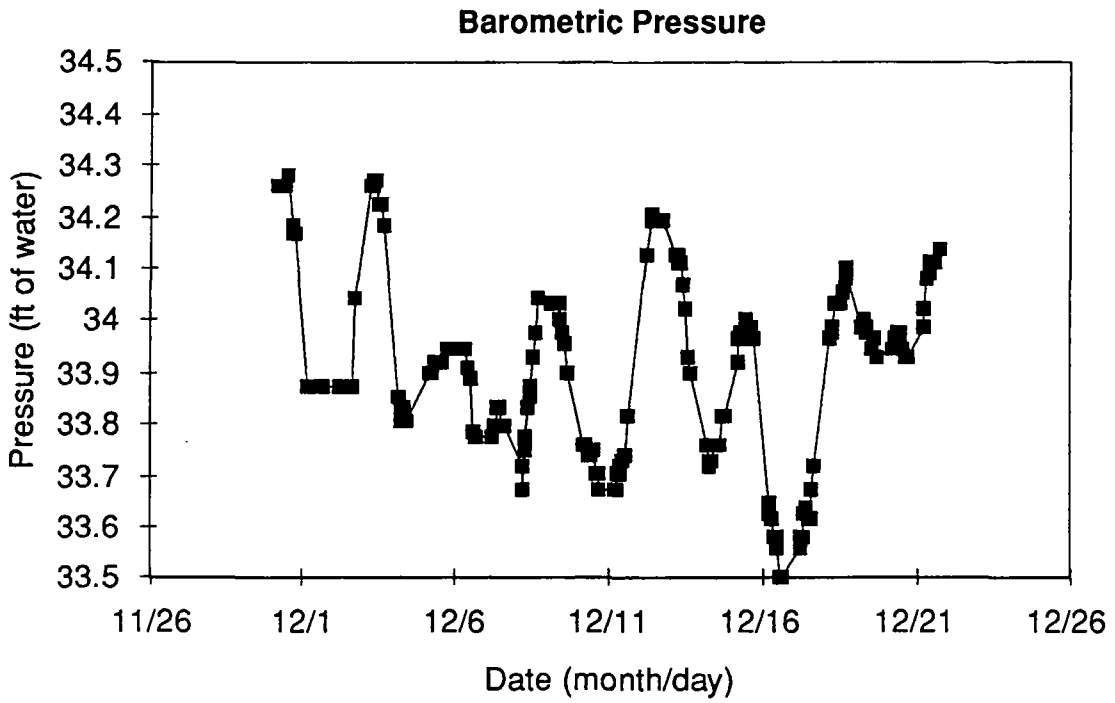


FIGURE **3-22**

BAROMETRIC PRESSURE CHANGES AND GROUNDWATER FLUCTUATIONS IN TW-07

MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913-1101.608 DRAWING NO. 48123 DATE 6/8/94 DRAWN BY TK

Golder Associates

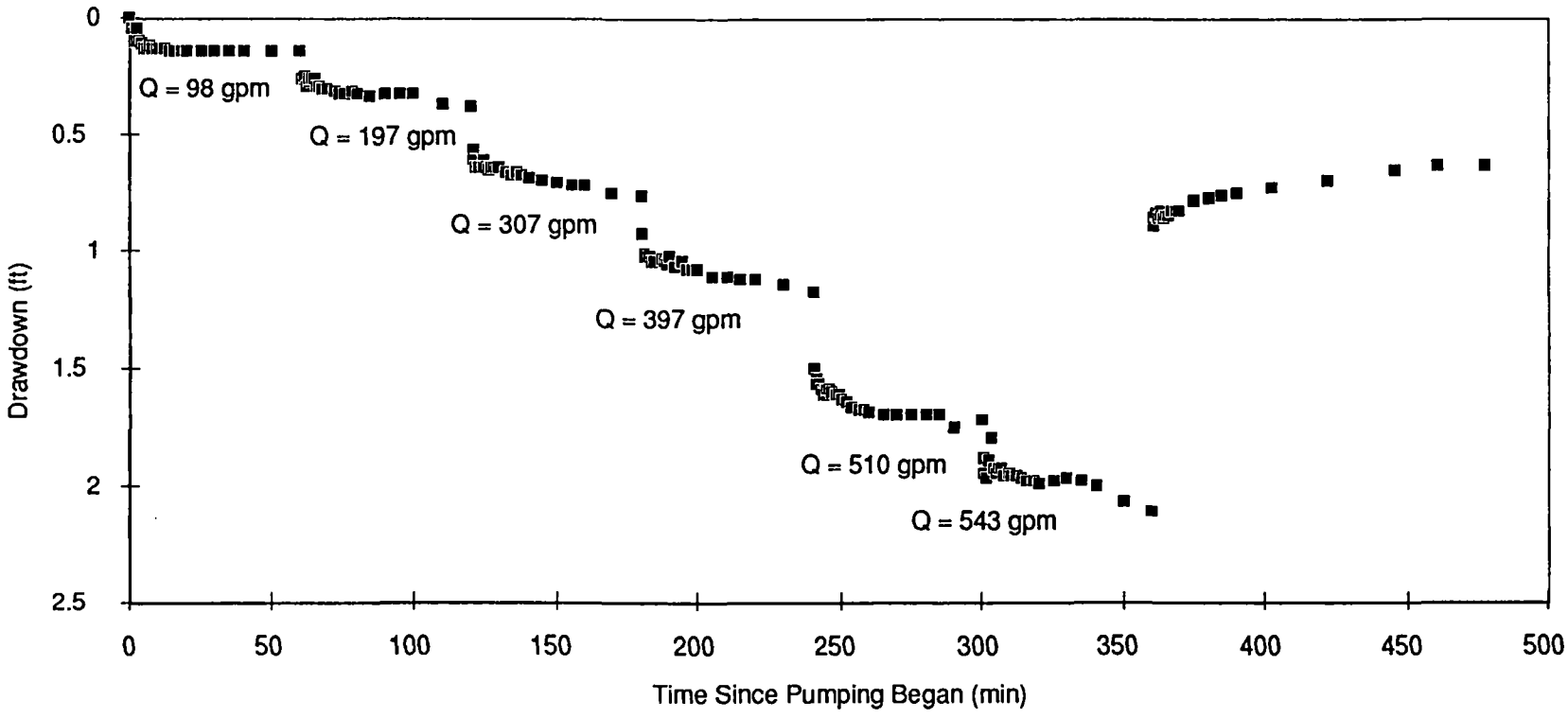


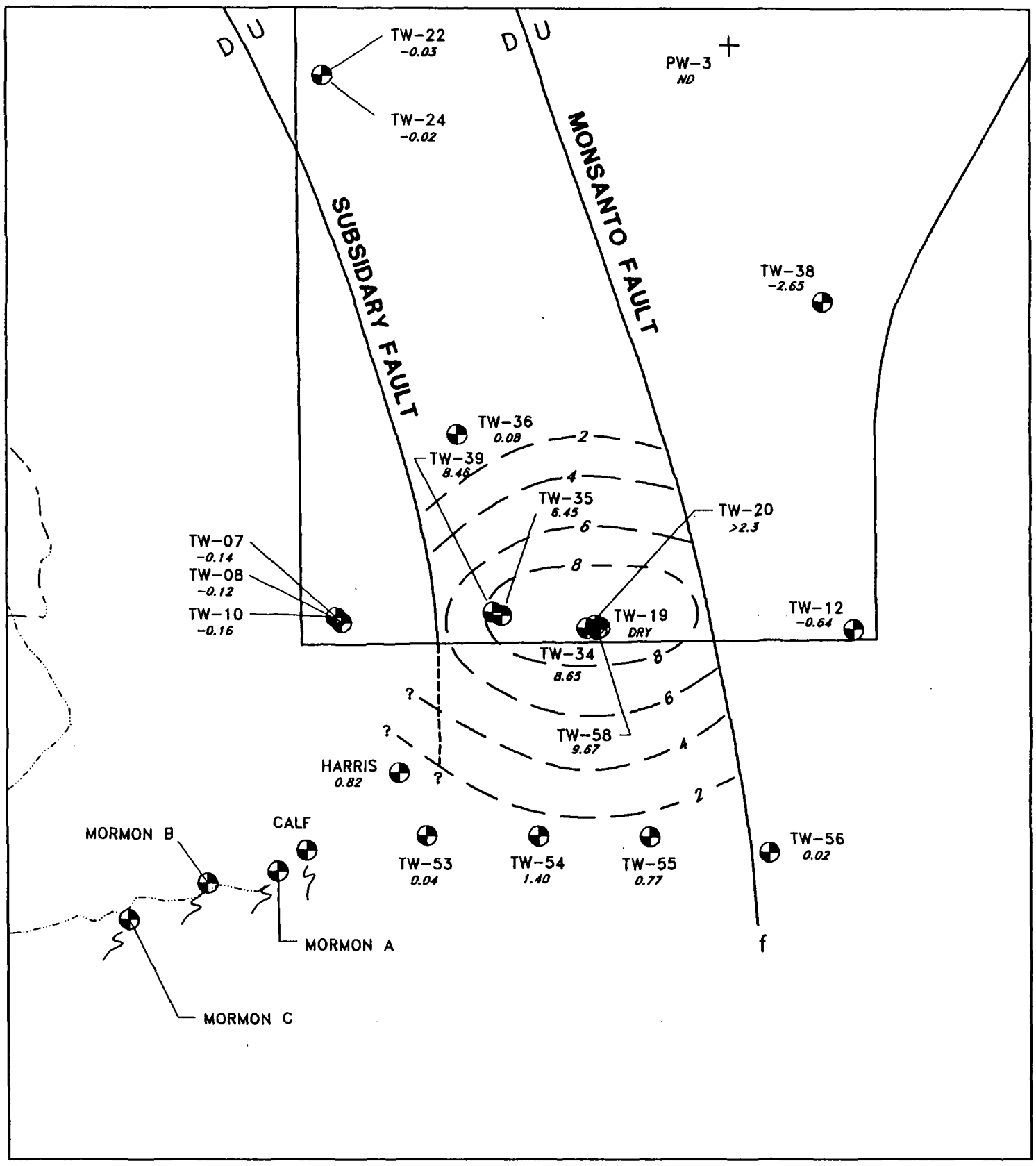
FIGURE **3-23**

STEP TEST DRAWDOWN IN TW-58

MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913 1101.608 DRAWING NO. 48721 DATE 6/8/94 DRAWN BY CB

Golder Associates



LEGEND

TW-39 *8.46*	Monitoring well location name and drawdown (feet) immediately prior to pump shutdown
+ PW-1	Production well location and name
CALF	Spring location and name
ND	No data
f	Fault (dashed where inferred)
4	Drawdown contour (feet)

0 160 320 METERS
0 600 1200 FEET

NOTE:
Test well TW-58 served as the pumping well for the aquifer test and was pumped at a constant rate of 500 gpm for 72 hours.

FIGURE **3-24**
AQUIFER TEST DRAWDOWN IN THE UPPER BASALT ZONE
MONSANTO/PHASE II RI REPORT/ID

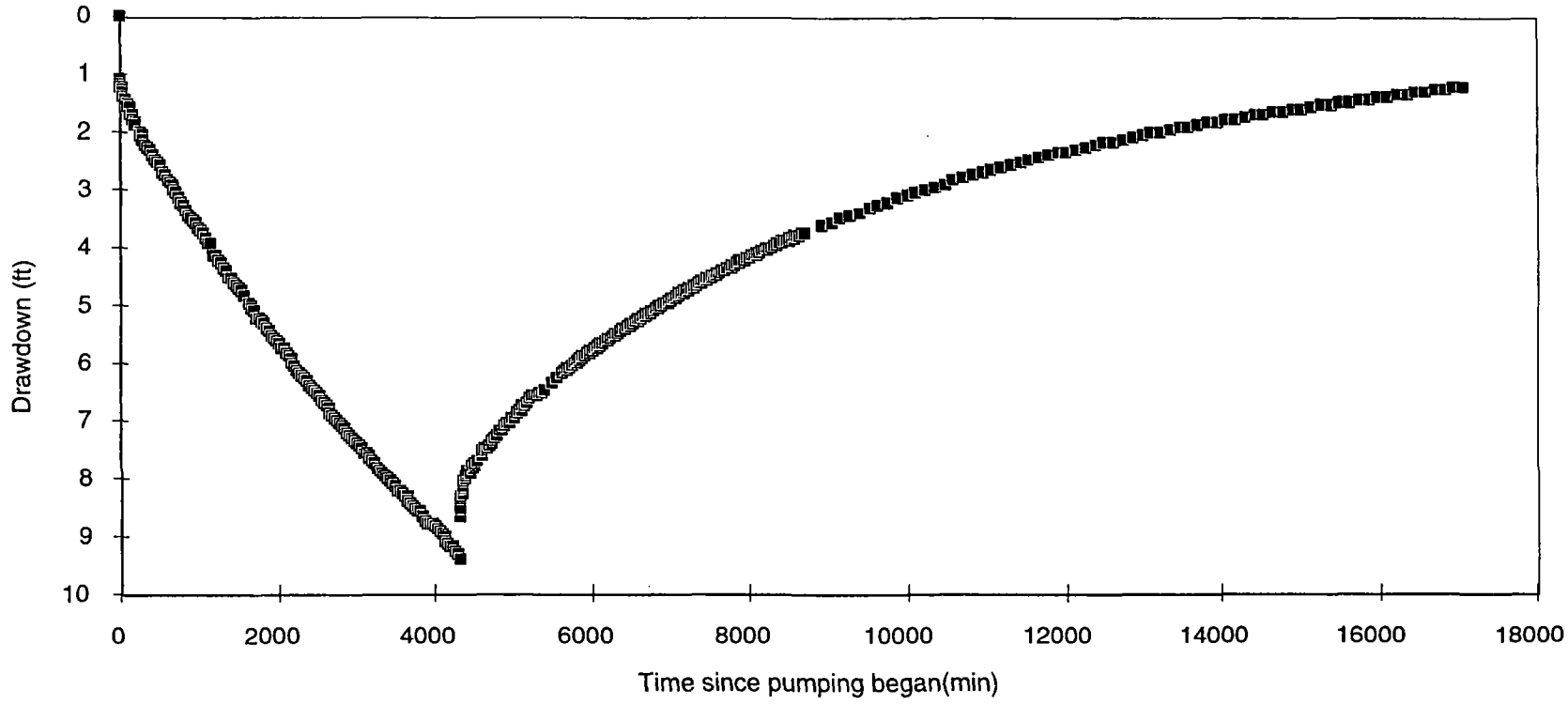


FIGURE **3-25**

CONSTANT-RATE TEST DRAWDOWN AND RECOVERY IN TW-58

MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913 1101.608 DRAWING NO. 48722 DATE 6/10/94 DRAWN BY CB

Golder Associates

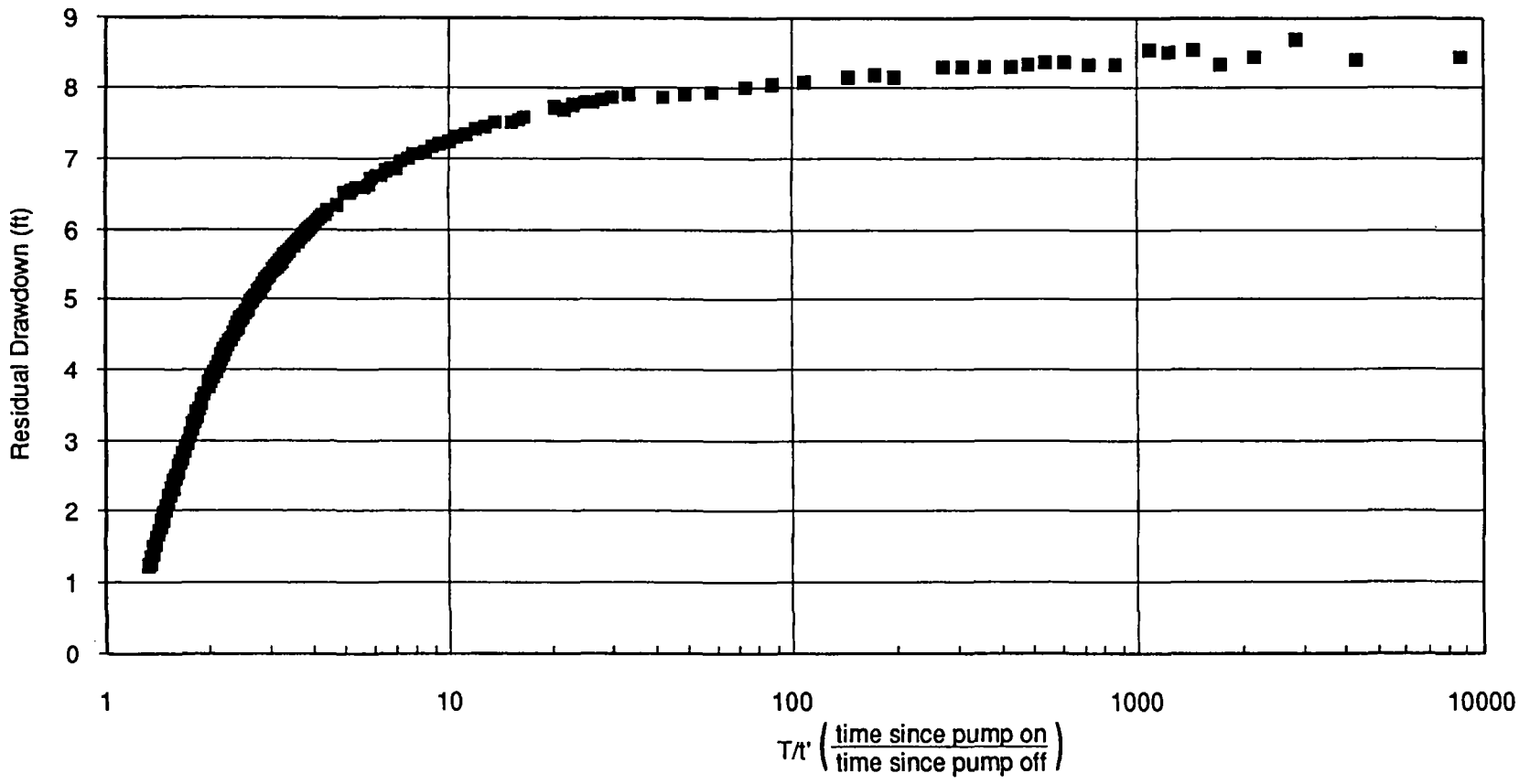


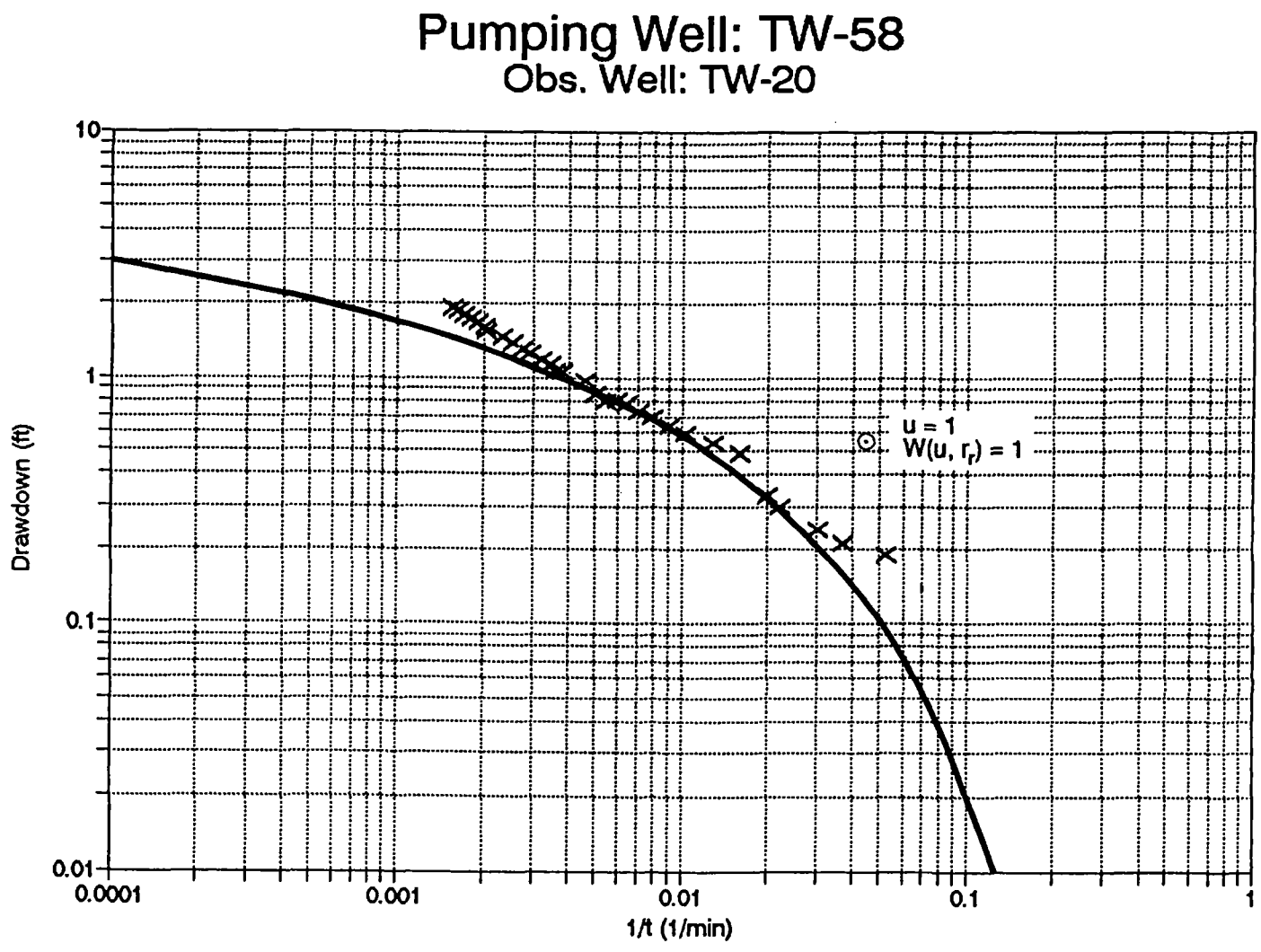
FIGURE **3-26**

RESIDUAL DRAWDOWN IN TW-58

MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913 1101.608 DRAWING NO. 48723 DATE 12/20/94 DRAWN BY CB

Golder Associates



Type curve

Field data

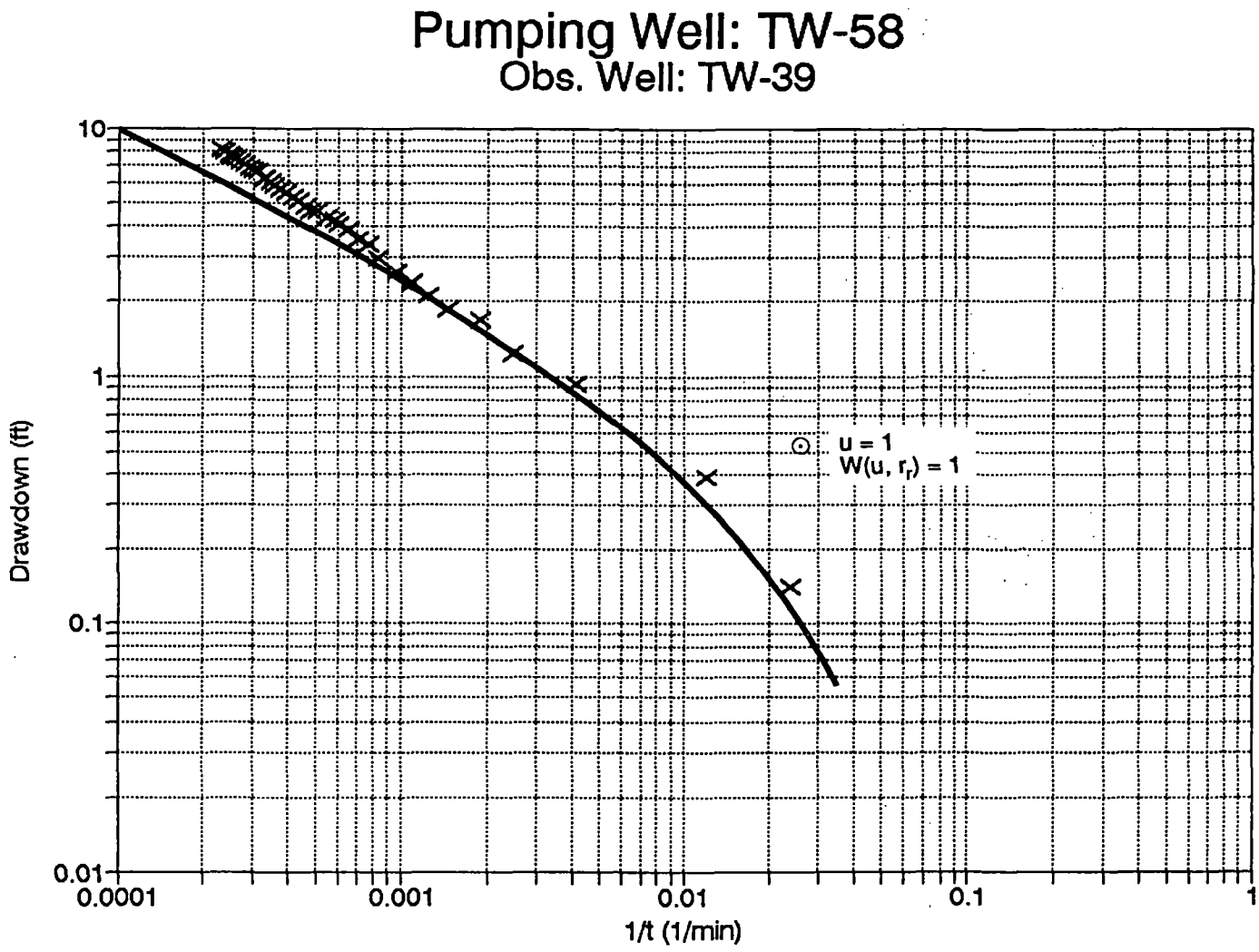
FIGURE **3-27**

BOUNDED AQUIFER TYPE-CURVE MATCH FOR TEST WELL TW-20

MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913-1101.608 DRAWING NO. 48132 DATE 3/11/94 DRAWN BY TK

Golder Associates



Type curve

Field data

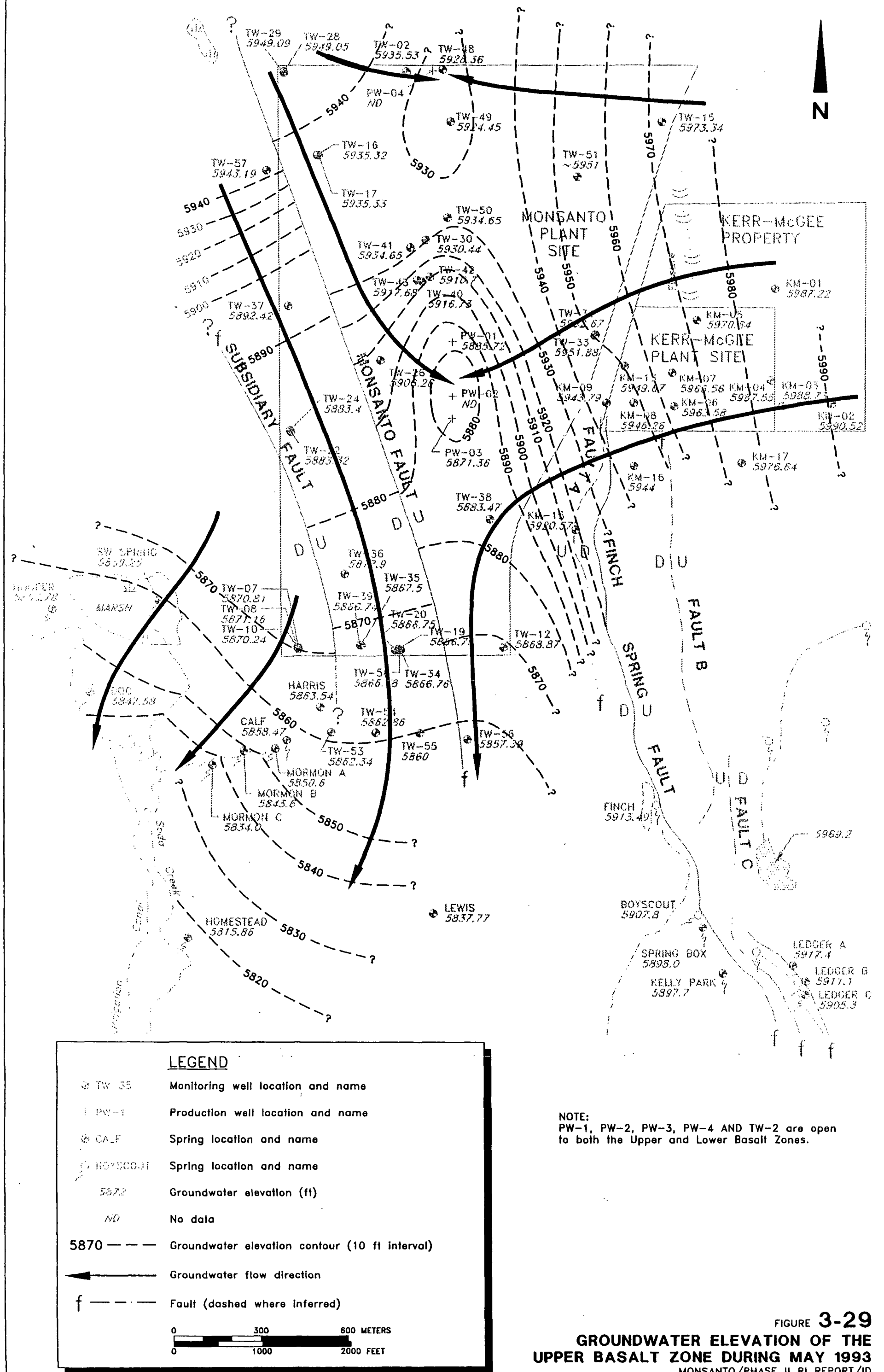
FIGURE **3-28**

BOUNDED AQUIFER TYPE-CURVE MATCH FOR TEST WELL TW-39

MONSANTO/PHASE II RI REPORT/ID

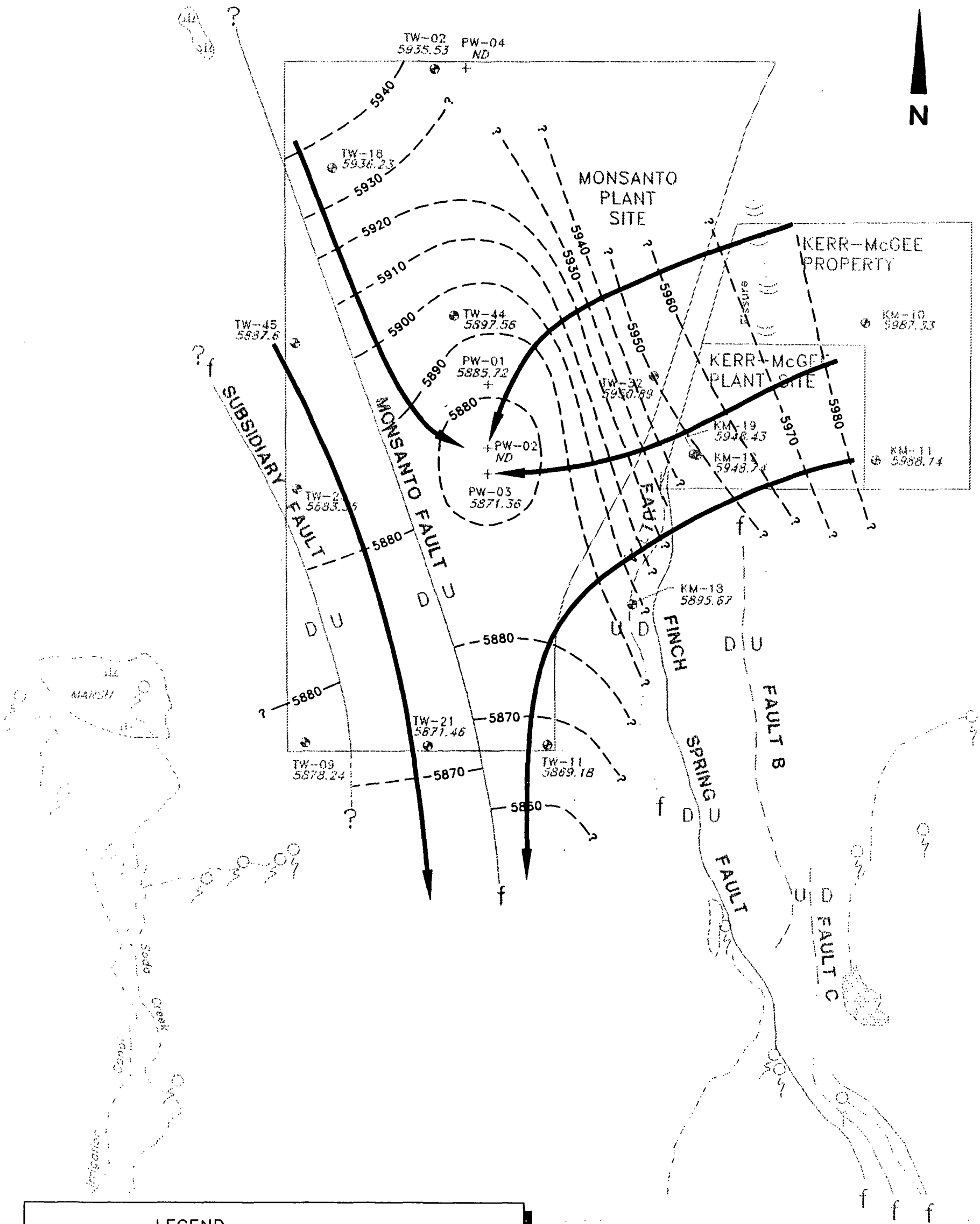
PROJECT NO. 913-1101.608 DRAWING NO. 48122 DATE 3/11/94 DRAWN BY TK

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 3-29
GROUNDWATER ELEVATION OF THE UPPER BASALT ZONE DURING MAY 1993
MONSANTO/PHASE II RI REPORT/ID



LEGEND

TW-35	Monitoring well location and name
PW-1	Production well location and name
CALF	Spring location and name
BUTSCOUT	Spring location and name
5872	Groundwater elevation (ft)
ND	No data
5870 — — —	Groundwater elevation contour (10 ft interval)
◄———	Groundwater flow direction
f — — · —	Fault (dashed where inferred)

0 300 600 METERS
0 1000 2000 FEET

NOTE:
PW-1, PW-2, PW-3, PW-4 AND TW-2 are open to both the Upper and Lower Basalt Zones.

FIGURE 3-30
GROUNDWATER ELEVATION OF THE LOWER BASALT ZONE DURING MAY 1993
MONSANTO/PHASE II RI REPORT/ID

\DJH\9131101\608\40241 6-10-94 10:09

Golder Associates

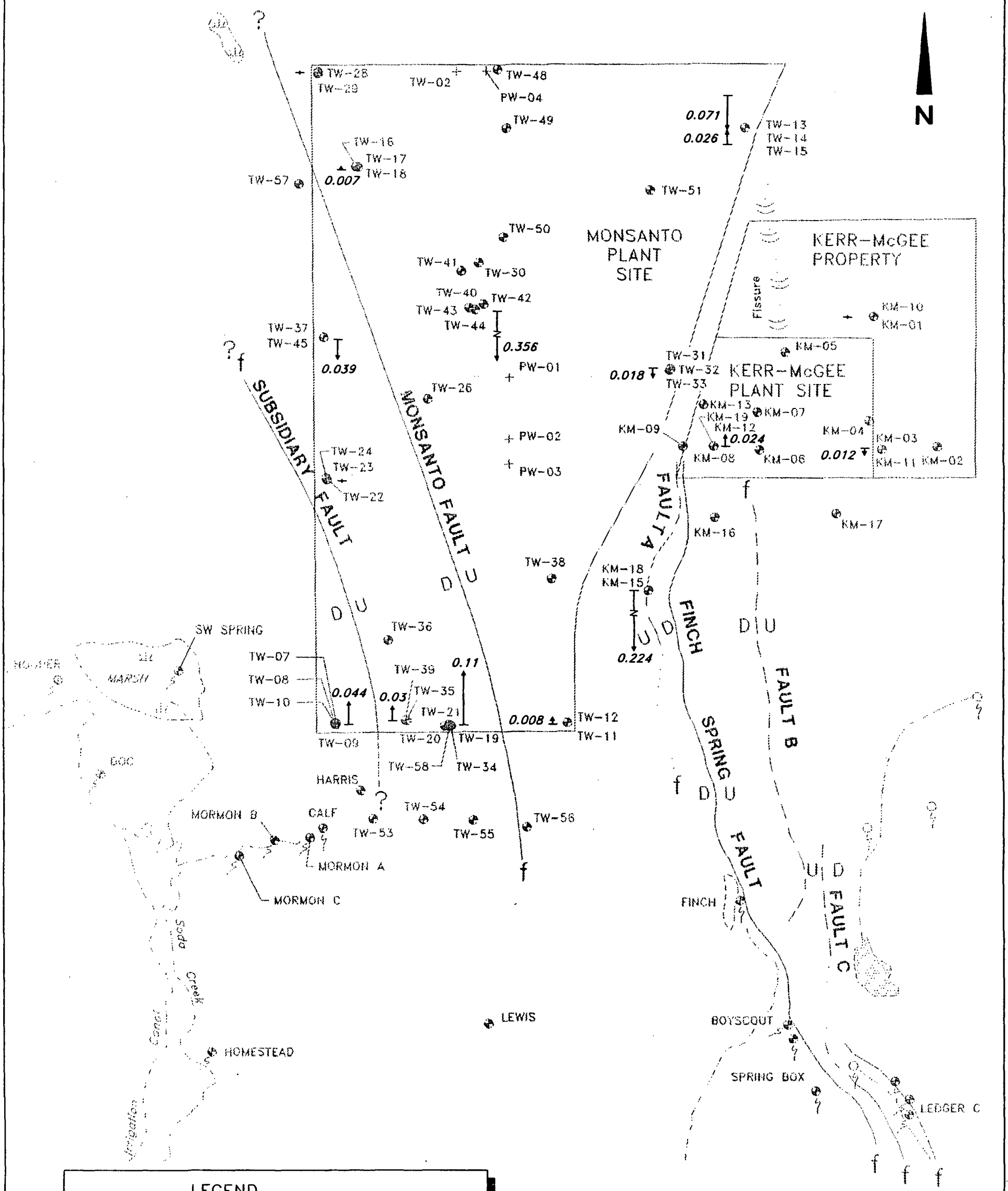
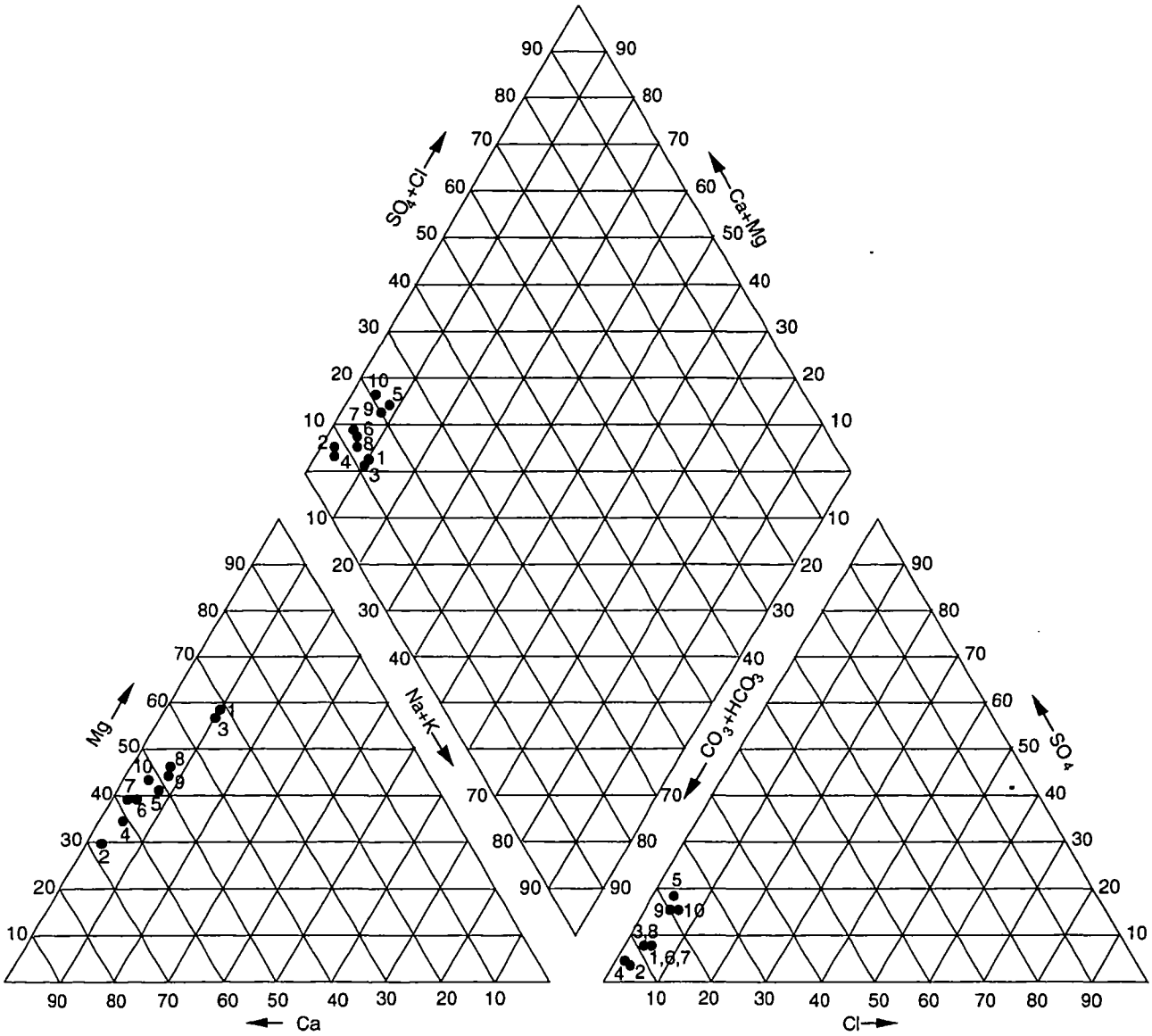


FIGURE 3-31
VERTICAL HYDRAULIC GRADIENTS MEASURED DURING MAY 1993
MONSANTO/PHASE II RI REPORT/ID

\DJH\9131101\608\42397 6-8-94 12:28

Golder Associates



Sample Key

1	Doc Kackley Spring	8	TW-28
2	Formation C Spring	9	TW-29
3	Hooper Spring	10	TW-48
4	Ledger C Spring		
5	PW-04		
6	TW-13		
7	TW-15		

Note: Data based on mean values for available sample results.

FIGURE **3-32**

PIPER DIAGRAM FOR GROUNDWATER IN THE VICINITY OF THE MONSANTO PLANT

MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913 1101.608 DRAWING NO. 48718 DATE 6/10/94 DRAWN BY CB

Golder Associates

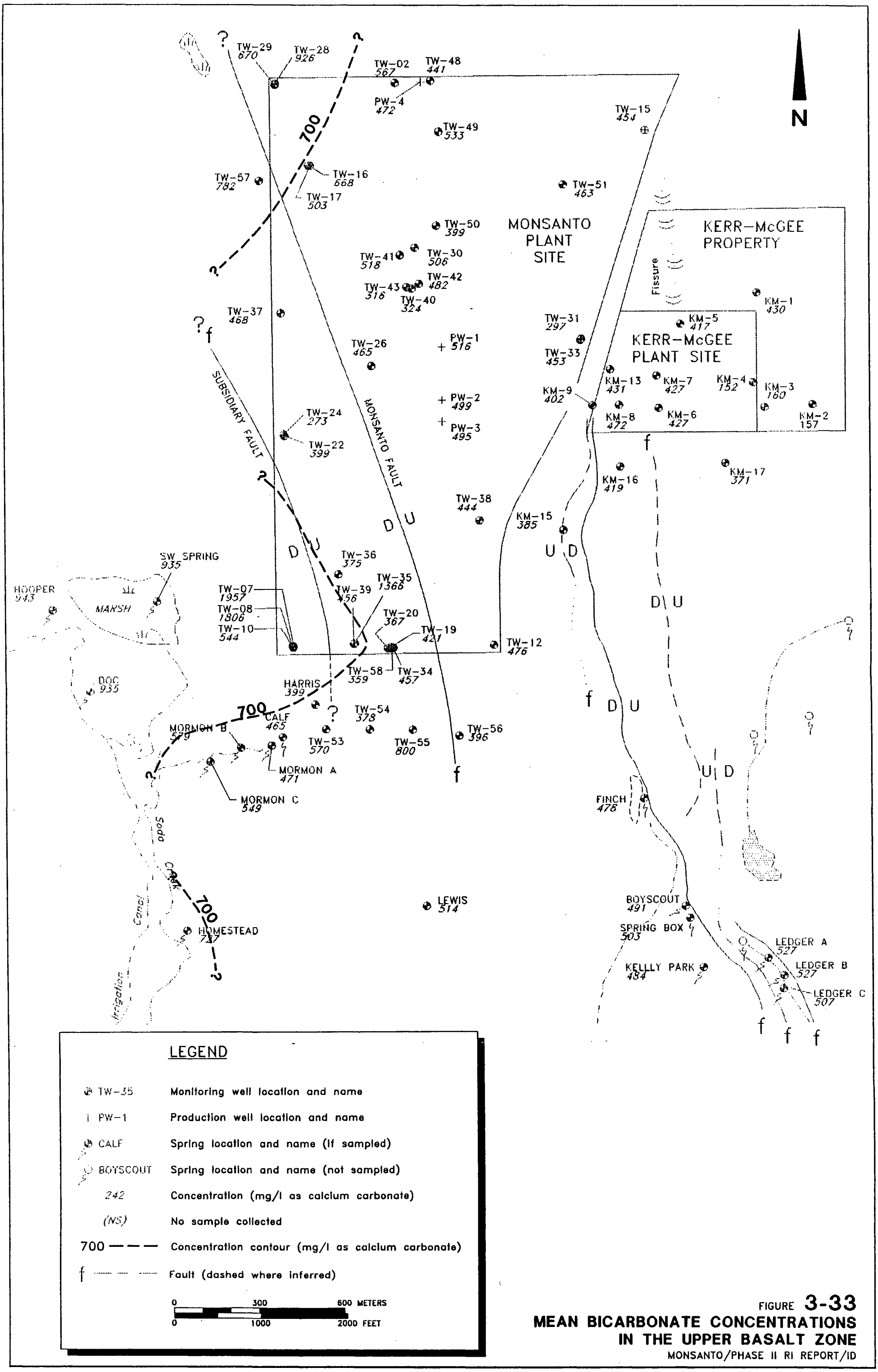


FIGURE 3-33
MEAN BICARBONATE CONCENTRATIONS IN THE UPPER BASALT ZONE
MONSANTO/PHASE II RI REPORT/ID

\DJH\9131101\608\43410 6-8-94 13:16 DRAWN JSS

Golder Associates

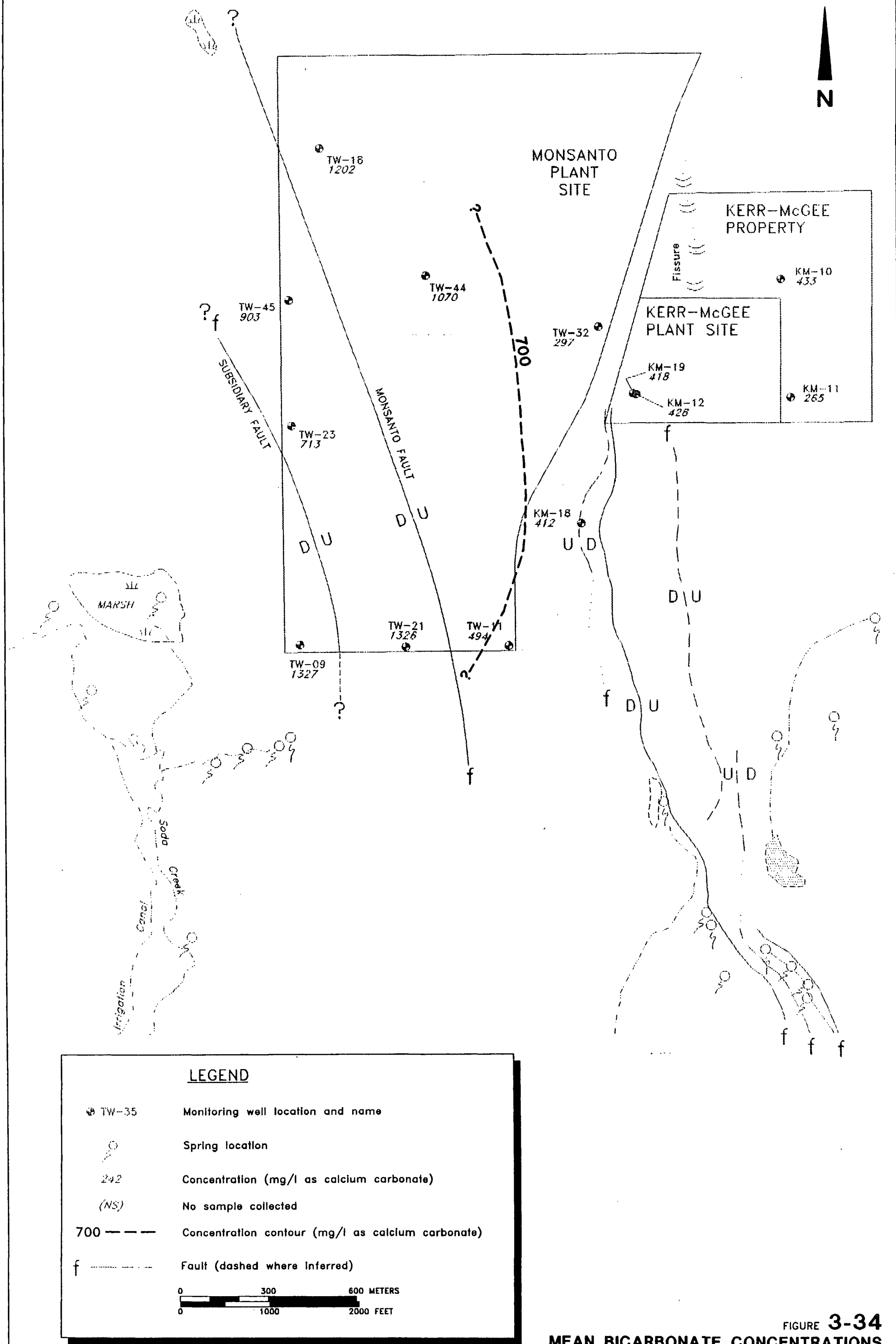


FIGURE 3-34
MEAN BICARBONATE CONCENTRATIONS IN THE LOWER BASALT ZONE
MONSANTO/PHASE II RI REPORT/ID

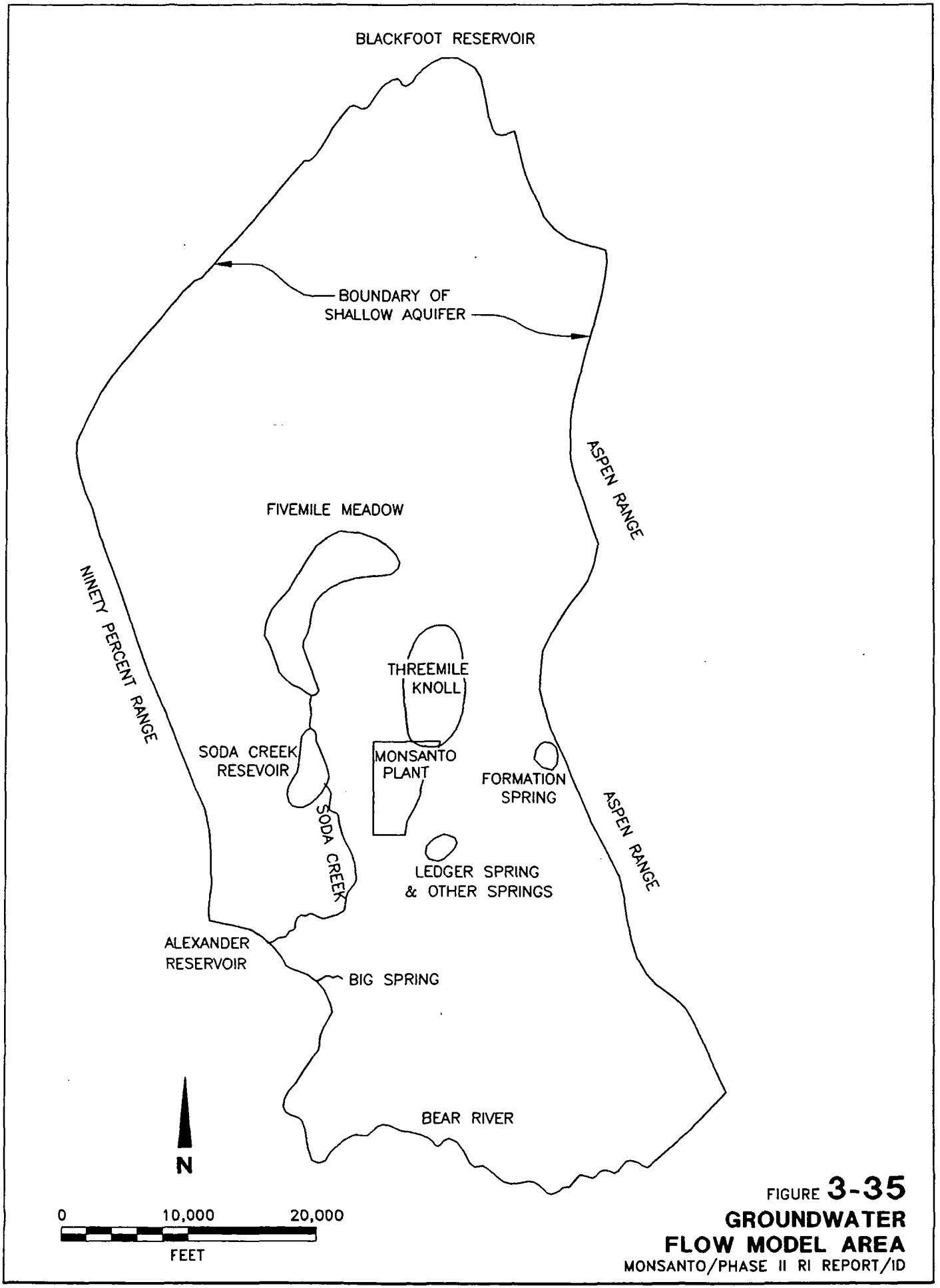


FIGURE **3-35**

GROUNDWATER FLOW MODEL AREA

MONSANTO/PHASE II RI REPORT/ID

DWG ID: \DJH\9131101\608\42463 DATE 6-8-94 12:32 DRAWN PM

Golder Associates

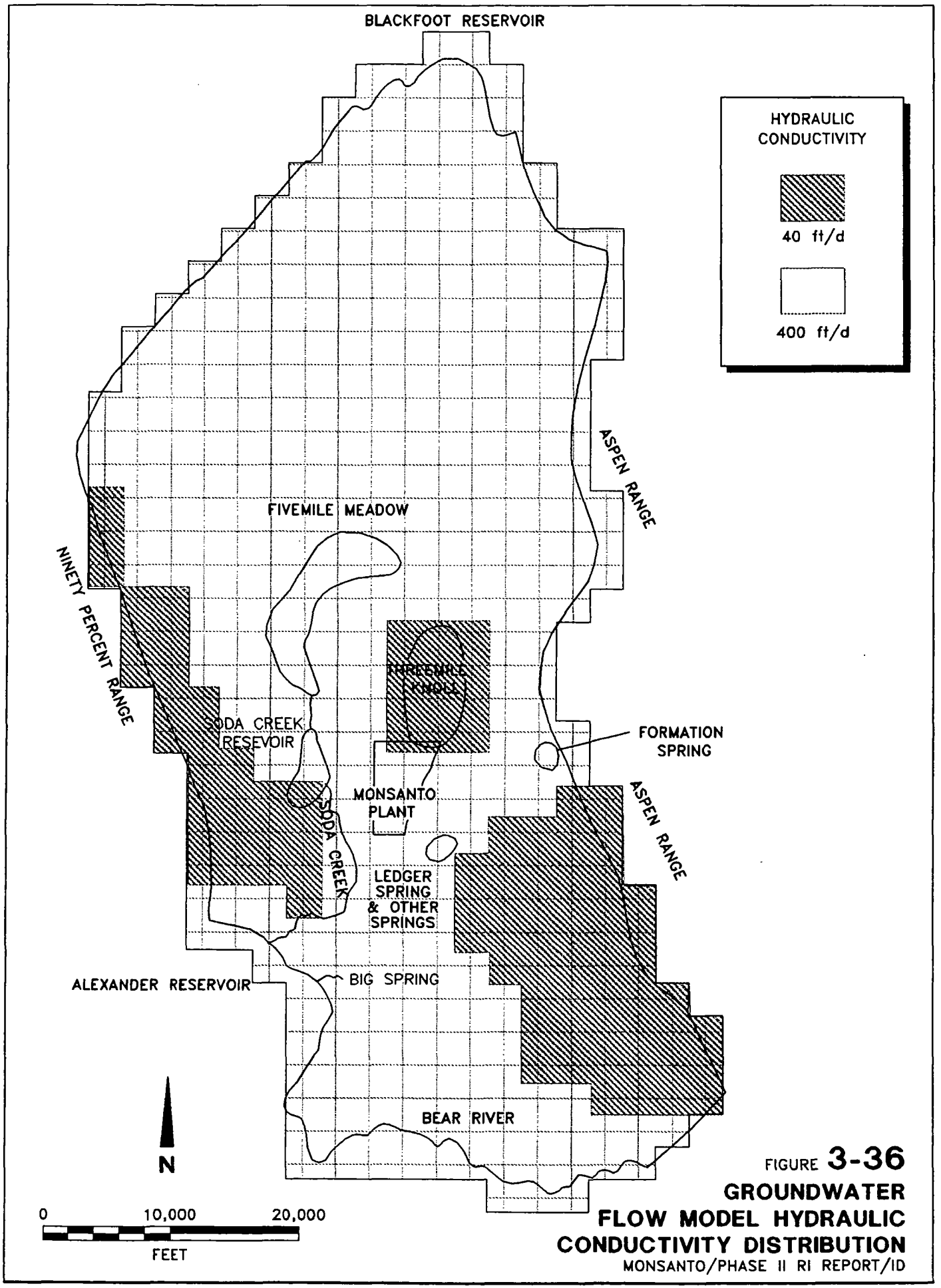


FIGURE **3-36**

GROUNDWATER FLOW MODEL HYDRAULIC CONDUCTIVITY DISTRIBUTION

MONSANTO/PHASE II RI REPORT/ID

DWG ID: \DJH\9131101\608\42464 DATE 6-8-94 12:35 DRAWN PM

Golder Associates

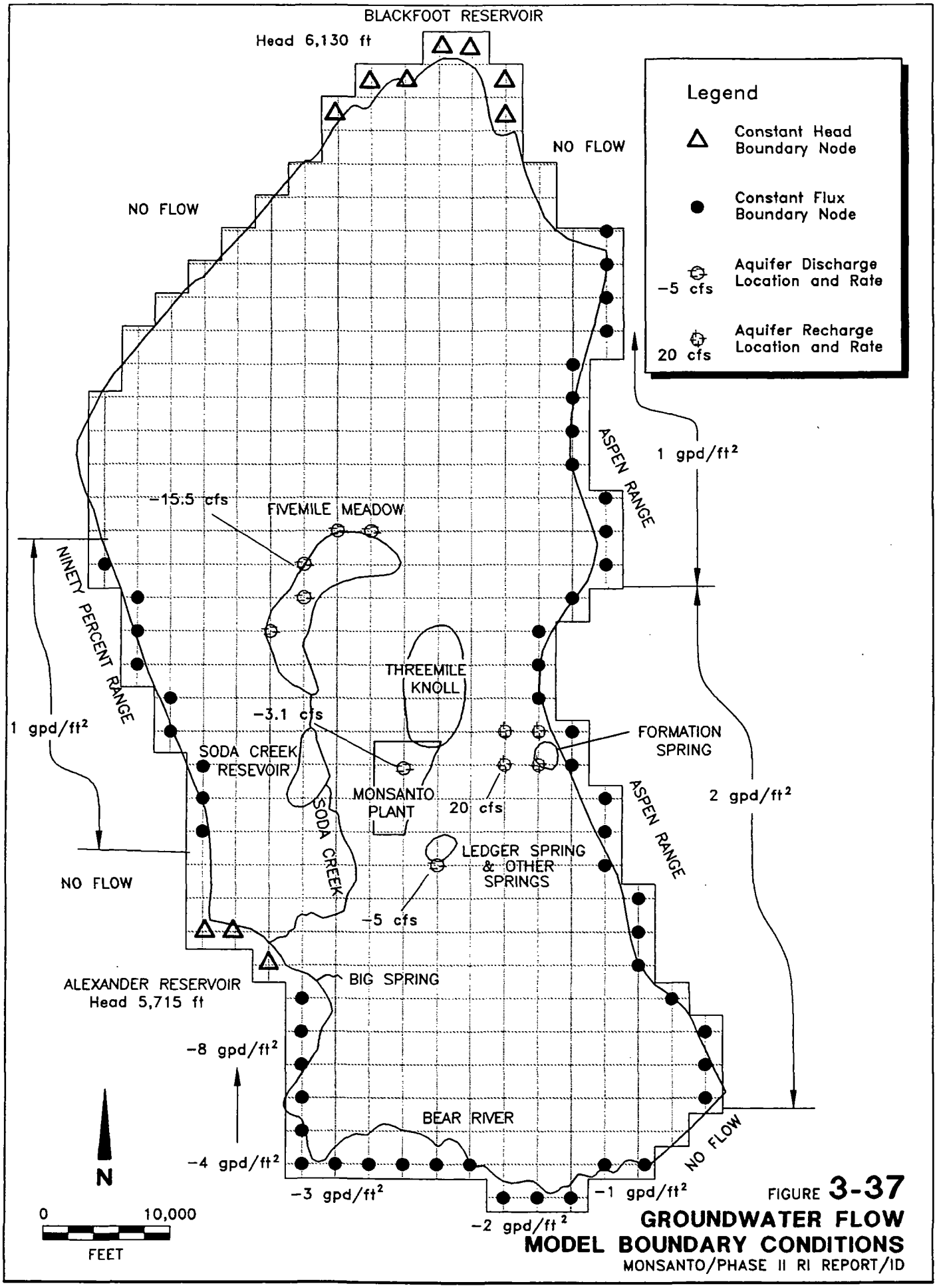


FIGURE 3-37

GROUNDWATER FLOW MODEL BOUNDARY CONDITIONS

MONSANTO/PHASE II RI REPORT/ID

DWG ID: \DJH\9131101\608\42465 DATE 6-8-94 12:38 DRAWN PM

Golder Associates

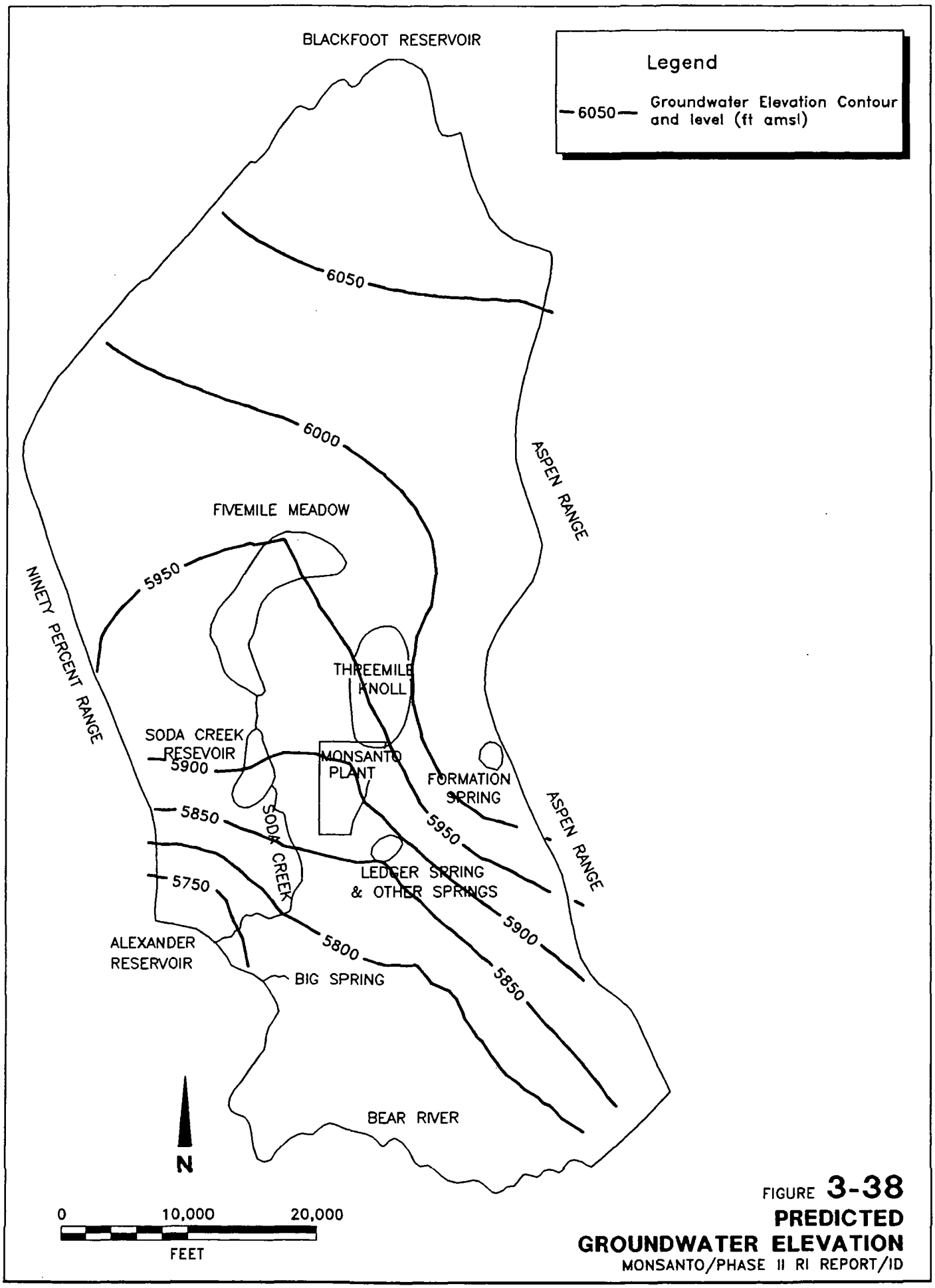


FIGURE **3-38**

PREDICTED GROUNDWATER ELEVATION

MONSANTO/PHASE II RI REPORT/ID

DWG ID: \DJH\9131101\608\42466 DATE 6-8-94 12:41 DRAWN PM

Golder Associates

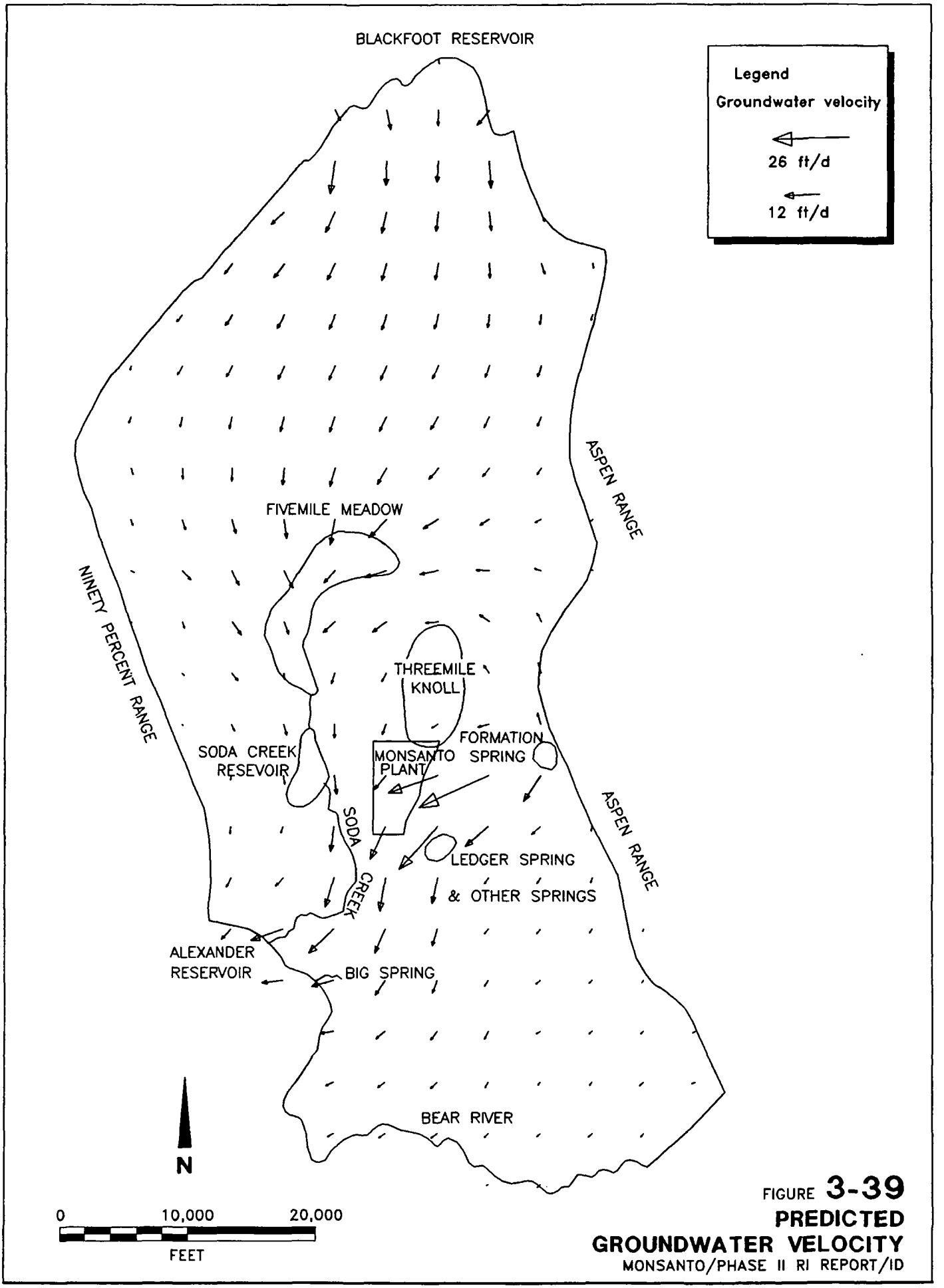


FIGURE **3-39**
PREDICTED GROUNDWATER VELOCITY
MONSANTO/PHASE II RI REPORT/ID

DWG ID: \DJH\9131101\608\42468 DATE 6-8-94 12:44 DRAWN PM

Golder Associates

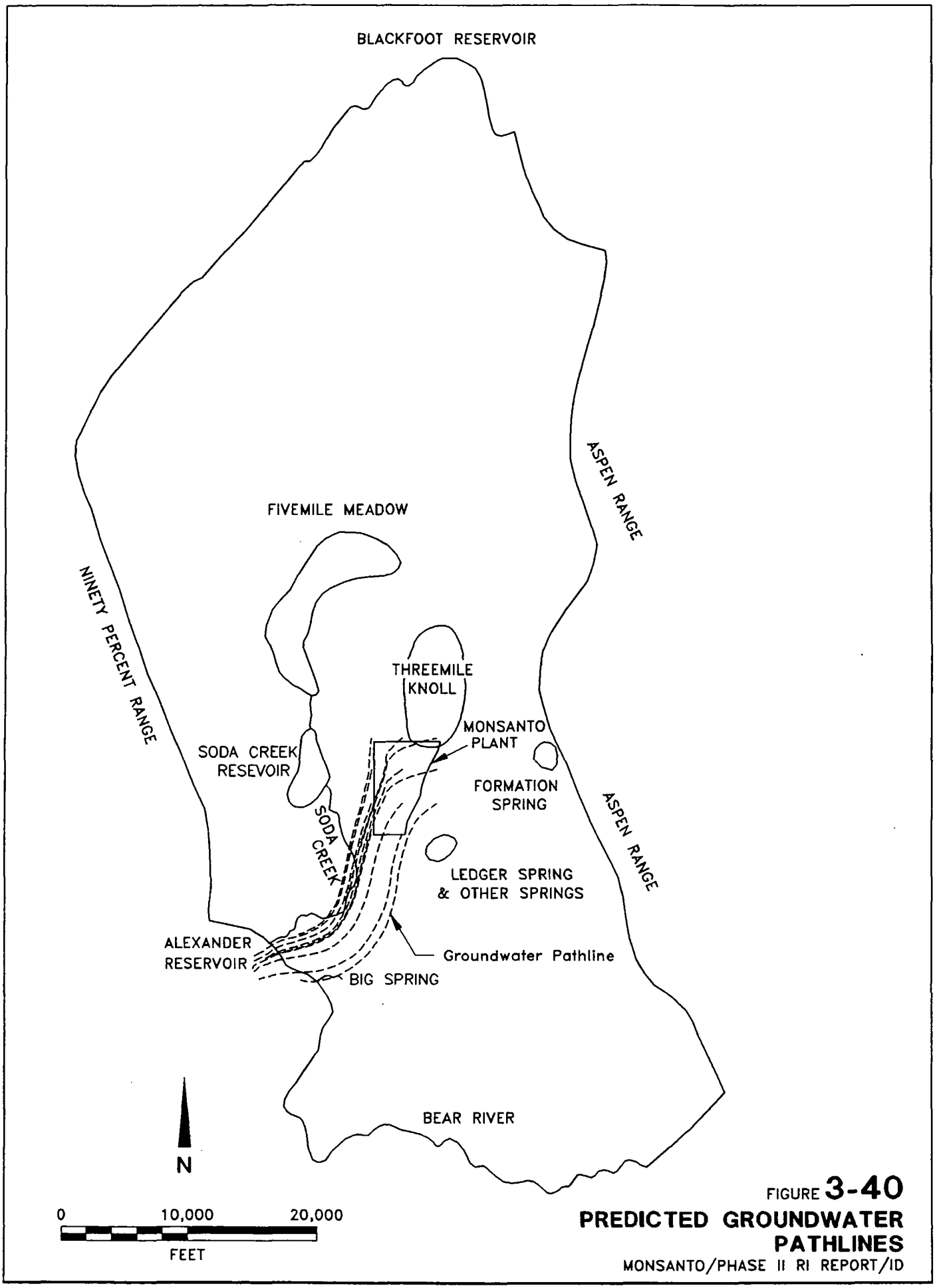


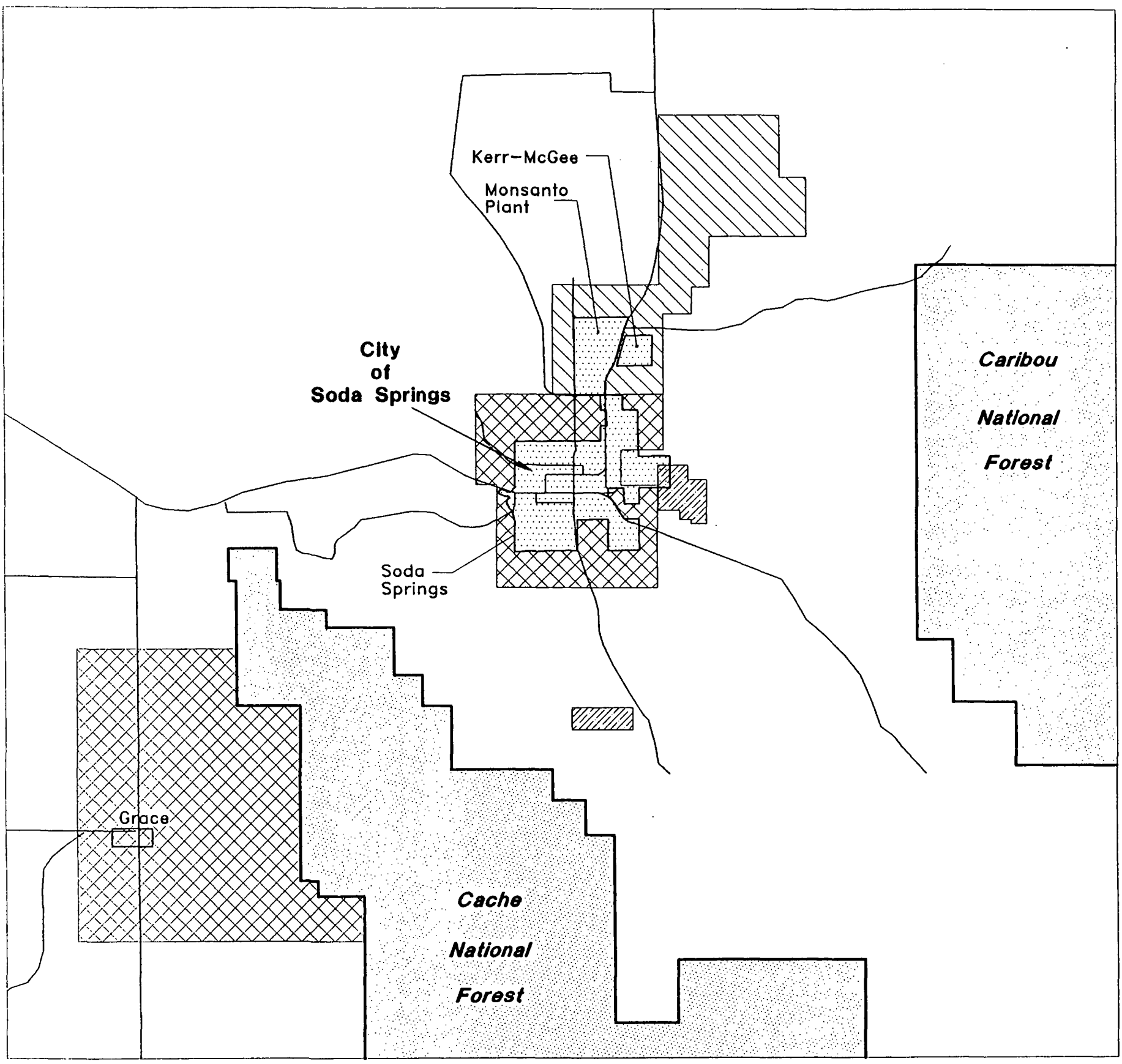
FIGURE 3-40

PREDICTED GROUNDWATER PATHLINES

MONSANTO/PHASE II RI REPORT/ID

DWG ID: \DJH\9131101\608\42467 DATE 6-8-94 12:46 DRAWN PM

Golder Associates



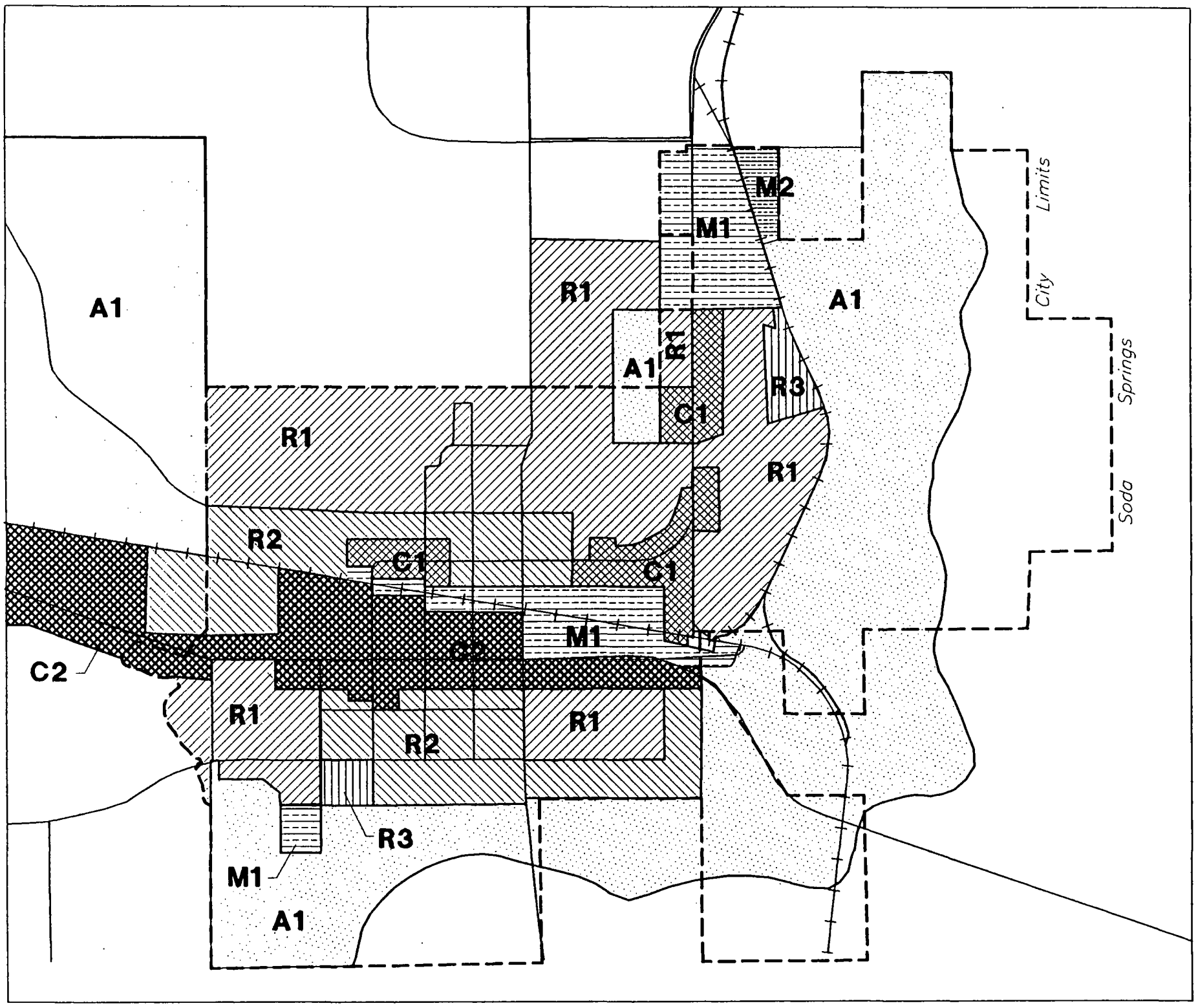
ZONING

- Industrial – heavy
- Residential – transitional
- Impact area

N

0 3000 6000 METERS
0 10000 20000 FEET

FIGURE **3-41**
REGIONAL LAND ZONING MAP
MONSANTO/PHASE II RI REPORT/ID



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

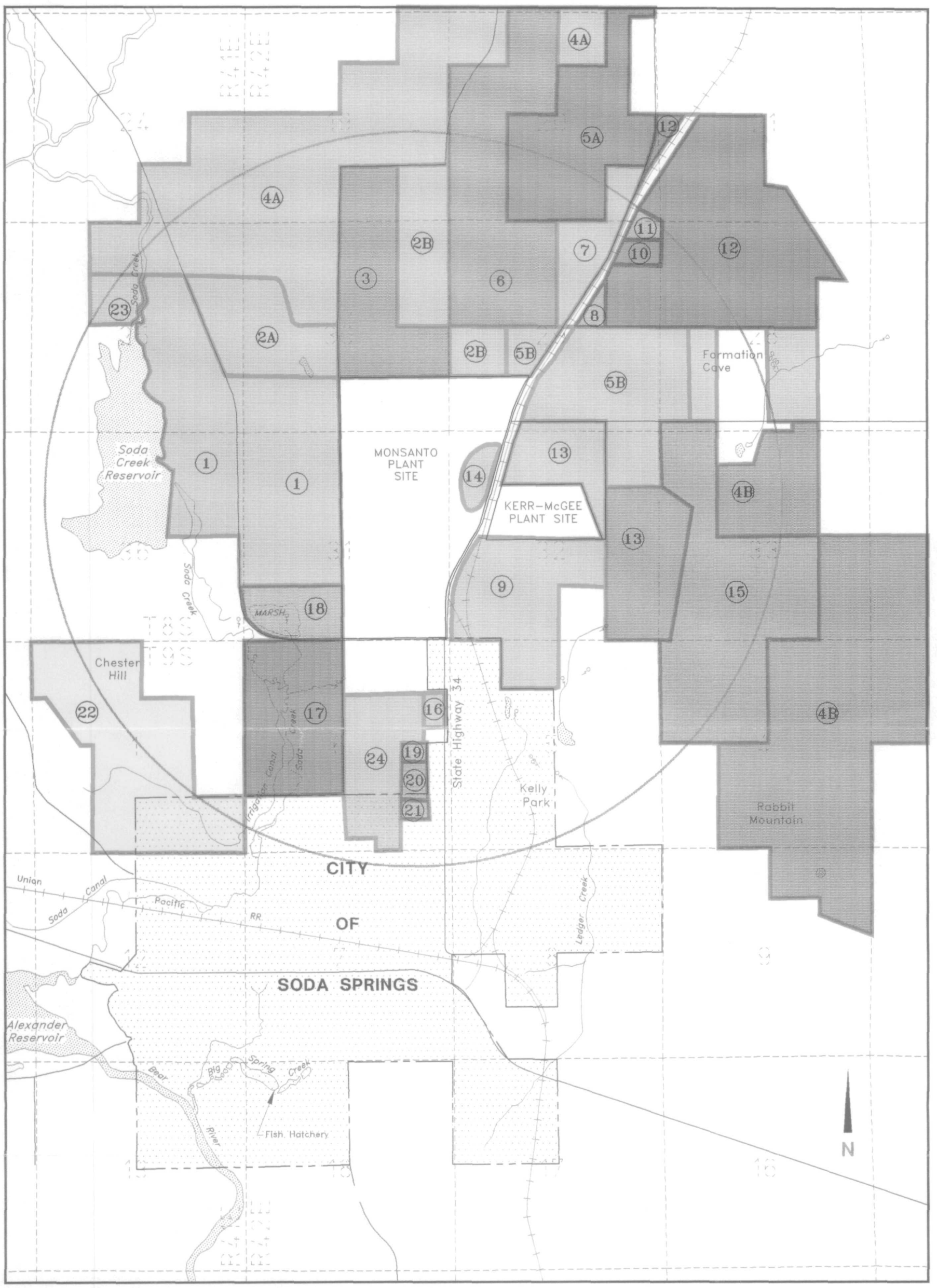
FIGURE **3-42**

CITY OF SODA SPRINGS LAND ZONING MAP

MONSANTO/PHASE II RI REPORT/ID

\DJH\9131101\608\42460 6-8-94 13:52

Golder Associates



LEGEND

- City of Soda Springs boundary
- Section lines
- Section number
- (24) Property ID number (see Table 3-15)
- Crops only
- Livestock only
- Crops and livestock
- Conservation Reserve Program
- Uncertain – probably crops only (as determined by drive-by survey)
- Uncertain – probably livestock only (as determined by drive-by survey)
- Non-agricultural (Nature Conservancy)
- Non-agricultural (other)

Note:
Encircled area represents approximately 2 km from Monsanto Plant boundaries.

0 750 1500 METERS
0 2500 5000 FEET

FIGURE 3-43
AGRICULTURAL LAND-USE SURVEY
MONSANTO/PHASE II RI REPORT/ID

\DJH\9131101\608\42637 12-19-94 10:28

Golder Associates

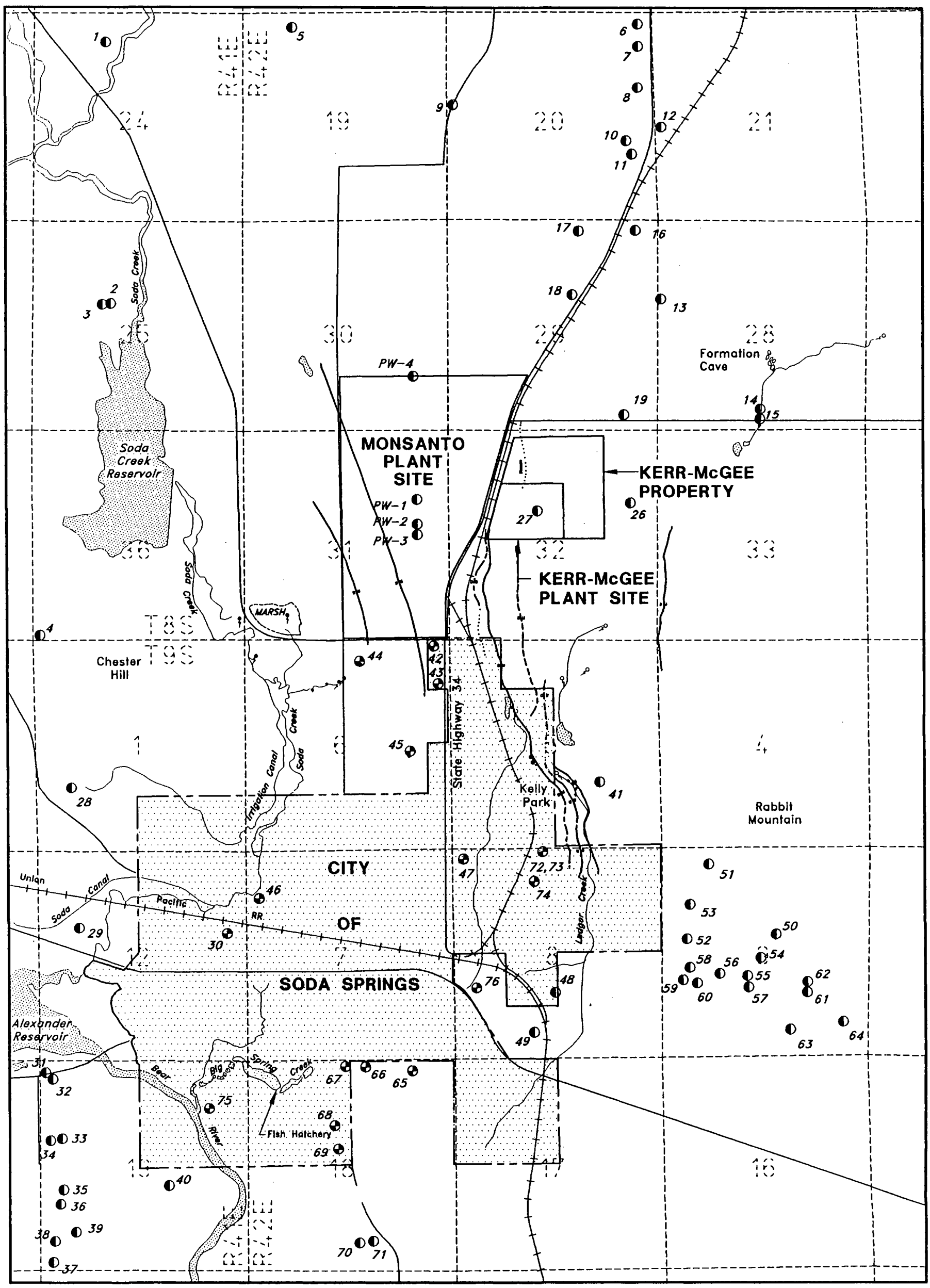


FIGURE 3-44
WELL INVENTORY
MONSANTO/PHASE II RI REPORT/ID

\DJH\9131101\608\42462 6-8-94 13:04

Golder Associates

Section 4

4. NATURE AND EXTENT OF CONSTITUENTS

This chapter describes the nature and extent of chemical constituents occurring in air, soil, sediment, and water at the Monsanto Plant. Constituent concentrations occurring in the phosphate ore, process raw materials, and by-products are also presented. A description of the physical characteristics of the Plant was provided in Chapter 3. An analysis of the fate and transport of selected chemical constituents is provided in Chapter 5.

Chapter 2 describes investigations involving the collection of numerous samples for chemical analyses. The analysis results for these samples are presented in this Chapter. The results of the chemical and radiochemical analyses used in this Chapter were validated for quality control purposes, as described in Appendix N. Blank-adjustments were made to the data at this time, which are also described in detail in Appendix N.

This chapter is organized according to the environmental media: air, surface water and sediments, soils, and groundwater. With the exception of the air medium, each section contains comparisons of the data first to background data and then to risk-based screening criteria. Through this process, constituents of potential interest are identified for each medium. With regard to the air medium, constituents of potential interest were developed by other means during preparation of the RI work plans. Thus, no further screening of the air quality data was necessary.

Following the screening analyses, and where it is appropriate depending on the data collected, graphical presentations of the constituents of potential interest are presented and described in terms of how concentrations have changed in time and in space. This approach to analyzing the data efficiently identifies those constituents that may be of most interest. Specific details concerning the screening process are described in Section 4.1.

4.1 Data Screening Rationale and Methods

Analyses of soil, sediment, and water samples included about forty different constituents. In order to make decisions concerning each constituent with regard to the remedial investigation, it was necessary to screen the constituents. The screening procedures (Figure 4-1) involve two sequential comparisons:

Step 1 The constituents are compared to control, or background data to determine if they occur at levels that are unnatural for the area. Constituents exceeding background screening criteria are classified as elevated constituents and are carried forward to step two;

Step 2 Elevated constituents from step one are compared to risk-based concentrations that are considered protective of human and ecological health (EPA-10 1991). Constituent concentrations exceeding the risk screening concentrations are classified as constituents of potential interest.

Constituents of potential interest are considered to be the only constituents that may pose a human health- or ecological-risk and are carried forward to the quantitative risk assessment. In many cases, though, a constituent of potential interest may be found to cause negligible risk by the quantitative risk assessment.

The remainder of this section provides specific details on calculations for comparisons with background and risk concentrations.

4.1.1 Comparisons to Background Concentrations

The background data set is comprised of constituent analyses for samples of soil, sediment, and water (surface water or groundwater) that are considered to be unaffected by activities at the Monsanto Plant. Background sampling locations are selected such that they will not show effects that are attributable to material releases at the Monsanto Plant.

Typically, background data for a particular constituent contains different concentrations, due primarily to variations in environmental conditions. For example, soil samples may originate from different parent materials, that can result in slightly different concentrations for certain constituents from one sample to another. Consequently, it is necessary to characterize the background data set using statistical methods. To characterize these data, the mean value and standard deviation are computed. The mean value represents the average concentration and the standard deviation represents the variability in data values about the average.

The comparison between background data and data collected at the Monsanto Plant is made as follows:

- The upper tolerance limit for each constituent for background data is determined;
- The maximum value for each constituent measured at the Monsanto Plant is identified from the Plant data set;
- The Plant maximum concentration is compared to the upper tolerance limit for the background data; and
- If the Plant maximum value exceeds the upper tolerance limit of the background data, the constituent is classified as elevated.

The upper tolerance limit of the background data set for a constituent is determined by statistical methods which are well documented in EPA (1989b). The upper tolerance limit, referred to as the UTL, is computed based on the background data for each constituent as follows:

$$UTL = M + KS$$

where:

UTL = Upper Tolerance Limit;
M = mean, or average, value for the background data set;
S = standard deviation for the background data set; and
K = tolerance factor.

The selection of the tolerance factor, K, is critical to the value computed for the UTL. For this Phase II RI report, the tolerance factor was obtained to determine the upper 95% confidence limit for the background population 95th percentile. Figure 4-2 shows this limit graphically for a hypothetical background data set.

As shown on Figure 4-3, the tolerance factor used to compute the UTL depends on the number of background samples. In sediment samples, if sample size was less than six, the maximum reported background concentration rather than the UTL was used to screen for background. For groundwater samples, if sample size was less than six a maximum value of K=3.711 was used. The purpose of using these alternatives for small sample sizes was to avoid developing an elevated UTL.

4.1.2 Comparisons to Risk Concentrations

Elevated constituents were subsequently screened against risk-based concentrations to determine their classification as a constituent of potential interest. To conduct the risk screening, the following steps were taken:

- Determine for the media under investigation: soil, sediment, or water; and the exposure pathways: inhalation, ingestion, or dermal absorption.

- Determine whether the specific constituents are carcinogenic or systemic toxins. Systemic toxins are considered to be those constituents which are non-carcinogens but are considered toxic substances.

- Make assumptions concerning the exposed individuals with regard to body weight, medium contact rate (e.g., kilograms of soil ingested per day or liters of water consumed per day), exposure duration, and exposure frequency.

- For carcinogens, determine the exposure concentration required for a lifetime incremental cancer risk (LICR) of 1 in 1 million (or 1E-06) for water and 1 in 10 million (or 1E-07) for soil.

- For systemic toxins, determine the concentration equivalent to one-tenth the published reference dose (RfD) --the dose at which a systemic health effect is observed. A value equal to one-tenth the RfD was chosen in consideration of additive effects that may be realized if an individual is simultaneously exposed to more than one toxic constituent. Within the suite of constituents under consideration, no more than two constituents are

known to have the same systemic toxic endpoint, e.g., both constituents affect the liver, or both constituents affect the blood. Consequently, one-tenth the RfD is considered to be a screening criteria that is protective of human health (EPA-10 1991).

Equations and parameter values used to determine the risk-based screening concentrations for each of the constituents are presented in the respective sections of this Chapter. The equations are based on EPA Superfund risk assessment guidance, as documented in EPA (1989a) and EPA-10 (1991). In computing the risk-based screening concentrations it is necessary to make assumptions concerning the exposed population. For this Phase II RI report, a residential scenario was assumed and parameter values such as body weights and exposure frequency and duration were obtained directly from EPA-10 (1991).

4.2 Source Materials

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.

4.2.1 Monsanto Plant Potential Sources of Constituent Releases

The potential sources of constituent release at the Monsanto Plant include material stockpiles, by-products, sewage evaporation ponds, material handling operations areas, and unpaved roads. Selected potential sources were sampled and analyzed during the Phase I and Phase II RI, as described in Section 2.1. As discussed in Section 2.1.2, constituents were analyzed in two sample types for potential source materials: total grain-size distribution and the -200 mesh (£ 74 μm diameter) samples. Analyses of total grain-size distribution were used to calculate a constituent mass balance for the plant. Constituent analyses of -200 mesh material was used to evaluate potential constituent emissions from material and by-product stockpiles around the site as fugitive dust. Constituent emissions from discrete sources and fugitive dust are discussed in more detail in Section 4.3.

Locations of the source sampling sites are shown in Figure 2-1. 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.

In addition to the chemical analyses summarized in Table 4-1, source materials were also evaluated by a gamma radiation survey (Section 2.1.3). Gamma radiation measurements were taken at Phase II source sampling locations (Figure 2-1) and at general survey locations (Figure 2-2). The results of this survey are summarized in Table 4-2. The survey measurements summarized in Table 4-2 have been corrected to a tissue-equivalent basis based on a correction factor developed by I.T. Corporation (Letter to Mr. T. Brincefield, EPA, from Mr. D. Banton, Golder Associates, November 23, 1994).

4.2.1.1 Material Stockpiles

Phosphate ore, coke, and quartzite are the principal raw materials used at the Soda Springs plant to produce elemental phosphorus. These materials are stockpiled in separate piles located northeast of the furnace building (Figure 1-3). The phosphate ore stockpile is divided into two piles (ore blend 1 and ore blend 2) on the basis of phosphorus content. Nodules are a product of phosphate ore beneficiation, in which the ore is heated in a kiln to reduce moisture and fuse the ore. The nodules are stored in piles at several locations around the site.

Results of chemical analyses for each of these stockpiles are shown in Table 4-1. The material stockpiles were evaluated for both the constituent mass balance and as potential constituent sources for fugitive dust emissions. Therefore, analyses are presented for both total grain-sizes and the -200 mesh fraction, except for the quartzite, which had no recoverable -200 mesh fraction.

In general, the two size fractions had equivalent constituent concentrations and any differences in constituent concentrations observed between the -200 mesh fraction and the total size distribution are generally no greater than a factor of two to four. Notable exceptions include arsenic in ore blend 1 and ore blend 2 and aluminum, fluoride, zinc, lead-210, polonium-210, radium-226, thorium-230, and uranium-238 in coke, and zinc in nodules.

4.2.1.2 By-Products and Ancillary Sources

By-products are the materials other than raw material, nodules, and elemental phosphorus that result from elemental phosphorus production. These by-products may be solid, liquid, or gas. The ancillary sources are produced at the plant as part of general plant operations and elemental phosphorus production. The following by-products or ancillary sources were sampled during the Phase I or Phase II RI.

Baghouse Dust. Baghouse dust samples were collected from piles in the northeast corner of the plant during Phase I of the RI. Three samples were collected from the baghouse dust piles at various locations (Figure 2-1) for chemical analysis. Only the -200 mesh fraction was analyzed. Results of chemical analysis are summarized in Table 4-1. These results show that the analyzed constituents are highly variable with standard deviations equivalent to the means. Concentrations of arsenic, cadmium, fluoride, and manganese are higher in the dust than in other source materials.

Calcium Silicate Slag. 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.

Samples were collected during Phase I and II of the RI from the slag piles at various locations (Figure 2-1) for chemical analysis. The results of these analyses are shown in Appendix C. Analytical results for the Phase II samples are summarized in Table 4-1. Old slag was differentiated from new slag to evaluate the ingrowth of radionuclide progeny (e.g., lead-210 and polonium-210). No distinction was made for particle-size because the slag is poured as a molten material and hardens to a solid mass. Therefore, grain size distinctions during analysis

would be an artifact of the sampling procedure. Consequently, only results for total analyses are shown.

The summary statistics in Table 4-1 show slag sample variability was very high for most radiological constituents, but old slag had higher lead-210 and polonium-210 activities than new slag. Sample variability of the non-radiological constituents was generally less than for radionuclides, except for constituents such as zinc. New slag had higher concentrations of vanadium than old slag. Previous testing on slag samples indicate that slag passes toxicity characteristic leaching procedures (TCLP) tests (Golder 1991).

Coke and Quartzite Slurry Pond. The coke and quartzite slurry pond was located in the southwest corner of the Plant and occupies an area of approximately 175,000 square feet. Three samples were collected during the Phase I RI (Figure 2-1) and the analytical results of the -200 mesh fraction are summarized in Table 4-1. This site has since been covered by slag and is no longer considered a source.

Ferrophosphorus Slag. This material is sold to Kerr-McGee Chemical Corporation for vanadium extraction. It is accumulated onsite (Figure 2-1) at a facility where it is mechanically broken down into sizes that can be easily transported by truck. Approximately twice a week the accumulated ferrophosphorus slag is transported by truck to Kerr-McGee (Figure 1-1).

Samples of the ferrophosphorus slag were collected to aid development of a constituent mass balance for the plant. The ferrophosphorus slag is high in chromium and vanadium (Table 4-1). It also contains some of the highest activities of uranium-238.

Nodule Fines. 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. Samples collected from these piles were analyzed for physical parameters only, however, the chemical composition should be similar to the phosphate ore or the nodules.

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. Constituents detected in the non-contact cooling water effluent (Table 4-3) are cadmium, calcium, fluoride, magnesium, nitrate-nitrogen, ortho-phosphate, selenium, sodium, and sulfate. Because the non-contact cooling water does not come into contact with the phosphorus production materials, groundwater is the source of constituents in the contact cooling water effluent.

Treater Dust. Treater dust piles consist of approximately 51,000 tons of material located in the north-central portion of the Plant. Samples were collected both from new treater dust (total size fractions) and the material stockpiles (old treater dust, -200 mesh fraction). The results are summarized in Table 4-1. New treater dust contains a notably higher concentration of fluoride than old treater dust.

Underflow Solids Piles. 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 during both

the Phase I and Phase II RI. Samples from the Phase I RI were analyzed as the -200 mesh fraction and samples from the Phase II RI were analyzed as the total size fraction. Results of chemical analyses are summarized in Table 4-1.

4.2.1.3 Onsite Roads

Five unpaved roads (ore haul road, west service road, east service road, quartzite haul road, and slag haul road; Figure 2-2) within the Monsanto Plant fenceline were sampled during the Phase II RI to evaluate the roads as potential sources. In addition to total analyses, the -200 mesh size fraction was analyzed for three of the roads (ore haul road, west service road, and east service road) to evaluate those roads as potential sources of fugitive dust emissions. Both the quartzite haul road and the slag haul road are constructed from quartzite gravel which has been shown to have a minimal content of constituents of potential interest. Therefore, the quartzite haul road and the slag haul road are considered to be unlikely sources of exposure. Analytical results are summarized in Table 4-4.

4.2.2 Other Potential Sources 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; and 4) Nu-West Industries phosphoric acid production and fertilizer facility.

An RI has been conducted at the Kerr-McGee plant (Dames and Moore 1993). Current and previous studies at Kerr-McGee indicate that calcium, chromium, copper, nickel, silver, uranium, and vanadium were detected in soils at the Kerr-McGee Plant at concentrations statistically greater than background, but there had not been a significant impact to soils outside the Kerr-McGee Plant. Elevated concentrations with respect to background of ammonia, arsenic, chloride, chromium, copper, iron, magnesium, manganese, molybdenum, nickel, nitrate, sodium, sulfate, and vanadium have been identified in groundwater below the site (Dames and Moore 1993). Tributyl phosphate and petroleum hydrocarbons were also detected in groundwater beneath the Kerr-McGee Site.

4.3 Air Quality

The elemental phosphorus process utilized at the Monsanto Plant results in permitted direct emissions of gases and particulate matter to the atmosphere. To reduce the quantities and types of materials released, emissions treatment equipment, such as scrubbers, precipitators, and filters, are used. Other emissions from the Plant, referred to as fugitive dust also occur. These emissions result primarily from material handling operations, wind erosion of material stockpiles, and vehicle traffic on unpaved roads within the Plant.

The air emissions from the Plant may be later deposited onto nearby soils and possibly ingested by humans and animals or assimilated by crops. Emissions that remain in suspension may be

inhaled or absorbed by living organisms. Depending on the associated toxicity of the emissions, impacts may or may not occur from the exposures.

The Federal Clean Air Act and the IDHW-BAQ regulate air emissions from the Monsanto Plant to ensure that ambient air quality remains safe for humans and the environment. The Monsanto Plant is in full-compliance with these air quality regulations. Thus, no adverse impacts are presumed to result from the Monsanto Plant air emissions. In the past several years, the Monsanto Plant air emissions have been reduced by planned improvements to the air treatment facilities and material handling operations. Section 1.5 summarizes a few of these improvements.

Air emissions and air quality data for the Monsanto Plant have been collected on-site by Monsanto and at nearby sampling stations by IDHW-BAQ. On-site testing provides data for Plant emissions. Data collected at IDHW-BAQ sampling stations provides data by which ambient air quality may be assessed. Information pertaining to these data is provided in the remainder of this section. Section 1.4.2 also provides information on previous air quality investigations.

4.3.1 Monsanto Plant Emissions

SENES (1993a and 1993b) presents a detailed evaluation of Plant emissions. This section summarizes a portion of this information. It is intended that the SENES reports will be consulted to fully assess Plant emissions.

The Monsanto Plant includes 15 permitted emissions facilities. These permits were issued to Monsanto by IDHW-BAQ. The permitted facilities covered in the Plant's air pollution source permit include the following:

1. Nodule crushing and screening scrubber
2. Scaleroom baghouse
3. Coke handling baghouse
4. Kiln cooler spray tower
5. Taphole fume collectors 7, 8, and 9
6. Coke and quartzite dryer baghouse
7. Natural gas fired boiler
8. Furnace stocking system dust collector
9. Coke and quartzite hopper baghouse
10. Coke unloading rail bunker baghouse
11. Furnace vent risers 7, 8, and 9
12. Ore hopper baghouse
13. CO dust collectors 7, 8, and 9
14. Kiln venturi scrubbers A, B, C, and D
15. Coke fines air conveyor baghouses (7)

In addition to permitted emissions facilities, the Monsanto Plant includes fugitive emissions sources. These sources include the following:

- fugitive emissions from material handling operations;
- fugitive emissions from wind erosion of stockpiles; and
- fugitive emissions from vehicle travel on unpaved haul roads.

4.3.1.1 Emissions Sampling and Analysis

Data to evaluate Plant air emissions are obtained in two ways: 1) stack emissions are collected and analyzed, and 2) source materials to the air emissions, such as dust, are collected and analyzed. When the emissions are collected directly, the analysis includes only chemical constituents. When parent materials are collected, the analyses include grain-size distribution in addition to analyses of chemical constituents. The grain-size distribution analyses are used in computer models or other calculations to estimate the fraction of material that may be entrained by wind and carried into the air.

The constituents of potential interest in air emissions from the Monsanto Plant were determined by EPA and Monsanto during the development of the Phase I- and Phase II-Work Plans (Golder 1991 and 1992c). The constituents selected include those constituents that must be monitored for the permitted facilities. This list of constituents, which includes particulate material, trace metals, fluorides, and radionuclides, was determined by soil sampling and studies of elemental phosphorus facilities at other locations in the US.

Direct measurements of air emissions from the Monsanto Plant have been taken several times in the late 1980s and early 1990s. In 1987, Monsanto measured particulate emissions from the scaleroom baghouse. In 1988, fluoride emissions were measured for the kiln cooler spray tower and the four kiln venturi scrubbers. During 1990, particulate emissions were measured for the kiln cooler spray tower, the four kiln venturi scrubbers, the nodule crushing and screening scrubber, and taphole fume collectors 7, 8, and 9. In 1991, taphole fume collectors 8 and 9 were again measured for particulate emissions. During 1992, particulate emissions, trace metals, and polonium-210 was measured in the four kiln venturi scrubbers.

Sampling of air emissions sources, such as the various material stockpiles and road materials, was conducted during Phases I and II of the RI. Analyses of these samples included grain-size distribution and chemical analyses for the constituents of interest. Section 2.1.2 summarizes these samples and analyses. SENES (1993a and 1993b) also summarizes these samples.

4.3.1.2 Estimated Air Emissions

Air emissions for the Monsanto Plant for the constituents of interest have been estimated for 1990 and 1991. These estimates and the results are presented in detail in SENES (1993a and 1993b).

Tables 4-5 and 4-6 summarize in detail the emission estimates for 1990. These tables also contain values for total emissions by constituent for 1991. As shown in the tables, little variability is observed between the 1990 and 1991 emission estimates. The variability that exists

is attributed primarily to climatic variability (i.e., wind speed), which affects the release of fugitive emissions. Emission estimates for both 1990 and 1991 were based on the 1990 Plant operations. Thus, operational variability is not represented in these results.

To estimate the Plant emissions, two approaches were used. For direct emission sources, such as stacks and baghouses, calculations were performed considering the available emissions measurements and facility operations data. For indirect, or fugitive emission sources, emission factor equations were used along with data for the parent material and climatic data. In most of the equations, it was necessary to make estimates for one or more equation parameters. These estimates were based on data reported in the literature for similar operations or based on data collected at Monsanto's facility in Tennessee. Derivation of these estimates is discussed in detail in SENES (1993a and 1993b).

4.3.2 Ambient Air Quality

IDHW-BAQ specifically monitored ambient air quality in the vicinity of the Monsanto Plant. These monitoring stations were site specific to the Monsanto Plant and were intended to provide data indicative of air quality impacts that may occur due to Plant operations. Air monitoring was also conducted by IDHW-BAQ near a neighboring facility to the north. The monitoring stations are shown on Figure 1-4.

Because the IDHW-BAQ data were site specific, ambient air-monitoring activities were not included in Phases I and II or the RI. Air dispersion modeling of air quality at off-site receptor locations was conducted as part of the RI and is presented in Chapter 5 and in SENES (1993b).

The remainder of this section summarizes the air quality data collected by IDHW-BAQ. These data consist of total suspended particulates (TSP) and respirable, or inhalable suspended particulates (PM_{10}). A complete listing of the IDHW-BAQ data is provided in SENES (1992).

4.3.2.1 Total Suspended Particulates

Ambient air quality monitoring data for the Monsanto Plant are available from three of the IDHW-BAQ monitoring stations, as shown on Figure 1-4. Each station was equipped with high volume air samplers that provided 24-hour TSP measurements. The sampling stations are no longer in use. The data were collected from the three stations during the following periods:

- Station 13-0420-026 - January 1986, to May 1988;
- Station 13-029-0029 - January 1986, to September 1988; and
- Station 13-0420-021 - January 1986, to September 1988.

Table 4-7 lists the geometric mean annual TSP concentrations and other data for these monitoring stations. These statistics are presented for the period from 1986 to 1988, although due to the data coverage, a geometric mean could not be calculated in 1988. Also shown in Table 4-7 are the 24-hour maximum TSP concentrations and the number of exceedances of air

quality criteria. As shown, there were no exceedances of the federal air quality standards based on annual average values. Per 40 CFR Part 50, the primary standard for TSP, based on the annual geometric mean value, is 0.075 mg/m^3. The corresponding secondary standard is 0.060 mg/m^3. One exceedance of the secondary standard for the 24-hour maximum (0.150 mg/m^3) occurred during 1987.

Based on a review of the data, it appeared there were a series of unusually high readings at Stations 13-0420-026 (Harris Ranch) and 13-0420-021 (Soda Springs Hospital). These measurements were observed during the period from August 31 to October 12, 1987. During this time, a nearby county road was under construction that involved the use of a dusty gravel. Stubble in a field adjacent to the Harris Ranch Station was also being burned at this time. The circumstances for these anomalous readings have been reportedly documented with IDHW-BAQ. To remove these affects from the results, the geometric mean annual TSP concentrations were also evaluated without data for the corresponding period of road construction and field burning. As expected, the geometric mean annual concentrations at the stations remained below the primary- and secondary-federal standards.

The data from the three stations reveal a seasonal behavior to the TSP concentrations. Larger values are observed during the summer months in comparison to the winter months. These data are also presented in Table 4-7. As shown, the winter versus summer geometric mean values are different by about a factor of two or more. These seasonal differences most likely reflect the effects of moisture and cold temperatures in reducing fugitive dust emissions from the Monsanto Plant and other sources in the general area during the winter months.

IDHW-BAQ also operated two additional TSP monitoring stations located to the north of the Monsanto Plant. These stations are shown as 13-029-0002 and 13-0420-027 on Figure 1-4. These stations were intended to provide air quality data for another facility to the north of the Monsanto Plant. Table 4-8 lists the geometric mean annual TSP concentrations and other data recorded at these two stations from 1986 to 1988. The data for these stations appear to be significantly different from the data collected at the three stations nearer to the Monsanto Plant (Table 4-3). Based on the sampling results for the two northern stations, it is concluded that these two stations are affected by sources of air emissions other than the Monsanto Plant and should not be used to evaluate air quality impacts from the Plant.

For example, the mean annual TSP concentrations at Station 13-029-0002 (Torgeson Residence) were significantly higher than at Station 13-0420-026 (Harris Ranch) during the period of May to September 1988. Station 13-0420-027 (south of the tailings pond) also recorded mean annual TSP concentrations 0.008 mg/m^3 to 0.016 mg/m^3 higher than at Station 13-0420-026 (Harris Ranch). The differences are more pronounced with regard to the number of exceedances of ambient 24-hour standards, and the magnitude of the maximum 24-hour concentrations. Frequent exceedances of the 24-hour standard occurred during the summer of 1988, with concentrations up to 0.499 mg/m^3 at Station 13-029-027. High concentrations were also recorded at Station 13-029-0002, but not as frequently.

4.3.2.2 Inhalable Particulates

Concentrations of inhalable suspended particulates, referred to as PM_{10}, have been measured at Station 16-029-0030 (Terrace Acres) located south of the Monsanto Plant (Figure 1-4). This sampling station was established in November 1989. Data from November 1989 to December 1990 were included in this analysis of ambient PM_{10} concentrations.

PM_{10} monitoring data are also available from Station 13-0420-027 located to the north of the Monsanto Plant (Figure 1-4). The PM_{10} sampler for this station was installed in January 1988. The PM_{10} sampler continued to operate until the end of June 1989, when sampling was interrupted. Sampling resumed in January 1990, and continued through July 1990. Due to the interruptions in sampling, 1988 is the only complete calendar year of data for comparison to ambient air quality standards. It is also noteworthy that the sampling frequencies for this station varied from one per six days to one per day to one per two days throughout the sampling period.

At Station 16-029-0030 (Terrace Acres), the arithmetic mean annual PM_{10} concentration was 0.027 mg/m^3. On a quarterly basis, the highest average three-month PM_{10} concentration occurred in the months of July through September and was 0.031 mg/m^3. On a seasonal basis, the average PM_{10} concentrations were as follows:

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 exceedances of the primary standard of 0.150 mg/m^3 (40 CFR Part 50). Similarly, there were no exceedances of the primary standard of 0.050 mg/m^3 (40 CFR Part 50) for the annual average concentrations.

At Station 13-0420-027, the annual arithmetic mean PM_{10} concentration for 1988 was 0.039 mg/m^3. For 1989 and 1990, which include only partial years of data, the mean annual PM_{10} concentrations were 0.028 and 0.033 mg/m^3, respectively. Thus, there were no exceedances 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 Station 16-029-0030 (Terrace Acres). There was only one exceedance of the 24-hour primary standard of 0.150 mg/m^3, which occurred in October 1988.

For the period from January to September 1988, both PM_{10} and TSP measurements were taken at Station 13-0420-027. These data provide an indication of the proportion of TSP comprised by inhalable particulates. Based on these data, the mean ratio of PM_{10} to TSP was 0.36. The median ratio was 0.33. Thus, PM_{10} makes up about 33% to 36% of TSP.

4.4 Surface Water and Stream 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 of the non-contact cooling water effluent to Soda Creek is a potential pathway that may expose humans or biota to potentially affected water or sediments via ingestion or direct contact. In order to evaluate these potential pathways, sampling activities in Soda Creek were included in the Phase I and II RI investigations.

Surface water from Soda Creek and the irrigation canal, associated sediments, and Monsanto Plant non-contact cooling water effluent were sampled and analyzed, both chemically and physically, as described in Section 2.3.2. Locations of the sampling sites for surface water and stream sediments are shown on Figures 2-3 and 2-4, respectively. The analytical results are summarized in Table 4-3.

Statistical analyses were performed on the analytical data from each medium to determine if the downstream sample group for each constituent was statistically different from the upstream (control) group. Downstream parameters that exceed and are significantly different from the levels in controls are regarded as elevated constituents.

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

As a result of the Phase II RI work to characterize surface water and sediment quality, it was determined that additional sampling and analysis was necessary. This additional work was completed during the summer of 1995, which coincided with the Phase II RI review period. A report was prepared to document these latter studies and is included in this report as Appendix G-4.

4.4.1 Surface Water Quality

4.4.1.1 Elevated Constituents in Surface Water

Soda Creek was sampled both upstream and downstream of the effluent discharge 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. Surface water samples were analyzed for constituents identified in Table 2-2.

Comparisons between control, or 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. Constituents not detected in either the effluent or downstream samples were not evaluated statistically. Non-detected

constituents in surface water included arsenic, beryllium, cadmium, chromium, copper, iron, lead, manganese, nickel, selenium, silver, vanadium, zinc, ammonia, carbonate, hydroxide, ortho-phosphate, gross alpha, radium-226, radium-228, radon-222, and uranium-238 (see Appendix G for complete analytical results). For constituents detected in at least one of the three samples in the downstream sample group, undetected constituent concentrations were represented by one-half the sample quantitation limit (SQL) to obtain an estimate of the actual concentration.

The statistical analysis performed on the surface-water chemical data was a one-sided t-test. Due to the small sample size, the UTL approach discussed in Section 4.1.1 was not used in this case. The t-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). No tests of normality were conducted because of small sample size, however, the t-test is sufficiently robust and is considered applicable for this analysis.

The t-test was performed on the sample groups data to test for differences in the distributions between the sample groups by comparing calculated values (t) (Table 4-9) with a tabulated value. For this sampling, the tabulated t-value based on four degrees of freedom (df = 4) and a confidence level of 95% (1-a = 0.95) is equal to 2.132. In order for the t-test to reject the null hypothesis that the population means are equal, calculated t-values need to be greater than 2.132.

Of the constituents statistically analyzed, the constituents which are regarded to have no effect 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:

calcium	nitrate-nitrogen
sodium	sulfate
chloride	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 nutrients and are considered to be non-toxic at the concentrations encountered in surface water and are thus eliminated from further consideration. Total dissolved solids are a secondary criteria and have no health risks and thus, are also eliminated from further consideration.

4.4.1.2 Surface Water Constituents of Potential Interest

A preliminary risk-based screening was used to evaluate the elevated constituents found in downstream surface water samples to determine the constituents of potential interest for the human health risk assessment. The maximum concentrations of each elevated constituent detected were compared against the risk-based criteria to identify the constituents of potential interest. For risk analysis purposes, each constituent is first evaluated to determine if it is an essentially non-toxic substance to humans under typical environmental conditions, if it is not, it is evaluated as a systemic toxin and/or a carcinogen. Substances that are human systemic toxins and carcinogens are subjected to further preliminary screening evaluation.

Systemic toxicity is evaluated in terms of a published EPA RfD (EPA 1994a and 1994b). Surface water concentrations resulting in a dose equivalent to a fraction of the applicable RfD are calculated. A benchmark equal to one-tenth of a hazard quotient (HQ) has been selected as a preliminary risk-based screening criterion.

None of the elevated analytes detected in surface water are carcinogens. Therefore carcinogenic risk was not evaluated in terms of constituent-specific LICR.

The screening criteria used are those concentrations that would be necessary to attain a dose equivalent to one-tenth of the RfD, for system toxins. All surface water screening criteria concentrations are derived using on-site residential exposure scenario factors from EPA (1989a) and EPA-10 (1991). The generic equation for calculating each risk-based concentration (RbC) is:

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

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

Intake	=	0.1*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)
RfD	=	Reference dose (constituent specific)

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
SF	=	Slope factor (varies according to constituent)

Exceedance of the RbC does not 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. On the other hand, if a constituent does not exceed the RbC, 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. Consequently, risk-based screening at this point in the process focuses attention on those constituents that could potentially pose a risk.

Table 4-10 presents a summary of the preliminary risk screening for downstream Soda Creek surface water. Nitrate-nitrogen is the only elevated constituent found in surface water samples collected from Soda Creek downstream of the effluent outfall that exceeds preliminary risk-based screening criteria. This exceedance is based on the unlikely exposure scenario of ingestion of surface water by infants. The nitrate-nitrogen concentration equals 1.16 (mg/L) and is approximately eight times less than the maximum contaminant limit (MCL) and maximum contaminant level goal (MCLG) for drinking water established by the EPA of 10 mg/L. Therefore, nitrate-nitrogen is eliminated as a constituent of potential interest for surface water.

4.4.2 Soda Creek Sediments

4.4.2.1 Elevated Constituents in Soda Creek Sediments

Phase I RI samples were collected up to 300 feet downstream of the effluent outfall, while Phase II stream sediments were collected along the entire length of Soda Creek downstream of the effluent outfall as described in Section 2.3.2 (Figure 2-4). Sediment samples collected during each phase were analyzed for the constituents listed in Table 2-2. Analytical data sheets are included in Appendices F and G. Based on the findings of the Phase I RI, the list of constituents analyzed in Phase II was reduced. The following discussion focuses on the findings of the Phase II RI.

The mean, standard deviation, and maximum detected value was determined for each constituent analyzed in sediments collected from the control (upstream) locations. Insufficient control samples were collected to use the UTL approach for determining the elevated constituents in downstream samples. Therefore, the elevated constituents in stream sediments were determined by comparisons with the maximum values in the control samples.

Any constituent with a maximum (or, in the case of pH, minimum) concentration exceeding the maximum detected concentration in control samples is considered an elevated constituent (i.e., with respect to control conditions). Data summaries and the elevated sediment constituents are presented in Table 4-11. The elevated constituents in Soda Creek sediments collected downstream of the effluent discharge are arsenic, cadmium, copper, nickel, selenium, silver, vanadium, and polonium-210.

Sediment samples collected from tributaries to Soda Creek (Homestead Spring, Mormon Spring, and Southwest Spring) showed elevated levels of a few constituents. Samples from Homestead Spring have elevated levels of copper, selenium, and polonium-210; samples from

Mormon Spring have elevated levels of cadmium, copper, nickel, selenium, silver, and polonium-210; and samples from Southwest Spring have elevated levels of copper.

4.4.2.2 Constituents of Potential Interest in Soda Creek Sediments

Sediments in Soda Creek are not considered a direct pathway for risk to human health. However, the presence of elevated constituents in Soda Creek sediments could represent a potential risk to ecological receptors that might use Soda Creek. As noted in Section 2.3.2, the biological toxicity of a limited number of Soda Creek sediment samples was determined using differences in algal growth and bacterial growth (enzyme activity) in downstream sediment samples relative to control samples. The results of the biological toxicity testing are shown in Table 4-12. These results show that samples collected upstream of the effluent outfall have an inherent toxicity relative to laboratory controls. The results for biological toxicity testing of sediment samples collected downstream of the effluent outfall are higher than the upstream samples.

The toxicity testing shows there may be a potential risk to environmental receptors using Soda Creek, but does not identify the constituents of potential interest. At the present time, neither EPA nor the State of Idaho have sediment quality criteria for metals or radionuclides. As a surrogate for screening purposes, sediment quality guidelines from Wisconsin and Ontario (as published in Ecology 1991) are used to identify constituents of potential interest from an ecological perspective. Maximum elevated constituent concentrations in sediments from downstream of the effluent outfall and the sediment quality criteria are shown in Table 4-13. The elevated constituents are considered constituents of potential interest based on this screening analysis although the relevance of the screening values to Soda Creek has yet to be demonstrated. No screening values for vanadium or polonium-210 are available, therefore, they are also considered constituents of potential interest as a conservative measure.

Figures 4-4 through 4-12 show sediment concentrations for the constituents of potential interest versus distance along Soda Creek. For comparison, the maximum value detected in control samples and the 95% UTL are also shown. Selenium and silver were not detected in control sediment samples, therefore only the maximum detection limit is shown for these constituents. The trend line shown on selected figures is a robust locally weighted regression. This regression is only used to smooth the data rather than to derive a predictive equation. A trend line is not shown for silver because most of the reported sediment concentrations were at detection limits.

As shown on the figures, sediment quality data varies along the stream bed with both increasing and decreasing trends. Except for nickel, the trend for constituent sediment concentrations is to increase to a maximum that is generally greater than 1,000 feet downstream of the outfall.

4.5 Soil Quality

Offsite soil samples were collected around the vicinity of the Monsanto Plant as part of the Phase I and Phase II RI. Samples were collected from 0" to 6" from all sites, samples from 0" to

1" were collected from all sites except contingent sample locations (Section 2.5.2 and Figure 2-5), and samples were collected from the subsurface (6" to 24") at selected locations (Figure 2-5). Analytical parameters evaluated during the Phase II RI were reduced as a consequence of risk-based screening during the Phase I RI (Golder 1992b). The following discussion focuses on constituents analyzed during the Phase II RI. Table 2-3 provides a listing of constituents analyzed in soil samples.

Additional control soil samples were collected during the Phase II RI and analyzed for the same parameters as the offsite soil samples. The number of control soil samples was increased from six in the Phase I RI to 20 for the Phase II RI. These additional control samples were collected to characterize the natural soil variability and to support the use of the UTL method for identifying elevated constituents (Section 4.1.1).

In addition to the chemical analyses, offsite soil and control soil sampling locations were evaluated by a gamma radiation survey (Section 2.1.3, Figures 2-5 and 2-6). The results of this survey are summarized in Table 4-14. The survey results have been corrected to a tissue equivalent basis. Gamma radiation ranged from 13.1 to 17.8 μR/hr at control soil sample locations and 13.1 to 17 μR/hr at offsite soil sample locations. There are no significant differences among soil sample locations.

The following sections discuss analyses of chemical constituents (radionuclides and metals) for soil samples collected from 0" to 1". This depth interval has been selected because it is assumed to be most available for human exposure. Previous evaluation of offsite soils collected during the Phase II RI showed that no constituent in soil profile samples collected 6" to 24" beneath the surface exceeded any screening criteria (Golder 1993c). Complete results of chemical analyses are presented in Appendices I and J.

4.5.1 Elevated Constituents

The UTL was determined from the control soil samples collected during the Phase I RI, resampled during the Phase II RI, and the additional control samples (Section 2.5.2) for the 0-to-1 inch depth interval. For each constituent, the control data set included 18 to 21 samples. Data were evaluated using BestFit (Palisade 1993) to determine the most appropriate distribution. For all constituents, the lognormal distribution most closely matched the sample data. Therefore, a lognormal distribution is used for determining the UTL. The method for the calculation of the tolerance limits is described in 4.1.1.

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 UTL.

The maximum detected concentrations found in soil sample data for each soil group was compared to the UTL to identify elevated constituents. Any constituent with a maximum concentration exceeding the tolerance limits was considered an elevated constituent (i.e., with

respect to control conditions). This is an objective screening procedure that does not evaluate environmental effects.

Summaries of these calculations and the elevated constituents for the 0-to-1 inch depth interval are presented in Table 4-15. The elevated constituents in soils are listed below.

aluminum	lead-210
arsenic	polonium-210
beryllium	radium-226
cadmium	thorium-230
chromium	uranium-238
fluoride	
manganese	
silver	
vanadium	
zinc	

4.5.2 Constituents of Potential Interest

Each elevated constituent was subjected to a preliminary risk screening using calculated or regulatory guidelines, where available, the process for which is described in detail in Section 4.1.2. No soil cleanup guidelines are available at present for any of the elevated constituents in soils at this site.

The RbCs are derived for the constituents using protective risk assessment assumptions from EPA (1989a) and EPA-10 (1991). The equation for calculating the RbC is based on ingestion of soils. The equation is given by:

$$RbC = \frac{(Intake)(AT)(CF)}{\left[\frac{IRxEDxEF}{BW}\right]_{adult} + \left[\frac{IRxEDxEF}{BW}\right]_{child}}$$

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

Intake	= 0.1*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)
RfD	= reference dose (constituent specific)

For carcinogens, the conservative assumptions are as follows:

Intake	= 1E-07/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)
SF	= slope factor (varies by constituent)

For radionuclides, the equations for determining RbCs are different, depending on exposure pathways. The equation to calculate RbCs for ingestion of soil with elevated radionuclides is given by:

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

where:

Intake	= 1E-07/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 radionuclides, an additional exposure pathway is included for calculating the RbC. The equation for calculating the RbC due to external exposure to soils with elevated radionuclides is given by:

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

where:

Intake	= 1E-07/SF
IR	= 24 hours/day
CF	= 1.14E-04 year/hour
EF	= 350 days/year
ED	= 30 years
SF	= slope factor (varies by constituent)

To evaluate the constituents of potential interest, the lower of the two RbCs computed is used for radionuclides. The results of the risk screening are shown in Table 4-16. The following is a list of the constituents of potential interest in the 0-to-1 inch depth interval:

arsenic lead-210

beryllium	polonium-210
cadmium	radium-226
vanadium	thorium-230
uranium-238	

The spatial distribution of soil samples that contain constituents of potential interest are shown in Figures 4-13 through 4-21. 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 (Table 4-17 and Figures 4-13 through 4-21). In general, the maximum concentrations of constituents of potential interest are found along the fenceline of the Monsanto Plant and concentrations decrease with increasing distance from the plant. In the case of beryllium, cadmium, manganese, radium-226, and uranium-238, only those sample locations at or very near the fenceline exceeded UTLs and RbCs.

4.6 Groundwater Quality

Groundwater from wells and springs at, and in the vicinity of, the Monsanto Plant were sampled and chemically analyzed during Phases I and II of the RI and during earlier investigations by Monsanto. The sampling results are used in this section to conduct the screening procedures discussed in Section 4.1 and to present the sampling results through the use of plume maps and time history plots.

A discussion of sampling procedures, locations, frequencies, and analytical constituents is provided in Section 2.6.5. In summary, a total of 60 well locations and 18 spring locations have been used to collect samples of groundwater from the mid-1980s to the present. These sampling locations are shown on Figures 2-8 and 2-9 and a listing of the chemical constituents analyzed is presented in Table 2-8. The chemical constituents include conventional water quality parameters (e.g., calcium, magnesium, pH, hardness, turbidity), trace metals, and selected radionuclides. The results of groundwater sampling are presented in tabular form in Appendix K.

4.6.1 Groundwater Quality Screening

Groundwater sampling data were used to conduct the screening procedures discussed in Section 4.1. Prior to conducting the screening procedures, certain data were eliminated from the groundwater database. The criteria for eliminating entire samples or individual sample results were as follows:

1. Elimination of filtered samples;
2. Elimination of unfiltered samples in which the turbidity exceeded 5 NTU;
3. Elimination of sample results for selenium that were measured prior to 1/1/93 (because of laboratory QA/QC concerns); and,
4. Elimination of sample results that were flagged R, or rejected, during data validation.

In applying the screening procedures, it was also necessary to consider certain aspects of the groundwater flow system. Firstly, as discussed in Section 3.7.2.5, two distinct types of groundwater, fresh and sodic, have been identified below the Monsanto Plant. Evaluations of groundwater quality were made among data from the same groundwater type. No cross-type comparisons were made due to distinct natural differences in the groundwater quality.

Secondly, as discussed in Sections 3.7.2.1 and 3.7.2.2, the groundwater flow system includes two principal aquifers referred to as the UBZ and the LBZ, respectively. Due primarily to faulting, these aquifers have been separated by barrier boundaries into five flow regions with little to no hydraulic continuity. Given these conditions, the groundwater screening procedures were also applied according to aquifer, UBZ or LBZ, and according to groundwater region, 1 through 5.

4.6.1.1 Control Groundwater Quality

As discussed in Section 4.1.1, control, or background groundwater quality data were used to compute UTLs for each chemical constituent that was subjected to the screening procedures. Control samples were obtained from wells and springs upgradient of any known sources of constituent releases at the Monsanto Plant. These sampling locations are identified in Table 4-18.

As shown in Table 4-18, the control sampling locations were separated according to groundwater type. The UTL calculations were also made according to groundwater type. Thus, a fresh and a sodic UTL was determined for each constituent. No distinction was considered necessary with regard to groundwater region. This approach also provided the largest number of control samples per constituent, while recognizing the distinctly different natural types of groundwater in the area.

In computing the UTLs, it was necessary to evaluate sample results that were reported as below the SQL. These results are assigned the U qualifier in the groundwater database and in Appendix K. Each result bearing the U qualifier (or any qualifier containing a U), was assigned a value equal to one-half the reported value. Thus, one-half the SQL was used in the statistical calculations. For those constituents that were not detected in any of the control samples (i.e., all results were qualified with a U), the UTL was assigned a value equal to the maximum SQL for the samples. Thus, no statistical calculations were made for these cases.

The UTLs for fresh- and sodic-groundwater are presented in Tables 4-19 and 4-20, respectively. For each constituent, the number of samples, the number of samples bearing a U qualifier (i.e., number of non-detects), the mean, the standard deviation, the maximum, the tolerance factor, and the UTL are reported.

The list of constituents included in Tables 4-19 and 4-20 are a subset of those measured in each groundwater sample. The constituents included represent unique components of the groundwater samples, rather than constituents which are a result of the sample. Thus, general water quality parameters were eliminated such as pH, electrical conductance, total dissolved solids, hardness, etc.

As shown in Tables 4-19 and 4-20, most of the sample sizes exceed 10 samples and several exceed from 25 to 50 samples. The majority of the tolerance factors are less than 2.5. There are only three constituents for which the sample size is less than 6 and the tolerance factor was reduced to a maximum value of 3.7110. In a few cases, the computed UTL exceeds the maximum control value.

4.6.1.2 Elevated Constituents in Groundwater

Groundwater quality data from on-site wells, wells immediately adjacent to the Monsanto Plant, and nearby springs were used in the screening analysis to identify elevated constituents, as described in Section 4.1.1. Table 4-18 identifies the screening wells and springs that were used. As indicated in Table 4-18, the wells and springs were categorized according to groundwater type, fresh or sodic, and groundwater region. The screening analysis to identify the elevated constituents was conducted according to these classifications.

As discussed in Section 4.1.1, the screening analysis involved comparing the maximum value for a constituent to the respective control UTL. The maximum value was determined from the entire set of wells and springs by groundwater type and region. In selecting the maximum value, the data were limited to results obtained since January 1, 1991. This limitation was imposed to account for declining trends that have been observed in the groundwater quality parameters below the Monsanto Plant. If older results were used, the maximum values in certain cases would be greater, reflecting the conditions of the past rather than the present. The data were also limited to sample results measured above the sample quantitation limit. Thus, results bearing a U qualifier were eliminated from consideration. This limitation prevented classification of a constituent as a result of unusually high sample quantitation levels.

Table 4-21 lists the maximum concentrations of constituents detected in each groundwater region by groundwater type, and their corresponding UTLs. Constituents with maximum values exceeding their corresponding UTLs are identified as elevated constituents in that groundwater region. A summary of the elevated constituents is provided below by groundwater type:

Fresh Groundwater	Sodic Groundwater
Alkalinity (bicarbonate)	Alkalinity (bicarbonate)
Aluminum	Aluminum
Ammonia-nitrogen	Ammonia-nitrogen
Arsenic	Cadmium
Beryllium	Calcium
Cadmium	Fluoride
Calcium	Iron
Chloride	Magnesium
Fluoride	Manganese
Iron	Nickel
Magnesium	Nitrate-nitrogen
Manganese	Orthophosphate as P
Molybdenum	Potassium
Nickel	Selenium

Fresh Groundwater	Sodic Groundwater
Nitrate-nitrogen	Sodium
Orthophosphate as P	Sulfate
Potassium	
Selenium	
Sodium	
Sulfate	
Vanadium	
Zinc	

It is noteworthy that the results of this screening include the UBZ-3 and LBZ-3 groundwater regions, which underlie the eastern part of the Monsanto Plant near the Kerr-McGee Plant. Groundwater plumes from below the Kerr-McGee Plant have migrated into the UBZ-3 and LBZ-3 groundwater regions below the Monsanto Plant

Calcium, magnesium, potassium, orthophosphate as P, and sodium are essential nutrients and are thus eliminated from further consideration in this report. Alkalinity (bicarbonate) is also an essentially non-toxic substances and is eliminated from further consideration in this report. Beryllium was detected only sporadically in groundwater below the Monsanto Plant, and has not been detected in groundwater since 1992, therefore, it is eliminated from further consideration in this report.

4.6.1.3 Constituents of Potential Interest

The elevated constituents that are retained for further consideration are subjected to preliminary risk-based screening to determine the constituents of potential interest, as discussed in Section 4.1.2. According to the risk-screening procedures, the maximum value for each constituent by groundwater type and region is compared to a constituent-specific RbC. The constituents with maximum concentrations exceeding the RbC are classified as constituents of potential interest.

The RbCs for groundwater are calculated in a manner identical to that for surface water ingestion (Section 4.4). The exposure conditions (i.e., intake, body weight, and time periods) are identical to those used for surface water ingestion. Reference dose data were obtained from the Integrated Risk Information System (IRIS, EPA 1994b). As a conservative measure, the intake value used to calculate the RbC is 10% of the reported reference dose.

In addition to comparison to RbCs, the maximum values for each constituent are compared to several regulatory water-quality guidelines. Constituents with maximum concentrations exceeding the regulatory guidelines are classified as constituents of potential interest. The regulatory guidelines used in this screening are listed below:

- Primary maximum contaminant levels (1°_MCLs) (40 CFR 141);
- Secondary maximum contaminant levels (2°_MCLs) (40 CFR 143);
- Chronic freshwater quality criteria (WQC-FWC) (EPA 1986a); and

- Specific water quality criteria for use classification (IDHW 1987).

Table 4-22 presents the maximum concentrations of the elevated constituents by groundwater region and type, and RbCs and regulatory guidelines. Constituents with maximum concentrations exceeding the RbCs or the lowest available regulatory guideline are retained for further review. Based on the screening procedure, the following is a summary of the fresh groundwater constituents that exceed RbCs and regulatory guidelines for the entire Plant: ammonia-nitrogen, arsenic, cadmium, chloride, fluoride, iron, manganese, molybdenum, nickel, nitrate-nitrogen, selenium, sulfate, vanadium, and zinc. For sodic groundwater, the following is a summary of constituents throughout the Plant that exceed RbCs and regulatory guidelines: cadmium, fluoride, iron, manganese, nitrate-nitrogen, selenium, and sulfate.

Chloride, iron, and sulfate maximum concentrations are only in exceedance of secondary MCLs. Since secondary MCLs are welfare-based rather than health-based criteria, they do not represent potential risks to human health. It is recommended that these constituents be eliminated from further consideration as constituents of potential interest.

4.6.2 Constituent Concentrations in Groundwater

This section presents groundwater quality data for the constituents exceeding risk-based concentrations identified in Section 4.6.1. Figures are presented showing the spatial distributions for the constituents in the vicinity of the Monsanto Plant. Time history plots based on groundwater samples from selected wells are also presented.

The spatial distributions of constituents are based on data collected during May 1993 (May 1992 for sodium). These data are generally representative of present conditions. Time history plots utilize data from the early 1980s to the most recent sampling round, which occurred during May 1994.

Ammonia-Nitrogen

Ammonia-nitrogen data for groundwater are presented on Figures 4-22 through 4-25. Figure 4-22 presents ammonia-nitrogen concentrations in the UBZ during May 1993. As shown, ammonia in groundwater occurs primarily in relation to the Kerr-McGee Plant. Concentrations below the Monsanto Plant are typically less than 1 mg/L as N. Remnant plumes of ammonia appear to exist in the northwest pond, hydroclarifier, and old underflow solids ponds areas. Figure 4-23 presents ammonia-nitrogen concentrations in groundwater in the LBZ during May 1993. Ammonia concentrations in the LBZ below the Monsanto Plant range from 0.08 to 0.73 mg/L as N. Occurrences of plumes in the LBZ below the Monsanto Plant are not well-defined.

Figures 4-24 and 4-25 present time history plots of ammonia groundwater concentrations. Figure 4-24 includes analyses of samples collected from wells in the general area of the old underflow solids ponds. In general, low concentrations of ammonia are observed in the groundwater in this area. As shown by the Mormon A Spring results, which are consistently below the sample quantitation limit, ammonia appears to be transformed prior to discharge into Mormon Creek. As shown on Figure 4-25, in the northwest pond/hydroclarifier area, ammonia

is typically not measured in the groundwater. Exceptions include Test Well 17 samples which contain low concentrations of ammonia.

Arsenic

Groundwater quality data for arsenic are presented on Figures 4-26 through 4-28. Data for May 1993 in the UBZ are shown on Figure 4-26. Groundwater plumes of arsenic are not readily discernable from these data. Low concentrations of arsenic occurred in samples from a few wells. In most samples arsenic could not be detected. Arsenic groundwater quality data for the LBZ are not shown because arsenic is not a constituent of potential interest in the LBZ.

Figure 4-27 presents time history plots of arsenic groundwater concentrations in the old underflow solids ponds area. As shown, low concentrations of arsenic are observed in those samples with measurable arsenic. At Mormon A Spring, arsenic is typically below detection limits. Figure 4-28 presents arsenic time history plots in the northwest pond/hydroclarifier area. Arsenic occurs more frequently and at higher concentrations in samples from wells in this area.

Cadmium

Groundwater quality data for cadmium are shown on Figures 4-29 through 4-32. Groundwater concentrations for cadmium in the UBZ during May 1993 are shown on Figure 4-29. Three distinct plume areas within the Plant fenceline can be recognized from these data. South of the Plant, cadmium was not measured in groundwater samples. Figure 4-30 presents cadmium groundwater concentrations during May 1993 for the LBZ. Low concentrations of cadmium are measured at few locations in groundwater samples from the LBZ.

Figure 4-31 presents time history plots for cadmium groundwater concentrations in the old underflow solids ponds area. At Test Well 37, which is located next to the old underflow solids ponds, cadmium concentrations have declined steadily since 1987. In Test Wells 22 and 36, which are further downgradient, cadmium concentrations have increased since about 1992, after a period of decline. It is not clear as to whether these trends reflect variability or an actual increase in cadmium groundwater concentrations in the areas of the test wells. Based on Plant information, there are no present surface sources of cadmium that could lead to increasing groundwater concentrations.

Figure 4-32 presents time history plots for cadmium in the northwest pond/hydroclarifier area. As shown for samples collected from Test Well 16, cadmium concentrations in groundwater are declining in the northwest pond area. Similar declining concentrations are also observed in the hydroclarifier area, as shown by data for Test Well 40. These declining trends are anticipated to continue based on the removal of historic sources of cadmium to groundwater.

Chloride

Groundwater concentrations for chloride are shown on Figures 4-33 through 4-36. Groundwater concentrations observed during May 1993 for the UBZ are shown on Figure 4-33. These data indicate three plume areas below the Monsanto Plant, and a fourth plume originating from the Kerr-McGee Plant. In the southwest corner of the Monsanto Plant, a small

plume is present. This plume is likely the result of sewage treatment ponds located in this area. These ponds were taken out of service during 1993. Chloride levels are expected to decline as a result of this action.

Figure 4-34 presents chloride groundwater quality data for the LBZ during May 1993. Two plume areas appear in these data: one below the old underflow solids ponds and one below the Kerr-McGee Plant. Chloride is not a constituent of potential interest in the LBZ below the Monsanto Plant.

Time history plots of chloride groundwater concentration in the old underflow solids ponds area are shown on Figure 4-35. These results indicate a mixture of trends in the chloride concentrations. At present, it appears that chloride concentrations are increasing in the area of Test Well 36 and Mormon A Spring. A slightly increasing trend may also be present in the area of Test Well 22. In the area of Test Well 37, the chloride trend appears to be decreasing, although the most recent data are oscillating.

Figure 4-36 presents time history plots of chloride groundwater concentration for the northwest pond/hydroclarifier area. These data indicate generally decreasing chloride concentrations with the exception of data collected at Test Well 41. These data indicate a recent increase, although no cause is know for this increase.

Fluoride

Groundwater quality data for fluoride are presented on Figures 4-37 through 4-40. Data for May 1993 for the UBZ are presented on Figure 4-30. These data indicate three fluoride plumes are present below the Monsanto Plant. The plume in the northwest pond/hydroclarifier area is characterized by lower concentrations than the other plumes and is also contained to the central area of the Plant. In the old underflow solids ponds area, the plume appears to have migrated to the south. A peak area of about 5 mg/L fluoride appears to exist at the southern fenceline. Lower concentrations are observed further south and west toward Mormon Creek. Figure 4-38 presents fluoride groundwater data for the LBZ during May 1993. These observations indicate much lower concentrations of fluoride in the LBZ. A remnant plume may be present in the area of the old underflow solids ponds. These fluoride concentrations are within the range of natural levels observed in groundwater in the Soda Springs area.

Figure 4-39 presents time history data for fluoride groundwater concentrations in the old underflow solids ponds area. Declining trends are observed in samples collected from Test Wells 36 and 22, and also in samples from Mormon A Spring. Concentrations observed in samples from Test Well 37 appear constant. These data may reflect a mineral equilibrium condition in the UBZ aquifer materials. The mineral fluorite (calcium fluoride), if present, could release fluoride into the groundwater as it dissolves, causing the appearance of a constant groundwater concentration. As the mineral dissolves, the actual mass loading to groundwater declines, although locally the concentration may appear constant (e.g., at a single well). As the mineral dissolves completely in the vicinity of the sampling locations, a declining trend in groundwater concentration will also be observed. Figure 4-40 presents time history plots of fluoride groundwater concentration in the northwest pond/hydroclarifier area. With the

exception of results for Test Well 41, these data indicate declining trends in the fluoride concentrations, which are consistent with the source history.

Iron

Groundwater quality data for iron are presented on Figures 4-41 through 4-44. Iron is observed to occur at uncommonly high natural concentrations in the sodic groundwater of the Soda Springs area. Natural iron concentrations determined from control samples for sodic groundwater have been measured at up to 8.5 mg/L. The iron most likely originates from minerals forming the basaltic lava. Both olivine and pyroxene are common iron-bearing minerals in the basalt.

Groundwater quality data for iron in the UBZ during May 1993 are presented on Figure 4-41. Four plume areas are vaguely defined by the data and occur below the Monsanto and Kerr-McGee Plants. The iron concentrations in groundwater are typically low, however, concentrations on the order of 1 mg/L occur at isolated locations. Figure 4-42 presents groundwater concentrations for iron in the LBZ during May 1993. As shown, iron concentrations are higher than is typically observed in groundwater and are much higher than is observed in the UBZ. As most of the LBZ consists of the sodic groundwater type, these iron concentrations reflect natural iron rather than releases from the Monsanto Plant.

Figure 4-43 presents time history plots of iron groundwater concentrations in the old underflow solids ponds area. These plots generally show an oscillating or erratic pattern to the observed iron concentrations. It is possible the iron concentration is sensitive to sample turbidity and that slight variations in turbidity cause significantly different iron measurements. Time history plots of iron groundwater concentrations in the northwest pond/hydroclarifier area are shown on Figure 4-44. These data also show an oscillating and erratic behavior to the iron concentration data.

Manganese

Groundwater concentrations for manganese are shown on Figures 4-45 through 4-48. Figure 4-45 presents manganese groundwater concentrations for the UBZ during May 1993. These data indicate two plumes originating from the Monsanto Plant and one from Kerr-McGee. Below the Monsanto Plant, the plumes are not well defined and many of the samples contained low concentrations of manganese that are comparable to natural concentrations in the area. Manganese groundwater concentrations in the LBZ are shown on Figure 4-46. These manganese concentrations are lower than in the UBZ.

Time history plots for manganese in groundwater in the old underflow solids ponds area are shown on Figure 4-47. These plots indicate concentrations are declining near to Test Wells 37, 36, and 22. The concentration observed in groundwater from Mormon A Spring appears to be constant at about 0.015 mg/L, which is similar to natural concentrations. Time history plots of manganese groundwater concentrations in the northwest pond/hydroclarifier area are shown on Figure 4-48. These data show declining concentrations of manganese in groundwater in this area. One exception, Test Well 17, indicates a constant concentration for manganese in groundwater of about 1.5 mg/L.

Molybdenum

Groundwater quality data for molybdenum are shown on Figures 4-49 through 4-52. Figure 4-49 presents molybdenum groundwater concentrations in the UBZ during May 1993. Three plume areas are moderately well-defined by these data. Two of the plumes occur below the Monsanto Plant in the area of the hydroclarifier and the area of the old underflow solids ponds. The third plume originates from the Kerr-McGee Plant. Figure 4-50 presents molybdenum groundwater quality data for the LBZ during May 1993. As shown, below the Monsanto Plant molybdenum was not measured in groundwater samples or was measured at low concentrations.

Figure 4-51 presents time history plots of the molybdenum groundwater concentrations in the northwest pond/hydroclarifier area. Samples collected from Test Well 40 indicate a declining trend in the molybdenum concentrations, whereas trends are not discernible in the results from samples collected at Test Wells 16, 17, and 41. Time history plots of molybdenum groundwater concentrations in the old underflow solids ponds area are shown on Figure 4-52. A declining trend in molybdenum concentration is indicated by the data for Test Well 36. Data applying to Test Wells 37 and 22 appear flat, indicating conditions of constant concentration, while at Mormon A Spring the sample data indicate increasing concentrations. Given these plots are based on data for only a 2 to 3 year time period, the trends are not well-defined and the data patterns may not reflect actual trends.

Nickel

Groundwater concentration data for nickel are presented on Figures 4-53 through 4-56. Data for the UBZ during May 1993 are presented on Figure 4-53. As shown, two small plume areas have been identified from these data. Most of the sample analyses reported the nickel concentration to be below the detection limit. In particular, nickel was not detected in the off-site wells and springs. Figure 4-54 presents the nickel concentrations in the LBZ. With one exception, nickel could not be measured in these samples.

Time history plots of nickel groundwater concentrations in the area of the old underflow solids ponds are shown on Figure 4-55. These data indicate an erratic behavior in the nickel groundwater concentrations, a result possibly attributable to the low concentrations that have been measured. Time history plots for nickel groundwater concentrations in the northwest pond/hydroclarifier area are shown on Figure 4-56. Most of these results indicate that nickel groundwater concentrations were below the sample quantitation limit.

Nitrate-Nitrogen

Groundwater concentration data for nitrate-nitrogen are shown on Figures 4-57 through 4-61. The data reported were actually measurements of nitrate plus nitrite as nitrogen. As analyses for nitrite (Section 2.6.5) indicate that nitrite is not present in the groundwater (all results measured below the sample quantitation limit), we have reported the combined result simply as nitrate-nitrogen.

Nitrate-nitrogen groundwater concentrations in the UBZ during May 1993 are presented on Figure 4-57. These data indicate three plume areas are present below the Monsanto and Kerr-McGee Plants. Below the Monsanto Plant, one of these plumes is in the area of the old underflow solids ponds. The nitrate-nitrogen concentrations range from about 5 to 10 mg/L as N. The other plume below the Monsanto Plant occurs in the northwest pond/ hydroclarifier area. Nitrate-nitrogen concentrations range from about 7 to 14 mg/L as N in this area. In comparison to control sample results, the nitrate concentrations in plume areas are only 1 to 3 times greater than background. As shown on Figure 4-57, nitrate groundwater concentrations in control samples from Test Wells 29 and 48 were measured at 5.08 and 4.5 mg/L as N, respectively. These results indicate that a source of nitrogen in groundwater exists to the north of the Monsanto Plant.

Figure 4-58 presents nitrate-nitrogen groundwater concentrations in the LBZ during May 1993. Nitrate-nitrogen groundwater concentrations in the LBZ were below the sample quantitation limit below the majority of the Monsanto Plant. Detections of nitrate-nitrogen in LBZ groundwater occurred along the eastern border of the Monsanto Plant and appear to have resulted from a source at the Kerr-McGee Plant.

Time history plots of nitrate groundwater concentrations in the old underflow solids ponds area are shown on Figure 4-59. As shown from the sample data, there has been variability in the nitrate-nitrogen groundwater concentrations over the past several years at the respective sampling locations. At present, slight increasing trends in nitrate-nitrogen concentration are observed in samples collected from Test Well 22 and from Mormon A Spring. Sample analyses for Test Well 37 indicate the nitrate-nitrogen concentration has been constant over the past few years. Data for Test Well 36 are variable and well-defined trends cannot be observed.

Figure 4-60 presents time history plots for nitrate-nitrogen groundwater concentrations in the northwest pond/hydroclarifier area. A declining trend in the nitrate-nitrogen groundwater concentration is observed in the data for Test Well 40. Trends are not as clear in the samples collected from Test Wells 16 and 41. Nitrate-nitrogen concentrations are consistently below the sample quantitation limit in samples from Test Well 17.

Selenium

Groundwater quality data for selenium are presented on Figures 4-61 and 4-62. Selenium concentrations in groundwater for the UBZ during May 1993 are shown on Figure 4-61. Two or possibly three plume areas are shown on Figure 4-62. The plume emanating from the old underflow solids ponds area appears to have had two peak areas at the time samples were collected. One of the peak areas occurs in the immediate area of the old underflow solids ponds. The other peak area is located along the southern fenceline of the Monsanto Plant. A third peak area, which may be a different plume, i.e., a plume originating from a different source, is shown in the area of Calf and Mormon Springs. The other plume area is in the central part of the Monsanto Plant and is related to the northwest pond and the old hydroclarifier. Selenium groundwater concentrations in the LBZ during May 1993 are shown on Figure 4-55. As indicated by these sample results, selenium has not been measured in the LBZ below the Monsanto Plant.

Time history plots for selenium concentrations in groundwater are not shown. During validation of laboratory analyses, it was decided that selenium results prior to 1993 were in error. Due to the small number of valid selenium results available (3 results), time history plots were not prepared. The data that are available indicate the selenium concentrations have remained roughly constant, with some oscillation, in samples collected from the old underflow solids ponds area. These same patterns occur in the northwest pond/hydroclarifier area, however, samples from Test Wells 16 and 40 indicate declining trends. As few data are available, trends in selenium concentrations are not well-defined.

Sodium

Figures 4-63 through 4-66 present groundwater quality data for sodium. Groundwater concentrations for sodium during May 1992 in the UBZ are shown on Figure 4-63. A small plume of sodium is shown to occur along the southern fenceline of the Monsanto Plant and also in the center of the Monsanto Plant near to the hydroclarifier. A larger plume is shown emanating from the Kerr-McGee Plant. Figure 4-64 presents sodium groundwater concentrations for the LBZ during May 1992. These data show much lower sodium concentrations than in the UBZ. Sodium groundwater concentrations measured in the LBZ below the Monsanto Plant are closely comparable to background levels. The only plume present in the LBZ occurs along the eastern border of the Monsanto Plant and is related to sources at the Kerr-McGee Plant.

Time history plots of sodium concentrations in groundwater in the old underflow solids area are shown on Figure 4-65. Declining trends are observed in the samples collected from Test Wells 37 and 22. Analyses of samples collected from Test Well 36 suggest an increasing trend. Sodium concentrations observed in samples from Mormon A Spring have varied over the past several years, but on average appear constant. Figure 4-66 presents time history plots of sodium groundwater concentrations in the northwest pond/hydroclarifier area. These data indicate the sodium concentrations have declined over the past several years. Analyses of samples from Test Well 40 are an exception, as sodium concentrations appear moderately constant at present following an initial decline during the early 1980s.

Sulfate

Sulfate groundwater concentration data are shown on Figures 4-67 through 4-70. Groundwater concentrations for the UBZ during May 1993 are shown on Figure 4-67. These data indicate two sulfate plumes that originated below the Monsanto Plant and a third plume that originated at Kerr-McGee. Below the Monsanto Plant, peak concentrations are about 400 to 600 mg/L and decline to background concentrations of 75 to 100 mg/L. Figure 4-68 presents sulfate groundwater concentrations in the LBZ during May 1993. Two plumes are shown, one of which is related to the Kerr-McGee Plant. Below the Monsanto Plant, LBZ sulfate concentrations are comparable to background, except for the area below the old underflow solids ponds.

Time history plots of sulfate groundwater concentrations in the old underflow solids ponds area are shown on Figure 4-69. These data indicate sulfate concentrations have generally declined from the early 1980s to the early 1990s. Recent data for Test Wells 22, 36, and Mormon

A Spring indicate that at present sulfate concentrations may be increasing at these locations. Time history plots of sulfate groundwater concentrations in the northwest pond/hydroclarifier area are shown on Figure 4-70. Declining trends are observed in samples collected from Test Wells 16 and 40. Data for Test Wells 17 and 41 indicate concentrations are variable.

Vanadium

Vanadium concentrations in groundwater are shown on Figures 4-71 through 4-74. Figure 4-71 presents vanadium groundwater concentrations in the UBZ during May 1993. As shown, in the old underflow solids ponds area, a diffuse vanadium plume exists in which concentrations are less than 0.1 mg/L. In the northwest pond/hydroclarifier area, similar concentrations of vanadium are observed. Along the eastern border of the Monsanto Plant, observations of vanadium in groundwater are a result of sources at the Kerr-McGee Plant. Figure 4-72 presents vanadium groundwater concentrations in the LBZ during May 1993. Below the majority of the Monsanto Plant, the vanadium concentrations are below or at sample detection levels. A vanadium plume located along the eastern border of the Monsanto Plant has resulted from activities at Kerr-McGee.

Time history plots of vanadium concentrations in the old underflow solids ponds area are shown on Figure 4-73. Ignoring those results that were below the detection limit, the data indicate moderately steady vanadium concentrations with possibly declining trends observed at Test Wells 37, 22, and Mormon A Spring. Figure 4-74 presents time history plots of vanadium groundwater concentrations in the northwest pond/hydroclarifier area. These data also include a large number of observations that were below detection limits. Considering only those results in which vanadium was detected, the data appear to indicate a weak declining trend.

Zinc

Groundwater quality data for zinc are presented on Figures 4-75 through 4-78. Zinc groundwater concentrations in the UBZ during May 1993 are presented on Figure 4-75. Three small plumes are shown by these data. Plumes in the northwest pond area and the old underflow solids ponds area consist of concentrations less than 5 mg/L. The small plume in the hydroclarifier area has a maximum measured zinc concentration of 6.36 mg/L. Figure 4-76 presents zinc groundwater concentration data for the LBZ during May 1993. As shown, zinc concentrations in the LBZ are less than 0.21 mg/L.

Time history plots of zinc groundwater concentrations in the old underflow solids ponds area are shown on Figure 4-77. These data indicate that on average zinc concentrations have declined over the past 10 years. It is possible that slight increases in zinc concentrations are presently occurring at the locations of Test Well 36 and Mormon A Spring. Figure 4-78 presents time history plots of zinc concentrations in groundwater in the northwest pond/hydroclarifier area. Samples collected from Test Wells 16 and 40 indicate that zinc concentrations have strongly declined since about 1985. Data from Test Wells 17 and 41 consist of low zinc concentrations that are both near the detection limit and comparable to background zinc concentrations.

TABLE 4-1

AVERAGE CONSTITUENT ANALYSIS OF SOURCE MATERIALS NONRADIONUCLIDES (MG/KG)

Source	Size	Aluminum	Arsenic	Beryllium	Cadmium	Chromium	Fluoride	Manganese	Molybdenum	Selenium	Silver	Vanadium	Zinc
Coke	-200	683 ± 93.6	2.4 ± 0.64	<0.45	<3.8	29 ± 24	72 ± 55	14 ± 3.0	2.0 ± 1.4	1.3 ± 0.81	0.28 ± 0.07	60 ± 85	43 ± 19
	Total	4,203 ± 3,225	2.6 ± 3.6	<1.2	<9.6	24 ± 14	5.5 ± 4.3	4.2 ± 0.95	0.73 ± 0.41	0.39 ± 0.26	0.80 ± 0.70	50 ± 35	199 ± 172
Old Nodules	-200	5,590 ± 394	11.4	<4.0	<7.7	546 ± 62	30 ± 8.0	65 ± 16	31 ± 8.7	8.3 ± 2.6	5.5 ± 1.4	1,182 ± 264	613 ± 346
New Nodules	Total	14,667 ± 2,145	3.0 ± 2.9	14 ± 0.32	11 ± 7.1	547 ± 164	13 ± 3.1	38 ± 9.7	14 ± 3.6	1.60 ± 0.95	5.2 ± 1.1	1,563 ± 71	11 ± 4.0
Ore Blend-1	-200	7,973 ± 1,787	24 ± 2.7	1.6 ± 0.35	121 ± 5.7	920 ± 195	43 ± 30	76 ± 12	31 ± 10	46 ± 23	2.3 ± 0.0	2,193 ± 220	2,803 ± 752
	Total	8,270 ± 2,038	<1.1	3.4 ± 0.12	120 ± 16	818 ± 45	59 ± 7.4	40 ± 4.2	19 ± 9.1	28 ± 9.4	R	1,530 ± 251	2,010 ± 376
Ore Blend-2	-200	8,933 ± 192	29 ± 7.2	1.3 ± 0.10	132 ± 3.0	828 ± 120	6.6 ± 1.5	61 ± 15	30 ± 1.6	65 ± 15	4.4 ± 1.5	1,947 ± 260	1,820 ± 26
	Total	18,600 ± 3,439	<1.1	4.5 ± 0.20	132 ± 19	1,098 ± 143	25 ± 18	35 ± 7.8	12 ± 3.1	41 ± 14	R	1,563 ± 286	1,270 ± 35
Quartzite	Total	1,205 ± 158	1.4 ± 0.50	0.067 ± 0.04	0.26 ± 0.031	2.1 ± 0.76	NM	<9.6	<0.86	<0.2	R	0.38 ± 0.14	6.1
Baghouse Dust	-200	12,450 ± 6,329	44 ± 37	3.1 ± 2.3	211 ± 261	309 ± 251	136 ± 98	104 ± 62	NM	0.40 ± 0.17	9.0 ± 8.0	452 ± 376	2,101 ± 2,210
Old Slag	Total	12,016 ± 9,434	1.7 ± 0.71	7.9 ± 1.3	15 ± 7.4	188 ± 51	50 ± 19	113 ± 39	2.3 ± 1.9	7.3 ± 1.7	2.4 ± 0.31	524 ± 293	1.9 ± 2.2
New Slag	Total	16,300 ± 781	<0.5	13 ± 0.21	21 ± 6.2	229 ± 108	51 ± 20	46 ± 2.2	1.0 ± 0.54	4.0 ± 3.2	1.2 ± 0.53	27 ± 76	25 ± 16
Slurry Pond	-200	16657 ± 10,326	232 ± 248	4.0 ± 1.1	285 ± 306	543 ± 414	215 ± 116	74 ± 6.6	NM	15.1 ± 8.19	16 ± 13	821 ± 650	3828 ± 3822
Ferrophos Slag	Total	5,213 ± 536	1.2 ± 0.15	57 ± 3.6	36 ± 4.6	28,833 ± 2,230	9.4 ± 0.34	846 ± 47	860 ± 45	0.37 ± 0.14	30 ± 12	60,067 ± 5,000	46 ± 14
Old Treater Dust	-200	8,517 ± 511	3.2 ± 2.1	<3.2	131 ± 2.6	283 ± 12	288 ± 21	230 ± 21	2.7 ± 1.5	33 ± 23	6.2± 1.7	479 ± 19	41,933 ± 10,625
New Treater Dust	Total	8,667 ± 1,250	3.3 ± 1.4	4.7 ± 3.3	40 ± 11	434 ± 45	8,473 ± 6,191	57 ± 8.6	6.9 ± 0.72	13 ± 2.2	66 ± 24	813 ± 76	2,730 ± 2,281
Underflow Solids	-200	26,000 ± 2,095	233 ± 20	5.7 ± 0.25	1,313 ± 364	1,019 ± 79	227 ± 167	179 ± 64	NM	208 ± 20	12 ± 3.6	1,637 ± 158	9,693 ± 1,379
Underflow Solids	Total	25,000 ± 1,769	93 ± 28	15 ± 1.3	1,197 ± 762	1,100 ± 17	623 ± 102	93 ± 3.9	36 ± 5.2	169 ± 33	57 ± 10	2020 ± 44	8,703 ± 2,773

TABLE 4-1 (Cont.)

AVERAGE CONSTITUENT ANALYSIS OF SOURCE MATERIALS
RADIONUCLIDES (pCi/g)

Source	Size	LEAD-210	POLONIUM-210	POTASSIUM-40	RADIUM-226	THORIUM-228	THORIUM-230	URANIUM-238
Coke	-200	3.6 ± 0.65	3.367 ± 2.5	<0.24	2.4 ± 1.2	0.27 ± 0.15	2.4 ± 1.6	2.0 ± 1.6
	Total	<0.48	0.28 ± 0.22	0.30 ± 0.34	0.20 ± 0.11	0.13 ± 0.058	0.43 ± 0.35	0.27 ± 0.15
Old Nodules	-200	<3.8	5.0 ± 3.6	<9.8	41 ± 1.0	0.43 ± 0.058	52 ± 1.7	43 ± 3.8
New Nodules	Total	<1.3	1.4 ± 0.76	4.2 ± 3.0	50 ± 2.1	0.33 ± 0.058	53 ± 2.5	47 ± 1.2
Ore Blend 1	-200	33 ± 0.58	35 ± 11.9	10 ± 0.058	32 ± 3.5	0.50 ± 0.17	38 ± 1.2	32 ± 2.1
	Total	42 ± 2.9	44 ± 8.5	<6	48 ± 2.1	0.45 ± 0.35	54 ± 6.4	42 ± 4.9
Ore Blend 2	-200	31 ± 5.8	28 ± 3.6	12 ± 1.8	29 ± 1.2	0.67 ± 0.31	32.0 ± 1.0	28 ± 2.1
	Total	38 ± 1.0	40 ± 5.1	5.1 ± 2.3	46 ± 3.0	0.40 ± 0.26	55 ± 9.5	41 ± 1.2
Quartzite	Total	<0.40	0.20 ± 0.17	0.55 ± 0.095	0.047 ± 0.025	0.083 ± 0.029	0.25 ± 0.23	<0.10
Baghouse Dust	-200	47 ± 50	48 ± 47	5.0 ± 3.0	20 ± 16	0.25 ± 0.18	19 ± 17	20 ± 17
New Slag	Total	<1.7	0.27 ± 0.29	4.0 ± 2.0	48 ± 3.6	0.43 ± 0.058	49 ± 9.2	43 ± 3.8
Old Slag	Total	6.2 ± 4.6	7.4 ± 8.5	3.6 ± 0.21	31 ± 20	0.33 ± 0.25	40 ± 3.5	37 ± 2.6
Slurry Pond	-200	62 ± 50	49 ± 44	6.0 ± 3.3	13 ± 3.6	0.33 ± 0.25	13 ± 5.1	9.8 ± 0.26
Ferrophos Slag	Total	<1.3	3.1 ± 1.4	<2.0	5.5 ± 3.2	<0.10	6.4 ± 2.9	97 ± 15
New Treater Dust	Total	115 ± 18.5	81 ± 7.0	68 ± 10	24 ± 2.1	0.33 ± 0.25	21 ± 2.1	19 ± 3.6
Old Treater Dust	-200	300 ± 65.6	180 ± 70.0	70 ± 30	20 ± 6.5	0.20 ± 0.17	18 ± 11	17 ± 8.6
Underflow solids	-200	250 ± 10	160 ± 88	10 ± 0.90	38 ± 3.8	0.43 ± 0.058	40 ± 3.2	35 ± 5.1
Underflow solids	Total	293 ± 85.0	340 ± 133	9.8 ± 1.3	38 ± 1.7	0.43 ± 0.23	43 ± 2.5	43 ± 5.7

Notes:
1. Size indicates particle-size of analyzed fraction; -200 indicates the less than 200 mesh size fraction and Total is all particle sizes.
2. Analysis shows mean concentration ± standard deviation.
3. Values shown as "<" are detection limit.
4. NM: not measured.
5. R: data rejected during data validation.

TABLE 4-2

MONSANTO PHASE 2
GAMMA RADIATION SURVEY AT SOURCE LOCATIONS

SURVEY READINGS			RESULTS					
							Tissue Equivalent	
	A	B	C	A	B	C	Average	St. Dev.
	(COUNTS/min)			(μR/hour)			(μR/hour)	
Source Samples								
COKE PILE 1	79.7	96.6	115	17.1	19.4	22.0	19.5	2.452
COKE PILE 2	69.7	79.7	63.8	15.7	17.1	14.9	15.9	1.116
COKE PILE 3	75.7	76.7	75.7	16.5	16.7	16.5	16.6	0.080
NEW NODULES 1	301	336	326	47.8	52.7	51.3	50.6	2.504
NEW NODULES 2	307	276	274	48.6	44.3	44.1	45.7	2.570
NEW NODULES 3	314	306	318	49.6	48.5	50.2	49.4	0.849
OLD NODULES 1	357	315	324	55.6	49.8	51.0	52.1	3.071
OLD NODULES 2	434	405	426	66.3	62.3	65.2	64.6	2.080
OLD NODULES 3	372	384	348	57.7	59.3	54.3	57.1	2.546
ORE BLEND 1	341	367	369	53.4	57.0	57.3	55.9	2.170
ORE BLEND 2	310	400	367	49.1	61.6	57.0	55.9	6.324
QUARTZITE	48.8	49.8	51.8	12.8	12.9	13.2	13.0	0.212
NEW SLAG 1	425	374	403	65.0	57.9	62.0	61.6	3.553
NEW SLAG 2	427	379	367	65.3	58.6	57.0	60.3	4.410
NEW SLAG 3	388	336	340	59.9	52.7	53.2	55.3	4.019
OLD SLAG 1	404	414	381	62.1	63.5	58.9	61.5	2.350
OLD SLAG 2	376	388	398	58.2	59.9	61.3	59.8	1.530
OLD SLAG 3	411	363	384	63.1	56.4	59.3	59.6	3.342
FERROPHOS SLAG 1	79.7	99.6	84.7	17.1	19.8	17.8	18.2	1.438
FERROPHOS SLAG 2	117	106	105	22.3	20.7	20.6	21.2	0.925
FERROPHOS SLAG 3	90.6	78.7	85.7	18.6	16.9	17.9	17.8	0.831
NEW TREATER DUST 1	280	307	279	44.9	48.6	44.8	46.1	2.206
NEW TREATER DUST 2	260	265	244	42.1	42.8	39.9	41.6	1.524
NEW TREATER DUST 3	266	244	259	42.9	39.9	42.0	41.6	1.561

TABLE 4-2

MONSANTO PHASE 2
GAMMA RADIATION SURVEY AT SOURCE LOCATIONS

SURVEY READINGS			RESULTS					
							Tissue Equivalent	
	A	B	C	A	B	C	Average	St. Dev.
UNDERFLOW SOLIDS 1	213	237	221	35.6	38.9	36.7	37.1	1.697
UNDERFLOW SOLIDS 2	261	318	286	42.3	50.2	45.7	46.0	3.968
UNDERFLOW SOLIDS 3	269	273	299	43.4	43.9	47.5	44.9	2.262
OLD TREATER DUST 1	225	210	207	37.3	35.2	34.8	35.7	1.339
OLD TREATER DUST 2	223	217	240	37.0	36.1	39.3	37.5	1.657
OLD TREATER DUST3	265	288	239	42.8	46.0	39.2	42.7	3.405
Site Survey								
BAG HOUSE DUST 1	130	133	122	24.1	24.5	22.9	23.8	0.790
BAG HOUSE DUST 2	102	125	117	20.2	23.4	22.3	21.9	1.622
BAG HOUSE DUST 3	113	124	132	21.7	23.2	24.3	23.1	1.325
BAG HOUSE DUST 4	119	146	147	22.5	26.3	26.4	25.1	2.206
PERIMETER SOILS 1	52.8	50.3	55.3	13.3	13.0	13.7	13.3	0.347
PERIMETER SOILS 2	48.6	60.1	53.5	12.8	14.3	13.4	13.5	0.802
PERIMETER SOILS 3	61.1	70.7	65.5	14.5	15.8	15.1	15.1	0.667
PERIMETER SOILS 4	71.2	74.7	77.7	15.9	16.4	16.8	16.4	0.452
PERIMETER SOILS 5	55.3	48.2	50.5	13.7	12.7	13.0	13.1	0.503
PERIMETER SOILS 6	51.1	63.8	57.8	13.1	14.9	14.0	14.0	0.882
SLAG PILE 1	156	142	144	27.7	25.7	26.0	26.5	1.052
SLAG PILE 2	193	217	185	32.8	36.1	31.7	33.5	2.313
SLAG PILE 3	208	181	205	34.9	31.1	34.5	33.5	2.055
SLAG PILE 4	199	229	247	33.6	37.8	40.3	37.3	3.368
SLAG PILE 5	218	219	227	36.3	36.4	37.5	36.7	0.685
SLAG PILE 6	130	141	158	24.1	25.6	27.9	25.9	1.959
SLAG PILE 7	107	98.6	88.7	20.9	19.7	18.3	19.6	1.272
SLAG PILE 8	134	135	134	24.6	24.8	24.6	24.7	0.080
SLAG PILE 9	181	190	199	31.1	32.4	33.6	32.4	1.250

TABLE 4-2

MONSANTO PHASE 2
GAMMA RADIATION SURVEY AT SOURCE LOCATIONS

SURVEY READINGS			RESULTS					
							Tissue Equivalent	
	A	B	C	A	B	C	Average	St. Dev.
SLAG PILE 10	204	195	203	34.3	33.1	34.2	33.9	0.685
UNDERFLOW SOLIDS 1	162	153	169	28.5	27.3	29.5	28.4	1.114
UNDERFLOW SOLIDS 2	171	160	175	29.8	28.2	30.3	29.4	1.079
UNDERFLOW SOLIDS 3	205	228	220	34.5	37.7	36.6	36.2	1.622
UNDERFLOW SOLIDS 4	191	226	171	32.5	37.4	29.8	33.2	3.867
UNDERFLOW SOLIDS 5	145	161	145	26.1	28.4	26.1	26.9	1.283
UNDERFLOW SOLIDS 6	109	105	134	21.1	20.6	24.6	22.1	2.183

Tissue Equivalent = [(counts/min)/conversion constant * 60]*0.5+6.
Conversion Constant = 216 counts/uR8;75

TABLE 4-3

SURFACE WATER QUALITY DATA

SAMPLE LOCATION SAMPLE DATE	EFFLUENT C (mg/L) 10/25/91	QUAL	DOWN A (mg/L) 10/25/91	QUAL	DOWN B (mg/L) 10/25/91	QUAL	DOWN C (mg/L) 10/25/91	QUAL
ALUMINUM	0.1		0.09		0.11		0.11	
ARSENIC	0.002	U	0.002	U	0.002	U	0.002	U
BERYLLIUM	0.001	U	0.001	U	0.001	U	0.001	U
CADMIUM	0.011		0.005	U	0.005	U	0.005	U
CALCIUM	128		88.4		83.7		86.2	
CHROMIUM	0.01	U	0.01	U	0.01	U	0.01	U
COPPER	0.008	U	0.005	U	0.005	U	0.005	U
IRON	0.04	U	0.54	U	0.54	U	0.59	U
LEAD	0.001	UJ	0.001	UJ	0.001	UJ	0.002	UJ
MAGNESIUM	60.3		76.5		75		78.7	
MANGANESE	0.005	U	0.06		0.063		0.063	
NICKEL	0.02	U	0.02	U	0.02	U	0.02	U
POTASSIUM	7.3		9.3		9.6		10	
SELENIUM	.02*							
SILVER	0.01	U	0.01	U	0.01	U	0.01	U
SODIUM	104		31.2		29.9		31.1	
VANADIUM	0.21		0.03	U	0.03	U	0.03	U
ZINC	0.031	U	0.012	U	0.015	U	0.008	U
LAB pH	8	J	7.1	J	7	J	7	J
SPECIFIC CONDUCTANCE	1430		1020		1030		1020	
TOTAL DISSOLVED SOLIDS	786		556		580		546	
AMMONIUM -NITROGEN	0.1	U	0.12	U	0.12	U	0.43	U
BICARBONATE	533		611		636		575	
CARBONATE	0		0		0		0	
CHLORIDE	153		29		30		25	
FLUORIDE	0.4		0.31		0.34		0.34	
HYDROXIDE	0		0		0		0	
NITRATE-NITROGEN	4.55		1.16		1.14		1.14	
SULFATE	96		42		42		42	
ORTHO-PHOSPHATE	1.08		0.21	U	0.24	U	0.22	U

*SAMPLE DATE IS 6/9/93

TABLE 4-4

ANALYTICAL RESULTS OF ROAD SAMPLES

Sample Location	Size	Aluminum	Q	Arsenic	Q	Beryllium	Cadmium	Q	Chromium	Fluoride	Manganese	Q	Molybdenum	Q	Selenium	Silver	Q	Vanadium	Zinc	Q
East Service Road	Total	11,100	J	43	J	1.6	378		403	123	119		14		NM	2.6		883	3,080	J
	SUB200	14,600		39		1.9	595		493	NM	130		16		48	2.1		990	3,900	
Ore Haul Road	Total	11,700	J	3.1	J	3.1	82	J	272	53	70		9.8	UJ	NM	4.6	J	565	249	J
	SUB200	10,600		11		1.9	135		440	NM	98		13		67	4.0		1,010	1,530	
Quartzite Haul Road	Total	3,200	J	0.11	R	1.9	44	J	83	52	38		2.6	UJ	NM	2.7	J	161	346	J
Slag Haul Road	Total	6,680		1.3		1.5	2.6		82	36	62	J	0.93	U	NM	1.1		121	38	
	duplicate	9,410		3.2	J	1.4	1.1		14	5.9	617	J	1.1	U	NM	0.060		20	51	
West Service Road	Total	10,200	J	4.9		3.7	171	J	161	24	91		6.9	UJ	NM	6.4	J	350	1,580	J
	SUB200	13,700		NM		2.2	358		269	NM	116		12		91	9.4		470	2,950	

TABLE 4-4 (Cont.)

ANALYTICAL RESULTS OF ROAD SAMPLES

Location	Size Fraction	LEAD-210			POLONIUM-210			POTASSIUM-40			RADIUM-226			THORIUM-228			THORIUM-230			THORIUM-232			URANIUM-234			URANIUM-238		
		Result	Error	Q	Result	Error	Q	Result	Error	Q	Result	Error	Q	Result	Error	Q	Result	Error	Q	Result	Error	Q	Result	Error	Q	Result	Error	Q
East Service Road	SUB200	180	10		260	20	J	10	1	J	31	1		0.6	0.2		32	1		0.6	0.2		28	2		28	2	
East Service Road	TOTAL	62	3		77	8					39	1		0.3	0.2		44	2		0.5	0.2		34	2		33	2	
Ore Haul Road	SUB200	51	6		56	8	J	7.6	1	J	29	1		0.6	0.2		34	1		1	0.3		25	1		27	1	
Ore Haul Road	TOTAL	29	4		27	7					31	1		0.4	0.2		32	1		0.3	0.2		29	1		32	1	
Quartzite Haul Road	TOTAL	22	3		22	5					16	1		0.4	0.2		17	1		0.2	0.1		14	1		14	1	
Slag Haul Road	TOTAL	7.1	2.8		7.8	2.3		4.7	1		29	1		0.2	0.4		25	3					25	3		24	3	
Slag Haul Road D	TOTAL	11	2		14	2		5	1		30	1		0.3	0.5		31	3					29	3		31	3	
West Service Road	SUB200	190	20		170	10	J	9.1	1.2		30	1		0.9	0.2		34	2		1.3	0.4		28	2		27	2	
West Service Road	TOTAL	60	6		110	10					42	1		0.5	0.2		44	2		0.8	0.2		37	1		43	2	

Notes:

Q: data qualifers, U is undetected, J is estimated, R is rejected.

0125crh1.4-4

TABLE 4-5

SUMMARY OF FACILITY EMISSIONS FOR PARTICULATES, TRACE METALS AND FLUORIDES (1990)

	SOURCES	ANNUAL EMISSION RATES (tons/yr)										
		TSP	PM_{10}	As	Be	Cd	Mn	Ag	V	Zn	Mo	F
1	Kiln Venturis (4)	70.4	54.7	0.0578	0.0051	0.9985	0.7318	0.0092	0.0356	2.0084	0.0392	2.7
	Kiln Cooler Spray Tower	26.3	13.8	0.0001	0.0001	0.0002	0.0017	0.0001	0.0311	0.0161	0.0008	0.9
	Nodule Crush/Screen	112.0	6.8	0.0005	0.0004	0.0006	0.0073	0.0006	0.1328	0.0688	0.0035	3.1
	THFCs (3)	22.7	22.2	0.0001	0.0001	0.0030	0.0052	0.0001	0.0109	0.9534	0.0001	8.1
	SUB-TOTAL	231.4	97.5	0.0585	0.0057	1.0023	0.7460	0.0100	0.2104	3.0467	0.0436	14.7
2	Scaleroom BH	3.5	2.8	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	0.0039	0.0001	<0.0001	0.079
	Stocking System BH	1.4	1.1	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0016	<0.0001	<0.0001	0.031
	All Other BHs	2.2	1.8	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	0.0001	<0.0001	0.008
	SUB-TOTAL	7.1	5.7	<0.0001	<0.0001	<0.0001	0.0002	<0.0001	0.0057	0.0003	<0.0001	0.118
3	Nodule Reclaim (pre-1993)	141.1	66.8	0.0006	0.0005	0.0008	0.0092	0.0008	0.1669	0.0863	0.0044	3.7
	Slag Pouring (Hot)	254.3	119.9	0.0004	0.0026	0.0049	0.0201	0.0005	0.1003	0.0035	0.0005	31.0
	UFS	0.05	0.02	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	0.0001	0.0004	<0.0001	0.0027
	All Other Mat. Handling	11.9	9.2	0.0001	<0.0001	0.0011	0.0018	<0.0001	0.0059	0.3314	<0.0001	1.7
	SUB-TOTAL	407.4	195.9	0.0011	0.0032	0.0069	0.0311	0.0014	0.2732	0.4216	0.0050	36.4
4	Ore	73.8	35.0	0.0020	0.0001	0.0093	0.0051	0.0003	0.1543	0.1734	0.0023	1.4
	UFS	135.6	64.2	0.0127	0.0020	0.1625	0.0126	0.0078	0.2742	1.1808	0.0049	7.1
	Slag	23.6	11.1	0.0001	0.0002	0.0004	0.0027	<0.0001	0.0064	0.0006	<0.0001	0.4
	All Other Stockpiles	23.9	10.7	0.0005	0.0001	0.0036	0.0037	0.0002	0.0113	0.4867	0.0003	0.4
	SUB-TOTAL	256.9	121.0	0.0153	0.0024	0.1758	0.0241	0.0083	0.4462	1.8415	0.0075	9.3
5	Haul Roads	19.9	11.0	0.0003	<0.0001	0.0042	0.0043	<0.0001	0.0106	0.0307	0.0002	0.4
	1990 TOTAL	922.7	431.1	0.0752	0.0113	1.1893	0.8057	0.0197	0.9461	5.3408	0.0563	60.9
	1991 TOTAL	903.6	427.8	0.0743	0.0110	1.1812	0.8034	0.0194	0.9080	5.6747	0.0554	60.2

1 - Permitted sources
2 - Baghouses (BH)
3 - Material handling fugitives UFS - Underflow Solids Piles
4 - Wind erosion (should be regarded as CONSERVATIVELY HIGH)
5 - Road dust

1021mmel.4-5

TABLE 4-6

SUMMARY OF FACILITY EMISSIONS FOR RADIONUCLIDES (1990)

SOURCES		ANNUAL EMISSION RATES (Ci/yr)					
		Pb-210	Po-210	Ra-226	Th-230	U-234	U-238
1	Kiln Venturis (4)	0.0604	0.2487	0.0007	0.0005	0.0011	0.0007
	Kiln Cooler Spray Tower	0.0001	0.0001	0.0010	0.0012	0.0010	0.0010
	Nodule Crush/Screen	0.0005	0.0005	0.0042	0.0053	0.0041	0.0043
	THFCs (3)	0.0062	0.0037	0.0004	0.0004	0.0003	0.0004
	SUB-TOTAL	0.0672	0.2530	0.0063	0.0074	0.0065	0.0064
2	Scaleroom BH	<0.0001	<0.0001	0.0001	0.0001	0.0001	0.0001
	Stocking System BH	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	All Other BHs	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	SUB-TOTAL	<0.0001	<0.0001	0.0002	0.0002	0.0002	0.0002
3	Nodule Reclaim (pre-1993)	0.0003	0.0003	0.0061	0.0067	0.0057	0.0058
	Slag Pouring (Hot)	0.0010	0.0008	0.0106	0.0103	0.0088	0.0091
	UFS	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	All Other Mat. Handling	0.0021	0.0012	0.0002	0.0001	0.0001	0.0001
	SUB-TOTAL	0.0034	0.0024	0.0169	0.0171	0.0146	0.0150
4	Ore	0.0021	0.0021	0.0021	0.0024	0.0020	0.0020
	UFS	0.0361	0.0418	0.0047	0.0053	0.0048	0.0053
	SLAG	0.0001	0.0002	0.0009	0.0009	0.0007	0.0008
	All Other Stockpiles	0.0035	0.0023	0.0004	0.0003	0.0003	0.0003
	SUB-TOTAL	0.0418	0.0464	0.0081	0.0089	0.0078	0.0084
5	Haul Roads	0.0013	0.0017	0.0005	0.0005	0.0005	0.0005
	1990 TOTAL	0.1137	0.3035	0.0320	0.0341	0.0296	0.0305
	1991 TOTAL	0.1145	0.3030	0.0311	0.0332	0.0287	0.0297

1 - Permitted sources
2 - Baghouses
3 - Material handling fugitives
4 - Wind erosion (should be regarded as CONSERVATIVELY HIGH)
5 - Road dust

TABLE 4-7

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]Exceedances 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]Exceedance of secondary standard of 0.150 mg/m^3 in 24 hours.
[d]Not available

0111arh1.4-7

TABLE 4-8

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]Exceedances of secondary standard of 0.150 mg/m^3 in 24 hours.
[b]Not available

0111crh1.4-8

TABLE 4-9

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-Nitrogen	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 α=0.05 and df=4 (Ott 1977).
*Calculated t-value exceeds tabulated t-value.

0111cth1.4-9

TABLE 4-10

PRELIMINARY RISK SCREENING OF ELEVATED CONSTITUENTS IN SURFACE WATER

Elevated Constituent	Maximum Concentration (mg/L)	Non-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/kd-d)	RBC (mg/L)						
chloride	30	-	-	None	250	None	None	250	230
nitrate-nitrogen	1.16	1.6[a,b]	1.04	10	None	10	None	None	None
sulfate	42	-	-	None	250	None	None	250	None

Notes:

RfD	Reference Dose
RBC	Risk-based concentration at hazard quotient of 0.1
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 1994b)
b	Value for nitrate only
c	based on infant exposure factors (EPA 1991)
	Shading indicates constituent of potential interest

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TABLE 4-11

ELEVATED CONSTITUENTS IN PHASE II SEDIMENT SAMPLES FROM SODA CREEK

Constituent	Units	Control Sediments			Downstream Sediments	
		Mean	Standard Deviation	Maximum Detected	Maximum Detected	Number of Exceedances
Arsenic	(mg/kg)	6.2	212	8.6	87.8	14
Cadmium	(mg/kg)	10.8	2.55	13.4	61	15
Copper	(mg/kg)	2.50	2.29	5	95.4	18
Iron	(mg/kg)	3,967	4,861	9,580	1,970	0
Molybdenum	(mg/kg)	6.5*		6.5	5	0
Nickel	(mg/kg)	55	5.77	62	153	5
Potassium	(mg/kg)	6,173	4,203	9,400	1,390	0
Selenium	(mg/kg)	0.38	0.15	0.6	347	19
Silver	(mg/kg)	<0.10	NM	<0.1	1.8	9
Vanadium	(mg/kg)	23	6.51	30	208	16
Polonium-210	(pCi/g)	0.67	0.21	0.9	3.3	5

Notes:
Shaded constituents are evaluated with respect to maximum concentration detected in background samples
* = Only one sample analyzed
< = detection limit

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TABLE 4-12

RESULTS OF SODA CREEK SEDIMENT BIOLOGICAL TOXICITY TEST

Sample	Bacteria Enzyme Activity NOEC (%)	Algal Growth Reduction % of Control
Upstream		
Control A	12.5	3
Control B	25	42
Control C	25	44
Mean	*21*	*30*
Downstream		
100 A	25	5
100 B	12.5	9
100 C	6.25	2
Mean	*15*	*5*
2400 A	6.25	10
2400 B	<6.25	15
2400 C	12.5	20
Mean	*7.3*	*15*

Notes:
NOEC = No observed effects concentration
Algal growth reduction reported at sample strength of 100%.

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TABLE 4-13

CONSTITUENTS OF POTENTIAL INTEREST IN SEDIMENTS

Elevated Constituent	Maximum Detected Concentration	Sediment Quality Criteria		
		Ontario*		Wisconsin*
		Low Effect	Severe Effect	Background
		(mg/kg)	(mg/kg)	(mg/kg)
Arsenic	87.8 mg/kg	6	33	10
Cadmium	61 mg/kg	0.6	10	1
Copper	95.4 mg/kg	16	110	100
Nickel	153 mg/kg	16	75	100
Selenium	347 mg/kg	NR	NR	1
Silver	1.8 mg/kg	0.5	NR	NR
Vanadium	208 mg/kg	NR	NR	NR
Polonium-210	3.3 mg/kg	NR	NR	NR

*Source: Ecology 1991.
NR - Not reported.
The relevance of these criteria to Soda Creek remain to be demonstrated.

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MONSANTO PHASE 2
GAMMA RADIATION SURVEY AT SOIL SAMPLE LOCATIONS

	SURVEY READINGS (COUNTS/min)			RESULTS (μR/hour)				
Sample Location	A	B	C	A	B	C	Average (μR/hour)	St. Dev.
Off-Site Soils				(Tissue Equivalent)				
MS2-1	48.8	65.7	55.8	12.8	15.1	13.8	13.9	1.179
MS2-2	nm	nm	nm	nr	nr	nr	nm	nm
MS2-3	66.7	77.7	70.7	15.3	16.8	15.8	16.0	0.773
MS2-4	60.8	75.7	54.8	14.4	16.5	13.6	14.9	1.495
MS2-5	66.7	56.8	67.7	15.3	13.9	15.4	14.9	0.837
MS2-6	63.8	69.7	71.7	14.9	15.7	16.0	15.5	0.570
MS2-7	69.7	65.7	nm	15.7	15.1		15.4	0.393
MS2-8	56.8	69.7	61.8	13.9	15.7	14.6	14.7	0.903
MS2-9	70.7	74.7	60.8	15.8	16.4	14.4	15.5	0.994
MS2-10	69.7	66.7	61.8	15.7	15.3	14.6	15.2	0.554
MS2-11	70.7	73.7	84.7	15.8	16.2	17.8	16.6	1.024
MS2-12	52.8	49.8	nm	13.3	12.9		13.1	0.295
MS2-13	63.8	57.8	74.7	14.9	14.0	16.4	15.1	1.190
MS2-14	51.8	55.8	56.8	13.2	13.8	13.9	13.6	0.367
MS2-15	60.8	71.7	65.7	14.4	16.0	15.1	15.2	0.758
MS2-16	59.8	56.8	65.7	14.3	13.9	15.1	14.4	0.629
MS2-17	56.8	64.7	66.7	13.9	15.0	15.3	14.7	0.727
MS2-18	75.7	82.7	65.7	16.5	17.5	15.1	16.4	1.187
MS2-19	63.8	58.8	62.8	14.9	14.2	14.7	14.6	0.367
MS2-20	65.7	69.7	69.7	15.1	15.7	15.7	15.5	0.321
MS2-21	59.8	73.7	50.8	14.3	16.2	13.1	14.5	1.602
MS2-22	72.7	66.7	56.8	16.1	15.3	13.9	15.1	1.115
MS2-23	52.8	63.8	71.7	13.3	14.9	16.0	14.7	1.318
MS2-24	71.7	83.7	70.7	16.0	17.6	15.8	16.5	1.005
MS2-25	69.7	71.7	54.8	15.7	16.0	13.6	15.1	1.283
MS2-26	56.8	50.8	69.7	13.9	13.1	15.7	14.2	1.341
MS2-27	77.7	94.6	77.7	16.8	19.1	16.8	17.6	1.355
MS2-28	80.7	72.7	73.7	17.2	16.1	16.2	16.5	0.605
MS2-29	62.8	57.8	75.7	14.7	14.0	16.5	15.1	1.283
MS2-30	69.7	82.7	85.7	15.7	17.5	17.9	17.0	1.181
MS2-31	54			15.0			15.0	n=1
MS2-32	56			15.6			15.6	n=1
MS2-33	52			14.4			14.4	n=1

MONSANTO PHASE 2
GAMMA RADIATION SURVEY AT SOIL SAMPLE LOCATIONS

	SURVEY READINGS (COUNTS/min)			RESULTS (μR/hour)				
Sample Location	A	B	C	A	B	C	Average (μR/hour)	St. Dev.
MS2-34	55			15.3			15.3	n=1
MS2-35	52			14.4			14.4	n=1
MS2-36	65.7	73.7	70.7	15.1	16.2	15.8	15.7	0.561
Background Soils								
Background-1	53.8	44.8	55.8	13.5	12.2	13.8	13.1	0.814
Background-2	44.8	69.7	68.7	12.2	15.7	15.5	14.5	1.958
Background-3	63.8	74.7	67.7	14.9	16.4	15.4	15.5	0.767
K-M Background-5	61.8	75.7	61.8	14.6	16.5	14.6	15.2	1.115
K-M Background-6	70.7	52.8	51.8	15.8	13.3	13.2	14.1	1.477
K-M Background-7	78.7	49.8	68.7	16.9	12.9	15.5	15.1	2.038
MCS-A1	64.5	80.3	53.5	15.0	17.2	13.4	15.2	1.871
MCS-A2	67.4	76.4	63.5	15.4	16.6	14.8	15.6	0.919
MCS-B1	76.4	75.4	56.5	16.6	16.5	13.8	15.6	1.557
MCS-B2	75.4	72.4	83.3	16.5	16.1	17.6	16.7	0.782
MCS-B3	74.4	72.4	76.4	16.3	16.1	16.6	16.3	0.278
MCS-C1	71.4	71.4	77.3	15.9	15.9	16.7	16.2	0.473
MCS-C2	70.4	74.4	60.5	15.8	16.3	14.4	15.5	0.994
MCS-D1	68.4	76.4	75.4	15.5	16.6	16.5	16.2	0.605
MCS-D2	73.4	61.5	73.4	16.2	14.5	16.2	15.6	0.954
MCS-E1	69.4	51.6	57.5	15.6	13.2	14.0	14.3	1.259
MCS-E2	69.4	62.5	60.5	15.6	14.7	14.4	14.9	0.649
MCS-F1	54.5	71.4	71.4	13.6	15.9	15.9	15.1	1.355
MCS-F2	74.4	75.4	61.5	16.3	16.5	14.5	15.8	1.077
MCS-G1	77.3	96.2	82.3	16.7	19.4	17.4	17.8	1.360

Samples collected 27 July to 30 July 1993.
Tissue Equivalent dose rate (MR/hour) = [(counts/min)/cc • 60] • 0.5 + 6
Where cc = 216 counts/MR

TAB4-14.XLS

TABLE 4-15

ELEVATED CONSTITUENTS IN SOILS

Constituent	Units	Control Soils (0-1 Inch)				Off-Site Soils (0-1 Inch)	
		Geometric Mean	Geometric Standard Deviation	Number Sampled	UTL[a]	Maximum Detected	Number of Exceedances
Aluminum	(mg/kg)	13,634	1.19	21	20,517	49,300	10/42
Arsenic	(mg/kg)	3.92	1.25	21	6.7	34	17/42
Beryllium	(mg/kg)	0.92	1.80	21	3.7	4.0	2/42
Cadmium	(mg/kg)	1.27	2.74	21	13.9	168	12/42
Chromium	(mg/kg)	15.18	1.58	21	44.7	325	9/42
Fluoride	(mg/kg)	1.16	2.05	20	6.5	136	31/42
Manganese	(mg/kg)	614.49	1.16	21	866	1,380	1/42
Molybdenum	(mg/kg)	0.93	1.41	18	2.2	2.9	1/17
Silver	(mg/kg)	$\leq$1.8		21	$\leq$1.8	13	12/42
Vanadanium	(mg/kg)	23.21	1.25	21	39.5	467	25/42
Zinc	(mg/kg)	76.75	1.21	21	122	2,670	26/42
pH - limit	(std. units)	6.77	0.83	21	8.73	7.8	0
pH - limit	(std. units)	6.77	0.83	21	4.81	6.5	0
Lead-210	(pCi/g)	2.12	1.39	21	4.59	65	22/42
Polonium-210	(pCi/g)	1.73	1.45	18	4.30	77	22/42
Radium-226	(pCi/g)	1.64	1.35	21	3.33	17	15/42
Thorium-228	(pCi/g)	1.10	1.28	21	1.96	1.6	0
Thorium-230	(pCi/g)	1.29	1.30	18	2.46	18	16/42
Uranium-238	(pCi/g)	1.45	1.26	18	2.56	16	18/42

Notes:

[a] UTL: upper tolerance limit - exp(ln(geometric mean) + K*ln(geometric standard deviation))); for α = 0.05 and p = 0.95, k = 2.453 for n=18, 2.396 for n=20, and 2.371 for n=21.

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TABLE 4-16

CONSTITUTENTS OF POTENTIAL INTEREST IN SOILS

CONSTITUENT	MAXIMUM SOIL CONCENTRATION (mg/kg)	Oral RfD (mg/kg-d)	Oral RBC at HQ=0.1 (mg/kg)	Inhalation RfD (mg/kg-d)	Inhalation RBC at HQ=0.1 (mg/kg)	Oral SF (mg/kg-d)	Oral RBC at ICR=1E-07 (mg/kg)
ALUMINUM	49,300	2.9	79,388				
ARSENIC	34	0.0003	8.21				
BERYLLIUM	4.0	0.005	137			4.3	0.015
CADMIUM	168	0.0005	13.7				
CHROMIUM	325	1	27,375				
FLUORIDE	136	0.04	1,095				
MANGANESE	1,380	0.005	137				
SELENIUM	109	0.005	137				
SILVER	13	0.005	137				
VANDANIUM	467	0.007	192				
ZINC	2,670	0.3	8,213				

CONSTITUENT	MAXIMUM SOIL CONCENTRATION (pCi/g)	External SF (g/yr/pCi)	External RBC at ICR=1E-7 (pCi/g)	Oral SF (1/pCi)	Oral RBC at ICR=1E-07 (pCi/g)
Radionuclides					
LEAD-210	65	1.60E-10	22	6.60E-10	0.12
POLONIUM-210	77	2.90E-11	120	2.60E-09	0.031
RADIUM-226	17	6.00E-06	0.00058	1.20E-10	0.66
THORIUM-228	1.6	5.60E-06	0.00062	5.50E-11	1.4
THORIUM-230	53	5.40E-11	64	1.30E-11	6.1
URANIUM-238	100	5.10E-08	0.068	2.00E-11	4.0

Notes:
RfD: Reference Dose — RBC: risk-based concentration
HQ: Hazard Quotient — ICR:Lifetime incremental Cancer Risk
SF: Slope Factor — Shading indicates constituent of potential interest
Fluoride evaluated as soluble fluoride.

TABLE 4-17

SUMMARY OF ELEVATED CONSTITUENTS AND CONSTITUENTS OF POTENTIAL INTEREST AT OFF-SITE SOIL SAMPLING LOCATIONS

Sample Location	Constituents Exceeding	
	Control UTL	Human-Health Criteria
S-1	Ag, Al, Cd, Cr, F, V, Zn, Pb-210, Po-210, Ra-226, U-238	Cd, Pb-210, Po-210, Ra-226, U-238
S2-3	Ag, As, Be, Cd, Cr, F, V, Zn, Pb-210, Po-210, Ra-226, Th-230, U-238	As, Be, V, Pb-210, Po-210, Ra-226, Th-230, U-238
S-4	Ag, As, Cd, Cr, F, Mn, V, Zn, Pb-210, Po-210, Ra-226, Th-230, U-238	As, Cd, V, Pb-210, Po-210, Ra-226, Th-230, U-238
S2-5	As, F, V,	As
S2-6	V, Zn, Pb-210, Po-210, Ra-226, U-238	Pb-210, Po-210, Ra-226, U-238
S-7	Ag, F, Zn,	None
S-8	Al, F, V, Zn, Pb-210, Po-210, Ra-226, Th-230, U-238	Pb-210, Po-210, Ra-226, U-238
S2-9	Ag, Al, As, Cd, Cr, F, V, Zn, Pb-210, Po-210, Ra-226, Th-230, U-238	As, Cd, Pb-210, Po-210, Ra-226, Th-230, U-238
S-10	Ag, Al, As, Cd, Cr, F, V, Zn, Pb-210, Po-210, Ra-226, Th-230, U-238	As, Cd, V
S2-11	Ag, As, Be, Cd, Cr, V, Zn, Pb-210, Po-210, Ra-226, Th-230, U-238	As, Be, Cd, V, Pb-210, Po-210, Ra-226, Th-230, U-238
S-12	Ag, Al, As, Cd, Cr, F, V, Zn, Pb-210, Po-210, Ra-226, Th-230, U-238	As, Cd, Pb-210, Po-210, Ra-226, U-238
S-13	Ag, Al, As, Cd, Cr, F, V, Zn, Pb-210, Po-210, Ra-226, Th-230, U-238	As, Cd, V, Pb-210, Po-210, Ra-226, Th-230, U-238
S-14	Ag, As, Cd, Cr, F, V, Zn, Pb-210, Po-210, Ra-226, Th-230, U-238	As, Cd, V, Pb-210, Po-210, Ra-226, Th-230, U-238
S-15	Ag, Al, F, V, Zn, Pb-210, Po-210, Ra-226, Th-230, U-238	Pb-210, Po-210, Ra-226, U-238
S-16	Al, F, V, Zn, Po-210, Th-230	None
PHASE II		
MS-1	None	None
MS-2	Al, V, Zn, Po-210	Po-210
MS-3	As, Cd, F, V, Zn, Pb-210, Po-210, Th-230	As, Pb-210, Po-210
MS-4	As,	As
MS-5	As, F, Zn	As
MS-6	F	None
MS-7	Ag, Al, As, Cd, Cr, F, Mo, V, Zn, Pb-210, Po-210, Th-230	As, Cd, V, Pb-210, Po-210, Th-230

TABLE 4-17 (Cont.)

SUMMARY OF ELEVATED CONSTITUENTS AND CONSTITUENTS OF POTENTIAL INTEREST AT OFF-SITE SOIL SAMPLING LOCATIONS

Sample Location	Constituents Exceeding	
	Control UTL	Human-Health Criteria
MS-8	F, V, Zn, Pb-210, Po-210	Pb-210, Po-210
MS-9	As, F, V	As
MS-10	F, Zn	None
MS-11	As, Cd, F, V, Zn, Pb-210, Po-210, Th-230	As, Pb-210, Po-210
MS-12	As, F, V, Zn	As
MS-13	F	None
MS-14	None	None
MS-15	None	None
MS-16	F	None
MS-17	None	None
MS-18	None	None
MS-19	None	None
MS-20	None	None
MS-21	None	None
MS-22	F,V	None
MS-23	None	None
MS-24	None	None
MS-25	F, V, Zn, Po-210	Po-210
MS-26	F	None
MS-27	As, F, V, Zn	As
MS-28	None	None
MS-29	F	None
MS-30	F, V, Zn, Pb-210, Po-210, Th-230, U-238	Pb-210, Po-210, U-238
MS-31	None	None
MS-32	None	None
MS-33	None	None
MS-34	None	None
MS-35	F, V, Zn, Po-210	Po-210

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TABLE 4-18

GROUNDWATER TYPE AND REGION DESIGNATIONS FOR WELLS AND SPRINGS

	Groundwater Region	Groundwater Type		
		Fresh		Sodic
Control Well Locations	UBZ-4	PW-04 TW-13 TW-15	TW-29 TW-48	TW-28
	UBZ-2			TW-57
Control Springs	UBZ-5	FORMATION FORMATION-A	FORMATION-B FORMATION-C	
	UBZ-1			DOC HOOPER
Screening Monitoring Wells and Spring Locations	LBZ-1			TW-09
	LBZ-2			TW-21 TW-23 TW-45
	LBZ-3	TW-11 TW-32		
	LBZ-4			TW-18 TW-44
	UBZ-1	CALF HARRIS MORMON-A MORMON-B	MORMON-C TW-10 TW-53	HOMESTEAD SW SPRING TW-07 TW-08
	UBZ-2	LEWIS TW-19 TW-20 TW-22 TW-24	TW-34 TW-36 TW-37 TW-39 TW-54	TW-35 TW-55
	UBZ-3	TW-12 TW-31 TW-33	TW-38 TW-56	
	UBZ-4	PW-01 PW-02 PW-03 TW-02 TW-14 TW-16 TW-17 TW-26	TW-30 TW-40 TW-41 TW-42 TW-43 TW-49 TW-50 TW-51	

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TABLE 4-19

BACKGROUND STATISTICS FOR FRESH GROUNDWATER

Constituent	Units	Sample Size	Number of Non-Detects[a]	Mean	Standard Deviation	Maximum Concentration[b]	Tolerance Factor	UTL[c]
Alkalinity (Bicarbonate)[d]	mg/l	36	0	5.02E+02	1.12E+02	860	2.1580	7.43E+02
Gross Alpha	pCi/L	9	8	2.73E+00	2.87E+00	12	3.0320	1.14E+01
Aluminum	mg/l	27	19	5.59E-02	4.92E-02	0.23	2.2632	1.67E-01
Ammonia-nitrogen	mg/l	28	28	6.71E-02	9.37E-02	0.60	2.2488	6.00E-01
Arsenic	mg/l	51	43	2.94E-03	4.12E-03	0.019	2.0607	1.14E-02
Beryllium	mg/l	18	17	1.25E-03	1.63E-03	0.007	2.4530	5.24E-03
Cadmium	mg/l	52	44	3.56E-03	3.68E-03	0.018	2.0564	1.11E-02
Calcium	mg/l	40	1	1.19E+02	5.81E+01	420	2.1260	2.42E+02
Chloride	mg/l	50	0	1.52E+01	1.52E+01	115	2.0650	4.66E+01
Chromium	mg/l	37	36	7.85E-03	2.92E-03	0.02	2.1500	1.41E-02
Copper	mg/l	29	27	1.30E-02	3.23E-02	0.18	2.2344	8.52E-02
Fluoride	mg/l	51	2	2.66E-01	1.47E-01	1	2.0607	5.69E-01
Iron	mg/l	51	36	5.50E-02	6.83E-02	0.36	2.0607	1.96E-01
Lead	mg/l	36	32	1.22E-02	2.80E-02	0.17	2.1580	7.27E-02
Magnesium	mg/l	40	0	4.77E+01	1.28E+01	78	2.1260	7.50E+01
Manganese	mg/l	50	30	1.41E-02	1.65E-02	0.06	2.0650	4.81E-02
Molybdenum	mg/l	17	17	1.13E-02	1.48E-02	0.10	2.4860	1.00E-01
Nickel	mg/l	27	25	8.07E-03	3.89E-03	0.026	2.2632	1.69E-02
Nitrate-nitrogen	mg/l	48	4	2.98E+00	1.61E+00	5.99	2.0758	6.33E+00
Orthophosphate as P	mg/l	7	3	9.93E-02	7.99E-02	0.21	3.4010	3.71E-01

TABLE 4-19 (Cont.)

BACKGROUND STATISTICS FOR FRESH GROUNDWATER

Constituent	Units	Sample Size	Number of Non-Detects[a]	Mean	Standard Deviation	Maximum Concentration[b]	Tolerance Factor	UTL[c]
Potassium	mg/l	39	1	3.62E+00	4.22E+00	28	2.1340	1.26E+01
Radium-226	pCi/L	16	12	5.83E-01	1.03E+00	3.4	2.5230	3.18E+00
Radium-228	pCi/L	8	8	2.13E-01	2.03E-01	0.8	3.1880	8.00E-01
Radon-222	pCi/L	11	2	6.00E+02	6.44E+02	2200	2.8150	2.41E+03
Selenium	mg/l	10	4	2.45E-03	2.53E-03	0.0075	2.9110	9.81E-03
Silver	mg/l	38	36	7.10E-03	4.25E-03	0.02	2.1420	1.62E-02
Sodium	mg/l	40	0	1.15E+01	6.98E+00	33	2.1260	2.63E+01
Sulfate	mg/l	51	0	5.18E+01	2.71E+01	110	2.0607	1.08E+02
Uranium (total)	mg/l	8	8	1.44E-03	9.04E-04	0.007	3.1880	7.00E-03
Vanadium	mg/l	51	40	3.94E-02	5.05E-02	0.20	2.0607	1.44E-01
Zinc	mg/l	50	39	2.25E-02	5.79E-02	0.41	2.0650	1.42E-01

Notes:
[a]Number of results below sample quantitation limit.
[b]Maximum value observed in background monitoring wells.
[c]Upper tolerance limit.
[d]Measured as calcium carbonate.

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TABLE 4-20

BACKGROUND STATISTICS FOR SODIC GROUNDWATER

Constituent	Units	Sample Size	Number of Non-Detects[a]	Mean	Standard Deviation	Maximum Concentration[b]	Tolerance Factor	UTL[c]
Alkalinity (Bicarbonate)[d]	mg/l	60	0	9.34E+02	1.29E+02	1320	2.0220	1.19E+03
Gross Alpha	pCi/L	7	3	6.79E+00	7.48E+00	19	3.4010	3.22E+01
Aluminum	mg/l	19	17	3.50E-02	3.51E-02	0.16	2.4230	1.20E-01
Ammonia-Nitrogen	mg/l	29	13	3.32E-01	2.58E-01	0.92	2.2344	9.09E-01
Arsenic	mg/l	71	55	4.11E-03	6.18E-03	0.042	1.9875	1.64E-02
Beryllium	mg/l	13	10	2.62E-03	3.22E-03	0.009	2.6700	1.12E-02
Cadmium	mg/l	73	66	3.04E-03	2.64E-03	0.017	1.9825	8.27E-03
Calcium	mg/l	63	0	1.19E+02	3.54E+01	205	2.0124	1.90E+02
Chloride	mg/l	75	0	2.49E+01	6.23E+01	540	1.9775	1.48E+02
Chromium	mg/l	60	54	1.12E-02	8.02E-03	0.06	2.0220	2.74E-02
Copper	mg/l	39	37	9.38E-03	4.65E-03	0.03	2.1340	1.93E-02
Fluoride	mg/l	76	1	3.68E-01	1.22E-01	0.62	1.9750	6.08E-01
Iron	mg/l	72	12	4.16E+00	2.96E+00	8.45	1.9850	1.00E+01
Lead	mg/l	60	52	1.31E-02	1.20E-02	0.10	2.0220	3.73E-02
Magnesium	mg/l	64	0	1.13E+02	2.09E+01	140	2.0092	1.55E+02
Manganese	mg/l	73	10	2.04E-01	1.30E-01	0.45	0.9825	4.62E-01
Molybdenum	mg/l	16	16	1.29E-02	1.86E-02	0.10	2.5230	1.00E-01
Nickel	mg/l	29	22	1.16E-02	7.48E-03	0.0352	2.2344	2.83E-02
Nitrate-Nitrogen	mg/l	74	31	8.26E-01	1.40E+00	5.26	1.9800	3.59E+00
Orthophosphate as P	mg/l	15	1	1.67E-01	1.08E-01	0.32	2.5660	4.45E-01

TABLE 4-20 (Cont.)

BACKGROUND STATISTICS FOR SODIC GROUNDWATER

Constituent	Units	Sample Size	Number of Non-Detects[a]	Mean	Standard Deviation	Maximum Concentration[b]	Tolerance Factor	UTL[c]
Potassium	mg/l	63	0	1.12E+01	3.13E+00	18.00	2.0124	1.75E+01
Radium-226	pCi/L	13	10	-7.31E-02	2.55E-01	0.40	2.6700	6.07E-01
Radium-228	pCi/L	3	3	5.00E-02	1.00E-01	0.30	3.7110	3.00E-01
Radon-222	pCi/L	4	2	2.08E+02	2.28E+02	500	3.7110	1.06E+03
Selenium	mg/l	9	6	2.19E-03	1.48E-03	0.0072	3.0320	6.68E-03
Silver	mg/l	58	54	1.07E-02	8.59E=03	0.10	2.0306	2.81E-02
Sodium	mg/l	65	0	3.05E+01	5.10E+00	53.00	2.0060	4.07E+01
Sulfate	mg/l	75	0	6.01E+01	1.73E+01	141	1.9775	9.42E+01
Uranium (total)	mg/l	3	3	1.00E-03	0.00E+00	0.002	3.7110	2.00E-03
Vanadium	mg/l	66	57	7.71E-02	1.03E-01	1.00	2.0028	2.83E-01
Zinc	mg/l	73	47	4.74E-02	9.67E-02	0.54	1.9825	2.39E-01

Notes:
[a]Number of results below sample quantitation limit.
[b]Maximum value observed in background monitoring wells.
[c]Upper tolerance limit.
[d]Measured as calcium carbonate.

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TABLE 4-21

ELEVATED CONSTITUENTS IN FRESH GROUNDWATER
BY GROUNDWATER REGION

Chemical Name	Upper Tolerance Limit	Maximum Concentrations by Groundwater Region				
		LBZ-3	UBZ-1	UBZ-2	UBZ-3	UBZ-4
Alkalinity (bicarbonate)	743	496	651	838	515	720
Alpha	11.4	6.0 U	4.0 U	4.0 U	9.0 U	11.0 U
Aluminum	0.167	0.263	0.145	0.987	0.213	0.22
Ammonia-nitrogen	0.60	0.733	0.10 U	3.65	100	1.65
Arsenic	0.0114	0.0097	0.0046	0.0111	0.0094	0.0264
Beryllium	0.00524	0.0090	0.0050 U	0.0060	0.0050	0.0070
Cadmium	0.0111	0.0048	0.0180	0.516	0.0074	7.92
Calcium	242	212	145	184	224	326
Chloride	46.6	267	178	411	516	755
Chromium	0.0141	0.010 U	0.010 U	0.010	0.010 U	0.010
Copper	0.0852	0.0050 U	0.0170 U	0.046	0.0140 U	0.021 U
Fluoride	0.569	0.230	4.11	19.93	0.34	7.68
Iron	0.196	0.201	0.759	0.940	0.226	1.73
Lead	0.0727	0.005 U	0.0050 U	0.0050	0.0050 UJ	0.005 U
Magnesium	75	82.7	107	130	109	190
Manganese	0.0481	0.020	0.0355	1.28	0.209	1.55
Molybdenum	0.10	0.608	0.0923	0.73	5.86	0.33

Note: Shading indicates concentration exceeds UTL and parameter is an elevated constituent.
NA = Not analyzed in this subgroup.
U = Not detected at sample quantitation limit given.

TABLE 4-21 (Cont.)

ELEVATED CONSTITUENTS IN FRESH GROUNDWATER
BY GROUNDWATER REGION

Chemical Name	Upper Tolerance Limit	Maximum Concentrations by Groundwater Region				
		LBZ-3	UBZ-1	UBZ-2	UBZ-3	UBZ-4
Nickel	0.0169	0.0108	0.0227	0.19	0.0108	0.121
Nitrate-nitrogen	6.33	8.94	16.5	12.2	16.7	20.3
Orthophosphate as P	0.371	0.1 U	0.61	0.76	1.70	5.8
Potassium	12.6	7.2	14.6	46.5	47.5	63
Radium-226	3.18	0.20 U	0.30 U	1.50	0.20 U	0.40
Radium-228	0.8	0.20 U	1.30 U	0.50 U	-0.30 U	0.20 U
Radon-222	2410	790	820	680	380	340
Selenium	0.00981	0.0018	0.408	0.935	0.0046	0.70
Silver	0.0162	0.010 U	0.010 U	0.010 U	0.010 U	0.0020
Sodium	26.3	172	100	177	590	338
Sulfate	108	654	442	612	1250	618
Uranium (total)	0.007	0.0020 U	0.0040 U	0.0090 U	0.0020 U	0.010 U
Vanadium	0.144	4.53	0.0307	0.143	5.62	0.190
Zinc	0.142	0.0376 U	0.266	4.36	0.107	9.3

Note: Shading indicates concentration exceeds UTL and parameter is an elevated constituent.
NA = Not analyzed in this subgroup.
U = Not detected at sample quantitation limit given.

TABLE 4-21 (Cont.)

ELEVATED CONSTITUENTS IN SODIC GROUNDWATER
BY GROUNDWATER REGION

Chemical Name	Upper Tolerance Limit	Maximum Concentrations by Groundwater Region				
		LBZ-1	LBZ-2	LBZ-4	UBZ-1	UBZ-2
Alkalinity (bicarbonate)	1190	1292.0000	1416	1341	1002	1452.0000
Alpha	32.2	1.0 U	3.0 U	-7.0 U	6.0 U	-5.0 U
Aluminum	0.120	0.23 U	0.35	0.126	0.0784	0.42
Ammonia-nitrogen	0.909	0.6290	0.931	0.38	0.658	0.20
Arsenic	0.0164	0.0015	0.0022	0.0031	0.0020 U	0.0020 U
Beryllium	0.0112	0.0010 U	0.0070	0.0050 U	0.0050 U	0.0050 U
Cadmium	0.00827	0.0067 U	0.0304	0.0269	0.005	0.0094 U
Calcium	190	158	146	99.5	116	235
Chloride	148	24	78.1	20.4	141	75.3
Chromium	0.0274	0.010 U	0.010 U	0.010 U	0.010 U	0.010 U
Copper	0.0193	0.0050 U	0.0110 U	0.0050 U	0.0160 U	0.0050 U
Fluoride	0.608	0.34	1.21	0.39	1.10	0.35
Iron	10.0	16.8	14.1	8.59	1.13	4.41
Lead	0.0373	0.0040 U	0.0050 U	0.0050 U	0.0050 U	0.0050 U
Magnesium	155	179	272	218	145	310
Manganese	0.462	0.495	0.675	0.404	0.286	0.165
Molybdenum	0.10	0.0113 U	0.0397	0.0141	0.0243	0.10 U
Nickel	0.0283	0.030	0.040	0.0328	0.030	0.0272

Note: Shading indicates concentration exceeds UTL and parameter is an elevated constituent
NA = Not analyzed in this subgroup
U = Not detected at sample quantitation limit given

TABLE 4-21 (Cont.)

ELEVATED CONSTITUENTS IN SODIC GROUNDWATER
BY GROUNDWATER REGION

Chemical Name	Upper Tolerance Limit	Maximum Concentrations by Groundwater Region				
		LBZ-1	LBZ-2	LBZ-4	UBZ-1	UBZ-2
Nitrate-nitrogen	3.59	0.50 U	0.50	0.36	7.7	3.35
Orthophosphate as P	0.445	NA	0.38	1.16	0.67	0.46
Potassium	17.5	17.2	28	21.9	15.4	18.0
Radium-226	0.607	-0.50 U	0.30 U	0.20 U	0.20 U	0.20 U
Radium-228	0.30	0.10 U	0.10 U	-0.10 U	0.4 U	0.10 U
Radon-222	1060	84	120 U	86	160 U	290
Selenium	0.00668	0.0060 U	0.0150 U	0.0150 U	0.035	0.206
Silver	0.0281	0.010 U	0.0002	0.010 U	0.010 U	0.010 U
Sodium	40.7	43	60	42.8	56.7	800
Sulfate	94.2	96	276	172	123	242
Uranium (total)	0.0020	0.0020 U	0.0020 U	0.0020 U	0.0020 U	0.0040 U
Vanadium	0.283	0.0273 U	0.0336	0.0199	0.0172	0.0190
Zinc	0.239	0.044 U	0.130	0.208	0.0784	0.0408 U

Note: Shading indicates concentration exceeds UTL and parameter is an elevated constituent
NA = Not analyzed in this subgroup
U = Not detected at sample quantitation limit given

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TABLE 4-22

RISK-BASED SCREENING OF ELEVATED CONSTITUENTS IN GROUNDWATER (FRESH)

Elevated Constituents[a]	Groundwater Region Maximum Concentration[b]					Oral Reference Dose	Risk-Based Concentration HQ = 0.1	Oral Slope Factor	Risk-Based Concentration ICR = 1E-06	Drinking Water Standard
	LBZ-3	UBZ-1	UBZ-2	UBZ-3	UBZ-4					
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/kg-d	mg/L	kg-d/mg	mg/L	mg/L
Aluminum	0.263	NE	0.987	0.213	0.22	2.9	10.6	NC	NC	0.05-2.0[c]
Ammonia-Nitrogen	0.733	NE	3.65	100	1.65	NA	NA	NC	NC	1.8[e]
Arsenic	NE	NE	NE	NE	0.0264	3.00E-04	0.0011	1.70E+00	5.0E-05	0.05[d]
Cadmium	NE	0.0180	0.516	NE	7.92	0.0005	0.0018	NC	NC	0.005[d]
Chloride	267	178	411	516	755	NA	NA	NC	NC	250[e]
Fluoride	NE	4.11	19.93	NE	7.68	0.04	0.15	NC	NC	2.0[e]
Iron	0.201	0.759	0.940	0.226	1.73	NA	NA	NC	NC	0.3[e]
Manganese	NE	NE	1.28	0.209	1.55	0.005	0.018	NC	NC	0.05[e]
Molybdenum	0.382	NE	0.73	5.86	0.33	5.00E-03	0.018	NC	NC	NA
Nickel	NE	0.0227	0.19	NE	0.121	2.00E-02	0.073	NC	NC	0.1[d]
Nitrate-Nitrogen	8.94	16.5	12.2	16.7	20.3	1.6	5.8	NC	NC	10.0[d]
Selenium	NE	0.408	0.935	NE	0.70	5.00E-03	0.018	NC	NC	0.05[d]
Sulfate	654	442	612	1250	618	NA	NA	NC	NC	250[e]
Vanadium	4.53	NE	NE	5.62	0.190	0.007	0.026	NC	NC	NA
Zinc	NE	0.266	4.36	NE	9.3	0.3	1.1	NC	NC	5.0[e]

TABLE 4-22 (Cont.)

RISK-BASED SCREENING OF ELEVATED CONSTITUENTS IN GROUNDWATER (SODIC)

Elevated Constituents[a]	Groundwater Region Maximum Concentration[b]					Oral Reference Dose	Risk-Based Concentration HQ = 0.1	Oral Slope Factor	Risk-Based Concentration ICR = 1E-06	Drinking Water Standard
	LBZ-1	LBZ-2	LBZ-4	UBZ-1	UBZ-2					
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/kg-d	mg/L	kg-d/mg	mg/L	mg/L
Aluminum	NE	0.35	0.126	NE	0.42	2.9	10.6	NC	NC	0.05-2.0[c]
Ammonia Nitrogen	NE	0.931	NE	NE	NE	NA	NA	NC	NC	1.8[e]
Cadmium	NE	0.0304	0.0269	NE	NE	0.0005	0.0018	NC	NC	0.005[d]
Fluoride	NE	1.21	NE	1.1	NE	0.04	0.15	NC	NC	2.0[c]
Iron	16.8	14.1	NE	NE	NE	NA	NA	NC	NC	0.3[c]
Manganese	0.495	0.675	NE	NE	NE	0.005	0.018	NC	NC	0.05[c]
Nickel	0.03	0.040	0.0328	0.03	NE	2.00E-02	0.073	NC	NC	0.1[d]
Nitrate Nitrogen	NE	NE	NE	7.7	NE	1.6	5.8	NC	NC	10.0[d]
Selenium	NE	NE	NE	0.035	0.206	5.00E-03	0.018	NC	NC	0.05[d]
Sulfate	96	276	172	123	242	NA	NA	NC	NC	250[c]

Shaded areas indicate constituents of potential interest.

a Constituents classified as elevated relative to background.
b Maximum value observed since 1/1/91 in site monitoring wells according to groundwater type and region.
c Secondary maximum contaminant level, set per the Federal Safe Drinking Water Act.
d Primary maximum contaminant level, set per the Federal Safe Drinking Water Act.
e Maximum allowable concentration of total ammonia from Idaho Department of Health and Welfare Rules and Regulations, 1994 Cold Water Biota criteria for the protection of freshwater aquatic life (Section 01.2250.03). Value based on pH = 7 and temperature = 11°C.
HQ Hazard quotient
ICR Incremental cancer risk
NA No available reference dose or water quality criteria.
NC Not classified as a carcinogen or not carcinogenic by this exposure route.
NE Not an elevated constituent in this groundwater region.

0123erh1.422

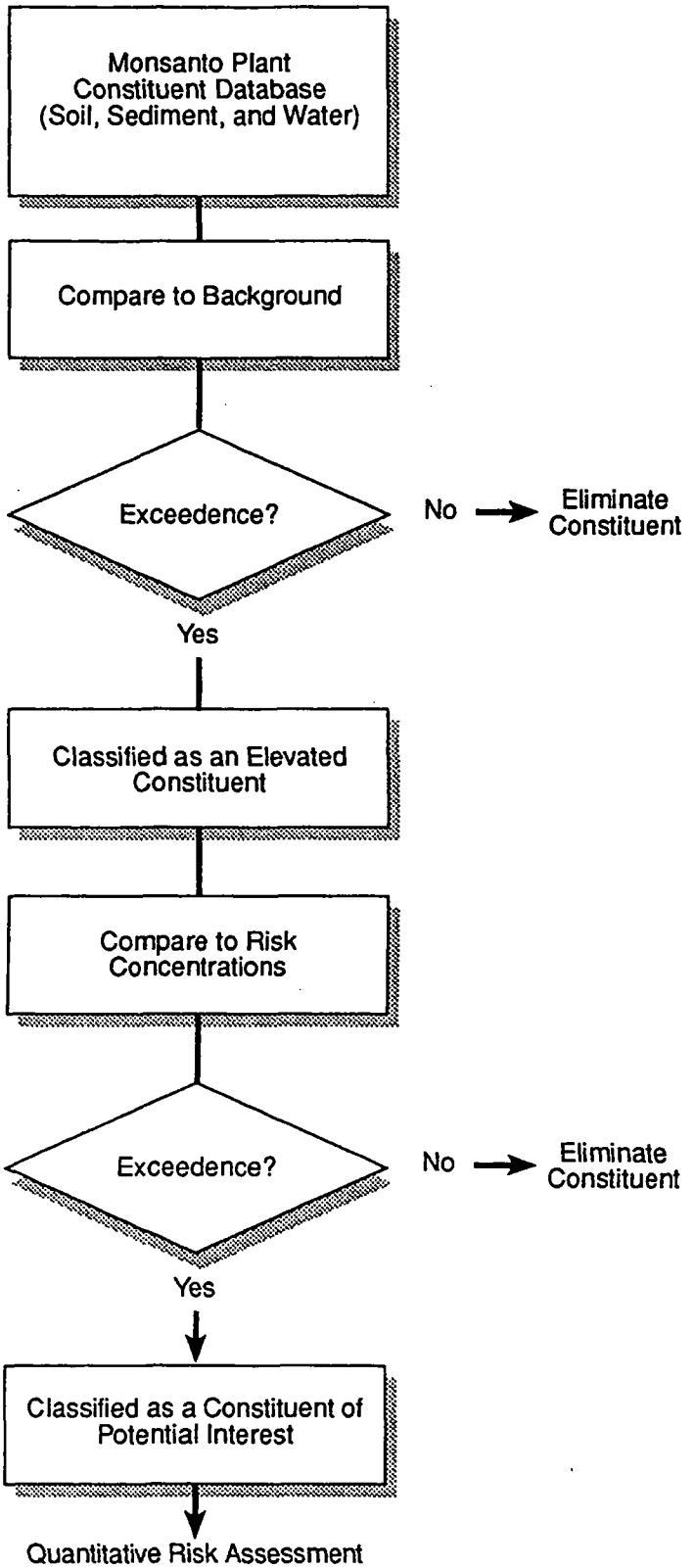

FIGURE **4-1**

CONSTITUENT SCREENING FLOWCHART

MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913-1101.608 DRAWING NO. 40976 DATE 10/20/94 DRAWN BY TB

Golder Associates

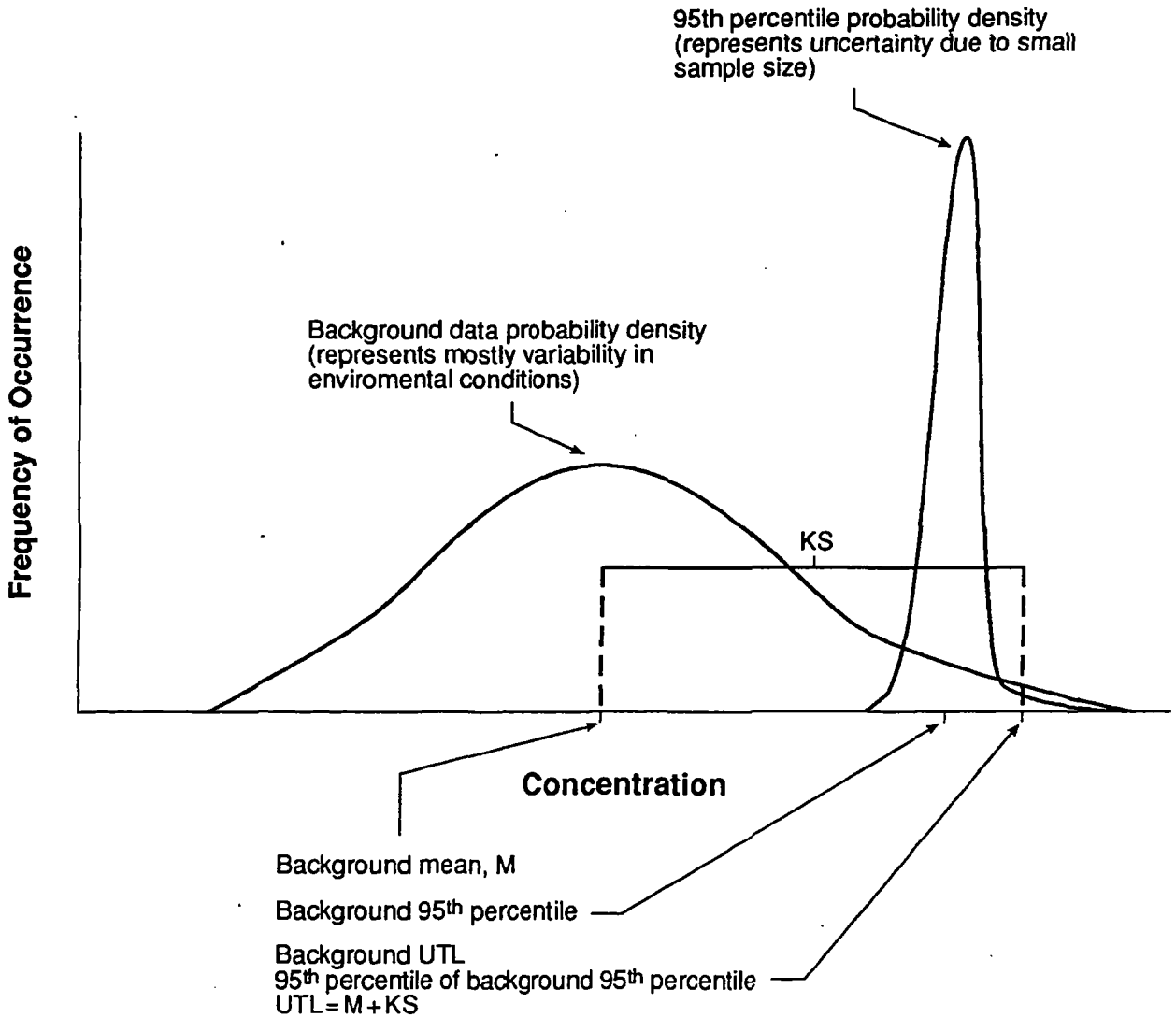

FIGURE **4-2**

CONSTITUENT BACKGROUND SCREENING CRITERIA

MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913-1101.608 DRAWING NO. 40974 DATE 09/09/94 DRAWN BY TB

Golder Associates

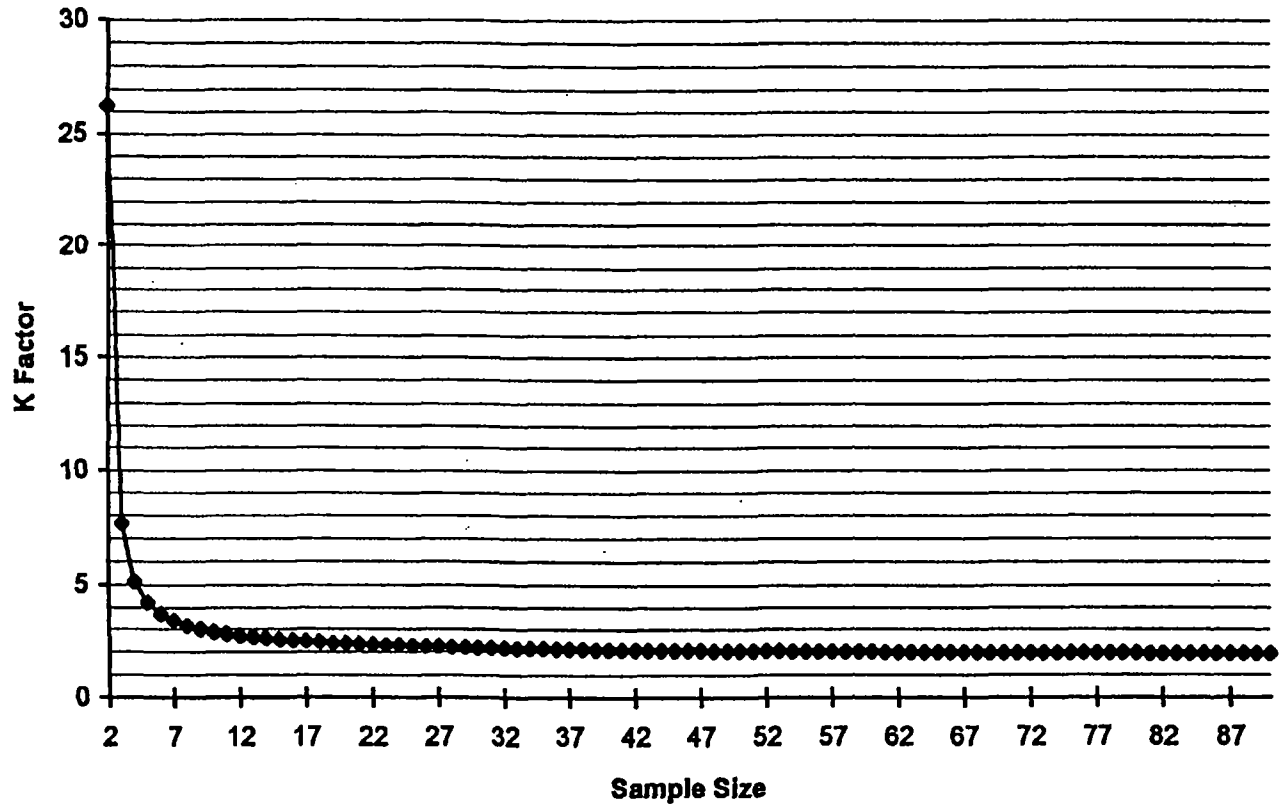

FIGURE **4-3**

CONSTITUENT BACKGROUND SCREENING TOLERANCE LIMIT FACTORS

MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913-1101.608 DRAWING NO. 40975 DATE 09/09/94 DRAWN BY TB

Golder Associates

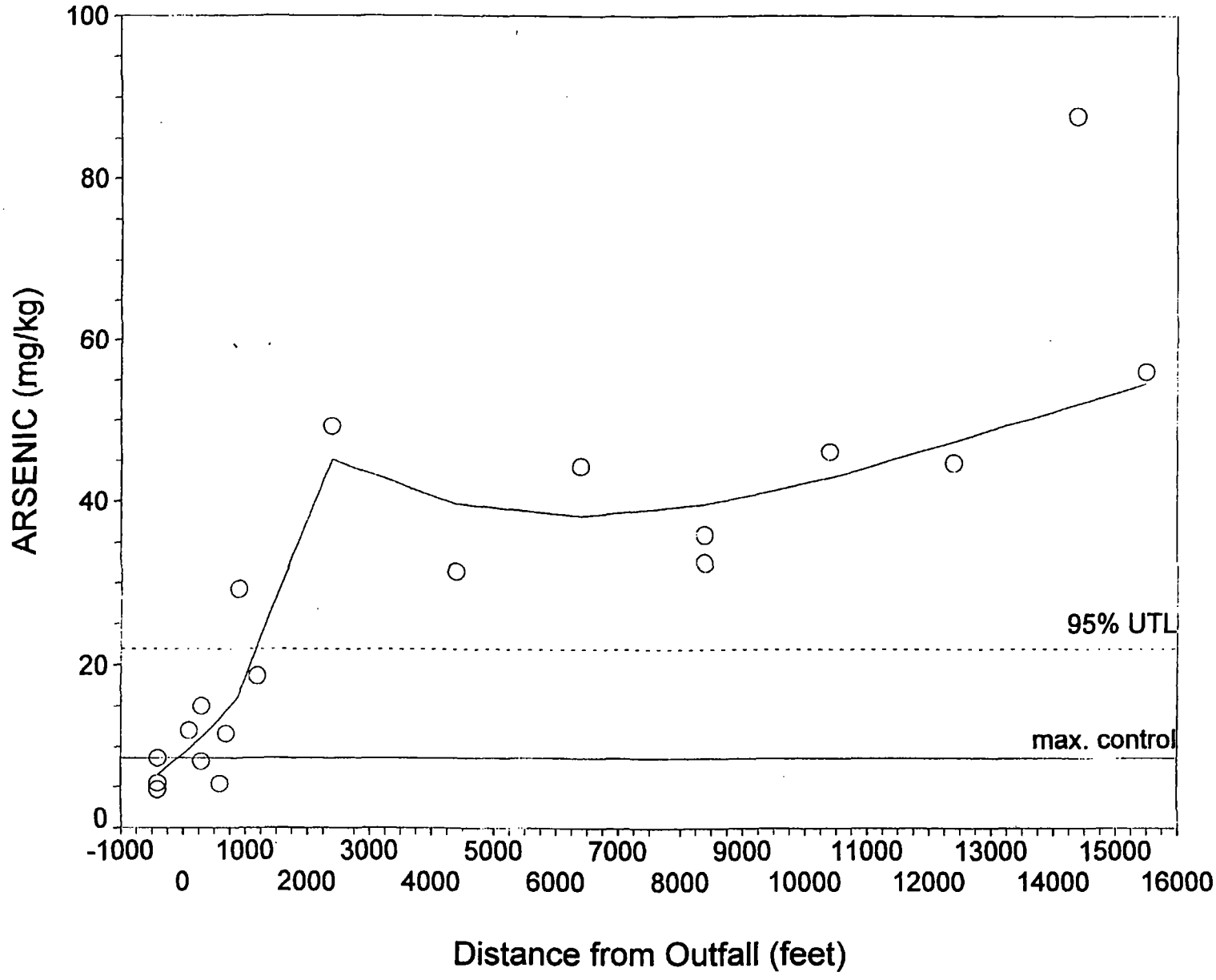

FIGURE **4-4**
SODA CREEK SEDIMENT QUALITY
ARSENIC
MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913 1101.608 DRAWING NO. 47669 DATE 1/25/95 DRAWN BY CB

Golder Associates

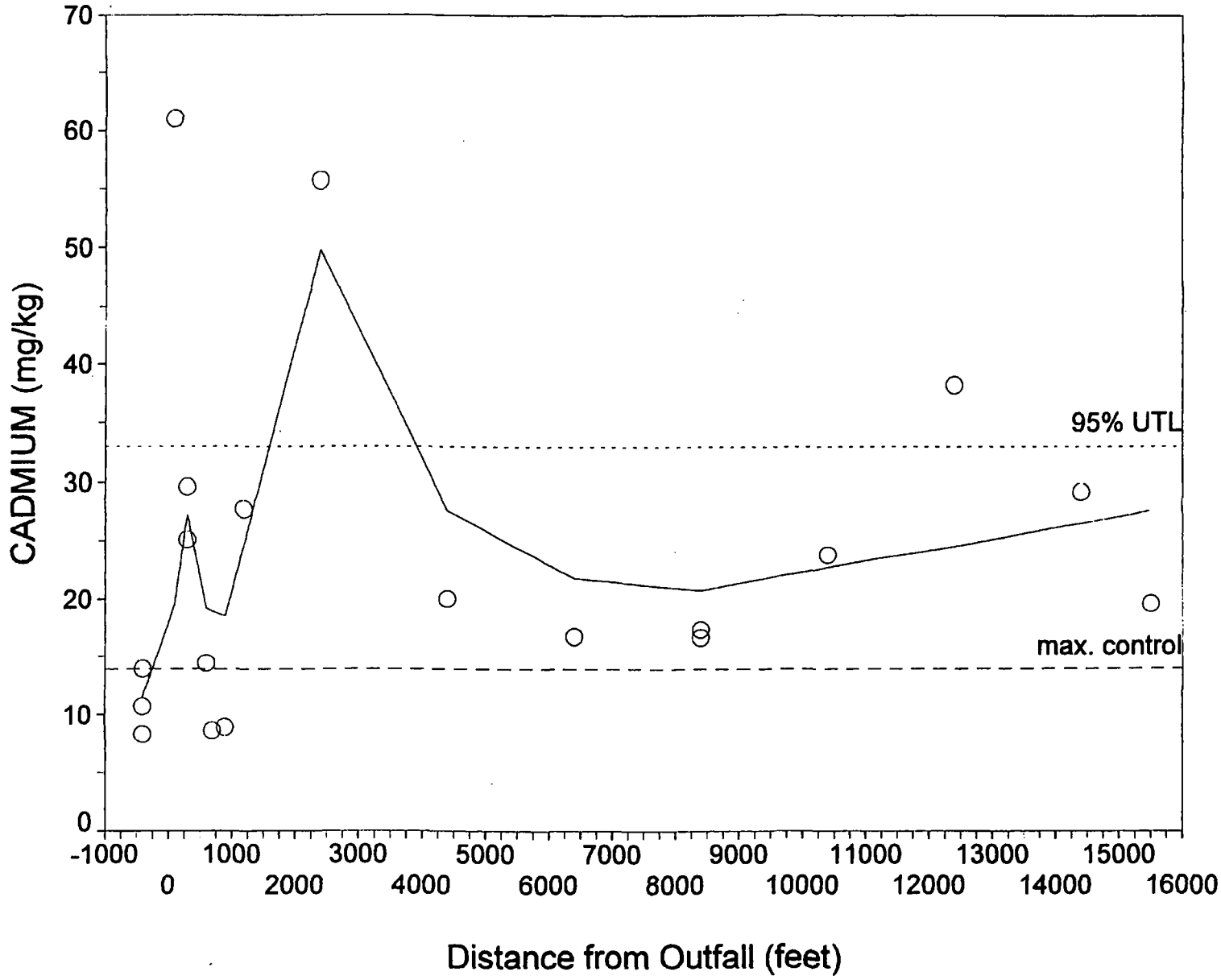

FIGURE **4-5**
SODA CREEK SEDIMENT QUALITY
CADMIUM
MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913 1101.608 DRAWING NO. 47670 DATE 1/25/95 DRAWN BY CB

Golder Associates

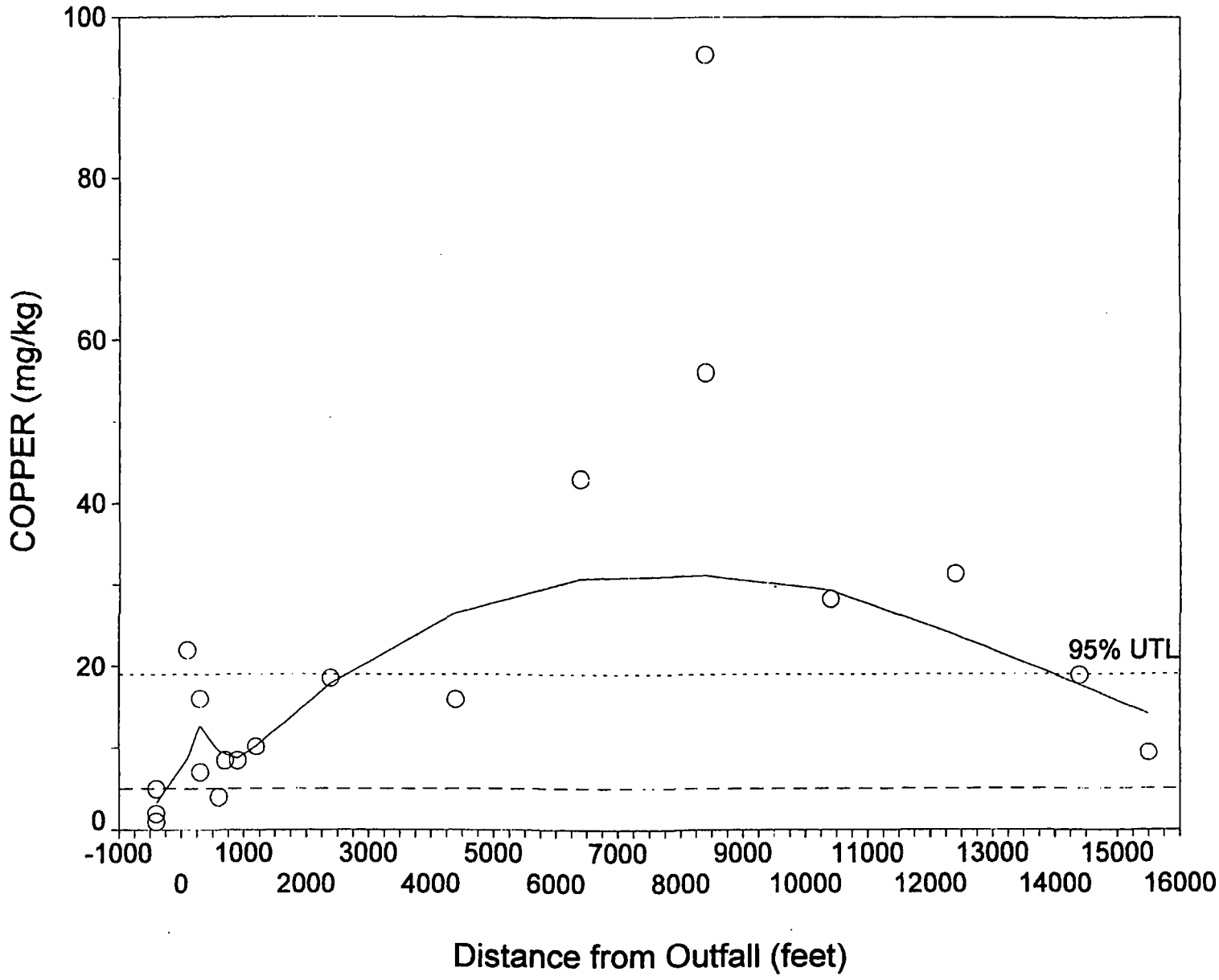

FIGURE **4-6**

SODA CREEK SEDIMENT QUALITY
COPPER

MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913 1101.608 DRAWING NO. 47671 DATE 1/25/95 DRAWN BY CB

Golder Associates

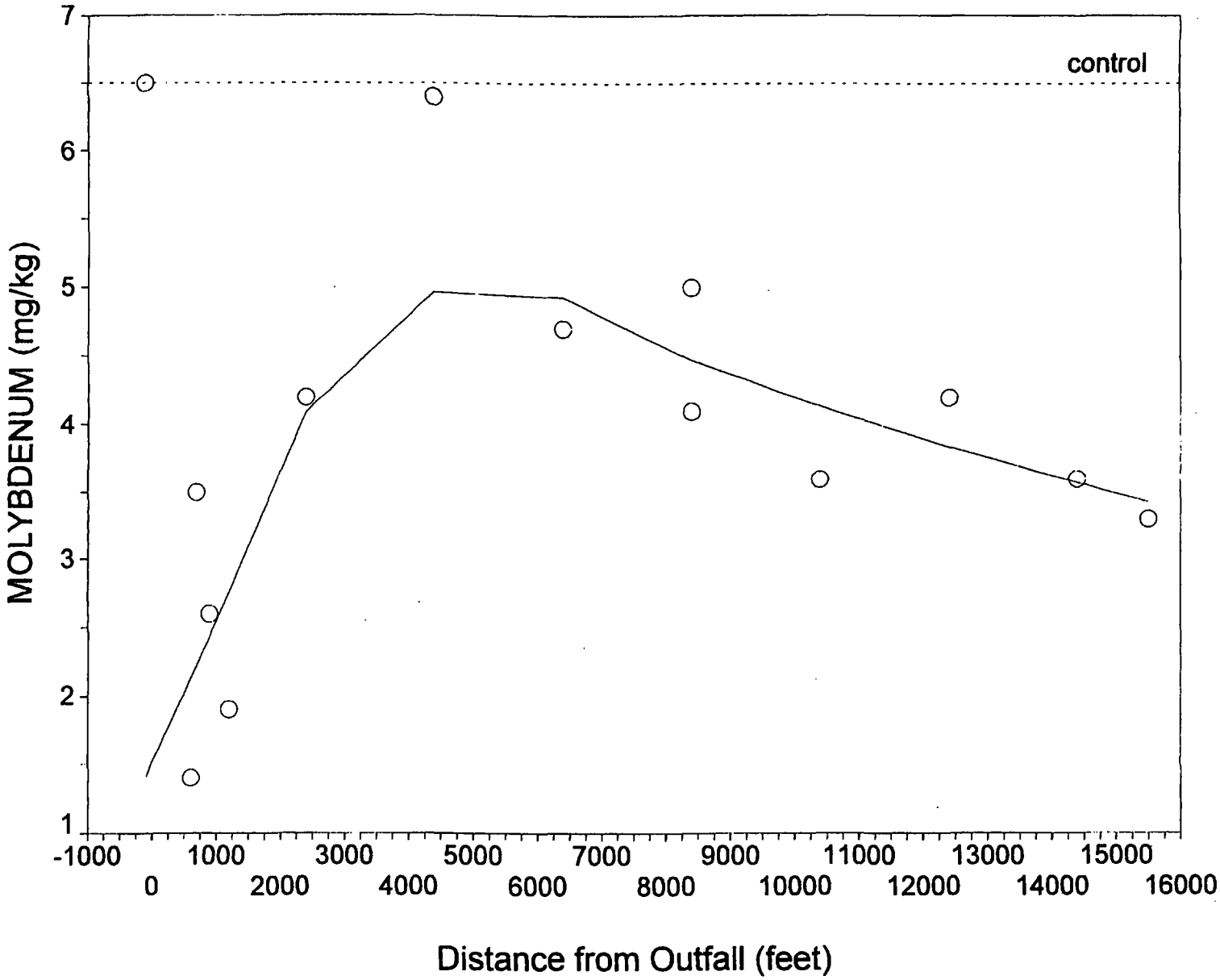

FIGURE **4-7**

SODA CREEK SEDIMENT QUALITY
MOLYBDENUM

MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913 1101.608 DRAWING NO. 47672 DATE 1/25/95 DRAWN BY CB

Golder Associates

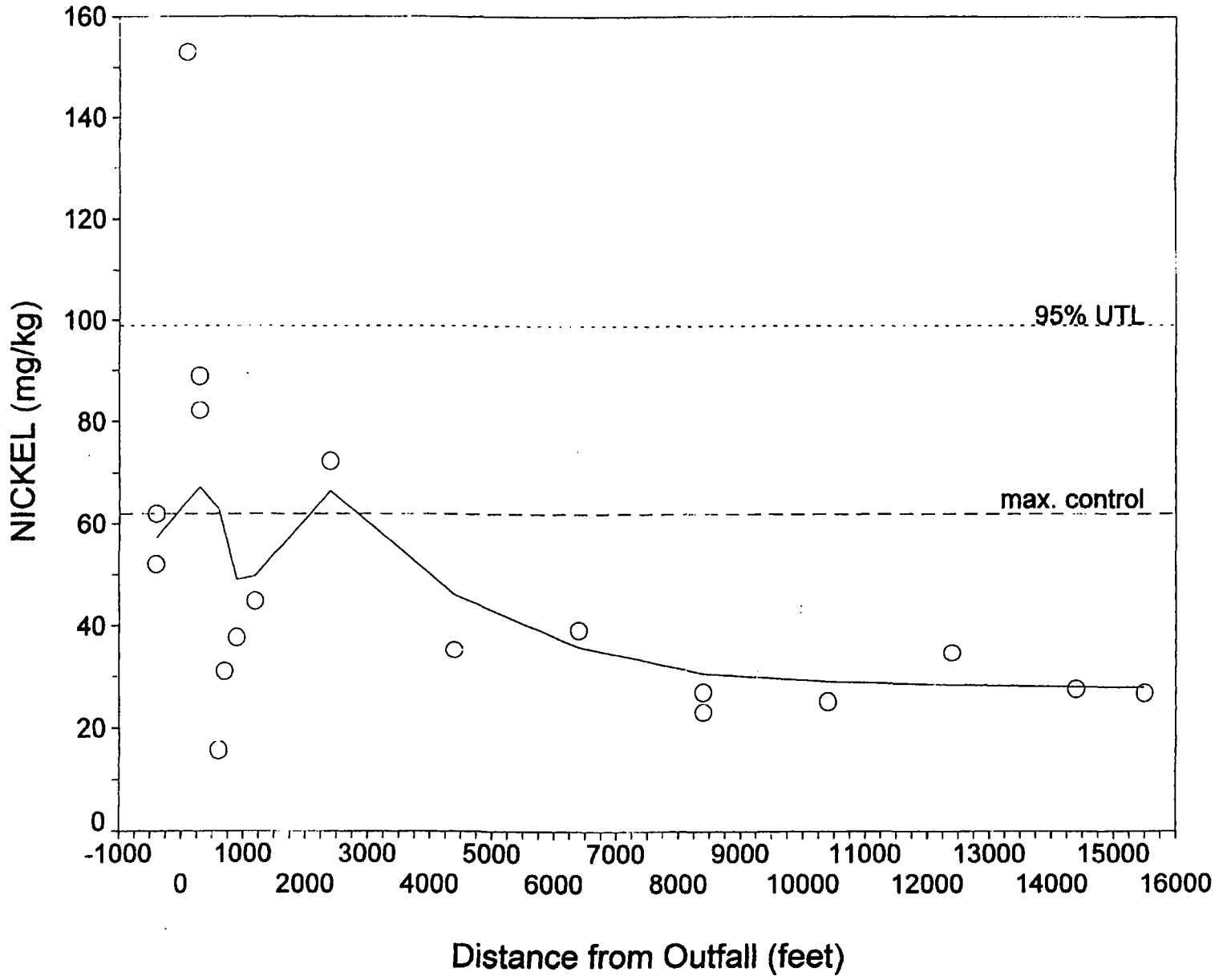

FIGURE **4-8**

SODA CREEK SEDIMENT QUALITY

NICKEL

MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913 1101.608 DRAWING NO. 47673 DATE 1/25/95 DRAWN BY CB

Golder Associates

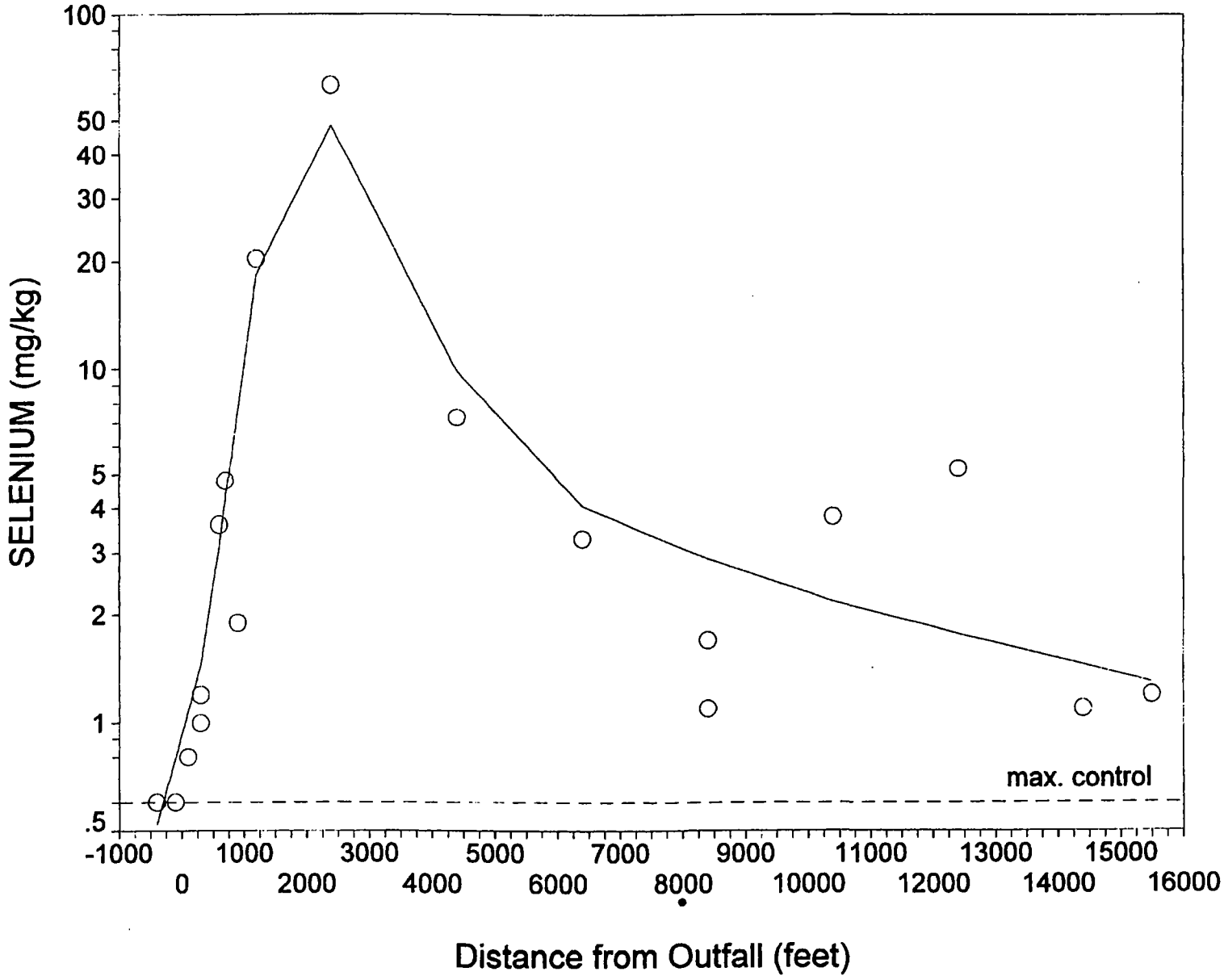

FIGURE **4-9**
SODA CREEK SEDIMENT QUALITY
SELENIUM
MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913 1101.608 DRAWING NO. 47674 DATE 1/25/95 DRAWN BY CB

Golder Associates

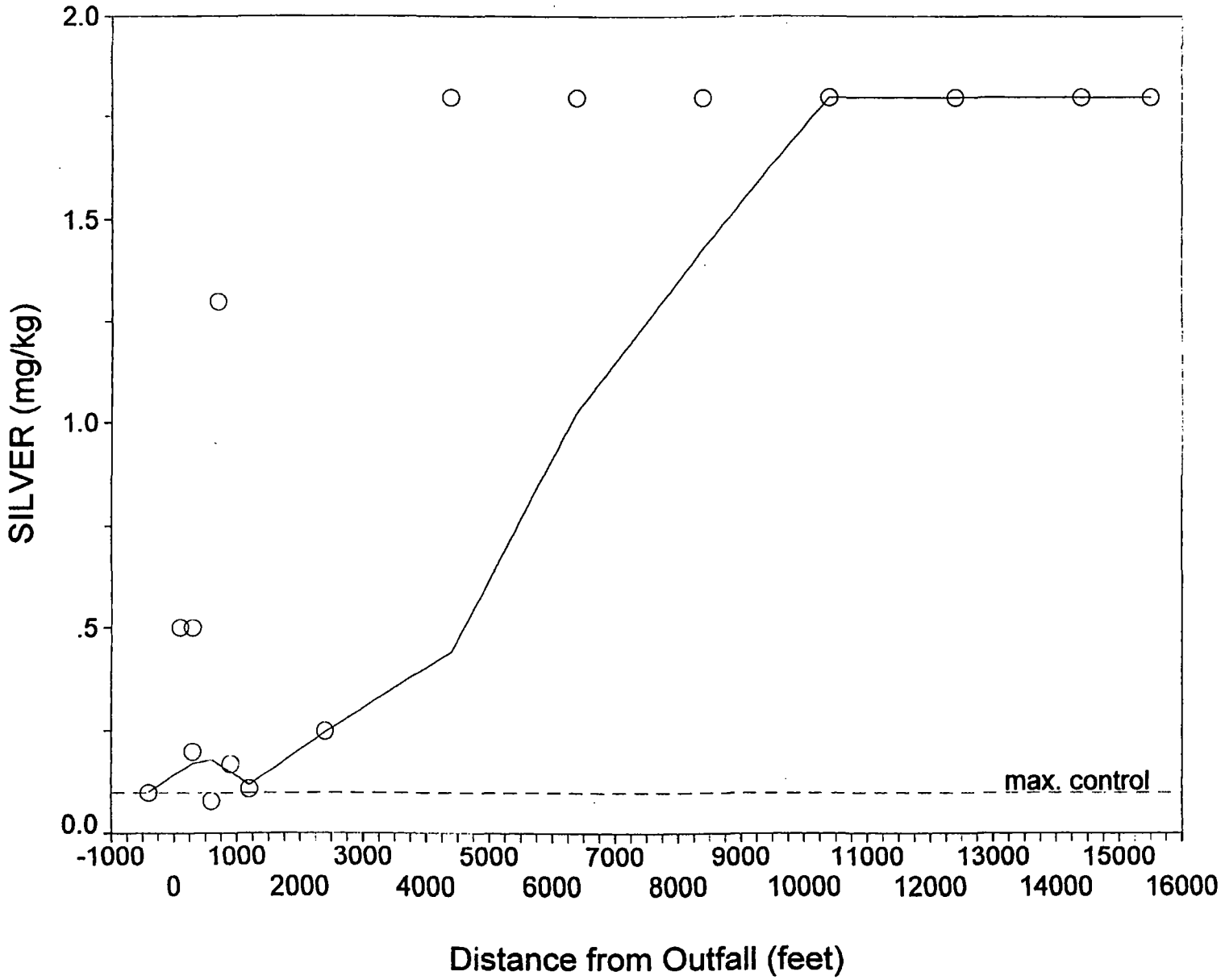

FIGURE **4-10**
SODA CREEK SEDIMENT QUALITY
SILVER
MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913 1101.608 DRAWING NO. 47675 DATE 1/25/95 DRAWN BY CB

Golder Associates

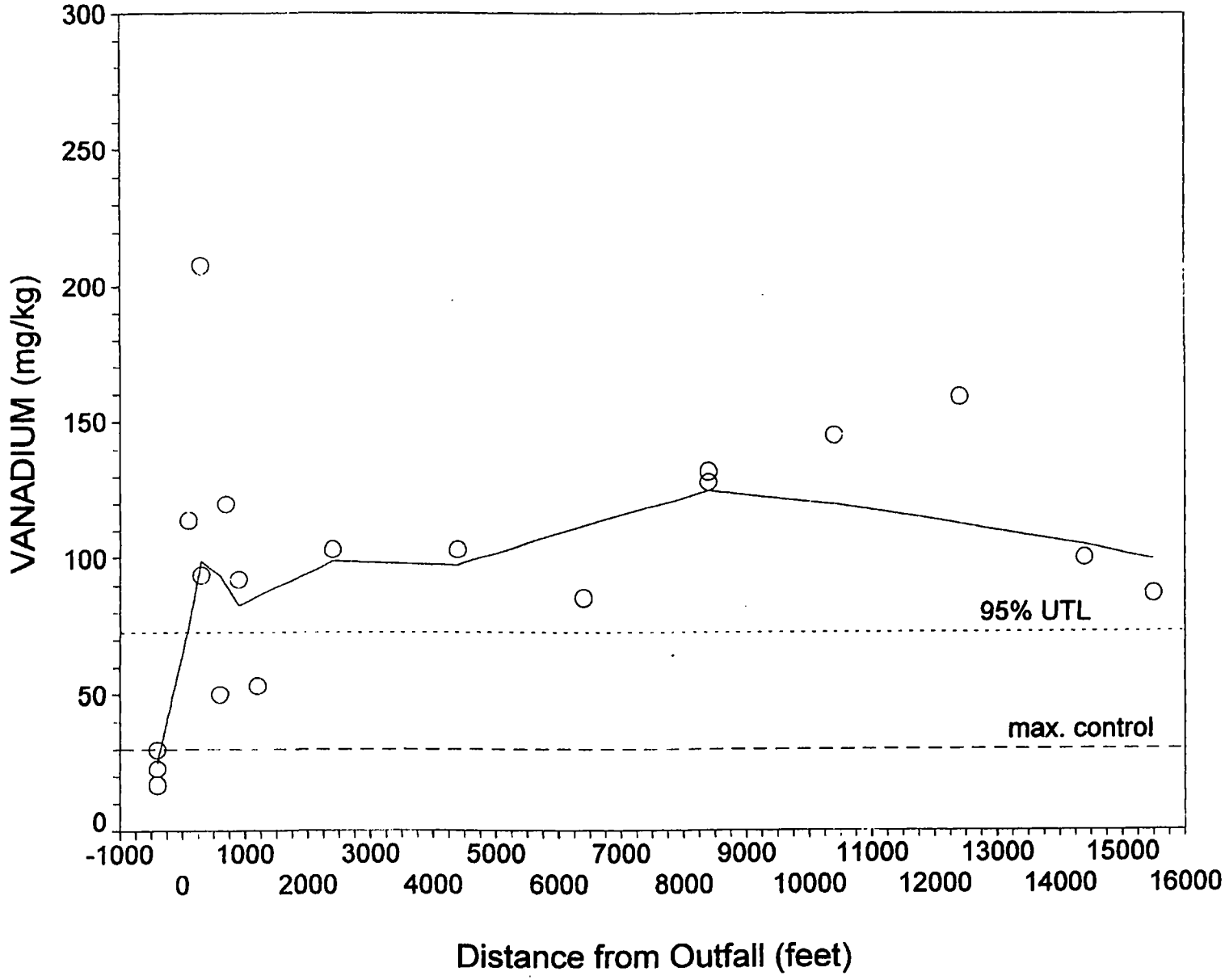

FIGURE **4-11**
SODA CREEK SEDIMENT QUALITY
VANADIUM
MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913 1101.608 DRAWING NO. 47676 DATE 1/25/95 DRAWN BY CB

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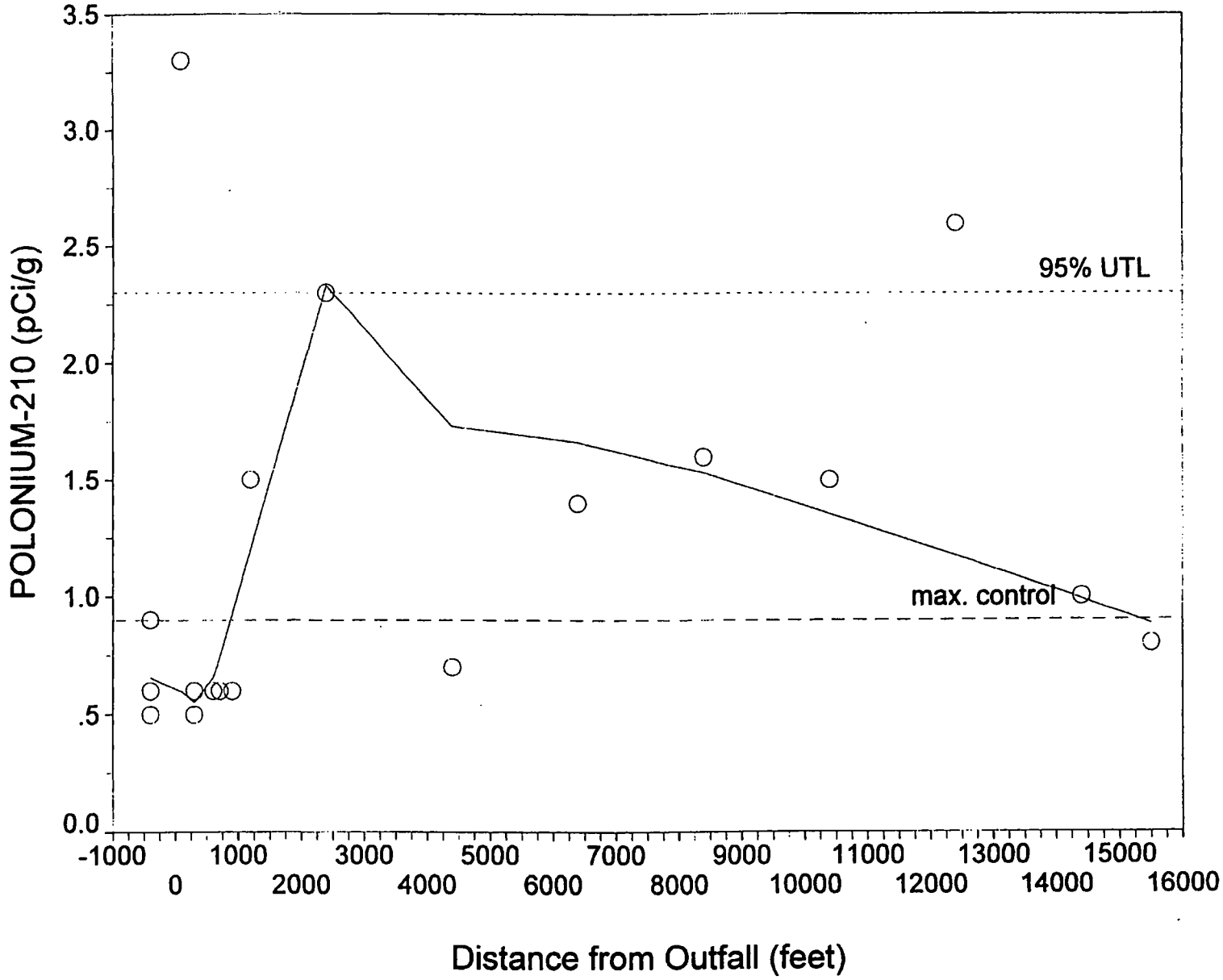
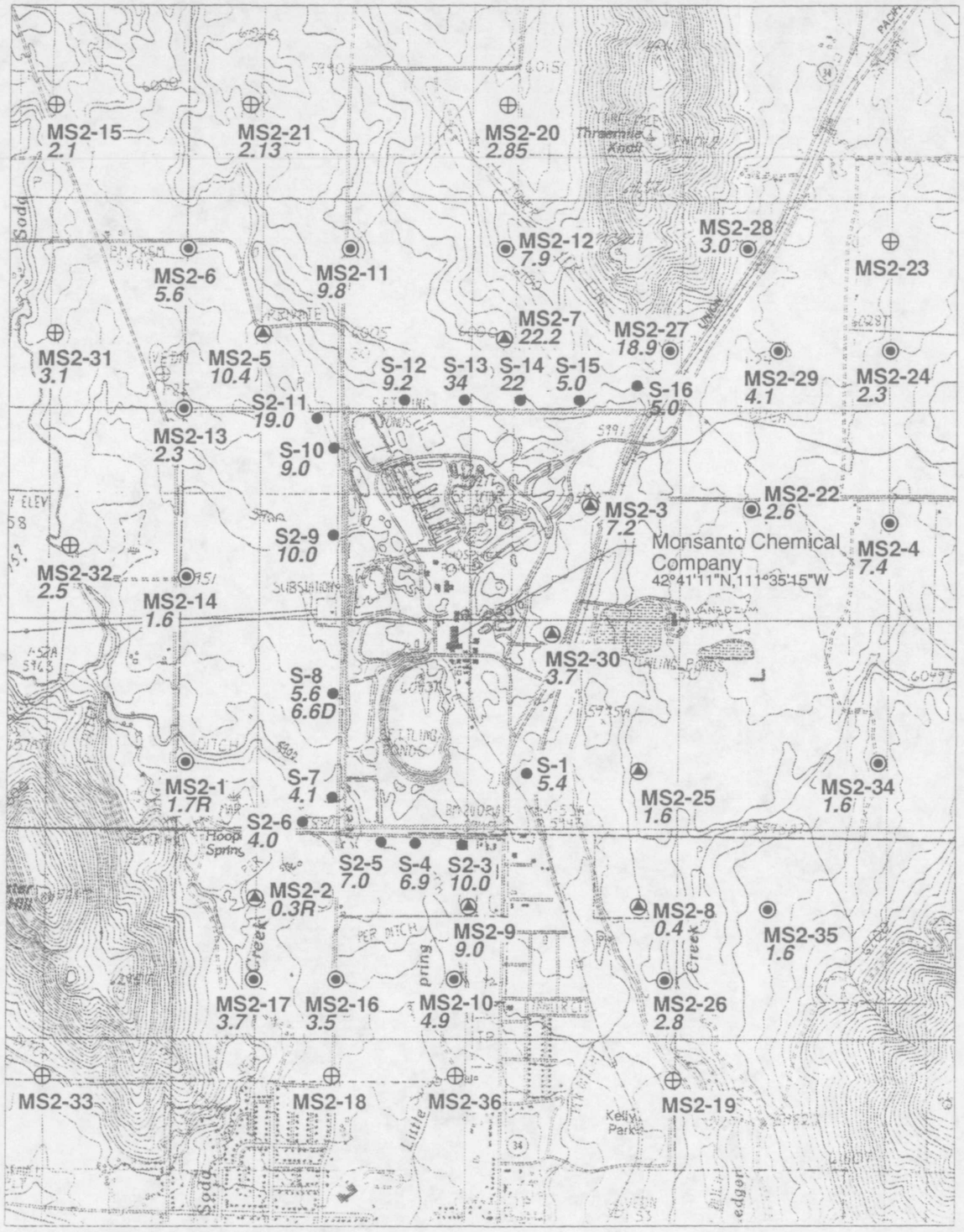


FIGURE **4-12**
SODA CREEK SEDIMENT QUALITY
POLONIUM-210
MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913 1101.608 DRAWING NO. 47677 DATE 1/25/95 DRAWN BY CB

Golder Associates



FROM: Soda Springs, Idaho Provisional Edition 1982

EXPLANATION

S-x or S2-x ●	Phase I Soil Sample Locations (0 – 1 and 0 – 6 inch sample intervals)
MS2-x ◉	Phase II Soil Profile Sample Locations (0-1, 0-6, 6-12, 12-24 inch sample intervals)
MS2-x ◎	Phase II Surface Soil Sample Locations (0-1 and 0-6 inch sample intervals)
MS2-x ⊕	Contingent Phase II Surface Soil Sampling Locations (0 – 6 inch sample interval)

The figure shows sample identification and concentration (second line) in mg/kg. All concentrations are from the 0 – 1 inch sample interval except contingent samples, which are 0-6 inch. An "R" suffix indicates rejected data and "D" indicates duplicate sample.

Arsenic

Upper Tolerance Limit (0-1 in) = 6.7 mg/kg

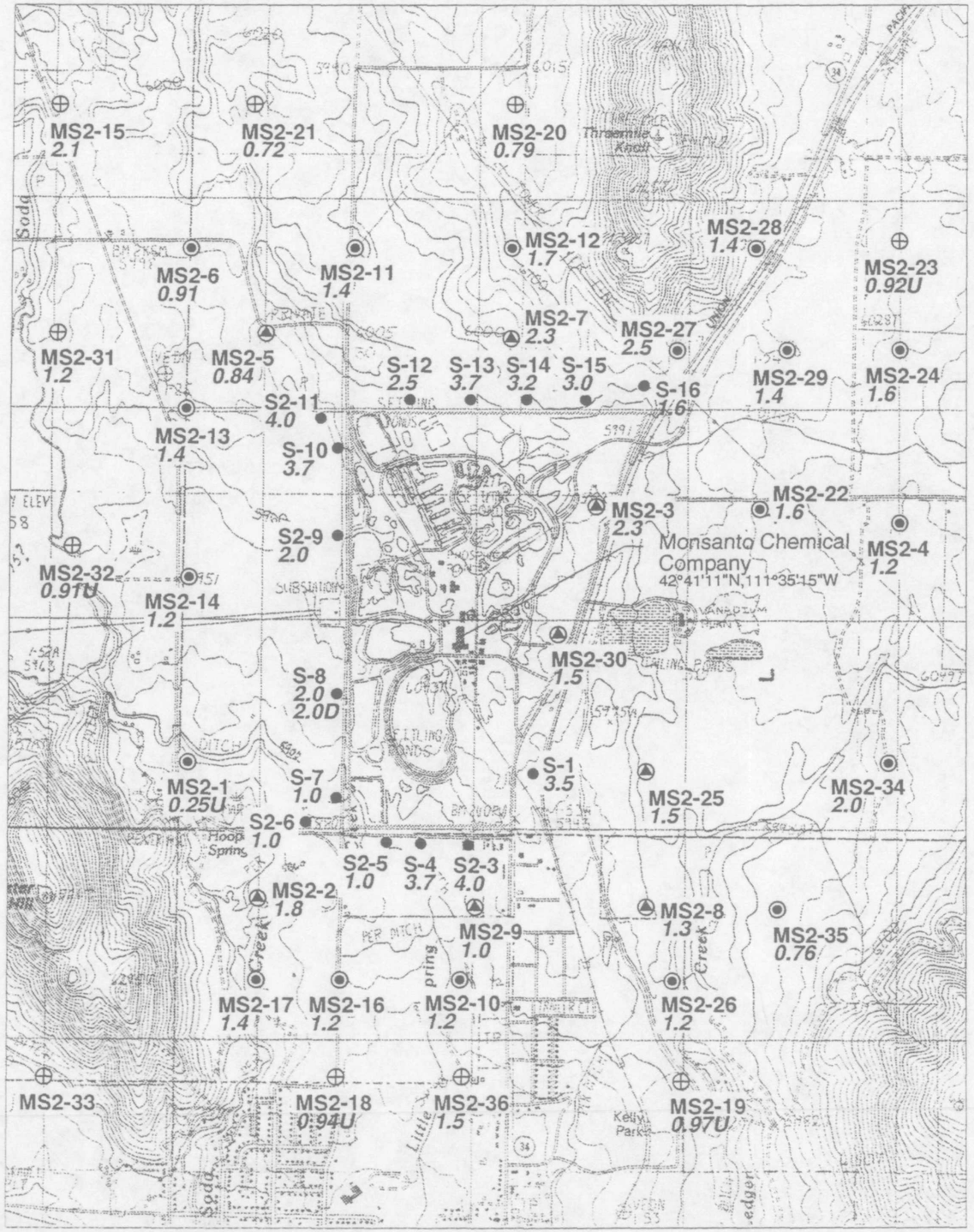
Human Health Risk-based Concentration = 8.2 mg/kg

0 2000
FEET

FIGURE **4-13**
SPATIAL DISTRIBUTION OF CONSTITUENTS OF POTENTIAL INTEREST IN SOILS – ARSENIC
MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913-1101608 DRAWING NO. 53529 DATE 1/25/95 DRAWN BY EA

Golder Associates



FROM: Soda Springs, Idaho Provisional Edition 1982

EXPLANATION

S-x or S2-x ●	Phase I Soil Sample Locations (0 – 1 and 0 – 6 inch sample intervals)
MS2-x ⊕	Phase II Soil Profile Sample Locations (0-1, 0-6, 6-12, 12-24 inch sample intervals)
MS2-x ⊙	Phase II Surface Soil Sample Locations (0-1 and 0-6 inch sample intervals)
MS2-x ⊕	Contingent Phase II Surface Soil Sampling Locations (0 – 6 inch sample interval)

The figure shows sample identification and concentration (second line) in mg/kg. All concentrations are from the 0 – 1 inch sample interval except contingent samples, which are 0-6 inch. A "U" suffix indicates the reported detection limit.

Beryllium

Upper Tolerance Limit (0-1 in) = 3.7 mg/kg

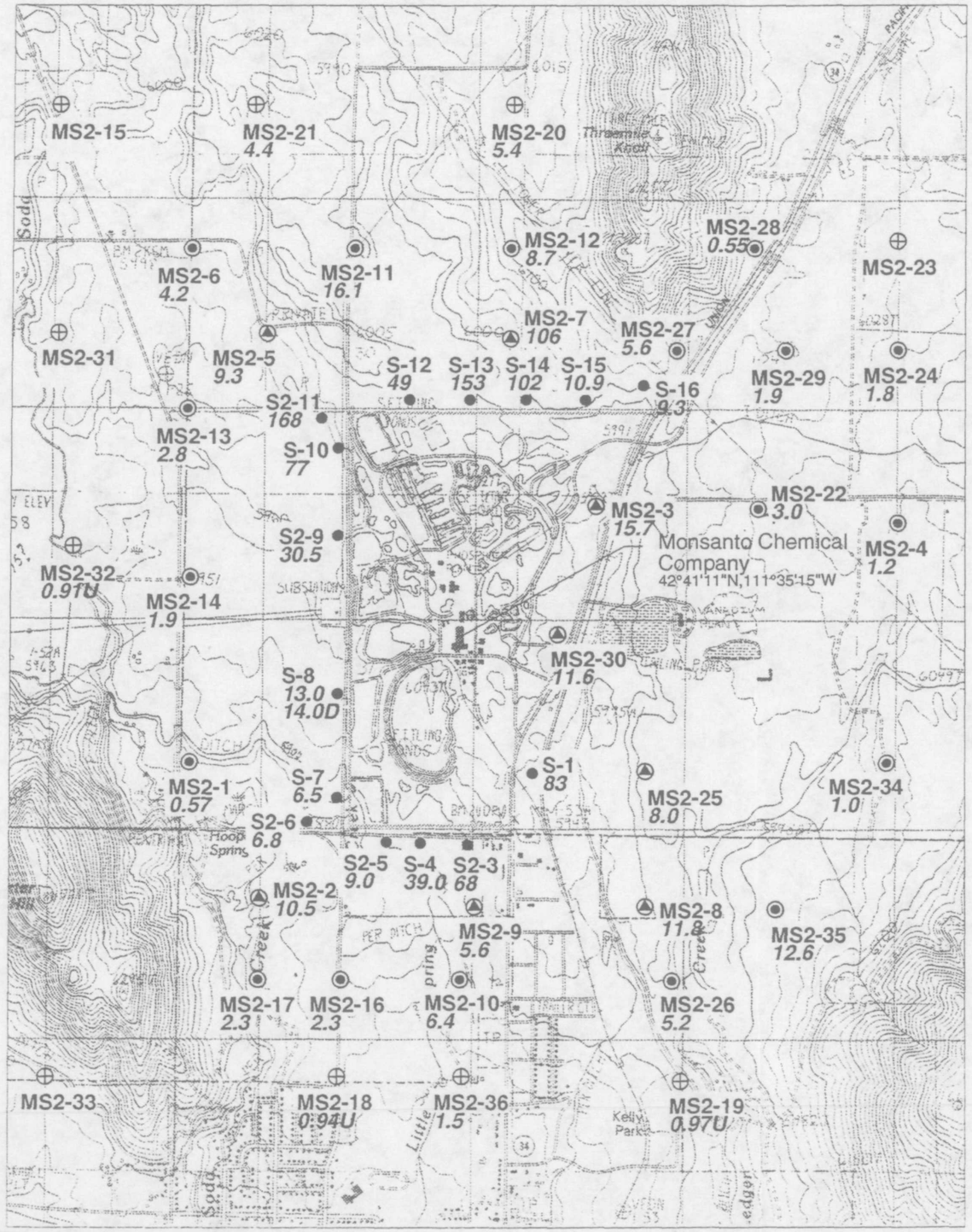
Human Health Risk-based Concentration = 0.015 mg/kg

0 2000
FEET

FIGURE **4-14**
SPATIAL DISTRIBUTION OF CONSTITUENTS OF POTENTIAL INTEREST IN SOILS – BERYLLIUM
MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913-1101.608 DRAWING NO. 53530 DATE 1/25/95 DRAWN BY EA

Golder Associates



FROM: Soda Springs, Idaho Provisional Edition 1982

EXPLANATION

S-x or S2-x ●	Phase I Soil Sample Locations (0 – 1 and 0 – 6 inch sample intervals)
MS2-x ▲	Phase II Soil Profile Sample Locations (0-1, 0-6, 6-12, 12-24 inch sample intervals)
MS2-x ◉	Phase II Surface Soil Sample Locations (0-1 and 0-6 inch sample intervals)
MS2-x ⊕	Contingent Phase II Surface Soil Sampling Locations (0 – 6 inch sample interval)

The figure shows sample identification and concentration (second line) in mg/kg. All concentrations are from the 0 – 1 inch sample interval except contingent samples, which are 0-6 inch. An "U" suffix indicates the reported detection limit. A "D" indicates duplicate sample.

Cadmium

Upper Tolerance Limit (0-1 in) = 13.9 mg/kg

Human Health Risk-based Concentration = 13.7 mg/kg

0 2000
FEET

FIGURE **4-15**
SPATIAL DISTRIBUTION OF CONSTITUENTS OF POTENTIAL INTEREST IN SOILS – CADMIUM
MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913-1101.608 DRAWING NO. 53531 DATE 1/25/95 DRAWN BY EA

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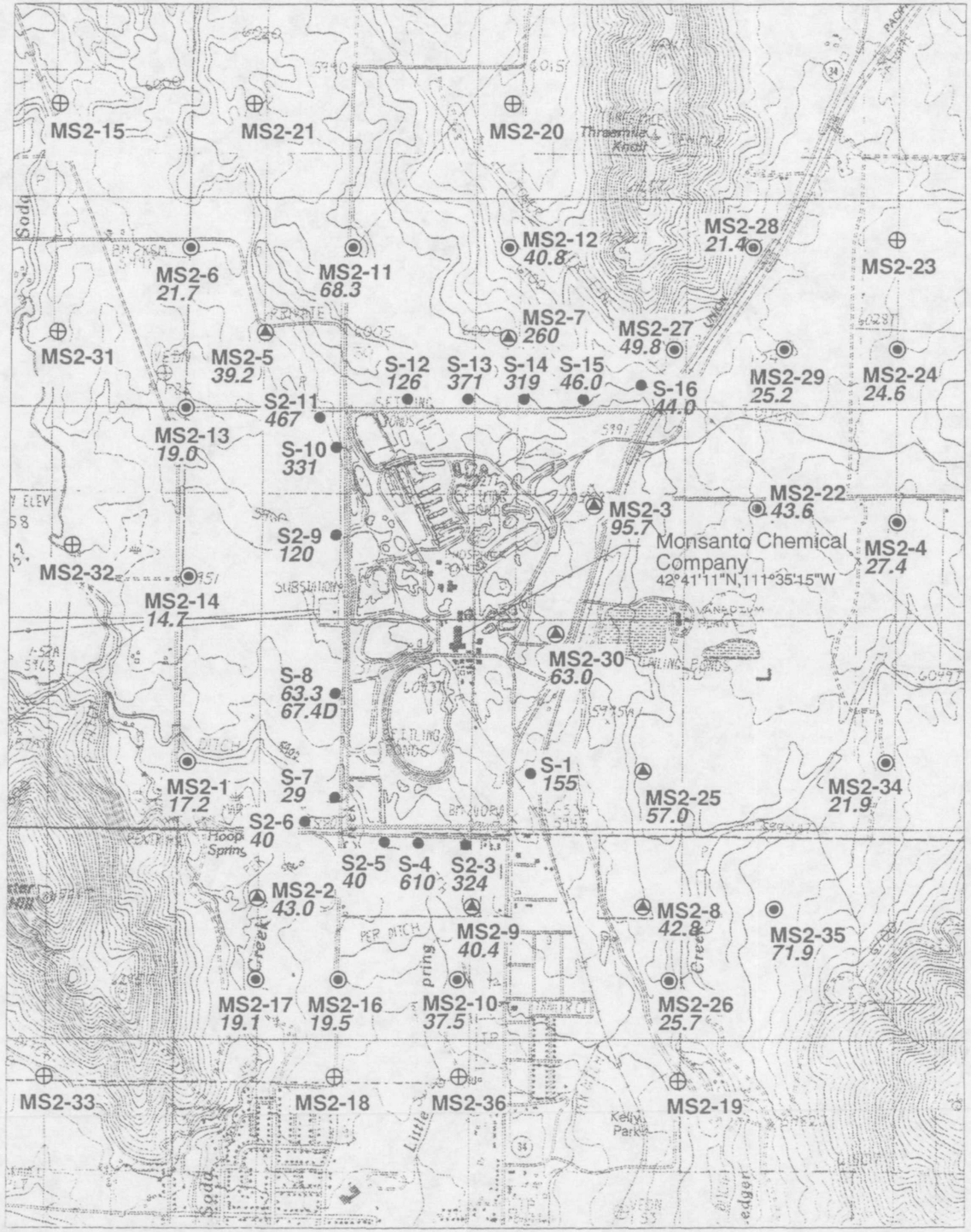

FROM: Soda Springs, Idaho Provisional Edition 1982

EXPLANATION

S-x or S2-x ●	Phase I Soil Sample Locations (0 – 1 and 0 – 6 inch sample intervals)
MS2-x ▲	Phase II Soil Profile Sample Locations (0-1, 0-6, 6-12, 12-24 inch sample intervals)
MS2-x ◉	Phase II Surface Soil Sample Locations (0-1 and 0-6 inch sample intervals)
MS2-x ⊕	Contingent Phase II Surface Soil Sampling Locations (0 – 6 inch sample interval)

The figure shows sample identification and concentration (second line) in mg/kg. All concentrations are from the 0 – 1 inch sample interval except contingent samples, which are 0-6 inch. A "D" suffix indicates duplicate sample.

Vanadium

Upper Tolerance Limit (0-1 in) = 39.5 mg/kg

Human Health Risk-based Concentration = 192 mg/kg

0 2000
FEET

FIGURE **4-16**
SPATIAL DISTRIBUTION OF CONSTITUENTS OF POTENTIAL INTEREST IN SOILS – VANADIUM
MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913-1101.608 DRAWING NO. 53533 DATE 1/25/95 DRAWN BY EA

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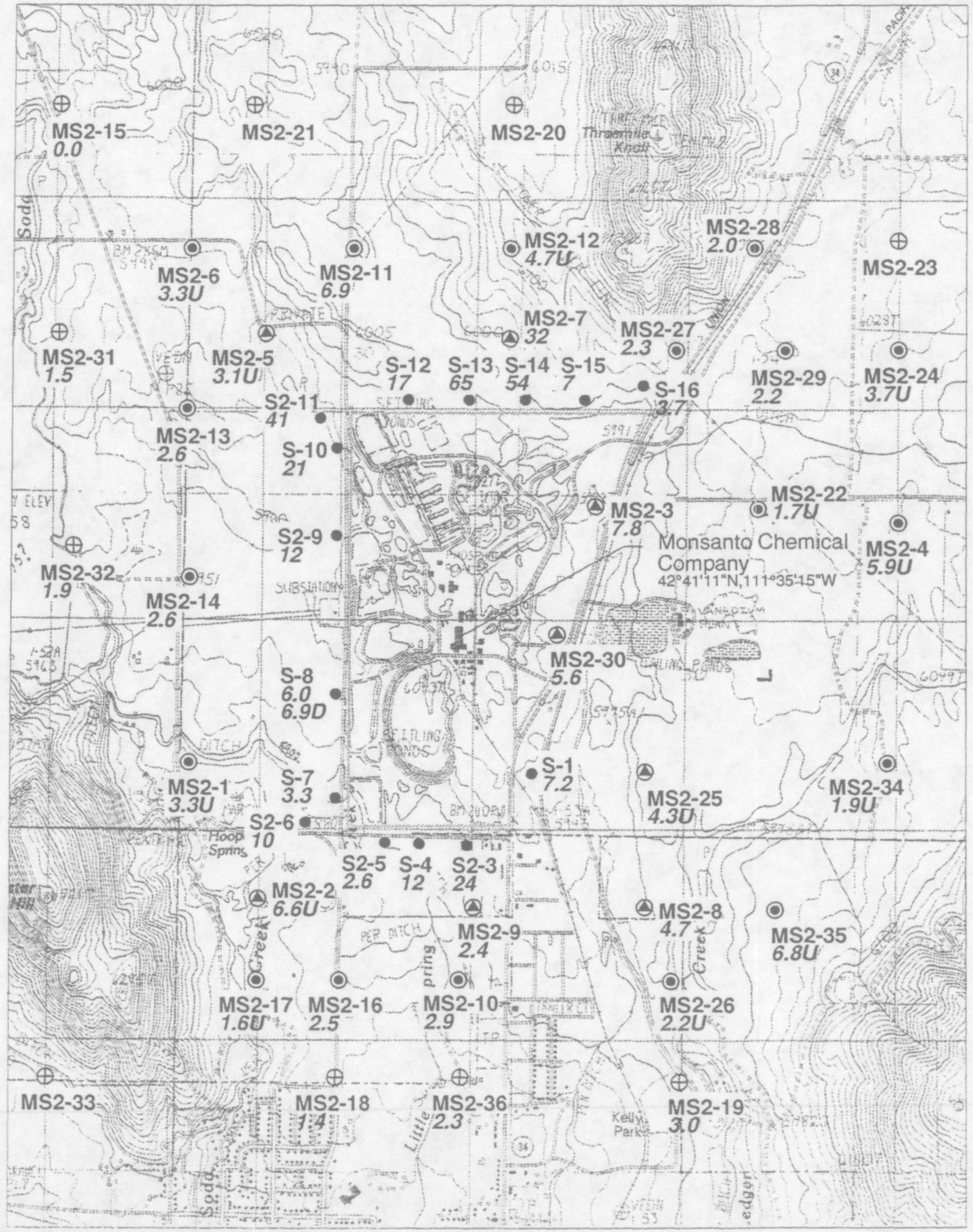

FROM: Soda Springs, Idaho Provisional Edition 1982

EXPLANATION

S-x or S2-x ●	Phase I Soil Sample Locations (0 – 1 and 0 – 6 inch sample intervals)
MS2-x ▲	Phase II Soil Profile Sample Locations (0-1, 0-6, 6-12, 12-24 inch sample intervals)
MS2-x ◉	Phase II Surface Soil Sample Locations (0-1 and 0-6 inch sample intervals)
MS2-x ⊕	Contingent Phase II Surface Soil Sampling Locations (0 – 6 inch sample interval)

The figure shows sample identification and concentration (second line) in pCi/g. All concentrations are from the 0 – 1 inch sample interval except contingent samples, which are 0-6 inch. A "U" suffix indicates the detection limit and a "D" indicates duplicate sample.

Lead-210

Upper Tolerance Limit (0-1 in) = 4.6 pCi/g

Human Health Risk-based Concentration = 0.12 pCi/g

0 2000
FEET

FIGURE **4-17**

SPATIAL DISTRIBUTION OF CONSTITUENTS OF POTENTIAL INTEREST IN SOILS – LEAD-210

MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913-1101.608 DRAWING NO. 53536 DATE 1/25/95 DRAWN BY EA

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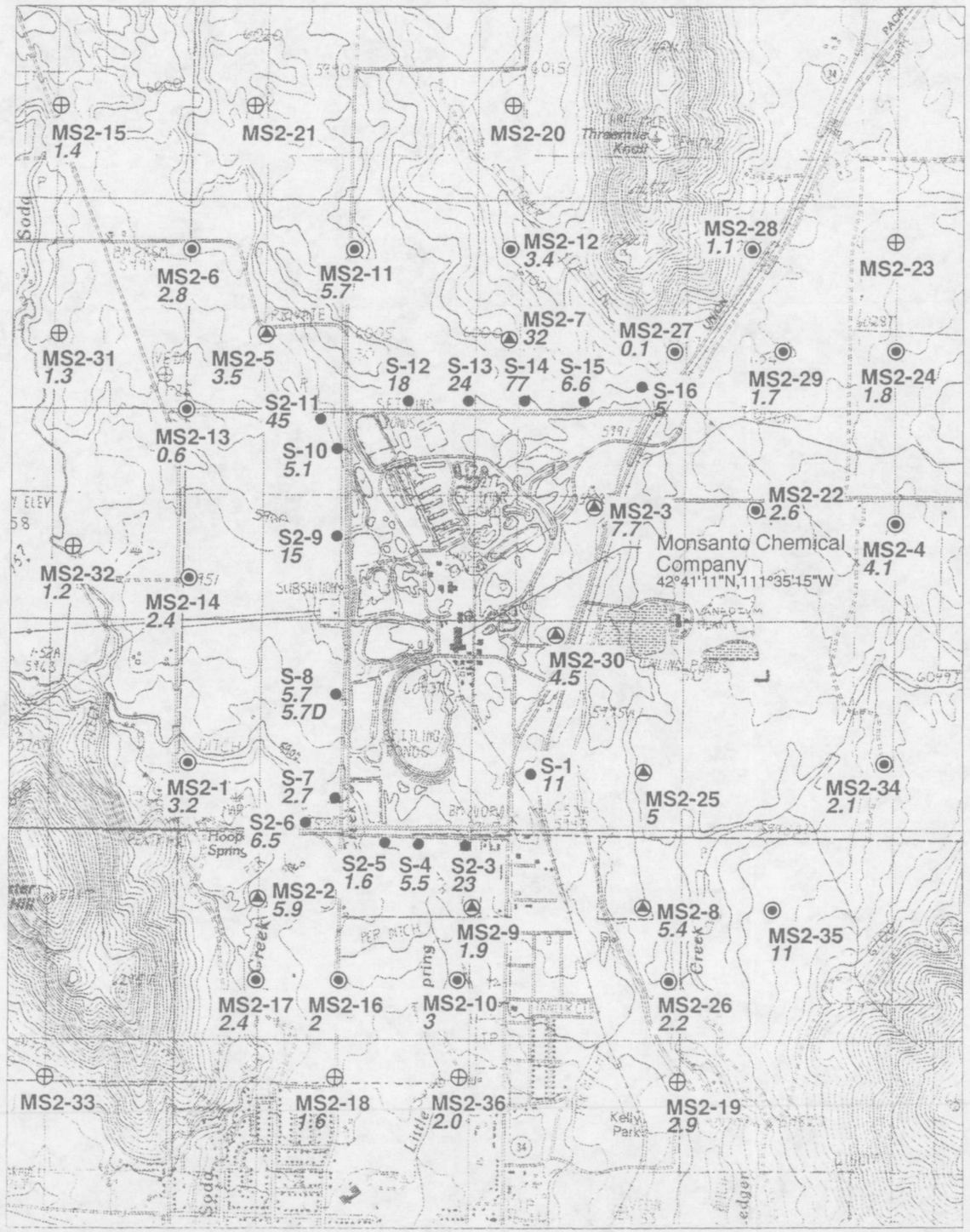

FROM: Soda Springs, Idaho Provisional Edition 1982

EXPLANATION

S-x or S2-x ●	Phase I Soil Sample Locations (0 – 1 and 0 – 6 inch sample intervals)
MS2-x ◬	Phase II Soil Profile Sample Locations (0-1, 0-6, 6-12, 12-24 inch sample intervals)
MS2-x ◉	Phase II Surface Soil Sample Locations (0-1 and 0-6 inch sample intervals)
MS2-x ⊕	Contingent Phase II Surface Soil Sampling Locations (0 – 6 inch sample interval)

The figure shows sample identification and concentration (second line) in pCi/g. All concentrations are from the 0 – 1 inch sample interval except contingent samples, which are 0-6 inch. A "D" suffix indicates duplicate sample.

Polonium-210

Upper Tolerance Limit (0-1 in) = 4.3 pCi/g

Human Health Risk-based Concentration = 0.031 pCi/g

0 2000
FEET

FIGURE **4-18**
SPATIAL DISTRIBUTION OF CONSTITUENTS OF POTENTIAL INTEREST IN SOILS – POLONIUM-210
MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913-1101.608 DRAWING NO. 53537 DATE 1/25/95 DRAWN BY EA

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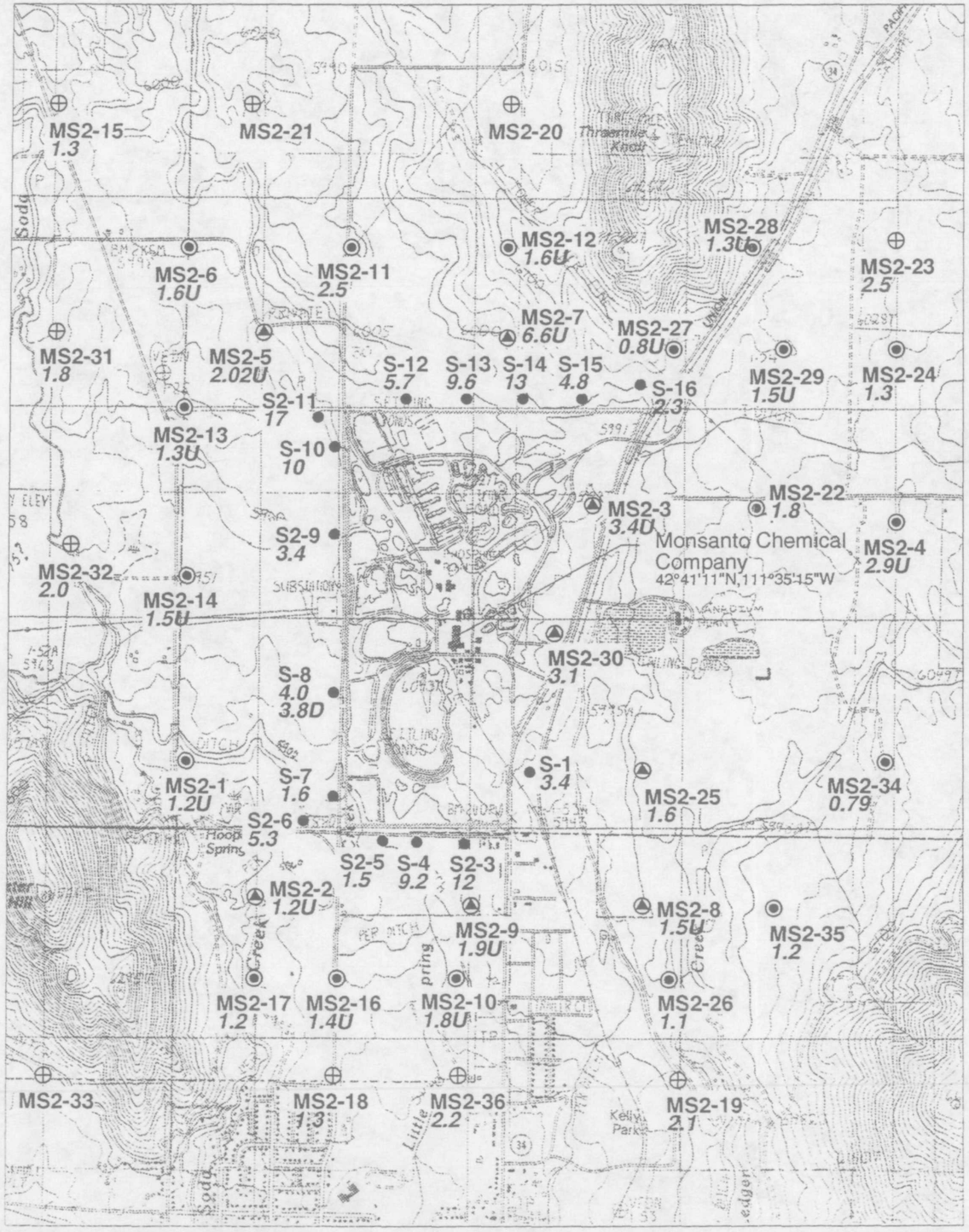

FROM: Soda Springs, Idaho Provisional Edition 1982

EXPLANATION

S-x or S2-x ●	Phase I Soil Sample Locations (0 – 1 and 0 – 6 inch sample intervals)
MS2-x ▲	Phase II Soil Profile Sample Locations (0-1, 0-6, 6-12, 12-24 inch sample intervals)
MS2-x ◉	Phase II Surface Soil Sample Locations (0-1 and 0-6 inch sample intervals)
MS2-x ⊕	Contingent Phase II Surface Soil Sampling Locations (0 – 6 inch sample interval)

The figure shows sample identification and concentration (second line) in pCi/g. All concentrations are from the 0 – 1 inch sample interval except contingent samples, which are 0-6 inch. A "U" suffix indicates the detection limit and a "D" indicates duplicate sample.

Radium-226

Upper Tolerance Limit (0-1 in) = 3.3 pCi/g

Human Health Risk-based Concentration = 5.8×10^{-4} pCi/g

0 2000
FEET

FIGURE **4-19**
SPATIAL DISTRIBUTION OF CONSTITUENTS OF POTENTIAL INTEREST IN SOILS – RADIUM-226
MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913-1101.608 DRAWING NO. 53538 DATE 1/25/95 DRAWN BY EA

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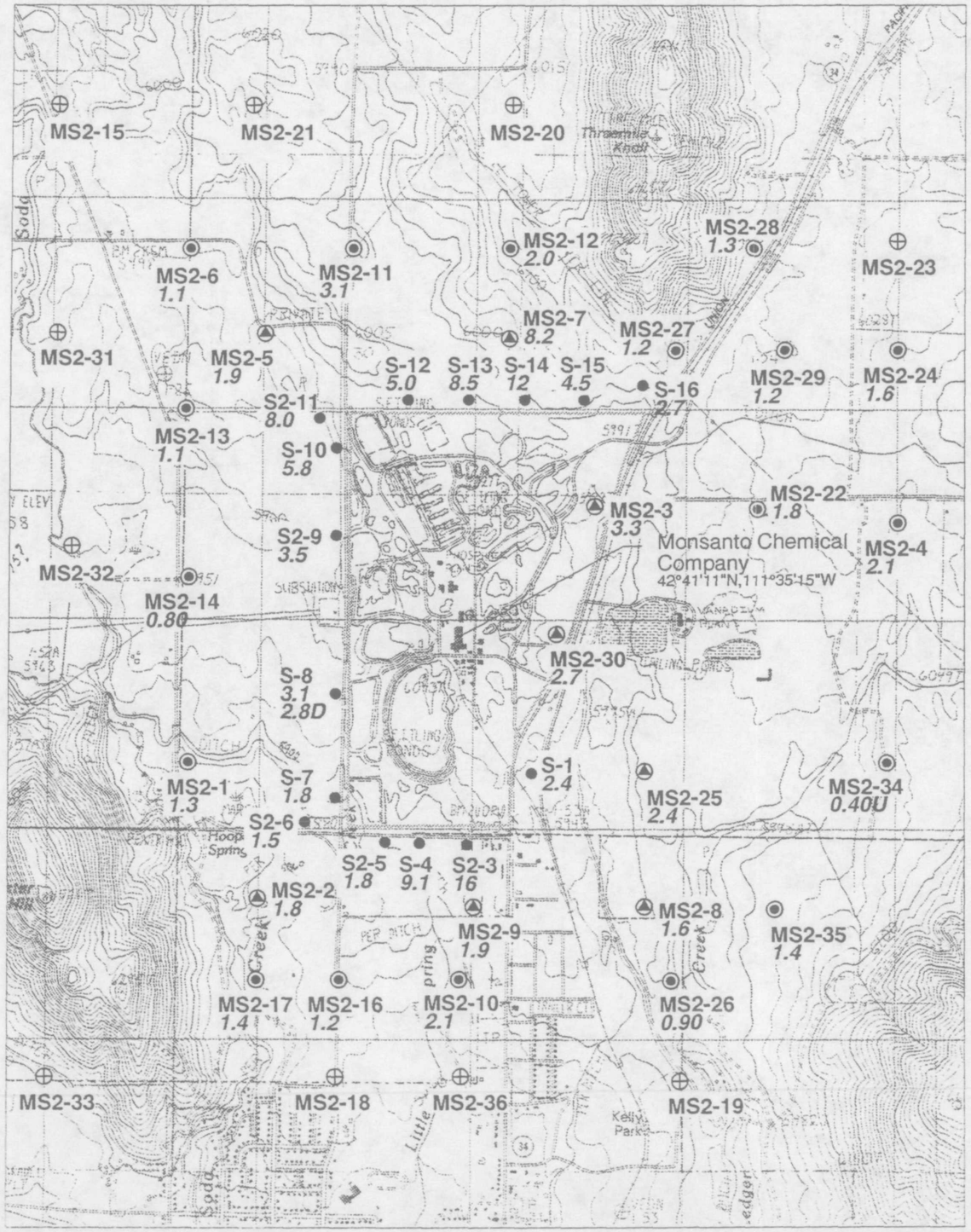


FROM: Soda Springs, Idaho Provisional Edition 1982

EXPLANATION

S-x or S2-x ●	Phase I Soil Sample Locations (0 – 1 and 0 – 6 inch sample intervals)
MS2-x ▲	Phase II Soil Profile Sample Locations (0-1, 0-6, 6-12, 12-24 inch sample intervals)
MS2-x ◉	Phase II Surface Soil Sample Locations (0-1 and 0-6 inch sample intervals)
MS2-x ⊕	*Contingent Phase II Surface Soil Sampling Locations* (0 – 6 inch sample interval)

The figure shows sample identification and concentration (second line) in pCi/g. All concentrations are from the 0 – 1 inch sample interval except contingent samples, which are 0-6 inch. A "U" suffix indicates the detection limit and a "D" indicates duplicate sample.

Thorium-230

Upper Tolerance Limit (0-1 in) = 2.5 pCi/g

Human Health Risk-based Concentration = 5.7 pCi/g

0 2000
FEET

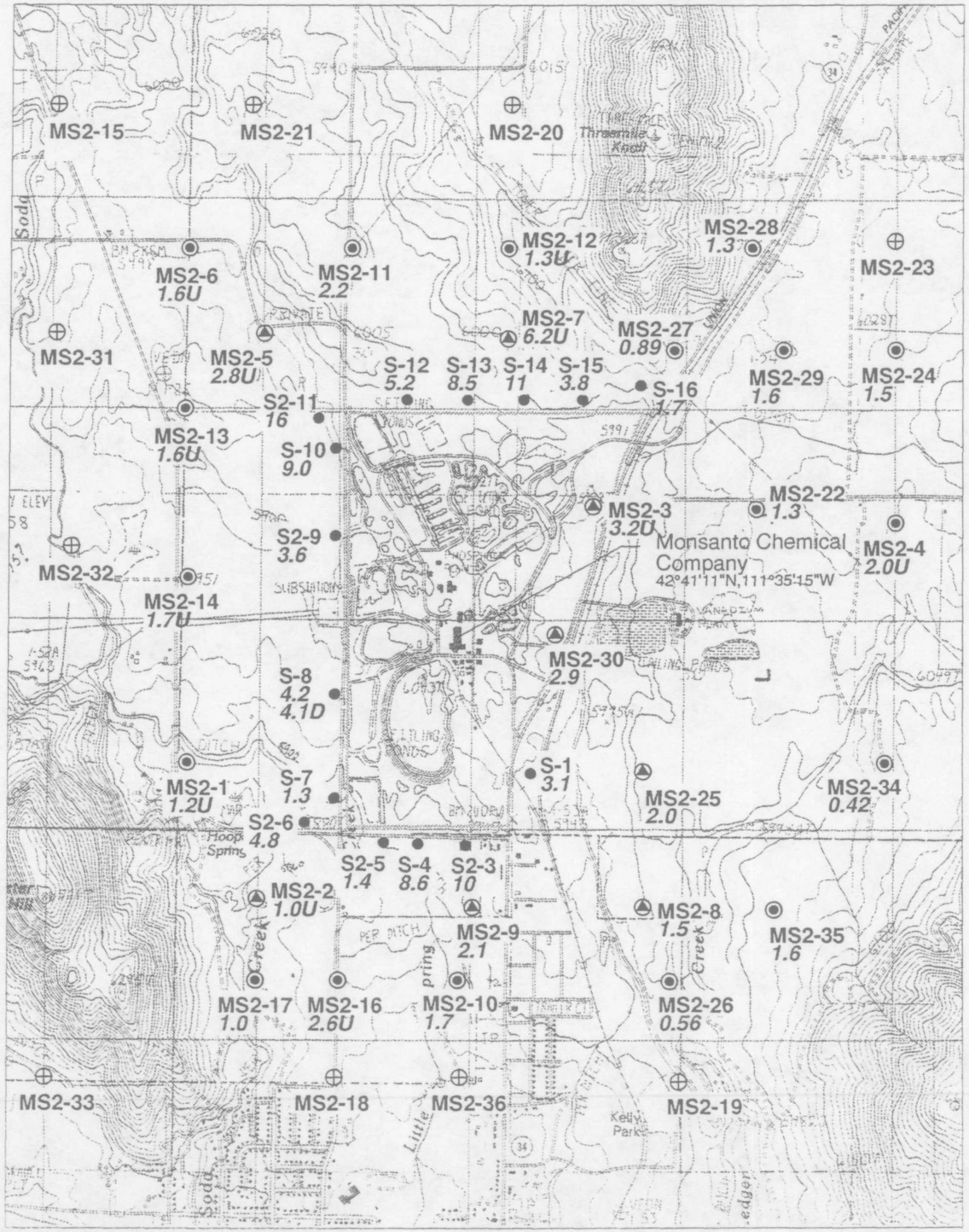
FIGURE **4-20**

SPATIAL DISTRIBUTION OF CONSTITUENTS OF POTENTIAL INTEREST IN SOILS – THORIUM-230

MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913-1101.608 DRAWING NO. 53540 DATE 1/25/95 DRAWN BY EA

Golder Associates



FROM: Soda Springs, Idaho Provisional Edition 1982

EXPLANATION

S-x or S2-x ●	Phase I Soil Sample Locations (0 – 1 and 0 – 6 inch sample intervals)
MS2-x ⊕	Phase II Soil Profile Sample Locations (0-1, 0-6, 6-12, 12-24 inch sample intervals)
MS2-x ⊙	Phase II Surface Soil Sample Locations (0-1 and 0-6 inch sample intervals)
MS2-x ⊕	Contingent Phase II Surface Soil Sampling Locations (0 – 6 inch sample interval)

The figure shows sample identification and concentration (second line) in pCi/g. All concentrations are from the 0 – 1 inch sample interval except contingent samples, which are 0-6 inch. A "U" suffix indicates the detection limit and a "D" indicates duplicate sample.

Uranium-238

Upper Tolerance Limit (0-1 in) = 2.6 pCi/g

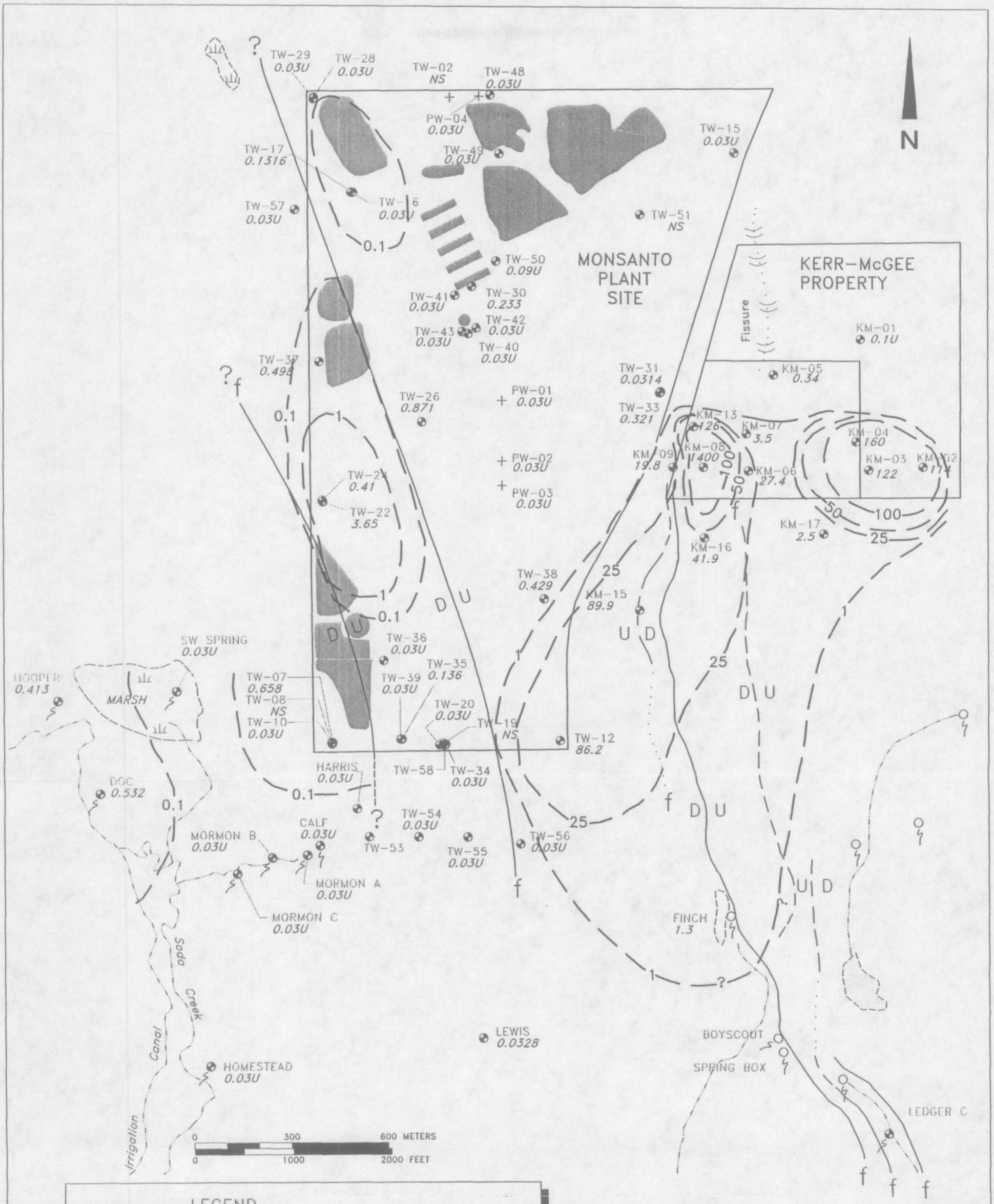
Human Health Risk-based Concentration = 0.068 pCi/g

0 2000
FEET

FIGURE **4-21**
SPATIAL DISTRIBUTION OF CONSTITUENTS OF POTENTIAL INTEREST IN SOILS –URANIUM-238
MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913-1101.608 DRAWING NO. 53541 DATE 1/25/95 DRAWN BY EA

Golder Associates



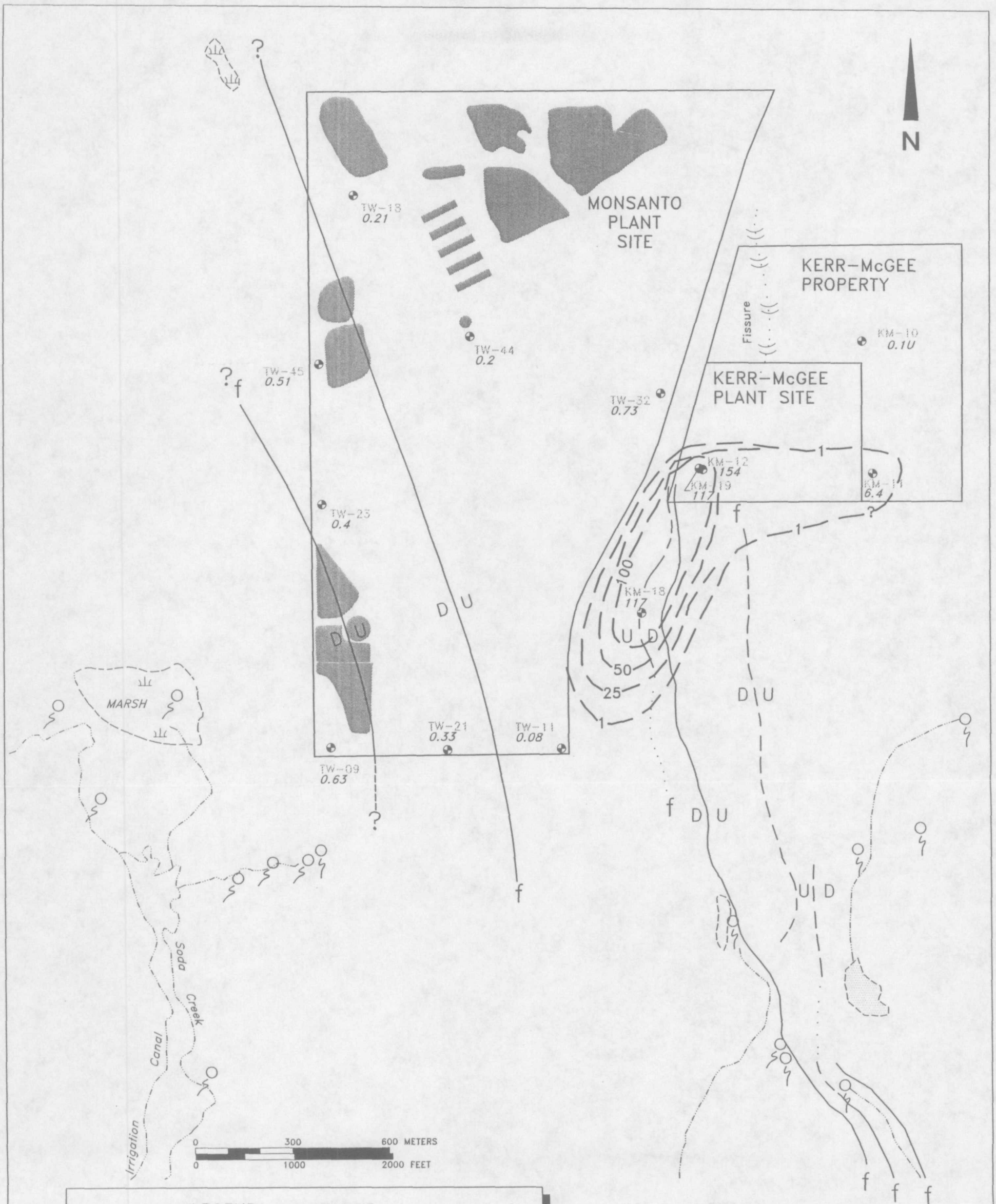
LEGEND

TW-35	Monitoring well location and name
+ PW-1	Production well location and name
CALF	Spring location and name (if sampled)
BOYSCOUT	Spring location and name (not sampled)
242	Concentration (mg/L as N) with qualifier (if any): CRDL = Contract Required Detection Limit; IDL = Instrument Detection Limit; U = Undetected; B = Detected between the CRDL and IDL; J = Estimated below IDL
NS	No sample collected
100 — —	Concentration contour (mg/l as N)
f — — · —	Fault (dashed where inferred)

FIGURE **4-22**

AMMONIA-NITROGEN GROUNDWATER CONCENTRATIONS IN THE UPPER BASALT ZONE DURING MAY 1993

MONSANTO/PHASE II RI REPORT/ID



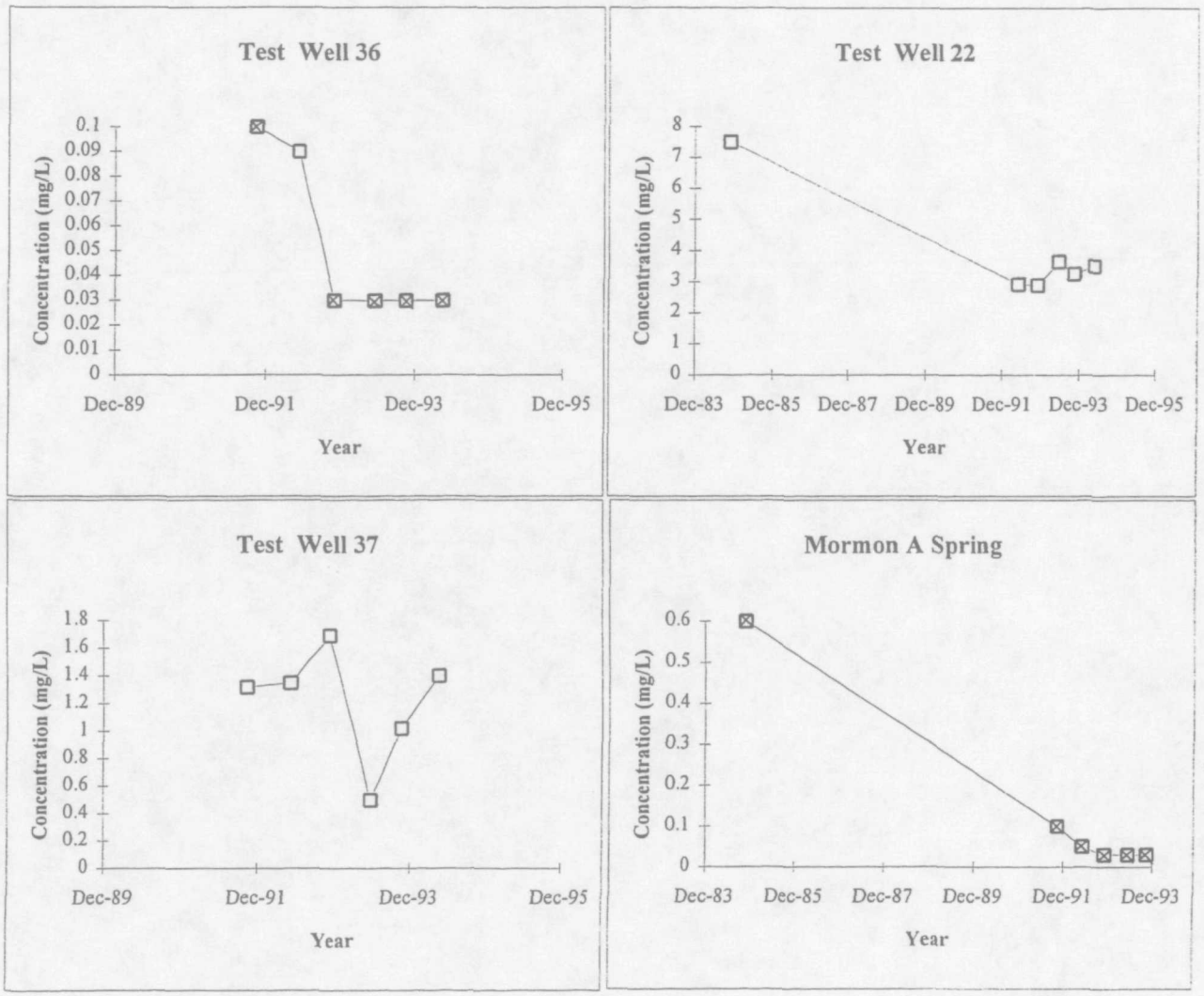
LEGEND

TW-35	Monitoring well location and name
+ PW-1	Production well location and name
CALF	Spring location and name (if sampled)
BOYSCOUT	Spring location and name (not sampled)
242	*Concentration (mg/L as N) with qualifier (if any):* CRDL = Contract Required Detection Limit IDL = Instrument Detection Limit U = Undetected B = Detected between the CRDL and IDL J = Estimated below IDL
NS	No sample collected
100 — —	Concentration contour (mg/L as N)
f — — · —	Fault (dashed where inferred)

FIGURE **4-23**

AMMONIA-NITROGEN GROUNDWATER CONCENTRATIONS IN THE LOWER BASALT ZONE DURING MAY 1993

MONSANTO/PHASE II RI REPORT/ID



□ Sample result

⊠ Sample result below detection limit

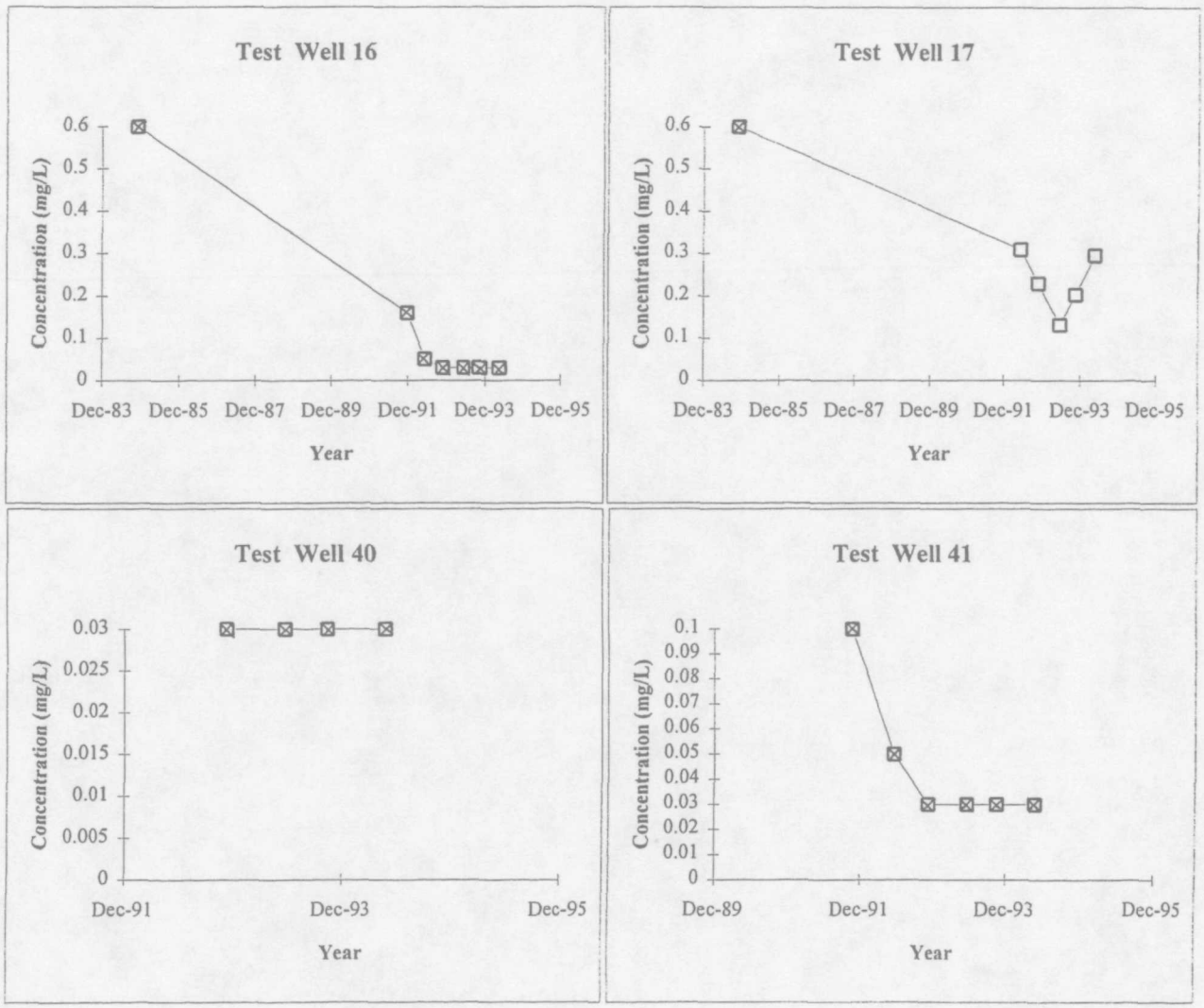
FIGURE **4-24**

AMMONIA - NITROGEN TIME HISTORY PLOTS IN THE OLD UNDERFLOW SOLIDS PONDS AREA

MONSANTO/PHASE II RI/ID

PROJECT NO.913 1101.608 DRAWING NO. 53501 DATE 2/1/95 DRAWN BY EA

Golder Associates



□ Sample result

⊠ Sample result below detection limit

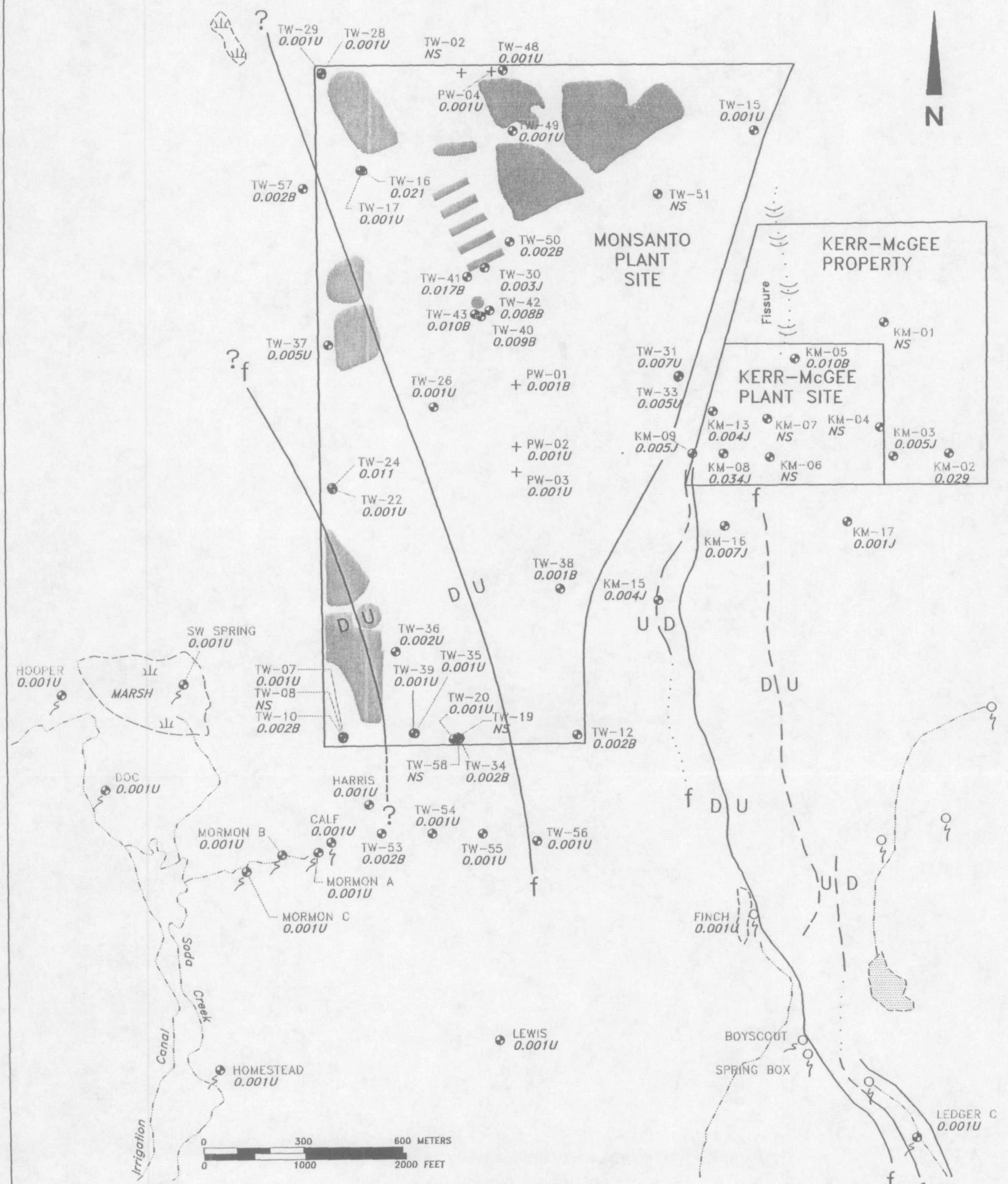
FIGURE **4-25**

AMMONIA - NITROGEN TIME HISTORY PLOTS IN THE NORTHWEST POND/HYDROCLARIFIER AREA

MONSANTO/PHASE II RI/ID

PROJECT NO.913 1101.608 DRAWING NO. 53502 DATE 2/1/95 DRAWN BY EA

Golder Associates



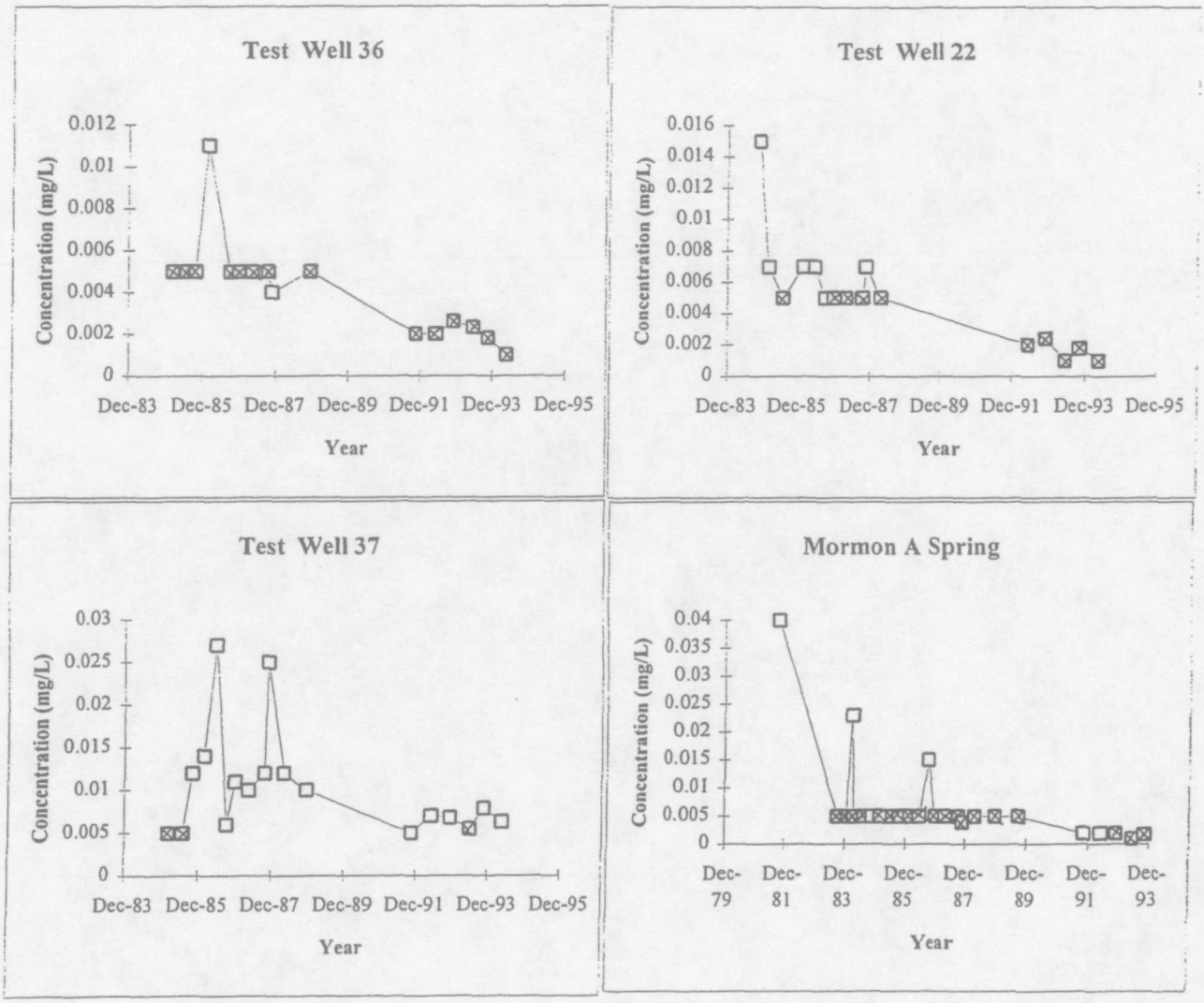
LEGEND

TW-35	Monitoring well location and name
PW-1	Production well location and name
CALF	Spring location and name (if sampled)
BOYSCOUT	Spring location and name (not sampled)
242	Concentration (mg/l) with qualifier (if any): CRDL = Contract Required Detection Limit; IDL = Instrument Detection Limit; U = Undetected; B = Detected between the CRDL and IDL; J = Estimated below IDL
NS	No sample collected
100	Concentration contour (mg/l)
f	Fault (dashed where inferred)

FIGURE 4-26
ARSENIC GROUNDWATER CONCENTRATIONS IN THE UPPER BASALT ZONE DURING MAY 1993
MONSANTO/PHASE II RI REPORT/ID

\JPM\9131101\608\51061 1-26-95 16:26

Golder Associates



□ Sample result

⊠ Sample result below detection limit

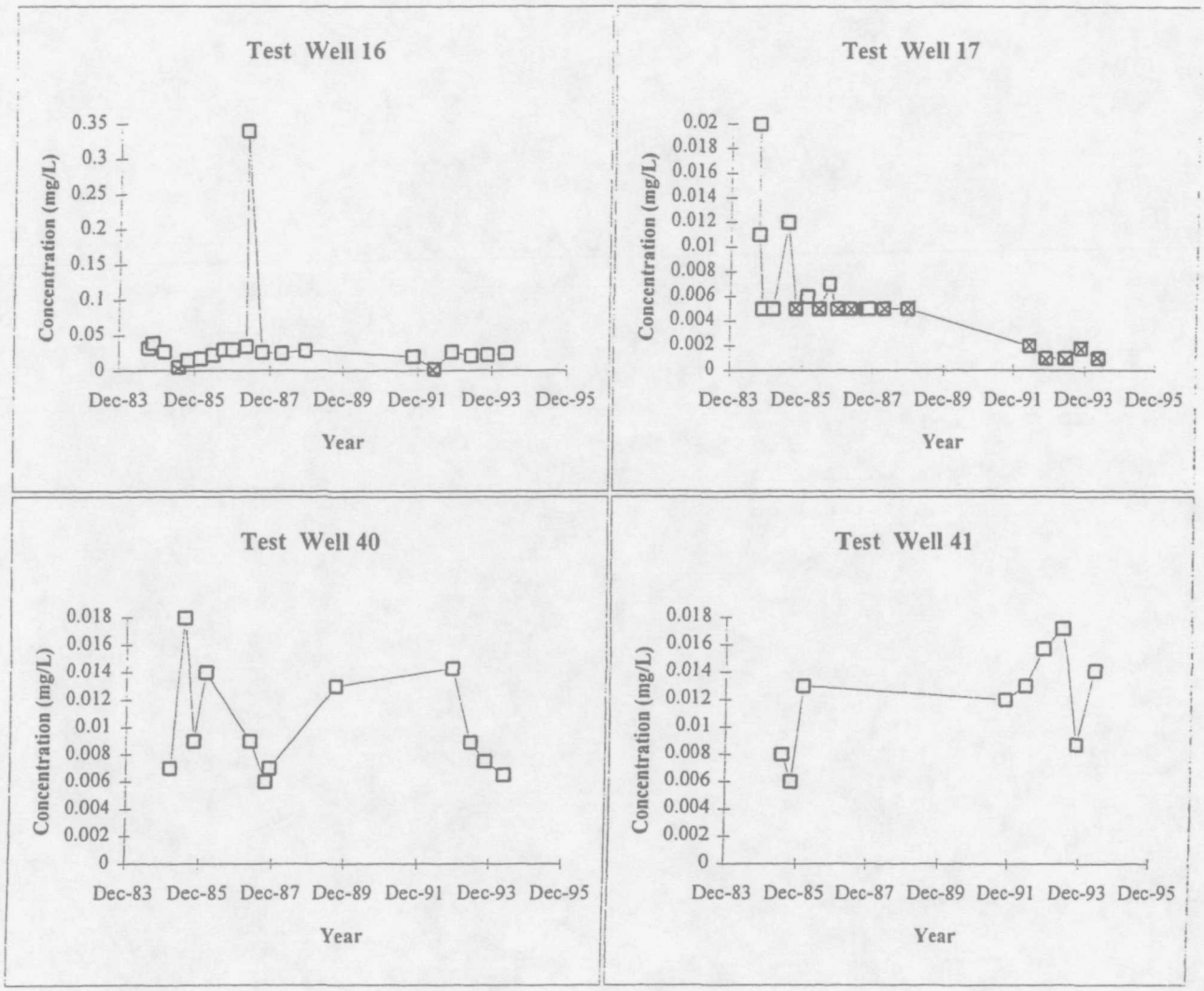
FIGURE **4-27**

ARSENIC TIME HISTORY PLOTS IN THE OLD UNDERFLOW SOLIDS PONDS AREA

MONSANTO/PHASE II RI/ID

PROJECT NO.913 1101.608 DRAWING NO. 53503 DATE 10/17/94 DRAWN BY EA

Golder Associates



□ Sample result

⊠ Sample result below detection limit

FIGURE **4-28**

ARSENIC TIME HISTORY PLOTS IN THE NORTHWEST POND/HYDROCLARIFIER AREA

MONSANTO/PHASE II RI/ID

PROJECT NO.913 1101.608 DRAWING NO. 53528 DATE 10/17/94 DRAWN BY EA

Golder Associates

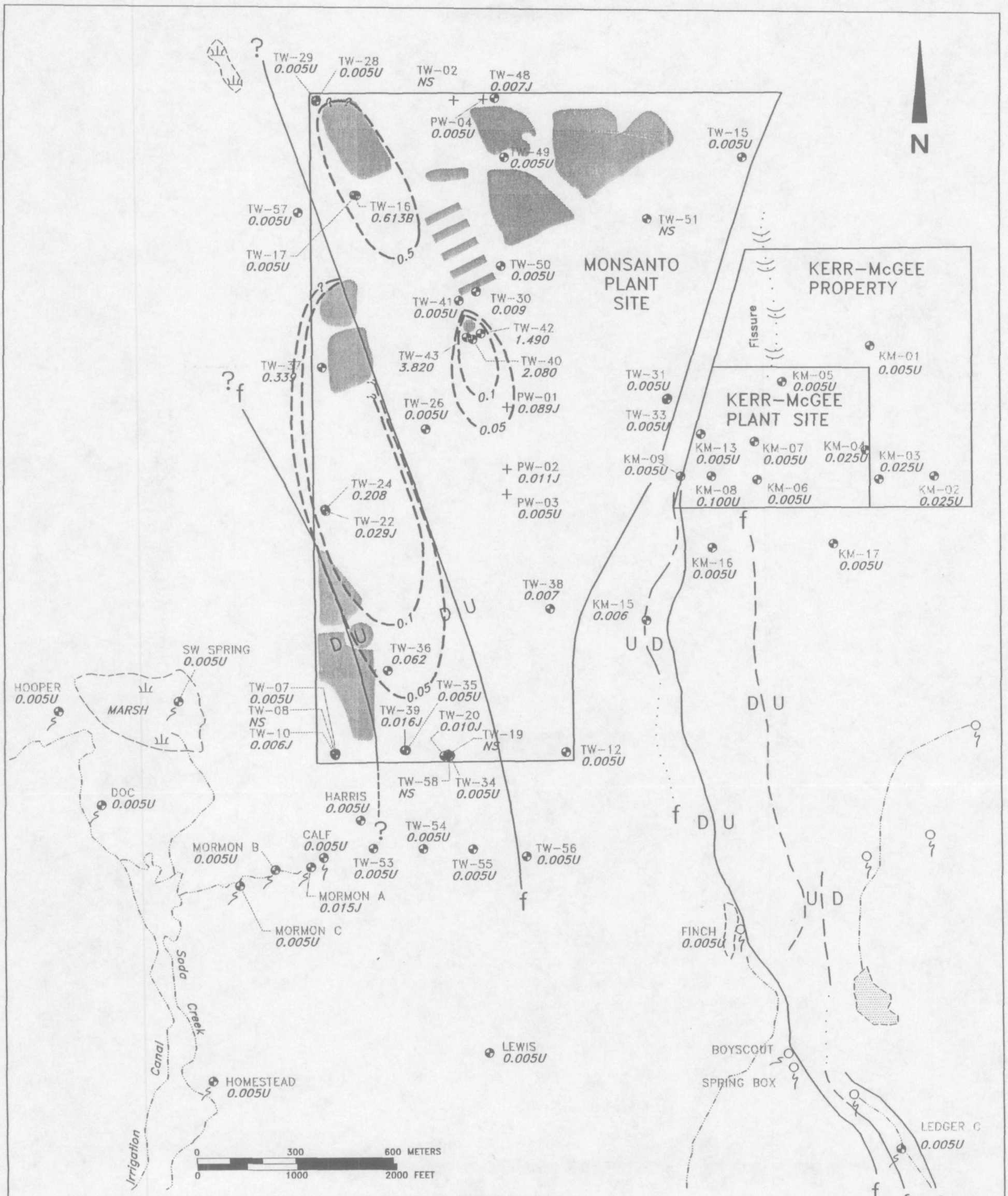
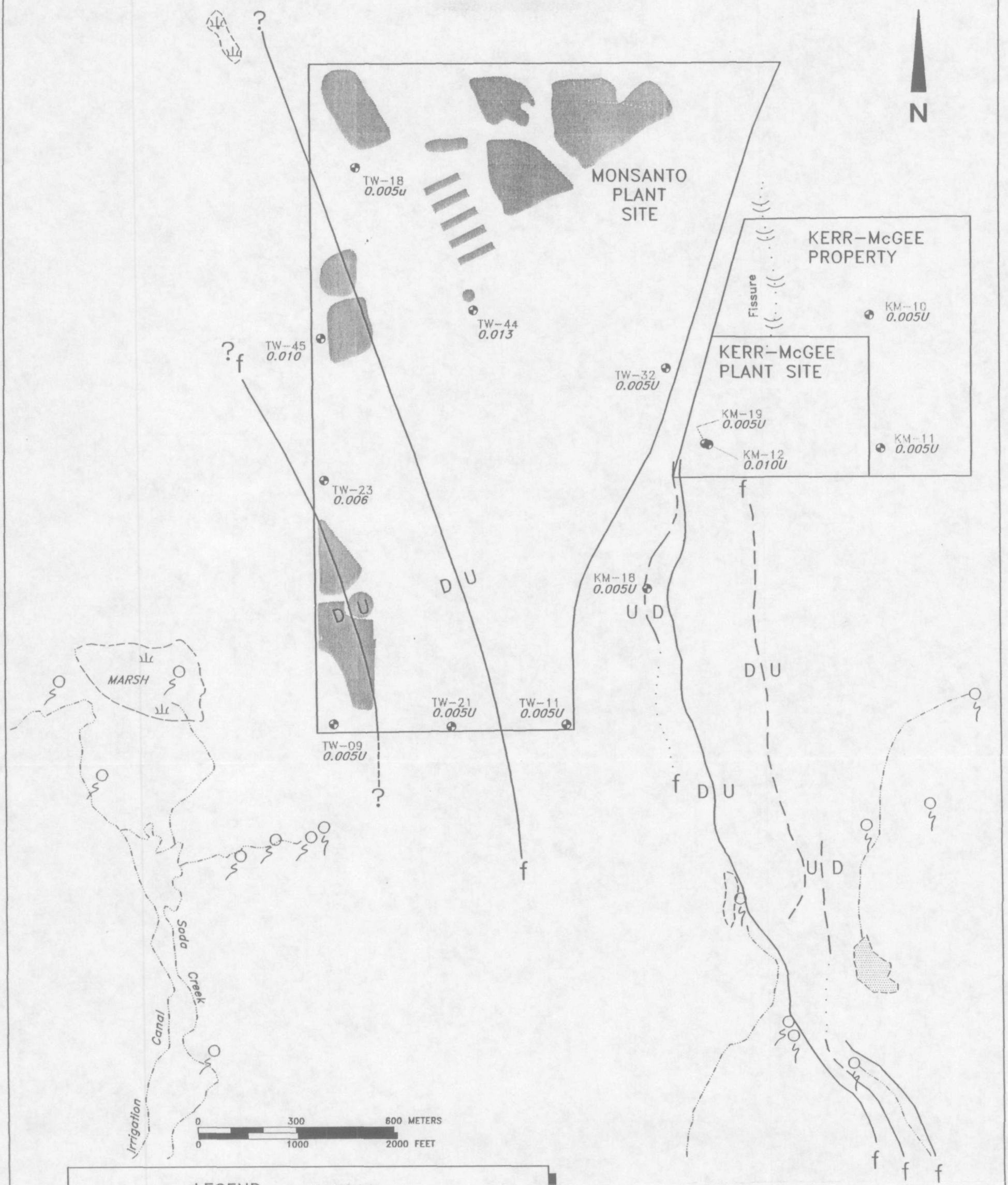


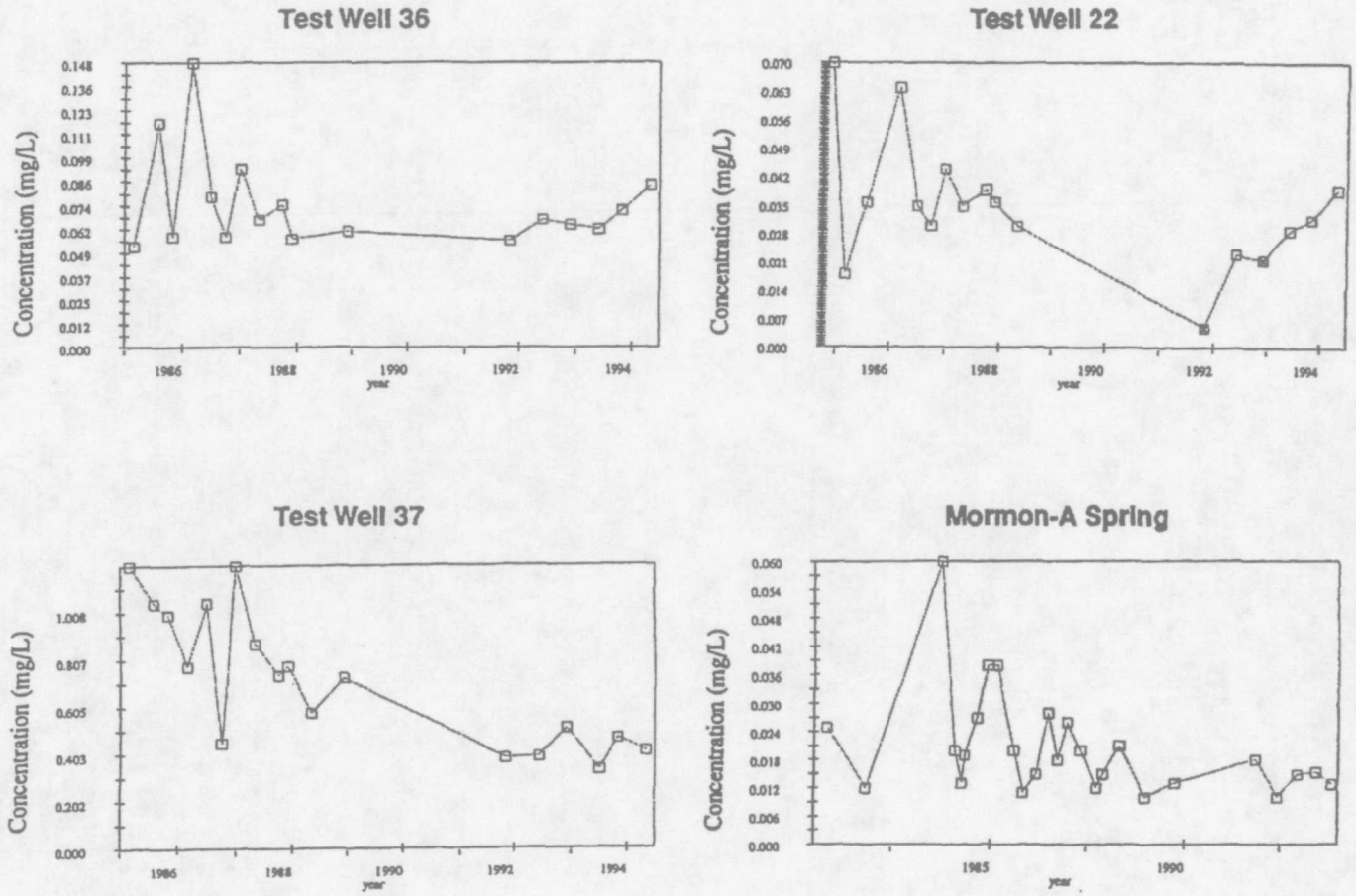
FIGURE 4-29
CADMIUM GROUNDWATER CONCENTRATIONS IN THE UPPER BASALT ZONE DURING MAY 1993
MONSANTO/PHASE II RI REPORT/ID



LEGEND

TW-35	Monitoring well location and name
PW-1	Production well location and name
CALF	Spring location and name (if sampled)
BOYSCOUT	Spring location and name (not sampled)
242	Concentration (mg/l) with qualifier (if any): CRDL = Contract Required Detection Limit; IDL = Instrument Detection Limit; U = Undetected; B = Detected between the CRDL and IDL; J = Estimated below IDL
NS	No sample collected
100	Concentration contour (mg/l)
f	Fault (dashed where inferred)

FIGURE 4-30
CADMIUM GROUNDWATER CONCENTRATIONS IN THE LOWER BASALT ZONE DURING MAY 1993
MONSANTO/PHASE II RI REPORT/ID



□ Sample result

⊠ Sample result below detection limit

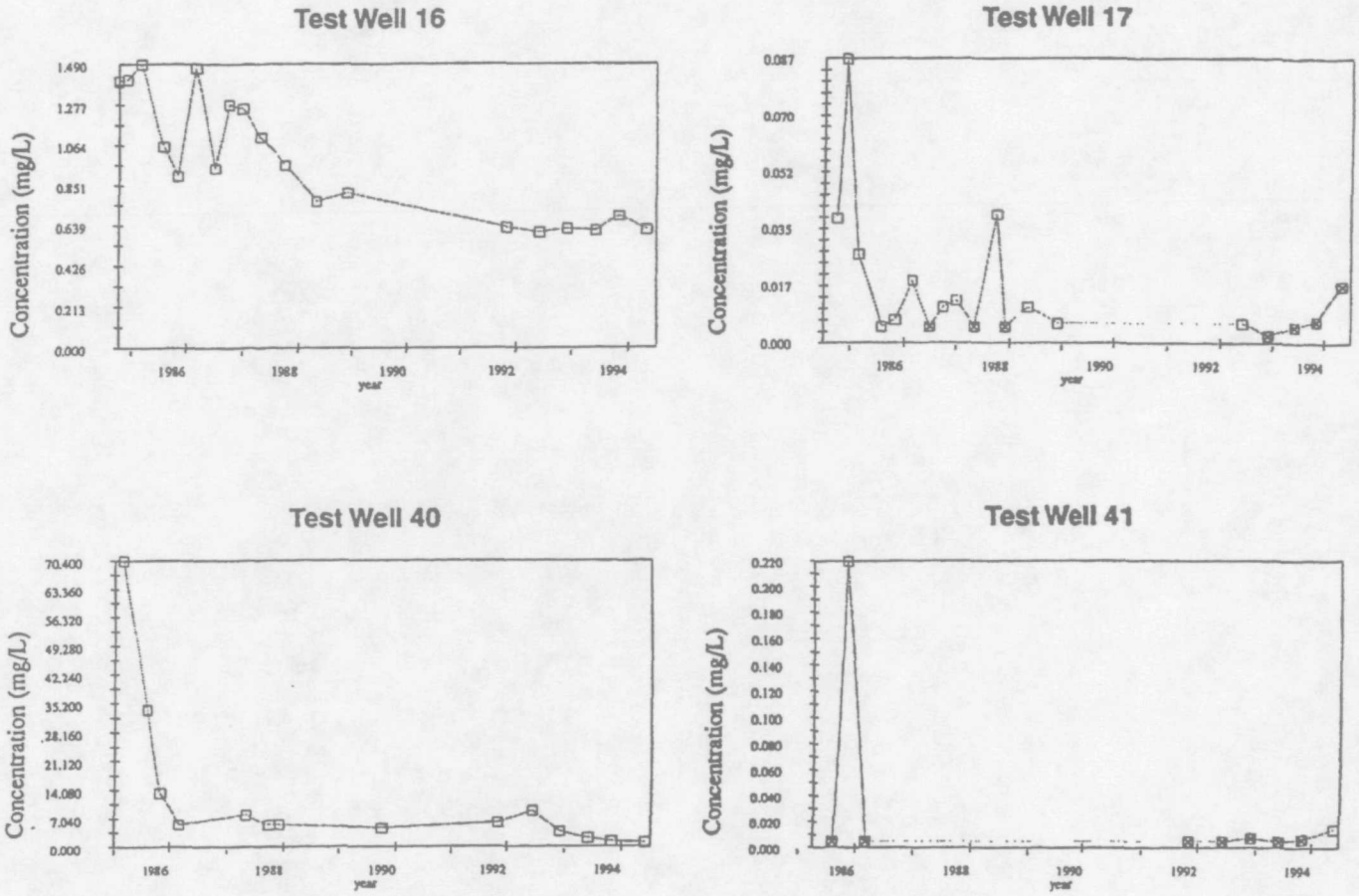
FIGURE **4-31**

CADMIUM TIME HISTORY PLOTS IN THE OLD UNDERFLOW SOLIDS PONDS AREA

MONSANTO/PHASE II RI/ID

PROJECT NO. 913 1101.608 DRAWING NO. 53504 DATE 3/16/95 DRAWN BY EA

Golder Associates



□ Sample result

⊠ Sample result below detection limit

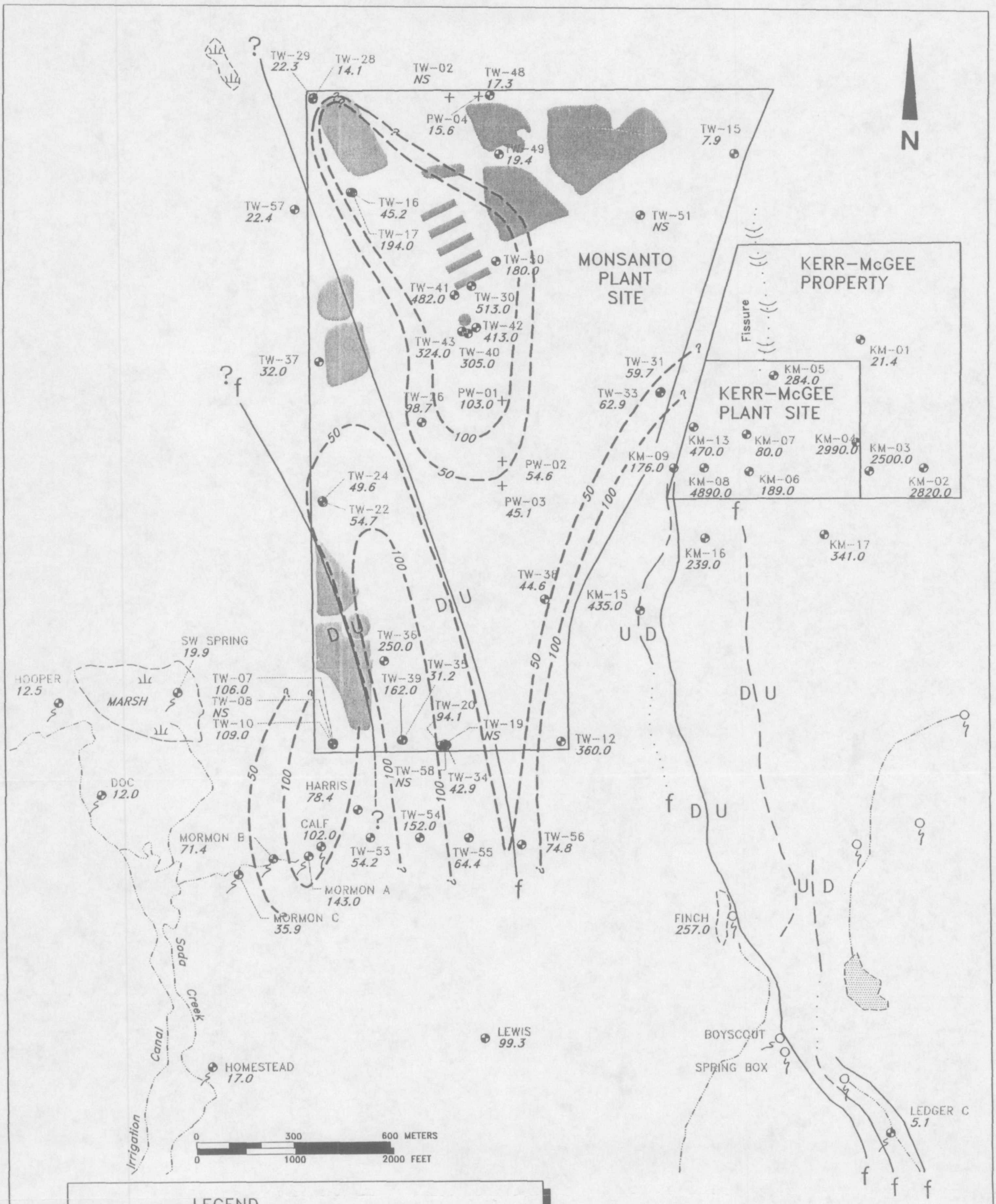
FIGURE **4-32**

CADMIUM TIME HISTORY PLOTS IN THE NORTHWEST POND/HYDROCLARIFIER AREA

MONSANTO/PHASE II RI/ID

PROJECT NO. 913 1101.608 DRAWING NO. 53505 DATE 3/16/95 DRAWN BY EA

Golder Associates



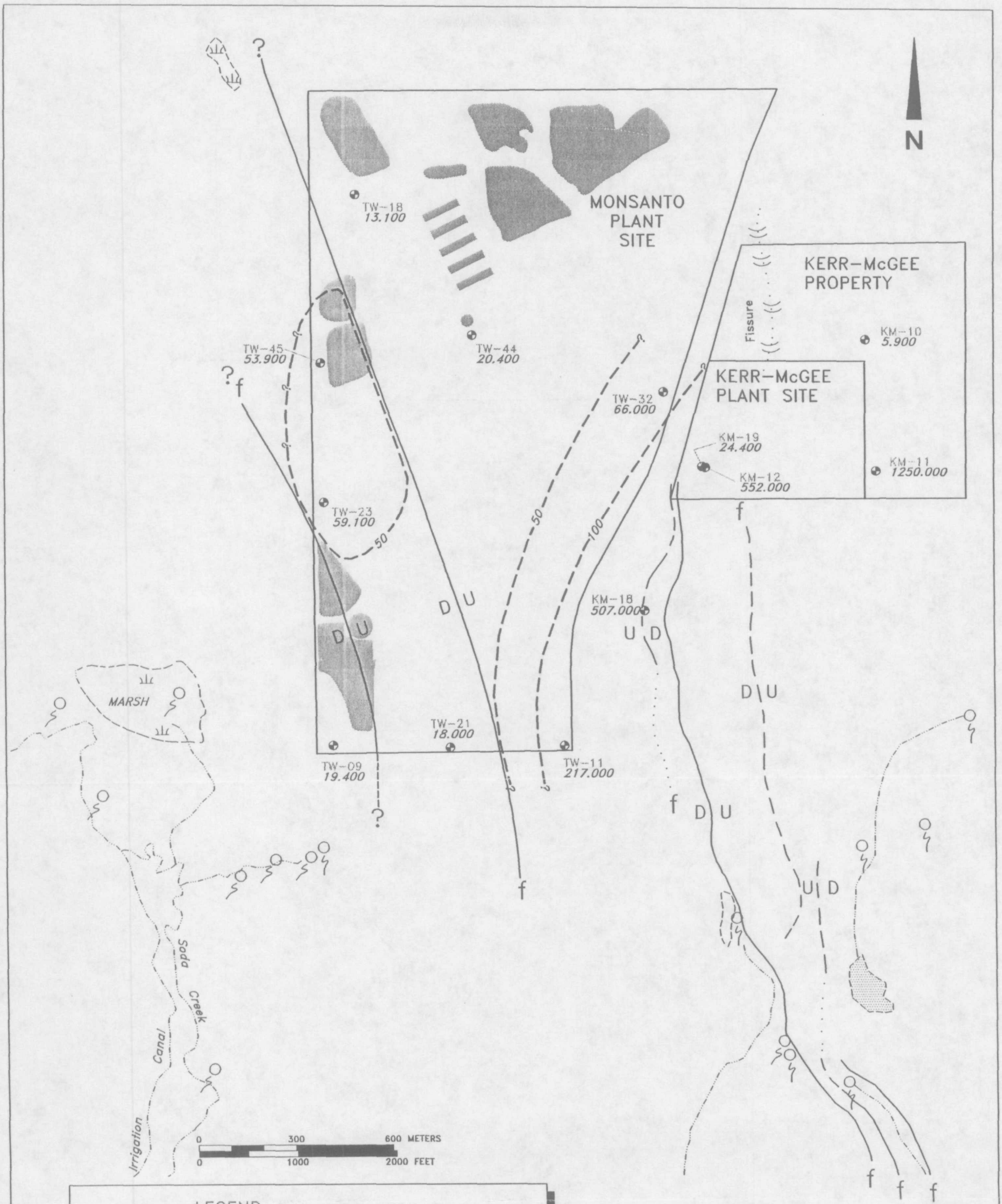
LEGEND

TW-35	Monitoring well location and name
+ PW-1	Production well location and name
CALF	Spring location and name (if sampled)
BOYSCOUT	Spring location and name (not sampled)
242	Concentration (mg/l) with qualifier (if any): CRDL = Contract Required Detection Limit; IDL = Instrument Detection Limit; U = Undetected; B = Detected between the CRDL and IDL; J = Estimated below IDL
NS	No sample collected
100 — —	Concentration contour (mg/l)
f — — · —	Fault (dashed where inferred)

FIGURE **4-33**

CHLORIDE GROUNDWATER CONCENTRATIONS IN THE UPPER BASALT ZONE DURING MAY 1993

MONSANTO/PHASE II RI REPORT/ID



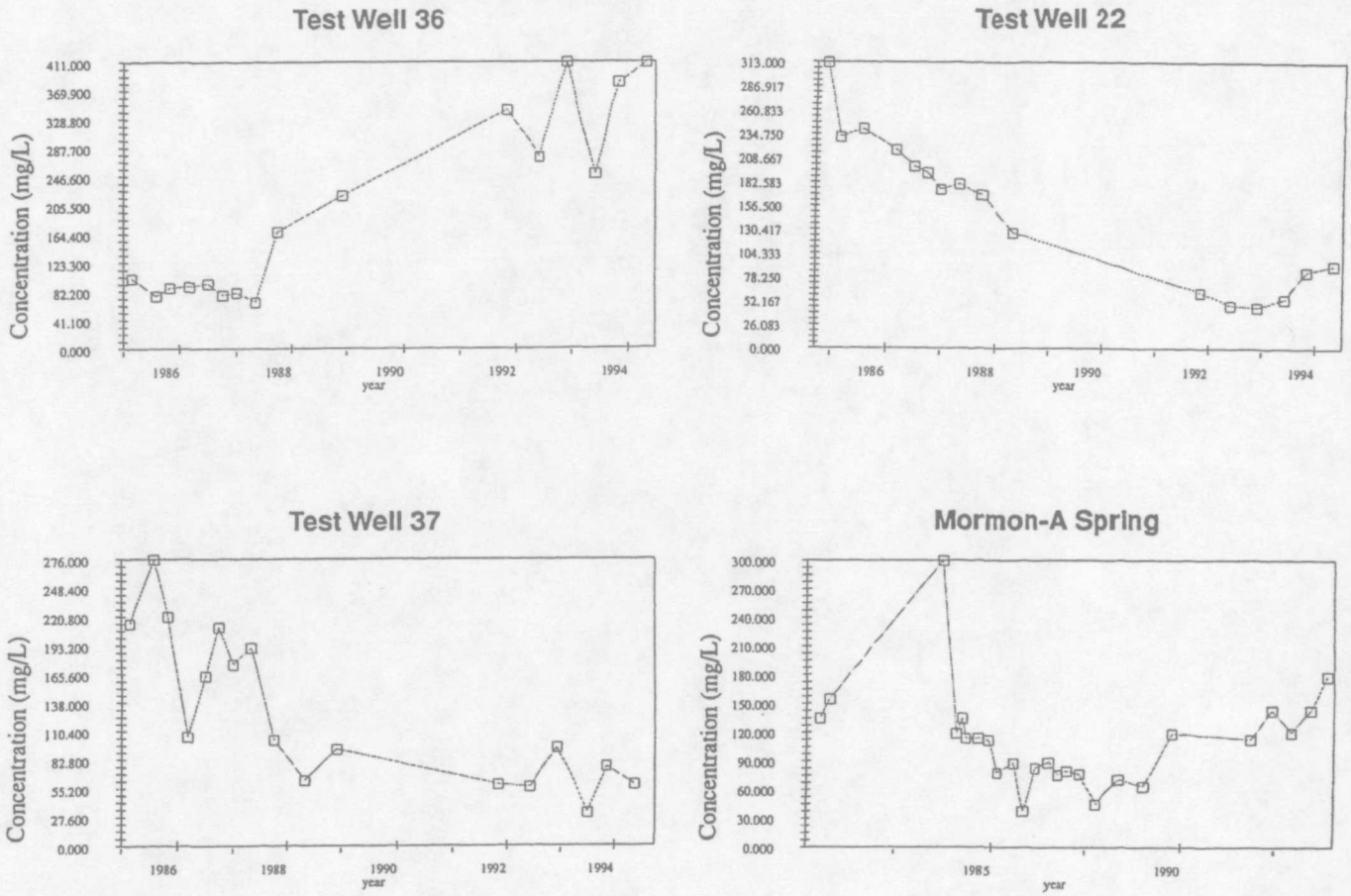
LEGEND

TW-35	Monitoring well location and name
+ PW-1	Production well location and name
CALF	Spring location and name (if sampled)
BOYSCOUT	Spring location and name (not sampled)
242	Concentration (mg/l) with qualifier (if any): CRDL = Contract Required Detection Limit IDL = Instrument Detection Limit U = Undetected B = Detected between the CRDL and IDL J = Estimated below IDL
NS	No sample collected
100 — —	Concentration contour (mg/l)
f — — · —	Fault (dashed where inferred)

FIGURE **4-34**

CHLORIDE GROUNDWATER CONCENTRATIONS IN THE LOWER BASALT ZONE DURING MAY 1993

MONSANTO/PHASE II RI REPORT/ID



□ Sample result

⊠ Sample result below detection limit

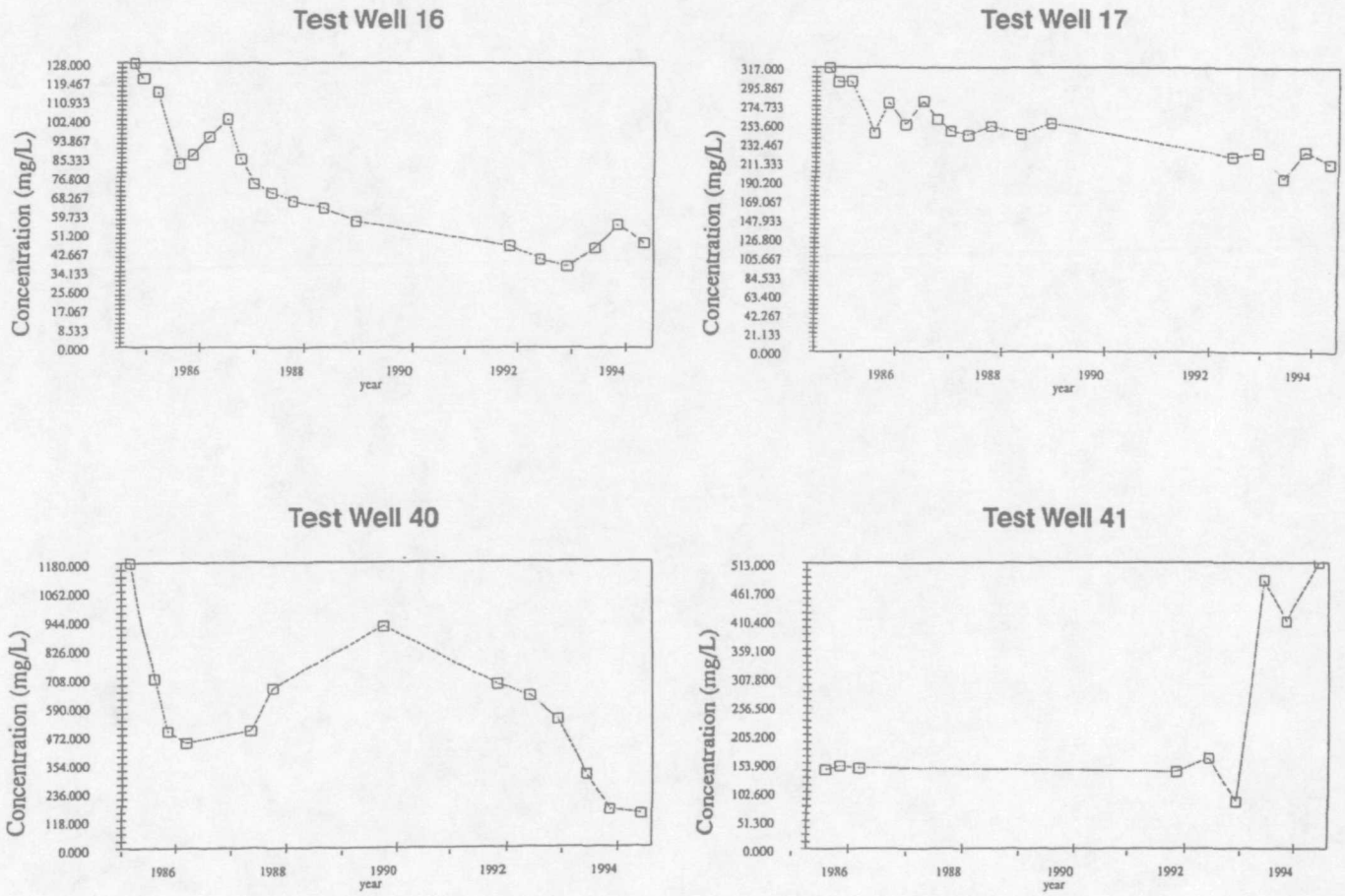
FIGURE **4-35**

CHLORIDE TIME HISTORY PLOTS IN THE OLD UNDERFLOW SOLIDS PONDS AREA

MONSANTO/PHASE II RI/ID

PROJECT NO.913 1101.608 DRAWING NO. 53506 DATE 10/17/94 DRAWN BY EA

Golder Associates



□ Sample result

⊠ Sample result below detection limit

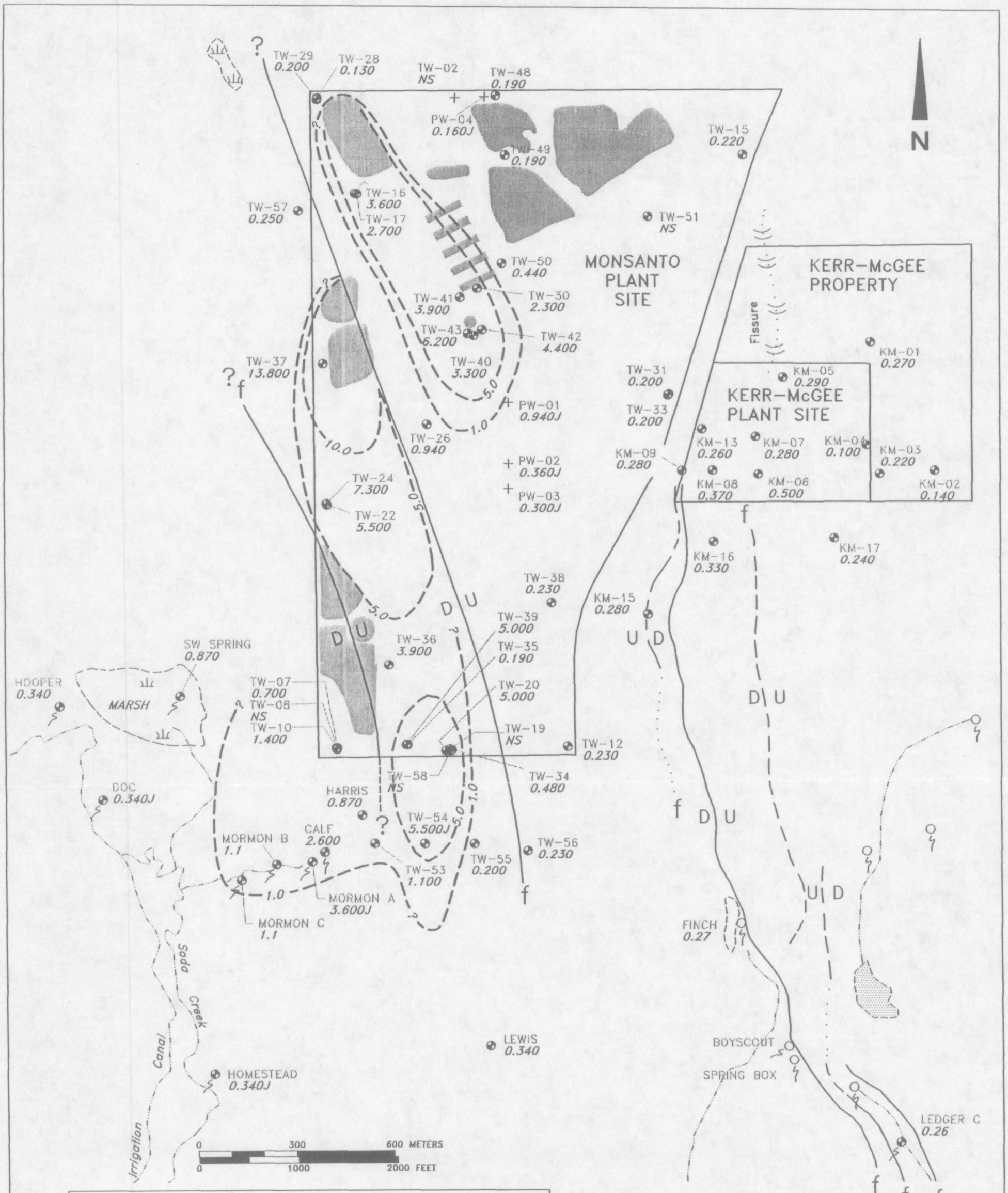
FIGURE **4-36**

CHLORIDE TIME HISTORY PLOTS IN THE NORTHWEST POND/HYDROCLARIFIER AREA

MONSANTO/PHASE II RI/ID

PROJECT NO.913 1101.608 DRAWING NO. 53507 DATE 10/17/94 DRAWN BY EA

Golder Associates



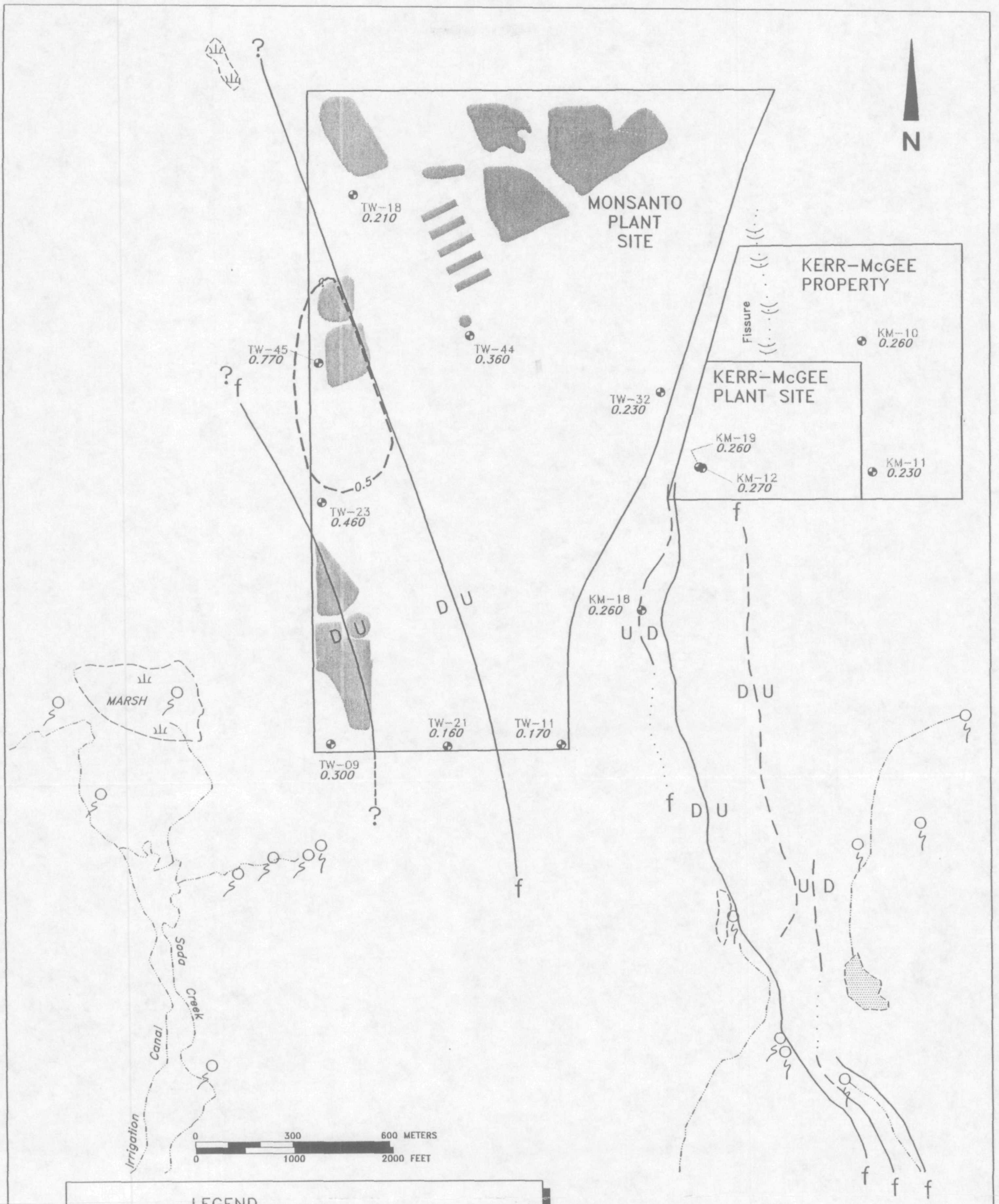
LEGEND

TW-35	Monitoring well location and name
+ PW-1	Production well location and name
CALF	Spring location and name (if sampled)
BOYSCOUT	Spring location and name (not sampled)
242	Concentration (mg/l) with qualifier (if any): CRDL = Contract Required Detection Limit; IDL = Instrument Detection Limit; U = Undetected; B = Detected between the CRDL and IDL; J = Estimated below IDL
NS	No sample collected
100	Concentration contour (mg/l)
f	Fault (dashed where inferred)

FIGURE **4-37**

FLUORIDE GROUNDWATER CONCENTRATIONS IN THE UPPER BASALT ZONE DURING MAY 1993

MONSANTO/PHASE II RI REPORT/ID



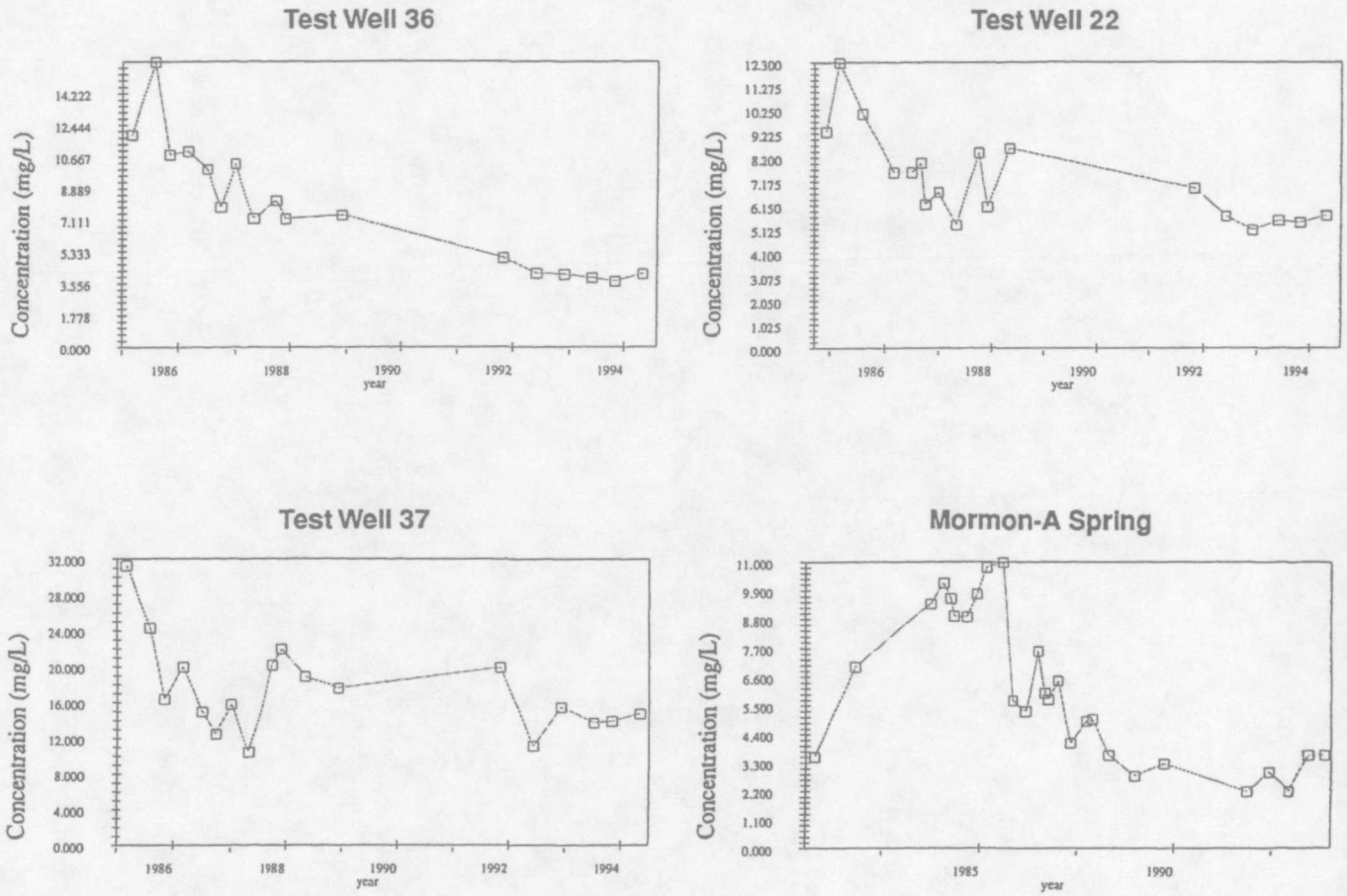
LEGEND

TW-35	Monitoring well location and name
+ PW-1	Production well location and name
CALF	Spring location and name (if sampled)
BOYSCOUT	Spring location and name (not sampled)
242	Concentration (mg/l) with qualifier (if any): CRDL = Contract Required Detection Limit IDL = Instrument Detection Limit U = Undetected B = Detected between the CRDL and IDL J = Estimated below IDL
NS	No sample collected
100 — —	Concentration contour (mg/l)
f — — · —	Fault (dashed where inferred)

FIGURE **4-38**

FLORIDE GROUNDWATER CONCENTRATIONS IN THE LOWER BASALT ZONE DURING MAY 1993

MONSANTO/PHASE II RI REPORT/ID



☐ Sample result

☒ Sample result below detection limit

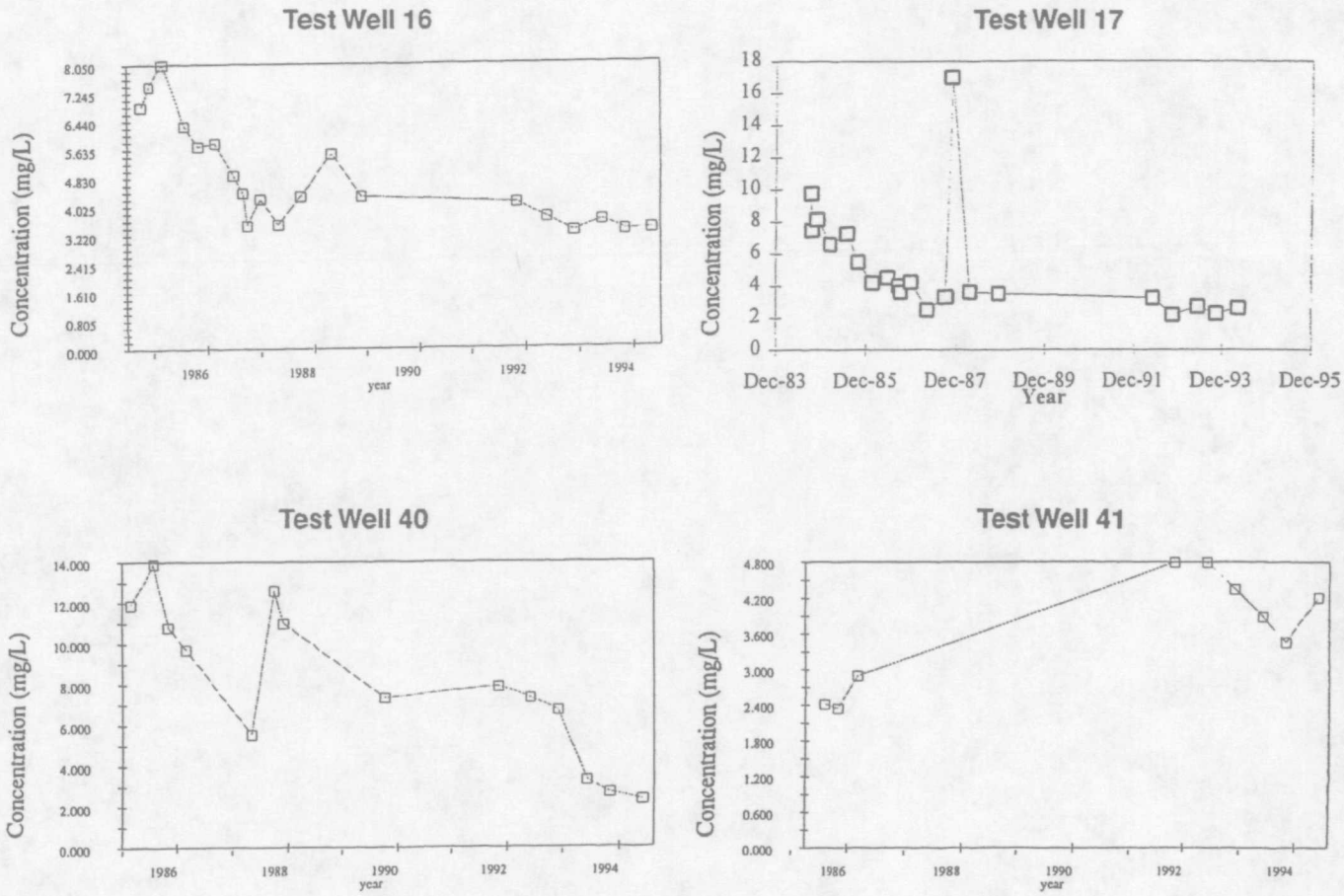
FIGURE **4-39**

FLUORIDE TIME HISTORY PLOTS IN THE OLD UNDERFLOW SOLIDS PONDS AREA

MONSANTO/PHASE II RI/ID

PROJECT NO.913 1101.608 DRAWING NO. 53508 DATE 10/17/94 DRAWN BY EA

Golder Associates



□ Sample result

⊠ Sample result below detection limit

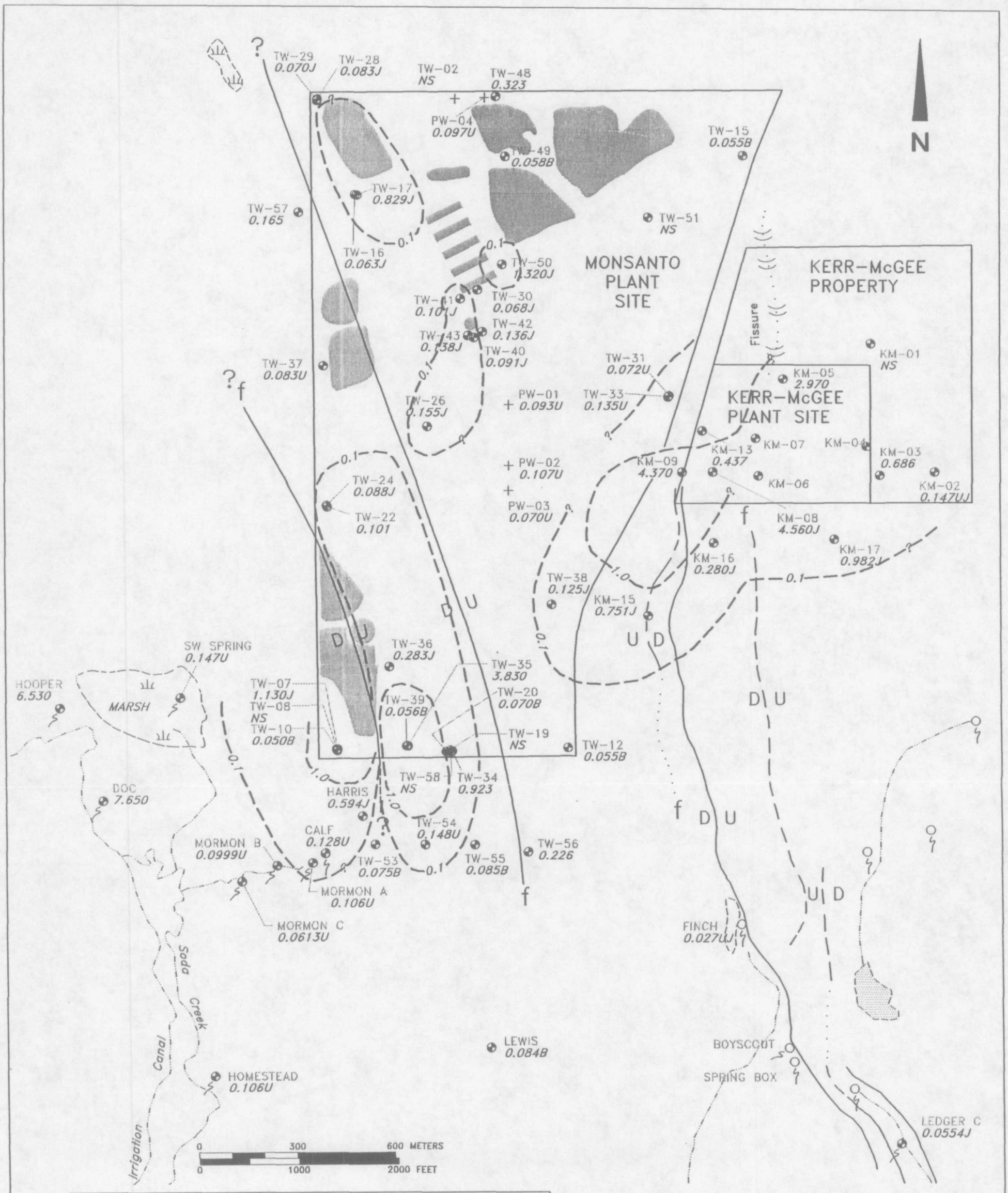
FIGURE **4-40**

FLUORIDE TIME HISTORY PLOTS IN THE NORTHWEST POND/HYDROCLARIFIER AREA

MONSANTO/PHASE II RI/ID

PROJECT NO.913 1101.608 DRAWING NO. 53509 DATE 10/17/94 DRAWN BY EA

Golder Associates



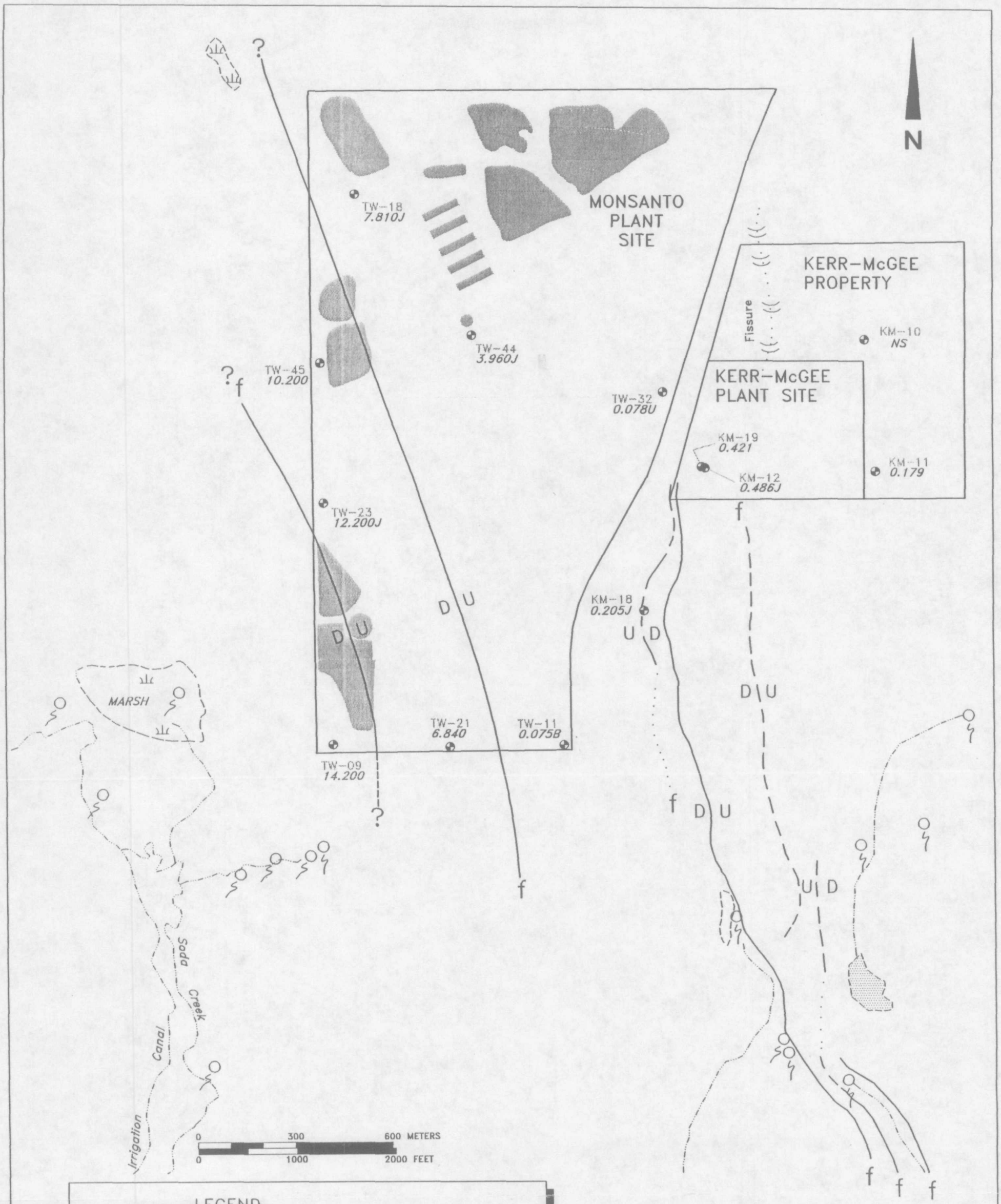
LEGEND

TW-35	Monitoring well location and name
PW-1	Production well location and name
CALF	Spring location and name (if sampled)
BOYSCOUT	Spring location and name (not sampled)
242	Concentration (mg/l) with qualifier (if any): CRDL = Contract Required Detection Limit; IDL = Instrument Detection Limit; U = Undetected; B = Detected between the CRDL and IDL; J = Estimated below IDL
NS	No sample collected
100 — — —	Concentration contour (mg/l)
f — — · —	Fault (dashed where inferred)

FIGURE **4-41**

IRON GROUNDWATER CONCENTRATIONS IN THE UPPER BASALT ZONE DURING MAY 1993

MONSANTO/PHASE II RI REPORT/ID



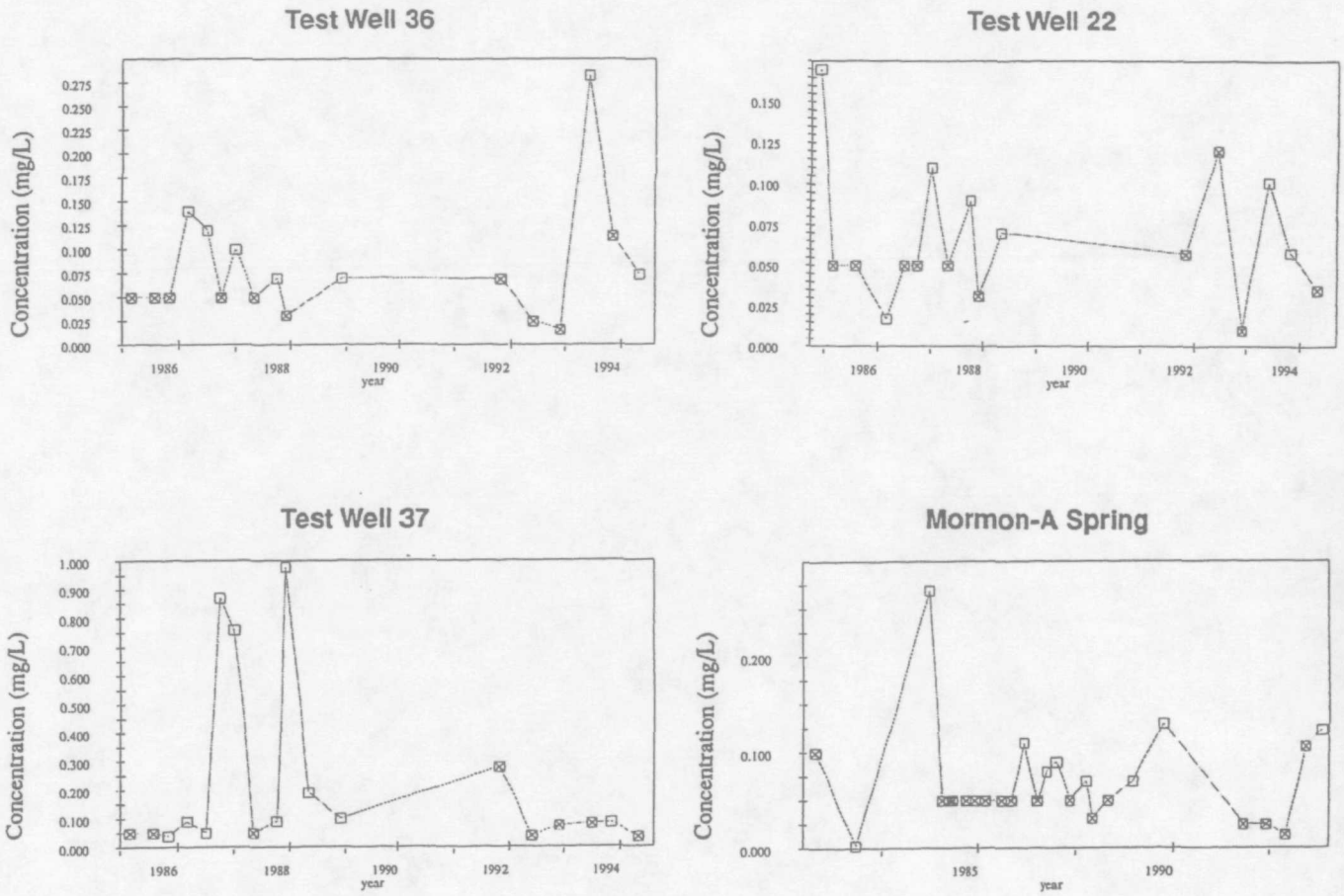
LEGEND

TW-35	Monitoring well location and name
+ PW-1	Production well location and name
CALF	Spring location and name (if sampled)
BOYSCOUT	Spring location and name (not sampled)
242	Concentration (mg/l) with qualifier (if any): CRDL = Contract Required Detection Limit IDL = Instrument Detection Limit U = Undetected B = Detected between the CRDL and IDL J = Estimated below IDL
NS	No sample collected
100 — —	Concentration contour (mg/l)
f — — · —	Fault (dashed where inferred)

FIGURE **4-42**

IRON GROUNDWATER CONCENTRATIONS IN THE LOWER BASALT ZONE DURING MAY 1993

MONSANTO/PHASE II RI REPORT/ID



□ Sample result

⊠ Sample result below detection limit

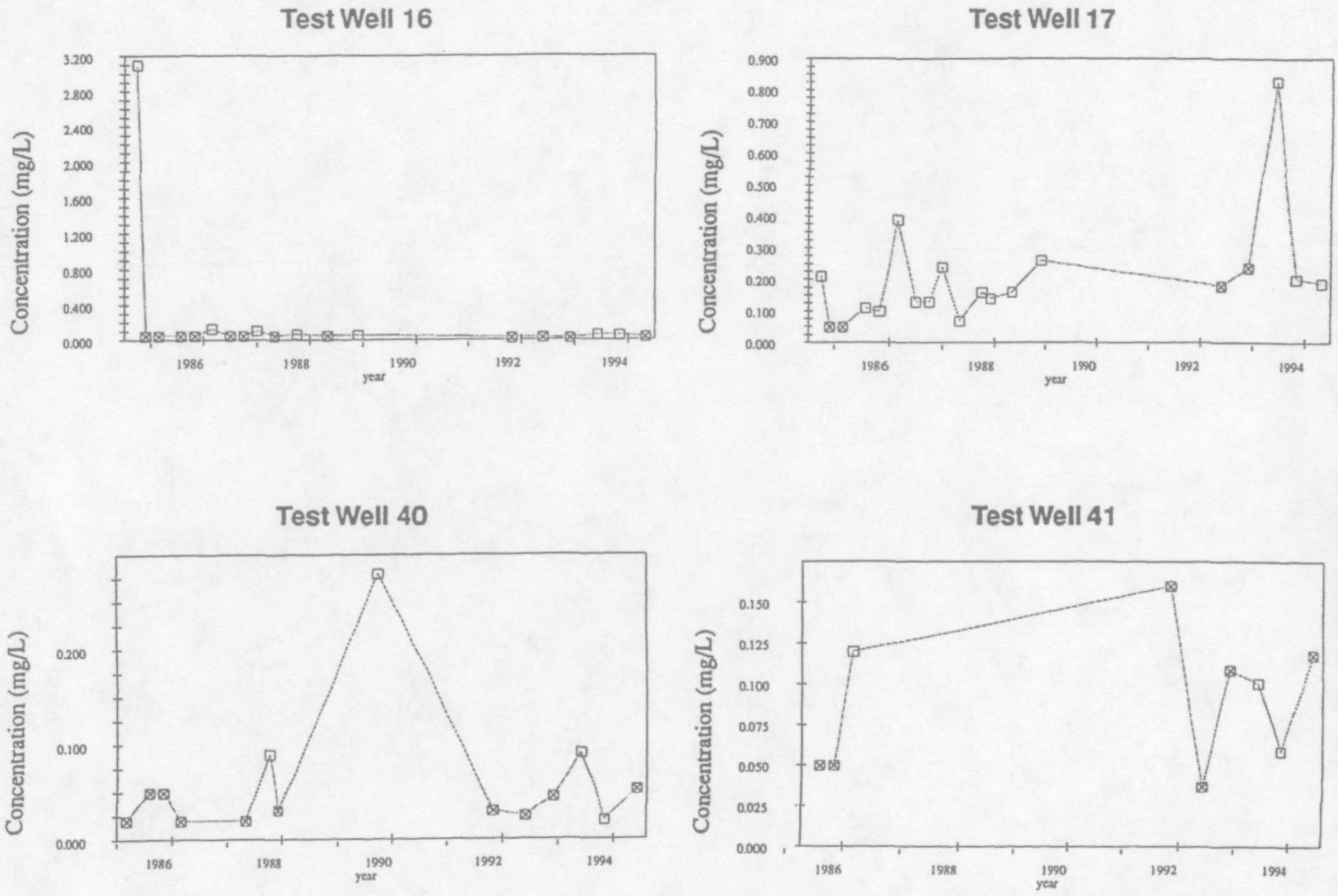
FIGURE **4-43**

IRON TIME HISTORY PLOTS IN THE OLD UNDERFLOW SOLIDS PONDS AREA

MONSANTO/PHASE II RI/ID

PROJECT NO.913 1101.608 DRAWING NO. 53510 DATE 10/17/94 DRAWN BY EA

Golder Associates



□ Sample result

⊠ Sample result below detection limit

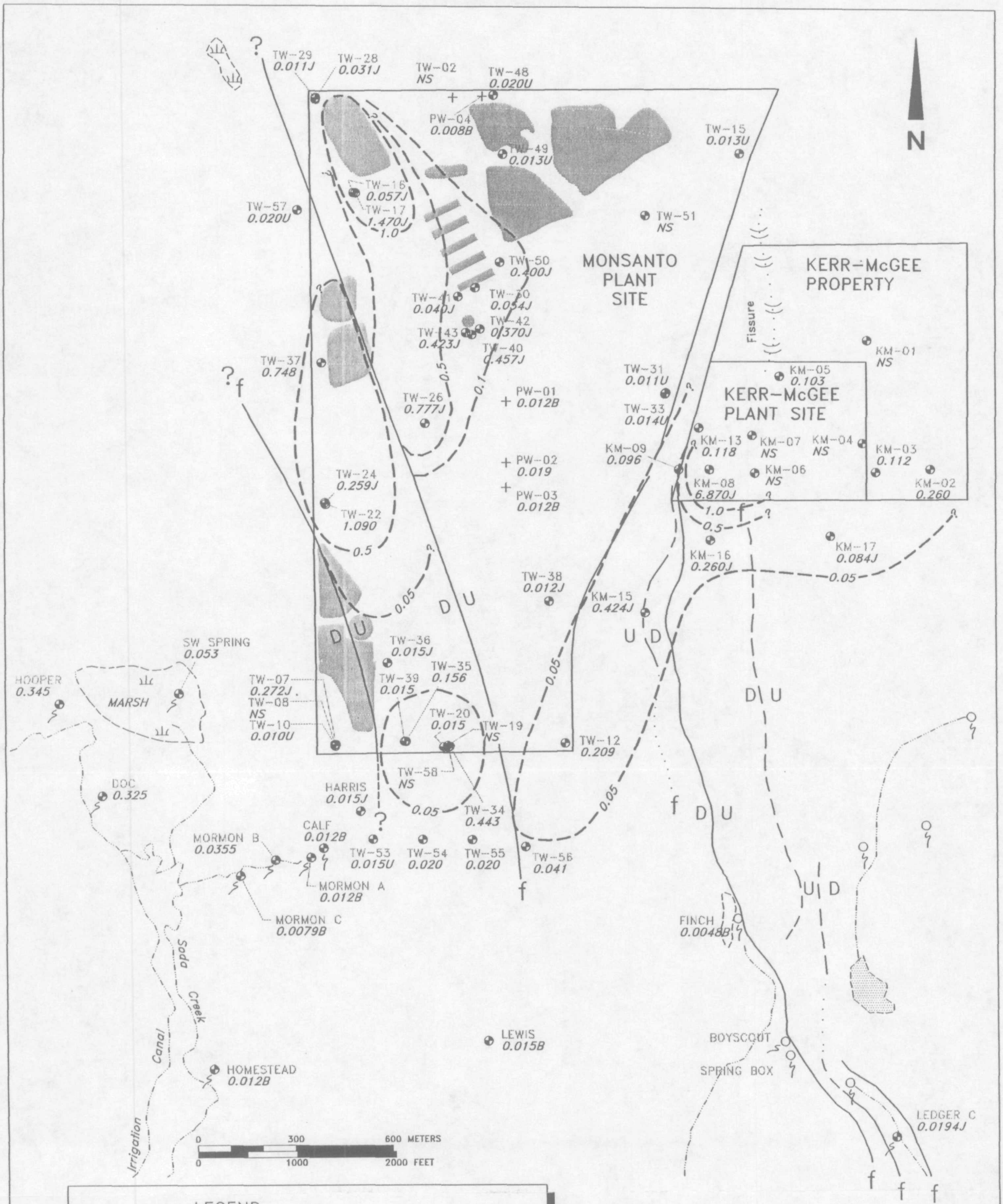
FIGURE **4-44**

IRON TIME HISTORY PLOTS IN THE NORTHWEST POND/HYDROCLARIFIER AREA

MONSANTO/PHASE II RI/ID

PROJECT NO.913 1101.608 DRAWING NO. 53511 DATE 10/17/94 DRAWN BY EA

Golder Associates



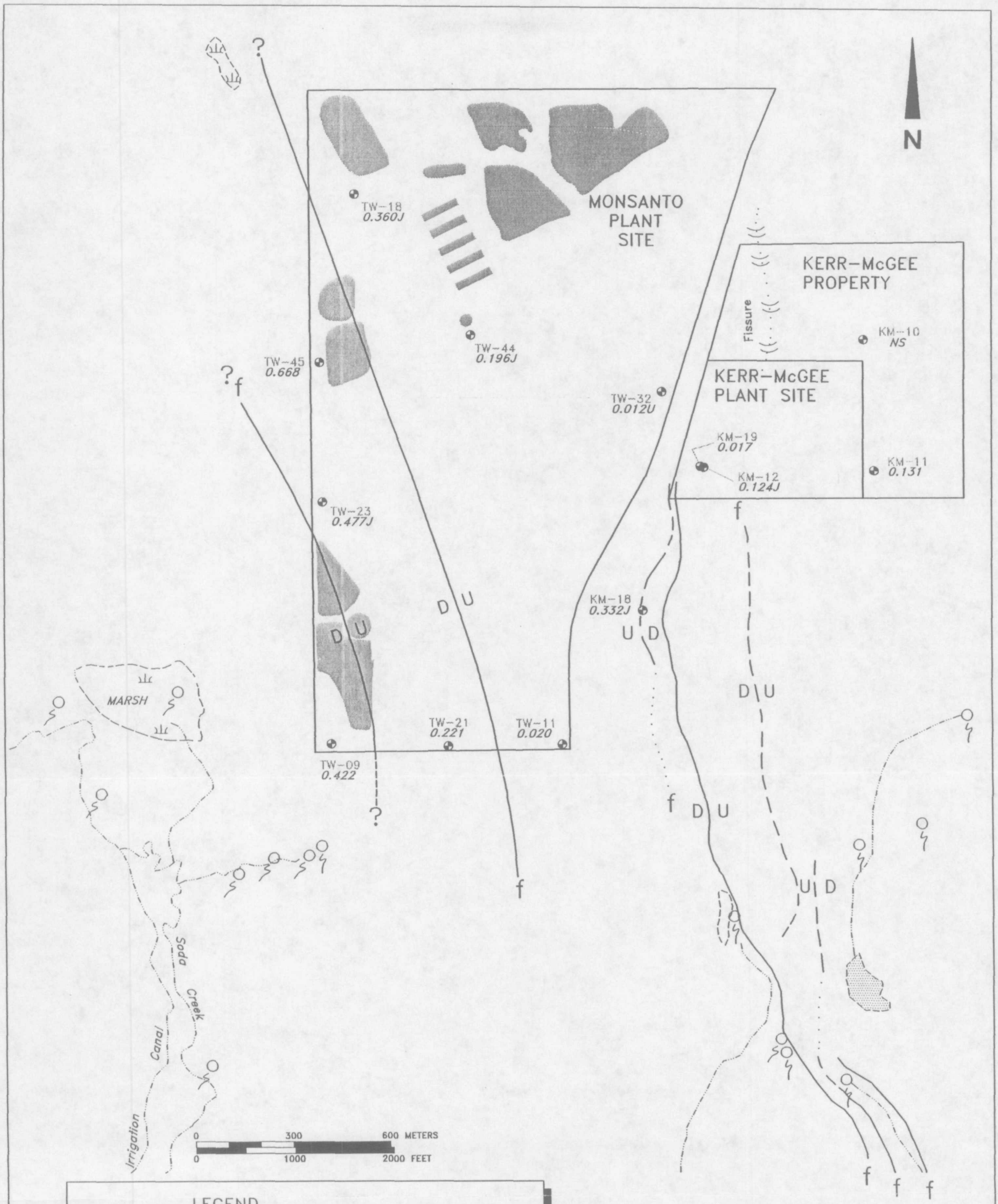
LEGEND

TW-35	Monitoring well location and name
+ PW-1	Production well location and name
CALF	Spring location and name (if sampled)
BOYSCOUT	Spring location and name (not sampled)
242	Concentration (mg/l) with qualifier (if any): CRDL = Contract Required Detection Limit; IDL = Instrument Detection Limit; U = Undetected; B = Detected between the CRDL and IDL; J = Estimated below IDL
NS	No sample collected
100	Concentration contour (mg/l)
f	Fault (dashed where inferred)

FIGURE **4-45**

MANGANESE GROUNDWATER CONCENTRATIONS IN THE UPPER BASALT ZONE DURING MAY 1993

MONSANTO/PHASE II RI REPORT/ID



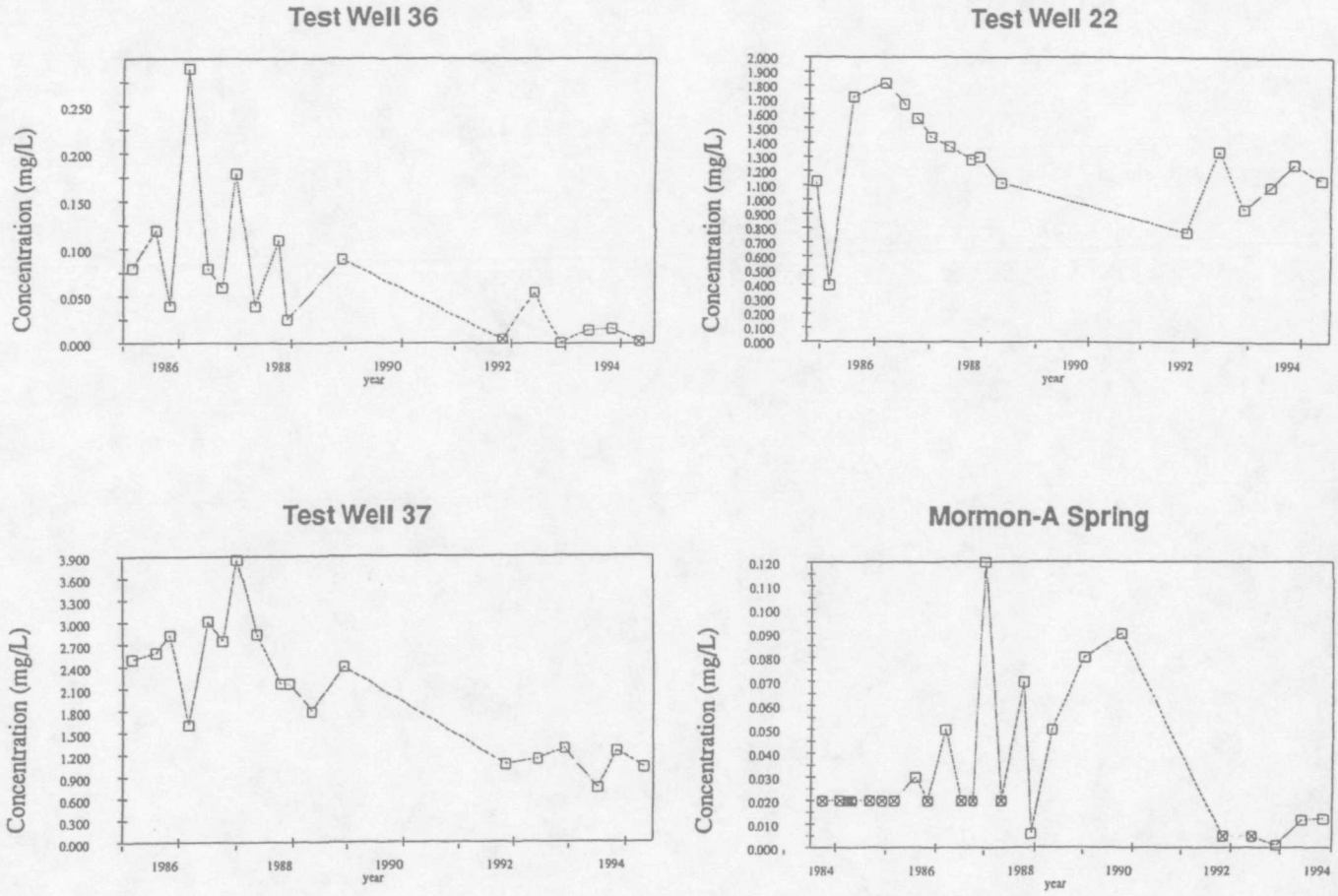
LEGEND

TW-35	Monitoring well location and name
+ PW-1	Production well location and name
CALF	Spring location and name (if sampled)
BOYSCOUT	Spring location and name (not sampled)
242	Concentration (mg/l) with qualifier (if any): CRDL = Contract Required Detection Limit IDL = Instrument Detection Limit U = Undetected B = Detected between the CRDL and IDL J = Estimated below IDL
NS	No sample collected
100	Concentration contour (mg/l)
f	Fault (dashed where inferred)

FIGURE **4-46**

MANGANESE GROUNDWATER CONCENTRATIONS IN THE LOWER BASALT ZONE DURING MAY 1993

MONSANTO/PHASE II RI REPORT/ID



□ Sample result

⊠ Sample result below detection limit

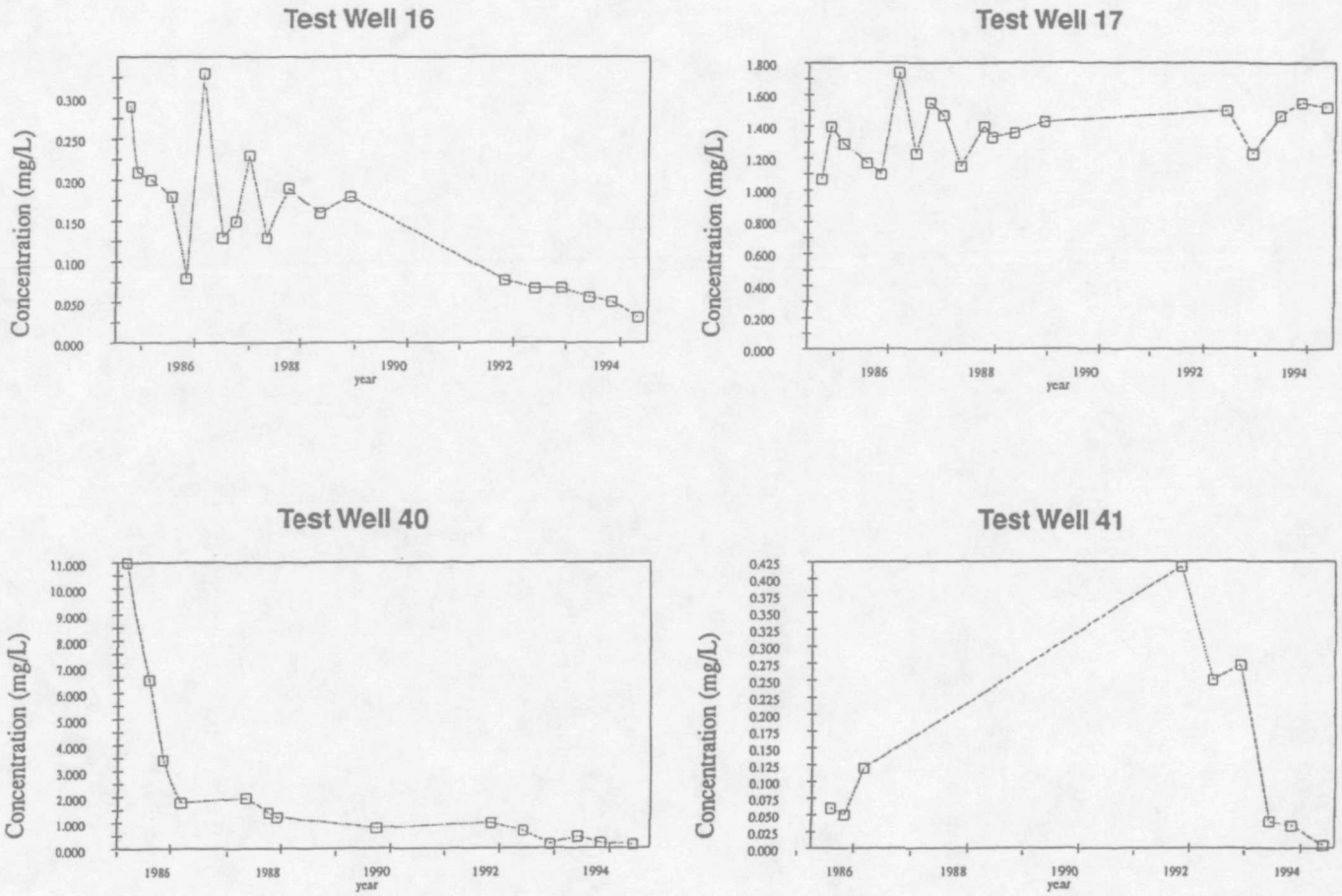
FIGURE **4-47**

MANGANESE TIME HISTORY PLOTS IN THE OLD UNDERFLOW SOLIDS PONDS AREA

MONSANTO/PHASE II RI/ID

PROJECT NO.913 1101.608 DRAWING NO. 53512 DATE 10/17/94 DRAWN BY EA

Golder Associates



☐ Sample result

☒ Sample result below detection limit

FIGURE **4-48**

MANGANESE TIME HISTORY PLOTS IN THE NORTHWEST POND/HYDROCLARIFIER AREA

MONSANTO/PHASE II RI/ID

PROJECT NO.913 1101.608 DRAWING NO. 53513 DATE 10/17/94 DRAWN BY EA

Golder Associates

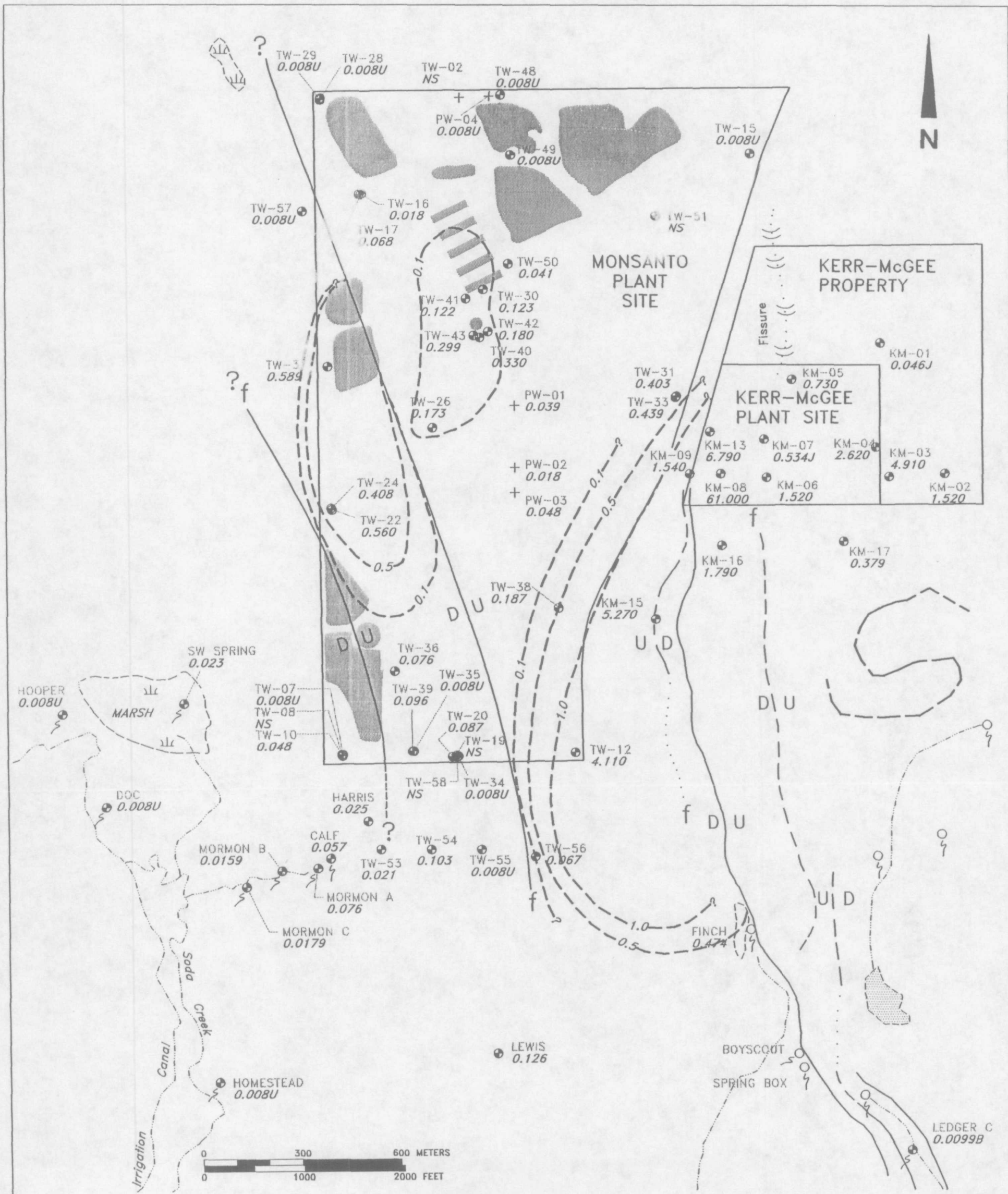
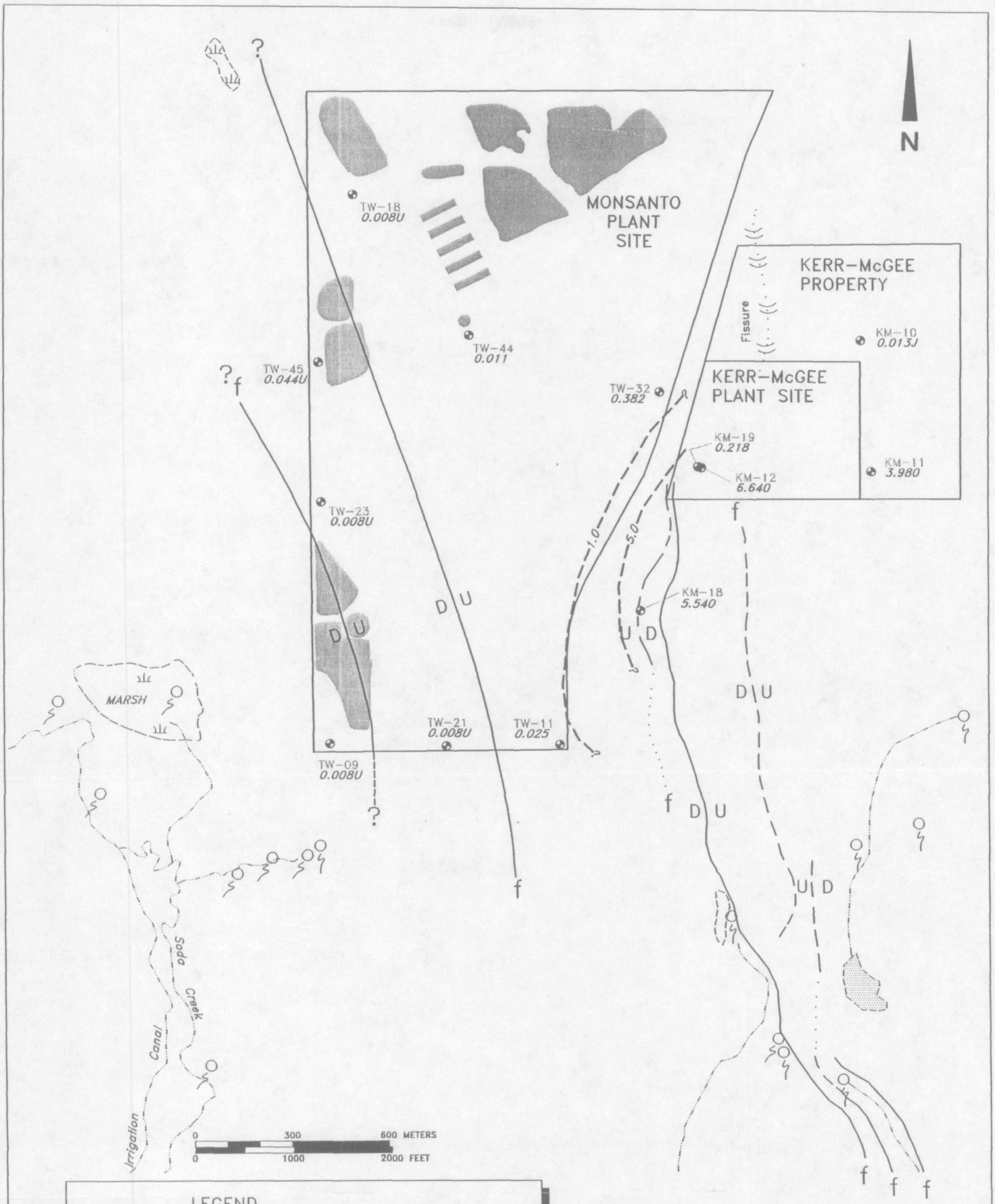


FIGURE 4-49
MOLYBDENUM GROUNDWATER CONCENTRATIONS IN THE UPPER BASALT ZONE DURING MAY 1993
MONSANTO/PHASE II RI REPORT/ID

\JPM\9131101\608\51080 1-26-95 16:49

Golder Associates



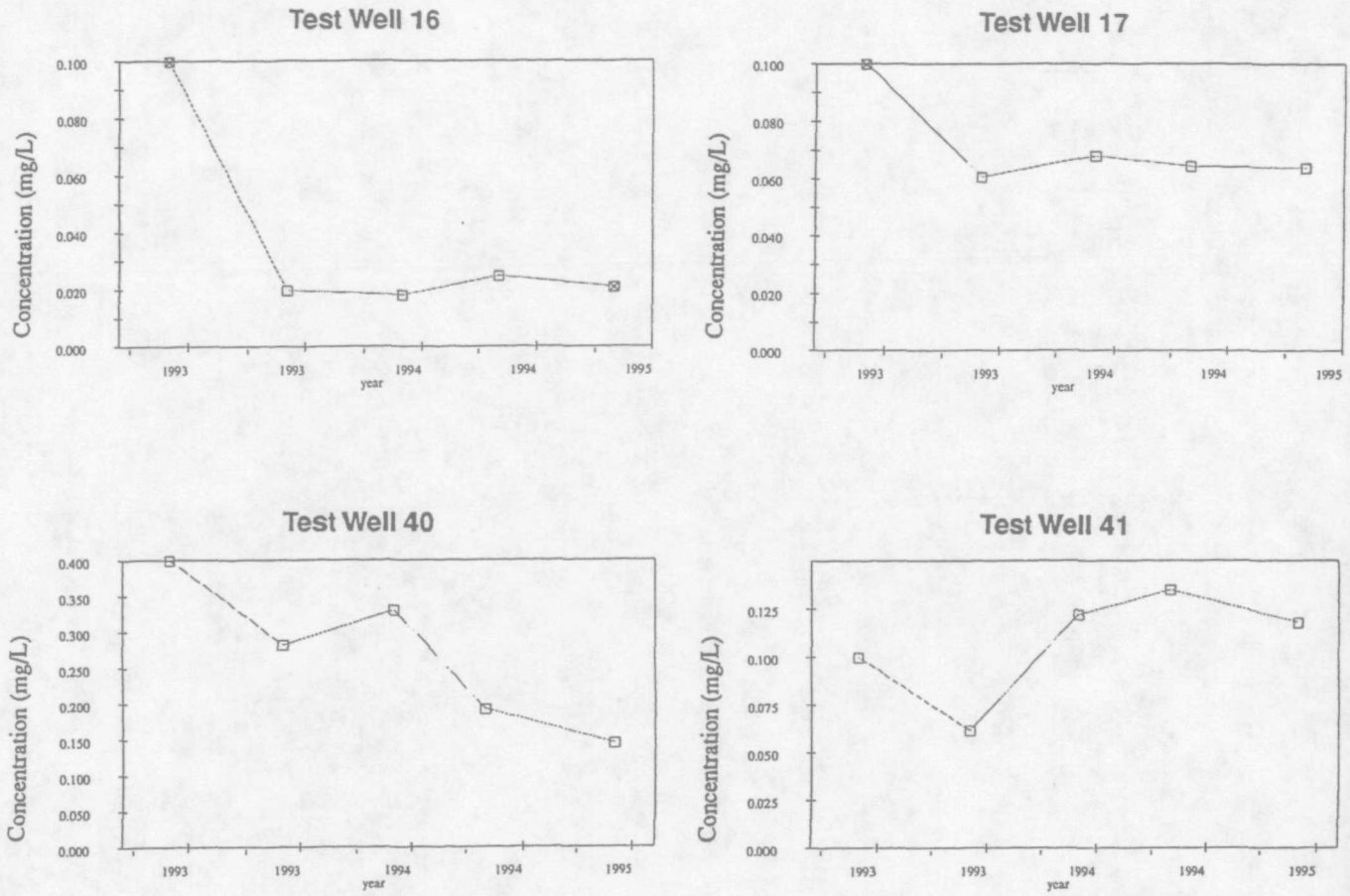
LEGEND

TW-35	Monitoring well location and name
+ PW-1	Production well location and name
CALF	Spring location and name (if sampled)
BOYSCOUT	Spring location and name (not sampled)
242	Concentration (mg/l) with qualifier (if any): CRDL = Contract Required Detection Limit IDL = Instrument Detection Limit U = Undetected B = Detected between the CRDL and IDL J = Estimated below IDL
NS	No sample collected
100 — —	Concentration contour (mg/l)
f — — · —	Fault (dashed where inferred)

FIGURE **4-50**

MOLYBDENUM GROUNDWATER CONCENTRATIONS IN THE LOWER BASALT ZONE DURING MAY 1993

MONSANTO/PHASE II RI REPORT/ID



□ Sample result

⊠ Sample result below detection limit

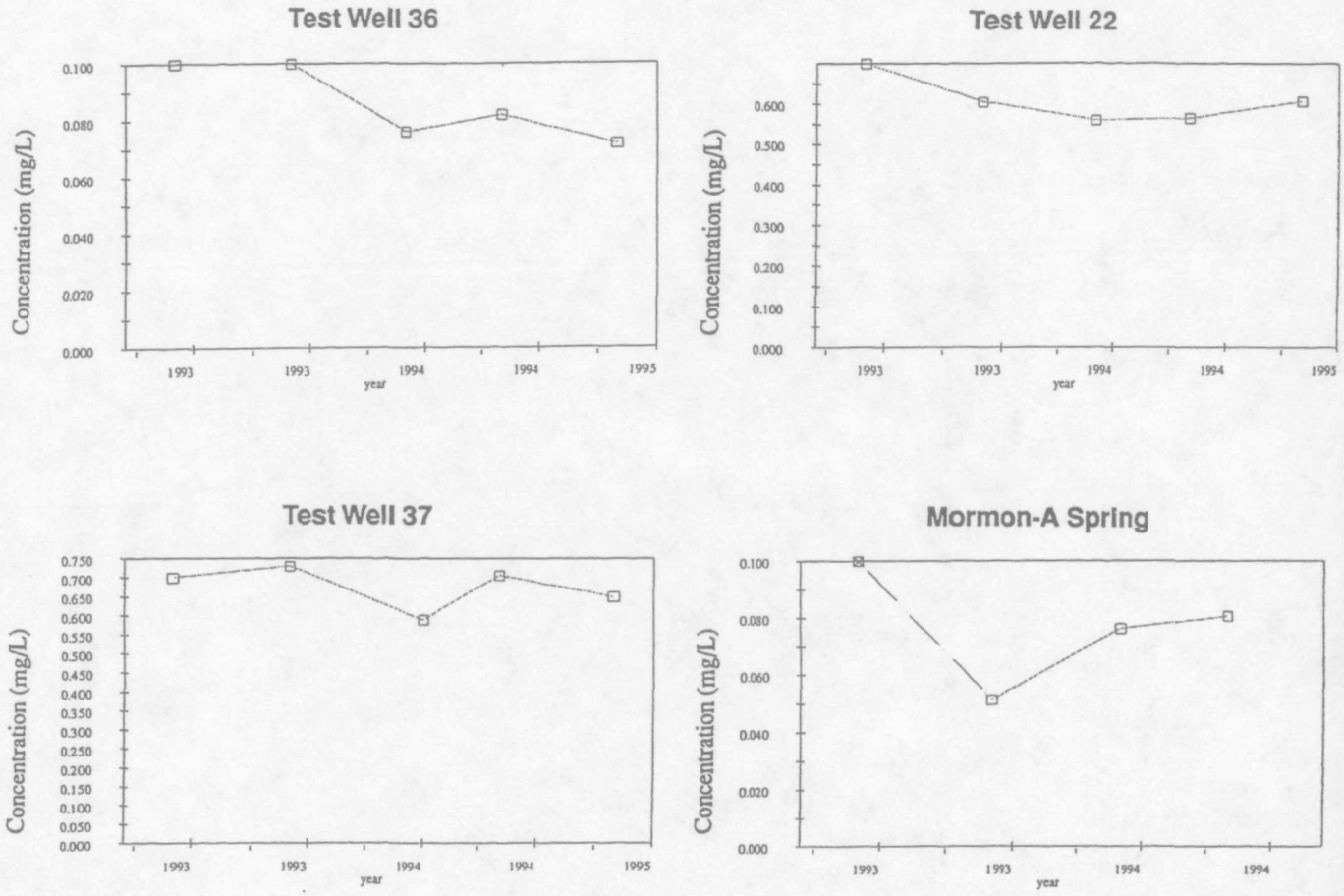
FIGURE **4-51**

MOLYBDENUM TIME HISTORY PLOTS IN THE NORTHWEST POND/HYDROCLARIFIER AREA

MONSANTO/PHASE II RI/ID

PROJECT NO.913 1101.608 DRAWING NO. 53514 DATE 10/17/94 DRAWN BY EA

Golder Associates



□ Sample result

⊠ Sample result below detection limit

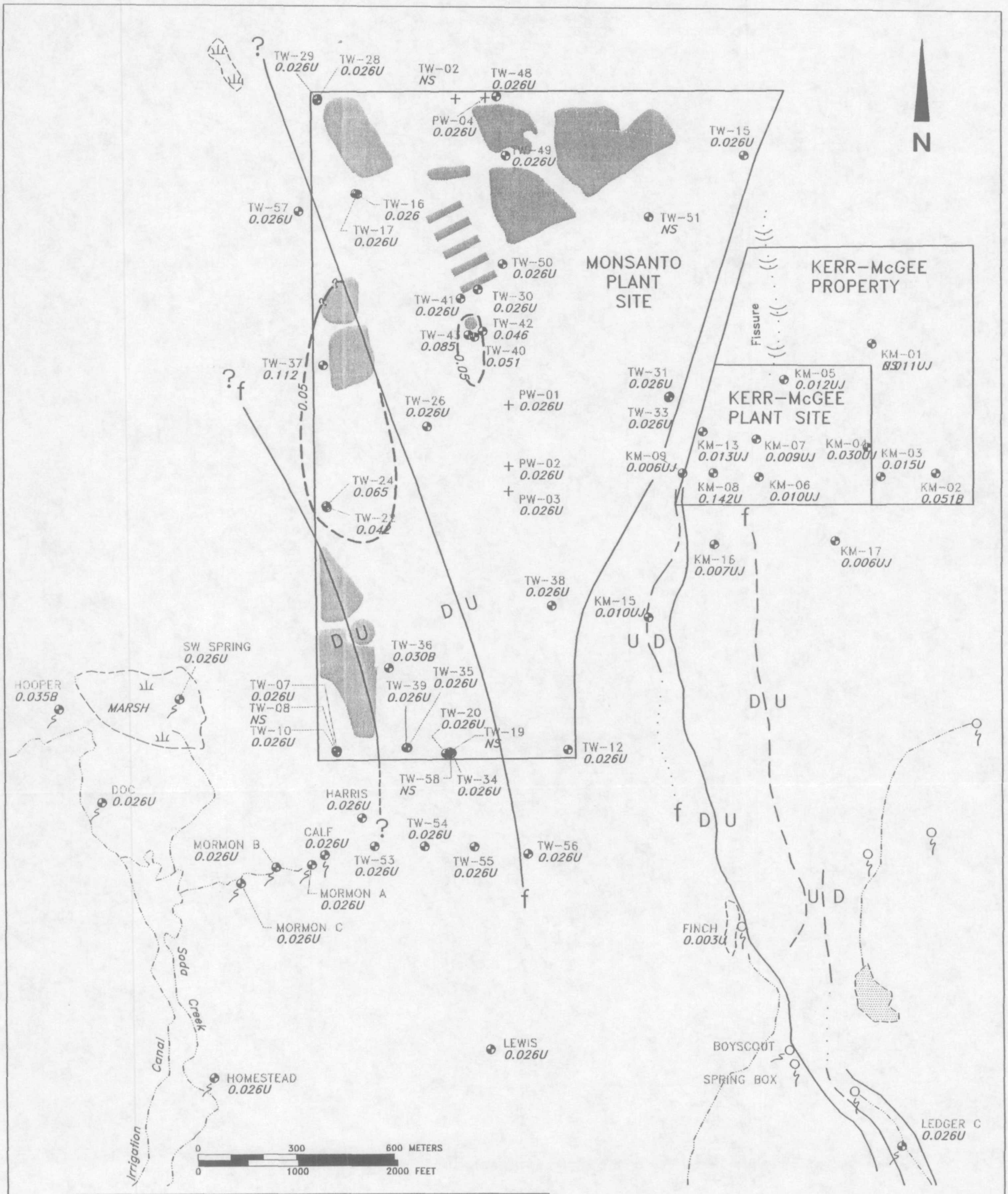
FIGURE **4-52**

MOLYBDENUM TIME HISTORY PLOTS IN THE OLD UNDERFLOW SOLIDS PONDS AREA

MONSANTO/PHASE II RI/ID

PROJECT NO.913 1101.608 DRAWING NO. 53515 DATE 10/17/94 DRAWN BY EA

Golder Associates



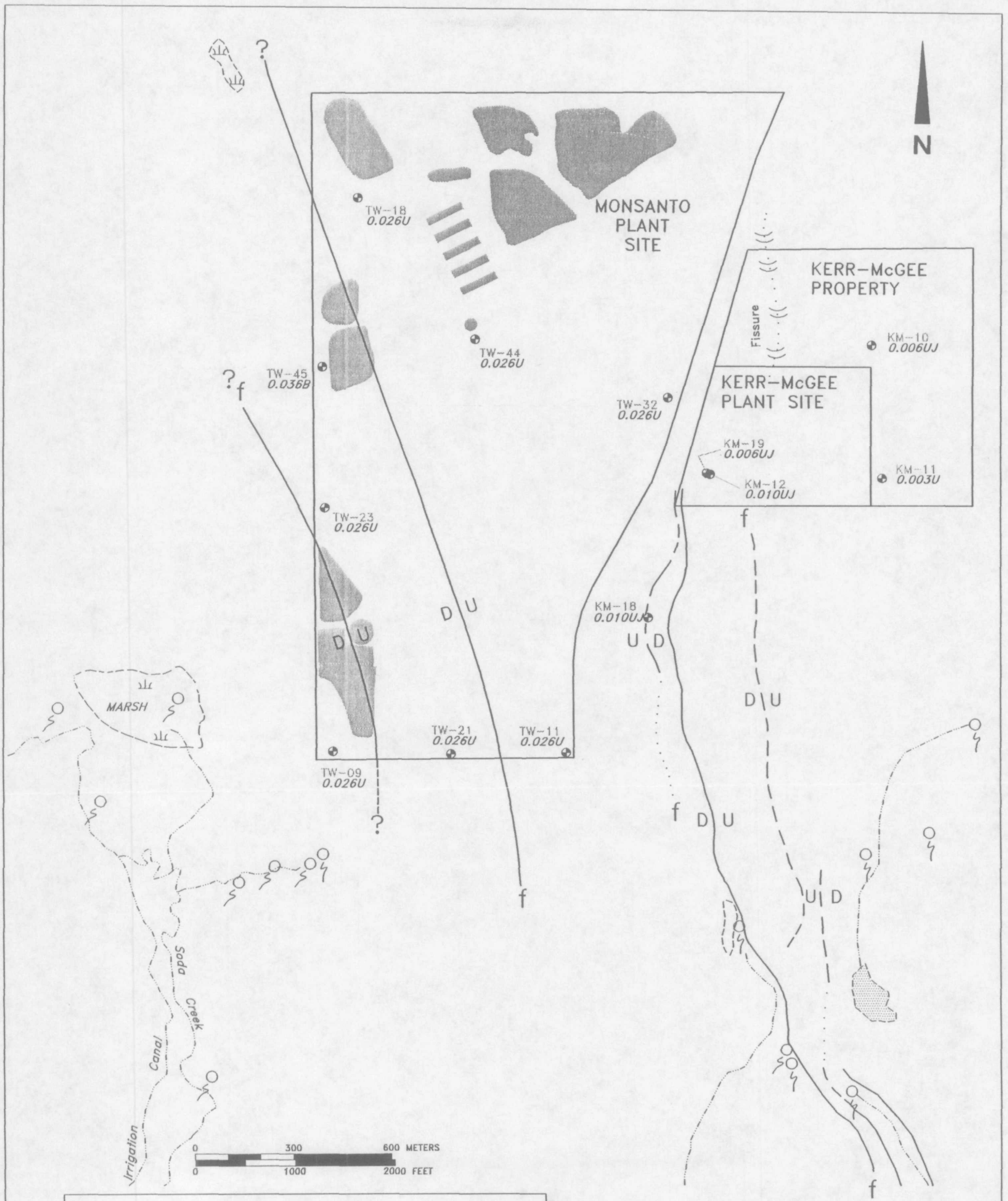
LEGEND

TW-35	Monitoring well location and name
PW-1	Production well location and name
CALF	Spring location and name (if sampled)
BOYSCOUT	Spring location and name (not sampled)
242	Concentration (mg/l) with qualifier (if any): CRDL = Contract Required Detection Limit; IDL = Instrument Detection Limit; U = Undetected; B = Detected between the CRDL and IDL; J = Estimated below IDL
NS	No sample collected
100	Concentration contour (mg/l)
f	Fault (dashed where inferred)

FIGURE **4-53**

NICKEL GROUNDWATER CONCENTRATIONS IN THE UPPER BASALT ZONE DURING MAY 1993

MONSANTO/PHASE II RI REPORT/ID



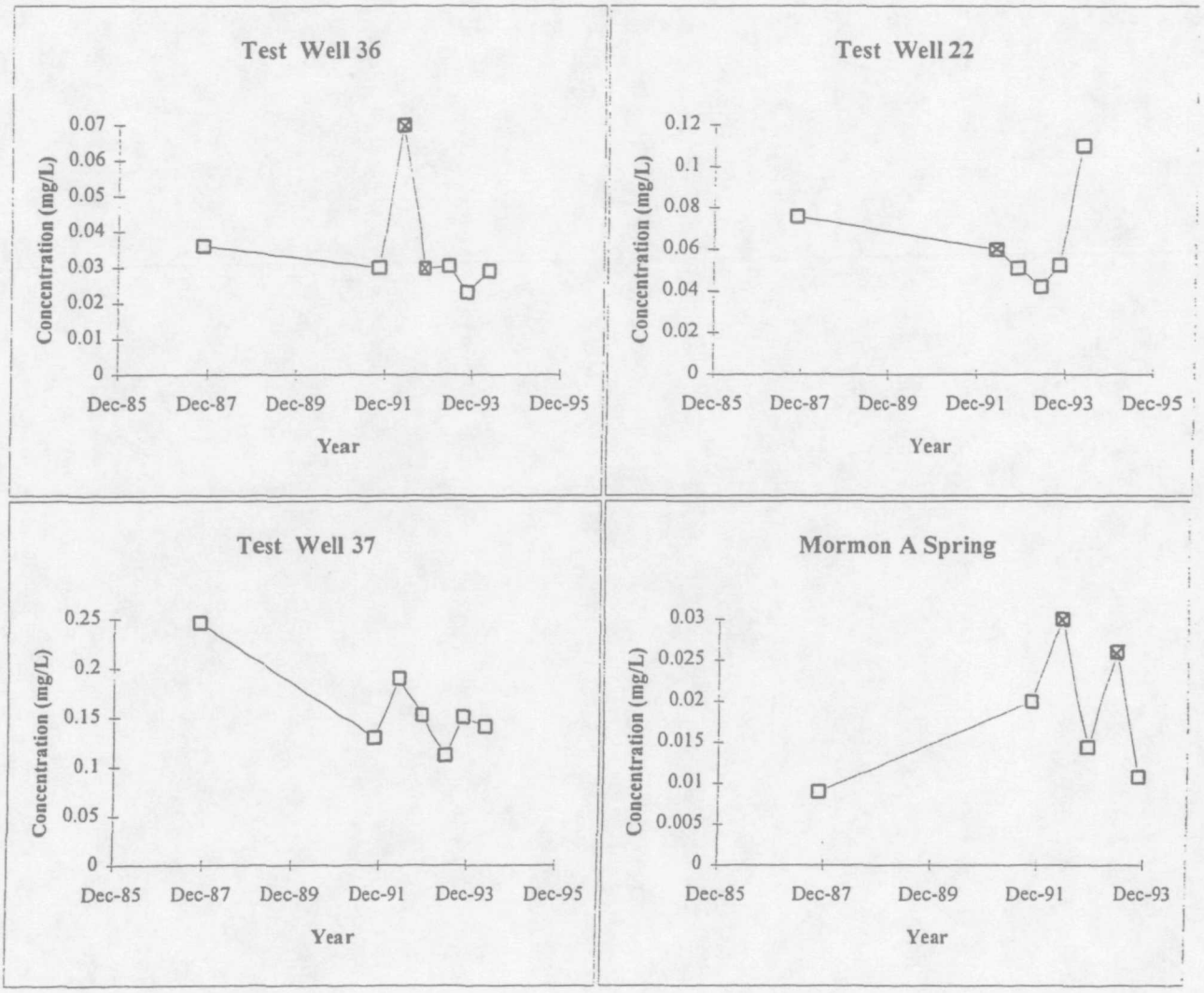
LEGEND

TW-35	Monitoring well location and name
+ PW-1	Production well location and name
CALF	Spring location and name (if sampled)
BOYSCOUT	Spring location and name (not sampled)
242	Concentration (mg/l) with qualifier (if any): CRDL = Contract Required Detection Limit IDL = Instrument Detection Limit U = Undetected B = Detected between the CRDL and IDL J = Estimated below IDL
NS	No sample collected
100	Concentration contour (mg/l)
f	Fault (dashed where inferred)

FIGURE **4-54**

NICKEL GROUNDWATER CONCENTRATIONS IN THE LOWER BASALT ZONE DURING MAY 1993

MONSANTO/PHASE II RI REPORT/ID



□ Sample result

⊠ Sample result below detection limit

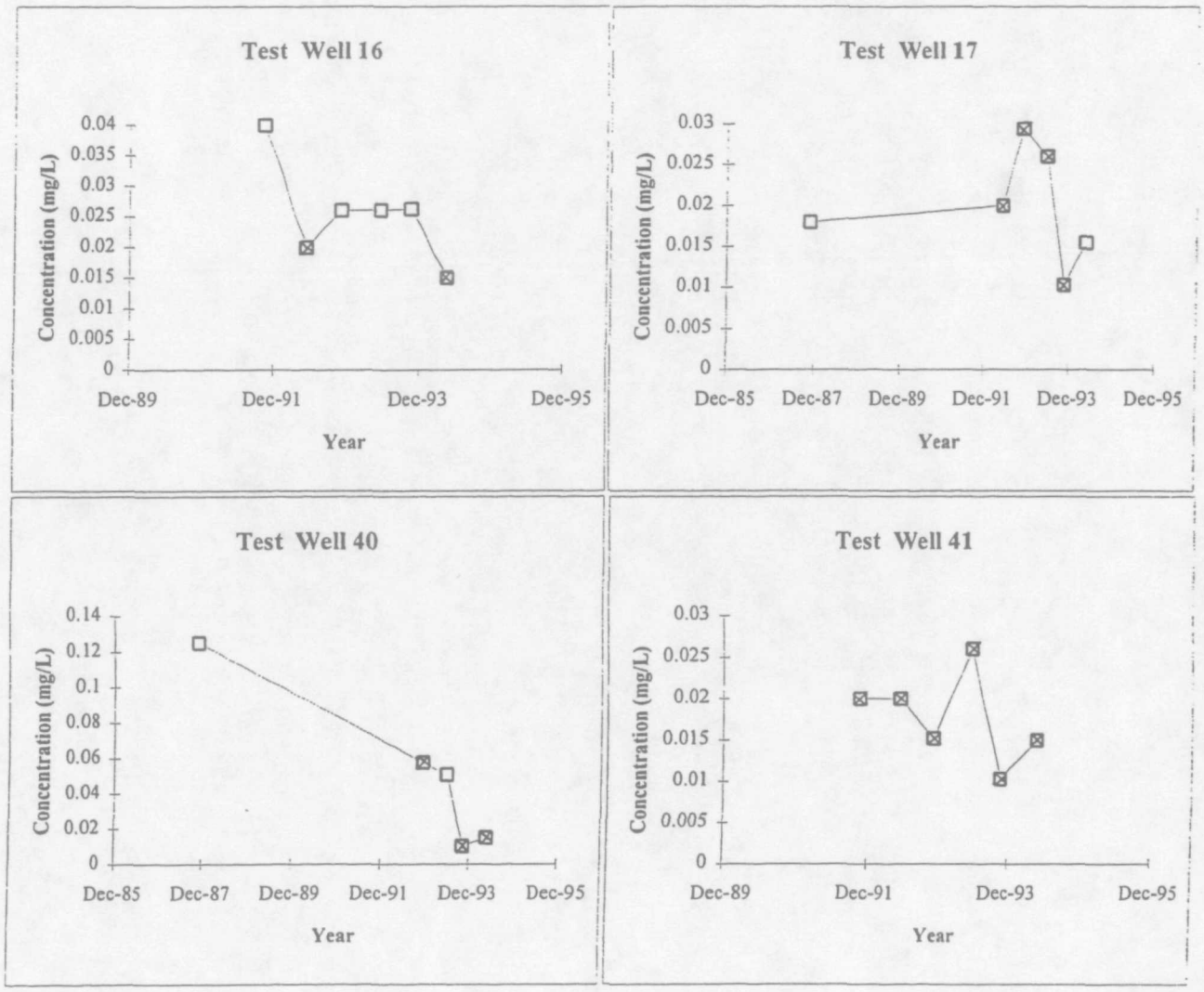
FIGURE **4-55**

NICKEL TIME HISTORY PLOTS IN THE OLD UNDERFLOW SOLIDS PONDS AREA

MONSANTO/PHASE II RI/ID

PROJECT NO.913 1101.608 DRAWING NO. 53516 DATE 10/17/94 DRAWN BY EA

Golder Associates



□ Sample result

⊠ Sample result below detection limit

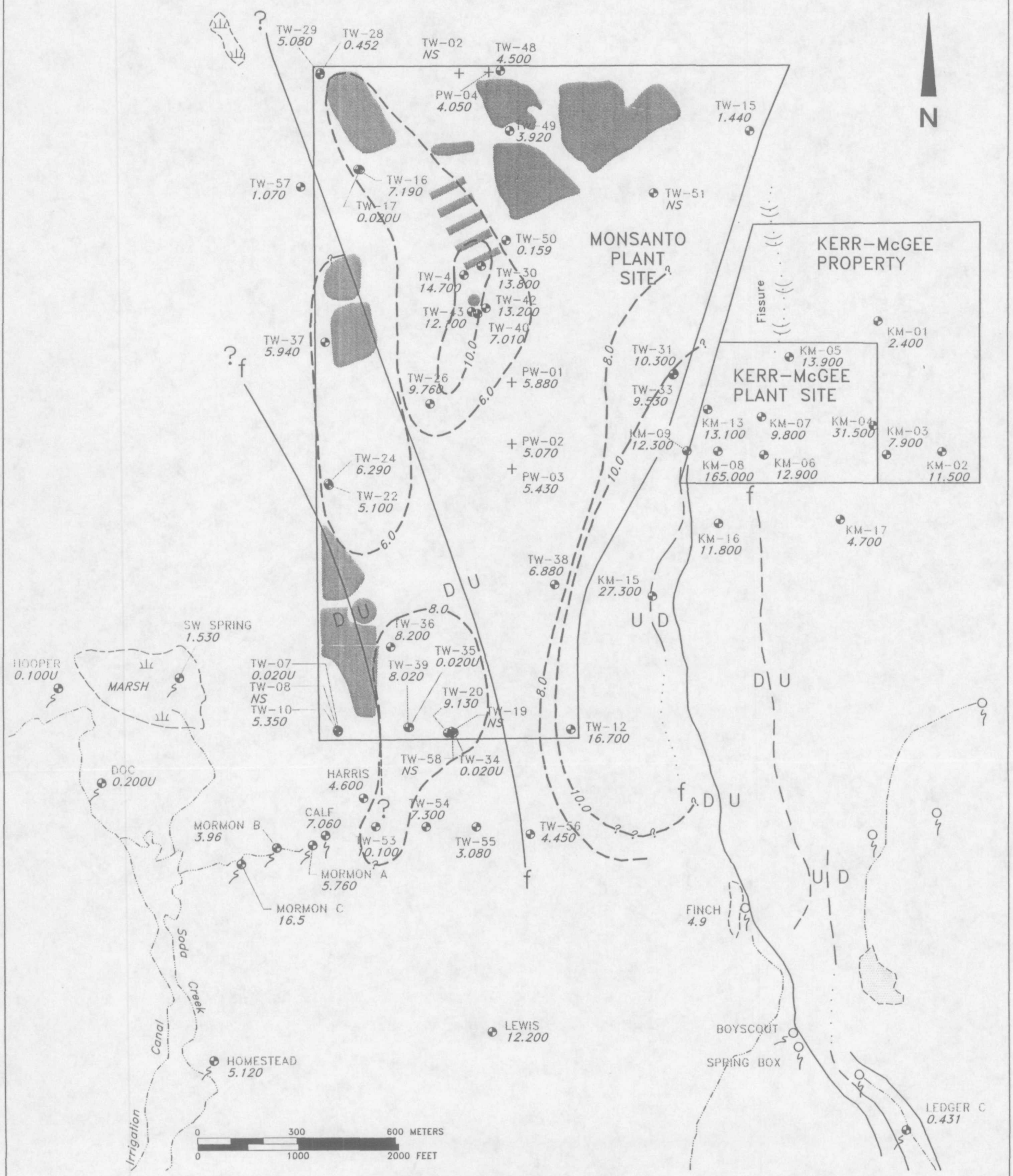
FIGURE **4-56**

NICKEL TIME HISTORY PLOTS IN THE NORTHWEST POND/HYDROCLARIFIER AREA

MONSANTO/PHASE II RI/ID

PROJECT NO.913 1101.608 DRAWING NO. 53517 DATE 10/17/94 DRAWN BY EA

Golder Associates



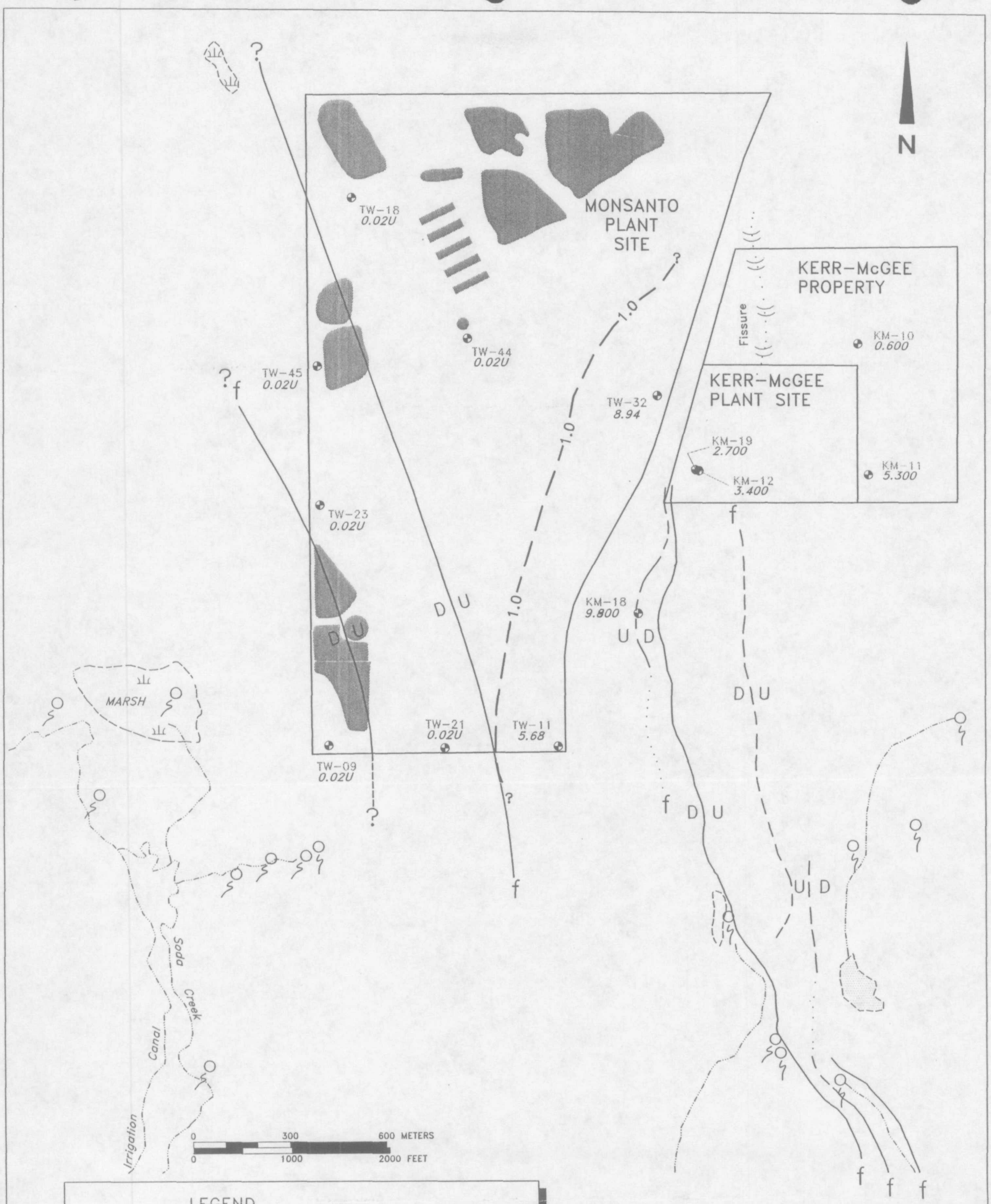
LEGEND

TW-35	Monitoring well location and name
+ PW-1	Production well location and name
CALF	Spring location and name (if sampled)
BOYSCOUT	Spring location and name (not sampled)
242	Concentration (mg/l) with qualifier (if any): CRDL = Contract Required Detection Limit; IDL = Instrument Detection Limit; U = Undetected; B = Detected between the CRDL and IDL; J = Estimated below IDL
NS	No sample collected
100 — —	Concentration contour (mg/l)
f — — · —	Fault (dashed where inferred)

FIGURE **4-57**

NITRATE-NITROGEN GROUNDWATER CONCENTRATIONS IN THE UPPER BASALT ZONE DURING MAY 1993

MONSANTO/PHASE II RI REPORT/ID



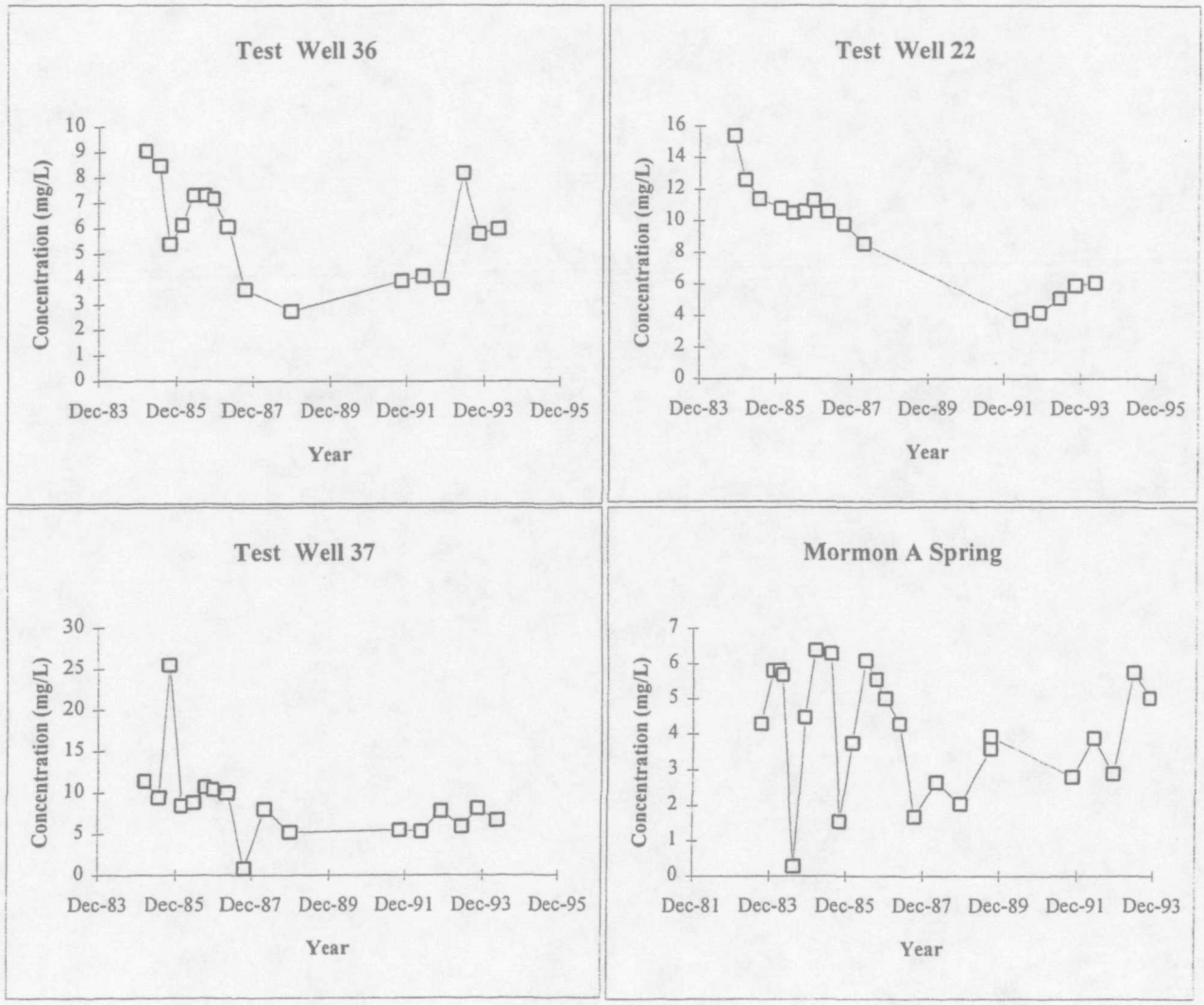
LEGEND

TW-35	Monitoring well location and name
PW-1	Production well location and name
CALF	Spring location and name (if sampled)
BOYSCOUT	Spring location and name (not sampled)
242	Concentration (mg/l) with qualifier (if any): CRDL = Contract Required Detection Limit; IDL = Instrument Detection Limit; U = Undetected; B = Detected between the CRDL and IDL; J = Estimated below IDL
NS	No sample collected
100	Concentration contour (mg/l)
f	Fault (dashed where inferred)

FIGURE 4-58

NITRATE-NITROGEN GROUNDWATER CONCENTRATIONS IN THE LOWER BASALT ZONE DURING MAY 1993

MONSANTO/PHASE II RI REPORT/ID



□ Sample result

⊠ Sample result below detection limit

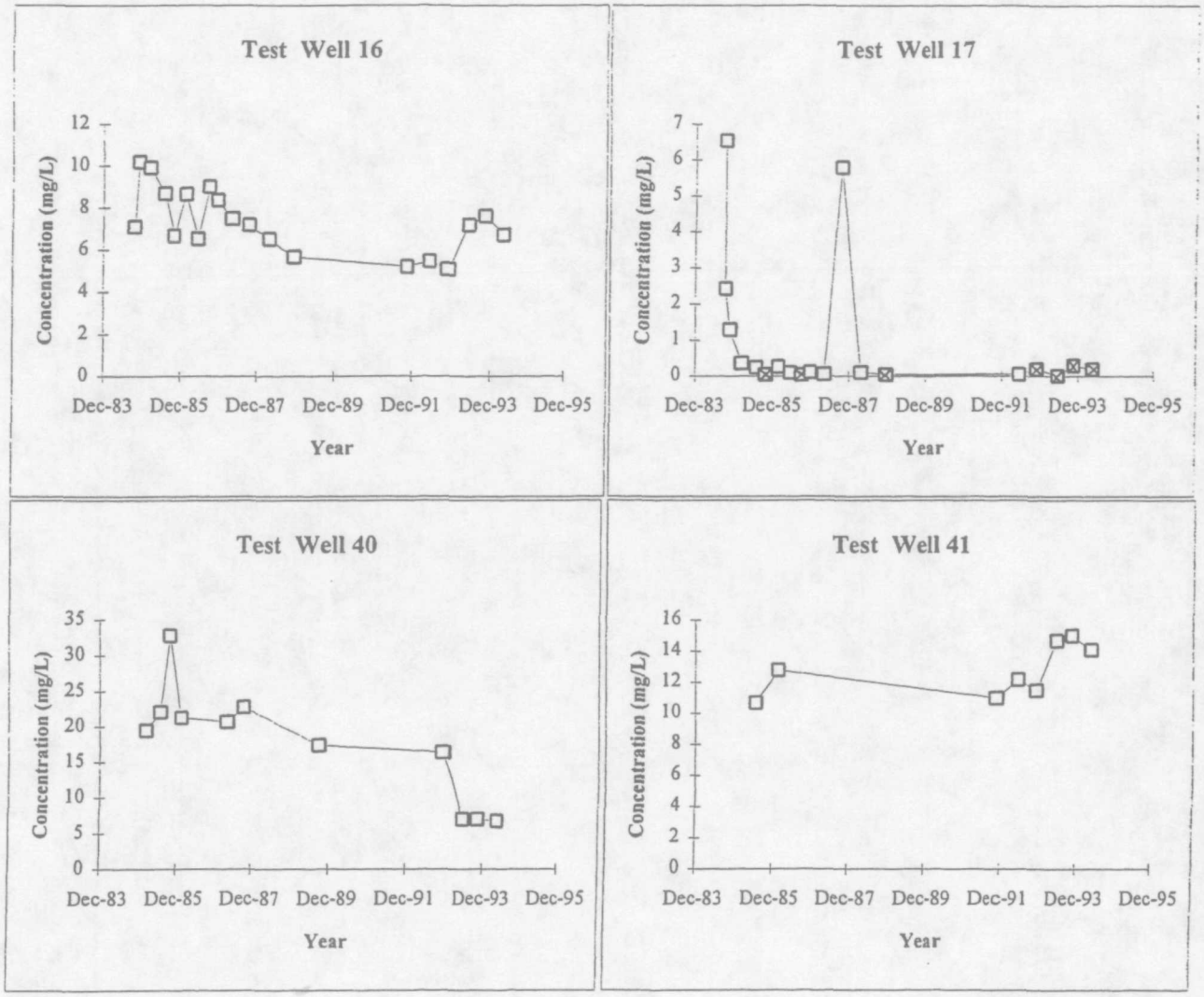
FIGURE **4-59**

NITRATE - NITROGEN TIME HISTORY PLOTS IN THE OLD UNDERFLOW SOLIDS PONDS AREA

MONSANTO/PHASE II RI/ID

PROJECT NO.913 1101.608 DRAWING NO. 53518 DATE 2/1/95 DRAWN BY EA

Golder Associates



□ Sample result

⊠ Sample result below detection limit

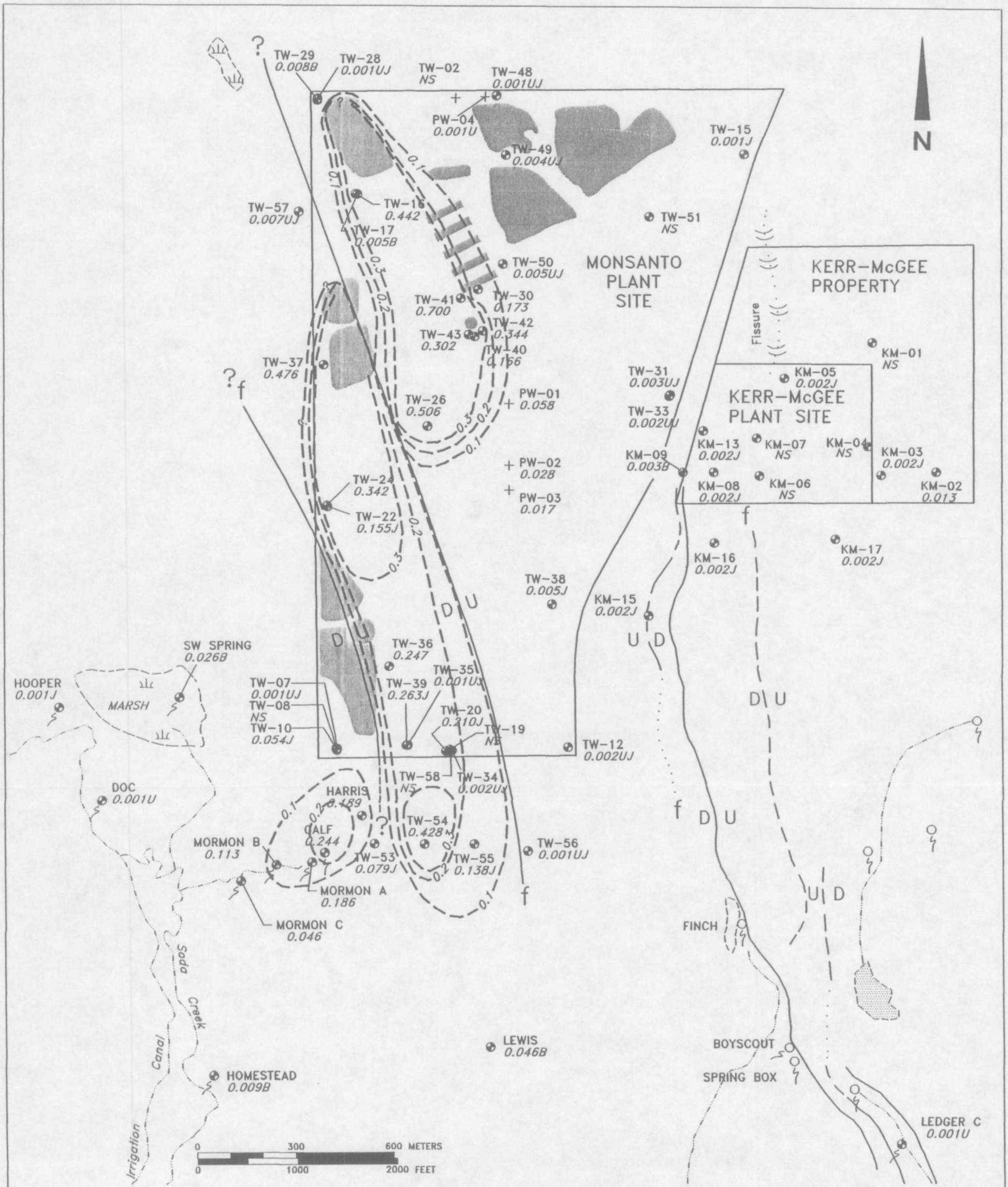
FIGURE **4-60**

NITRATE - NITROGEN TIME HISTORY PLOTS IN THE NORTHWEST POND/HYDROCLARIFIER AREA

MONSANTO/PHASE II RI/ID

PROJECT NO.913 1101.608 DRAWING NO. 53519 DATE 2/1/95 DRAWN BY EA

Golder Associates



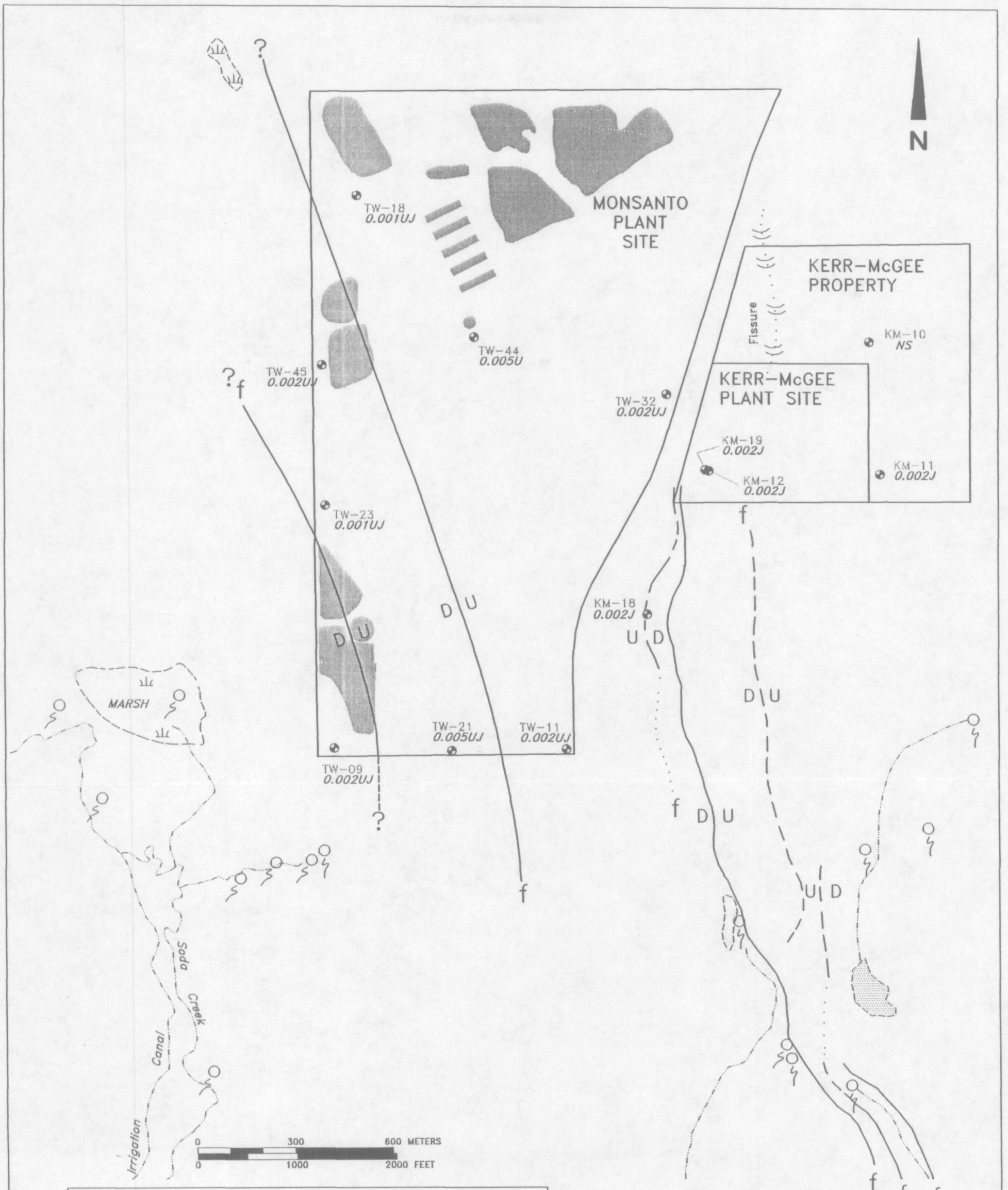
LEGEND

TW-35	Monitoring well location and name
+ PW-1	Production well location and name
CALF	Spring location and name (if sampled)
BOYSCOUT	Spring location and name (not sampled)
242	Concentration (mg/l) with qualifier (if any): CRDL = Contract Required Detection Limit IDL = Instrument Detection Limit U = Undetected B = Detected between the CRDL and IDL J = Estimated below IDL
NS	No sample collected
100 — —	Concentration contour (mg/l)
f — — · —	Fault (dashed where inferred)

FIGURE **4-61**

SELENIUM GROUNDWATER CONCENTRATIONS IN THE UPPER BASALT ZONE DURING MAY 1993

MONSANTO/PHASE II RI REPORT/ID



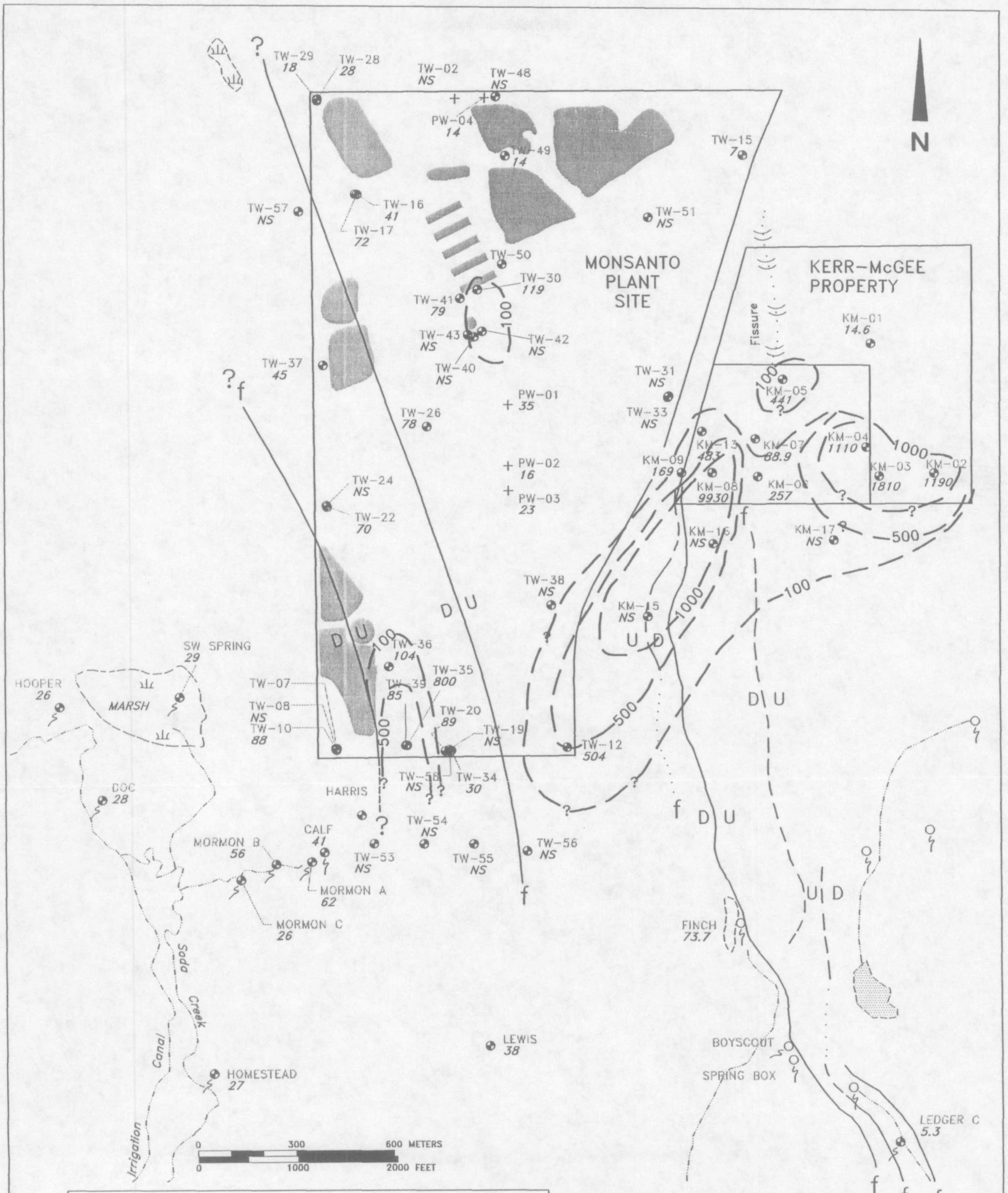
LEGEND

TW-35	Monitoring well location and name
PW-1	Production well location and name
CALF	Spring location and name (if sampled)
BOYSCOUT	Spring location and name (not sampled)
242	Concentration (mg/l) with qualifier (if any): CRDL = Contract Required Detection Limit; IDL = Instrument Detection Limit; U = Undetected; B = Detected between the CRDL and IDL; J = Estimated below IDL
NS	No sample collected
100	Concentration contour (mg/l)
f	Fault (dashed where inferred)

FIGURE **4-62**

SELENIUM GROUNDWATER CONCENTRATIONS IN THE LOWER BASALT ZONE DURING MAY 1993

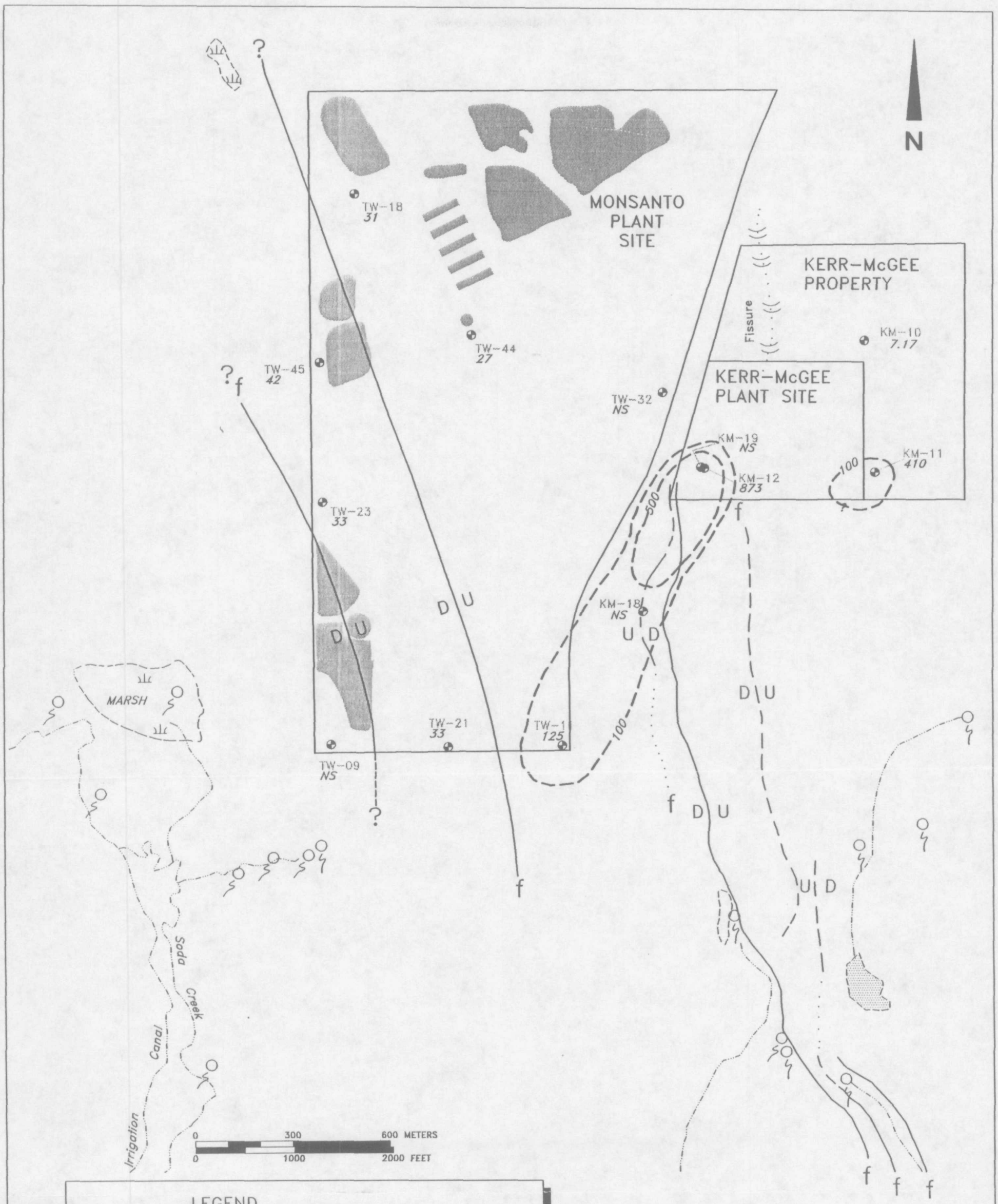
MONSANTO/PHASE II RI REPORT/ID



LEGEND

TW-35	Monitoring well location and name
+ PW-1	Production well location and name
CALF	Spring location and name (if sampled)
BOYSCOUT	Spring location and name (not sampled)
242	Concentration (mg/l) with qualifier (if any): CRDL = Contract Required Detection Limit; IDL = Instrument Detection Limit; U = Undetected; B = Detected between the CRDL and IDL; J = Estimated below IDL
NS	No sample analysis for constituent
100	Concentration contour (mg/l)
f	Fault (dashed where inferred)

FIGURE 4-63
SODIUM GROUNDWATER CONCENTRATIONS IN THE UPPER BASALT ZONE DURING MAY 1992
MONSANTO/PHASE II RI REPORT/ID



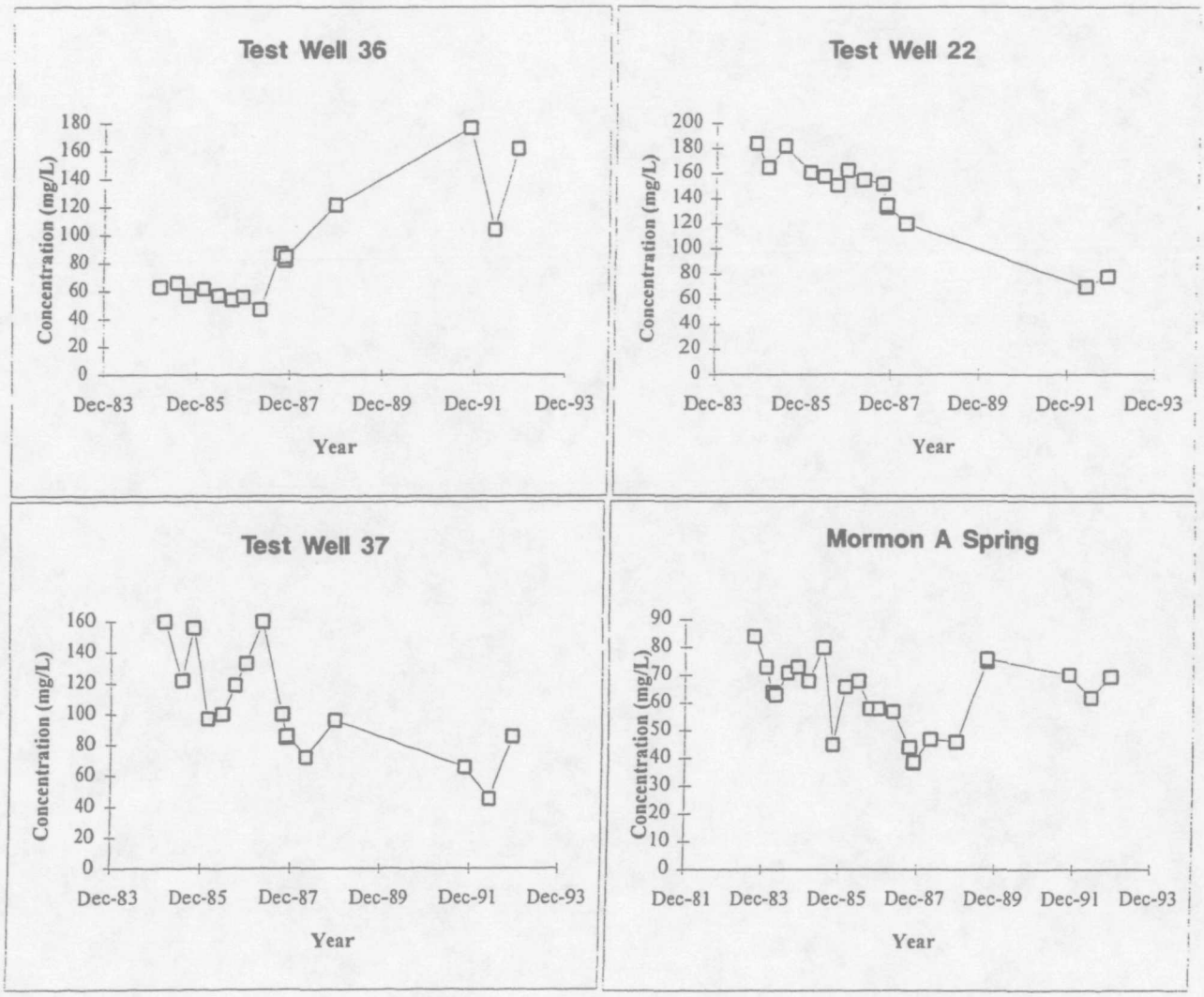
LEGEND

TW-35	Monitoring well location and name
+ PW-1	Production well location and name
CALF	Spring location and name (if sampled)
BOYSCOUT	Spring location and name (not sampled)
242	Concentration (mg/l) with qualifier (if any): CRDL = Contract Required Detection Limit IDL = Instrument Detection Limit U = Undetected B = Detected between the CRDL and IDL J = Estimated below IDL
NS	No sample analysis for constituent
100 — — —	Concentration contour (mg/l)
f — — · —	Fault (dashed where inferred)

FIGURE **4-64**

SODIUM GROUNDWATER CONCENTRATIONS IN THE LOWER BASALT ZONE DURING MAY 1992

MONSANTO/PHASE II RI REPORT/ID



□ Sample result

⊠ Sample result below detection limit

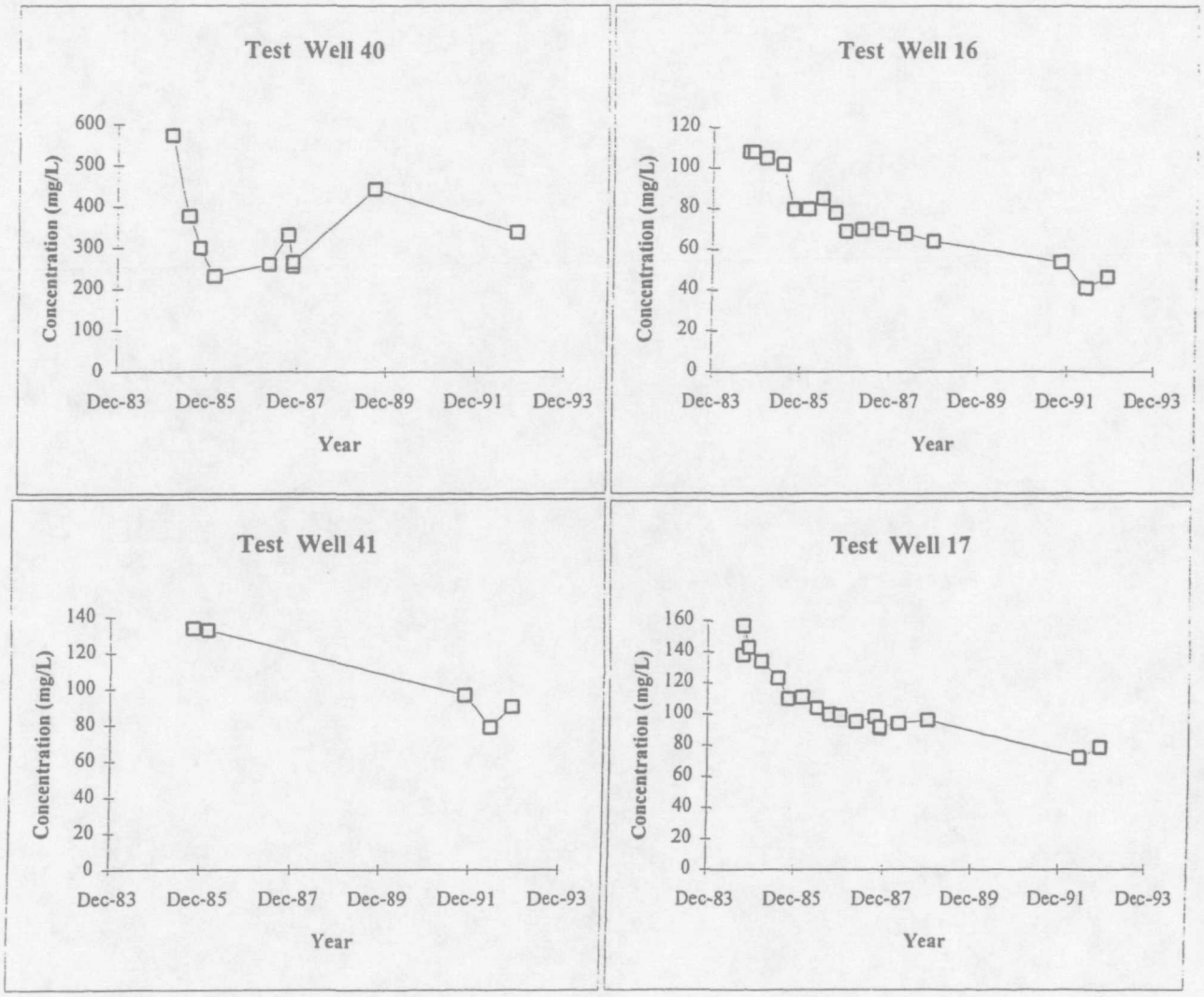
FIGURE **4-65**

SODIUM TIME HISTORY PLOTS IN THE OLD UNDERFLOW SOLIDS PONDS AREA

MONSANTO/PHASE II RI/ID

PROJECT NO.913 1101.608 DRAWING NO. 53520 DATE 10/17/94 DRAWN BY EA

Golder Associates



□ Sample result

⊠ Sample result below detection limit

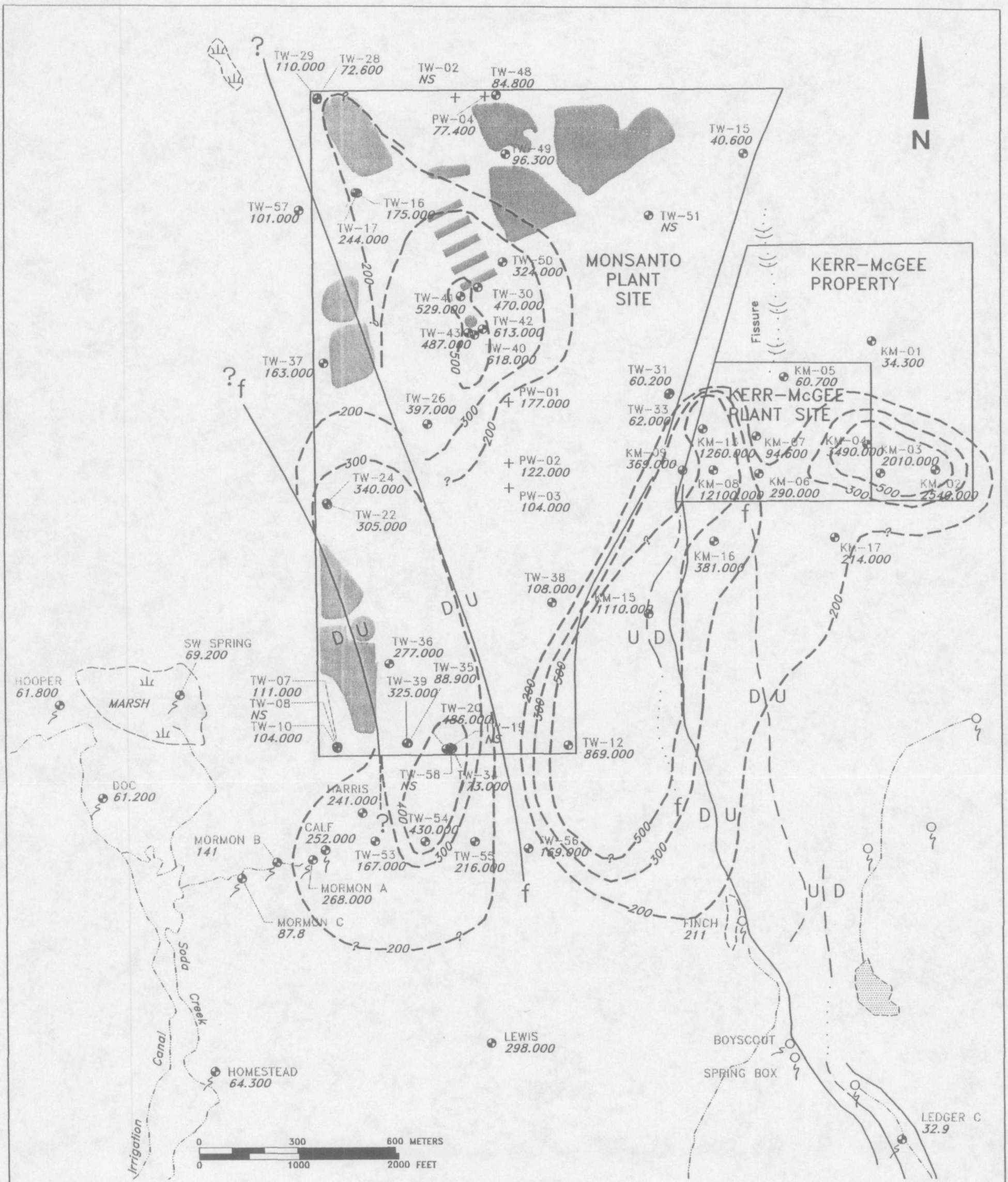
FIGURE **4-66**

SODIUM TIME HISTORY PLOTS IN THE NORTHWEST POND/HYDROCLARIFIER AREA

MONSANTO/PHASE II RI/ID

PROJECT NO.913 1101.608 DRAWING NO. 53521 DATE 10/17/94 DRAWN BY EA

Golder Associates



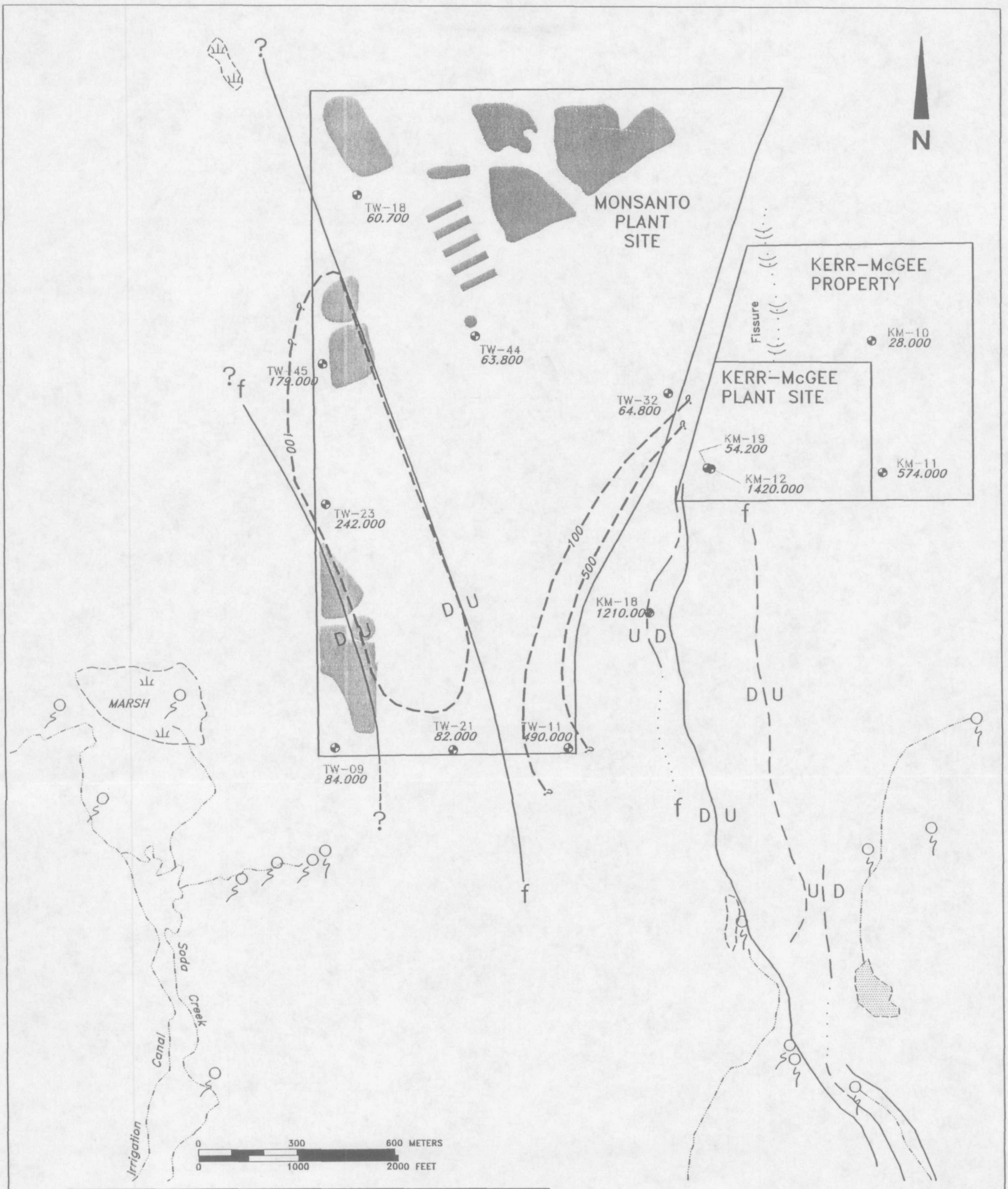
LEGEND

TW-35	Monitoring well location and name
+ PW-1	Production well location and name
CALF	Spring location and name (if sampled)
BOYSCOUT	Spring location and name (not sampled)
242	Concentration (mg/l) with qualifier (if any): CRDL = Contract Required Detection Limit; IDL = Instrument Detection Limit; U = Undetected; B = Detected between the CRDL and IDL; J = Estimated below IDL
NS	No sample collected
100	Concentration contour (mg/l)
f	Fault (dashed where inferred)

FIGURE **4-67**

SULFATE GROUNDWATER CONCENTRATIONS IN THE UPPER BASALT ZONE DURING MAY 1993

MONSANTO/PHASE II RI REPORT/ID



LEGEND

TW-35	Monitoring well location and name
+ PW-1	Production well location and name
CALF	Spring location and name (if sampled)
BOYSCOUT	Spring location and name (not sampled)
242	Concentration (mg/l) with qualifier (if any): CRDL = Contract Required Detection Limit IDL = Instrument Detection Limit U = Undetected B = Detected between the CRDL and IDL J = Estimated below IDL
NS	No sample collected
100 — —	Concentration contour (mg/l)
f — — · —	Fault (dashed where inferred)

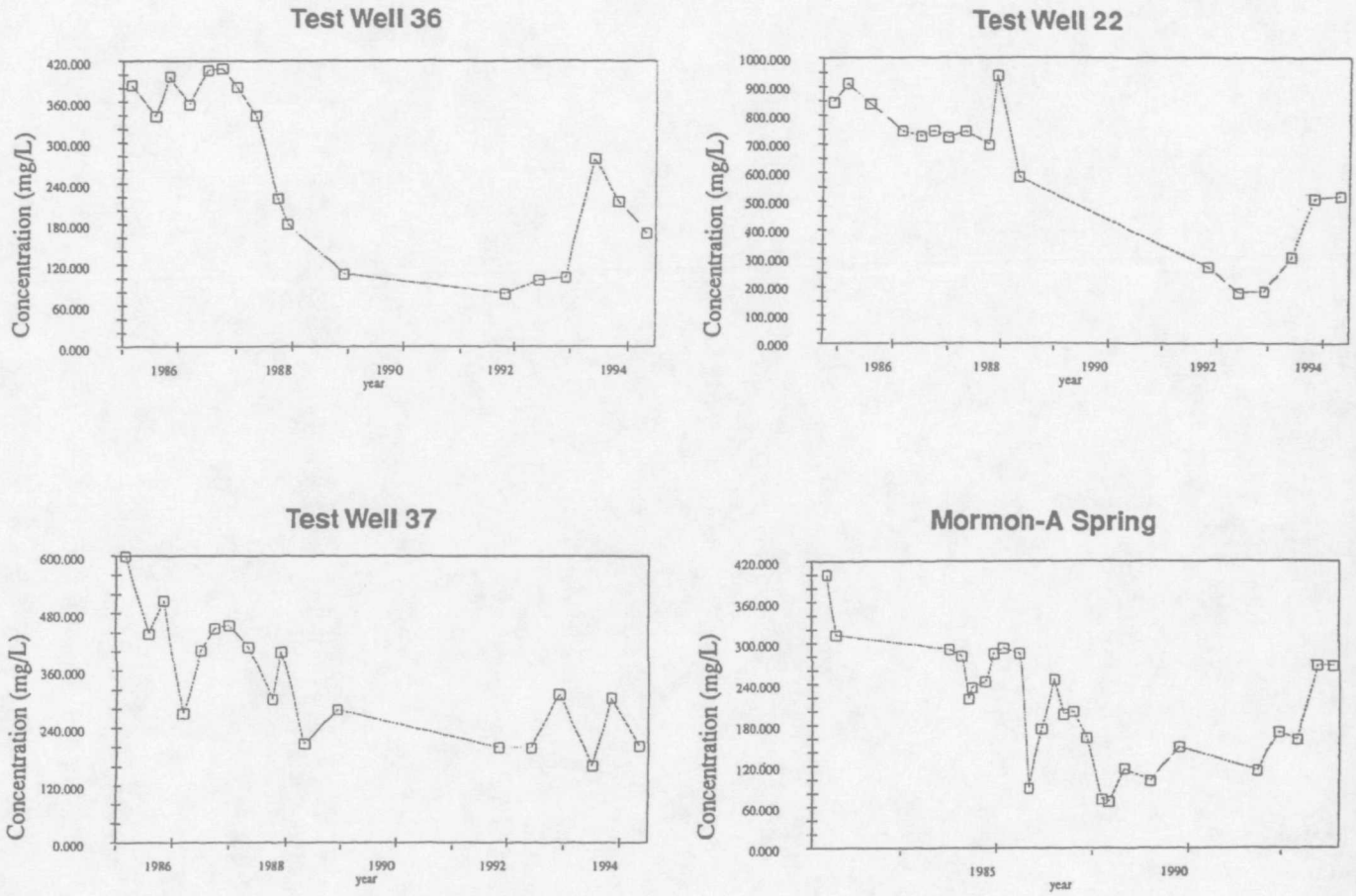
FIGURE **4-68**

SULFATE GROUNDWATER CONCENTRATIONS IN THE LOWER BASALT ZONE DURING MAY 1993

MONSANTO/PHASE II RI REPORT/ID

\JPM\9131101\608\51069 1-26-95 17:13

Golder Associates



□ Sample result

⊠ Sample result below detection limit

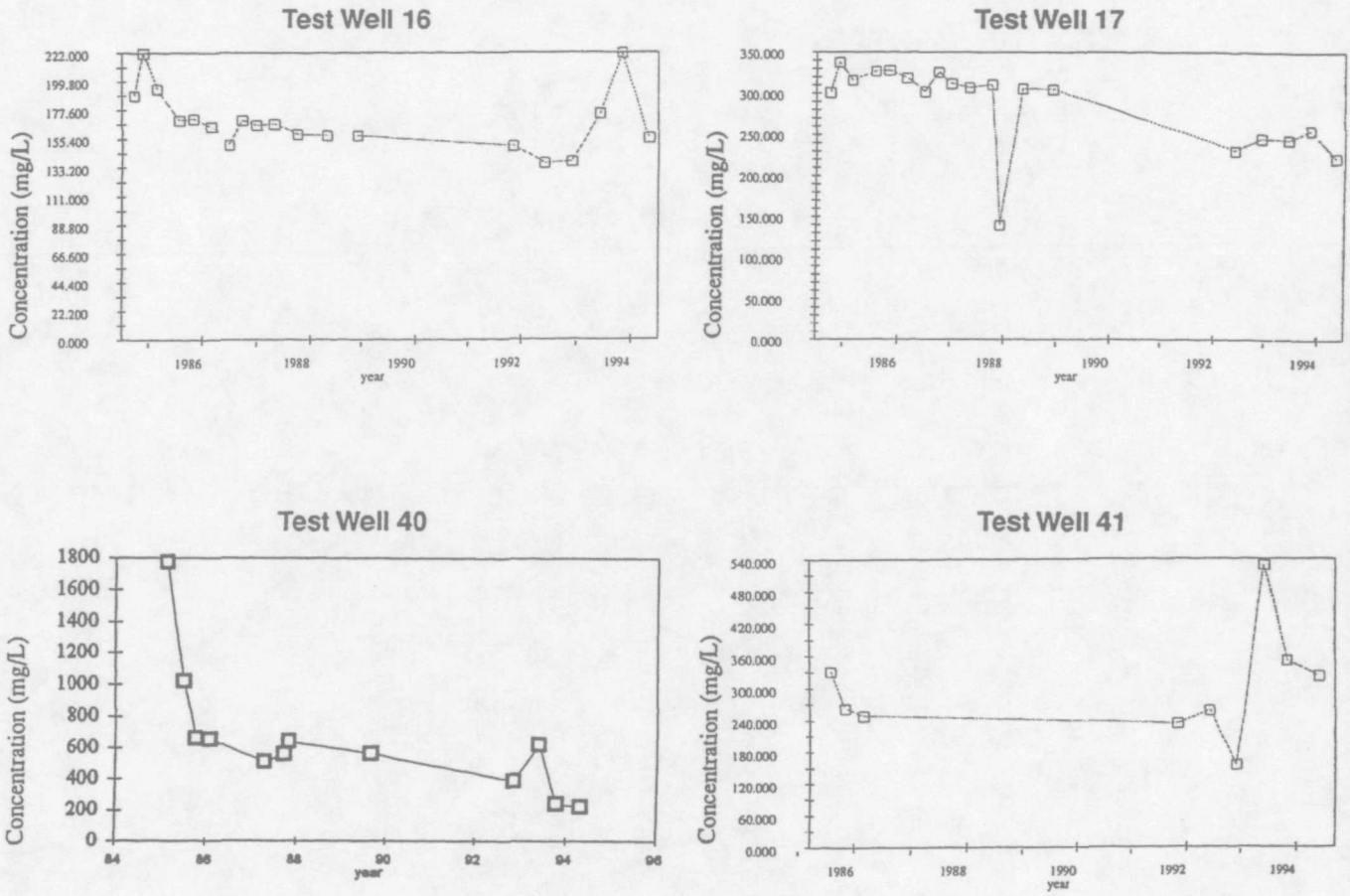
FIGURE **4-69**

SULFATE TIME HISTORY PLOTS IN THE OLD UNDERFLOW SOLIDS PONDS AREA

MONSANTO/PHASE II RI/ID

PROJECT NO.913 1101.608 DRAWING NO. 53522 DATE 10/17/94 DRAWN BY EA

Golder Associates



□ Sample result

⊠ Sample result below detection limit

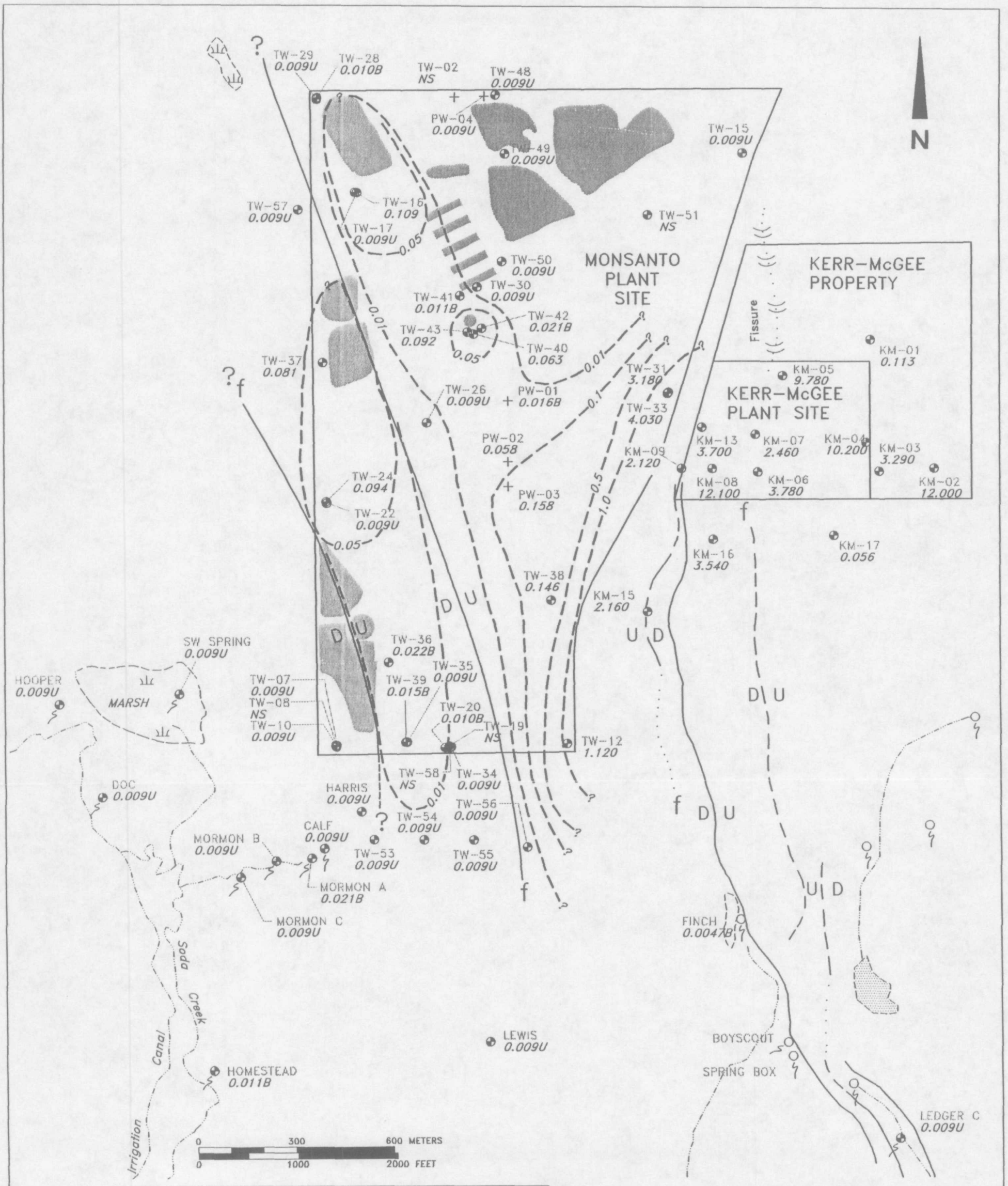
FIGURE **4-70**

SULFATE TIME HISTORY PLOTS IN THE NORTHWEST POND/HYDROCLARIFIER AREA

MONSANTO/PHASE II RI/ID

PROJECT NO.913 1101.608 DRAWING NO. 53523 DATE 10/17/94 DRAWN BY EA

Golder Associates



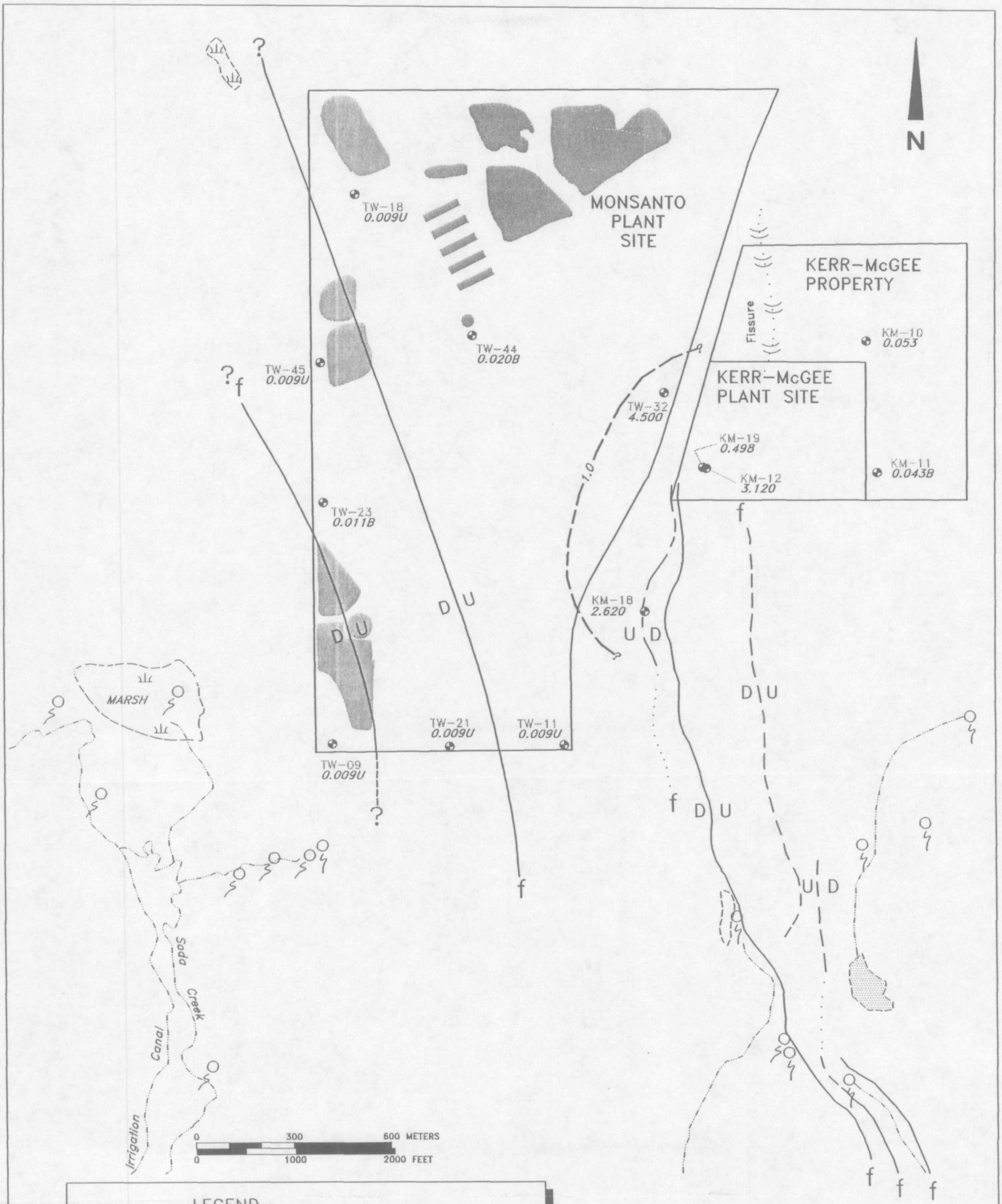
LEGEND

TW-35	Monitoring well location and name
+ PW-1	Production well location and name
CALF	Spring location and name (if sampled)
BOYSCOUT	Spring location and name (not sampled)
242	Concentration (mg/l) with qualifier (if any): CRDL = Contract Required Detection Limit; IDL = Instrument Detection Limit; U = Undetected; B = Detected between the CRDL and IDL; J = Estimated below IDL
NS	No sample collected
100	Concentration contour (mg/l)
f	Fault (dashed where inferred)

FIGURE **4-71**

VANADIUM GROUNDWATER CONCENTRATIONS IN THE UPPER BASALT ZONE DURING MAY 1993

MONSANTO/PHASE II RI REPORT/ID



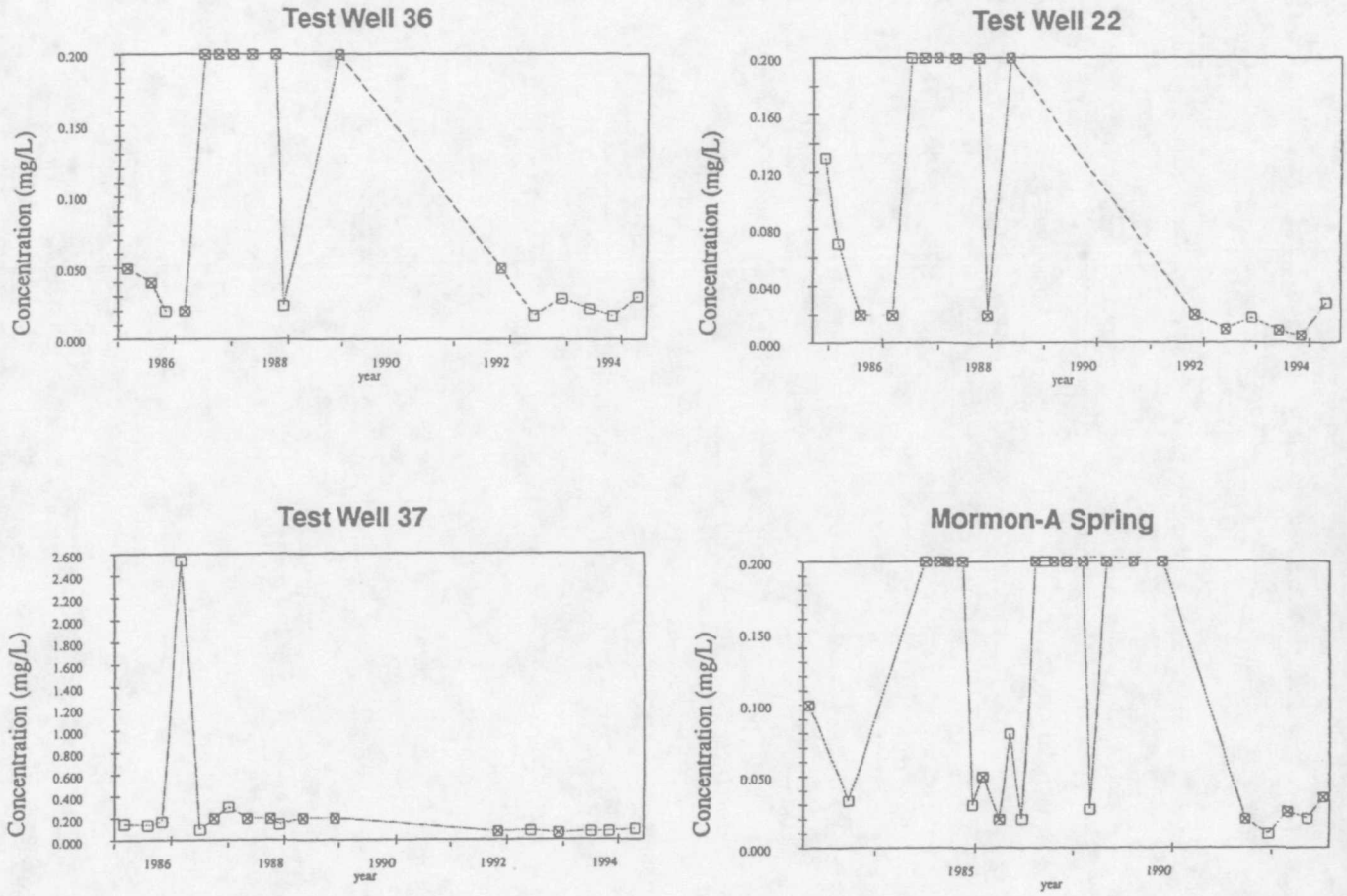
LEGEND

TW-35	Monitoring well location and name
+ PW-1	Production well location and name
CALF	Spring location and name (if sampled)
BOYSCOUT	Spring location and name (not sampled)
242	Concentration (mg/l) with qualifier (if any): CRDL = Contract Required Detection Limit IDL = Instrument Detection Limit U = Undetected B = Detected between the CRDL and IDL J = Estimated below IDL
NS	No sample collected
100 — —	Concentration contour (mg/l)
f — — · —	Fault (dashed where inferred)

FIGURE **4-72**

VANADIUM GROUNDWATER CONCENTRATIONS IN THE LOWER BASALT ZONE DURING MAY 1993

MONSANTO/PHASE II RI REPORT/ID



□ Sample result

⊠ Sample result below detection limit

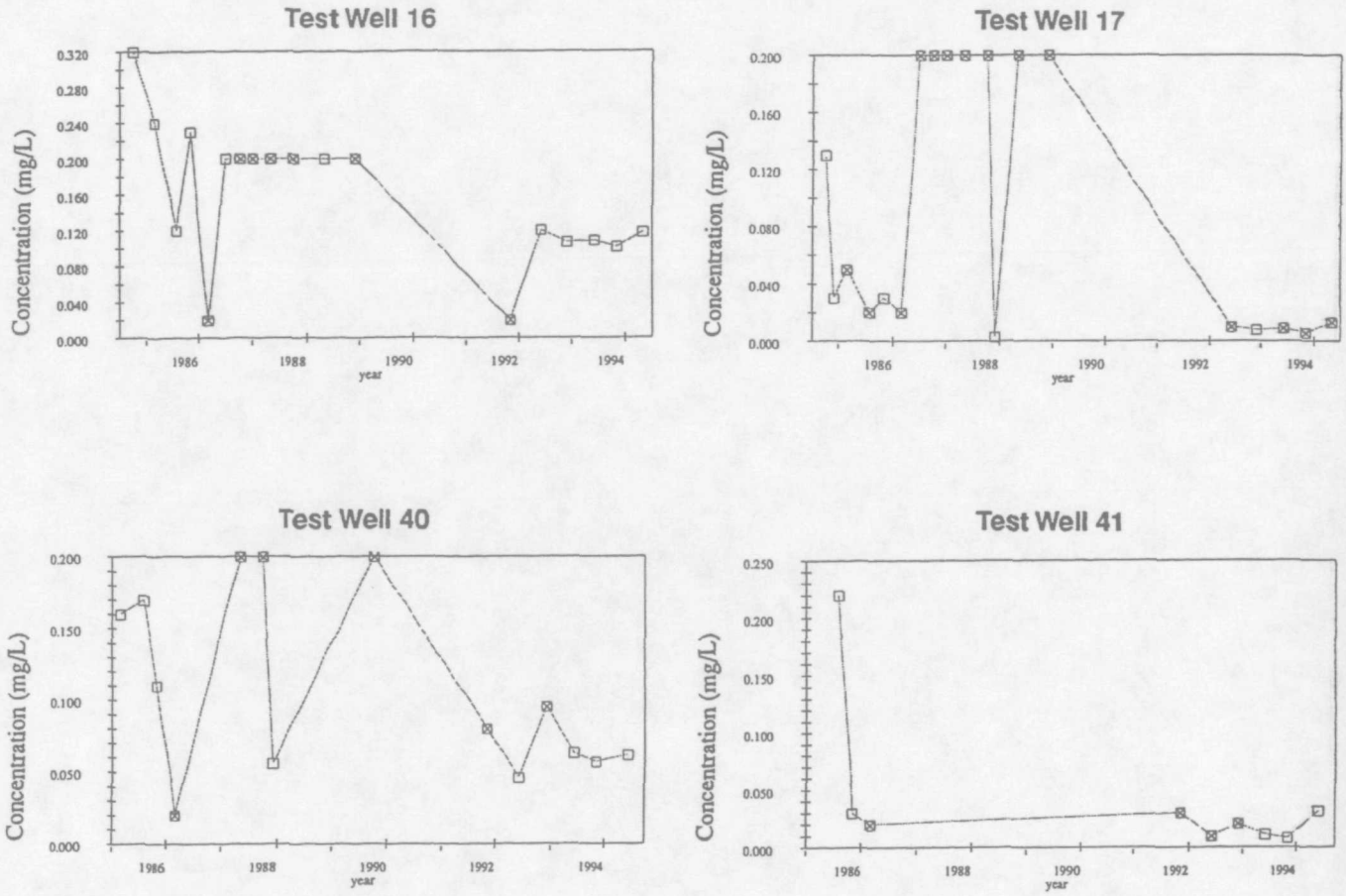
FIGURE **4-73**

VANADIUM TIME HISTORY PLOTS IN THE OLD UNDERFLOW SOLIDS PONDS AREA

MONSANTO/PHASE II RI/ID

PROJECT NO.913 1101.608 DRAWING NO. 53524 DATE 10/17/94 DRAWN BY EA

Golder Associates



□ Sample result

⊠ Sample result below detection limit

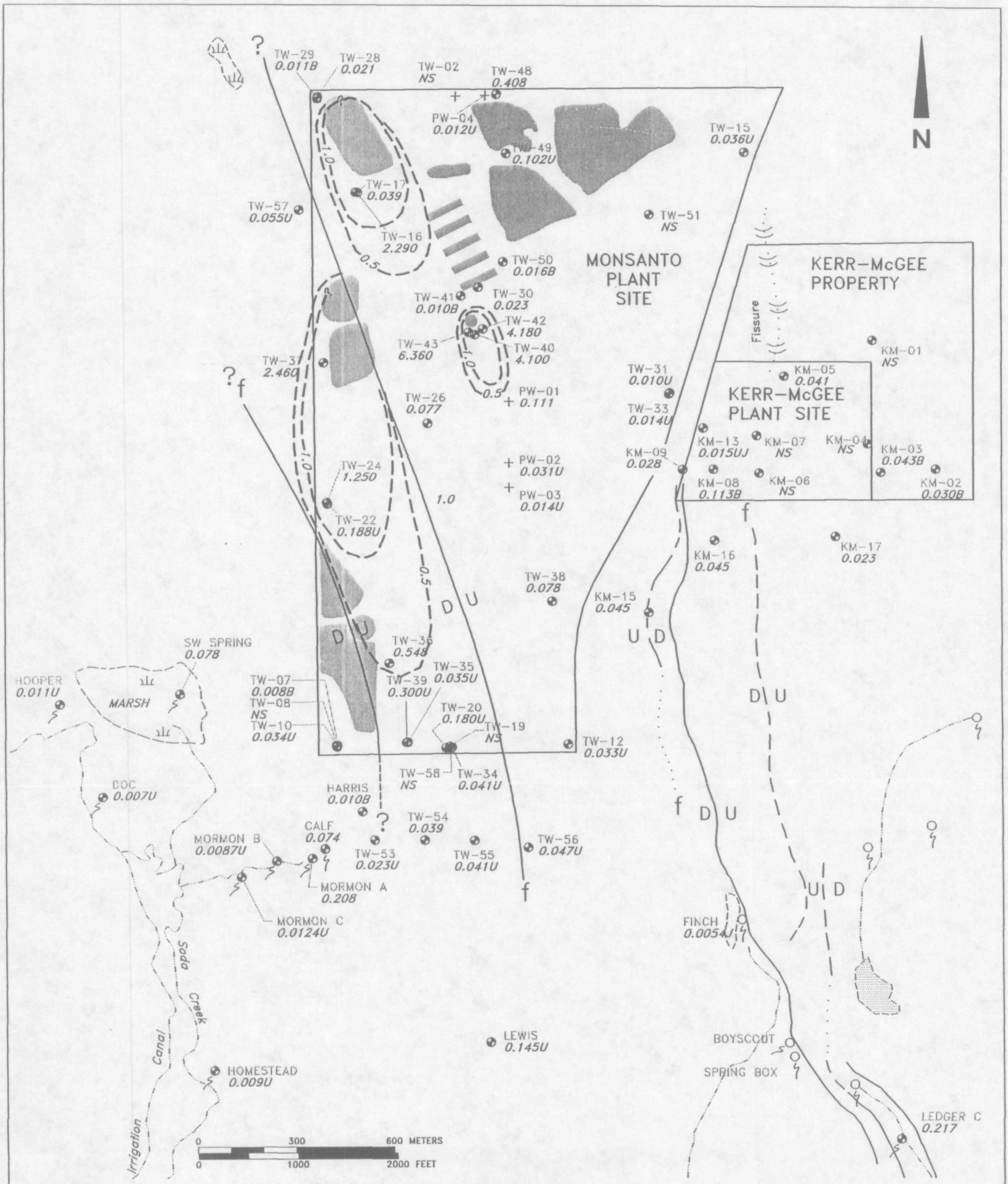
FIGURE **4-74**

VANADIUM TIME HISTORY PLOTS IN THE NORTHWEST POND/HYDROCLARIFIER AREA

MONSANTO/PHASE II RI/ID

PROJECT NO.913 1101.608 DRAWING NO. 53525 DATE 10/17/94 DRAWN BY EA

Golder Associates



LEGEND

TW-35	Monitoring well location and name
PW-1	Production well location and name
CALF	Spring location and name (if sampled)
BOYSCOUT	Spring location and name (not sampled)
242	Concentration (mg/l) with qualifier (if any): CRDL = Contract Required Detection Limit IDL = Instrument Detection Limit U = Undetected B = Detected between the CRDL and IDL J = Estimated below IDL
NS	No sample collected
100	Concentration contour (mg/l)
f	Fault (dashed where inferred)

FIGURE **4-75**

ZINC GROUNDWATER CONCENTRATIONS IN THE UPPER BASALT ZONE DURING MAY 1993

MONSANTO/PHASE II RI REPORT/ID

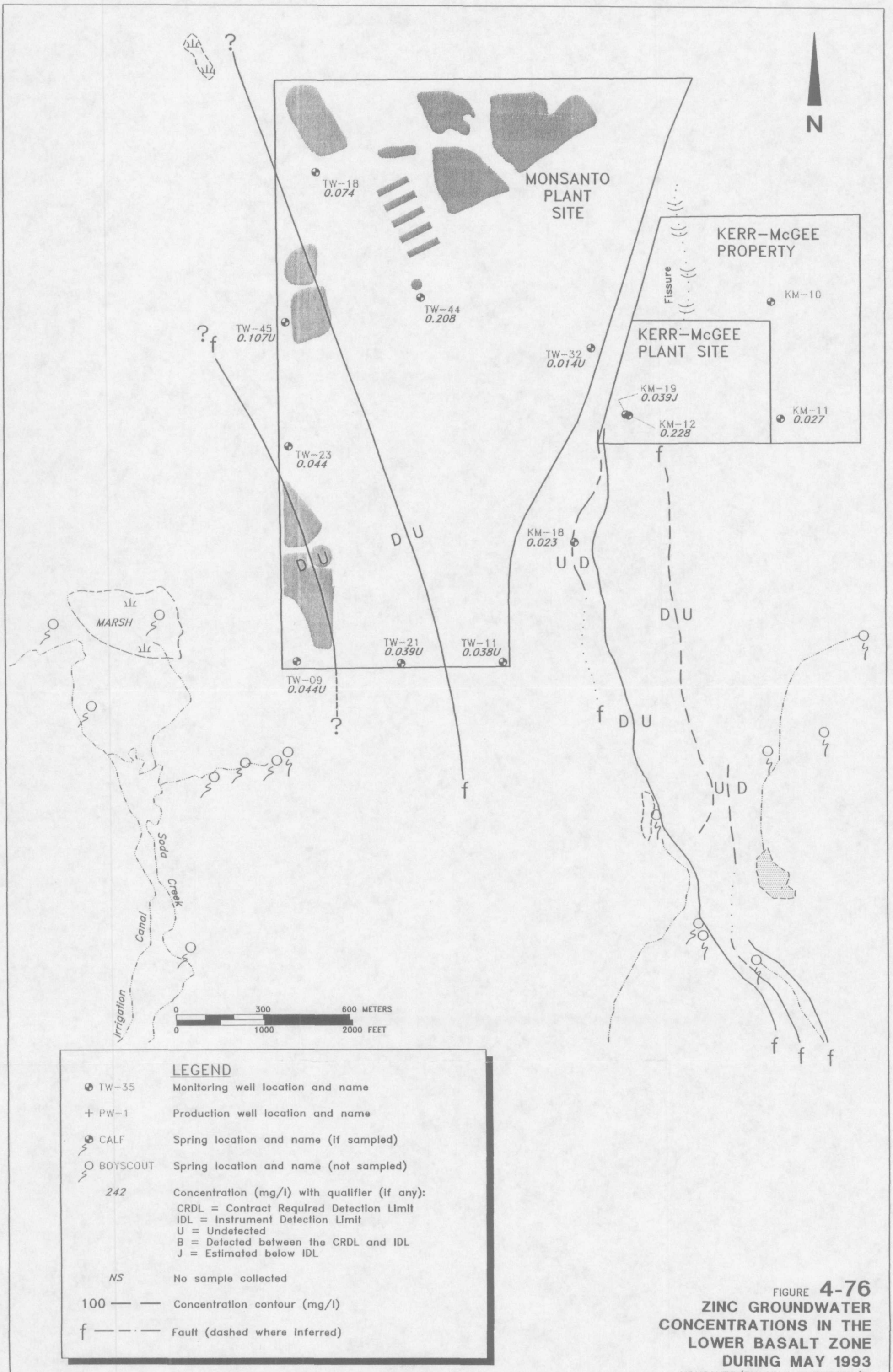
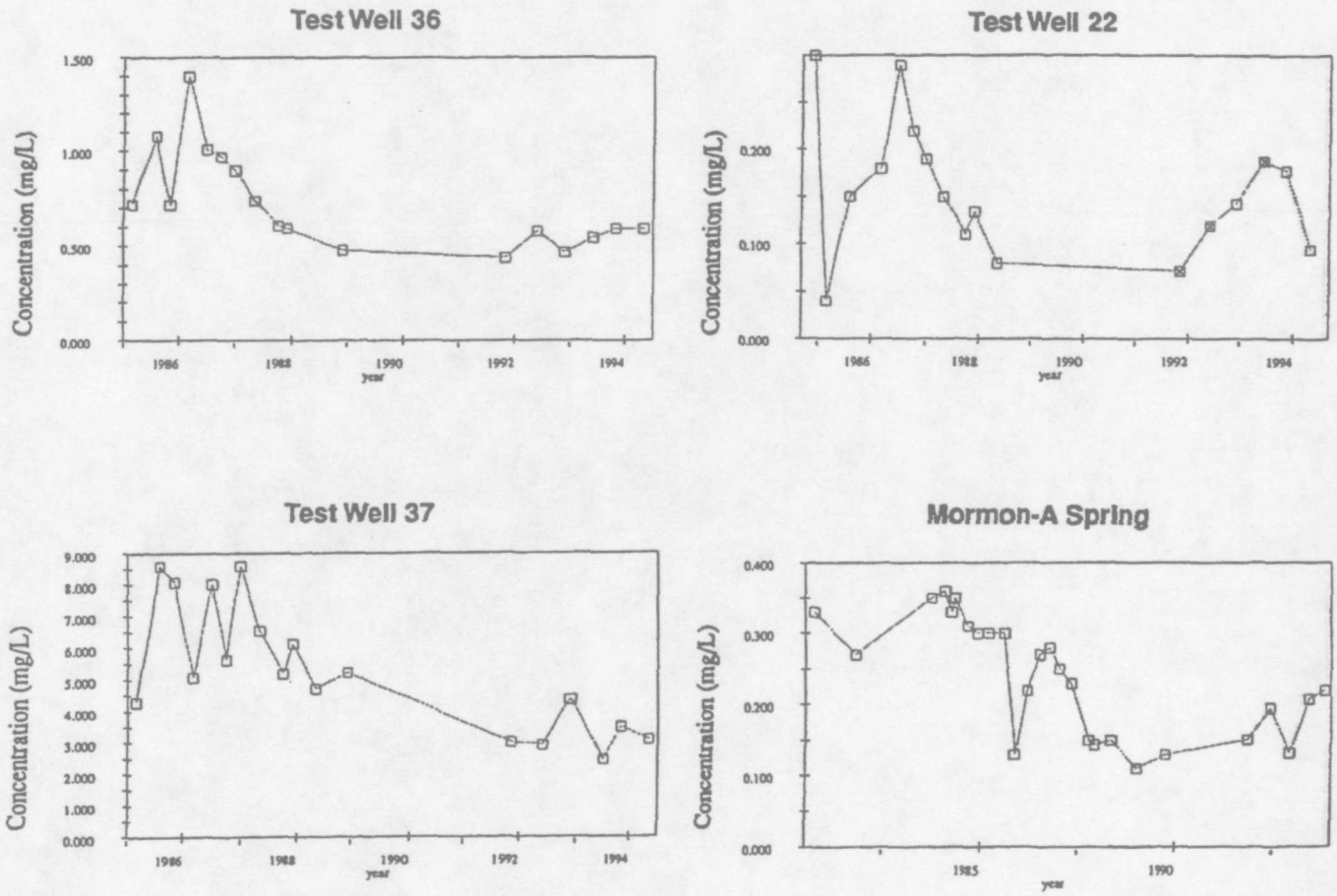


FIGURE 4-76
ZINC GROUNDWATER CONCENTRATIONS IN THE LOWER BASALT ZONE DURING MAY 1993
MONSANTO/PHASE II RI REPORT/ID



□ Sample result

⊠ Sample result below detection limit

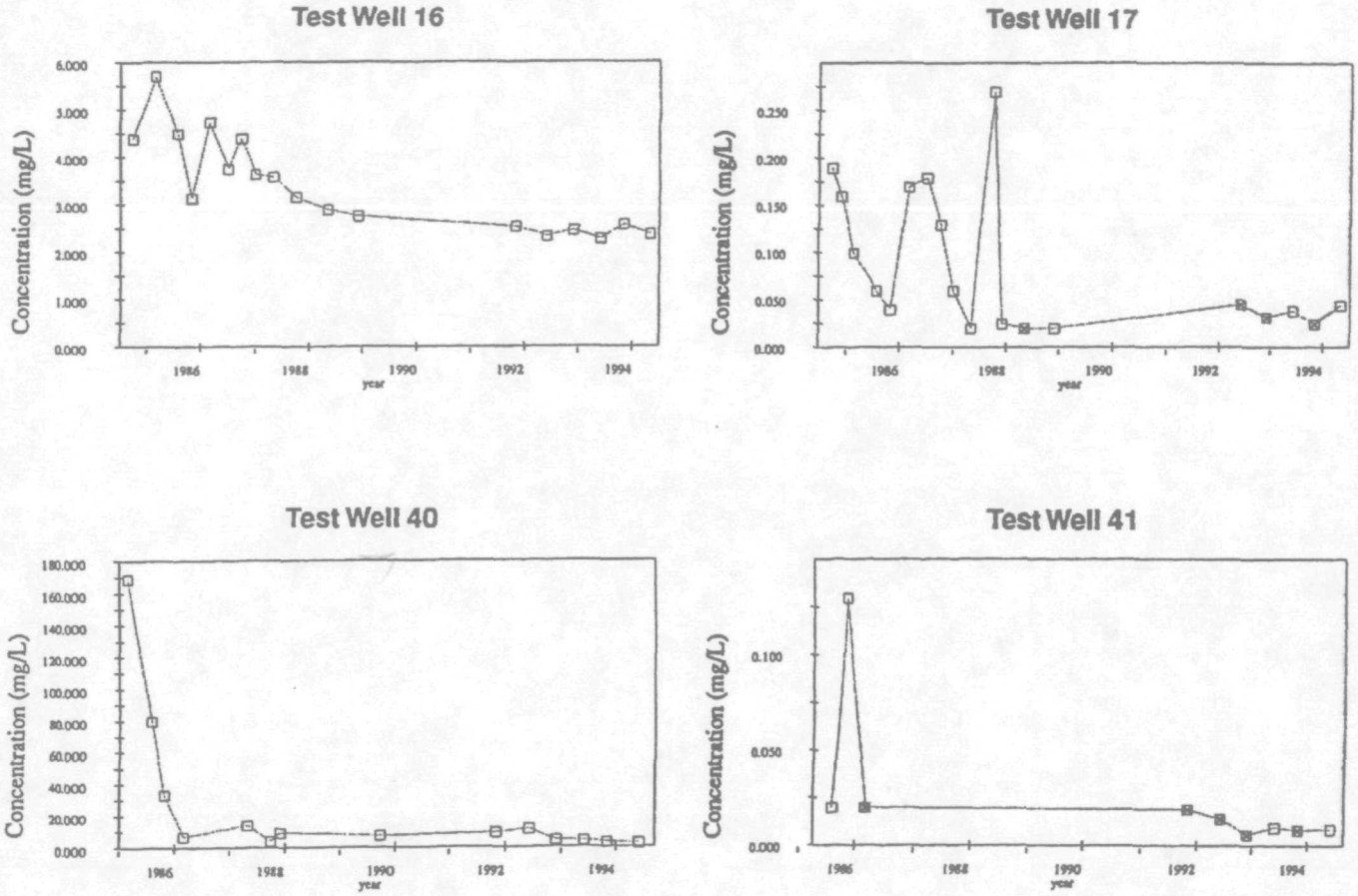
FIGURE **4-77**

ZINC TIME HISTORY PLOTS IN THE OLD UNDERFLOW SOLIDS PONDS AREA

MONSANTO/PHASE II RI/ID

PROJECT NO. 913 1101.608 DRAWING NO. 53526 DATE 3/16/95 DRAWN BY EA

Golder Associates



□ Sample result

⊠ Sample result below detection limit

FIGURE **4-78**

ZINC TIME HISTORY PLOTS IN THE NORTHWEST POND/HYDROCLARIFIER AREA

MONSANTO/PHASE II RI/ID

PROJECT NO. 913 1101.608 DRAWING NO. 53527 DATE 3/16/95 DRAWN BY EA

Golder Associates

5. CONSTITUENT FATE AND TRANSPORT ANALYSIS

Constituent fate refers to the natural evolution of a constituent in the environment. Constituent transport refers to the ability, or inability, for a constituent to migrate in various environmental media, air, soil, rock, and water. This chapter analyzes the fate and transport of constituents of potential interest that were identified in Chapter 4.

5.1 Constituent Fate

This section provides information on the environmental fate of the constituents of potential interest. These constituents are summarized according to environmental medium in Table 5-1. A discussion of the environmental fate of each constituent is presented below.

5.1.1 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 1984).

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 specification, 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.

5.1.2 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. 1991b).

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.

5.1.3 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 ($Cd^{2+} \cdot 6H_2O$), 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).

5.1.4 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).

5.1.5 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. The upper limit for fluoride concentration for consideration as toxic for livestock drinking water is 2.0 mg/L (Bohn, et al. 1979).

5.1.6 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).

5.1.7 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 dependent 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).

5.1.8 Molybdenum

The primary mineral form of molybdenum is molybdenide (MoS_2), which is commonly found in association with iron- and titanium-containing minerals. Molybdenum sulfides are oxidized during weathering to yield primarily anionic compounds. MoO_4^{2-} is the major solution species

above pH 4.2, with $HMoO_4^-$ the next most common. Below pH 4.2, H_2MoO_4 is the most common species in solution.

Molybdenum concentrations in groundwater typically occur in the range of < 1.0 to 30 ppm (Dragun 1988). Molybdenum in soil is commonly found in the range of 0.2 to 5 ppm (Lindsay 1979). The soil-water adsorption coefficient for molybdenum in soils and clays has been observed to range from 0.4 to 400 ml/g (Dragun 1988). Although molybdenum is mobile in soils and groundwater in its anionic states, these anions are easily precipitated by organic matter, calcium carbonate, and the cations of several metals such as iron (Kabata-Pendias and Pendias 1984). Because both the physical state of molybdenum and the various precipitation reactions are highly dependent upon pH and Eh, the net potential for molybdenum migration in soils and groundwater is difficult to predict.

5.1.9 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).

5.1.10 Nitrate

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.

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.

5.1.11 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).

5.1.12 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.

5.1.13 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).

5.1.14 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).

5.1.15 Thorium

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 products formed by the decay of uranium-238. The half life of thorium-230 is about 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. 1989c).

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. 1989c). 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. 1989c).

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 thorium 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. 1989c).

5.1.16 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 mm). Deposition on surface water and its transport to sediments is probably the ultimate fate of atmospheric uranium (Syracuse Research Corp. 1989d).

5.1.17 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, 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 released 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).

5.1.18 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, Inc. 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, Inc. 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, Inc. 1989b).

In the aquatic environment, transport is controlled by the specification 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, Inc. 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, Inc. 1989b).

5.2 Constituent Transport

This section presents transport analyses for constituents of potential interest in air, groundwater and surface water. These media are considered the most important with regard to off-site transport of constituents related to the Monsanto Plant. Transport in stream sediments is also a potentially important transport mechanism. However, as new data are being collected for stream sediments, a discussion of this transport mechanism is deferred to a later date.

5.2.1 Potential Pathways of Constituent Transport

In order to provide a focus for the transport analyses, it is important to identify the exposure pathways that may lead to human health- or ecological-risk. A pathway is a specific transport process, often involving multiple environmental media, that terminates 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 potential pathways for exposure to constituents of potential interest through the air, soil, and water media. As shown, source media include primarily air and groundwater. By inter-media transport, soil, surface water, and stream sediments also become transport media. Exposures to the constituents through these media may be possible to humans and wildlife (i.e., land animals, vegetation, and aquatic life). The principal types of exposure are ingestion, inhalation, and absorption.

5.2.2 Transport in Air

A preliminary evaluation of air emission impacts was presented as part of the Phase I RI/FS evaluation for the facility (Golder 1992b). The Phase I air dispersion analysis was limited to emissions of TSP, inhalable particulates (PM_{10}), fluoride and cadmium. The preliminary

analysis of these constituents in the Phase I RI identified uncertainties in the available data for source characterization and in the methods for modeling emissions from material handling operations.

A detailed inventory of source emissions was prepared and submitted to the EPA on May 27, 1993, as an interim deliverable to the Phase II RI (SENES 1993a). The emission estimates presented in the interim deliverable report were subsequently modified to incorporate the recommendations of the EPA (Memorandum to Mr. T. Brincefield, EPA from B. Ryan, EPA, July 15, 1993) prior to conducting the Phase II RI air dispersion modeling assessment. A copy of the revised emission inventory used as input to the modeling is provided in SENES (1993b).

Air dispersion modeling for the Phase II RI was used to calculate annual average ambient concentrations and deposition rates for TSP, PM_{10}, and trace constituents in TSP, including:

Inorganics	Radionuclides
arsenic (As)	lead-210 (Pb-210)
beryllium (Be)	polonium-210 (Po-210)
cadmium (Cd)	radium-226 (Ra-226)
fluoride (F)	thorium-230 (Th-230)
manganese (Mn)	uranium-234 (U-234)
molybdenum (Mo)	uranium-238 (U-238)
silver (Ag)	
vanadium (V)	
zinc (Zn)	

The primary sources of trace constituent emissions were identified (SENES 1993b) as:

- the kiln venturi scrubbers;
- wind erosion of the underflow solids stockpile;
- slag handling operations;
- nodule handling operations;
- taphole fume collectors;
- nodule crushing and screening scrubber; and
- kiln cooler spray tower.

However, as discussed in the Phase II RI air dispersion modeling report (see Appendix A in SENES 1993b), there remain some residual uncertainties about the emission rates of some trace constituents from a number of sources. A second round of stack sampling was commissioned in August 1994. The results from this set of samples were unavailable at the time that the dispersion analysis was completed. A discussion of the results and significance of the new stack sampling data is presented in Appendix E-1.

The source terms for the air transport assessment presented in this section were based on the operational process material flows at the facility during 1990. Air emissions from the facility were calculated for 1990 and 1991 assuming the same operational scenario for both years. The operational scenario modeled was at full plant capacity.

5.2.2.1 Modeling Methodology

The impact of facility operations on local air quality was assessed using mathematical dispersion models to calculate ground level annual average concentrations and deposition rates. Stack and thermally-buoyant emissions were modeled using the short-term version of the EPA-approved Industrial Source Complex (ISC) model, while fugitive dust emissions from wind erosion of stockpiles, material handling operations, and vehicular traffic on unpaved haul roads were modeled using the EPA-approved Fugitive Dust Model (FDM).

Standard regulatory default options were invoked for:

- final plume rise;
- stack-tip downwash;
- buoyancy-induced dispersion;
- calms processing routine;
- no use of the missing data processing routine;
- default wind profile exponents;
- default vertical potential temperature gradients;
- "upper bound" values for supersquat buildings; and
- no exponential decay for RURAL mode.

The building wake effects option was invoked for all point sources in ISC model runs. For emissions from hot slag disposal operations on the slag stockpile, ISC modeling runs were conducted both with, and without, the building wake effects option as discussed below, and the most conservative estimate of predicted concentrations was recommended for use in the risk assessment (SENES 1993b).

Sources of Emissions

Table 5-2 lists all of the sources included in the modeling analysis and the acronyms used to identify the sources in the tabulated results presented in the dispersion modeling report (SENES 1993b). Figures 5-2 and 5-3 depict the location of the sources relative to the facility boundaries. Table 5-3 lists the individual stack parameters used in the ISC model for each source. Hourly stack emission rates for all constituents modeled are provided in the dispersion modeling report (SENES 1993b, Appendix A).

The source groups considered in the modeling analysis consisted of the following:

Permitted Sources

- four kiln venturi scrubbers (stacks KVS- A,- B,- C,- D);
- kiln cooler spray tower (KCST);
- nodule crushing and screening scrubber (NCSS); and
- three taphole fume collectors (THFC#7, #8, #9).
- scaleroom baghouse;

- stocking system baghouse;
- coke/quartzite dryer baghouse;
- coke/quartzite satellite baghouse;
- ore satellite baghouse;
- coke fines air conveyor baghouse; and
- CO dust collectors (one for each furnace).

In view of the relatively small contribution to total facility emissions from each baghouse, and in order to reduce the total number of sources to be considered in the modeling analysis, the baghouses were grouped into a single volume source in the ISC model (identified as BAGVOL in Figure 5-2). The basal area for the volume source was estimated as approximating the length and width of the facility complex from the southern end of the furnace buildings to the dryer building because the various baghouses are distributed throughout this portion of the facility. The rectangular shape of this area of 14,884 m^2 was converted to a square of equal area for input to ISC. The height of the volume source was estimated at 15.2 meters. The sum of the hourly baghouse emission rates was used as the emission rate for the baghouse volume source.

Material Handling Operations

Fugitive emissions from material handling operations of the ore, coke, quartzite, underflow solids, treater dust, and baghouse dust stockpiles were combined with wind erosion from each stockpile for modeling in FDM as area sources (Figure 5-3). Due to the thermal buoyancy of the fugitive emissions from the nodule reclaim area and the hot slag pot pouring operations, the fugitive emissions resulting from these operations were treated separately from the wind erosion of the nodule and slag stockpiles. The emissions due to wind erosion of the nodule and slag stockpiles were modeled using FDM (Figure 5-3), while the material handling operations were modeled using the ISC model (Figure 5-2). Similarly, the fugitive emissions resulting from furnace tapping operations were also modeled using the ISC model. The parameters used to define emissions from each of these three sources are discussed below.

Slag Disposal Operations

Discussions with the EPA have resulted in a general consensus that the emissions resulting from the disposal of hot slag onto the slag stockpile would be best simulated as a buoyant puff release (see Memorandum from B. Ryan, July 15, 1993). Currently available regulatory models do no easily lend themselves, however, to evaluating such sources using large meteorological data bases as required for the Phase II RI. Therefore, SENES (1993a) proposed to simulate these emissions as a pseudo-stack source. Temperature, plume rise and vertical velocity data derived from observations at iron and steel mills during furnace building slag tapping operations are then used to define stack parameters in the ISC model. EPA agreed in principle with this approach, although concerns were expressed by the EPA about the representativeness of using a single pseudo-stack point source to characterize emissions from slag disposal operations whose locations on the stockpile were not constant throughout the year and plume entrainment in the airflow in the lee of the stockpile.

Following discussions with EPA, it was agreed that the spatial representativeness of the pseudo-stack releases would be addressed by using a series of pseudo-stack release points on

the stockpile. On the matter of plume entrainment in the lee of the stockpile, it was agreed that the pseudo-stack release points would be characterized as short-stacks, and that the mass of the stockpile would be characterized as a series of stepped blocks. This approach treats the pseudo-stacks as if they were short stacks on a building. Plume entrainment from these releases can then be simulated by invoking the building wake effects option in the ISC model.

Figure 5-4 illustrates the stepped-block characterization used in the modeling. The slag disposal operations were distributed over five locations on the stockpile to simulate variations in the location of slag pot tipping operations over the period of a year. Since emissions from slag pouring occur along the entire pathlength of the molten slag from the top of the stockpile to the base, the releases were modeled as pseudo-stacks at three points along the pathlength: top, mid-point, and bottom. It was assumed that 60% of the emissions from each slag pot tipped would occur at the top of the stockpile, 30% would occur at the mid-point of the pathlength, and 10% would be released at the base of the stockpile. The temperature of the exhaust plume was also varied from 300°C at the top of the stockpile to 150°C at the bottom, based on the temperature range reported during slag tapping operations in the iron and steel industry (see Appendix E, SENES 1993a). Thus, the slag disposal emissions were modeled as pseudo-stacks at a total of 15 release points on the stockpile (sources #12 to #26, Figure 5-2): five at the top, five at the mid-point, and five at the base of the stockpile.

Nodule Reclaim Area

Prior to September 1992, material handling operations in the nodule reclaim area consisted of: 1) nodule discharge from the kiln via a chute into a pit, 2) pickup by clam from the pit, 3) deposit to a stockpile, 4) loader pickup from the stockpile, 5) loadout to a hopper for feed to the nodule crushing/screening scrubber. Emissions from these activities were uncontrolled. The combined emissions from these operations were modeled as a volume source (NODVOL, Figure 5-2) in the ISC model having dimensions 55 m by 55 m by 12.2 m.

As noted in the detailed inventory of source emissions (SENES 1993a), significant changes were made to the operations in this portion of the facility in September 1992. Thus, the current emissions and resultant impacts are expected to be lower by a factor of about 2 than those which are presented in this analysis for 1990 and 1991.

Furnace Building Tapping Operations

After adjusting the emission estimates using the EPA-recommended venturi scrubber control efficiency of 90% for all three furnaces, the fugitive emissions from slag tapping operations were modeled as a single volume source (FURBLDG, Figure 5-2) using the dimensions of the three furnace buildings to define the dimensions of the source (see Table 5-3).

Unpaved Haul Roads

The five unpaved haul roads included in the modeling analysis consist of the following:

- ore haul road (out);
- quartzite haul road;

- slag haul road;
- east service road; and
- west service road.

These sources were modeled as line sources in the FDM model as depicted in Figure 5-3.

Receptor Locations

Average annual ambient concentrations and deposition rates were calculated for particulates, fluorides, and specified trace metals and radionuclides for a rectangular 3 km by 3 km grid (400 meter grid spacing), as well as at discrete receptor locations within a 5 km by 5 km grid area. The ambient concentrations and deposition rates at each grid and discrete receptor point were calculated using hourly emission rates and hourly wind speed and direction data. The cumulative results were then averaged to compute the annual average concentration ($\mu g/m^3$ or $\mu Ci/m^3$) and deposition rate ($g/m^2/yr$ or $\mu Ci/m^2/yr$). The results were summarized in tabular format for discrete receptor locations and graphically for the rectangular receptor grid.

The off-site discrete receptors are shown on Figure 5-5 and listed in Table 5-4. These receptors included the nearest residential/commercial properties (Receptors 1-6), the four schools in Soda Springs (Receptors 7-10), the locations of current and historical TSP and PM_{10} monitoring stations around Soda Springs and Conda (Receptors 11-16), and the locations of historical fluoride-in-vegetation sampling stations (Receptors 17-32). In addition, discrete receptor points were located at 100 meter intervals along the property line (not shown in Figure 5-5), and were used to identify the point of maximum concentration or deposition at the facility boundary.

5.2.2.2 Predicted Ambient Concentrations

The dispersion modeling analysis indicates that air emissions from the facility are generally transported along a NNE-SSW axis, in accordance with the prevailing wind directions. The predicted ambient concentrations during 1991 were not significantly different from 1990 for most receptor locations. Predicted concentration levels in 1991 were less than 10% higher than in 1990 for some sources, although the emission rates modeled for 1991 were approximately 5% lower for most constituents than in 1990.

Since the operational scenario for 1991 was assumed to be the same as for 1990, the emissions from point sources were largely similar for both years and the primary difference in predicted ambient concentrations between 1990 and 1991 was the magnitude of the fugitive emissions from wind erosion of material stockpiles. Due to the spotty data record for 1988 and 1989 at the site, it was not possible to evaluate the representativeness of the 1990 and 1991 wind speed data at Soda Springs. However, a comparison of 1990 wind speed data at Pocatello with average data for the six year period 1985-90 indicated that the 1990 data at Pocatello were fairly representative of long-term average conditions (Supporting Document No. 1, SENES, 1992). 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.

Based on the dispersion modeling analysis for 1990 and 1991, it was concluded that ambient concentration levels for most trace constituents may vary by approximately $\pm$15% on a year-to-year basis at off-site locations. The two exceptions are for concentrations of manganese and zinc. In the case of manganese, the 1991 modeling results for kiln venturi stack A (STA in Table 4.6.2) are incorrect as a result of an error intransposing data from model output files to the spreadsheet file. For predicted zinc concentrations, the differences in concentrations are greater than 30% at some discrete recepotor sites in 1991 than in 1990. These differences are caused by the variability in stack sampling particulate data for THFC #8. Since the THFC's are a significant source of Zn emissions, the year-to-year variations in ambient concentrations of Zn may exceed $\pm$15%.

The primary sources which individually may contribute $\geq$10% to the total ambient concentration at the property line and beyond were identified as:

- wind erosion of the underflow solids stockpile;
- stack emissions from the kiln venturi scrubbers;
- nodule reclaim area operations;
- fugitive emissions from slag disposal operations; and
- stack emissions from the taphole fume collectors.

Of these sources, the UFS stockpile is the single most significant source contributing to maximum estimated concentrations at the north property line for particulates in general, as well as for most of the trace constituents modeled.

The general pattern of particulate concentrations due to facility emissions is depicted in Figures 5-6 and 5-7 for TSP and PM_{10}. The predicted concentrations of trace constituents at discrete off-site receptor locations are listed in Tables 5-5 through 5-8.

Total Suspended Particulate Matter (TSP)

The effect of combined emissions from all sources at the facility in 1990 would have resulted in ambient TSP concentrations from 15 $\mu g/m^3$ to 72 $\mu g/m^3$ along various portions of the north property line, from 18 $\mu g/m^3$ to 42 $\mu g/m^3$ along the south property line, and from 12 $\mu g/m^3$ to 40 $\mu g/m^3$ along the east and west property lines. Predicted maximum concentrations along the north property line were approximately 9 $\mu g/m^3$ lower for 1991 than for 1990, but were virtually unchanged along the east, west or south property lines.

Approximately 75% of the predicted maximum effect of 72 $\mu g/m^3$ along the north property line was attributable to fugitive dust emissions from two sources, namely the underflow solids stockpile and the nodule reclaim area. Operations for the latter source have been altered since September 1992 such that emissions from this source have been significantly reduced in comparison to the modeled emissions for 1990 and 1991. Thus, the UFS stockpile represents the largest single source currently contributing to facility effects along the north property line.

At Receptor 12, the location of the former ambient air monitoring station at the Harris Ranch, the predicted incremental TSP of 33 $\mu g/m^3$ in 1990 and 33.5 $\mu g/m^3$ in 1991 was higher than the estimated incremental TSP of 23 to 27 $\mu g/m^3$ based on monitoring data collected in 1986 to 88

(Chapter 4). A better fit with the observed concentrations can be obtained by modeling the emissions from slag disposal operations without using the building wake effects option in the ISC model. The latter method yielded a predicted concentration at the Harris Ranch of 25 $\mu g/m^3$ in both 1990 and 1991, in good agreement with measured concentrations during the period 1986-88. Therefore, the higher predicted concentrations obtained by using the building wake effects option in the ISC model for this source provide a conservative estimate of TSP and may overestimate actual TSP south and southwest of the facility property line.

Using the more conservative method of modeling the slag disposal operations, the predicted effects at the locations of the nearest residential/commercial receptors ranged from about 24 to 25 $\mu g/m^3$ at Receptor 2 directly south of the facility, to about 15 $\mu g/m^3$ in the southeast corner of the facility (Receptors 3 and 4), and 3 to 6 $\mu g/m^3$ at Receptors 6 and 1, northeast and southwest of the facility, respectively. At the four schools in Soda Springs (Receptors 7-10), the Terrace Acres Trailer Court (Receptor 16) and at the hospital (Receptor 13), predicted impacts in TSP concentrations ranged from 6 to 10 $\mu g/m^3$. The effects on receptors in the Conda area (Receptors 14 and 15) was estimated at less than 2 $\mu g/m^3$.

Inhalable Particulates (PM_{10})

The overall pattern of PM_{10} concentrations due to facility emissions is similar to the pattern for TSP concentrations, with PM_{10} concentrations being approximately one-half the predicted concentration for TSP. It is estimated that PM_{10} concentrations due to facility emissions would have ranged from 7 $\mu g/m^3$ to 35 $\mu g/m^3$ along the north property line in 1990, from 7 to 21 $\mu g/m^3$ along the south and west property lines, and from 6 to 14 $\mu g/m^3$ along the east property line. As with TSP, fugitive emissions from the underflow solids stockpile and the nodule reclaim area accounted for most of the PM_{10} levels (73%) at the north end of the facility and approximately half of the PM_{10} levels along the east, west and south property lines. Predicted maximum concentrations along the north property line in 1991 were unchanged from those in 1990.

For the calendar year 1990, the arithmetic mean annual concentration at the Terrace Acres Mobile Court monitoring site (Receptor 16) was 26.8 $\mu g/m^3$. The predicted PM_{10} concentration at this location due to facility emissions was estimated at 3.7 $\mu g/m^3$ in 1990 and 4.1 $\mu g/m^3$ in 1991. Therefore, the emissions due to facility operations were estimated to contribute only about 15% of the PM_{10} measured at this site.

The PM_{10} concentrations at the nearest residential/commercial receptors were estimated to range from 8-13 $\mu g/m^3$ at the southeast corner of the facility (Receptors 2, 3 and 4) to <2-3 $\mu g/m^3$ northeast and southwest of the facility (Receptors 1 and 6). The highest estimated concentrations for discrete receptor locations were predicted for the Harris Ranch (Receptor 12) at 17-18 $\mu g/m^3$. Predicted effects at the hospital and four schools in Soda Springs were approximately 3-5 $\mu g/m^3$, while the predicted impacts around Conda were less than 1 $\mu g/m^3$.

Trace Constituents

Tables 5-5 to 5-8 summarize the predicted ambient concentrations for particulates, fluorides, trace metals and radionuclides in 1990 and 1991 at the nearest residential/commercial receptor sites, as well as in Soda Springs and Conda. The concentrations at these sites are compared

with the maximum predicted concentration along the north property line. These data reflect the most conservative estimates for the purposes of conducting human health risk assessments.

The most significant sources contributing to ambient off-site concentrations were as follows:

Underflow Solids Stockpile was estimated to be the dominant source for concentrations of all constituents along the north property line, and a significant (i.e. >10%) source for As, Be, Cd, Ag, V, Zn, Mo, Pb-210, Po-210, U-234 and U-238 (9% for Ra-226 and Th-230) along the south property line. The underflow solids stockpile was also a significant contributor to the relatively lower concentrations at receptors beyond the property line for TSP, PM_{10}, As, Be, Cd, Ag, V, Zn, Mo, F, Pb-210, Po-210, Ra-226, Th-230, U-234 and U-238. It should be emphasized, however, that the significance of the underflow solids stockpiles is based on calculated emission rates due to wind erosion, and the methods used in calculating these rates are judged to be conservatively high (SENES 1993a), and may overestimate actual emissions from this source.

Nodule Reclaim Area may be a primary source for concentrations of TSP, PM_{10}, V, Mo, Ra-226, Th-230, U-234 and U-238 along the north property line, as well as a primary source for TSP, PM_{10}, Be, Mn, Ag, V, Mo, Ra-226, Th-230, U-234, and U-238 along the south property line. The nodule reclaim area was also a significant contributor to the lower concentrations at receptors beyond the property line for TSP, PM_{10}, Be, Ag, V, Mo, Ra-226, Th-230, U-234 and U-238. It should be noted, however, that changes made to the operations of the nodule reclaim area in September 1992 have significantly reduced emissions (i.e. >60%) from this source compared to the emissions used in the current analysis for 1990 and 1991.

Kiln Venturi Scrubbers were a significant (i.e. >10%) source of As, Cd, Mn, Mo and Po-210 at the north property line, and for As, Be, Cd, Mn, Ag, Mo, Pb-210 and Po-210 at the south property line. The significance of this source for Mn is uncertain due to an anomalously high measured emission rate during one stack sampling run on one of the four stacks in 1992.

Slag Disposal Operations were calculated to be primarily a source of TSP, PM_{10}, V, F, Ra-226, Th-230, U-234 and U-238 along the south property line, as well as at receptors beyond the property line. The significance of these emissions to TSP and PM_{10} concentrations may be overestimated, depending upon the method used to model this source. The concentrations listed in Tables 5-5 to 5-8 represent the more conservative method which resulted in predicted TSP concentrations at the Harris Ranch site (Receptor 12) that were approximately 33% higher than those observed during the 1986-88 monitoring program. The less conservative modeling method resulted in good agreement between predicted and observed TSP concentrations, although the results did not take into consideration possible differences in meteorological variables during the 1986-88 monitoring program and the modeling analysis for 1990-91 presented in this report. For the non-volatile radionuclides, the differences between the two methods resulted in predicted concentrations which were about 35-40% higher at off-site receptor locations south of the facility using the more conservative approach. In addition, there remain uncertainties about the actual mass particulate emission rate for this operation.

Taphole Fume Collectors were calculated to be a primary source of Zn at the south property line and a significant source of Pb-210 at the south property line and beyond.

Slag Stockpile may contribute approximately 7-8% of the non-volatile radionuclides in the ambient concentration levels along the southern property line but only 2-3% at receptors beyond the property line. However, the estimated emission rate due to wind erosion may be conservatively high based on the method used to calculate the fugitive emissions. Much of the surface material consists of large blocks of consolidated slag which are not easily eroded by wind. Furthermore, most of the south- and east-facing side slopes of the stockpile have been covered with topsoil and revegitated with grass. Thus, the analysis presented in this report may overestimate the significance of this source for current conditions.

It should also be noted that fugitive dust emissions from the haul roads were generally estimated to be negligible. Only the slag haul road contributed more than 1% to the total predicted ambient concentration for any of the trace constituents, and then only for Cd and Mn at the south property line.

5.2.2.3 Predicted Deposition Rates

The dispersion modeling analysis indicates that air emissions from the facility are generally transported along a NNE-SSW axis, in accordance with the prevailing wind directions. The predicted deposition rates during 1991 were not significantly different from 1990 for most receptor locations. Predicted deposition levels in 1991 were less than 10% higher than in 1990 for some sources, although the emission rates modeled for 1991 were approximately 5% lower for most constituents than in 1990.

Since the operational scenario for 1991 was assumed to be the same as for 1990, the emissions from point sources were largely similar for both years and the primary difference in predicted deposition rates between 1990 and 1991 was the magnitude of the fugitive emissions from wind erosion of material stockpiles. Due to the spotty data record for 1988 and 1989 at the site, it was not possible to evaluate the representativeness of the 1990 and 1991 wind speed data at Soda Springs. However, a comparison of 1990 wind speed data at Pocatello with average data for the six year period 1985-90 indicated that the 1990 data at Pocatello were fairly representative of long-term average conditions (Supporting Document No. 1, SENES, 1992). 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. Based on the dispersion modeling analysis for 1990 and 1991, it was concluded that ambient concentration levels for most trace constituents may vary by approximately $\pm$15% on a year-to-year basis at off-site locations.

The primary sources which individually may contribute $\geq$10% to the total annual average deposition rates of trace constituents were identified as:

- wind erosion of the underflow solids stockpile;
- stack emissions from the nodule crushing/screening scrubber;
- wind erosion of the ore stockpile;
- wind erosion of the treater dust stockpile; and
- wind erosion of the slag stockpile.

Of these, the UFS stockpile appeared to be the most significant source for the deposition of trace constituents along the north property line, as well as being a primary contributor to the deposition of As, Cd, Ag, Zn, Pb-210 and Po-210 along the south property line. On the other hand, the nodule crushing/screening scrubber stack was estimated to be the primary source for the deposition of Be, Mn, V, Mo, F, Ra-226, Th-230, U-234 and U-238 along the south property line.

There are two potential sources of uncertainty related to the estimated emissions from the UFS stockpile and the nodule crushing/screening scrubber. In the case of the former, the estimated emissions due to wind erosion of the stockpile represent a theoretical calculation which may be deemed to be conservatively high, thereby overestimating potential effects. For the nodule crushing/screening scrubber, the significance of the stack emissions to deposition rates is in part determined by the particle size distribution assumed for the deposition modeling analysis. In the absence of a measured particle size distribution, a size distribution was assumed from published sources for similar processes. Furthermore, the absolute magnitude of the particulate emissions from this source is uncertain based on previous stack sampling results.

The general pattern of particulate deposition due to facility emissions is depicted in Figures 5-8 and 5-9 for TSP and PM_{10}. The predicted deposition rates for trace constituents at discrete off-site receptor locations are listed in Tables 5-9 through 5-12.

Total Suspended Particulate Matter (TSP)

The maximum predicted deposition rate for TSP was predicted to occur along the north property line. Approximately 70% of the maximum value of 53.2 $g/m^2/yr$ was derived from UFS stockpile emissions. The remainder was composed primarily of emissions from the nodule crushing/screening scrubber (12%), the baghouse dust stockpile (8%), the ore stockpile (5%) and the nodule reclaim area (4%). By comparison, the maximum predicted deposition rate at the south property line was 13.9 $g/m^2/yr$. The relative contribution from sources consisted of 54% from the nodule crushing/screening scrubber, 15% from wind erosion of the slag stockpile, 12% from the UFS stockpile, 7% from the nodule reclaim area, 5% from the ore stockpile and 3% from the slag haul road.

Predicted deposition rates at the nearest residential/commercial receptors ranged from 4.5-7.0 $g/m^2/yr$ in the southeast corner of the facility (Receptor 2, 3 and 4) to 1-2 $g/m^2/yr$ northeast and southwest of the facility (Receptors 1 and 6). Deposition rates at the Harris Ranch were about 7.5 $g/m^2/yr$ (Receptor 12). At the four schools in Soda Springs (Receptors 7-10), the Terrace Acres Trailer Court (Receptor 16), and the hospital (Receptor 13), the deposition rates ranged from 0.6 to 1.7 $g/m^2/yr$. The effect at Conda was estimated to be about 0.3-0.4 $g/m^2/yr$ (Receptors 14 and 15).

Inhalable Particulate (PM_{10})

The predicted maximum deposition rate for PM_{10} also occurred along the north property line. Approximately 75% of the maximum rate of 24.3 $g/m^2/yr$ was due to UFS stockpile emissions, 9% from baghouse dust stockpile emissions, and 5% each from the ore stockpile and nodule reclaim area. At the south property line, the maximum deposition rate was 5.1 $g/m^2/yr$. Of this,

28% was calculated to be derived from the slag stockpile, 21% from the UFS stockpile, 13-14% each from the nodule crushing/screening scrubber and the nodule reclaim area, 9% from the ore stockpile and 6% from the slag haul road.

The PM_{10} deposition rates at the nearest residential/commercial receptors were estimated at 1-2 $g/m^2/yr$ at the southeast corner of the facility (Receptors 2, 3 and 4), 0.3-0.4 $g/m^2/yr$ northeast and southwest of the facility (Receptors 1 and 6), and 2 $g/m^2/yr$ at the HarrisRanch (Receptor 12). Deposition rates in Soda Springs (Receptors 7-10, 13) were about 0.2-0.4 $g/m^2/yr$, while the impact at Conda was about 0.1-0.2 $g/m^2/yr$.

Trace Constituents

Tables 5-9 through 5-12 summarize the predicted deposition rates for particulates, fluorides, trace metals and radionuclides in 1990 and 1991 at the nearest residential/commercial receptor sites, as well as in Soda Springs and Conda. The deposition rates at these sites are compared with the maximum predicted deposition rates along the north property line.

The most significant sources contributing to off-site deposition rates were as follows:

Underflow Solids Stockpile was calculated to be a dominant source for deposition of all constituents along the north property line, and a significant (i.e. $\geq$10%) source for all constituents along the south property line. The stockpile was also a significant source for the deposition of all constituents beyond the property line.

Nodule Crushing/Screening Scrubber was estimated to be a significant (i.e. $\geq$10%) source of TSP, Mo, Ra-226, Th-230, U-234 and U-238 deposition along the north property line and a primary source of TSP, PM_{10}, As, Be, Mn, Ag, V, Zn, Mo, F, Ra-226, Th-230, U-234 and U-238 along the south property line and beyond.

Ore Stockpile was a significant (i.e. $\geq$10%) source of As at receptor sites beyond the property line north and south of the facility, and a significant source of V at receptor sites northeast of the facility.

Treater Dust Stockpile was a significant (i.e., $\geq$10%) source of Zn at the south property line and at receptor sites beyond the property line south of the facility.

Slag Stockpile was a significant (i.e., $\geq$10%) source of Be, Mn, Ra-226, Th-230, U-234 and U-238 along the south property line and of Be and Mn deposition beyond the south property line.

5.2.3 Transport in Groundwater

Three primary plume areas have been identified below the Monsanto Plant and are of interest with regard to groundwater transport. These plumes occur below the northwest pond, the hydroclarifier, and the old underflow solids ponds, which are shown on Figure 1-3. Figure 4-29 depicts these plume areas with regard to the constituent cadmium.

A fourth plume, which is not well-defined, may be present in the southwest corner of the Plant below the former sewage evaporation ponds and the non-contact cooling water effluent settling pond. A fifth plume is present along the eastern border of the Plant, however, this plume originated below the Kerr-McGee Plant and is not addressed with regard to transport.

Chapter 4 presented discussion and figures concerning the constituents of potential interest identified in groundwater. As was shown from this information, the plume originating from below the old underflow solids ponds appears to be the only plume that has potential for transport beyond the present plant boundaries. Thus, only this plume was evaluated by quantitative analysis of transport.

Plumes in the central area of the plant emanating from below the northwest pond and the hydroclarifier are captured by production wells that withdraw groundwater for processing. These plumes are limited to the central area of the plant as long as the production wells continue to operate and provide a hydraulic control. The plume in the southwest corner of the plant discharges through springs located along Soda Creek and Mormon Creek. Hence, this plume also is limited with regard to further transport to the south.

5.2.3.1 Solute Transport Modeling Method

Solute transport modeling utilized a solution prepared by Domenico (1987) that was modified and coded into a computer program by Golder Associates Inc. Prior to conducting the modeling, a solution provided in Bear (1979) was intended for use. This solution, however, provided poor results in terms of aquifer concentrations (e.g., concentrations in excess of the source area were estimated downgradient from the source) and was abandoned for the solution prepared by Domenico (1987). Both solutions are based on the same partial differential equation of transport, however, Domenico's solution better handles the distributed constituent source (Bear's solution more aptly applied to a point source). A listing of the computer program is provided in Appendix L.

The transport solution is based on a mass balance for a non-decaying dissolved solute. The dissolved solute is transported by advection, due to the bulk groundwater flow, and by hydrodynamic dispersion, due to the variations in groundwater flow velocity at the pore scale. Retardation of the solute resulting from sorption (i.e., either solute precipitation or solute adsorption to minerals) also is accounted for when appropriate.

The solution presented by Domenico (1987) is the following:

$$C(x,y,t) = \frac{C_0}{4}\mathrm{erfc}[(x-vt)/2(\alpha_x vt)^{1/2}] \\ (\mathrm{erf}[(y+Y/2)/2(\alpha_y x)^{1/2}] - \mathrm{erf}[(y-Y/2)/2(\alpha_y x)^{1/2}]) \qquad (2)$$

where

C(x,y,t)	is the solute concentration at location x,y and time t (mass/volume),
C_0	is the source concentration at x = 0 and -Y/2 < y < Y/2 (mass/volume),
erfc(x)	is the complementary error function of the argument x,

erf(x)	is the error function of the argument x,
v	is the transport velocity (ft/d),
α_x	is the dispersivity along x (ft),
α_y	is the dispersivity along y (ft), and
Y	is the width of the source normal to the flow direction (ft).

Using Equation 2, the concentration of a solute can be predicted at various locations and various times. The source term represented by C_0 is assumed to be continuous and constant. Equation 2 can also include retardation effects if necessary by modifying the transport velocity. Under conditions of no retardation, i.e., R = 1, the transport velocity is equal to the seepage velocity of the groundwater. If retardation is known to influence the transport of a constituent, the seepage velocity is divided by the retardation parameter.

It should be noted that Equation 2 applies to transport in only two-dimensions, rather than three. The solution has been intentionally reduced to two-dimensions because the aquifer is thin in the vicinity of the Monsanto Plant and transport in three dimensions is anticipated to be limited because of low-permeability basalt that envelopes the UBZ-2 region of the groundwater flow system. Calculations of concentration by Equation 2 are made with the assumption of a constant concentration over the full thickness of the aquifer.

Because Equation 2 applies to a constant source, it was modified to account for the time-varying source observed at the Monsanto Plant. Historical information indicates the source of constituents to groundwater was continuous over a finite period of time and is currently declining, thus, the solution for an indefinitely constant source is inappropriate.

Equation 2 can be modified to account for the source term behavior by a method referred to as superposition (Bear 1979). The modified equation is the following:

$$C'(x,y,t) = C(x,y,t|C_0) + \sum_{i=1}^{N} C(x,y,t-t_i|C_i - C_{i-1}) \qquad (3)$$

where the notation $C(x,y,t-t_i|C_i-C_{i-1})$ is used to indicate a calculation carried out with Equation 2 substituting $t-t_i$ for t and C_i-C_{i-1} for C_0. The term to the right of the equal sign and left of the sum is simply Equation 2. The superposition method, as indicated in Equation 3, is nothing more than a sum of solutions to Equation 2 computed for different initial times, t_i, and different source concentrations, C_i-C_{i-1}. For example, if the source began with concentration C_0 at time t = 0 and then stopped abruptly at time $t = t_i$, the sum of Equation 3 would include only one term. The source value in this term would be $-C_0$. Hence, the continuous source beginning at time zero is cancelled by a negative continuous source beginning at time t_i. The result is a finite constant source of concentration C_0 over the time period from 0 to t_i. This logic can be applied to fit any conceivable step function representing the concentration at the source location.

The source term, representing constituents entering groundwater in the area of the old underflow solids ponds, began in about 1963 and was substantially reduced in 1983 when the ponds were taken out of use. A hypothetical function representing the actual source term is shown on Figure 5-10. As this function represents the conditions at the water table below the

ponds, the active period of the ponds has been shifted by 1 year to allow for vadose zone transport. As shown on Figure 5-10, the source concentration is shown to remain approximately constant when the ponds where in use and then to decline exponentially after closure of the ponds.

For the purposes of modeling solute transport from the old underflow solids ponds, the source concentration is represented by an analytical function. This function, also shown in Figure 5-10, consists of a constant segment that occurs during the period when the ponds were active followed by an exponentially declining segment. This function is defined as follows:

$$C(t) = \begin{bmatrix} 0, t < 1964 \\ C, 1964 < t < 1984 \\ Ce^{-r(t-1984)}, t > 1984 \end{bmatrix} \quad (4)$$

where

- C(t) is the source concentration at time t (mass/volume),
- C is the source concentration during the active period of the ponds (mass/volume),
- r is the source decay rate (yr^{-1}), and
- t is the time (yr).

As Equation 3 cannot directly implement the exponential decay function shown in Equation 4, it is necessary to approximate this function as a series of steps. To obtain the transport modeling results, the exponential function was computed for 4-year intervals and C(t) was assigned the interval midpoint concentration. For example, the source concentration over the period from 1988 to 1992 was assigned a concentration value of C(1990), as computed from Equation 4.

5.2.3.2 Source Area History

The old underflow solids ponds were used to dewater solids as part of the elemental phosphorus production process. In this use, a slurry was directed to the ponds and the liquid portion was allowed to drain into the ground. The solid material remaining in the ponds was a low grade phosphate ore that was excavated and recycled. In 1987 the ponds were closed and capped with molten slag and bentonite. At this time drainage to groundwater stopped and the slag and bentonite cap also provided a barrier to rainfall and snowmelt. Earlier work (Golder 1993a) estimated a recharge rate to groundwater through the slag and bentonite cap of 0.2 inches per year. Although it is unknown, this recharge rate is likely of order 1,000 times less than the recharge through the source area during the active period of the ponds.

Based on observations of declining groundwater concentrations in the source area (e.g., Test Well 37 shown on Figure 4-31) it appears the release of mass to groundwater is declining. The mass released to groundwater under present conditions may arise from dissolution of residual materials in the pore space of the vadose zone and aquifer and/or continued drainage of vadose zone liquids to groundwater. The former mechanism is considered more likely as almost 8 years has passed since the ponds were closed and it is likely the vadose zone moisture content has reached a steady state condition. Under this condition, little if any moisture is expected to

drain from the vadose zone to the water table in the source area. The slag and bentonite cap at ground surface is a barrier to infiltration.

5.2.3.3 Constituents of Potential Interest

Constituents of potential interest were identified according to groundwater type and region in Chapter 4. The old underflow solids ponds overly the UBZ-2, which includes both fresh and sodic groundwater types. As listed in Table 5-1, the constituents of potential interest for the UBZ-2 include the following:

Cadmium
Fluoride
Manganese
Molybdenum
Nitrate
Selenium

Groundwater quality data for each of these constituents was presented in Chapter 4. These constituents are the focus of the transport modeling conducted for the UBZ-2 plume.

5.2.3.4 Hydraulic Transport Parameters

Transport modeling requires input of hydraulic parameters as well as chemical parameters. Hydraulic parameters, which are independent of the constituent, include the groundwater velocity and dispersivity. Values determined for these parameters are presented below.

Groundwater Velocity

Based on the groundwater flow modeling described in Section 3.7.3, groundwater seepage velocity was determined to average 10 ft/d in the UBZ-2 groundwater region to the south of the Monsanto Plant. This value for groundwater velocity is slightly higher than the velocity estimates from Darcy Law calculations based on hydrogeologic data collected from the Plant. Consequently, the model results will tend to predict shorter travel times than are indicated by the hydrogeologic data obtained for the Plant.

Dispersivity

Data for longitudinal dispersivity in many different aquifer conditions was compiled by Gelhar et al. (1985). In the transport calculations presented below, longitudinal dispersivity values, a_x, were obtained from the "best fit" curve drawn through the data of Gelhar et al., as shown on Figure 5-11. Dispersivity values were determined for three observation locations that were selected for output of concentration time histories from the transport model. These locations include an intermediate point in the aquifer 500 ft south of the Monsanto Plant boundary (5,000 feet from the source area), a location at Soda Creek (8,500 feet from the source area), and a location at the Bear River (18,500 feet from the source area). These locations are schematically shown on Figure 5-12.

The transverse dispersivity, a_y, was obtained by assuming a value for the ratio of transverse- to longitudinal-dispersivity. This ratio was assumed to be 0.01 due to the faulting in the UBZ-2 groundwater region which restricts lateral spreading of dissolved constituents.

Table 5-13 presents the dispersivity values used in the solute transport modeling. As the transverse dispersivity values were very close in value, a constant value of 3 ft was used in the model calculations as a simplification. The results of the model were found to be insensitive to the value of the transverse dispersivity within the range of the estimated values shown in Table 5-13.

5.2.3.5 Chemical Transport Parameters

The source concentration and retardation parameters are referred to as chemical parameters because they depend directly on the constituent of potential interest. Data for these parameters are presented below.

Source Concentration

The source concentration was defined as a constant segment followed by an exponentially declining segment, as shown on Figure 5-10. The constant segment of the function requires a groundwater concentration value for the active period of the old underflow solids ponds, from 1964 to 1984. The exponentially decaying segment requires a decay rate parameter. These data have not been measured directly for the constituents of potential interest and were estimated for the solute transport modeling. The first step to estimate the parameters consisted of estimating the decay rate. The decay rate was then used along with current groundwater quality data to back-calculate the source concentration during the period from 1964 to 1984.

The decay rate was estimated from time history data collected at the Monsanto Plant from about 1985 to present. For a declining time history of groundwater concentration in the source area and assuming an exponential decay model, the source concentration decay rate, r, is computed as follows:

$$r = -\frac{\ln \frac{C(t_2)}{C(t_1)}}{t_2 - t_1} \qquad (5)$$

where $C(t_i)$ is the source area groundwater concentration at time t_1 or t_2. This equation is identical to that used for determining concentrations of a decaying radioactive isotope, but has been rearranged to solve for the decay constant (e.g., see Kreysig 1983, p. 5).

For each constituent of potential interest, the source area groundwater concentration was obtained from analyses for samples collected from Test Well 37 (Figure 3-19). Time t_1 ranged from 1985 to 1987 and time t_2 ranged from 1992 to 1993. The average concentration in the neighborhood of either time t_1 or time t_2 was visually estimated from x-y plots of the time history data. Table 5-14 presents data and results for each constituent of potential interest. Time history data for each constituent of potential interest were presented in Chapter 4.

Given the estimated decay rate for the exponentially declining source concentration, the source area concentration for the period from 1964 to 1984 was estimated as follows:

$$C(1984) = \frac{C(t_1)}{e^{-r(t_1-1984)}} \qquad (6)$$

As shown on Figure 5-10, the concentration during this period is constant, thus, it can be estimated by estimating the concentration occurring in 1984. Values for C(1984) are shown in Table 5-14 for each constituent of potential interest.

There were a few special cases to deal with in evaluating the parameters for the source concentration. Time history data for molybdenum and selenium concentrations were lacking for Test Well 37. For both constituents an average decay rate was assigned and the value of C(1984) was computed based on the currently observed groundwater concentration. The average decay rate was based on computed decay rates for aluminum, arsenic, cadmium, nickel, vanadium, and zinc.

Nitrate also required special treatment because it occurs at significant levels in background groundwater. The background concentrations were based on chemical analyses of groundwater samples collected from Test Well 57 in November, 1992. As shown on Figure 3-29, Test Well 57 is directly up-gradient from the old underflow solids ponds in the UBZ-2 groundwater region. The background concentrations was subtracted from the observed concentration in the source area prior to computing the decay rate. The background concentration was subsequently added to the modeling result. The background concentration was 0.96 mg/L for nitrate.

Fluoride also was a constituent that required special handling. The fluoride groundwater concentration time history in Test Well 37 is shown on Figure 4-32 and does not reveal that concentrations are declining. Following a sharp decline from 1985 to 1986, the fluoride concentration remains steady. To account for this pattern, a step function was used for the source term that included two constant segments. The first segment occurred from 1964 to 1984 with a concentration level of 40 mg/L and the second segment occurred afterwards with a concentration level of 17 mg/L. Although a step function is supported by the time history data, historical information on the source area indicates the source concentrations will decline. Unfortunately, data are not currently available to estimate a rate of decline.

The transport model solution is an adaptation of a constant source model, thus, it cannot handle the exponentially decaying source concentration when written as a function. Rather, the exponential function must be fit to a series of steps. For the transport modeling, a 4-year step size was used to fit the exponential decline of the source concentration. This approximation was found to provide smooth predicted concentration time histories. Table 5-15 presents the discrete source values used in the transport modeling.

The transport model distributes the source over a line of length Y. The value of Y represents the width of the source normal to the direction of transport, which coincides with the direction of groundwater flow. The modeling results presented below were based on a value of Y equal to 600 ft, which is slightly larger than the surface extent of the Ponds.

Retardation Parameters

Chemical reactions that result in the temporary removal of a dissolved constituent from solution are represented by the retardation parameter. These reactions, referred to as sorption reactions, include both precipitation and adsorption. In both types of reactions it is assumed the dissolved and sorbed phases of the constituent are in equilibrium. The result of either reaction is a decline in the transport rate of the constituent. No mass is removed from transport by retardation processes. This model of the retardation process is potentially conservative, especially with regard to metal constituents. It is possible for certain constituents to become permanently fixed in the aquifer media, thus, mass is actually removed in these cases.

Retardation is a function of the solute and the porous medium (Dragun 1988). The retardation parameter, R, is computed as follows:

$$R = 1 + \frac{\rho_b}{n} K_d \tag{7}$$

where

K_d is the distribution coefficient (ml/g),
r_b is the bulk density of the porous medium (g/ml), and
n is the porosity of the porous medium.

The distribution coefficient indicates the tendency for the solute to adhere to the solid phase of the porous medium or to precipitate from pore water. The bulk density and porosity are used for the purpose of a units conversion.

Table 5-16 presents distribution coefficients obtained from Dragun (1988) and the corresponding retardation parameters for the constituents of potential interest. Distribution coefficients shown in Table 5-16 are based on a variety of data for soils and clay materials. The data are non-specific to the Monsanto Plant and were assumed to be representative of the basalt interbed materials. In computing the retardation coefficient, the bulk density was assigned a value of 2 g/ml and the porosity a value of 0.25 ml/ml, values assumed to represent the basalt interbeds below the Monsanto Plant (Freeze and Cherry 1979). Based on these parameters the retardation, R, is equal to $1+8K_d$.

As shown in Table 5-16, distribution coefficients were available for four constituents, cadmium, manganese, molybdenum and selenium. For these constituents, with the exception of selenium, the retardation parameter was computed from the minimum value for the distribution coefficient. As selenium in groundwater typically complexes with oxygen and forms an anion, the retardation was assigned a value of 1, i.e., no retardation occurs. Use of the minimum retardation value for the other constituents was a conservative approach with respect

to the travel time of the constituents. Thus, the modeling results provide the earliest arrival times at the observation locations for the constituents of potential interest.

Data were lacking for the distribution coefficient for several of the constituents of potential interest. These constituents included fluoride and nitrate. To conduct the transport analysis, it was necessary to estimate retardation values for these parameters. If the constituent typically occurs as an anion (a negatively charged species) in groundwater, the retardation parameter was assumed equal to 1, i.e., no retardation occurs. A retardation value of 1 was assigned to fluoride and nitrate.

5.2.3.6 Transport Modeling Results

Constituent concentrations were predicted at three locations in the shallow basalt aquifer for the UBZ-2 plume. The three observation locations were located along the plume centerline (i.e., y-coordinate = 0), which coincides with the maximum concentration in the plume at the particular x-coordinate value. These locations are shown on Figure 5-12. The x-coordinate values for the three locations were 5,000 ft, 8,500 ft, and 18,500 ft. The first location at 5,000 ft occurs approximately 500 ft south of the Monsanto Plant southern fence line near the location of Test Wells 54 and 55. The second location at 8,500 ft occurs at the estimated approximate discharge point of the plume into Soda Creek, if the plume were in fact to follow a pathway to Soda Creek. The third location at 18,500 ft occurs at the estimated approximate discharge point of the plume into Bear River, if the plume were in fact to follow a pathway to Bear River. Based on hydrogeological analysis (Chapter 3), it appears that groundwater from the UBZ-2 region discharges to Soda Creek rather than directly to the Bear River.

Figures 5-13 through 5-18 present predicted time histories for the constituents at the three observation locations. The general pattern observed in the results consists of a sharp rise to a plateau representing the onset of pond usage. The plateau then continues during the active period for the ponds. Following the active period, the concentrations decline to background levels over time periods from 20 years to 100 years. The occurrence of a plateau in the predicted time histories indicates that steady-state conditions in the aquifer were predicted to occur during the active period of the ponds. Except for cadmium, the predicted maximum concentration exists or has already occurred at the three observation locations. With respect to cadmium, the maximum concentration in groundwater discharging to Soda Creek is predicted to occur around the year 2000 and that at Bear River is predicted to occur around the year 2035.

Cadmium concentrations in groundwater are known to be controlled by the mineral otavite, a cadmium carbonate mineral. Earlier geochemical modeling of groundwater in the UBZ-2 groundwater region (Golder 1993a) showed that otavite is likely to exist in the aquifer. In equilibrium with otavite, the dissolved cadmium concentration should remain constant at about 0.06 mg/L. Figure 5-25 presents predicted cadmium time histories assuming the maximum source concentration occurring during the period from 1964 to 1984 was 0.07 mg/L, a value slightly higher than the otavite equilibrium concentration. As shown by Figure 5-19, the position of the time history curves is unchanged, however, the maximum concentrations are lower by a factor of 2.

Fluoride also is a constituent of potential interest that commonly forms a mineral, and hence may be subject to a solubility control. Fluoride was predicted to be in equilibrium with fluorite, a calcium fluoride mineral, by the earlier geochemistry modeling (Golder 1993a). In equilibrium with fluorite, the fluoride concentration will be limited to about 3.8 mg/L. Figure 5-20 presents predicted fluoride time histories assuming the present day source is constant at 4 mg/L. As shown in Figure 5-20, the steady-state conditions which are predicted to exist now and into the future are a factor of about 4 less than shown on Figure 5-14, which was created without consideration of solubility controls.

5.2.3.7 Interpretations

The solute transport modeling provided reasonable predictions of groundwater concentrations for nitrate and selenium. Poor predictions were obtained by the transport modeling for cadmium, fluoride, manganese and molybdenum. In these cases, the model substantially overestimated the currently observed concentrations. Table 5-17 presents a comparison of predictions with observations from Test Wells 54 and 55. Both of these test wells are shown on Figure 5-12 and are located about 500 ft to 750 ft south of the Monsanto Plant southern fence line.

In attempting to obtain a better fit of predictions to observations, the model was calibrated to down-gradient groundwater concentrations observed in 1992 and 1993. By considering model sensitivity and the input data, the retardation parameter was determined to be the only calibration parameter that could alter concentrations to the extent necessary. The source term was not a candidate for model calibration because it was developed by calibration to Test Well 37. Other parameters such as the source width and the dispersivities were considered to have minor effects on the model predictions.

Based on calibration to cadmium and manganese, which are two constituents with good time history data, very large retardation values (R = 50 for cadmium and R = 45 for manganese) were necessary to match the low observed concentrations. This same pattern was anticipated to be observed for the other constituents and the calibration was not completed. In calibrating the model to cadmium and manganese, we found a discrepancy in the predicted model trends. The predicted trends obtained using the large retardation values were increasing rather than decreasing at down-gradient locations. Based on the time history data at Test Wells 22 and 36 where we observe decreasing trends, the model incorrectly predicted increasing trends. Thus, it appears the calibration based on retardation was not appropriate for comparing predictions to observations and that there are other processes occurring in the aquifer that reduce the down-gradient concentrations.

The results of the calibration indicate that certain constituents become fixed in the aquifer materials as they migrate down-gradient. The fixation of constituents within the aquifer material will lower the down-gradient concentrations below those which would be predicted by the transport model (as the transport model assumes equilibrium partitioning). This fixation process, which is primarily ion exchange, is expected for cations and is discussed by Dragun (1988). The constituents to which this transport process applies include cadmium, manganese and molybdenum. For these parameters the model predictions are overestimates due to the

transport processes considered by the model and the results cannot be improved by model calibration.

TABLE 5-1

SUMMARY OF CONSTITUENTS OF POTENTIAL INTEREST

CONSTITUENT	ENVIRONMENTAL MEDIA				
	Air	Surface Water	Stream Sediment	Soil	Groundwater
Arsenic	x		x	x	
Beryllium	x			x	
Cadmium	x		x	x	x
Chloride					
Copper			x		
Fluoride	x				x
Iron					
Lead-210	x			x	
Manganese	x				x
Molybdenum	x				x
Nickel			x		
Nitrate					x
Polonium-210	x		x	x	
Radium-226	x			x	
Selenium			x		x
Silver	x		x		
Thorium-230	x			x	
Uranium-234	x				
Uranium-238	x			x	
Vanadium	x		x	x	
Zinc	x				

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TABLE 5-2

KEY TO AIR EMISSION SOURCES

Source	ID[1]	Type
Kiln venturi scrubbers - Stack A - Stack B - Stack C - Stack D	 KVS-A KVS-B KVS-C KVS-D	 point point point point
Taphole fume collectors - #7 furnace - #8 furnace - #9 furnace	 THFC 7 THFC 8 THFC 9	 point point point
Kiln cooler spray tower	KCST	point
Nodule curbing/screening scrubber	NCSS	point
Baghouses (9)	BAGVOL	volume
Nodule reclaim area	NODVOL	volume
Furnace building fugitives	FURBLDG	volume
Slag disposal - without building wake effects option - with building wake effects option	 SLGST SLGST*BLDG	 15 pseudo-stack 15 pseudo-stacks
Ore stockpile - wind erosion & material handling fugitives	ORE	area
Quartzite stockpile - wind erosion & material handling fugitives	QRTZ	area
Coke stockpile - wind erosion & material handling fugitives	COKE	area
Coal stockpile - wind erosion	COAL	area
Nodule stockpiles - non-active; wind erosion - active; wind erosion & material handling fugitives	 NODN NODA	 area
Underflow solids stockpiles - wind erosion & material handling fugitives	UFS	area
Baghouse dust stockpile - wind erosion & material handling fugitives	BAG	area

TABLE 5-2

KEY TO AIR EMISSION SOURCES (Cont.)

Source	ID[1]	Type
Treater dust stockpile - wind erosion & material handling fugitives	TRT	area
Slag stockpile - wind erosion	SLG	area
Slag (cold dumping) - material handling fugitives	$SLGC1_1$, SLGC2	2 areas
Ore haul road - vehicle travel fugitives	RDORE	line
Quartzite haul road - vehicle travel fugitives	RDQRZ	line
Slag haul road - vehicle travel fugitives	RDSLG	line
East Service Road - vehicle travel fugitives	RDSRE	line
West Service Road - vehicle travel fugitives	RDSRW	line

[1]Source ID refers to sources depicted in Figures 5-2 and 5-3, and also listed in Tables 4.1.1 to r.17.2 and 5.1.1 to 5.17.2 of the air dispersion modelling report (SENES 1993b).

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TABLE 5-3

SOURCE CHARACTERISTICS USED IN MODELING POINT AND VOLUME SOURCES

SOURCES	STACK PARAMETERS				BUILDING DIMENSIONS		
	HEIGHT (m)	DIAMETER (m)	VELOCITY (m/s)	TEMPERATURE °C	LENGTH (m)	WIDTH (m)	HEIGHT (m)
THFC #7	29.3	0.9	17.6	42.2	64	40.2	40.5
#8	36.0	0.9	18.8	40.6	64	40.2	40.5
#9	22.3	0.9	16.8	43.3	48.2	48.2	48.8
KCST	36.0	3.9	7.8	50.0	164.6	29.0	12.2
Kiln Venturi Scrubbers							
A	27.7	1.4	21.8	70.6			
B	27.7	1.4	20.7	70.6			
C	27.7	1.4	19.0	70.6			
D	27.7	1.4	21.7	70.6			
NCSS	24.7	3.5	7.4	45.6	24.4	21.3	15.2
Baghouses (volume source)					122	122	15.2
Furnace Building (volume source)					394	158	160
Nodule Reclaim Area (volume source)					55	55	12.2

TABLE 5-3 (Cont.)

SOURCE CHARACTERISTICS USED IN MODELING POINT AND VOLUME SOURCES

SOURCES	PSEUDO-STACK PARAMETERS				STOCKPILE "BUILDING" DIMENSIONS		
	HEIGHT (m)	DIAMETER (m)	VELOCITY (m/s)	TEMPERATURE °C	LENGTH (m)	WIDTH (m)	HEIGHT (m)
Slag Disposal (15 pseudo-stacks)							
SA1	10	17	4.3	300.0	60	60	32
SA2	10	17	4.3	200.0	60	60	23
SA3	10	17	4.3	150.0	0	0	0
SB1	10	17	4.3	300.0	60	60	32
SB2	10	17	4.3	200.0	60	60	23
SB3	10	17	4.3	150.0	60	60	14
SC1	10	17	4.3	300.0	120	120	44
SC2	10	17	4.3	200.0	180	180	34
SC3	10	17	4.3	150.0	420	420	14
SD1	10	17	4.3	300.0	120	120	44
SD2	10	17	4.3	200.0	180	180	34
SD3	10	17	4.3	150.0	300	300	30
SE1	10	17	4.3	300.0	120	120	44
SE2	10	17	4.3	200.0	180	180	34
SE3	10	17	4.3	150.0	300	300	30

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TABLE 5-4

DISCRETE RECEPTOR LOCATIONS

DISCRETE RECEPTORS	UTM COORDINATES	
	Northing (m)	Easting (m)
Nearest Neighbours		
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
Schools in Soda Springs		
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
Historical Air Quality Monitoring Sites		
11. Hooper Springs - TSP Monitoring (13-420-029)	4,728,714	449,762
12. Harris Ranch - TSP Monitoring (13-420-026)	4,724,809	451,523
13. Soda Springs Hospital - TSP Monitoring (13-420-021)	4,722,283	450,250
14. Conda - TSP/PM_{10} Monitoring (13-420-027)	4,731,024	454,756
15. Conda - TSP Monitoring (13-420-002)	4,732,300	454,000
16. Terrace Acres Mobile Court - PM_{10} Monitoring (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.

1118mmc1.5-4

TABLE 5-5

SUMMARY OF ANNUAL AVERAGE CONCENTRATIONS ($\mu g/m^3$) OF PARTICULATES, TRACE METALS AND FLUORIDES (1990)

RECEPTOR	SPM	PM_{10}	As	Be	Cd	Mn	Ag	V	Zn	Mo	F
1	6.11	3.13	1.96E-4	3.97E-5	2.54E-3	1.05E-3	9.86E-5	7.13E-3	2.96E-2	1.79E-4	2.95E-1
2	24.17	12.48	6.07E-4	1.38E-4	8.05E-3	4.53E-3	2.68E-4	2.31E-2	7.90E-2	6.04E-4	1.41
3	14.95	7.80	5.25E-4	1.03E-4	7.16E-3	3.89E-3	2.16E-4	1.67E-2	6.23E-2	4.92E-4	7.61E-1
4	14.47	7.50	4.84E-4	9.36E-5	6.74E-3	3.84E-3	1.93E-4	1.49E-2	5.63E-2	4.52E-4	8.16E-1
5	10.31	5.31	3.87E-4	6.74E-5	5.59E-3	3.31E-3	1.41E-4	1.04E-2	4.09E-2	3.49E-4	6.26E-1
6	3.39	1.70	2.08E-4	2.93E-5	3.11E-3	1.79E-3	6.91E-5	3.79E-3	1.73E-2	1.59E-4	1.99E-1
7	9.20	4.74	3.36E-4	5.79E-5	4.92E-3	3.02E-3	1.19E-4	8.98E-3	3.56E-2	3.10E-4	5.80E-1
8	6.16	3.16	2.67E-4	4.19E-5	4.03E-3	2.56E-3	8.63E-5	6.00E-3	2.55E-2	2.37E-4	3.93E-1
9	6.13	3.15	2.62E-4	4.12E-5	3.96E-3	2.54E-3	8.35E-5	5.95E-3	2.52E-2	2.37E-4	3.93E-1
10	9.47	4.88	3.39E-4	5.82E-5	4.98E-3	3.09E-3	1.19E-4	9.14E-3	3.66E-2	3.18E-4	6.09E-1
11	3.26	1.61	2.37E-4	3.01E-5	3.76E-3	2.64E-3	5.85E-5	3.24E-3	1.71E-2	1.97E-4	1.90E-1
12	33.00	17.14	6.30E-4	1.63E-4	8.02E-3	4.64E-3	3.12E-4	3.07E-2	9.84E-2	7.36E-4	2.00
13	7.38	3.79	3.03E-4	4.81E-5	4.57E-3	2.91E-3	9.81E-5	7.08E-3	2.97E-2	2.76E-4	4.79E-1
14	1.74	0.86	1.19E-4	2.54E-5	1.85E-3	1.21E-3	3.28E-5	1.77E-3	8.77E-3	9.44E-4	1.08E-1
15	1.79	0.88	1.45E-4	1.78E-5	2.30E-3	1.54E-3	3.67E-5	1.80E-3	9.75E-3	1.13E-4	1.10E-1
16	7.15	3.66	2.99E-4	4.80E-5	4.44E-3	2.74E-3	1.01E-4	7.05E-3	2.91E-2	2.63E-4	4.52E-1
Maximum Concentration	72.0	34.8	5.15E-3	8.36E-4	6.69E-2	9.82E-3	3.01E-3	1.25E-1	5.06E-1	2.51E-3	3.53

NOTE: Maximum concentration occurs along the north property line.

1118mxo1.5-5

TABLE 5-6

SUMMARY OF ANNUAL AVERAGE CONCENTRATIONS ($\mu Ci/m^3$) OF RADIONUCLIDES (1990)

RECEPTOR	Pb-210	Po-210	Ra-226	Th-230	U-234	U-238
1	5.54E-10	7.52E-10	2.31E-10	2.48E-10	2.15E-10	2.25E-10
2	1.50E-9	2.37E-9	9.30E-10	9.73E-10	8.38E-10	8.74E-10
3	1.23E-9	2.09E-9	5.53E-10	5.92E-10	5.12E-10	5.33E-10
4	1.10E-9	1.96E-9	5.45E-10	5.77E-10	4.99E-10	5.19E-10
5	8.24E-10	1.61E-9	3.91E-10	4.14E-10	3.57E-10	3.72E-10
6	4.08E-10	8.84E-10	1.26E-10	1.35E-10	1.18E-10	1.23E-10
7	7.03E-10	1.42E-9	3.53E-10	3.72E-10	3.21E-10	3.33E-10
8	5.19E-10	1.16E-9	2.35E-10	2.48E-10	2.14E-10	2.22E-10
9	5.04E-10	1.14E-9	2.34E-10	2.48E-10	2.14E-10	2.22E-10
10	7.06E-10	1.44E-9	3.64E-10	3.84E-10	3.31E-10	3.44E-10
11	3.69E-10	1.06E-9	1.21E-10	1.31E-10	1.13E-10	1.16E-10
12	1.69E-9	2.40E-9	1.28E-9	1.35E-9	1.16E-9	1.20E-9
13	5.89E-10	1.31E-9	2.83E-10	2.99E-10	2.57E-10	2.67E-10
14	2.02E-10	5.25E-10	6.52E-11	6.98E-11	6.05E-11	6.26E-11
15	2.31E-10	6.50E-10	6.63E-11	7.12E-11	6.18E-11	6.38E-11
16	5.97E-10	1.27E-9	2.73E-10	2.89E-10	2.49E-10	2.59E-10
Maximum Concentration	1.57E-8	1.91E-8	2.67E-9	2.97E-9	2.65E-9	2.88E-9

NOTE: Maximum concentrations occurs along the north property line.

1118mzc1.5-6

TABLE 5-7

SUMMARY OF ANNUAL AVERAGE CONCENTRATIONS ($\mu g/m^3$) OF PARTICULATES, TRACE METALS AND FLUORIDES (1991)

RECEPTOR	SPM	PM_{10}	As	Be	Cd	Mn	Ag	V	Zn	Mo	F
1	6.60	3.41	2.19E-4	4.64E-5	2.92E-3	1.49E-3	1.06E-4	8.14E-3	3.40E-2	2.02E-4	3.17E-1
2	25.46	13.42	6.44E-4	1.39E-4	8.50E-3	5.48E-3	3.07E-4	2.51E-2	1.05E-1	6.27E-4	1.50
3	15.48	8.23	5.58E-4	1.02E-4	7.51E-3	4.55E-3	2.36E-4	1.77E-2	7.89E-2	4.97E-4	8.02E-1
4	15.22	8.07	5.08E-4	9.44E-5	6.98E-3	4.52E-3	2.13E-4	1.62E-2	7.37E-2	4.63E-4	8.58E-1
5	10.97	5.77	4.07E-4	6.86E-5	5.82E-3	3.99E-3	1.55E-4	1.14E-2	5.38E-2	3.60E-4	6.65E-1
6	2.81	1.41	1.88E-4	2.42E-5	2.83E-3	1.94E-3	6.09E-5	3.26E-3	1.71E-2	1.37E-4	1.70E-1
7	9.67	5.07	3.58E-4	5.87E-5	5.23E-3	3.77E-3	1.30E-4	9.62E-3	4.66E-2	3.21E-4	6.18E-1
8	6.52	3.40	2.91E-4	4.28E-5	4.39E-3	3.29E-3	9.43E-5	6.44E-3	3.33E-2	2.50E-4	4.25E-1
9	6.23	3.24	2.79E-4	4.05E-5	4.24E-3	3.20E-3	8.90E-5	6.06E-3	3.20E-2	2.39E-4	4.16E-1
10	10.37	5.44	3.68E-4	6.06E-5	5.42E-3	3.99E-3	1.32E-4	1.01E-3	4.89E-2	3.37E-4	6.88E-1
11	2.83	1.42	1.86E-4	2.27E-5	2.92E-3	2.42E-3	4.77E-5	2.76E-3	1.62E-2	1.52E-4	1.70E-1
12	33.50	17.73	6.63E-4	1.61E-4	8.55E-3	5.60E-3	3.46E-4	3.15E-2	1.28E-1	7.18E-4	2.11
13	8.06	4.20	3.48E-4	5.17E-5	5.28E-3	4.04E-3	1.11E-4	7.88E-3	3.99E-2	3.09E-4	5.25E-1
14	1.40	0.70	1.01E-4	1.20E-5	1.59E-3	1.24E-3	2.75E-5	1.44E-3	8.44E-3	7.79E-4	9.05E-2
15	1.75	0.88	1.31E-4	1.54E-5	2.08E-3	1.67E-3	3.38E-5	1.77E-3	1.05E-2	1.04E-4	1.09E-1
16	7.76	4.06	3.28E-4	5.02E-5	4.88E-3	3.55E-3	1.12E-4	7.79E-3	3.96E-2	2.83E-4	4.98E-1
Maximum Concentration	62.9	30.6	4.69E-3	7.35E-4	6.03E-2	2.66E-3	1.15E-1	4.61E-1	2.22E-3	6.03E-2	3.09

NOTE: Maximum concentration occurs along the north property line.

1118mxcl.5-7

TABLE 5-8

SUMMARY OF ANNUAL AVERAGE CONCENTRATION ($\mu Ci/m^3$) OF RADIONUCLINES (1991)

RECEPTOR	Pb-210	Po-210	Ra-226	Th-230	U-234	U-238
1	5.93E-10	8.54E-10	2.47E-10	2.70E-10	2.32E-10	2.42E-10
2	1.67E-9	2.51E-9	9.59E-10	1.01E-9	8.71E-10	9.04E-10
3	1.35E-9	2.20E-9	5.59E-10	6.06E-10	5.21E-10	5.42E-10
4	1.22E-9	2.05E-9	5.60E-10	6.00E-10	5.16E-10	5.36E-10
5	9.17E-10	1.69E-9	4.08E-10	4.36E-10	3.74E-10	3.88E-10
6	3.68E-10	8.04E-10	1.03E-10	1.11E-10	9.62E-10	1.00E-10
7	7.80E-10	1.52E-9	3.65E-10	3.88E-10	3.33E-10	3.45E-10
8	5.83E-10	1.27E-9	2.45E-10	2.61E-10	2.24E-10	2.32E-10
9	5.56E-10	1.22E-9	2.34E-10	2.49E-10	2.14E-10	2.21E-10
10	8.02E-10	1.58E-9	3.93E-10	4.17E-10	3.58E-10	3.71E-10
11	3.06E-10	8.30E-10	1.05E-10	1.13E-10	9.75E-11	1.00E-10
12	1.89E-9	2.54E-9	1.27E-9	1.34E-9	1.15E-9	1.19E-9
13	6.87E-10	1.52E-9	3.04E-10	3.24E-10	2.78E-10	2.88E-10
14	1.74E-10	4.51E-10	5.16E-11	5.55E-11	4.80E-11	4.96E-11
15	2.16E-10	5.91E-10	6.42E-11	6.92E-11	5.98E-11	6.16E-11
16	6.86E-10	1.41E-9	2.90E-10	3.09E-10	2.65E-10	2.75E-10
Maximum Concentration	1.39E-8	1.72E-8	2.32E-9	2.59E-9	2.31E-9	2.50E-9

NOTE: Maximum concentration occurs along the north property line.

1118mcl.5-8

TABLE 5-9

SUMMARY OF ANNUAL AVERAGE DEPOSITION RATES ($g/m^2/yr$) OF PARTICULATES, TRACE METALS AND FLUORIDES (1990)

RECEPTOR	SPM	PM_{10}	As	Be	Cd	Mn	Ag	V	Zn	Mo	F
1	1.51	0.32	3.20E-5	8.61E-6	3.39E-4	1.21E-4	2.07E-5	1.93E-3	4.92E-3	4.47E-5	5.58E-2
2	6.94	2.05	1.31E-4	4.31E-5	1.39E-3	6.21E-4	8.16E-5	7.78E-3	1.60E-2	1.72E-4	1.96E-1
3	5.22	1.42	1.13E-4	3.18E-5	1.19E-3	4.36E-4	7.00E-5	6.51E-3	1.35E-2	1.47E-4	1.55E-1
4	4.50	1.15	8.53E-5	2.62E-5	8.73E-4	3.84E-4	5.35E-5	5.37E-3	1.07E-2	1.23E-4	1.30E-1
5	2.94	0.73	6.49E-5	1.76E-5	6.80E-4	2.48E-4	4.01E-5	3.70E-3	7.77E-3	8.43E-5	8.82E-2
6	1.17	0.37	4.34E-5	8.71E-6	4.93E-4	1.04E-4	2.52E-5	1.68E-3	5.03E-3	3.57E-5	3.94E-2
7	1.62	0.41	3.49E-5	9.50E-6	3.49E-4	1.40E-4	2.07E-5	2.00E-3	4.35E-3	4.57E-5	4.78E-2
8	0.77	0.21	1.85E-5	4.59E-6	1.81E-4	6.80E-5	1.02E-5	9.77E-4	2.28E-3	2.20E-5	2.28E-2
9	0.60	0.17	1.69E-5	3.80E-6	1.74E-4	5.50E-5	9.42E-6	7.69E-4	2.12E-3	1.74E-5	1.87E-2
10	1.40	0.35	3.32E-5	8.48E-6	3.41E-4	1.21E-4	1.99E-5	1.77E-3	4.19E-3	4.07E-5	4.28E-2
11	0.92	0.25	2.01E-5	5.07E-6	1.98E-4	8.61E-5	1.12E-5	1.15E-3	2.86E-3	2.69E-5	2.68E-2
12	7.46	1.90	1.21E-4	4.24E-5	1.24E-3	6.53E-4	7.89E-5	8.40E-3	1.58E-2	1.92E-4	2.10E-1
13	0.71	0.20	1.77E-5	4.33E-6	1.77E-4	6.45E-5	9.96E-6	8.82E-4	2.22E-3	2.03E-5	2.17E-2
14	0.37	0.13	1.46E-5	2.82E-6	1.67E-4	3.58E-5	8.21E-6	5.16E-4	1.83E-3	1.06E-5	1.23E-2
15	0.35	0.13	1.45E-5	2.78E-6	1.65E-4	3.25E-5	8.15E-6	5.06E-4	1.82E-3	1.04E-5	1.20E-2
16	1.45	0.37	3.32E-5	8.72E-6	3.43E-4	1.27E-4	2.01E-5	1.81E-3	4.18E-3	4.18E-5	4.38E-2
Maximum Deposition	50.2	21.9	3.74E-3	6.10E-4	4.77E-2	4.44E-3	2.29E-3	9.22E-2	3.65E-1	1.71E-3	2.31

Note: Maximum deposition occurs along the north property line.

1118mmc1.5-9

TABLE 5-11

SUMMARY OF ANNUAL AVERAGE DEPOSITION RATES ($g/m^2/yr$) OF PARTICULATES, TRACE METALS AND FLUORIDES (1991)

RECEPTOR	TSP	PM_{10}	As	Be	Cd	Mn	Ag	V	Zn	Mo	F
1	1.81	0.33	3.39E-5	1.00E-5	3.35E-4	1.44E-4	2.30E-5	2.39E-3	4.97E-3	5.44E-5	5.39E-2
2	7.00	2.03	1.39E-4	4.14E-5	1.40E-3	7.43E-4	9.47E-5	8.14E-3	1.64E-2	1.76E-4	1.99E-1
3	5.37	1.46	1.31E-4	3.20E-5	1.33E-3	5.91E-4	8.09E-5	7.00E-3	1.47E-2	1.52E-4	1.62E-1
4	4.80	1.21	1.02E-4	2.78E-5	1.02E-3	5.19E-4	6.61E-5	6.01E-3	Q.Q7E-	1.34E-4	1.42E-1
5	3.10	0.74	6.81E-5	1.78E-5	6.78E-4	3.71E-4	4.30E-5	3.98E-3	2	8.92E-5	9.26E-2
6	1.11	0.35	4.39E-5	8.21E-5	4.82E-4	2.10E-4	2.48E-5	1.68E-3	8.12E-3	3.39E-5	3.75E-2
									4.80E-3		
7	1.72	0.40	3.69E-5	9.63E-6	3.48E-4	2.40E-4	2.26E-5	2.21E-3	4.31E-3	4.96E-5	5.07E-2
8	0.82	0.22	2.01E-5	4.73E-6	1.84E-4	1.59E-4	1.11E-5	1.07E-3	2.26E-3	2.37E-5	2.42E-2
9	0.62	0.18	1.73E-5	4.05E-6	1.74E-4	1.35E-4	1.01E-5	8.14E-4	2.05E-3	1.76E-5	1.90E-2
10	1.47	0.35	3.42E-5	8.60E-6	3.37E-4	2.13E-4	2.10E-5	1.92E-3	4.13E-3	4.30E-5	4.44E-2
11	0.72	0.19	1.76E-5	4.66E-6	1.82E-4	1.75E-4	1.08E-5	9.39E-4	2.51E-3	2.10E-5	2.19E-2
12	7.52	1.90	1.39E-4	4.29E-5	1.41E-3	6.47E-4	9.64E-5	8.85E-3	1.70E-2	1.96E-4	2.15E-1
13	0.81	0.21	2.06E-5	4.70E-6	1.82E-4	1.69E-4	1.11E-5	1.06E-3	2.32E03	2.35E-5	2.39E-2
14	0.33	0.12	1.46E-5	2.51E-6	1.60E-4	7.18E-5	7.99E-6	5.19E-4	1.73E-3	9.81E-6	1.13E-2
15	0.32	0.12	1.44E-5	2.48E-6	1.57E-4	7.32E-5	7.96E-6	5.07E-4	1.71E-3	9.58E-6	1.10E-2
16	1.67	0.40	3.65E-5	9.34E-6	3.47E-4	2.41E-4	2.22E-5	2.16E-3	4.27E-3	4.84E-5	4.94E-2
Maximum Deposition	53.2	24.3	3.71E-3	5.53E-4	4.95E-2	5.17E-3	2.05E-3	9.47E-2	3.56E-1	1.64E-3	2.35

Note: Maximum deposition occurs along the north property line.

1118mmc1.511

TABLE 5-12

SUMMARY OF ANNUAL AVERAGE DEPOSITION RATES ($\mu Ci/m^2/yr$) OF RADIONUCLIDES (1991)

RECEPTOR	Pb-210	Po-210	Ra-226	Th-230	U-234	U-238
1	9.33E-11	1.02E-10	7.28E-11	8.71E-11	7.03E-11	7.34E-11
2	3.54E-10	3.98E-10	2.93E-10	3.20E-10	2.65E-10	2.76E-10
3	3.35E-10	3.81E-10	2.20E-10	2.49E-10	2.05E-10	2.14E-10
4	2.58E-10	2.92E-10	1.98E-10	2.25E-10	1.84E-10	1.92E-10
5	1.73E-10	1.96E-10	1.26E-10	1.46E-10	1.19E-10	1.24E-10
6	1.19E-10	1.37E-10	4.39E-10	4.99E-10	4.17E-11	4.41E-11
7	8.82E-11	1.01E-10	7.01E-11	8.14E-11	6.63E-11	6.92E-11
8	4.46E-11	5.17E-11	3.31E-11	3.83E-11	3.13E-11	3.26E-11
9	4.25E-11	4.93E-11	2.51E-11	2.85E-11	2.35E-11	2.46E-11
10	8.58E-11	9.80E-11	5.95E-11	6.93E-11	5.66E-11	5.91E-11
11	4.62E-11	5.25E-11	2.92E-11	3.35E-11	2.75E-11	2.87E-11
12	3.59E-10	3.99E-10	3.10E-10	3.49E-10	2.86E-10	2.98E-10
13	4.46E-11	5.19E-11	3.26E-11	3.76E-11	3.07E-11	3.21E-11
14	4.05E-11	4.61E-11	1.30E-11	1.43E-11	1.21E-11	1.28E-11
15	4.02E-11	4.58E-11	1.26E-11	1.39E-11	1.17E-11	1.25E-11
16	8.79E-11	1.00E-10	6.78E-11	7.87E-11	6.42E-11	6.70E-11
Maximum Deposition	1.06E-8	1.43E-8	2.08E-9	2.17E-9	1.92E-9	2.07E-9

Note: Maximum deposition occurs along the north property line.

1118mzel.512

TABLE 5-13

GROUNDWATER TRANSPORT MODELING HYDRAULIC DISPERSIVITY PARAMETERS

Dispersivity (ft)	Observation at 5,000 ft (Aquifer)	Observation at 8,500 ft (Soda Creek)	Observation at 18,500 ft (Bear River)
Longitudinal	231 ft	312 ft	460 ft
Transverse	2.3 ft	3.1 ft	4.6 ft

1118mzc1.513

TABLE 5-14

GROUNDWATER TRANSPORT MODELING
SOURCE CHARACTERIZATION PARAMETERS

Constituent	t_1 (yr)	$C(t_1)$ (mg/L)	t_2 (yr)	$C(t_2)$ (mg/L)	r (yr^{-1})	C(1984) (mg/L)
Cadmium	1985	1.22	1992	0.44	0.146	1.41
Fluoride[a]	1988	17	1992	17	0.	40
Manganese	1987	3	1992	1.3	0.167	4.95
Molybdenum[b]	--	--	1993	0.76	0.125	2.07
Nitrate-Nitrogen[c]	1986	9.1	1992	4.04	0.135	11.9
Selenium[b]	--	--	1992.5	0.52	0.125	1.51

[a] Source function arranged as a step function with levels of 40 mg/L and 17 mg/L (see text below).
[b] Decay rate is average rate for aluminum, arsenic, cadmium, manganese, vanadium, and zinc.
[c] Background concentration of 0.96 was subtracted from observed concentrations.

1118mxc1.514

TABLE 5-15

TRANSPORT MODELING CONSTITUENT SOURCE CONCENTRATIONS

Year	Cadmium	Chloride	Fluoride	Manganese	Molybdenum	Nitrate-N	Selenium
	0.146	0.228	NA	0.167	0.125	0.135	0.125
1964	1.410	364.000	40.000	4.950	2.070	11.900	1.510
1984	1.053	230.708	17.000	3.544	1.612	9.084	1.176
1988	0.587	92.680	17.000	1.817	0.978	5.294	0.713
1992	0.327	37.231	17.000	0.932	0.593	3.085	0.433
1996	0.183	14.957	17.000	0.478	0.360	1.798	0.262
2000	0.102	6.008	17.000	0.245	0.218	1.048	0.159
2004	0.057	2.414	17.000	0.126	0.132	0.611	0.097
2008	0.032	0.970	17.000	0.064	0.080	0.356	0.059
2012	0.018	0.390	17.000	0.033	0.049	0.207	0.036
2016	0.010	0.156	17.000	0.017	0.030	0.121	0.022
2020	0.005	0.063	17.000	0.009	0.018	0.070	0.013
2024	0.003	0.025	17.000	0.004	0.011	0.041	0.008
2028	0.002	0.010	17.000	0.002	0.007	0.024	0.005
2032	0.001	0.004	17.000	0.001	0.004	0.014	0.003
2036	0.001	0.002	17.000	0.001	0.002	0.008	0.002
2040	0.000	0.001	17.000	0.000	0.001	0.005	0.001
2044	0.000	0.000	17.000	0.000	0.001	0.003	0.001
2048	0.000	0.000	17.000	0.000	0.001	0.002	0.000
2052	0.000	0.000	17.000	0.000	0.000	0.001	0.000
2056	0.000	0.000	17.000	0.000	0.000	0.001	0.000
2060	0.000	0.000	17.000	0.000	0.000	0.000	0.000
2064	0.000	0.000	17.000	0.000	0.000	0.000	0.000
2068	0.000	0.000	17.000	0.000	0.000	0.000	0.000
2072	0.000	0.000	17.000	0.000	0.000	0.000	0.000
2076	0.000	0.000	17.000	0.000	0.000	0.000	0.000
2080	0.000	0.000	17.000	0.000	0.000	0.000	0.000
2084	0.000	0.000	17.000	0.000	0.000	0.000	0.000
2088	0.000	0.000	17.000	0.000	0.000	0.000	0.000
2092	0.000	0.000	17.000	0.000	0.000	0.000	0.000
2096	0.000	0.000	17.000	0.000	0.000	0.000	0.000
2100	0.000	0.000	17.000	0.000	0.000	0.000	0.000
2104	0.000	0.000	17.000	0.000	0.000	0.000	0.000
2108	0.000	0.000	17.000	0.000	0.000	0.000	0.000
2112	0.000	0.000	17.000	0.000	0.000	0.000	0.000

TABLE 5-16

RETARDATION PARAMETERS FOR
GROUNDWATER TRANSPORT MODELING

Constituent	Distribution Coefficient Range[a] (ml/g)	Distribution Coefficient Mean (ml/g)	Retardation Parameter
Cadmium	1.3 - 27	1.9	11.
Fluoride	--	--	1
Manganese	0.2 - 10,000	5.0	2.6
Molybdenum	0.4 - 400	3.	4.2
Nitrate-Nitrogen	--	--	1
Selenium	1.2 - 8.6	1.	1

[a] Distribution coefficients (range and mean) were obtained from Dragun (1988).

1118mmel.516

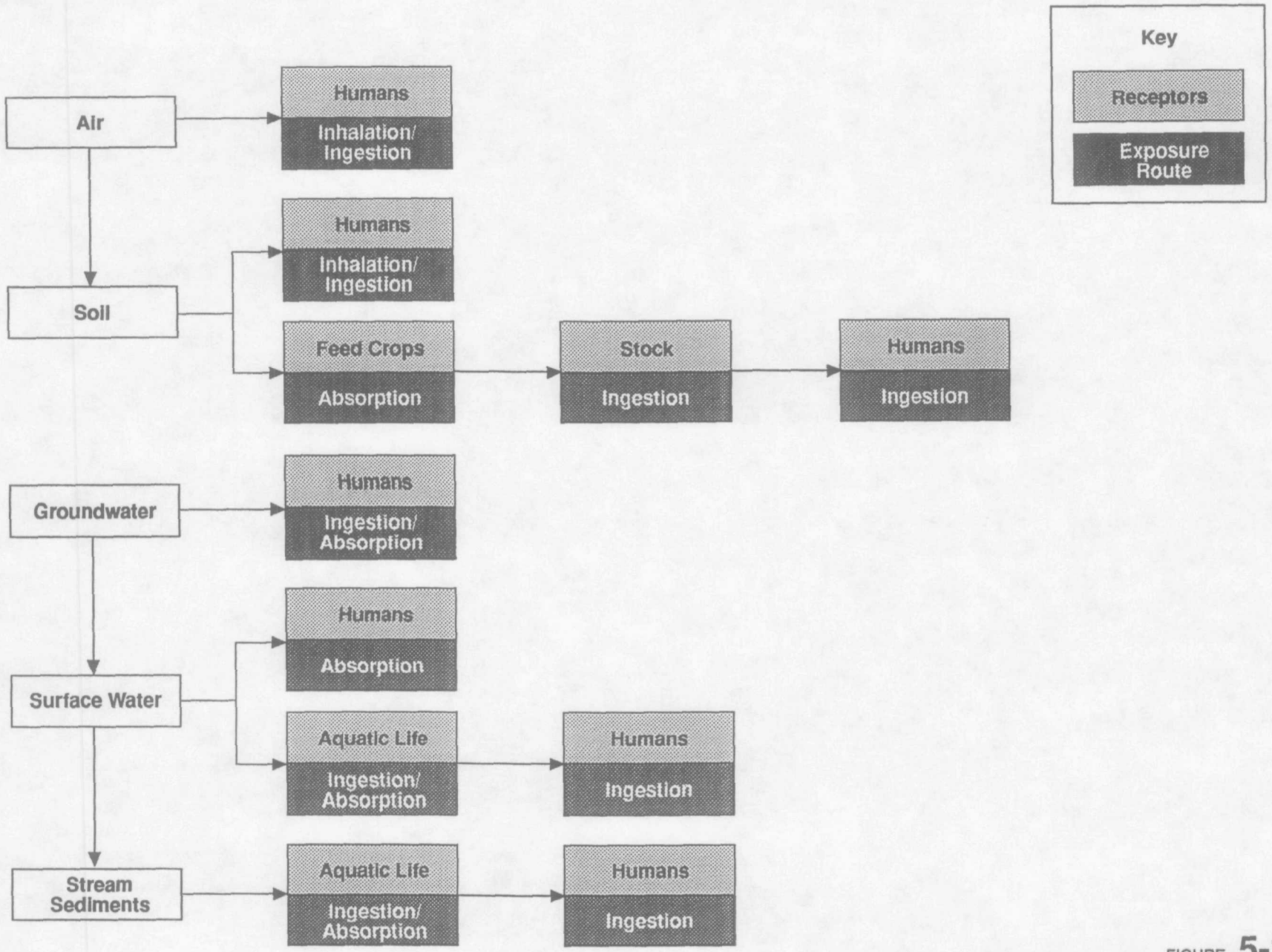
TABLE 5-17

COMPARISON BETWEEN PREDICTED AND OBSERVED GROUNDWATER CONCENTRATIONS

Constituent	Model Output @ 5,000 ft (mg/L)	Test Well 54, May, 1993 (mg/L)	Test Well 55, May, 1993 (mg/L)
Cadmium	1.26 (0.062)[a]	0.005 U	0.005 U
Fluoride	15.5 (3.6)[b]	5.5	0.20
Manganese	1.96	0.028	0.02
Molybdenum	1.32	0.104	0.008 U
Nitrate-Nitrogen	4.9	7.38	3.08
Selenium	0.538	0.635	0.138 J

[a]Value in parentheses is prediction with otavite solubility control.
[b]Value in parentheses is prediction with fluorite solubility control. U undetected, B questionable, J estimated value.

1118msc1.517



* Generic - subject to revision during the risk assessment.

FIGURE **5-1**

POTENTIAL PATHWAYS FOR HUMAN AND ENVIRONMENTAL EXPOSURES

MONSANTO/PHASE II REPORT/ID

PROJECT NO. 913-1101.608 DRAWING NO. 50256 DATE 2/1/95 DRAWN BY TK

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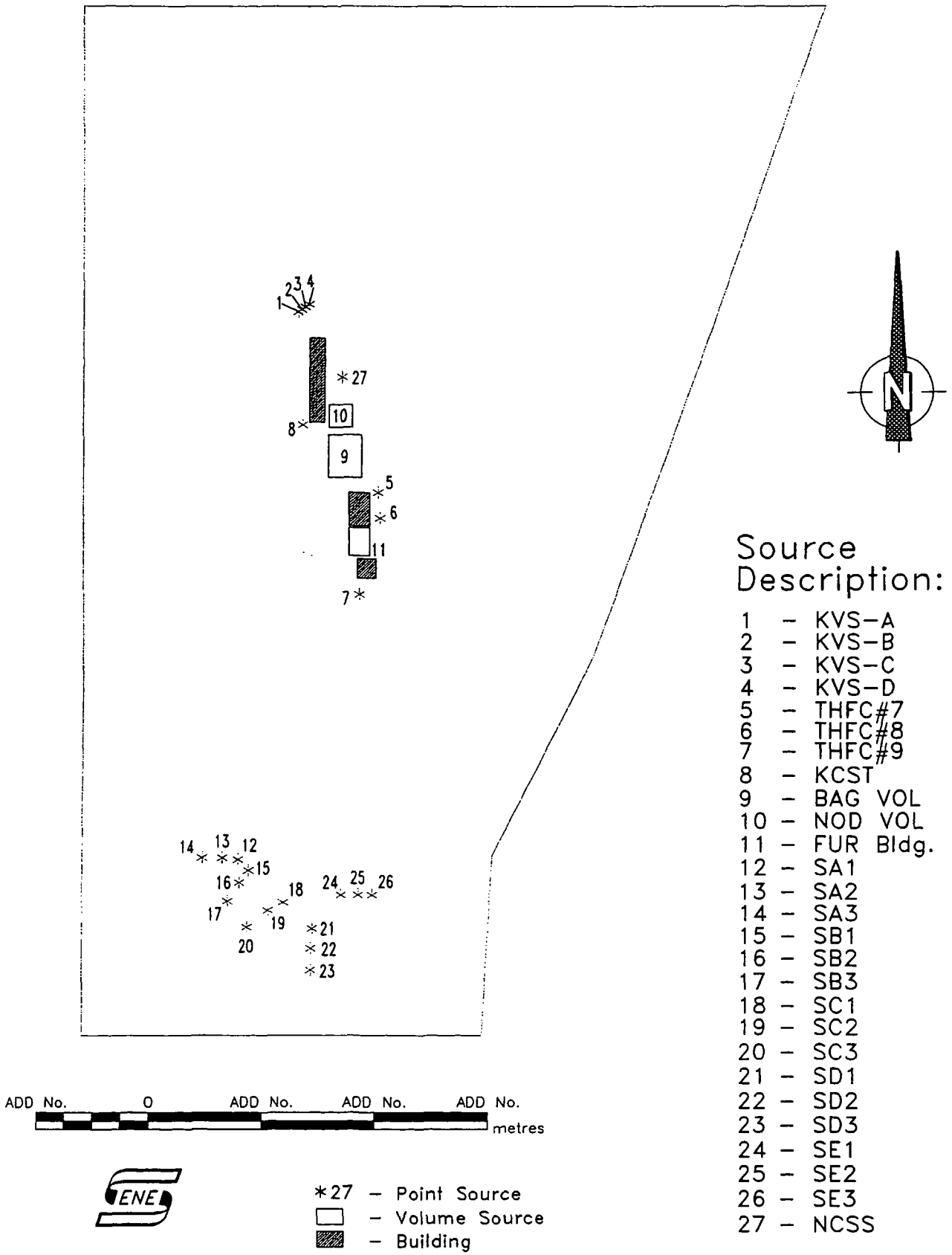


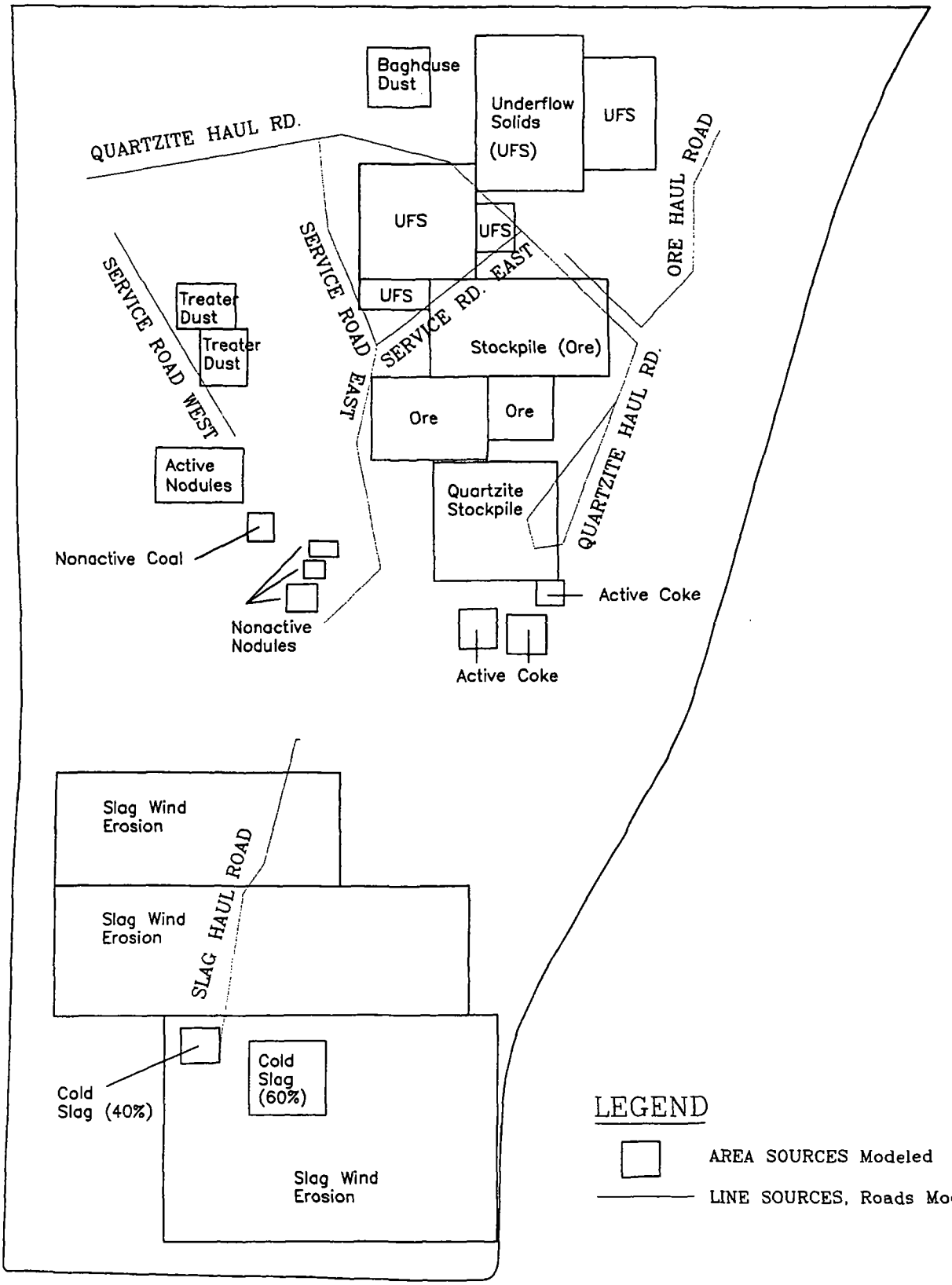
Source Description:

1 – KVS–A
2 – KVS–B
3 – KVS–C
4 – KVS–D
5 – THFC#7
6 – THFC#8
7 – THFC#9
8 – KCST
9 – BAG VOL
10 – NOD VOL
11 – FUR Bldg.
12 – SA1
13 – SA2
14 – SA3
15 – SB1
16 – SB2
17 – SB3
18 – SC1
19 – SC2
20 – SC3
21 – SD1
22 – SD2
23 – SD3
24 – SE1
25 – SE2
26 – SE3
27 – NCSS

FIGURE **5-2**

POINT AND VOLUME SOURCES MODELLED WITH ISC

MONSANTO/PHASE II RI REPORT/ID



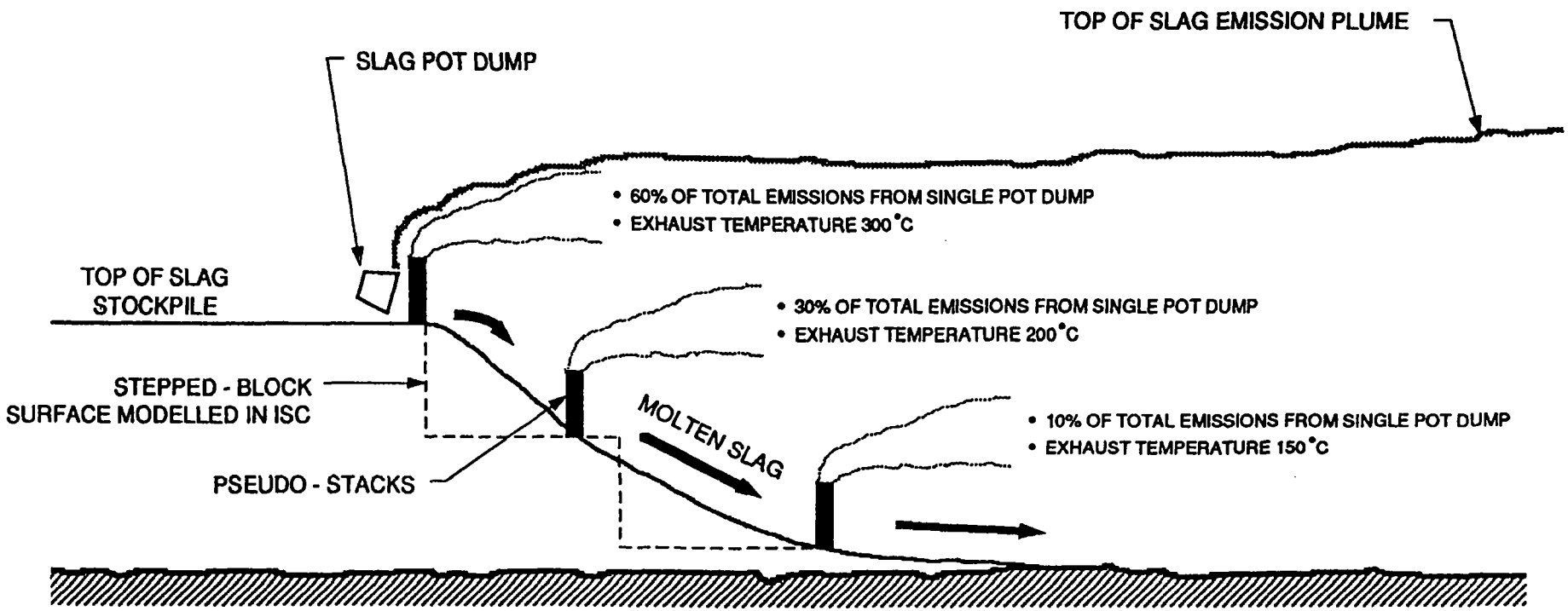
100 0 100 200 300 400 500 600

Metres

FIGURE **5-3**

MONSANTO LINE & AREA SOURCES

MONSANTO/PHASE II RI REPORT/ID



NOTE:

SLAG POURING EMISSIONS WERE ASSUMED TO OCCUR AT FIVE LOCATIONS ON THE STOCKPILE OVER THE PERIOD OF ONE YEAR. TOTAL ANNUAL EMISSIONS WERE EQUALLY DISTRIBUTED AMONG THE FIVE LOCATIONS AND ASSIGNED TO THREE PSEUDO - STACKS AT EACH LOCATION AS ILLUSTRATED ABOVE.

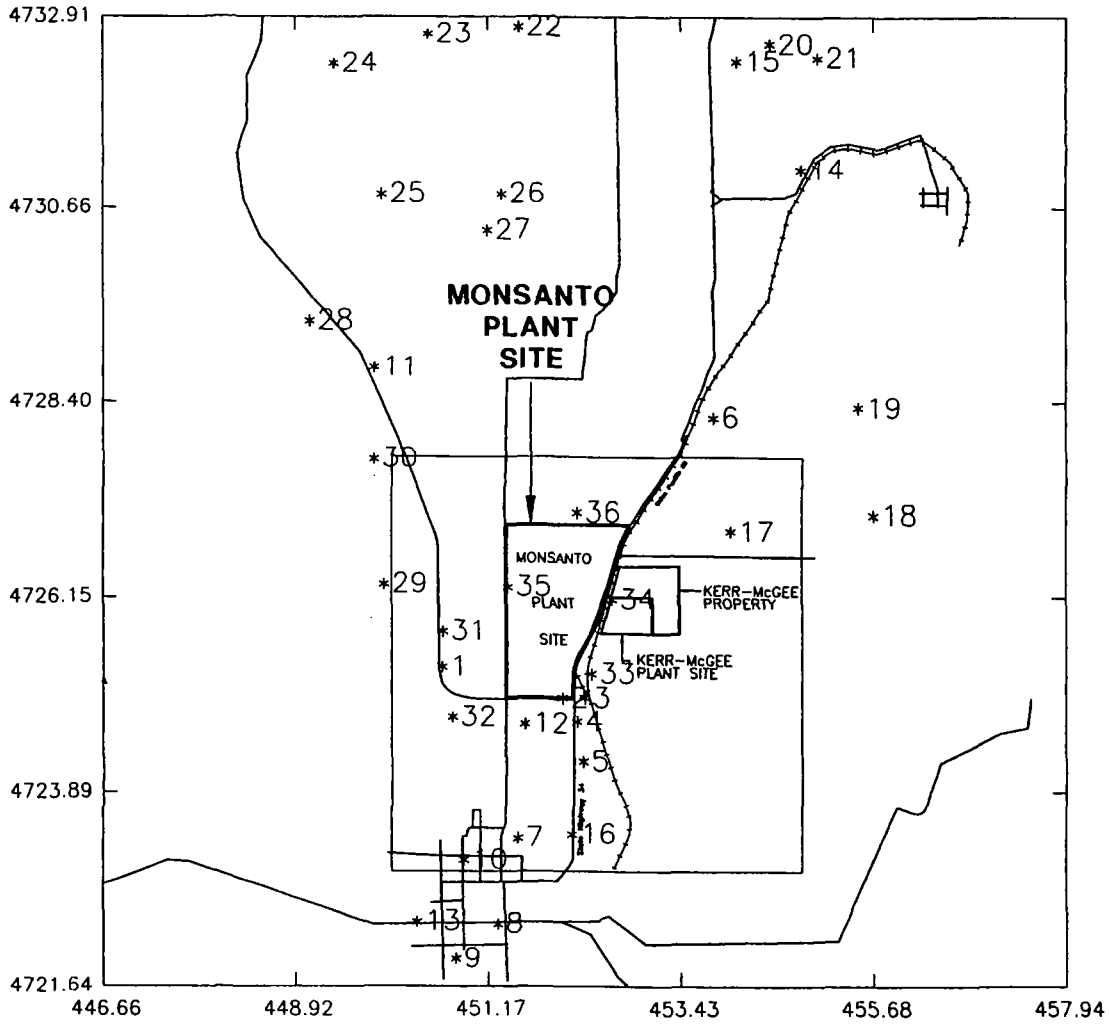
FIGURE **5-4**

SCHEMATIC ILLUSTRATION OF SLAG POURING SOURCE CHARACTERIZATION

MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913 1101.608 DRAWING NO. 54040 DATE 11/17/94 DRAWN BY TB

Golder Associates



EXPLANATION:

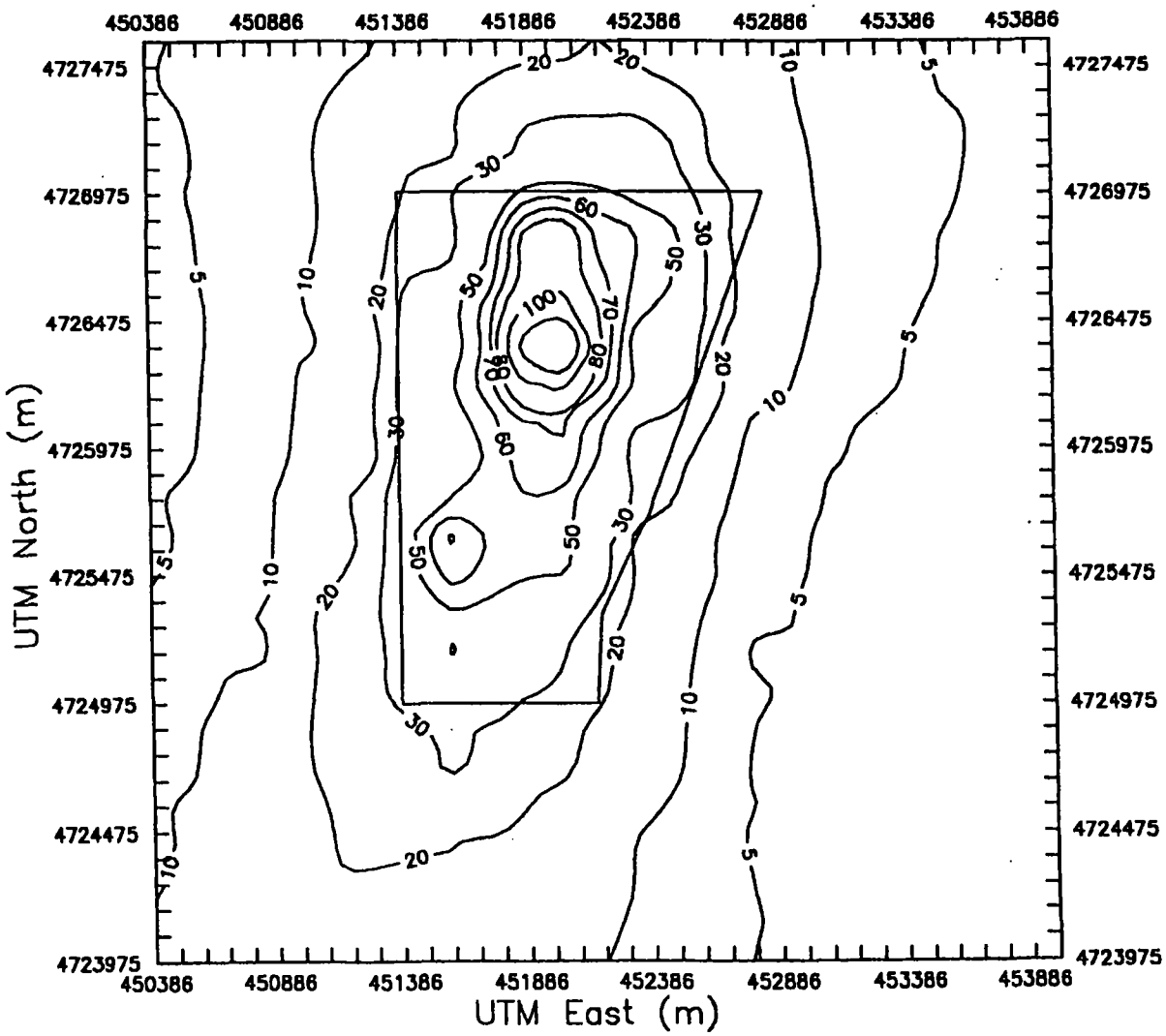
*18 Receptor Location

4721.64 UTM Coordinates (x1000m)

FIGURE **5-5**

LOCATION OF DISCRETE RECEPTORS RELATIVE TO MONSANTO PLANT PROPERTY LINE SODA SPRINGS, IDAHO

MONSANTO/PHASE II RI REPORT/ID



Note:

Conservative estimate of concentrations based on use of building wake effects option in ISC for modelling slag disposal on the slag stockpile as described in Section 3.2.3.

In areas of steep concentration gradients along the property line, the isopleth value may differ somewhat from the actual predicted concentrations due to variations introduced by the interpolation method. For actual concentration along the property line, refer to the respective tables in Appendix C.

FIGURE **5-6**

CONSERVATIVE ESTIMATE OF ANNUAL AVERAGE CONCENTRATIONS (ug/m3) OF SUSPENDED PARTICULATE MATTER (SPM) IN 1990

MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913 1101.608 DRAWING NO. 64041 DATE 11/17/94 DRAWN BY TB

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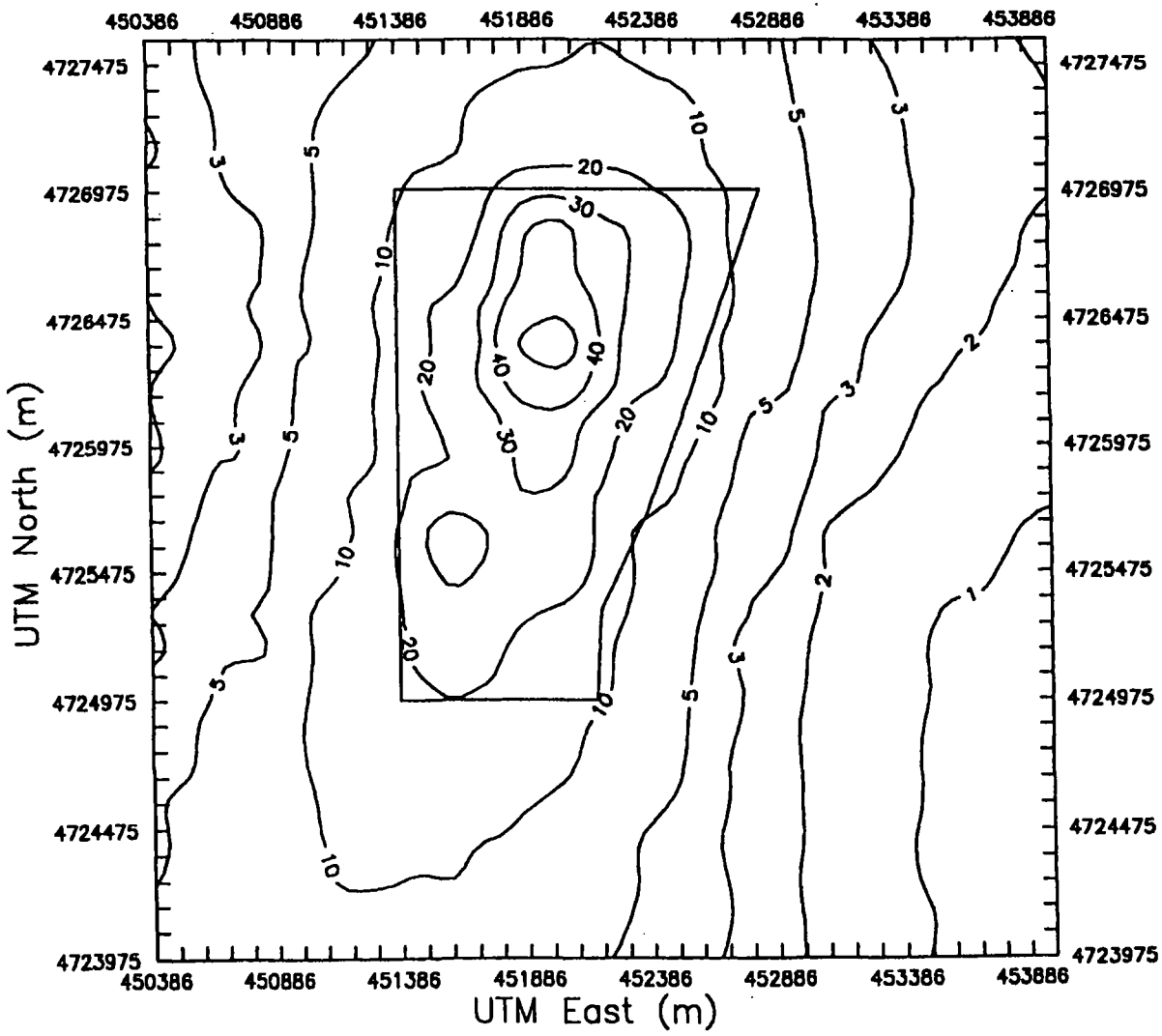


Note:

Conservative estimate of concentrations based on use of building wake effects option in ISC for modelling slag disposal on the slag stockpile as described in Section 3.2.3.

In areas of steep concentration gradients along the property line, the isopleth value may differ somewhat from the actual predicted concentrations due to variations introduced by the interpolation method. For actual concentration along the property line, refer to the respective tables in Appendix C.

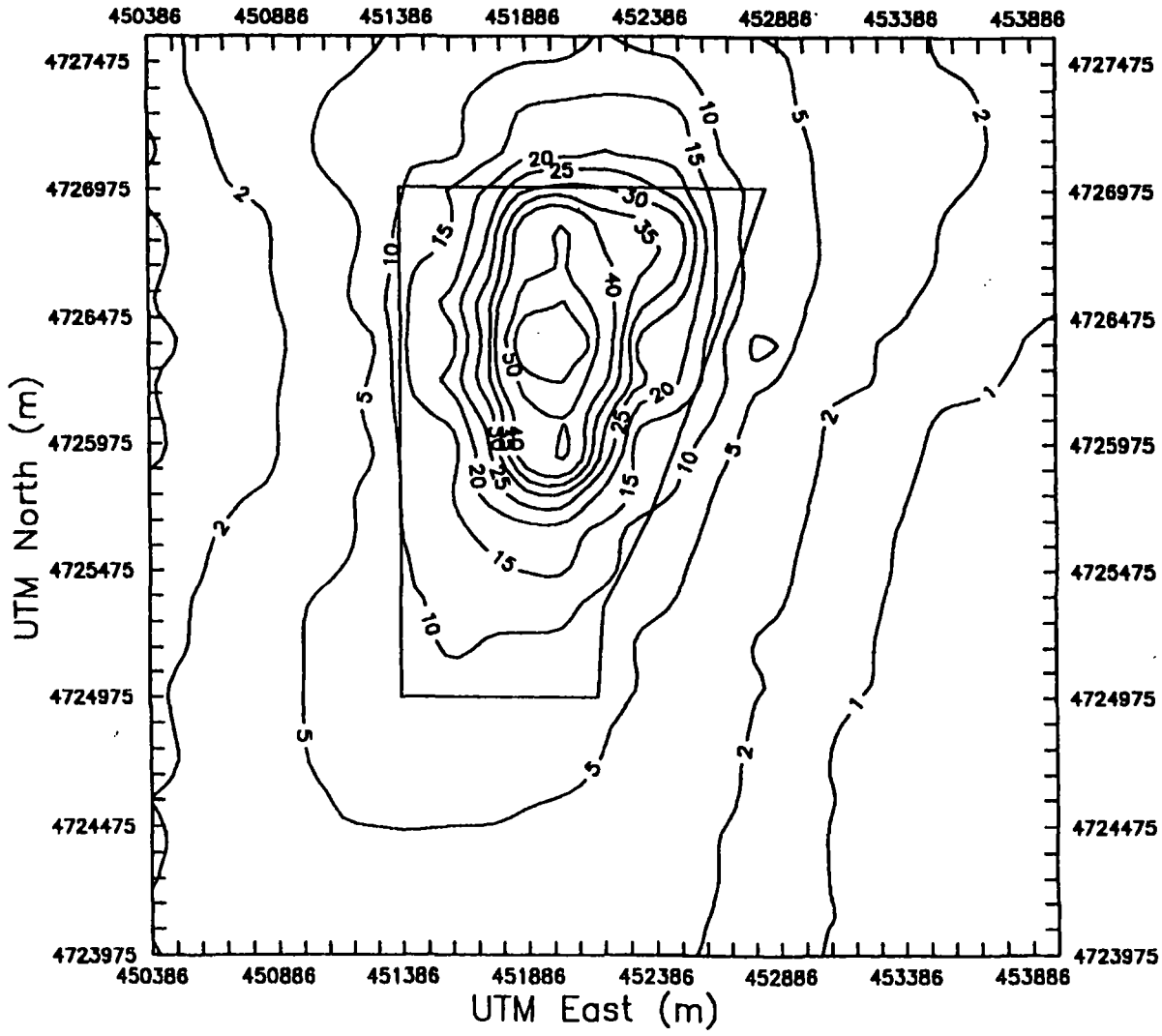
FIGURE **5-7**

CONSERVATIVE ESTIMATE OF ANNUAL AVERAGE CONCENTRATIONS (ug/m3) OF INHALABLE PARTICULATE MATTER (PM10) IN 1990

MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913 1101.608 DRAWING NO. 54042 DATE 11/17/94 DRAWN BY TB

Golder Associates



Note:

In areas of steep deposition gradients along the property line, the isopleth value may differ somewhat from the actual predicted depositions due to variations introduced by the interpolation method. For actual deposition along the property line, refer to the respective tables in Appendix C.

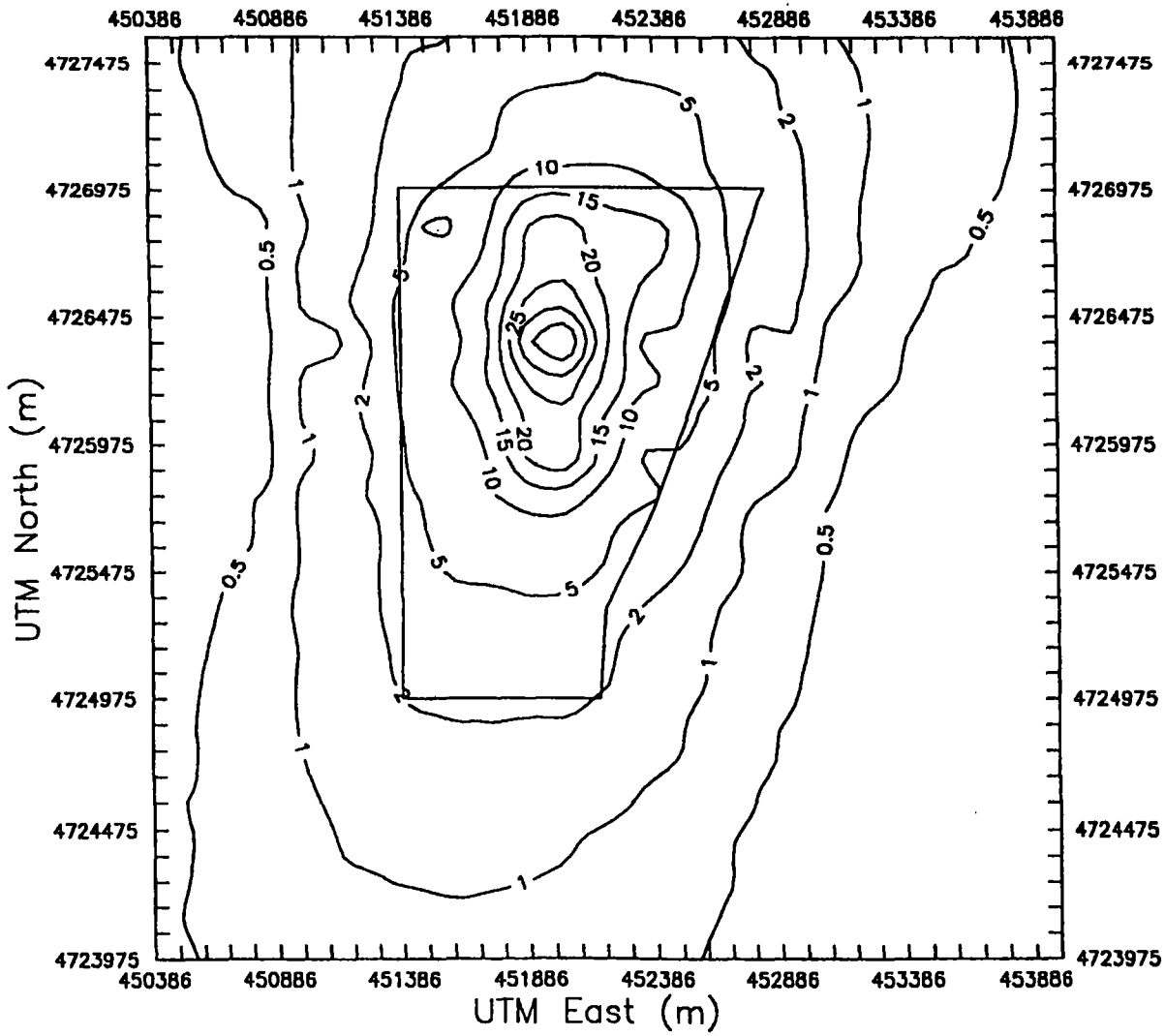
FIGURE **5-8**

ANNUAL AVERAGE DEPOSITION RATES (g/m2/year) FOR SUSPENDED PARTICULATE MATTER (SPM) IN 1990

MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913 1101.608 DRAWING NO. 54043 DATE 11/17/94 DRAWN BY TB

Golder Associates



Note:

In areas of steep deposition gradients along the property line, the isopleth value may differ somewhat from the actual predicted depositions due to variations introduced by the interpolation method. For actual deposition along the property line, refer to the respective tables in Appendix C.

FIGURE **5-9**

ANNUAL AVERAGE DEPOSITION RATES (g/m2/year) FOR INHALABLE PARTICULATE MATTER (PM10) IN 1990

MONSANTO/PHASE II RI REPORT/ID

PROJECT NO. 913 1101.608 DRAWING NO. 54044 DATE 11/17/94 DRAWN BY TB

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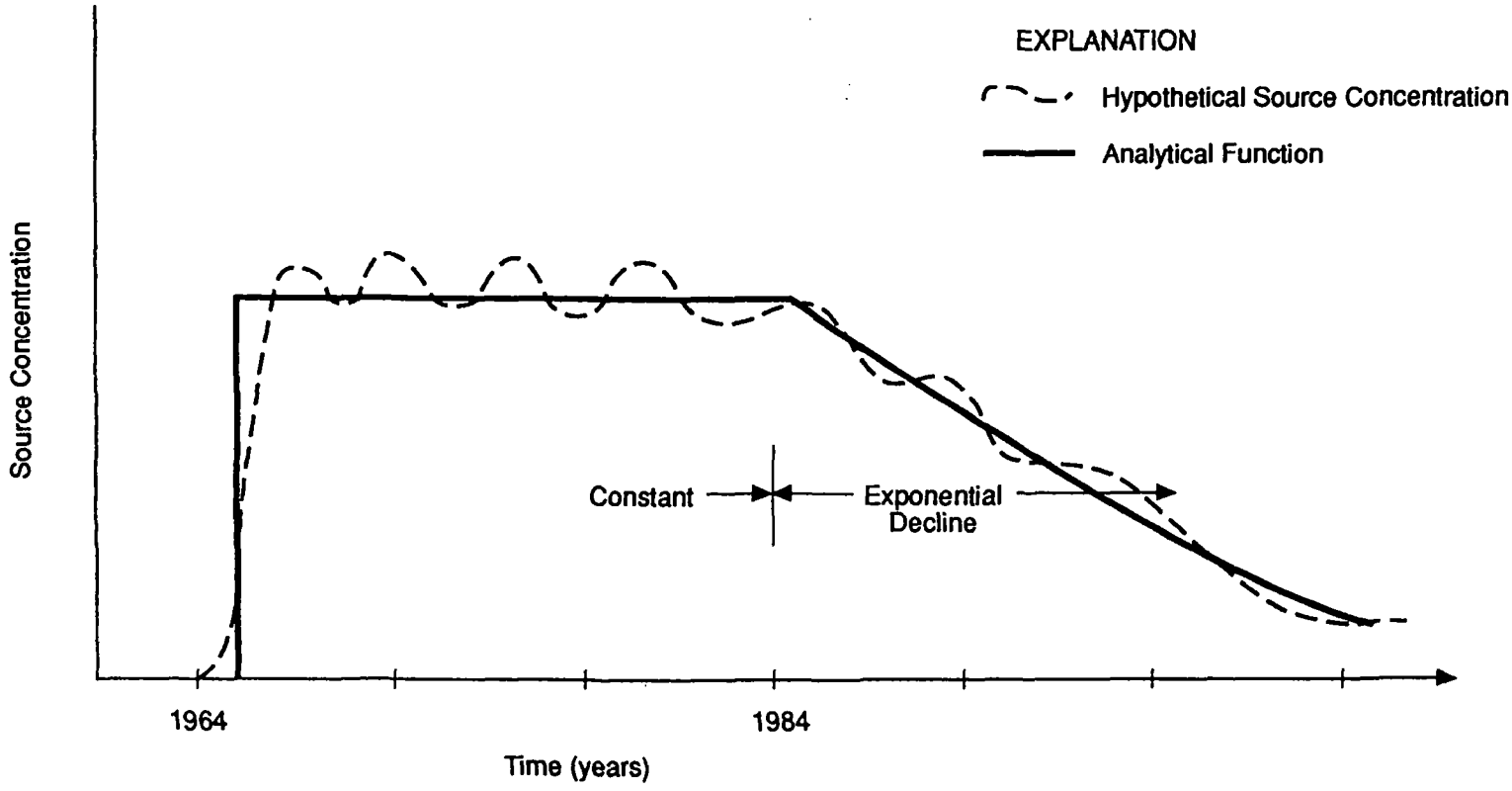

FIGURE **5-10**
HYPOTHETICAL SOURCE CONCENTRATION TIME HISTORY
MONSANTO/PHASE II RI/ID

PROJECT NO. 913-1101.608 DRAWING NO. 55156 DATE 11/11/94 DRAWN BY CB

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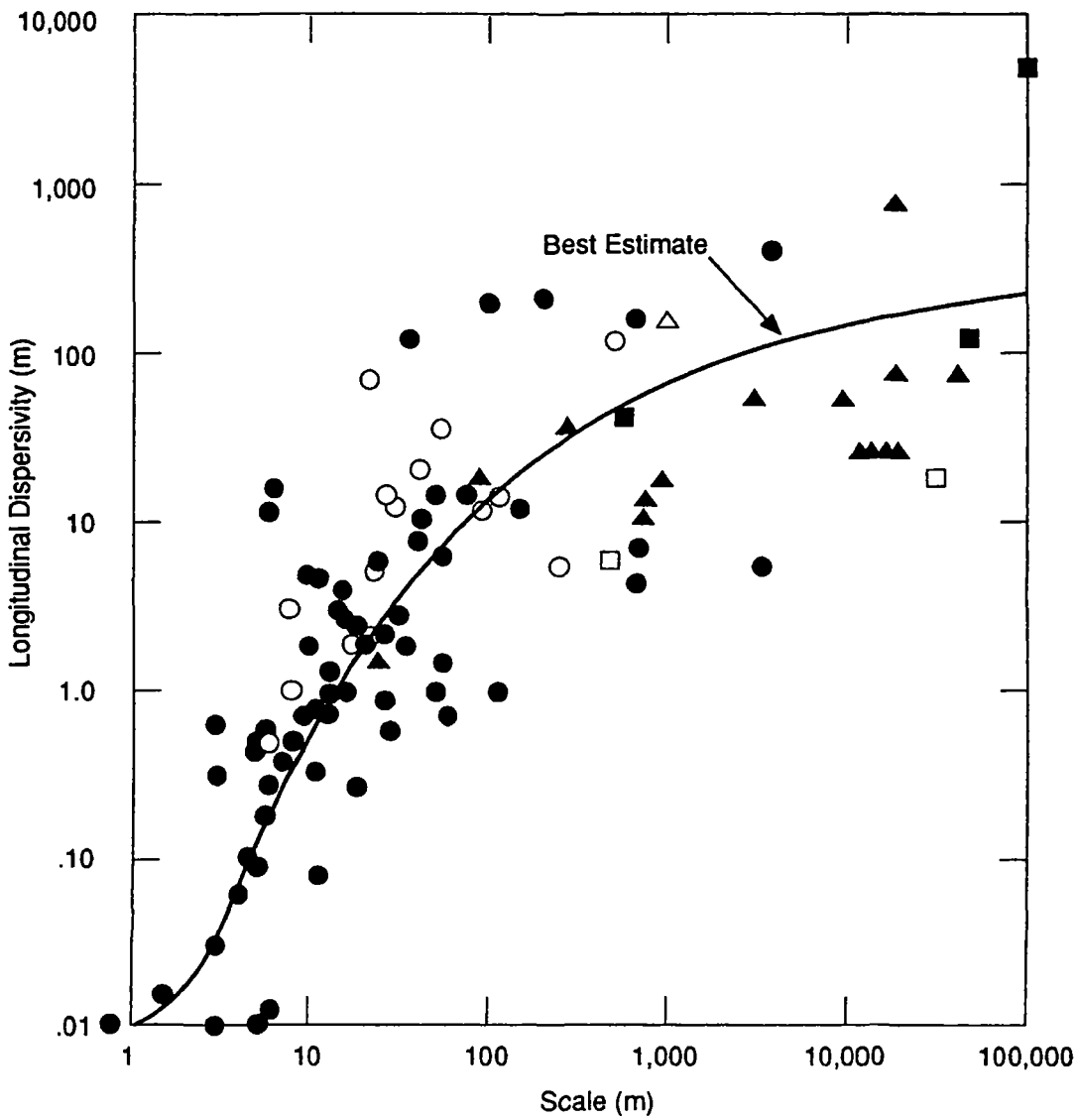

● Based on Field Tracer Tests

▲ Based on Contamination Sites

■ Based on Environmental Tracers

Open symbol indicates fractured media
Solid symbol indicates porous media

Adapted from Gelhar et al., 1985

FIGURE **5-11**
SCALE DEPENDENCY OF DISPERSIVITY
MONSANTO/PHASE II RI/ID

PROJECT NO. 913 1101.608 DRAWING NO. 50274 DATE 11/8/94 DRAWN BY EA

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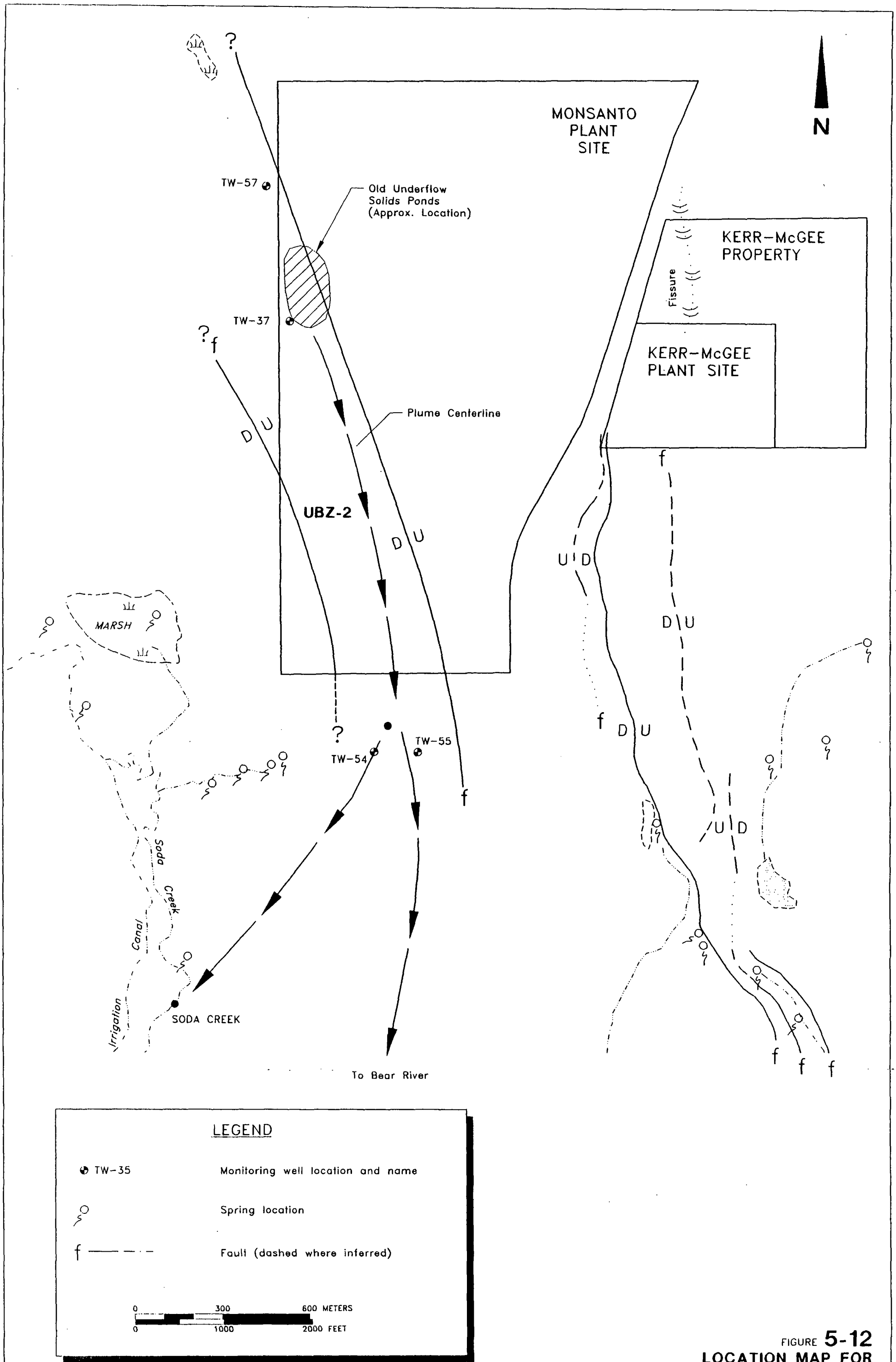

FIGURE 5-12
LOCATION MAP FOR TRANSPORT MODELING
MONSANTO/PHASE II RI REPORT/ID

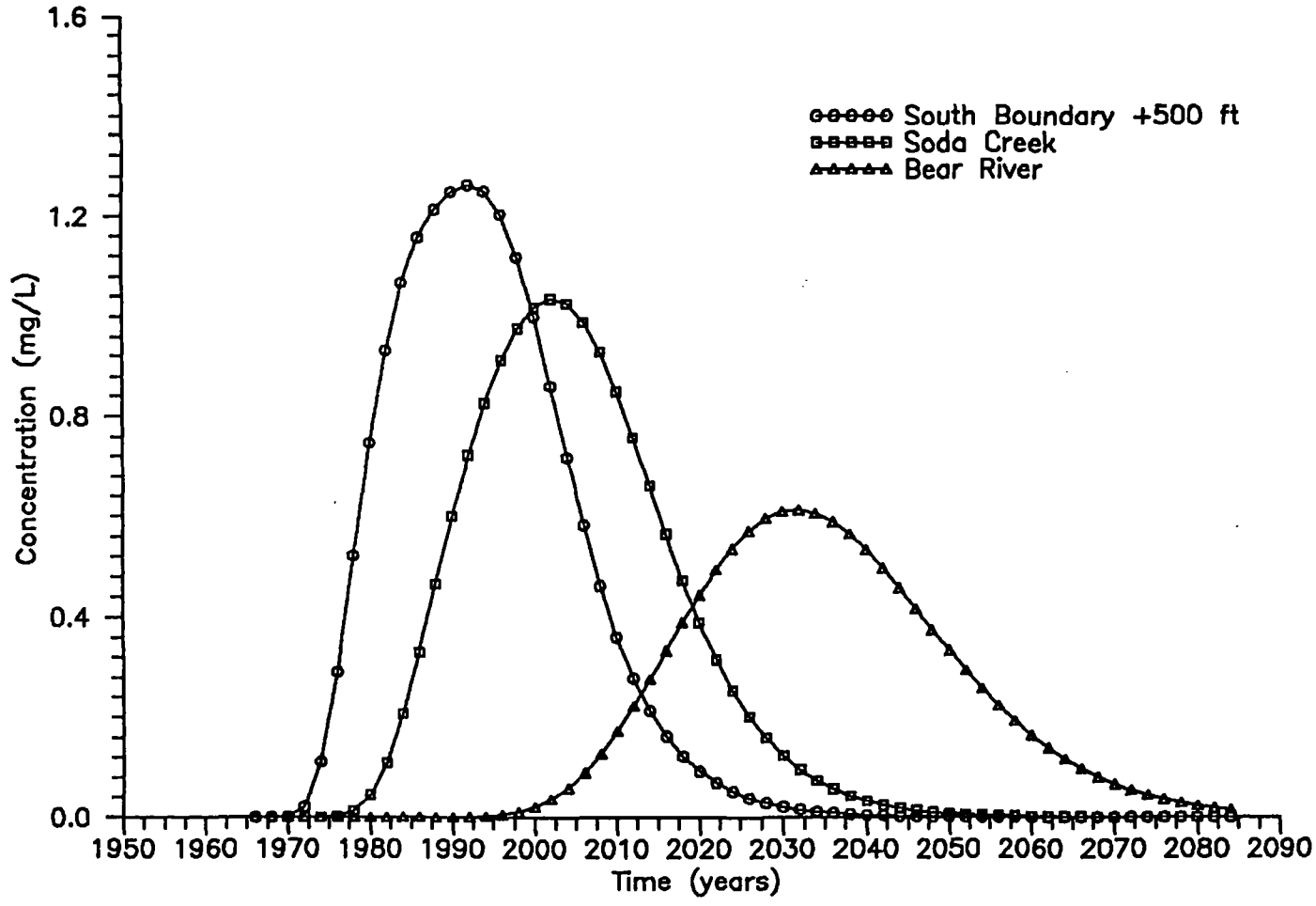

FIGURE **5-13**
PREDICTED CADMIUM CONCENTRATIONS IN GROUNDWATER
MONSANTO/PHASE II RI/ID

PROJECT NO. 913-1101.608 DRAWING NO. 50292 DATE 1/27/95 DRAWN BY CB

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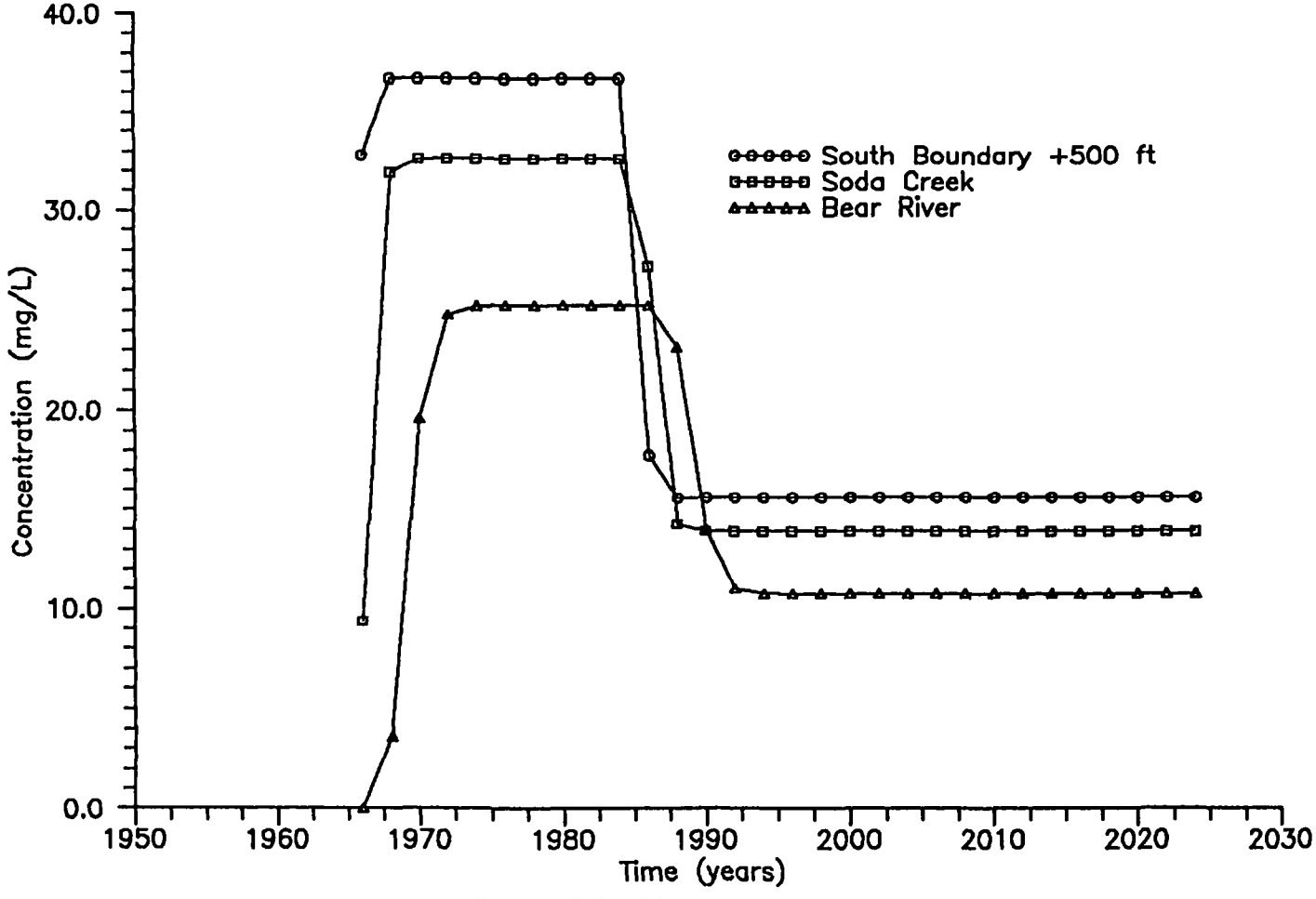

FIGURE **5-14**
PREDICTED FLUORIDE CONCENTRATIONS IN GROUNDWATER
MONSANTO/PHASE II RI/ID

PROJECT NO. 913-1101.608 DRAWING NO. 50284 DATE 1/27/95 DRAWN BY CB

Golder Associates

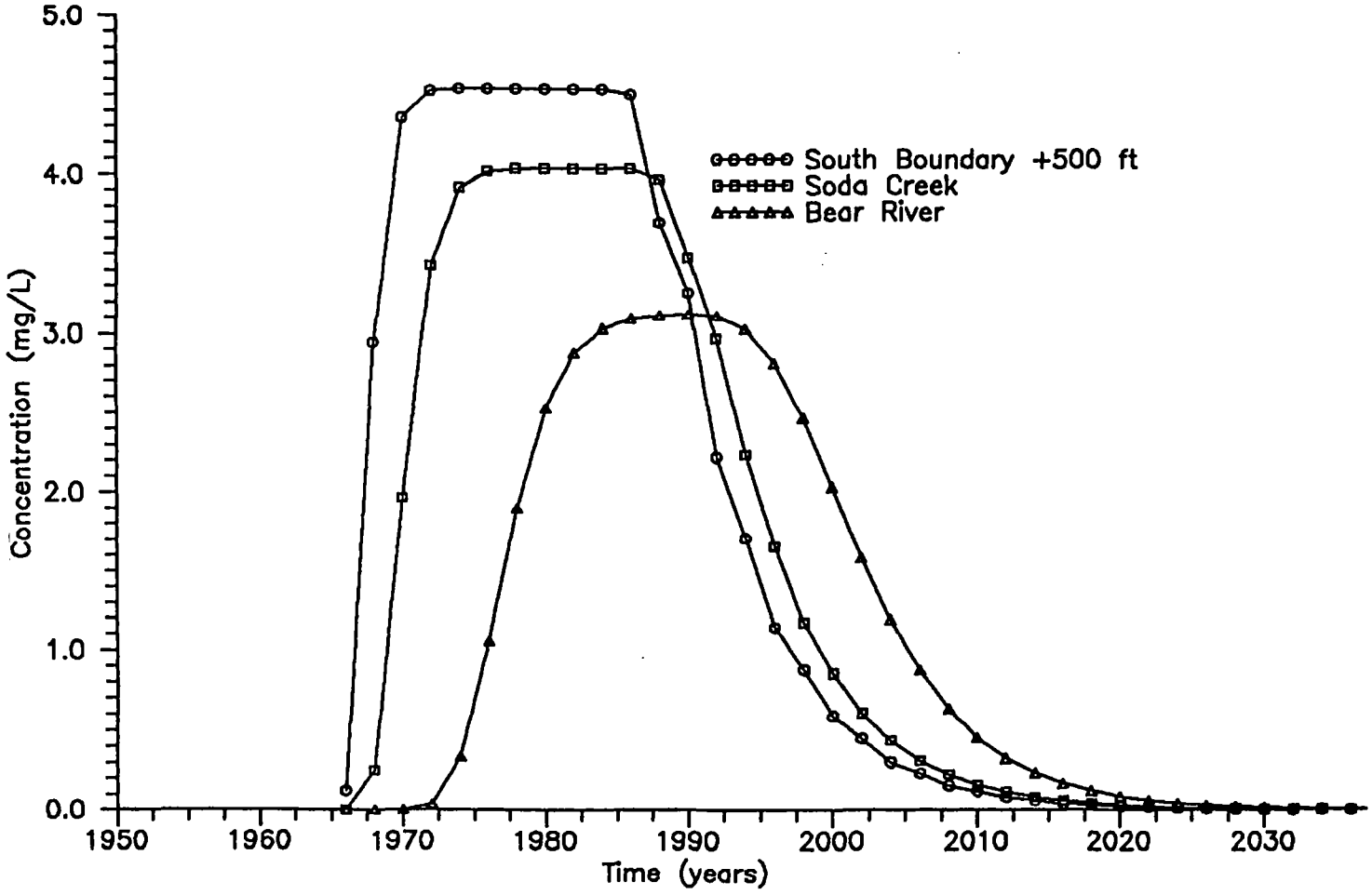

FIGURE **5-15**
PREDICTED MANGANESE CONCENTRATIONS IN GROUNDWATER
MONSANTO/PHASE II RI/ID

PROJECT NO. 913-1101.608 DRAWING NO. 50285 DATE 1/27/95 DRAWN BY CB

Golder Associates

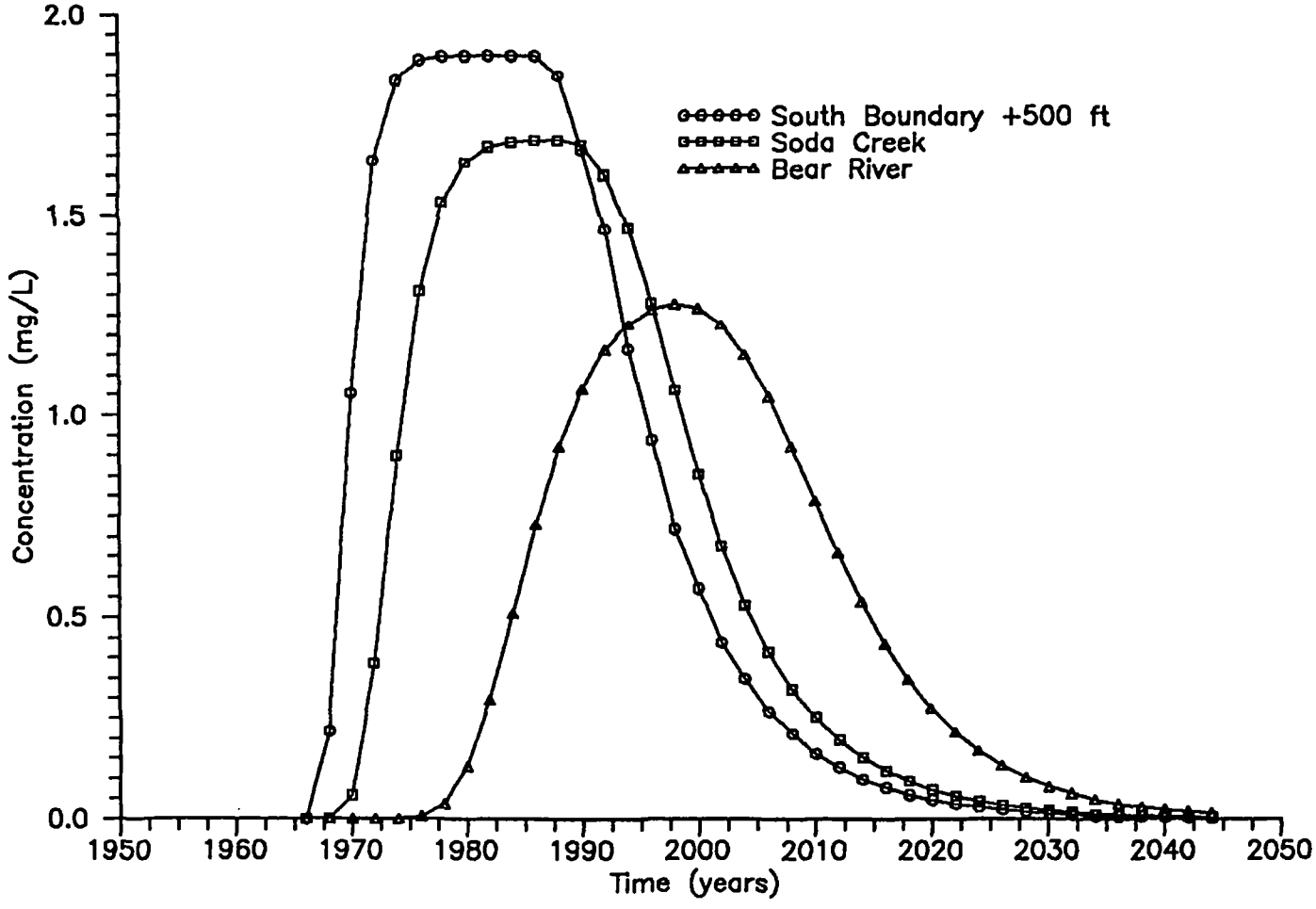

FIGURE **5-16**
PREDICTED MOLYBDENUM CONCENTRATIONS IN GROUNDWATER
MONSANTO/PHASE II RI/ID

PROJECT NO. 913-1101.608 DRAWING NO. 50286 DATE 1/27/95 DRAWN BY CB

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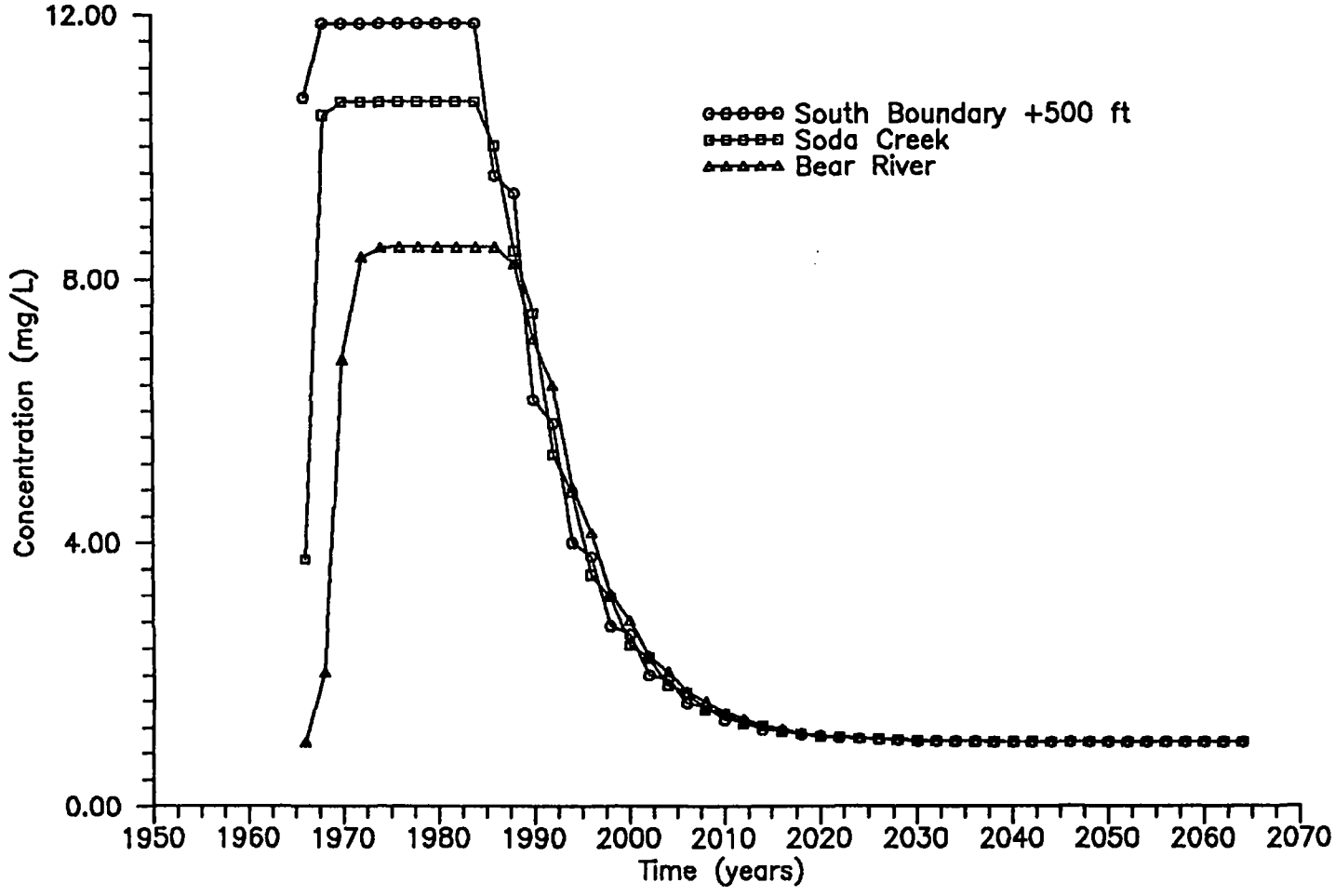

FIGURE **5-17**

PREDICTED NITRATE - NITROGEN CONCENTRATIONS IN GROUNDWATER

MONSANTO/PHASE II RI/ID

PROJECT NO. 913-1101.608 DRAWING NO. 50288 DATE 2/1/95 DRAWN BY CB

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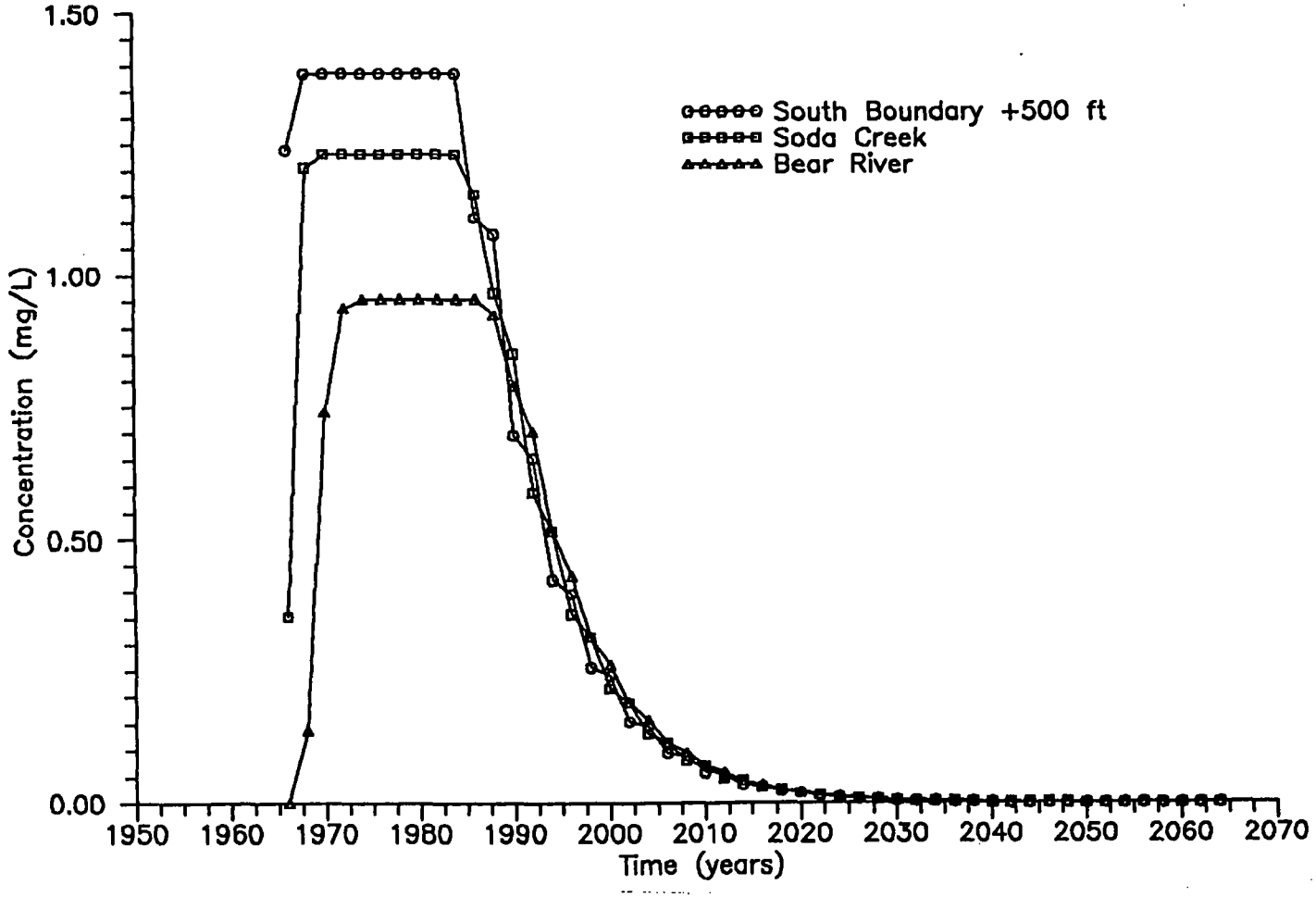

FIGURE **5-18**

PREDICTED SELENIUM CONCENTRATIONS IN GROUNDWATER

MONSANTO/PHASE II RI/ID

PROJECT NO. 913-1101.608 DRAWING NO. 50289 DATE 1/27/99 DRAWN BY CB

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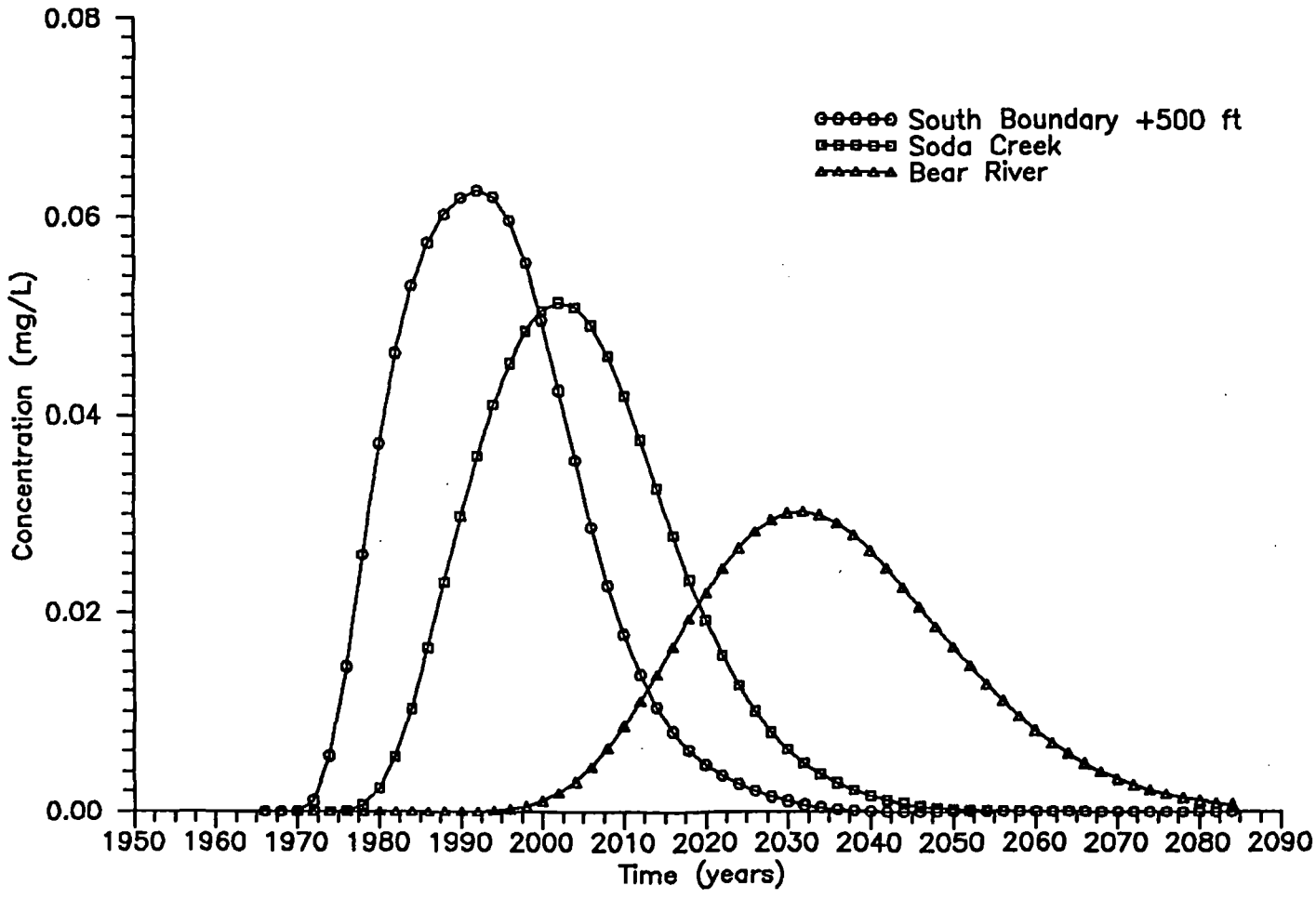

FIGURE **5-19**

PREDICTED CADMIUM CONCENTRATIONS WITH OTAVITE SOLUBILITY CONTROL

MONSANTO/PHASE II RI/ID

PROJECT NO. 913-1101.608 DRAWING NO. 50292 DATE 1/27/95 DRAWN BY CB

Golder Associates

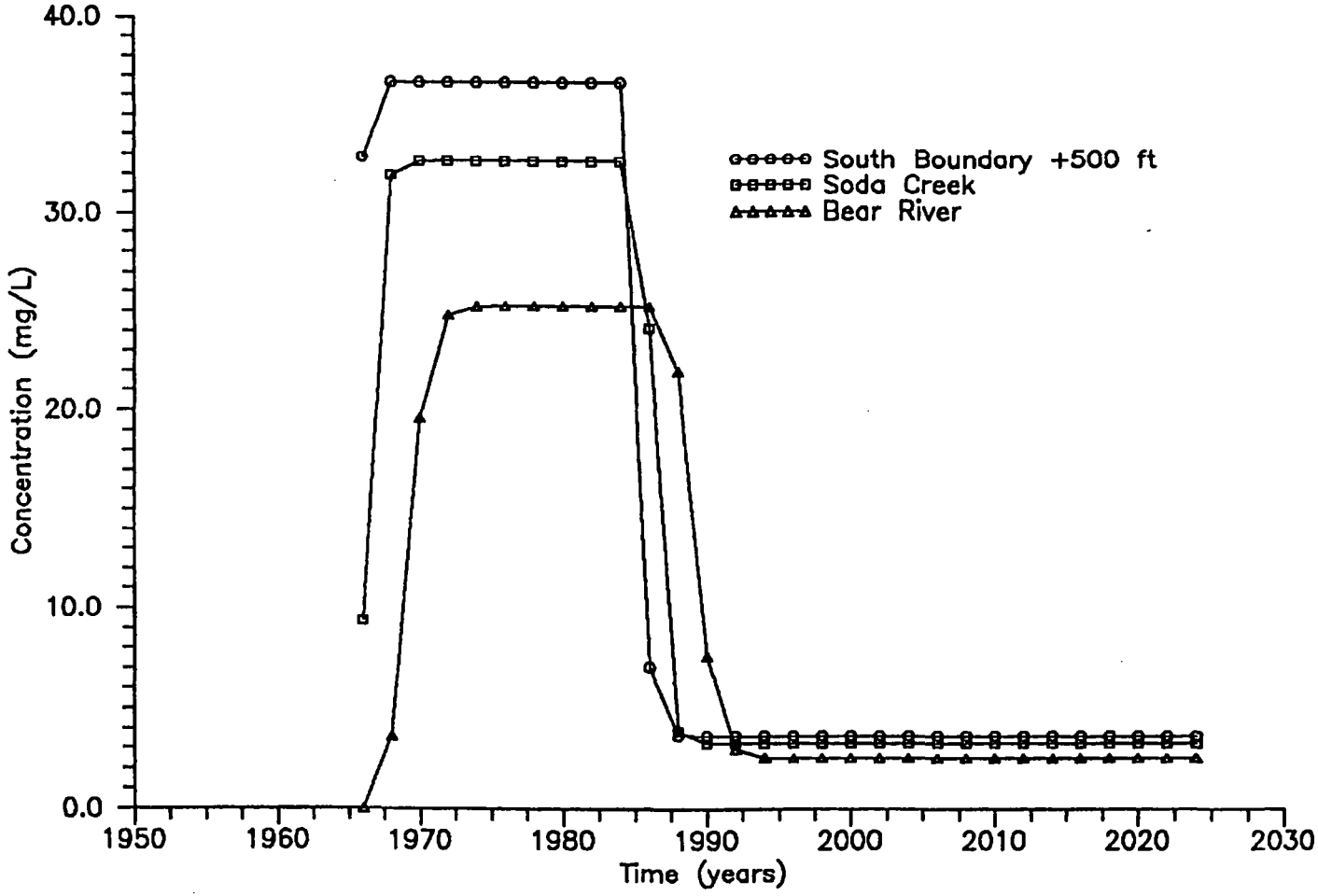

FIGURE **5-20**

PREDICTED FLUORIDE CONCENTRATIONS WITH FLUORITE SOLUBILITY CONTROL AFTER 1984

MONSANTO/PHASE II RI/ID

PROJECT NO. 913-1101.608 DRAWING NO. 50292 DATE 1/27/95 DRAWN BY CB

Golder Associates