ARSENIC AND SELENIUM IN SOILS AND SHALLOW GROUND WATER IN THE TURTLE LAKE, NEW ROCKFORD, HARVEY PUMPING, LINCOLN VALLEY, AND LaMOURE IRRIGATION AREAS OF THE GARRISON DIVERSION UNIT, NORTH DAKOTA

By W.R. Berkas and S.C. Komor

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 96-4205

Prepared in cooperation with the

BUREAU OF RECLAMATION

Bismarck, North Dakota

1996

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
GORDON P. EATON, Director

For additional information
write to:

District Chief
U.S. Geological Survey
Water Resources Division
821 East Interstate Avenue
Bismarck, ND 58501

Copies of this report can be
purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
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By W.R. Berkas *and* S.C. Komor

Abstract

The Garrison Diversion Unit project was authorized as part of the Pick-Sloan Missouri River Basin program to divert water from Lake Sakakawea to irrigation areas in North Dakota. A special Garrison Commission was created to evaluate an environmental concern that return flow from the irrigation areas might contain metals in toxic concentrations. This report summarizes the results of detailed investigations of the Turtle Lake, New Rockford, Harvey Pumping, Lincoln Valley, and LaMoure irrigation areas. A total of 223 soil samples were collected from the irrigation areas and analyzed for elemental composition. Water extractions were done on 40 of the 223 soil samples using a 1:5 soil-to-water extraction method, and the solution from the extraction was analyzed for elemental composition. A total of 52 ground-water samples were collected and analyzed for inorganic constituents and organic carbon.

Average arsenic concentrations in the entire soil column ranged from 1.0 milligram per kilogram in the Harvey Pumping irrigation area to 70 milligrams per kilogram in the New Rockford irrigation area. Average selenium concentrations ranged from less than 0.1 milligram per kilogram in the Turtle Lake, New Rockford, Harvey Pumping, and Lincoln Valley irrigation areas to 6.0 milligrams per kilogram in the Turtle Lake irrigation area. In the Turtle Lake irrigation area, average arsenic and selenium concentrations generally increased with depth through the topsoil, oxidized soil, and transition soil but decreased in the reduced soil at the bottom of the sampled horizons. Average arsenic concentrations in the New Rockford irrigation area follow the same pattern as in the Turtle Lake irrigation area, but selenium concentrations do not show a clear pattern of variation with depth. In the Harvey Pumping and Lincoln Valley irrigation areas, arsenic and selenium concentrations do not appear to vary systematically with depth. No correlation is shown between the concentrations in soils and soil extracts, indicating that, based on conditions of laboratory soil-water extraction experiments, trace-element concentrations in soils are not good predictors of trace-element concentrations in irrigation return flow.

Arsenic concentrations in the aquifers ranged from less than 1 microgram per liter to 27 micrograms per liter. Arsenic concentrations generally were larger in the deep part of the aquifers underlying the Turtle Lake and New Rockford irrigation areas than in the shallow part of the aquifers. In the shallow part of the aquifers, where oxidizing conditions prevail, arsenic is strongly adsorbed to soil particles. In the deep part of the aquifers, where reducing conditions prevail, arsenic is more mobile.

Selenium concentrations in the aquifers ranged from less than 1 microgram per liter to 4 micrograms per liter. Little difference existed between the selenium concentrations in the shallow part of the aquifers underlying the irrigation areas and the concentrations in the deep part of the aquifers.

INTRODUCTION

The Garrison Diversion Unit (GDU) project was authorized by Congress in 1944 as part of the Pick-Sloan Missouri River Basin program (Public Law 78-534). The purpose of the GDU project is to divert Missouri River water from Lake Sakakawea to areas in east-central and southeastern North Dakota for agricultural, environmental, industrial, municipal, and recreational uses. In 1984, Congress passed legislation (Public Law 98-360, section 207) that recognized that the GDU project raised significant issues of environmental, economic, and international concern. In order to evaluate these concerns and to advise Congress about future development of the project, a special Garrison Commission was created. One of the Commission's recommendations was that irrigation lands be surveyed to identify "...soil characteristics which might result in toxic or hazardous irrigation return flows."

In recent studies of irrigated lands in the western United States, problems were identified in areas where soils are underlain by and derived from marine sediments (Gilliom and others, 1989). The marine sediments contain natural accumulations of potentially toxic elements, such as selenium. Under conditions of intense leaching followed by evaporation, the elements can concentrate in soils and potentially create a hazard for wildlife. Such problems were identified in the western San Joaquin Valley of California (Ohlendorf and others, 1986; Fujii and others, 1988), the Middle Green River Basin in Utah (Stephens and others, 1988; Peltz and Waddell, 1991), and the Kendrick Reclamation project area in Wyoming (Peterson and others, 1988; See and others, 1991). Concern has arisen that similar problems could develop in irrigated areas in the GDU because the irrigation areas of the GDU are underlain by material derived from marine sediments and evaporation is greater than precipitation.

The U.S. Geological Survey, in cooperation with the Bureau of Reclamation, investigated the occurrence and distribution of trace elements in soils and ground water in areas that may receive irrigation return flow from the GDU (Goolsby and others, 1989). The major goal of the investigation was to determine the total and water-extractable concentrations of arsenic and selenium in the soils and the dissolved concentrations of these elements in the ground water. An additional goal was to evaluate the potential for arsenic and selenium mobilization because of irrigation with water from the GDU. In the reconnaissance phase of the investigation, samples were collected from the Turtle Lake, New Rockford, Lincoln Valley, Harvey Pumping, LaMoure, and West Oakes irrigation areas. In the detailed phase of the investigation, trace-element distributions in soils and shallow ground water in the West Oakes irrigation area were evaluated (Goolsby and others, 1989). Similar detailed investigations were to be conducted for the other five irrigation areas. Specific objectives of the detailed investigations were to (1) determine the inorganic chemical composition of the soils and ground water, (2) determine the arsenic and selenium concentrations and distributions in the soils and ground water, (3) evaluate whether the arsenic and selenium concentrations are large enough to threaten human health or wildlife, and (4) investigate the differences between arsenic and selenium concentrations in reduced parts of the aquifers and in oxidized parts of the aquifers underlying the irrigation areas.

The purpose of this report is to summarize the results of the detailed investigations of the Turtle Lake, New Rockford, Harvey Pumping, Lincoln Valley, and LaMoure irrigation areas. More discussion is presented for the Turtle Lake and New Rockford irrigation areas because more soil and water samples were collected in those areas than in the other three areas.

Description of Irrigation Areas

The five irrigation areas (fig. 1) encompass 56,500 acres (table 1). The largest irrigation area is the New Rockford area and the smallest is the Harvey Pumping area. The LaMoure irrigation area is fairly large but is made up of many small areas next to the James River.

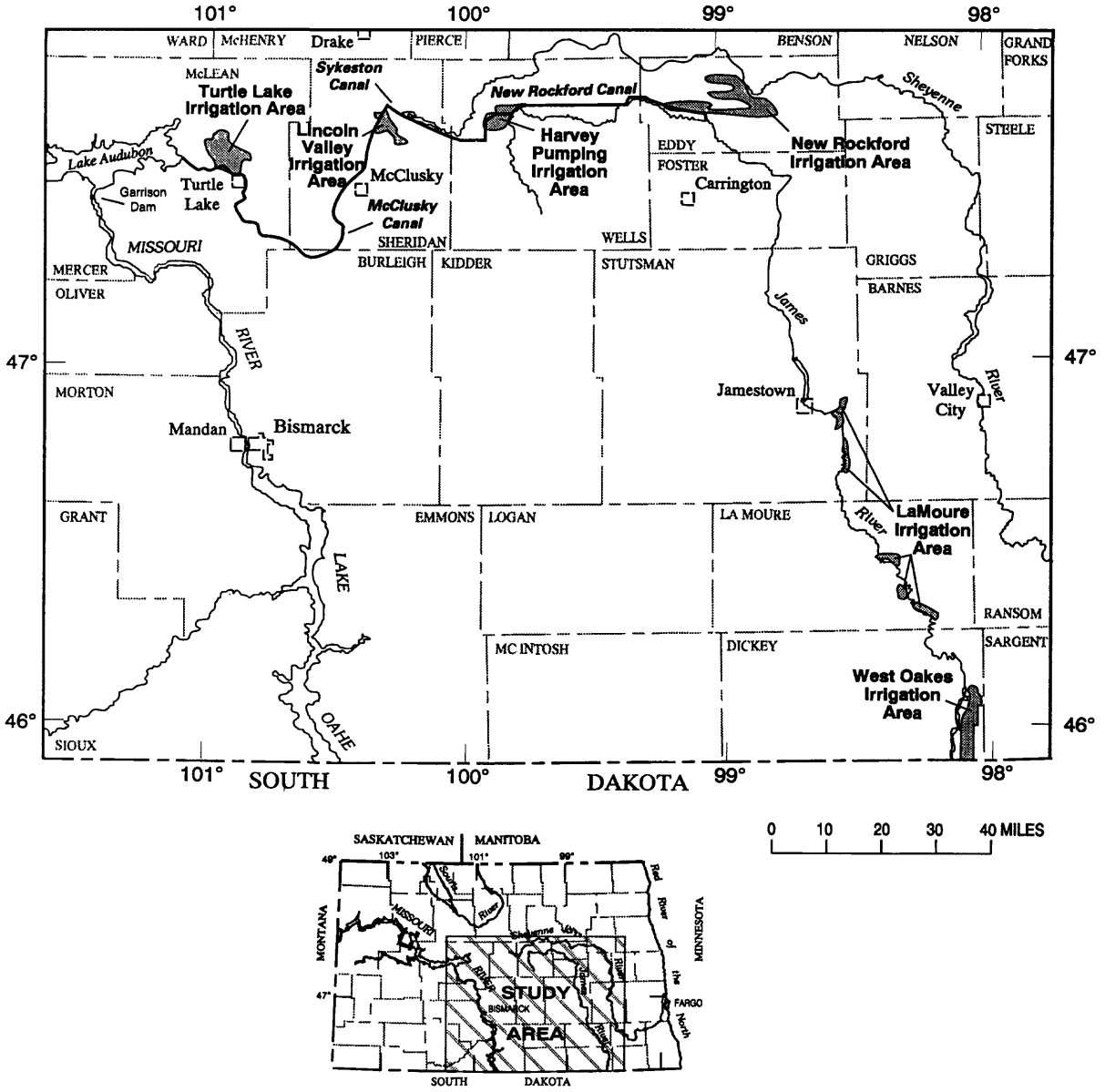


Figure 1. Location of irrigation areas of the Garrison Diversion Unit, North Dakota.

Table 1. Size of selected irrigation areas in the Garrison Diversion Unit

	Size (acres)
Turtle Lake irrigation area	13,700
New Rockford irrigation area	20,935
Harvey Pumping irrigation area	2,000
Lincoln Valley irrigation area	6,515
LaMoure irrigation area	13,350

The irrigation areas have an interior dry continental climate. Summers tend to be hot, and winters tend to be cold and dry. For example, at Carrington, N. Dak., the mean annual temperature (1951-80) is 38.7°F, the January mean is 3.9°F, and the July mean is 68.1°F (U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data and Information Service, 1982). Precipitation occurs mostly in the summer (fig. 2). The average annual precipitation (1951-80) is

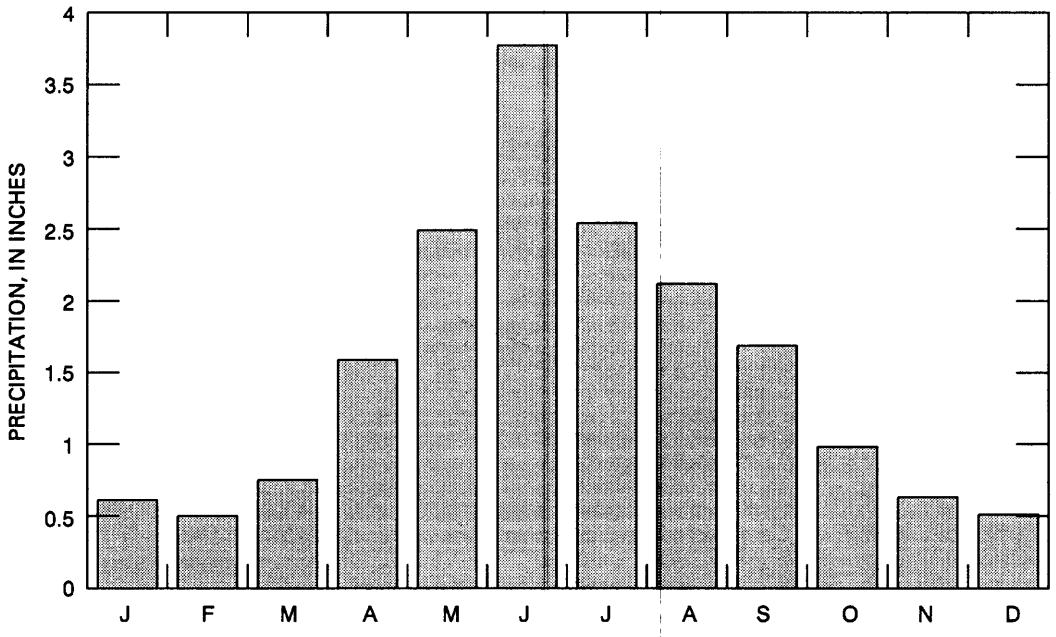


Figure 2. Mean monthly precipitation at Carrington, North Dakota (1951-80). [Data from U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data and Information Service, 1982.]

18.18 inches, and the average annual free-water-surface evaporation ranges from 28 to 30 inches (Farnsworth and others, 1982). A drought occurred in the irrigation areas from 1988 to 1992. Annual precipitation totals were 10.04 inches in 1988, 18.17 inches in 1989, and 16.65 inches in 1990 (U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, 1989-91). As a result of the drought, measured water levels in many of the wells in the five irrigation areas declined and some parts of the soils that were under reduced conditions became oxidized.

Glacial sediments overlie the bedrock in the irrigation areas. The bedrock consists of Cretaceous-age marine shales that typically have high arsenic and selenium concentrations. Shale chips are present in some places in the soils developed on the glacial sediments. Surficial aquifers occur in all of the glacial deposits in the irrigation areas.

The major depositional landforms in the irrigation areas are glaciated plains, outwash plains, alluvial plains, ground moraines, dead-ice moraines, and end moraines (Bluemle, 1965, 1971, 1981; Bluemle and others, 1967; fig. 3). The glaciated plains consist of a nonbedded mixture of clay, silt, and sand with some pebbles, cobbles, and boulders (glacial till) that was modified by running meltwater that washed the land surface in some areas and deposited sands and gravels in others. The outwash plains generally consist of stratified sands and gravels deposited by meltwater. The alluvial plains are glacial outwash that consists of poorly sorted sand and gravel generally deposited on stagnant ice and later collapsed when the underlying ice melted. The ground moraines, dead-ice moraines, and end moraines consist of till. Sufficient detail to show the landforms in which the Harvey Pumping, Lincoln Valley, and LaMoure irrigation areas are located is not given in figure 3. The Lincoln Valley irrigation area is within a glaciated plain, and the Turtle Lake, New Rockford, and Harvey Pumping irrigation areas are within outwash plains. The LaMoure irrigation area is made up of several small areas along the James River that are formed of alluvium from glacial meltwater.

The five irrigation areas are located close to the McClusky Canal, the New Rockford Canal, or the James River and contain soils that have drainage characteristics appropriate for overhead irrigation. Drainage lines are planned for the Turtle Lake, New Rockford, Harvey Pumping, and Lincoln Valley irrigation areas to maintain the water table at about 6 feet below land surface. Drainage lines are not planned for the LaMoure irrigation area because the nearby James River should provide adequate drainage for the sandy soils in that area.

Sample Collection and Analysis

Soil samples were collected from many sites in each irrigation area except the LaMoure area. The samples were collected by personnel from the U.S. Geological Survey and the Bureau of Reclamation and analyzed at the U.S. Geological Survey, Geologic Division, laboratory in Lakewood, Colo. Total concentrations of trace elements were measured, and soils that contained large concentrations of arsenic or selenium were analyzed further to determine water-extractable concentrations of trace elements.

Water samples were collected by personnel from the U.S. Geological Survey and analyzed at the U.S. Geological Survey, Water Resources Division, laboratory in Arvada, Colo. Where possible, samples were collected from the top and bottom of the surficial aquifers to evaluate vertical variations in water quality. Areal variations were evaluated by sampling water from several different parts of each aquifer.

Soil Samples

Soil samples were collected in continuous profiles from the land surface to glacial till. A 4-foot-long, 4-inch-diameter soil tube was used to collect samples from the surface soils to a depth of 3 feet at most locations. Below 3 feet, samples were collected using a 6-inch continuous-flight spiral auger. The surface of the core material from the soil tube and from the auger flight was removed with a stainless-steel blade to eliminate possible contaminated material. The core material then was laid on epoxy-coated plywood boards, described, classified, separated into soil horizons, and photographed. For each soil horizon, a sample was collected from the interior of the core, placed in a plastic bag, and shipped to the U.S. Geological Survey, Geologic Division, laboratory in Lakewood, Colo., for processing.

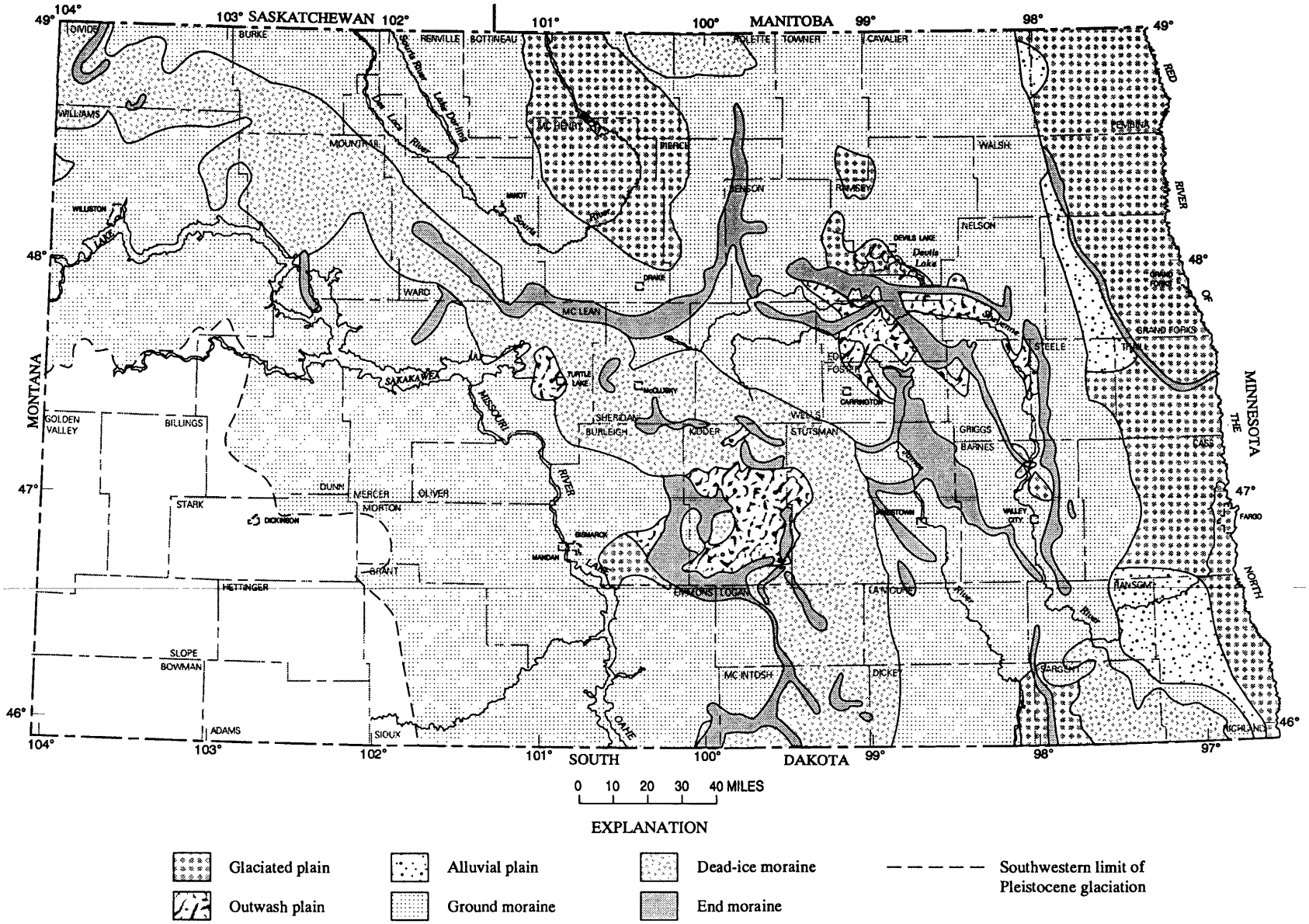


Figure 3. Generalized glacial map of North Dakota. [Modified from North Dakota Geological Survey, n.d.]

A total of 223 soil samples were submitted for total elemental analysis. The samples were analyzed using a combination of inductively-coupled argon plasma/optical emission spectroscopy (ICAP/OES), hydride generation/atomic absorption spectroscopy (HG/AAS), and cold vapor/atomic absorption spectroscopy (CV/AAS). Details for all procedures are given in Baedecker (1987) and Goolsby and others (1989). The constituents analyzed for, the methods of analysis, and the minimum reporting levels are given in supplement 1.

Of the 223 soil samples, soil water from 40 samples was analyzed using a 1:5 soil-to-water extraction method. A representative 5-gram aliquot of soil was weighed at the laboratory and combined with 25 milliliters of deionized water in a 3-ounce polyethylene bottle. The solution from the extraction was analyzed using ICAP/OES and HG/AAS. Details for all procedures are given in Baedecker (1987) and Goolsby and others (1989). The constituents analyzed for, the methods of analysis, and the minimum reporting levels are given in supplement 2.

Water Samples

Water samples were collected from observation wells in the five irrigation areas and one sample was collected from a drain in the New Rockford area. All wells were constructed of 2-inch-diameter polyvinyl chloride (PVC) pipe and had about 2 feet of 10-slot screen at the bottom. The casing joints were glued. All wells constructed before July 1989 had well screens at the bottom of the aquifer. The annular area around each well stem was filled with pea-sized gravel from a local source, and a bentonite seal was placed 1 to 2 feet below land surface.

An additional well was placed next to an existing well if the water table was greater than 3 feet above the top of the well screen. The bottom of the new well screen was placed 3 feet below the water table. The annular area around the well stem was filled with silica sand to 1 foot above the top of the well screen. Material from the hole was used to fill the annular area to within 3 feet of the land surface, and bentonite was used to seal the remaining area. The new wells were given a new identification number that consisted of adding the letter A or B to the existing well's number.

The wells were purged with a pitcher pump 1 day before sampling. At least three volumes of the water standing in the well casing was removed to insure that water samples from the well reflected the composition of water in the surrounding aquifer.

A bladder pump was used to collect water samples from most wells. When the depth to water in the well was less than 2 feet, a peristaltic pump was used. The bladder in the bladder pump was made of Teflon, and the discharge hose was made of neoprene. The hoses on the peristaltic pump were made of Tygon. The discharge hoses from the pumps were connected to a flowthrough chamber where specific conductance, pH, temperature, and dissolved oxygen were measured at 15-minute intervals. After these parameters stabilized, aliquots of water were collected for field and laboratory analyses.

Specific-conductance, pH, temperature, and dissolved oxygen were measured by meters attached to probes in the flowthrough chamber. If the dissolved-oxygen concentrations were less than 0.8 milligram per liter, the water was analyzed for dissolved oxygen with a Hach spectrophotometer using an AccuVac ampoule and the indigo carmine method (Hach Company, 1988). The water was analyzed for sulfide with a Hach spectrophotometer using an AccuVac ampoule and the methylene blue method and for ferrous iron using an AccuVac ampoule and the 1,10 phenanthroline method (Hach Company, 1988). Field alkalinity was determined using incremental titration with sulfuric acid.

After field parameters were measured, a 250-milliliter polyethylene bottle was filled with water for laboratory determinations of specific conductance, pH, alkalinity, and dissolved solids. Laboratory determinations of specific conductance, pH, and alkalinity were requested as a check on the field measurements. Next, a stainless-steel filtering apparatus that had a 0.45-micrometer silver-membrane filter was filled with water. The water was forced through the filter with nitrogen gas and directed into a 125-milliliter baked-glass bottle. This water sample was chilled to 4°C and preserved for determination of dissolved organic carbon concentrations.

A 0.45-micrometer plate filter that was flushed with about 1 liter of water was used to collect the remaining samples. Water was collected in 250-milliliter polyethylene bottles for determination of anion concentrations and 500-milliliter acid-rinsed polyethylene bottles for determination of cation and trace-element concentrations. The samples collected for determination of cation and trace-element concentrations were preserved with 2 milliliters of nitric acid. Next, water was collected in 250-milliliter acid-rinsed glass bottles and preserved with 10 milliliters of a nitric acid and potassium dichromate solution for determination of dissolved mercury concentrations. Finally, water was collected in 250-milliliter brown polyethylene bottles, preserved with 1 milliliter of a mercuric chloride solution, and chilled to 4°C for determination of nutrient concentrations.

A total of 52 water samples were collected from the five irrigation areas. The samples were analyzed for nutrients and organic carbon within 10 days of sample collection and for common ions and trace elements within 4 months of sample collection. The constituents analyzed for, the methods of analysis, and the minimum reporting levels are given in supplement 3. Procedures for each method are given in Wershaw and others (1987) and Fishman and Friedman (1989).

Quality Assurance

A few of the samples were split before being sent to the laboratory in order to obtain two analyses of the same sample. Results for the split samples then were compared to determine the amount of possible error that could result from sampling, site location, and analytical procedures. A total of three soil samples were selected at random, split, and analyzed using a 1:5 soil-to-water extraction method. The maximum differences between the paired soil samples are given in table 2. A total of five water samples were selected at random, split, and analyzed. The maximum differences between the paired water samples are given in table 3.

Differences between paired samples are given in tables 2 and 3 as actual values or as rounding units. Actual values are given when samples cover a range that has the same rounding. Rounding units are given when samples cover a range where the rounding changes. For example, the dissolved sodium pairs from ground water (table 3) ranged from 8.3 to 44 milligrams per liter. Values between 1.0 and 9.9 are rounded to the nearest 0.1 unit, and values between 10 and 99 are rounded to the nearest 1 unit. A difference of 1 milligram per liter will cover the degree of significance for values between 1.0 and 9.9; thus, rounding units are reported.

Most of the differences between the paired soil samples are within one rounding unit, as indicated by a maximum difference of zero. This means that errors resulting from sampling, site location, and analytical procedures probably had little effect on the reported concentration. Other maximum differences were at or greater than one rounding unit. For example, the maximum difference between the selenium concentrations for the paired samples was one, meaning that the true selenium concentration may not be the concentration reported but that the concentration should be within 1 microgram per kilogram.

Table 2. Maximum difference between paired extracts from a 1:5 soil-to-water extraction conducted on soil samples collected from irrigation areas of the Garrison Diversion Unit

[mg/kg, milligrams per kilogram; <, less than; µg/kg, micrograms per kilogram]

Constituent	Maximum difference between paired samples	Range of concentrations
Aluminum (mg/kg)	3	<5 to 10
Antimony (mg/kg)	0	<0.5
Arsenic (µg/kg)	0	<10
Barium (mg/kg)	0.2	<0.1 to 0.4
Beryllium (mg/kg)	0	<0.1
Bismuth (mg/kg)	0	<1
Boron (mg/kg)	0	<0.5 to 0.7
Cadmium (mg/kg)	0	<0.2
Calcium (mg/kg)	32	50 to 670
Cerium (mg/kg)	0	<0.4
Chromium (mg/kg)	0	<0.1
Cobalt (mg/kg)	0	<0.1
Copper (mg/kg)	0.2	<0.1 to 0.2
Iron (mg/kg)	5	<5 to 10
Lanthanum (mg/kg)	0	<0.2
Lead (mg/kg)	0	<0.4
Lithium (mg/kg)	0.1	<0.2 to 0.5
Magnesium (mg/kg)	One rounding unit	10 to 340
Manganese (mg/kg)	0	<0.4 to 2
Molybdenum (mg/kg)	0	<0.2 to 0.2
Nickel (mg/kg)	0	<0.2
Phosphorus (mg/kg)	0	<5
Potassium (mg/kg)	10	10 to 84
Selenium (µg/kg)	1	1 to 75
Silicon (mg/kg)	24	30 to 99
Silver (mg/kg)	0	<0.2
Sodium (mg/kg)	One rounding unit	6 to 210
Strontium (mg/kg)	One rounding unit	<0.2 to 5
Thorium (mg/kg)	0	<0.4
Tin (mg/kg)	0	<0.5
Titanium (mg/kg)	0	<5
Vanadium (mg/kg)	0	<0.2
Wolfram (mg/kg)	0	<0.5
Yttrium (mg/kg)	0	<0.2
Zinc (mg/kg)	0	<0.2
Zirconium (mg/kg)	0	<0.2

Table 3. Maximum difference between paired ground-water samples collected from irrigation areas of the Garrison Diversion Unit

[mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter]

Constituent	Maximum difference between paired samples	Range of concentrations
Calcium, dissolved (mg/L)	Two rounding units	60 to 190
Magnesium, dissolved (mg/L)	1	30 to 55
Sodium, dissolved (mg/L)	Three rounding units	8.3 to 44
Potassium, dissolved (mg/L)	Six rounding units	1.8 to 13
Sulfate, dissolved (mg/L as SO_4)	Two rounding units	30 to 480
Chloride, dissolved (mg/L)	Six rounding units	4.0 to 18
Fluoride, dissolved (mg/L)	One rounding unit	<0.1 to 3
Silica, dissolved (mg/L as SiO_2)	0	20 to 30
Nitrite, dissolved (mg/L as N)	0.004	0.002 to 0.012
Nitrite plus nitrate, dissolved (mg/L as N)	Six rounding units	0.04 to 18
Ammonia, dissolved (mg/L as N)	0.01	<0.01 to 0.16
Orthophosphorus, dissolved (mg/L as P)	0	<0.01
Arsenic, dissolved (µg/L)	1	<1 to 6
Boron, dissolved (µg/L)	10	60 to 140
Iron, dissolved (µg/L as Fe)	Two rounding units	<3 to 5,900
Lithium, dissolved (µg/L)	1	17 to 34
Manganese, dissolved (µg/L)	One rounding unit	1 to 2,000
Mercury, dissolved (µg/L)	0	<0.1
Molybdenum, dissolved (µg/L)	1	<1 to 1
Selenium, dissolved (µg/L)	1	<1 to 3
Strontium, dissolved (µg/L)	10	170 to 460
Organic carbon, dissolved (mg/L)	0.1	1.6 to 3.1

Most of the differences between the paired water samples are greater than one rounding unit. This means that errors resulting from sampling, site location, and analytical procedures affected the reported concentration.

GEOCHEMISTRY OF ARSENIC AND SELENIUM

Arsenic and selenium are of primary concern in this study because of potentially toxic effects. If soils in the GDU contain large concentrations of arsenic or selenium, the planned irrigation and drainage activities might mobilize and concentrate the elements. The following discussion of the geochemistry of arsenic and selenium was taken from Welch and others (1988) and Jacobs (1989).

Arsenic toxicity, ranked in order from greatest to least, is as follows: arsine (valence -3), organo-arsine compounds, arsenites (+3) and oxides (+3), arsenates (+5), arsonium metals (+1), and native arsenic (0). Arsenic in ground water generally is present as an oxyanion--arsenate ($H_nAsO_4^{3-n}$), arsenite ($H_nAsO_3^{3-n}$), or both. The dominant aqueous species, under varying pH and redox conditions at equilibrium, are shown in figure 4. In oxidizing soil and aquatic environments, arsenic is strongly adsorbed on hydrous oxides and hydroxides of iron, particularly goethite. In environments having redox potentials low enough to reduce iron to the ferrous form, arsenic can be released from the iron minerals and become mobile.

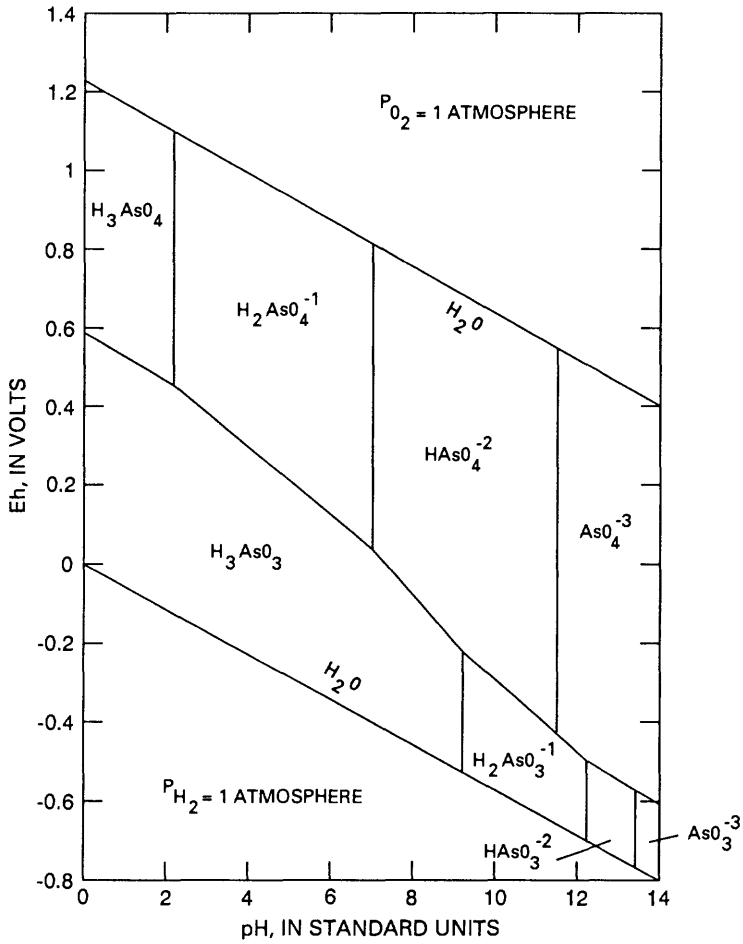


Figure 4. Fields of stability for forms of arsenic as a function of Eh and pH. [Modified from Welch and others, 1988.]

The maximum contaminant level for arsenic in drinking water is 50 micrograms per liter (North Dakota Department of Health, 1994). Arsenic toxicity to freshwater aquatic life varies with the arsenic species. The chronic criterion for arsenic in the +3 valence (arsenites and oxides) is 190 micrograms per liter, and the chronic criterion for arsenic in the +5 valence (arsenate) is 48 micrograms per liter (U.S. Environmental Protection Agency, 1986).

Selenium can exist in oxidation states of -2, 0, +4, and +6 (fig. 5). Selenides (oxidation state -2, as in Se^{-2}) and elemental selenium (oxidation state 0, as in Se^0) are stable in reducing environments. Selenites (oxidation state +4, as in SeO_3^{-2}) occur in mildly oxidizing environments. Selenates (oxidation state +6, as in SeO_4^{-2}) occur in alkaline strongly oxidizing environments. Selenides and elemental selenium are virtually insoluble in water and, therefore, are immobile. Selenites are relatively soluble but are strongly adsorbed on goethite and other iron oxides. Thus, in the presence of iron oxides, selenites are relatively immobile. However, other oxyanions, such as phosphate, can replace selenites on iron oxides, thereby mobilizing the selenites. Selenates are quite soluble and mobile in soils and aquatic environments. Theoretically, between pH 7 and 8, selenates would predominate only at oxidation potentials (Eh) larger than about 0.4 volt.

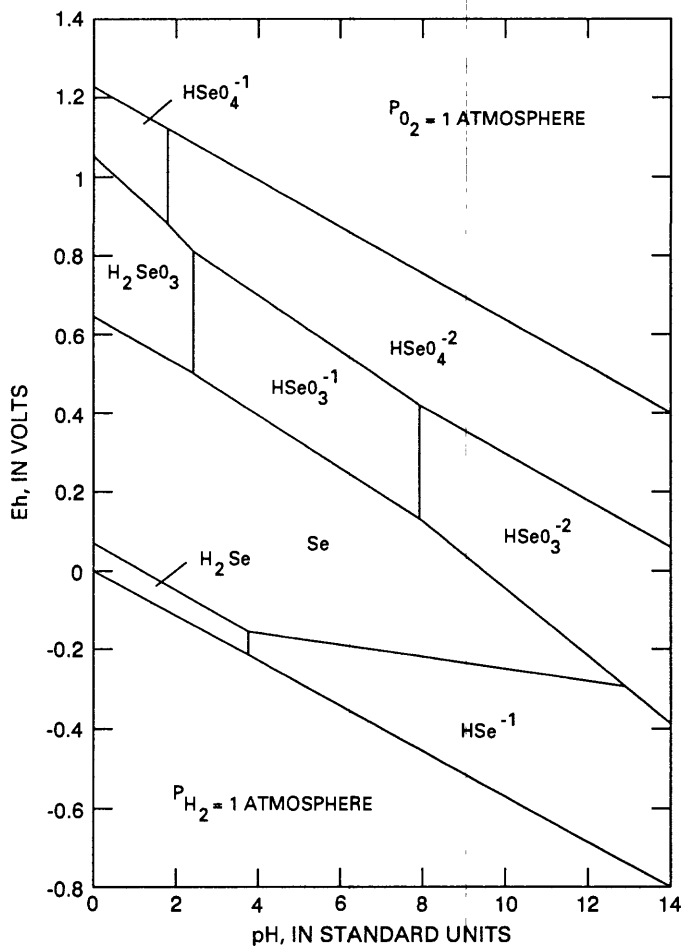


Figure 5. Fields of stability for forms of selenium as a function of Eh and pH. [Modified from McNeal and Balestrieri, 1989.]

The maximum contaminant level for selenium in drinking water is 50 micrograms per liter (North Dakota Department of Health, 1994). The chronic criterion for freshwater aquatic life is 35 micrograms per liter (U.S. Environmental Protection Agency, 1986).

The mobility of arsenic and selenium is dependent upon the oxidation state of arsenic and selenium compounds. Reduced arsenic species are more mobile than oxidized arsenic species, but oxidized selenium species are more mobile than reduced selenium species. Oxidized compounds occur when oxygen is present. In soils, oxidized conditions occur when the soil is not saturated with water or when the soil is saturated with water and the dissolved-oxygen concentration is measurable (usually greater than 1 milligram per liter). Reduced conditions occur when the soil is saturated with water and the dissolved-oxygen concentration is not measurable.

ARSENIC AND SELENIUM IN SOILS AND SHALLOW GROUND WATER

Turtle Lake Irrigation Area

Hydrogeologic sections of the aquifer underlying the Turtle Lake irrigation area (figs. 6 and 7) were determined from borehole logs of observation wells in the irrigation area. The altitude of the water table in the Turtle Lake irrigation area on August 20-21, 1990, is shown in figure 8.

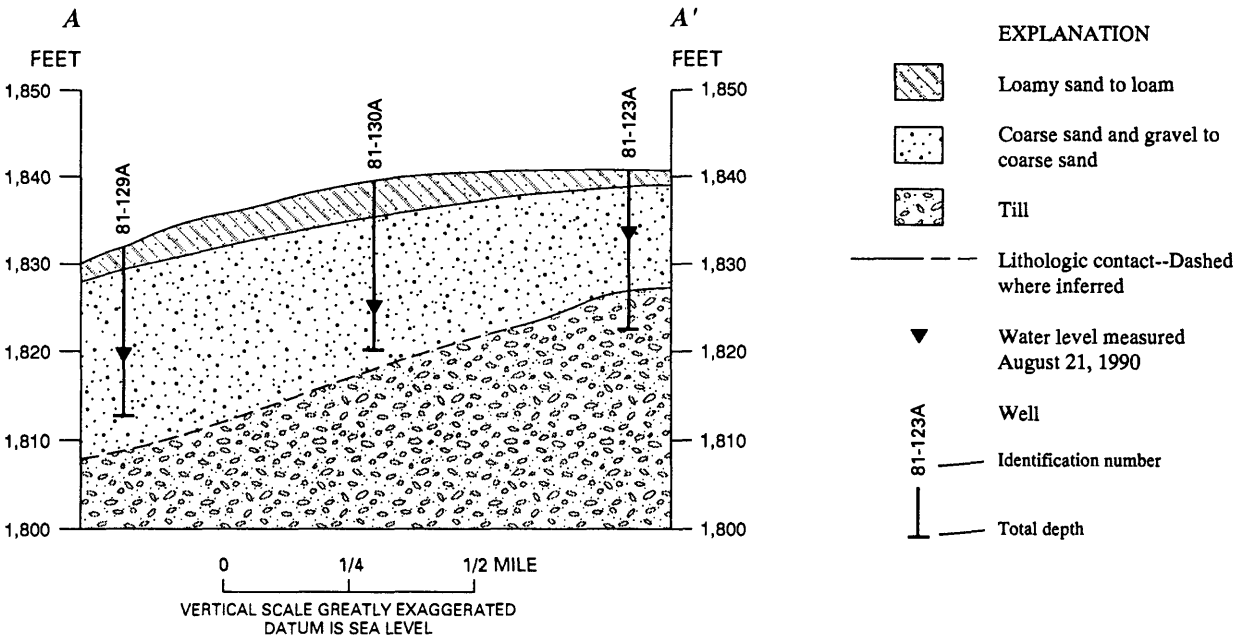


Figure 6. Hydrogeologic section A-A' through the Turtle Lake irrigation area. [Trace of section shown in figure 8.]

Soil Chemistry

Soil samples were collected from 16 sites adjacent to observation wells in the Turtle Lake irrigation area. Chemical analyses of the soils are given in supplement 4 by order of increasing depth at each location and in supplement 5 by soil series and soil horizon. Soil horizons were defined, in order of increasing depth, as the topsoil, the oxidized soil, the transition soil between the oxidized and reduced soils, and the reduced soil. Topsoils were black and within 3 feet of the land surface; oxidized soils were tan and dry and occurred above the water table; transition soils were mottled tan, red, and black and occurred near the water table; and reduced soils were black, wet, and sometimes had a rotten-egg smell. The soils were categorized by the Bureau of Reclamation (Kurt Webber, written commun., 1990).

Arsenic concentrations ranged from 2.4 to 54 milligrams per kilogram, and selenium concentrations ranged from less than 0.1 to 6.0 milligrams per kilogram. Average arsenic and selenium concentrations in the entire soil column are plotted in figure 9. No areal pattern is apparent for large average arsenic concentrations. Average selenium concentrations generally were smallest in the northern part of the irrigation area.

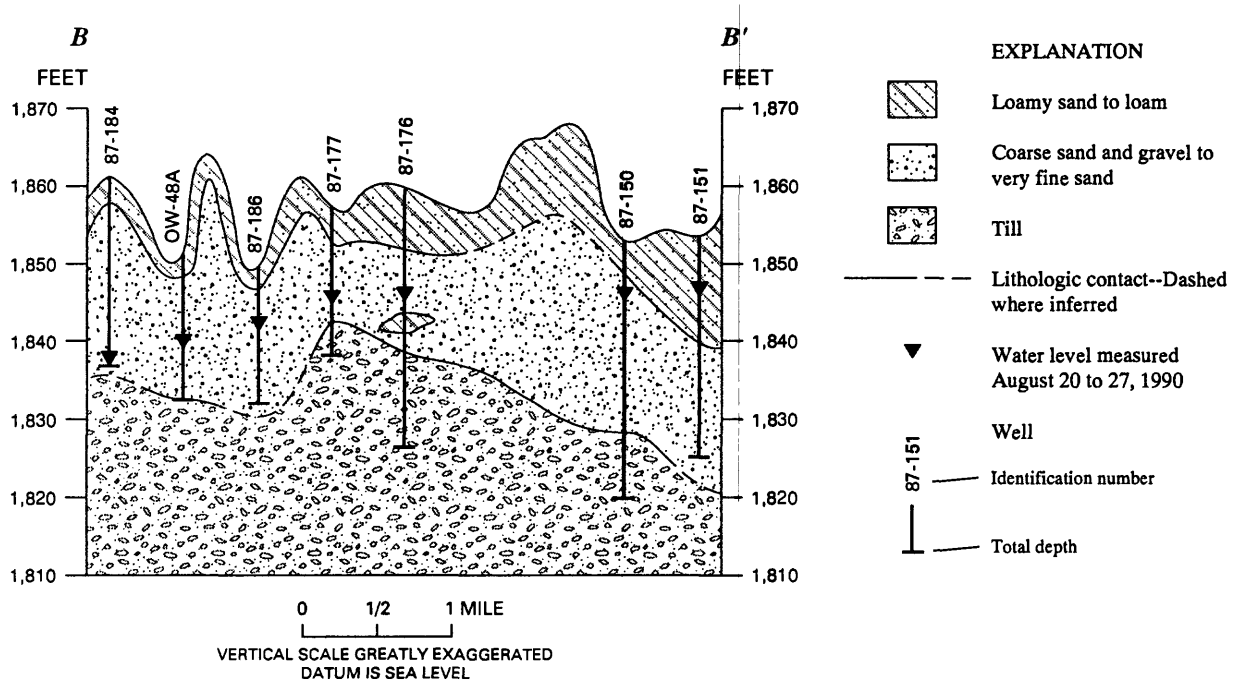


Figure 7. Hydrogeologic section B-B' through the Turtle Lake irrigation area. [Trace of section shown in figure 8.]

Analysis of variance was used to evaluate chemical variability of soils in the Turtle Lake irrigation area (supplement 6). Because the concentrations were not normally distributed, an analysis of variance was done on ranked soils data. A total of three null hypotheses were tested for each chemical constituent. In null hypothesis A, the median constituent concentrations in each soil horizon are equal; in null hypothesis B, the median constituent concentrations in each soil series are equal; and in null hypothesis C, the median constituent concentrations in each soil horizon within each soil series are equal. The null hypotheses were accepted at the 0.05 probability level. All three null hypotheses were rejected for arsenic, indicating that arsenic concentrations vary among soil horizons and soil series and also among soil horizons within each soil series. For selenium, null hypothesis A was rejected but null hypotheses B and C were accepted, indicating that selenium concentrations vary among soil horizons but not among soil series or among soil horizons within each soil series.

Average arsenic, iron, manganese, and selenium concentrations are given in table 4 for each of the defined soil horizons. Iron and manganese are sensitive to reduction-oxidation (redox) conditions and their behavior should be similar to that of arsenic and opposite that of selenium. Average arsenic and selenium concentrations generally increase with depth through the topsoil, oxidized soil, and transition soil but decrease in the reduced soil at the bottom of the sampled horizons. Iron and manganese concentrations have the same general pattern, possibly because redox-sensitive constituents in shallow parts of the aquifer were leached downward by percolating water. Although the constituents would be strongly adsorbed onto soil particles in shallow oxidized parts of the soil horizon, net movement of the constituents downward through the soil column probably occurs over time. The constituents are relatively soluble in the deep reduced part of the aquifer and, therefore, partition into the pore water, leaving smaller concentrations in the soil.

The average arsenic concentration in 19 soil extracts was 13 micrograms per kilogram, and the maximum was 37 micrograms per kilogram (supplement 7). The extracts contained an average of 0.2 percent of the total arsenic in the soil. The average selenium concentration in 19 soil extracts was

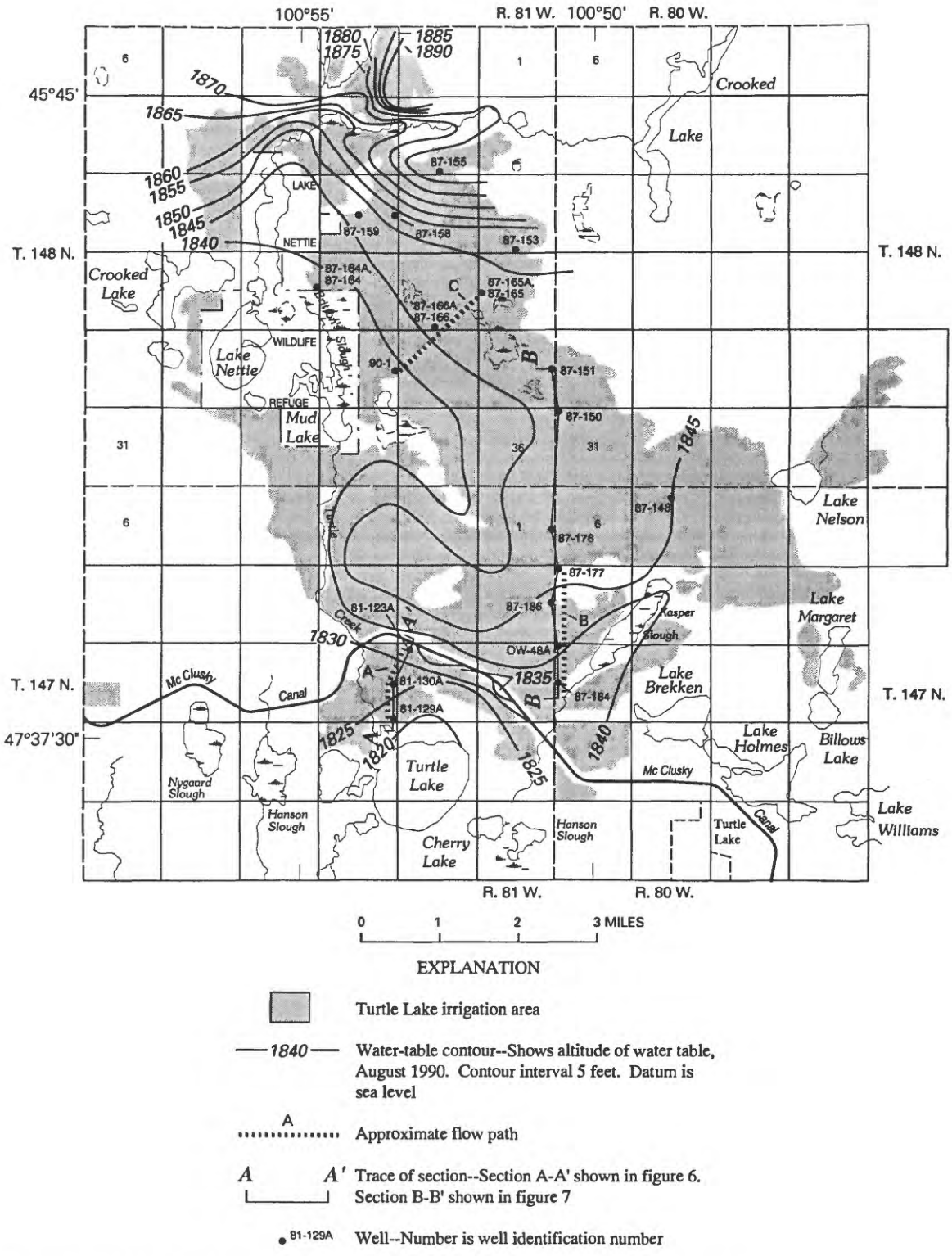


Figure 8. Altitude of water table in the Turtle Lake irrigation area, August 20-21, 1990.

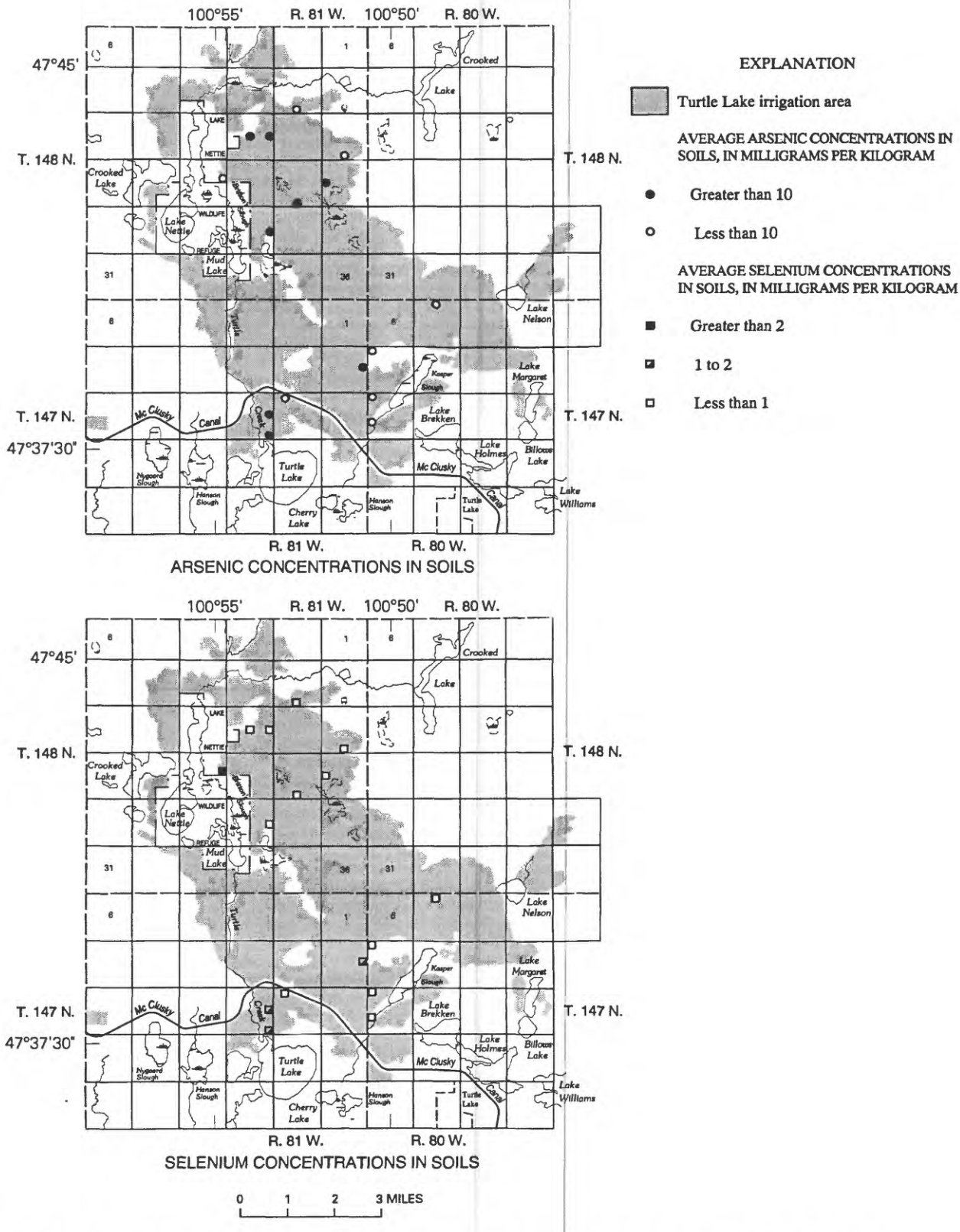


Figure 9. Average arsenic and selenium concentrations in soils from the Turtle Lake irrigation area, 1990.

Table 4. Sample size, average concentration, and standard deviation for arsenic, iron, manganese, and selenium in soil horizons in the Turtle Lake irrigation area, July 1990

[N, number of samples; SD, standard deviation; mg/kg, milligrams per kilogram]

Constituent	Topsoil			Oxidized soil			Transition soil			Reduced soil		
	N	Average concentration	SD	N	Average concentration	SD	N	Average concentration	SD	N	Average concentration	SD
Arsenic (mg/kg)	16	7.1	3.8	16	10	3.0	10	16	15	5	7.7	6.4
Iron (percent)	16	2.62	.38	16	2.98	.50	10	3.94	1.92	5	3.34	1.26
Manganese (mg/kg)	16	1,040	333	16	1,890	1,400	10	2,760	2,000	5	889	190
Selenium (mg/kg)	16	.4	.2	16	.3	.3	10	1.2	1.2	5	.9	.4

16 micrograms per kilogram, and the maximum was 55 micrograms per kilogram. The extracts contained an average of 1.8 percent of the total selenium in the soil. Arsenic and selenium concentrations in soils were compared to arsenic and selenium concentrations in soil extracts (fig. 10). No correlation is shown

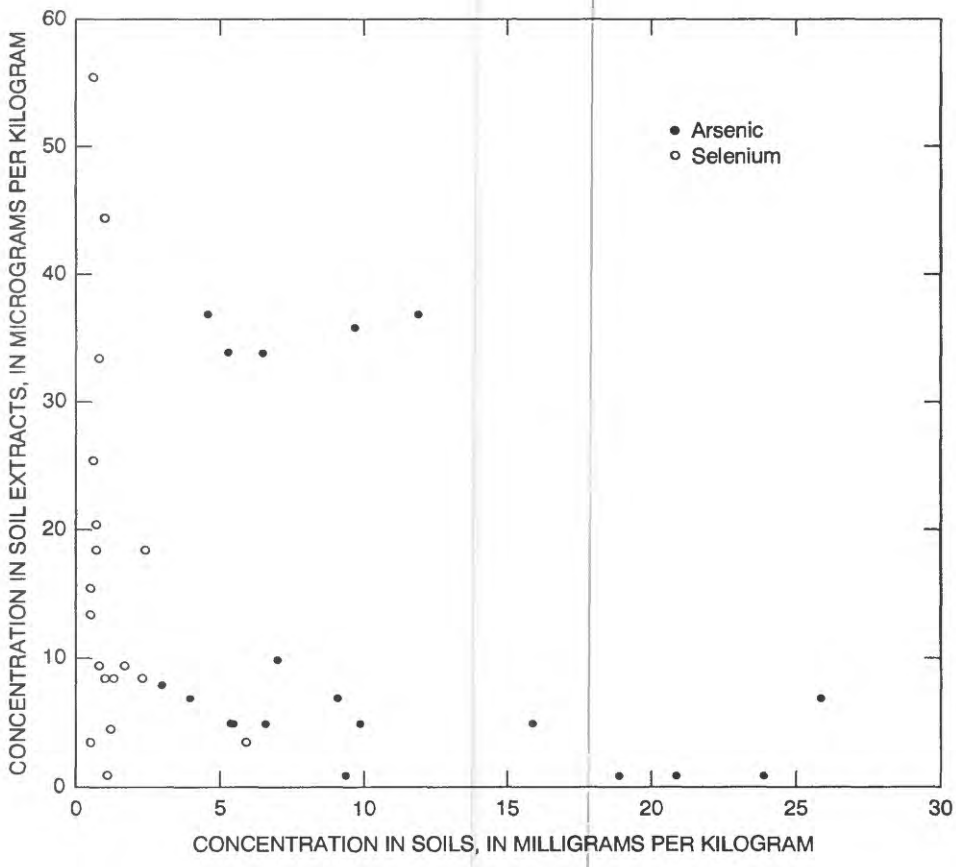


Figure 10. Arsenic and selenium concentrations in soils and soil extracts from the Turtle Lake irrigation area.

between the concentrations in soils and the concentrations in extracts, indicating that, based on conditions of laboratory soil-water extraction experiments, trace-element concentrations in soils are not good predictors of trace-element concentrations in irrigation return flow.

Water Chemistry

Water samples were collected from near the water table (the shallow part of the aquifer) and from the bottom of the aquifer (the deep part of the aquifer). Where the water table was within 3 feet of the bottom of the aquifer, samples were collected only from the bottom of the aquifer. Chemical analyses for both the shallow and deep parts of the aquifer are given in supplement 8. A statistical summary of data for the shallow wells is given in table 5, and a statistical summary of data for the deep wells is given in table 6. If constituent concentrations were less than the minimum reporting level, a log-probability regression was used to estimate the mean concentration (Helsel and Cohn, 1988).

Table 5. Statistical summary of physical-property and chemical-constituent data for the shallow part of the aquifer underlying the Turtle Lake irrigation area, September 1990

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; --, not determined; °C, degrees Celsius; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter]

Type of data	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
	Sample size	Maximum	Minimum	Mean	90	75	Median 50	25	10
Physical property									
Specific conductance (µS/cm)	10	1,040	346	650	1,020	758	660	493	356
pH (standard units)	10	8.01	7.29	--	8.01	7.90	7.68	7.45	7.30
Temperature, water (°C)	10	21.4	12.3	15.8	21.2	18.8	14.7	13.8	12.3
Oxygen, dissolved (mg/L)	10	5.4	.19	2.2	5.4	4.2	1.8	.37	.21
Chemical constituent									
Calcium, dissolved (mg/L)	10	130	37	69	125	78	66	48	38
Magnesium, dissolved (mg/L)	10	51	11	32	50	37	33	26	12
Sodium, dissolved (mg/L)	10	120	.7	28	114	46	8.5	5.7	.9
Potassium, dissolved (mg/L)	10	13	1.1	4.0	12	4.5	3.2	2.2	1.1
Bicarbonate, dissolved (mg/L as HCO_3)	10	410	164	296	406	348	288	255	173
Sulfate, dissolved (mg/L as SO_4)	10	300	19	88	289	111	56	28	20
Sulfide, dissolved (mg/L as S)	10	.010	<.001	.005	.010	.008	.006	.002	<.001
Chloride, dissolved (mg/L)	10	15	2.6	6.3	15	9.5	4.2	3.6	2.6
Fluoride, dissolved (mg/L)	10	.5	<.1	.2	.5	.2	.1	<.1	<.1
Silica, dissolved (mg/L as SiO_2)	10	32	20	27	32	29	28	26	20
Nitrite, dissolved (mg/L as N)	10	.035	<.001	.013	.034	.026	.008	.002	<.001
Nitrite plus nitrate, dissolved (mg/L as N)	10	22	<.01	6.8	22	16	.60	.04	<.01
Ammonia, dissolved (mg/L as N)	10	.38	<.01	.05	.35	.04	.01	<.01	<.01
Orthophosphorus, dissolved (mg/L as P)	10	.01	<.01	<.01	.01	<.01	<.01	<.01	<.01
Arsenic, dissolved (µg/L)	10	1	<1	<1	1	1	1	<1	<1
Boron, dissolved (µg/L)	10	300	20	102	291	188	50	38	21
Iron, dissolved (µg/L as Fe)	10	44	<3	11	43	16	4	<3	<3
Ferrous iron, dissolved (µg/L as Fe)	10	40	<10	16	40	18	10	<10	<10
Lithium, dissolved (µg/L)	10	62	4	25	60	38	20	13	5
Manganese, dissolved (µg/L)	10	2,600	<1	493	2,480	785	68	1	1

Table 5. Statistical summary of physical-property and chemical-constituent data for the shallow part of the aquifer underlying the Turtle Lake irrigation area, September 1990—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; --, not determined; °C, degrees Celsius; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter]

Type of data	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
	Sample size	Maximum	Minimum	Mean	90	75	Median 50	25	10
Mercury, dissolved (µg/L)	10	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Molybdenum, dissolved (µg/L)	10	5	<1	2	5	3	2	<1	<1
Selenium, dissolved (µg/L)	10	3	<1	<1	3	1	<1	<1	<1
Strontium, dissolved (µg/L)	10	430	91	224	426	315	195	110	93
Organic carbon, dissolved (mg/L)	10	5.9	1.7	2.8	5.6	3.2	2.4	2.0	1.7

Table 6. Statistical summary of physical-property and chemical-constituent data for the deep part of the aquifer underlying the Turtle Lake irrigation area, September 1990

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; --, not determined; °C, degrees Celsius; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter]

Type of data	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
	Sample size	Maximum	Minimum	Mean	90	75	Median 50	25	10
Physical property									
Specific conductance (µS/cm)	5	990	518	682	990	870	590	539	518
pH (standard units)	5	7.52	7.10	--	7.52	7.50	7.41	7.16	7.10
Temperature, water (°C)	5	14.7	8.3	11.2	14.7	13.2	10.9	9.3	8.3
Oxygen, dissolved (mg/L)	5	1.9	.08	.52	1.9	1.1	.18	.11	.08
Chemical constituent									
Calcium, dissolved (mg/L)	5	110	77	88	110	104	78	78	77
Magnesium, dissolved (mg/L)	5	50	26	34	50	44	30	26	26
Sodium, dissolved (mg/L)	5	35	9.2	15	35	23	11	9.6	9.2
Potassium, dissolved (mg/L)	5	11	3.1	4.9	11	8.3	4.7	4.2	4.0
Bicarbonate, dissolved (mg/L as HCO_3)	5	576	308	371	576	456	322	311	308
Sulfate, dissolved (mg/L as SO_4)	5	76	36	62	76	76	67	47	36
Sulfide, dissolved (mg/L as S)	5	.005	.003	.004	.005	.004	.003	.003	.003
Chloride, dissolved (mg/L)	5	11	4.0	5.9	11	8.3	4.7	4.2	4.0
Fluoride, dissolved (mg/L)	5	.2	<.1	.1	.2	.2	.1	<.1	<.1
Silica, dissolved (mg/L as SiO_2)	5	28	20	25	28	28	26	22	20
Nitrite, dissolved (mg/L as N)	5	.002	<.001	.001	.002	.002	.001	.001	<.001
Nitrite plus nitrate, dissolved (mg/L as N)	5	.04	<.01	.02	.04	.04	.03	<.01	<.01
Ammonia, dissolved (mg/L as N)	5	.20	<.01	.06	.20	.12	.05	.02	<.01
Orthophosphorus, dissolved (mg/L as P)	5	.09	<.01	.02	.09	.06	<.01	<.01	<.01
Arsenic, dissolved (µg/L)	5	27	1	7	27	16	4	2	1
Boron, dissolved (µg/L)	5	70	40	58	70	70	60	45	40
Iron, dissolved (µg/L as Fe)	5	970	<3	428	970	885	310	32	<3
Ferrous iron, dissolved (µg/L as Fe)	5	1,040	10	442	1,040	905	310	45	10
Lithium, dissolved (µg/L)	5	48	15	25	48	35	21	16	15
Manganese, dissolved (µg/L)	5	630	<1	344	630	625	290	90	<1

Table 6. Statistical summary of physical-property and chemical-constituent data for the deep part of the aquifer underlying the Turtle Lake irrigation area, September 1990—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; --, not determined; °C, degrees Celsius; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter]

Type of data	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
	Sample size	Maximum	Minimum	Mean	90	75	Median 50	25	10
Mercury, dissolved (µg/L)	5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Molybdenum, dissolved (µg/L)	5	4	<1	1	4	3	<1	<1	<1
Selenium, dissolved (µg/L)	5	2	<1	<1	2	<1	<1	<1	<1
Strontium, dissolved (µg/L)	5	390	99	254	390	365	220	159	99
Organic carbon, dissolved (mg/L)	5	3.7	1.4	2.6	3.7	3.4	2.9	1.6	1.4

Water in the aquifer underlying the Turtle Lake irrigation area is fresh (less than 1,000 milligrams per liter of dissolved solids) and slightly alkaline. The major-ion composition of water from 15 shallow and deep wells sampled in September 1990 is shown in figure 11. The cations--calcium, magnesium, and

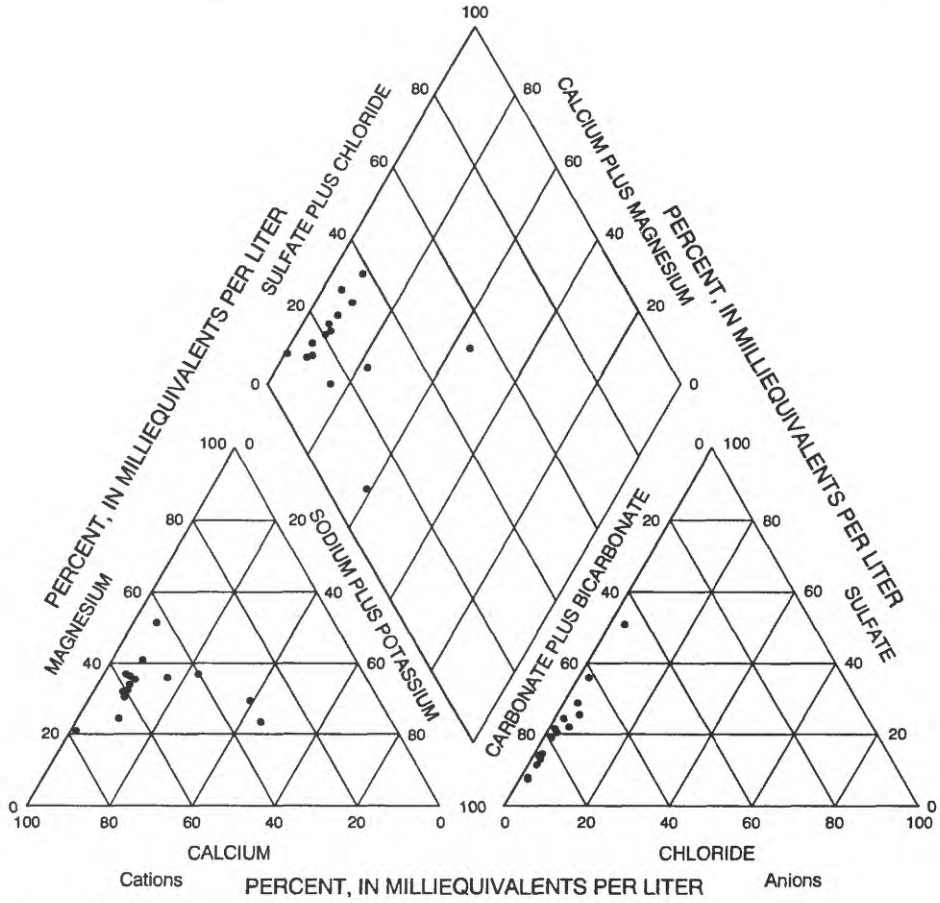


Figure 11. Major-ion composition of water in the aquifer underlying the Turtle Lake irrigation area.

sodium plus potassium--are plotted as percentages of the total cation concentrations, and the anions--bicarbonate plus carbonate, chloride, and sulfate--are plotted as percentages of the total anion concentrations. Calcium and bicarbonate were the predominant ions in most of the samples. Generally, as the total ion concentration increased, the major-ion composition changed from a calcium bicarbonate type to a sodium calcium sulfate bicarbonate type. Analysis of the water samples by use of the chemical equilibrium model WATEQ4F (Ball and Nordstrom, 1991) indicates that most of the water samples were saturated with respect to aragonite, calcite, dolomite, and iron-oxide minerals and undersaturated with respect to gypsum.

Chemical reactions that govern the major-ion composition of water in the aquifer underlying the Turtle Lake irrigation area probably include dissolution and precipitation of calcite, dissolution of gypsum, and ion exchange with clay minerals. Precipitation of soluble minerals in the unsaturated zone results from evapotranspiration, and dissolution of these minerals during periods of recharge may affect the chemical evolution of the water (Freeze and Cherry, 1979). The extent and nature of these reactions were not determined in this investigation.

Wells along ground-water flow paths (fig. 8) were sampled to evaluate lateral change in water quality in the aquifer. Flow paths were defined as being approximately perpendicular to water-table contours. Plans were to sample wells along four flow paths in the Turtle Lake irrigation area, but most of the wells in the northern part of the area went dry during the study. Flow path A is south of the McClusky Canal and extends from well 81-123A to 81-130A to 81-129A. Flow path B extends from well 87-177 to 87-186 to OW-48A to 87-184. Flow path C extends from well 87-165A to 87-166A to 90-1.

As water flows through an aquifer, dissolved-solids concentrations generally increase because of mineral dissolution along the flow path. In the Turtle Lake irrigation area, dissolved-solids concentrations, as indicated by specific conductance (table 7), did not show a definite increase along any of the flow paths. Rather, specific-conductance values vary sporadically along the flow paths, increasing in some places and decreasing in others. Lack of a consistent trend in specific conductance probably reflects compositional variability and the complexity of flow paths in the aquifer. The aquifer underlying the Turtle Lake irrigation area represents a collapsed glacial-outwash plain. The sand layer throughout the area is not uniform, and the flow paths through the aquifer probably are more complicated than shown by the generalized water-table contours in figure 8.

Table 7. Specific conductance, arsenic, and selenium in selected wells in the Turtle Lake irrigation area, September 1990

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; µg/L, micrograms per liter; <, less than]

Flow path	Identification number	Specific conductance (µS/cm)	Arsenic, dissolved (µg/L)	Selenium, dissolved (µg/L)
A	81-123A	1,040	1	<1
A	81-130A	690	1	1
A	81-129A	690	<1	1
B	87-177	870	<1	<1
B	87-186	990	4	<1
B	OW-48A	442	1	<1
B	87-184	720	<1	2
C	87-165A	630	1	<1
C	87-166A	346	1	<1
C	90-1	510	<1	<1

Concentrations of dissolved ions were compared to determine if the distributions in the shallow and deep parts of the aquifer underlying the Turtle Lake irrigation area were equal. Water-quality data commonly are not normally distributed, so a nonparametric Wilcoxon's rank sum test was used to compare the two groups of data. The null hypothesis for the tests was that the median constituent concentrations of dissolved ions or the median values of specific conductance, pH, temperature, or dissolved oxygen were equal. The null hypotheses were accepted at the 0.05 probability level. Results of the Wilcoxon's rank sum tests are given in supplement 9.

In the aquifer underlying the Turtle Lake irrigation area, the null hypothesis was rejected for pH, temperature, dissolved oxygen, calcium, nitrite, nitrite plus nitrate, arsenic, and iron. pH and temperature values and dissolved-oxygen, nitrite, and nitrite plus nitrate concentrations were larger in the shallow part of the aquifer than in the deep part of the aquifer. Calcium, arsenic, and iron concentrations were larger in the deep part of the aquifer than in the shallow part of the aquifer.

Arsenic and Selenium Occurrence

In the shallow part of the aquifer underlying the Turtle Lake irrigation area, the mean arsenic concentration was less than 1 microgram per liter, and the maximum was 1 microgram per liter. In the deep part of the aquifer, the mean arsenic concentration was 7 micrograms per liter, and the maximum was 27 micrograms per liter. The increase in arsenic concentrations with depth reflects the change from oxidizing to reducing conditions in the aquifer. In the shallow part of the aquifer, where oxidizing conditions prevail, arsenic probably is in the +5 oxidation state and is strongly adsorbed to soil particles. In the deep part of the aquifer, where reducing conditions prevail, arsenic probably is in the +3 oxidation state.

The mean selenium concentration was less than 1 microgram per liter in both the shallow and deep parts of the aquifer. The maximum selenium concentration in the shallow part of the aquifer was 3 micrograms per liter and the maximum in the deep part of the aquifer was 2 micrograms per liter. The small selenium concentrations reflect the small selenium concentrations in the soil.

No large changes in arsenic or selenium concentrations occurred along the three flow paths defined in the Turtle Lake irrigation area (table 7). The consistently small arsenic and selenium concentrations show that the elements are not increasing significantly along the flow paths.

New Rockford Irrigation Area

Hydrogeologic sections of the aquifer underlying the New Rockford irrigation area (figs. 12 and 13) were determined from borehole logs of observation wells in the irrigation area. The altitude of the water table in the New Rockford irrigation area on August 22-28, 1990, is shown in figure 14.

Soil Chemistry

Soil samples were collected from 15 sites adjacent to observation wells in the New Rockford irrigation area. Chemical analyses of the soils are given in supplement 10 by order of increasing depth at each location and in supplement 11 by soil series and soil horizon. Soil horizons were defined as the topsoil, the oxidized soil, the transition soil between the oxidized and reduced soils, and the reduced soil. Topsoils were black and within 3 feet of the land surface; oxidized soils were tan and dry and occurred above the water table; transition soils were mottled tan, red, and black and occurred near the water table; and reduced soils were black, wet, and sometimes had a rotten-egg smell. The soils were categorized by the Bureau of Reclamation (Kurt Webber, written commun., 1990).

Arsenic concentrations ranged from 2.5 to 70 milligrams per kilogram, and selenium concentrations ranged from less than 0.1 to 3.5 milligrams per kilogram. Average arsenic and selenium concentrations in the entire soil column are plotted in figure 15. Large and small average arsenic and selenium concentrations do not appear to show a systematic distribution throughout the irrigation area.

Analysis of variance was used to evaluate chemical variability of soils in the New Rockford irrigation area (supplement 12). Because the concentrations were not normally distributed, an analysis of variance was done on ranked soils data. A total of three null hypotheses were tested for each chemical constituent. In null hypothesis A, the median constituent concentrations in each soil horizon are equal; in null hypothesis B, the median constituent concentrations in each soil series are equal; and in null hypothesis C, the median constituent concentrations in each soil horizon within each soil series are equal. The null hypotheses were accepted at the 0.05 probability level. For arsenic, null hypothesis A was rejected but

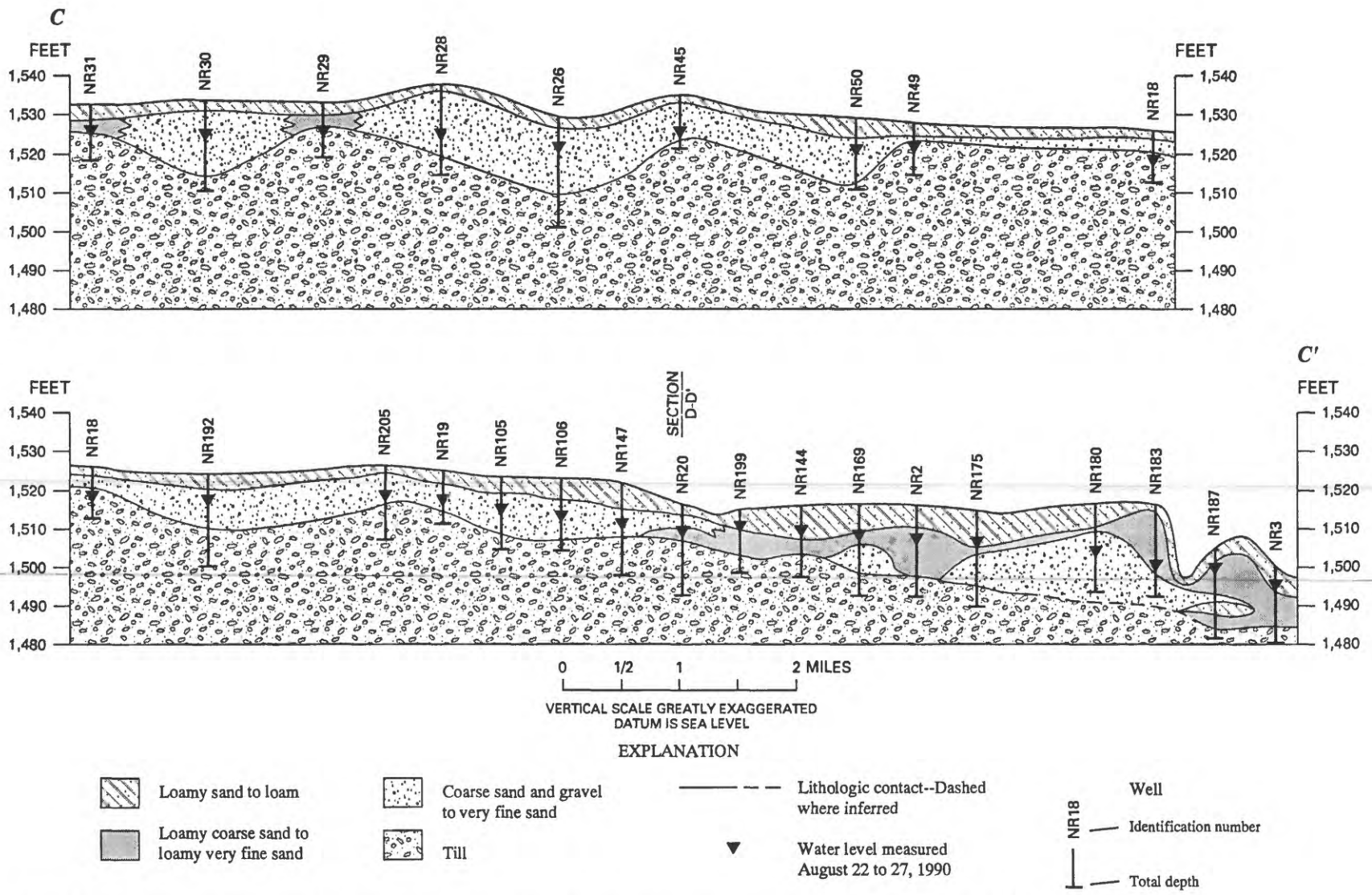


Figure 12. Hydrogeologic section C-C' through the New Rockford irrigation area. [Trace of section shown in figure 14.]

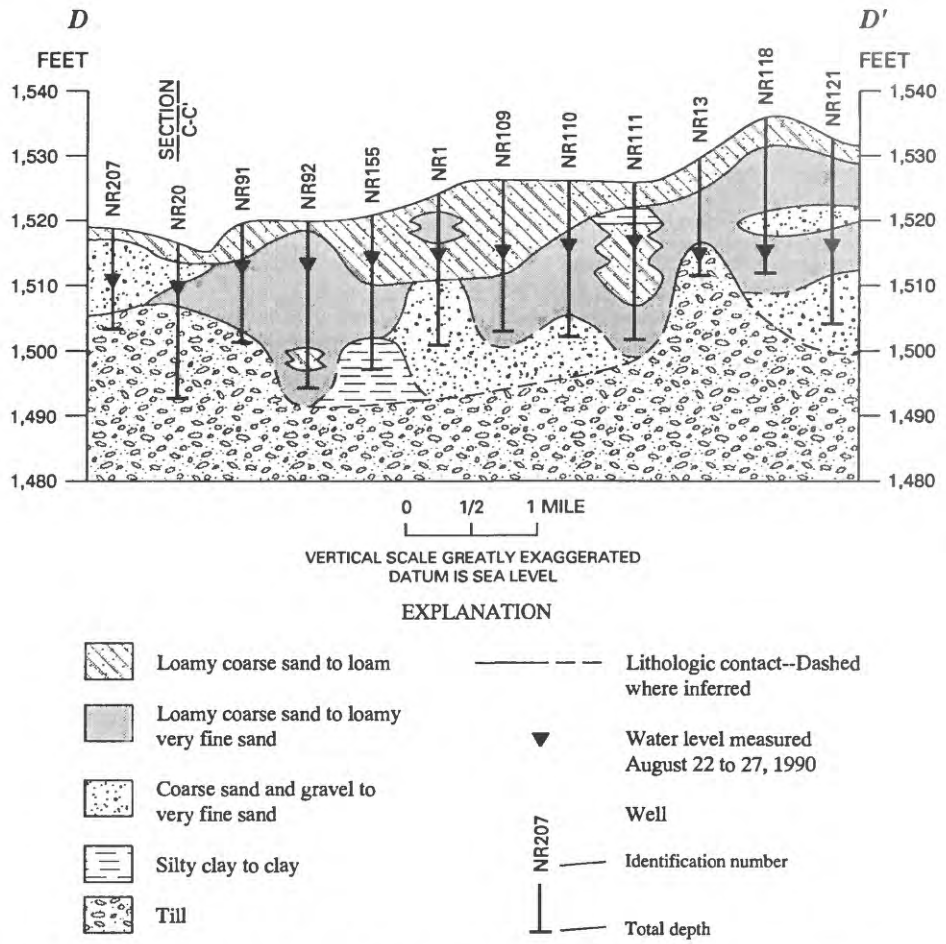


Figure 13. Hydrogeologic section D-D' through the New Rockford irrigation area. [Trace of section shown in figure 14.]

null hypotheses B and C were accepted, indicating that arsenic concentrations vary among soil horizons but not among soil series or among soil horizons within each soil series. For selenium, null hypothesis B was accepted but null hypotheses A and C were rejected, indicating that selenium concentrations do not vary among soil series but do vary among soil horizons and among soil horizons within each soil series.

Average arsenic, iron, manganese, and selenium concentrations are given in table 8 for each of the defined soil horizons. Average arsenic, iron, and manganese concentrations increase with depth through the topsoil, oxidized soil, and transition soil but decrease in the reduced soil at the bottom of the sampled horizons. The same pattern occurred in the Turtle Lake irrigation area and may be explained by trace elements in shallow parts of the aquifer being leached downward by percolating water. Selenium concentrations do not show a clear pattern of variation with depth.

The average arsenic concentration in 15 soil extracts was 9 micrograms per kilogram, and the maximum was 19 micrograms per kilogram (supplement 13). The extracts contained an average of 0.2 percent of the total arsenic in the soil. The average selenium concentration in 15 soil extracts was 15 micrograms per kilogram, and the maximum was 60 micrograms per kilogram. The extracts contained an average of 1.2 percent of the total selenium in the soil. Arsenic and selenium concentrations in soils were compared to arsenic and selenium concentrations in soil extracts (fig. 16). No correlation is shown between the concentrations in soils and the concentrations in extracts, indicating that, based on conditions

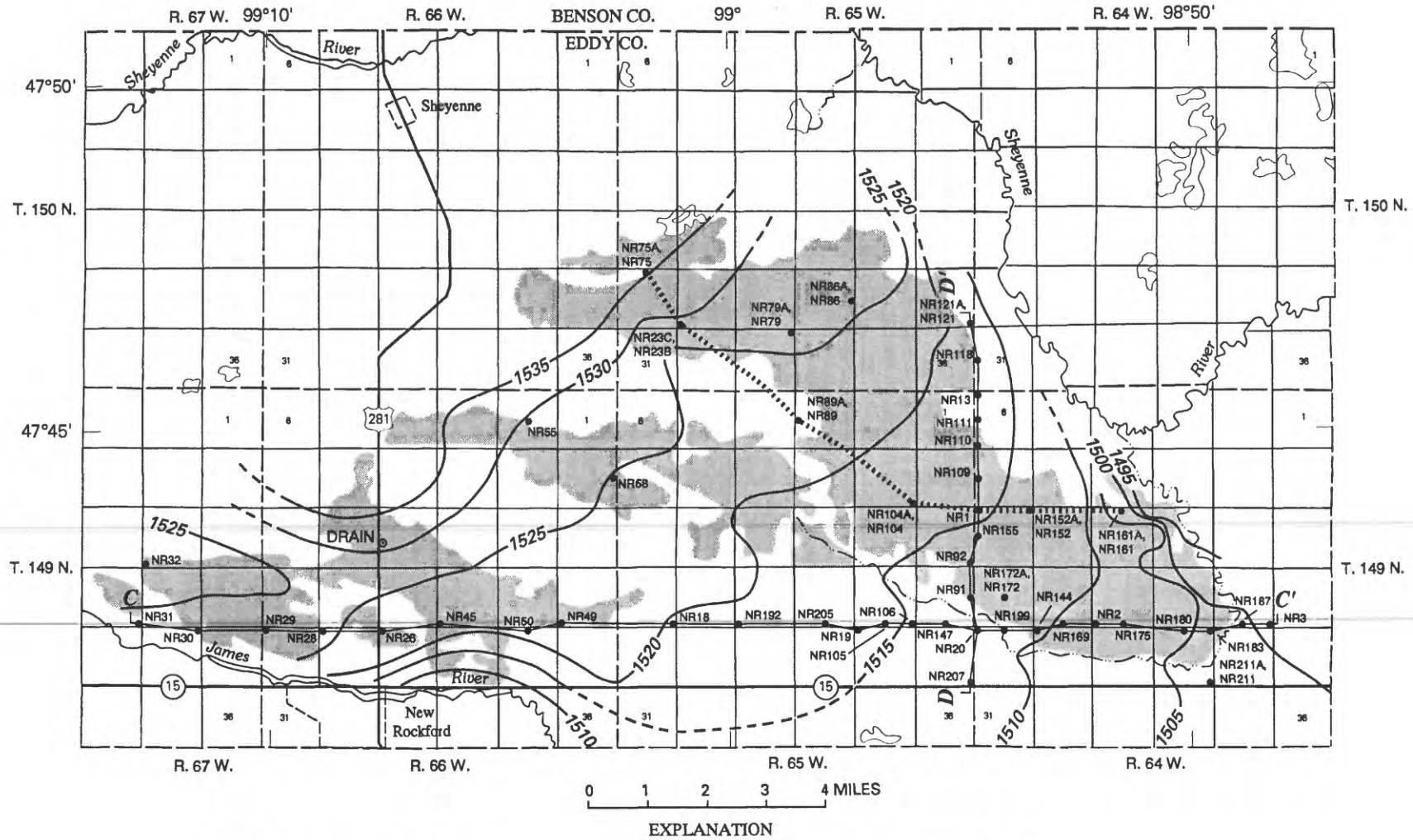


Figure 14. Altitude of water table in the New Rockford irrigation area, August 22-28, 1990.

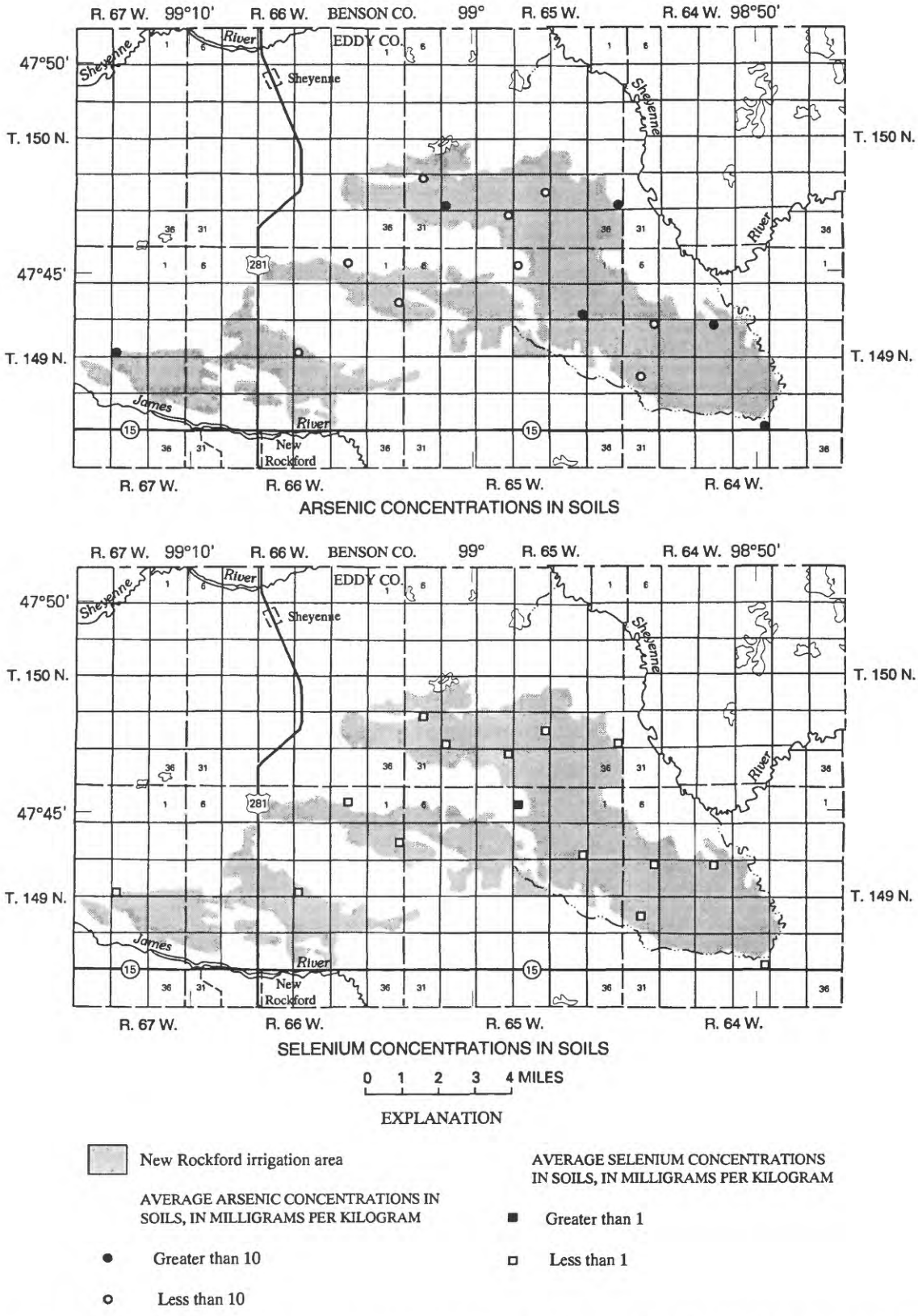


Figure 15. Average arsenic and selenium concentrations in soils from the New Rockford irrigation area, 1990.

Table 8. Sample size, average concentration, and standard deviation for arsenic, iron, manganese, and selenium in soil horizons in the New Rockford irrigation area, July 1990

[N, number of samples; SD, standard deviation; mg/kg, milligrams per kilogram]

Constituent	Topsoil			Oxidized soil			Transition soil			Reduced soil		
	N	Average concentration	SD	N	Average concentration	SD	N	Average concentration	SD	N	Average concentration	SD
Arsenic (mg/kg)	14	4.5	1.0	15	6.6	2.7	15	15	12	13	10	9.3
Iron (percent)	14	2.18	.38	15	2.49	.48	15	2.98	.76	13	2.88	.67
Manganese (mg/kg)	14	1,140	437	15	1,810	872	15	3,720	2,760	13	1,960	2,230
Selenium (mg/kg)	14	.4	.2	15	.1	.1	15	1.0	1.0	13	1.0	.6

of laboratory soil-water extraction experiments, trace-element concentrations in soils are not good predictors of trace-element concentrations in irrigation return flow.

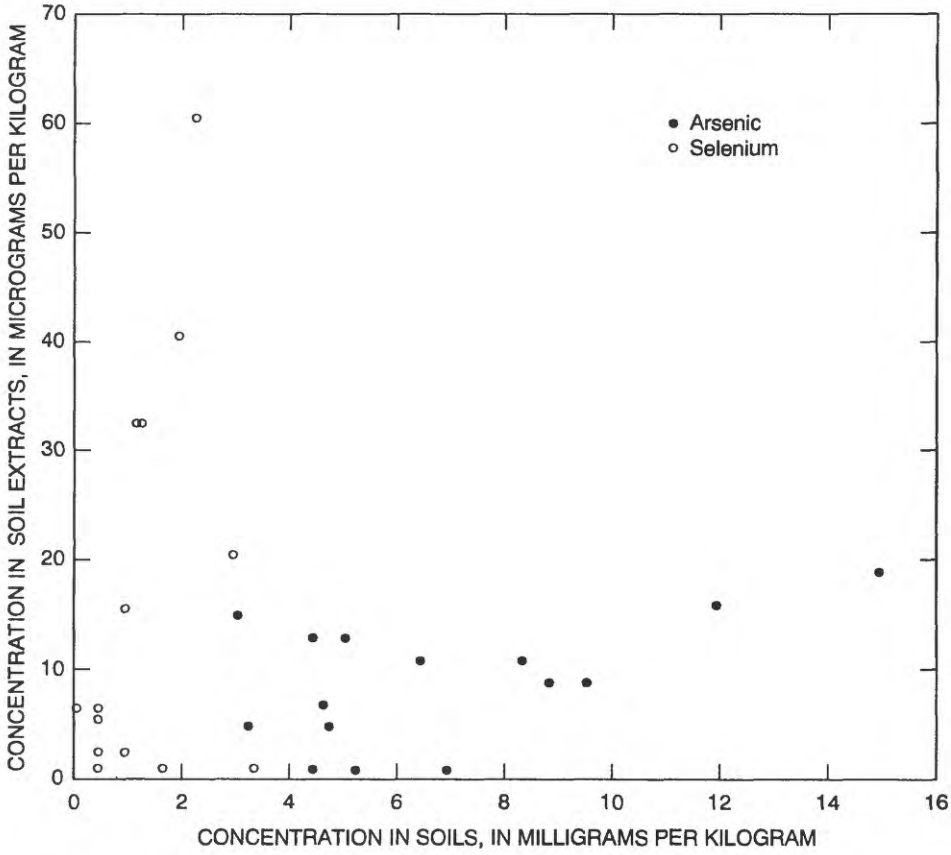


Figure 16. Arsenic and selenium concentrations in soils and soil extracts from the New Rockford irrigation area.

Water Chemistry

Water samples were collected from near the water table (the shallow part of the aquifer) and from the bottom of the aquifer (the deep part of the aquifer). Where the water table was within 3 feet of the bottom of the aquifer, samples were collected only from the bottom of the aquifer. Chemical analyses for both the shallow and deep parts of the aquifer are given in supplement 14. A statistical summary of data for the shallow wells and a drain is given in table 9, and a statistical summary of data for the deep wells is given in table 10. If constituent concentrations were less than the minimum reporting level, a log-probability regression was used to estimate the mean concentration (Helsel and Cohn, 1988).

Water in the aquifer underlying the New Rockford irrigation area is fresh (less than 600 milligrams per liter of dissolved solids) and slightly alkaline. The major-ion composition of water from 23 shallow and deep wells and 1 drain sampled in September 1990 is shown in figure 17. Calcium and bicarbonate were the predominant ions in most of the samples. As the total ion concentration increased, the major-ion composition changed from a calcium bicarbonate type to a calcium magnesium sulfate bicarbonate type.

Table 9. Statistical summary of physical-property and chemical-constituent data for the shallow part of the aquifer underlying the New Rockford irrigation area, October 1990

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; --, not determined; °C, degrees Celsius; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter]

Type of data	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
	Sample size	Maximum	Minimum	Mean	90	75	Median 50	25	10
Physical property									
Specific conductance (µS/cm)	13	1,490	425	780	1,460	975	677	514	425
pH (standard units)	13	7.78	7.11	--	7.71	7.56	7.34	7.28	7.12
Temperature, water (°C)	13	12.2	7.1	9.8	12.1	11.2	9.9	8.4	7.5
Oxygen, dissolved (mg/L)	13	6.6	.59	2.2	5.6	3.0	1.6	1.0	.70
Chemical constituent									
Calcium, dissolved (mg/L)	13	150	54	91	146	103	88	69	58
Magnesium, dissolved (mg/L)	13	82	17	38	76	48	37	21	18
Sodium, dissolved (mg/L)	13	140	3.1	37	128	58	18	4.0	3.2
Potassium, dissolved (mg/L)	13	8.3	1.3	4.0	7.6	5.8	3.9	2.2	1.4
Bicarbonate, dissolved (mg/L as HCO_3)	13	581	181	344	552	402	337	261	199
Sulfate, dissolved (mg/L as SO_4)	13	550	10	158	498	285	71	32	17
Sulfide, dissolved (mg/L as S)	13	.039	<.001	.006	.028	.007	.001	<.001	<.001
Chloride, dissolved (mg/L)	13	37	2.6	14	34	18	15	4.6	2.6
Fluoride, dissolved (mg/L)	13	.3	<.1	.1	.3	.2	.1	.1	<.1
Silica, dissolved (mg/L as SiO_2)	13	35	22	28	34	30	29	25	23
Nitrite, dissolved (mg/L as N)	13	.060	<.001	.013	.051	.019	.006	.002	.001
Nitrite plus nitrate, dissolved (mg/L as N)	13	12	.01	4.9	12	8.2	4.5	2.2	.01
Ammonia, dissolved (mg/L as N)	13	.05	<.01	.01	.04	.02	.01	<.01	<.01
Orthophosphorus, dissolved (mg/L as P)	13	.09	<.01	.02	.08	.04	<.01	<.01	<.01
Arsenic, dissolved (µg/L)	13	6	<1	2	5	3	1	<1	<1
Boron, dissolved (µg/L)	13	140	30	56	112	60	50	40	34
Iron, dissolved (µg/L as Fe)	13	1,100	<3	89	668	14	<3	<3	<3
Ferrous iron, dissolved (µg/L as Fe)	13	1,060	<10	87	644	15	<10	<10	<10
Lithium, dissolved (µg/L)	13	75	10	29	64	42	24	15	11
Manganese, dissolved (µg/L)	13	820	2	330	820	575	230	54	15

Table 9. Statistical summary of physical-property and chemical-constituent data for the shallow part of the aquifer underlying the New Rockford irrigation area, October 1990—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; --, not determined; °C, degrees Celsius; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter]

Type of data	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
	Sample size	Maximum	Minimum	Mean	90	75	Median 50	25	10
Mercury, dissolved (µg/L)	13	0.4	<0.1	<0.1	0.3	0.1	<0.1	<0.1	<0.1
Molybdenum, dissolved (µg/L)	13	2	<1	<1	2	2	<1	<1	<1
Selenium, dissolved (µg/L)	13	4	<1	1	4	2	<1	<1	<1
Strontium, dissolved (µg/L)	13	430	77	230	422	330	210	140	77
Organic carbon, dissolved (mg/L)	13	8.6	1.4	3.5	8.0	4.7	2.5	2.2	1.3

Table 10. Statistical summary of physical-property and chemical-constituent data for the deep part of the aquifer underlying the New Rockford irrigation area, October 1990

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; --, not determined; °C, degrees Celsius; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; >, greater than]

Type of data	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
	Sample size	Maximum	Minimum	Mean	90	75	Median 50	25	10
Physical property									
Specific conductance (µS/cm)	11	807	451	545	766	592	533	464	452
pH (standard units)	11	7.70	7.07	--	7.70	7.60	7.43	7.38	7.10
Temperature, water (°C)	11	16.6	3.8	8.6	16.1	13.6	6.4	5.0	3.8
Oxygen, dissolved (mg/L)	11	1.8	.14	.63	1.7	.90	.44	.18	.14
Chemical constituent									
Calcium, dissolved (mg/L)	11	87	54	69	86	75	70	62	55
Magnesium, dissolved (mg/L)	11	40	18	24	38	27	21	20	18
Sodium, dissolved (mg/L)	11	63	4.0	21	57	28	20	5.7	4.2
Potassium, dissolved (mg/L)	11	6.3	2.3	3.9	6.2	4.9	3.7	2.6	2.3
Bicarbonate, dissolved (mg/L as HCO_3)	11	534	195	306	508	339	286	254	198
Sulfate, dissolved (mg/L as SO_4)	11	92	9.4	61	91	75	66	40	16
Sulfide, dissolved (mg/L as S)	11	.019	<.001	.006	.018	.011	.003	<.001	<.001
Chloride, dissolved (mg/L)	11	17	2.8	8.3	16	12	8.7	3.8	2.9
Fluoride, dissolved (mg/L)	11	.2	.1	.2	.2	.2	.2	.1	.1
Silica, dissolved (mg/L as SiO_2)	11	34	26	29	34	29	28	26	26
Nitrite, dissolved (mg/L as N)	11	.010	<.001	.002	.009	.003	.002	<.001	<.001
Nitrite plus nitrate, dissolved (mg/L as N)	11	3.7	<.01	.37	3.0	.10	.01	<.01	<.01
Ammonia, dissolved (mg/L as N)	11	.19	.01	.09	.19	.14	.07	.03	.01
Orthophosphorus, dissolved (mg/L as P)	11	.07	<.01	.02	.06	.03	.02	<.01	<.01
Arsenic, dissolved (µg/L)	11	14	<1	4	12	5	3	3	1
Boron, dissolved (µg/L)	11	140	30	63	130	70	60	40	30
Iron, dissolved (µg/L as Fe)	11	4,800	6	1,080	4,300	2,000	410	25	7
Ferrous iron, dissolved (µg/L as Fe)	11	>3,000	10	950	2,880	2,110	410	50	10
Lithium, dissolved (µg/L)	11	47	8	20	43	22	17	15	9
Manganese, dissolved (µg/L)	11	730	27	402	710	610	390	250	48

Table 10. Statistical summary of physical-property and chemical-constituent data for the deep part of the aquifer underlying the New Rockford irrigation area, October 1990—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; --, not determined; °C, degrees Celsius; mg/L, milligrams per liter; <, less than; µg/L, micrograms per liter; >, greater than]

Type of data	Descriptive statistics				Value at which indicated percent of all sample values is less than or equal to that shown				
	Sample size	Maximum	Minimum	Mean	90	75	Median 50	25	10
Mercury, dissolved (µg/L)	11	0.2	<0.1	0.1	0.2	0.2	<0.1	<0.1	<0.1
Molybdenum, dissolved (µg/L)	11	2	<1	<1	2	2	<1	<1	<1
Selenium, dissolved (µg/L)	11	<1	<1	<1	<1	<1	<1	<1	<1
Strontium, dissolved (µg/L)	11	330	100	185	310	230	170	130	100
Organic carbon, dissolved (mg/L)	11	5.5	1.2	2.7	5.5	3.0	2.3	1.9	1.2

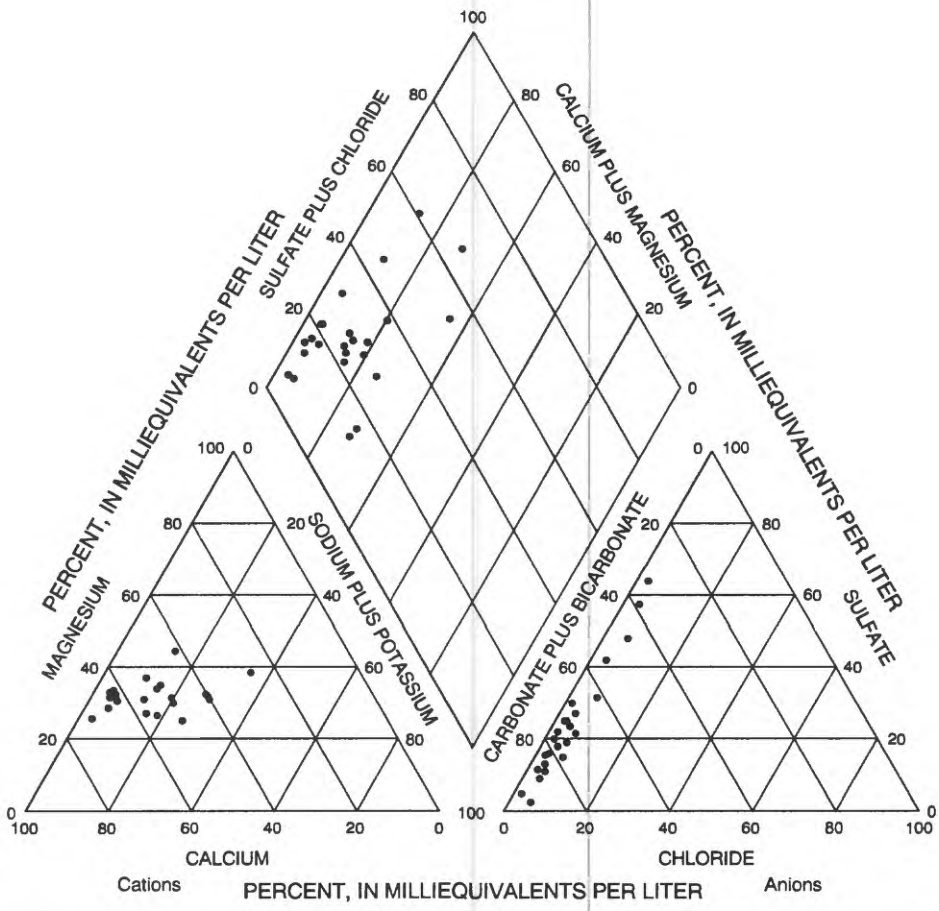


Figure 17. Major-ion composition of water in the aquifer underlying the New Rockford irrigation area.

Analysis of the water samples by use of the chemical equilibrium model WATEQ4F (Ball and Nordstrom, 1991) indicates that most of the water samples were saturated with respect to iron-oxide minerals and undersaturated with respect to aragonite, calcite, dolomite, and gypsum.

Chemical reactions that govern the major-ion composition of water in the aquifer underlying the New Rockford irrigation area probably include dissolution of calcite and gypsum and ion exchange with clay minerals. Precipitation of soluble minerals in the unsaturated zone results from evapotranspiration, and dissolution of these minerals during periods of recharge probably affect the chemical evolution of the water. The extent and nature of these reactions were not determined in this investigation.

Wells along one long flow path (fig. 14) were sampled to evaluate lateral changes in water quality in the aquifer. Water flows southeast from well NR75 to NR161. Generally, specific-conductance values increase along the flow path (table 11), indicating an increase in dissolved solids.

Concentrations of dissolved ions were compared to determine if the distributions in the shallow and deep parts of the aquifer underlying the New Rockford irrigation area were equal. Water-quality data commonly are not normally distributed, so a nonparametric Wilcoxon's rank sum test was used to compare the two groups of data. The null hypothesis for the tests was that the median constituent concentrations of dissolved ions or the median values of specific conductance, pH, temperature, or dissolved oxygen were

Table 11. Specific conductance, arsenic, and selenium in selected wells in the New Rockford irrigation area, October 1990

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; µg/L, micrograms per liter; <, less than]

Identification number	Specific conductance (µS/cm)	Arsenic, dissolved (µg/L)	Selenium, dissolved (µg/L)
NR75	592	5	<1
NR23B	585	4	<1
NR89	603	<1	<1
NR104	538	2	<1
NR152	457	3	<1
NR161	807	14	<1

equal. The null hypotheses were accepted at the 0.05 probability level. Results of the Wilcoxon's rank sum tests are given in supplement 15.

In the aquifer underlying the New Rockford irrigation area, the null hypothesis was rejected for dissolved oxygen, calcium, magnesium, nitrite, nitrite plus nitrate, ammonia, arsenic, iron, and selenium. Dissolved-oxygen, calcium, magnesium, nitrite, nitrite plus nitrate, and selenium concentrations were larger in the shallow part of the aquifer than in the deep part of the aquifer. Dissolved ammonia, arsenic, and iron concentrations were larger in the deep part of the aquifer than in the shallow part of the aquifer.

Arsenic and Selenium Occurrence

In the shallow part of the aquifer underlying the New Rockford irrigation area, the mean arsenic concentration was 2 micrograms per liter, and the maximum was 6 micrograms per liter. In the deep part of the aquifer, the mean arsenic concentration was 4 micrograms per liter, and the maximum was 14 micrograms per liter. The increase in arsenic concentrations with depth probably reflects the change from oxidizing to reducing conditions in the aquifer.

The mean selenium concentration in the shallow part of the aquifer was 1 microgram per liter, and the maximum was 4 micrograms per liter. The mean and maximum selenium concentrations in the deep part of the aquifer were less than 1 microgram per liter. The small selenium concentrations reflect the small selenium concentrations in the soil.

Arsenic concentrations generally do not increase or decrease systematically along the flow path defined in the New Rockford irrigation area (table 11). The increase of arsenic concentrations at the end of the flow path reflects the comparatively large arsenic concentration in soil at the screen depth of well NR161. Water from sample NR161A, which was collected from well NR161, had an arsenic concentration of 61 milligrams per kilogram between 11 and 13 feet (supplement 10). Selenium concentrations were less than 1 microgram per liter in all wells along the flow path.

Harvey Pumping Irrigation Area

A hydrogeologic section of the aquifer underlying the Harvey Pumping irrigation area (fig. 18) was determined from borehole logs of observation wells in the irrigation area. The altitude of the water table in the Harvey Pumping irrigation area on September 4, 1990, is shown in figure 19. The ground-water flow is east and west of a ground-water high that extends from northeast to southwest.

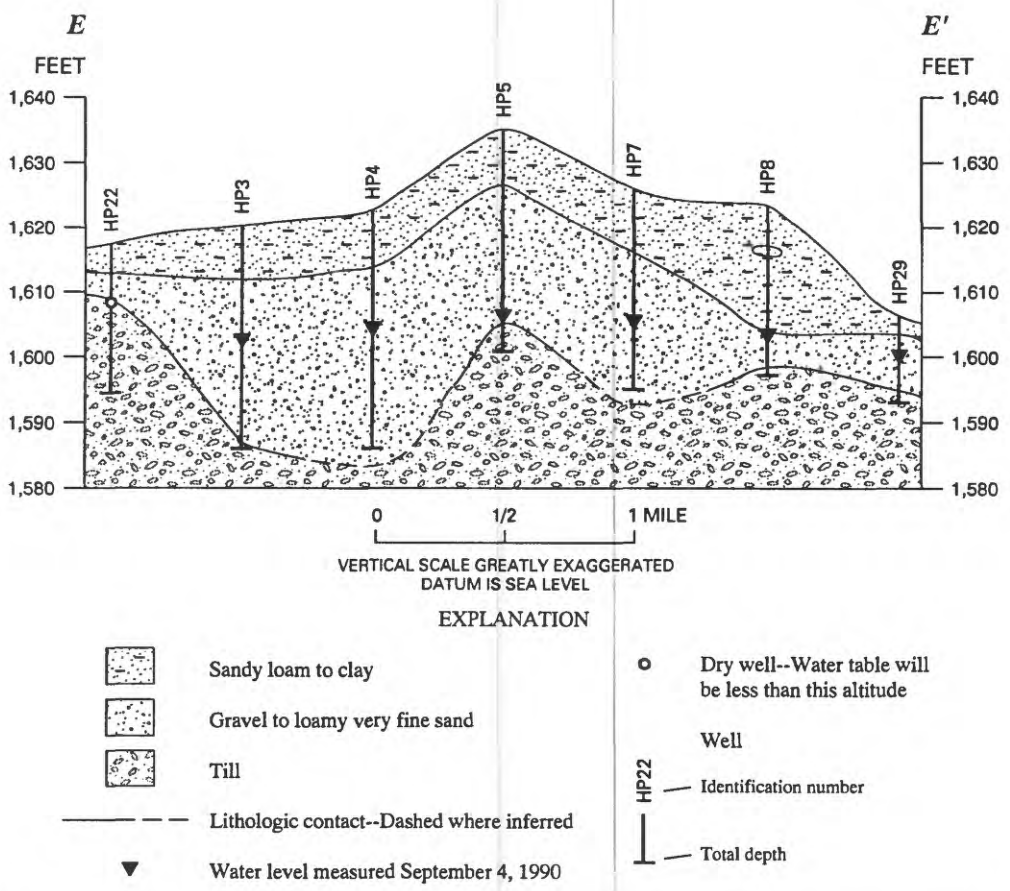


Figure 18. Hydrogeologic section E-E' through the Harvey Pumping irrigation area. [Trace of section shown in figure 19.]

Soil Chemistry

Soil samples were collected from three sites adjacent to observation wells in the Harvey Pumping irrigation area. Chemical analyses of the soils are given in supplement 16 by order of increasing depth at each location. The aquifer underlying the irrigation area consists of sand and gravel that can reach 30 feet in thickness. The sand layer (fig. 18) represents glacial outwash.

Arsenic concentrations ranged from 1.0 to 9.7 milligrams per kilogram, and selenium concentrations ranged from less than 0.1 to 5.4 milligrams per kilogram. Average arsenic and selenium concentrations in the entire soil column are shown in figure 20. The average concentrations are similar for each of the three sampling sites.

Average arsenic, iron, manganese, and selenium concentrations are given in table 12 for each of the defined soil horizons. The concentrations do not appear to vary systematically with depth.

Arsenic concentrations in three soil extracts ranged from less than 10 to 42 micrograms per kilogram, and selenium concentrations ranged from 24 to 650 micrograms per kilogram (supplement 17). The extracts contained an average of 1.8 percent of the total arsenic in the soil and 7.0 percent of the total selenium in the soil. Arsenic and selenium concentrations in soils were compared to arsenic and selenium

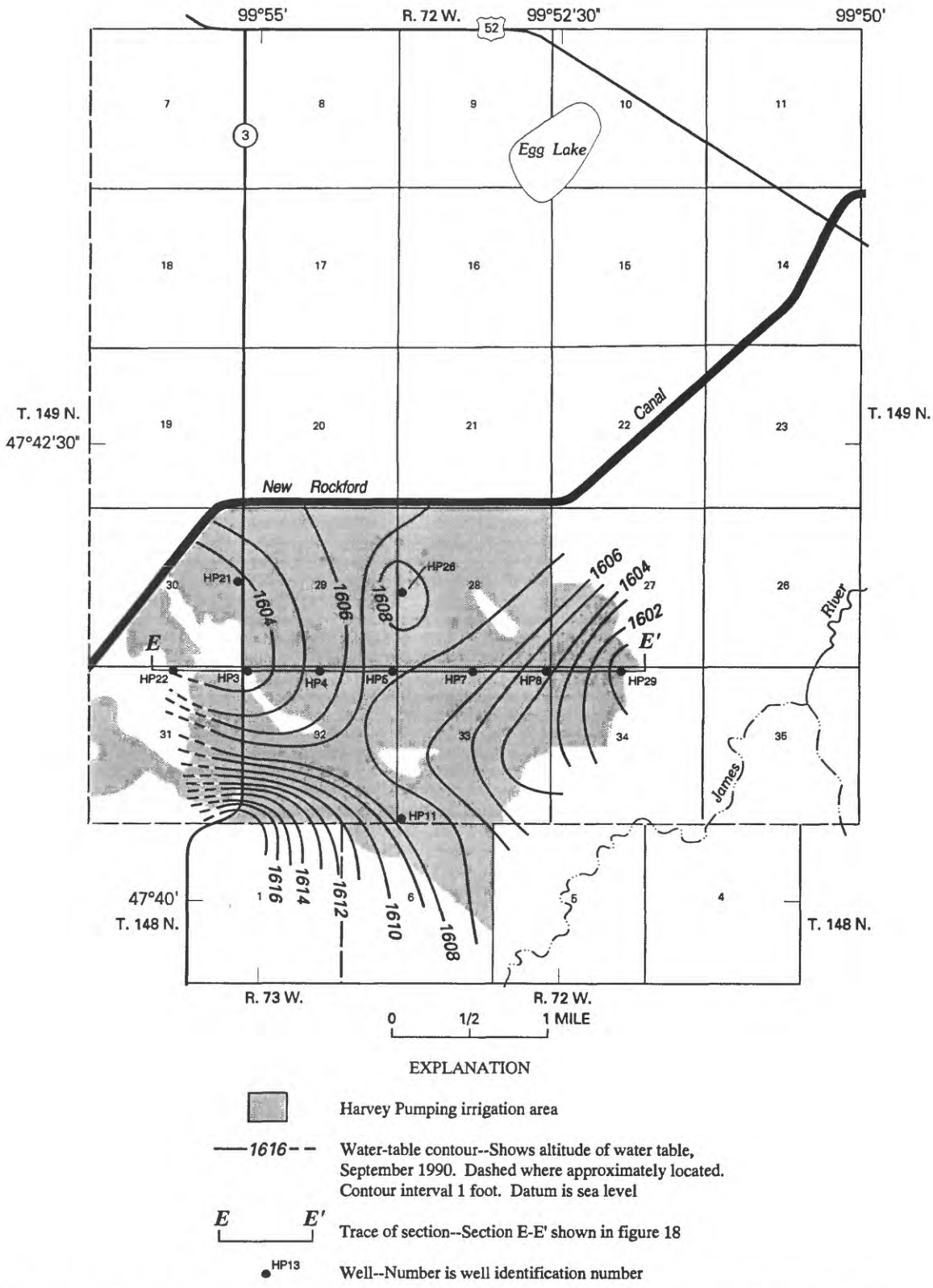
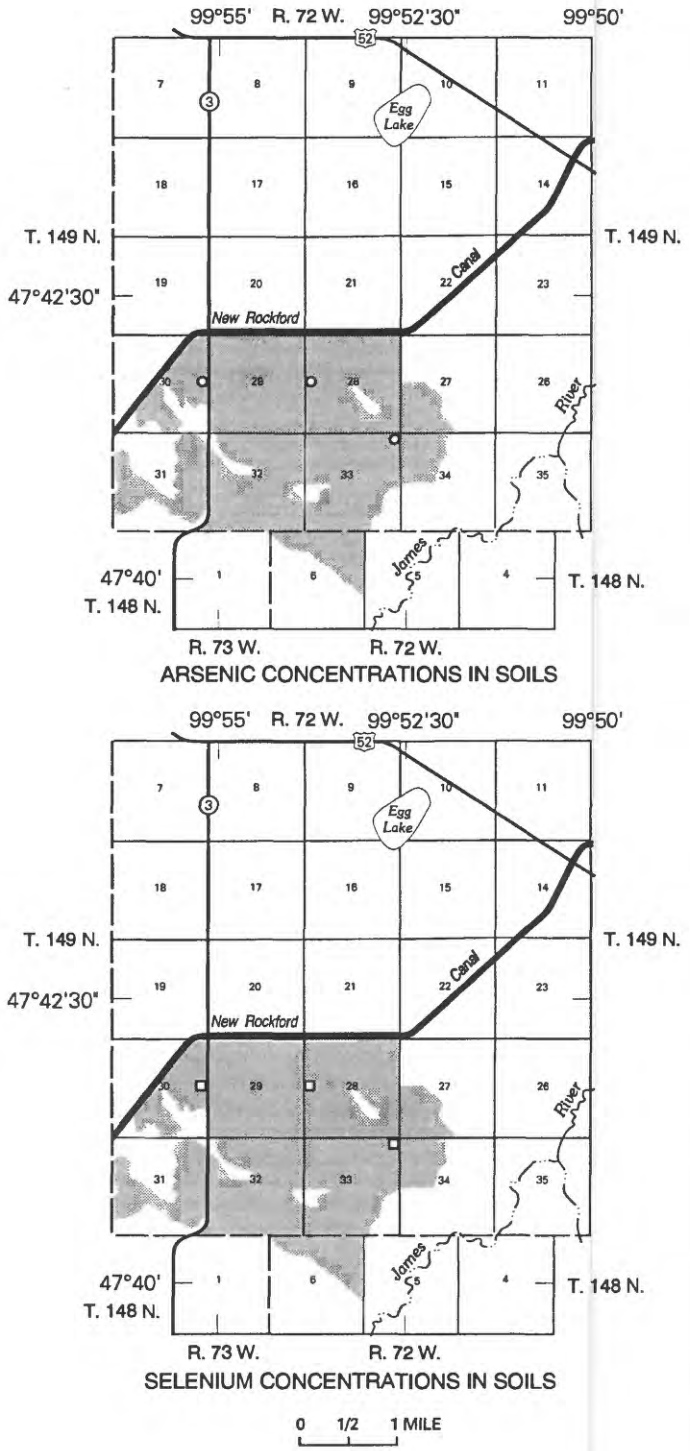


Figure 19. Altitude of water table in the Harvey Pumping irrigation area, September 4, 1990. [Data from Dick Lunde, Bureau of Reclamation, written commun., 1990.]



EXPLANATION

Harvey Pumping irrigation area

AVERAGE ARSENIC CONCENTRATIONS IN SOILS, IN MILLIGRAMS PER KILOGRAM

Less than 10

AVERAGE SELENIUM CONCENTRATIONS IN SOILS, IN MILLIGRAMS PER KILOGRAM

Less than 1

Figure 20. Average arsenic and selenium concentrations in soils from the Harvey Pumping irrigation area, 1990.

Table 12. Sample size, average concentration, and standard deviation for arsenic, iron, manganese, and selenium in soil horizons in the Harvey Pumping irrigation area, August 1990

[N, number of samples; SD, standard deviation; mg/kg, milligrams per kilogram]

Constituent	Topsoil			Oxidized soil			Transition soil			Reduced soil		
	N	Average concentration	SD	N	Average concentration	SD	N	Average concentration	SD	N	Average concentration	SD
Arsenic (mg/kg)	3	5.9	1.3	3	6.3	0.4	3	3.3	3.4	2	6.6	1.6
Iron (percent)	3	2.20	.16	3	2.07	1.9	3	2.19	.55	2	2.41	.11
Manganese (mg/kg)	3	542	99	3	549	79	3	675	645	2	580	95
Selenium (mg/kg)	3	.3	.1	3	.1	.1	3	2.1	2.9	2	.8	.6

concentrations in soil extracts (fig. 21). No correlation is shown between arsenic concentrations in soils and arsenic concentrations in extracts. Selenium concentrations in soils and extracts may be positively correlated, but the comparison is based on only three samples.

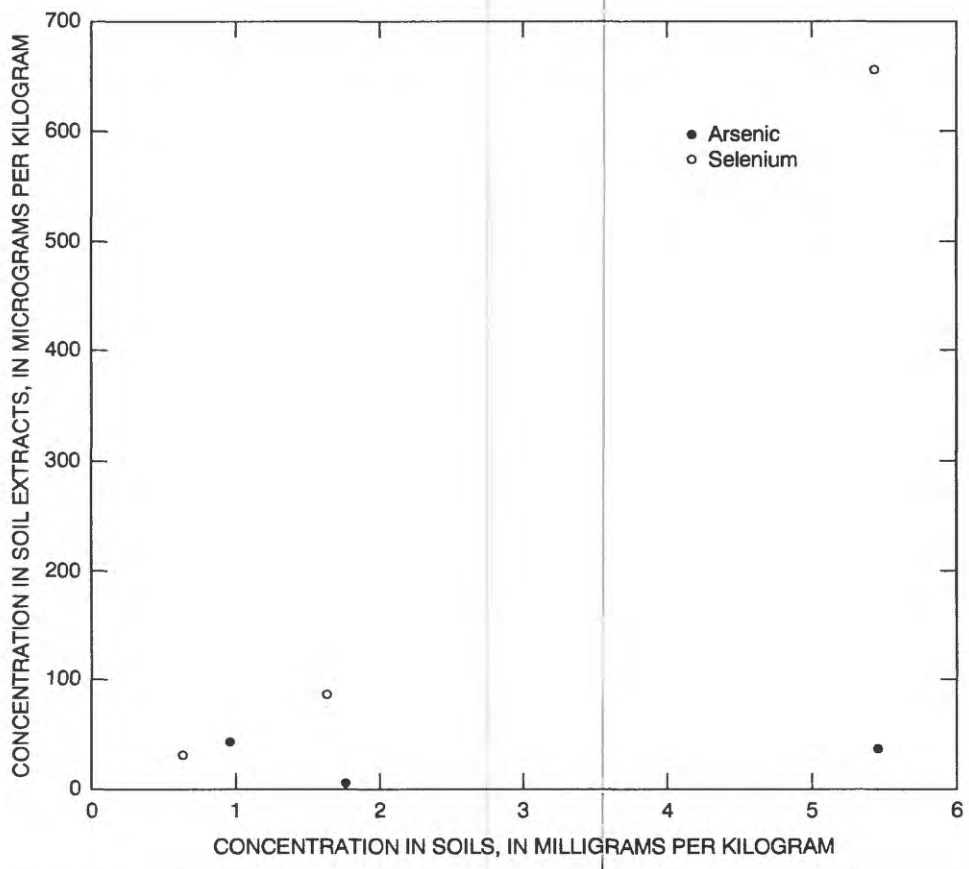


Figure 21. Arsenic and selenium concentrations in soils and soil extracts from the Harvey Pumping irrigation area.

Water Chemistry

Chemical analyses for four water samples are given in supplement 18. The major-ion composition of water from four wells sampled in September and October 1990 is shown in figure 22. Calcium and bicarbonate were the predominant ions in most of the samples. Analysis of the water samples by use of the chemical equilibrium model WATEQ4F (Ball and Nordstrom, 1991) indicates that most of the water samples were saturated with respect to iron-oxide minerals and undersaturated with respect to aragonite, calcite, dolomite, and gypsum.

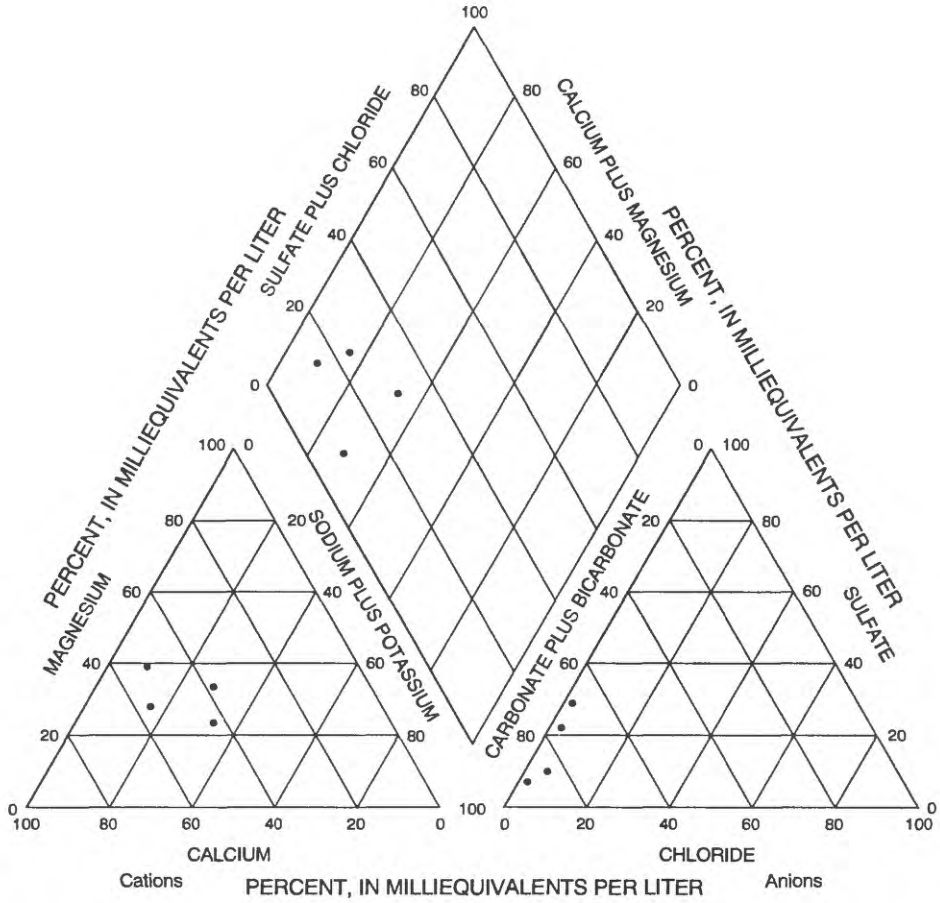


Figure 22. Major-ion composition of water in the aquifer underlying the Harvey Pumping irrigation area.

Arsenic and Selenium Occurrence

Arsenic and selenium concentrations in samples from the four wells were small. The maximum dissolved arsenic concentration was 2 micrograms per liter, and two samples had concentrations less than the minimum reporting level of 1 microgram per liter. The maximum dissolved selenium concentration was 1 microgram per liter, and two samples had concentrations less than the minimum reporting level of 1 microgram per liter.

Lincoln Valley Irrigation Area

A hydrogeologic section of the aquifer underlying the Lincoln Valley irrigation area (fig. 23) was determined from borehole logs of observation wells in the irrigation area. The altitude of the water table in the Lincoln Valley irrigation area on August 30, 1990, is shown in figure 24. The ground-water flow is principally from west to east.

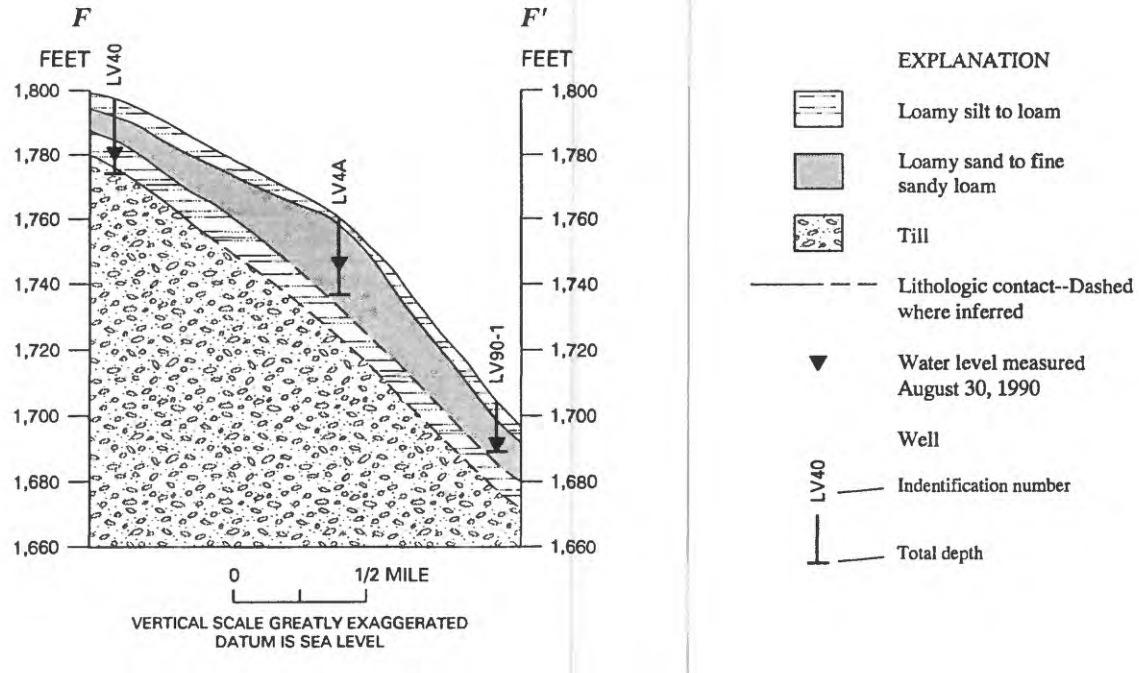


Figure 23. Hydrogeologic section F-F' through the Lincoln Valley irrigation area. [Trace of section shown in figure 24.]

Soil Chemistry

Soil samples were collected from four sites in the Lincoln Valley irrigation area. Chemical analyses of the soils are given in supplement 19 by order of increasing depth. The aquifer consists of a sandy loamy material, which characteristically has a small hydraulic conductivity of about 4 feet per day (Shaver and Schuh, 1990, p. 57).

Arsenic concentrations ranged from 2.0 to 9.9 milligrams per kilogram, and selenium concentrations ranged from less than 0.1 to 0.7 milligram per kilogram. Average arsenic and selenium concentrations in the entire soil column are shown in figure 25. The average concentrations are similar for each of the four sampling sites.

Average arsenic, iron, manganese, and selenium concentrations are given in table 13 for each of the defined soil horizons. The concentrations do not appear to vary systematically with depth.

Arsenic concentrations in three soil extracts were less than 10 micrograms per kilogram, and selenium concentrations ranged from 72 to 82 micrograms per kilogram (supplement 20). The extracts contained an average of less than 0.1 percent of the total arsenic in the soil and 12 percent of the total selenium in the soil. Selenium concentrations in soils were compared to selenium concentrations in soil extracts (fig. 26). Selenium concentrations in soils and extracts may be positively correlated, but the comparison is based on only three samples.

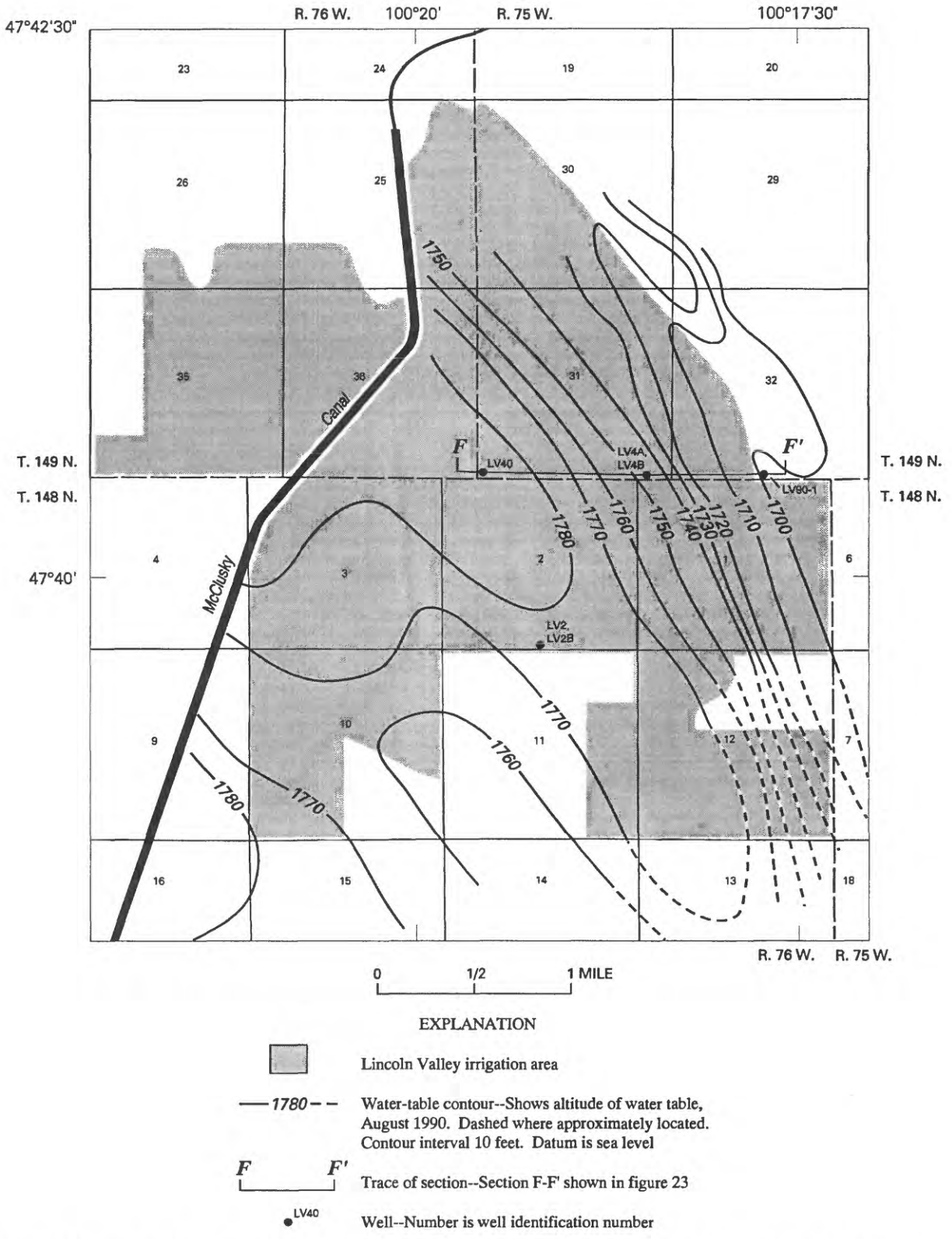


Figure 24. Altitude of water table in the Lincoln Valley irrigation area, August 30, 1990. [Data from Dick Lunde, Bureau of Reclamation, written commun., 1990.]

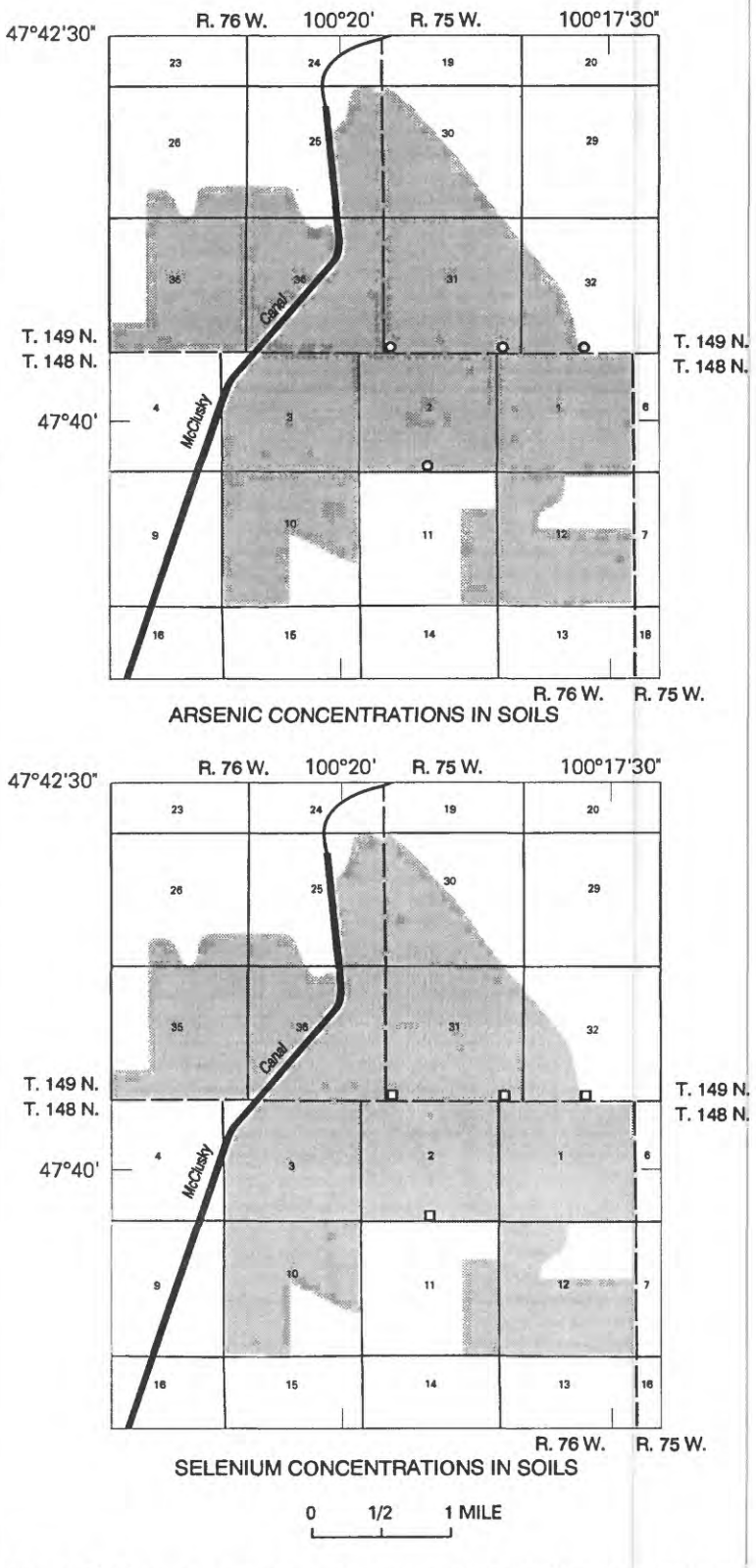


Figure 25. Average arsenic and selenium concentrations in soils from the Lincoln Valley irrigation area, 1990.

Table 13. Sample size, average concentration, and standard deviation for arsenic, iron, manganese, and selenium in soil horizons in the Lincoln Valley irrigation area, August 1990

[N, number of samples; SD, standard deviation; mg/kg, milligrams per kilogram]

Constituent	Topsoil			Oxidized soil			Transition soil			Reduced soil		
	N	Average concentration	SD	N	Average concentration	SD	N	Average concentration	SD	N	Average concentration	SD
Arsenic (mg/kg)	4	7.6	1.3	4	6.7	0.8	3	7.8	0.7	3	6.5	0.6
Iron (percent)	4	2.28	.10	4	2.20	.32	3	2.48	.46	3	2.35	.37
Manganese (mg/kg)	4	591	61	4	465	128	3	762	304	3	923	747
Selenium (mg/kg)	4	.3	.2	4	.1	.1	3	.3	.2	3	.5	.2

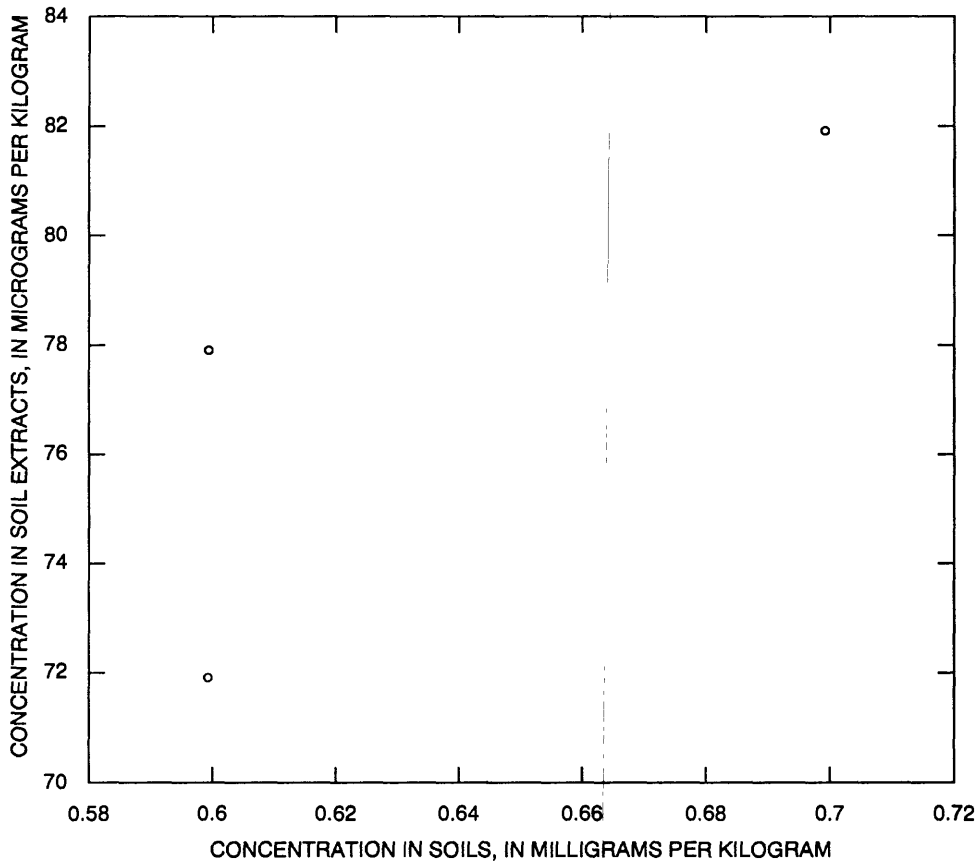


Figure 26. Selenium concentrations in soils and soil extracts from the Lincoln Valley irrigation area.

Water Chemistry

Chemical analyses for four water samples are given in supplement 21. The major-ion composition of water from four shallow and deep wells sampled in September 1990 is shown in figure 27. The composition of the water in each well is different. The general flow path of the ground water is from well LV40 to LV4A to LV90-1 (fig. 24). The water at well LV40 is a calcium bicarbonate type. As the water moves toward well LV4A, the dissolved-solids concentration increases and the water changes to a calcium magnesium sulfate type. The dissolved-solids concentration increases again from well LV4A to LV90-1, and the water changes to a sodium magnesium sulfate type. Because of the small hydraulic conductivity of the aquifer, the ground water moves slowly. The slow movement increases the time water is in contact with the aquifer material and, thus, increases the potential of the water to acquire additional dissolved minerals. Analysis of the water samples by use of the chemical equilibrium model WATEQ4F (Ball and Nordstrom, 1991) indicates that most of the water samples were saturated with respect to aragonite, calcite, dolomite, and iron-oxide minerals and undersaturated with respect to gypsum.

Arsenic and Selenium Occurrence

Arsenic and selenium concentrations in samples from the four wells were small. All of the arsenic concentrations were less than the minimum reporting level of 1 microgram per liter. The maximum

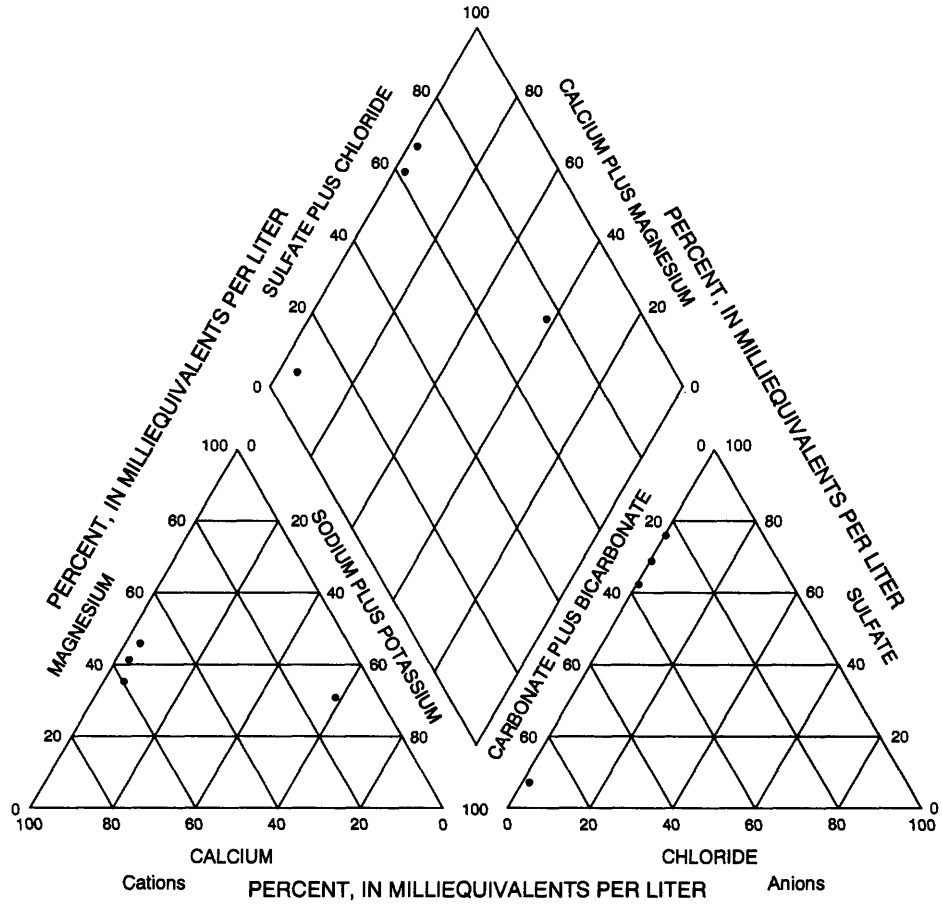


Figure 27. Major-ion composition of water in the aquifer underlying the Lincoln Valley irrigation area.

selenium concentration was 2 micrograms per liter, and three samples had concentrations less than the minimum reporting level of 1 microgram per liter.

LaMoure Irrigation Area

The LaMoure irrigation area (fig. 1) consists of several small areas that are suitable for irrigation. The ground water in each area is not necessarily hydrologically connected.

Water Chemistry

Chemical analyses for five water samples are given in supplement 22. The major-ion composition of water from the five deep wells sampled in October 1990 is shown in figure 28. The major-ion composition of each sample is assumed to represent local conditions. The water types indicate that each small irrigation area in the LaMoure irrigation area has a characteristic water quality. Generally, the water ranges from a calcium bicarbonate sulfate type to a sodium bicarbonate sulfate type. Analysis of the water samples by use of the chemical equilibrium model WATEQ4F (Ball and Nordstrom, 1991) indicates that most of the water samples were saturated with respect to aragonite, calcite, dolomite, and iron-oxide minerals and undersaturated with respect to gypsum.

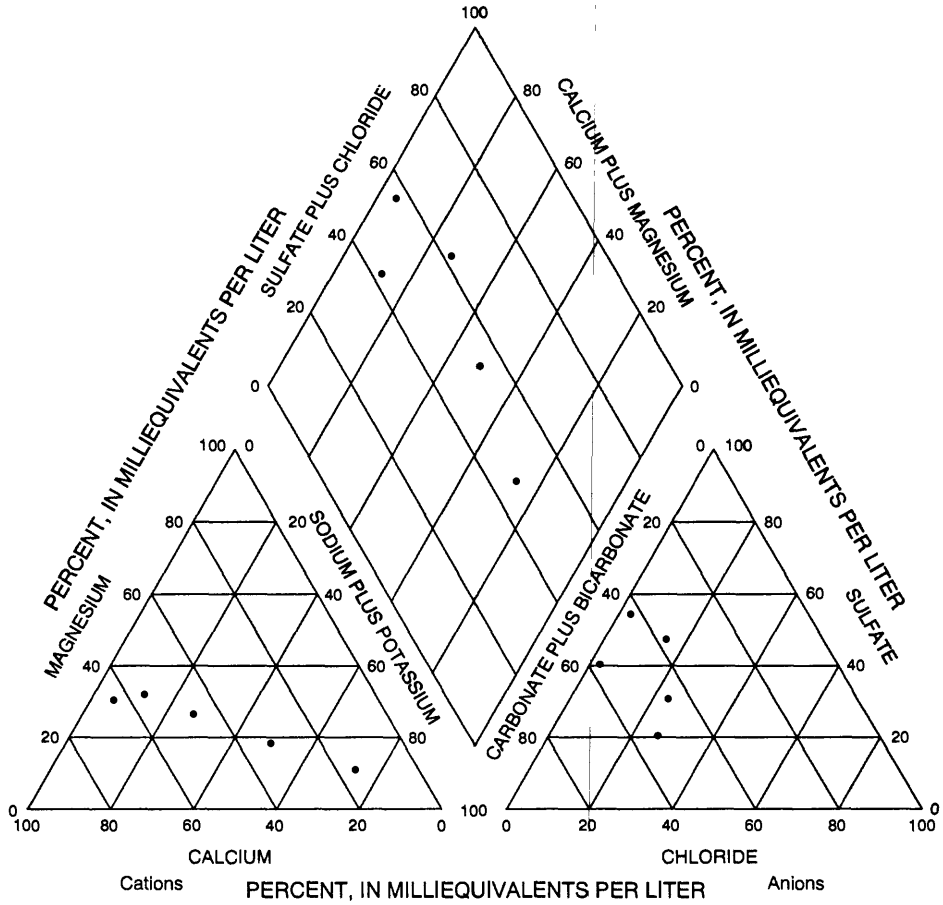


Figure 28. Major-ion composition of water in the aquifer underlying the LaMoure irrigation area.

Arsenic and Selenium Occurrence

Arsenic and selenium concentrations in samples from the five wells were small. The maximum arsenic concentration was 12 micrograms per liter, and the minimum concentration was 2 micrograms per liter. All of the selenium concentrations were less than the minimum reporting level of 1 microgram per liter.

POTENTIAL FOR ARSENIC AND SELENIUM MOBILIZATION IN THE GARRISON DIVERSION UNIT

Water extractions of soils were done to evaluate the effects of leaching by irrigation water. No correlation was shown between arsenic or selenium concentrations in soils and soil extracts, indicating that laboratory-leaching experiments cannot be used to accurately predict arsenic or selenium concentrations in irrigation drainage or runoff in the GDU. The laboratory soil-water extraction experiments were conducted for oxic conditions (in the presence of oxygen) and, thus, did not accurately depict conditions in reduced soils. Arsenic tends to be strongly adsorbed in oxidized soils and mobile in reduced soils. Selenium tends to be mobile in oxidized soils and immobile in reduced soils. Oxidizing all soils causes arsenic to be immobile and selenium to be mobile. Further, redox reactions that would change the

speciation of arsenic and selenium in the soils usually are caused by anaerobic bacteria that would have died as a result of sample collection and preparation.

The soil-water extraction experiments showed that only small percentages of the total arsenic and selenium in soils were released to water (fig. 29). For all of the analyzed soil samples, the extracts contained an average of 0.3 percent of the total arsenic in the soil and 3.0 percent of the total selenium in the soil. These small percentages indicate that short-term leaching of soils in the GDU is unlikely to produce large arsenic or selenium concentrations.

The natural equivalent of the soil-water extraction experiments occurs each time rain percolates through unsaturated soils. The number of soil samples from the Turtle Lake and New Rockford irrigation areas was adequate to evaluate the behavior of arsenic and selenium under natural leaching conditions. In both of these irrigation areas, arsenic concentrations increased with depth through the topsoil, oxidized soil, and transition soil and then decreased in the reduced soil. The same pattern was shown by iron and manganese, which, like arsenic and selenium, are sensitive to redox conditions. Selenium concentrations followed the same pattern in the Turtle Lake irrigation area but not in the New Rockford irrigation area. The pattern of chemical variation with depth may be attributed to downward leaching of the elements by percolating water. Therefore, although the soil-water extraction experiments showed that only small amounts of arsenic and selenium are released from soils over short periods, net movement of the elements downward through the soil column can occur over longer periods.

Arsenic concentrations in ground water generally were larger in the deep parts of the aquifers, where reducing conditions prevailed, than in the shallow parts of the aquifers. Arsenic concentrations were uniformly small in oxidized parts of the aquifers. These findings reflect the increased solubility of arsenic in reducing environments and the decreased solubility in oxidizing environments. Selenium concentrations did not define clear patterns of variation with depth, possibly, in part, because of the complexities of selenium speciation and adsorption as described earlier. Arsenic and selenium concentrations did not vary systematically along flow paths.

The maximum contaminant level for arsenic and selenium in drinking water is 50 micrograms per liter for both constituents (North Dakota Department of Health, 1994). Although water in the GDU is not to be used for a drinking-water supply, arsenic and selenium concentrations in ground water and soil extracts were compared to these maximum contaminant levels. The ground-water samples collected during this study did not contain arsenic or selenium concentrations in excess of the drinking-water limits. Arsenic concentrations in soil extracts were less than the drinking-water limit, but selenium concentrations in the extracts were greater than the drinking-water limit in some samples. Extracts that contained selenium concentrations exceeding the maximum contaminant level were from the Turtle Lake, New Rockford, Harvey Pumping, and Lincoln Valley irrigation areas.

ARSENIC AND SELENIUM CONCENTRATIONS IN IRRIGATION AREAS OF THE GARRISON DIVERSION UNIT AND IN OTHER IRRIGATION AREAS IN THE WESTERN UNITED STATES

One of the major environmental concerns regarding the diversion of irrigation water to the irrigation areas of the GDU is that the return water may have arsenic and selenium concentrations large enough to produce adverse effects on the ecosystem. All of the irrigation areas of the GDU consist of deposits that overlie marine sedimentary rocks of Cretaceous age and, thus, are susceptible to large selenium concentrations. A method to determine the potential for ecological problems in irrigation areas because of selenium is given by Seiler (1995). The method requires knowledge of the geology of the irrigation

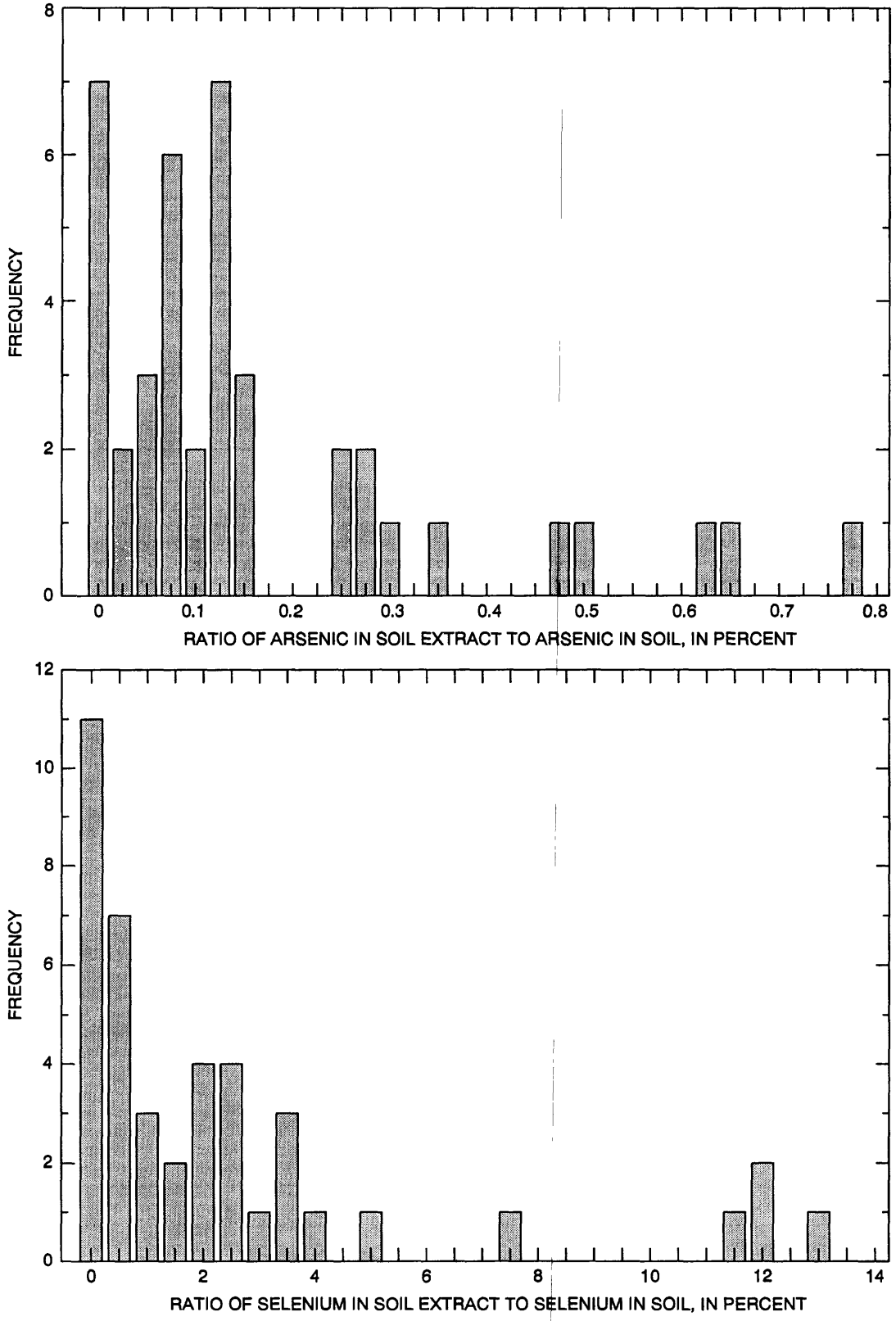


Figure 29. Distributions of arsenic in soil extracts to arsenic in soils and selenium in soil extracts to selenium in soils from the Turtle Lake, New Rockford, Harvey Pumping, and Lincoln Valley irrigation areas.

area, the average annual free-water-surface evaporation, and the average annual precipitation. When the evaporation index, which is equal to the average annual free-water-surface evaporation divided by the average annual precipitation, is greater than 2.5, problems caused by selenium are possible. The evaporation indexes for the irrigation areas of the GDU range from 1.5 to 1.7, indicating that problems caused by selenium are unlikely. A similar method is not available to determine the potential for ecological problems in irrigation areas because of arsenic.

Another method to determine the potential for problems resulting from arsenic and selenium concentrations in irrigation areas of the GDU is to compare the concentrations to those in irrigation areas that have had problems. A summary of arsenic concentrations in water from irrigation areas of the GDU and arsenic concentrations in water from other irrigation areas in the western United States is given in table 14. A summary of selenium concentrations is given in table 15.

Arsenic concentrations in water from irrigation areas of the GDU were considerably smaller than concentrations in ground water and surface water from irrigation areas in the western United States that have had problems (table 14). Median arsenic concentrations in areas of the GDU were less than 5 micrograms per liter, but median concentrations in other areas in the western United States generally were much larger than 5 micrograms per liter. Maximum arsenic concentrations in areas of the GDU were less than 50 micrograms per liter (the maximum contaminant level for drinking water), but maximum concentrations in other areas in the western United States were much larger than 50 micrograms per liter. Problems resulting from arsenic concentrations in return flow from irrigation areas of the GDU are unlikely.

Selenium concentrations in water from irrigation areas of the GDU also were considerably smaller than concentrations in ground water and surface water from other irrigation areas in the western United States (table 15). Median selenium concentrations in areas of the GDU were less than the reporting limit of 1 microgram per liter, but median concentrations in other areas in the western United States were much larger than the reporting limit. Some of the other areas had median concentrations that were larger than 50 micrograms per liter (the maximum contaminant level for drinking water) and larger than 35 micrograms per liter (the chronic criterion for freshwater aquatic life). Maximum selenium concentrations in areas of the GDU were less than the maximum contaminant level for drinking water, but maximum concentrations in some of the other areas in the western United States were greater than the chronic criterion for freshwater aquatic life. Deformed birds have been found in the Middle Green River Basin and in the Kendrick Reclamation project area, and tissue analysis positively identified selenium as the cause of the deformities (Seiler, 1995). Problems resulting from selenium concentrations in return flow from irrigation areas of the GDU are unlikely.

SUMMARY AND CONCLUSIONS

The Garrison Diversion Unit (GDU) project was authorized as part of the Pick-Sloan Missouri River Basin program to divert water from Lake Sakakawea to the Turtle Lake, New Rockford, Harvey Pumping, Lincoln Valley, and LaMoure irrigation areas. A special Garrison Commission was created to evaluate an environmental concern that return flow from the irrigation areas might contain metals in concentrations that would be toxic to the environment. This report summarizes the results of detailed investigations of the irrigation areas done in 1990. Specific objectives of the investigations were to (1) determine the inorganic chemical composition of the soils and ground water, (2) determine the arsenic and selenium concentrations and distributions in the soils and ground water, (3) evaluate whether the arsenic and selenium concentrations are large enough to threaten human health or wildlife, and (4) investigate the differences between arsenic and selenium concentrations in reduced parts of the aquifers and in oxidized parts of the aquifers underlying the irrigation areas.

Table 14. Summary of arsenic concentrations in water from irrigation areas of the Garrison Diversion Unit, North Dakota, and from other irrigation areas in the western United States

[µg/L, micrograms per liter; <, less than; --, no reference]

Irrigation area	Number of samples	Minimum (µg/L)	Median (µg/L)	Maximum (µg/L)	Reference
Irrigation areas of the Garrison Diversion Unit					
Turtle Lake irrigation area, North Dakota	15	<1	1	27	--
New Rockford irrigation area, North Dakota	24	<1	3	14	--
Harvey Pumping irrigation area, North Dakota	4	<1	<1	2	--
Lincoln Valley irrigation area, North Dakota	4	<1	<1	<1	--
LaMoure irrigation area, North Dakota	5	2	3	12	--
Other irrigation areas in the western United States					
Humbolt Wildlife Management Area, Nevada (surface water)	34	33	71	760	Seiler and others, 1993
Malheur National Wildlife Refuge, Oregon (surface water)	14	1	7	330	Rinella and Schuler, 1991
Stillwater Wildlife Management Area, Nevada (ground water)	64	2	295	1,400	Hoffman and others, 1989 Rowe and others, 1991
Stillwater Wildlife Management Area, Nevada (surface water)	185	<1	76	7,500	Hoffman and others, 1989 Rowe and others, 1991

Table 15. Summary of selenium concentrations in water from irrigation areas of the Garrison Diversion Unit, North Dakota, and from other irrigation areas in the western United States

[µg/L, micrograms per liter; <, less than; --, no reference]

Irrigation area	Number of samples	Minimum (µg/L)	Median (µg/L)	Maximum (µg/L)	Reference
Irrigation areas of the Garrison Diversion Unit					
Turtle Lake irrigation area, North Dakota	15	<1	<1	3	--
New Rockford irrigation area, North Dakota	24	<1	<1	4	--
Harvey Pumping irrigation area, North Dakota	4	<1	<1	1	--
Lincoln Valley irrigation area, North Dakota	4	<1	<1	2	--
LaMoure irrigation area, North Dakota	5	<1	<1	<1	--
Other irrigation areas in the western United States					
Benton Lake National Wildlife Refuge, Montana	6	<1	10	580	Knapton and others, 1988
San Joaquin Valley, California (drains tributary to San Luis drain)	7	145	320	870	Izbicki, 1984
San Joaquin Valley, California (inflow to San Luis drain)	11	<2	200	1,400	Presser and Barns, 1985
San Joaquin Valley, California (sumps and agricultural drains)	17	8	84	4,200	Presser and Barns, 1985
San Joaquin Valley, California (observation wells, sumps, and drains)	130	<1	6	3,800	Deveral and others, 1984
Gunnison River Basin, Colorado (ground water)	66	<1	22	1,300	Butler and others, 1991, 1994
Gunnison River Basin, Colorado (surface water)	343	<1	13	380	Butler and others, 1991, 1994
Kendrick Reclamation project area, Wyoming (ground water)	22	<1	255	14,000	Peterson and others, 1988 See and others, 1991
Kendrick Reclamation project area, Wyoming (surface water)	326	<1	12	5,300	Peterson and others, 1988 See and others, 1991
Middle Green River Basin, Utah (ground water)	221	<1	20	16,000	Stephens and others, 1988 Peltz and Waddell, 1991
Middle Green River Basin, Utah (surface water)	196	<1	28	8,300	Stephens and others, 1988 Peltz and Waddell, 1991
Pine River project area, Colorado and New Mexico (ground water)	10	30	125	4,800	Butler and others, 1992
Pine River project area, Colorado and New Mexico (surface water)	43	<1	2	94	Butler and others, 1992

A total of 223 soil samples were collected and analyzed for elemental composition. Of the 223 soil samples, 40 soil-water extractions were done using a 1:5 soil-to-water extraction method, and the solutions from the extractions were analyzed for elemental composition. Average arsenic and selenium concentrations in the entire soil columns of the Turtle Lake, New Rockford, Harvey Pumping, and Lincoln Valley irrigation areas were evaluated to determine the areal patterns of concentrations in the areas. In the Turtle Lake irrigation area, large arsenic concentrations do not appear to show a systematic distribution throughout the area, and selenium concentrations generally are smallest in the northern part of the area. In the New Rockford irrigation area, large and small arsenic and selenium concentrations do not appear to show a systematic distribution throughout the area. Too few soil samples were collected in the Harvey Pumping and Lincoln Valley irrigation areas to show areal patterns of the concentrations. Ranges in arsenic and selenium concentrations in soils from the Turtle Lake, New Rockford, Harvey Pumping, and Lincoln Valley irrigation areas are given in the following table:

Irrigation area	Arsenic (milligrams per kilogram)	Selenium (milligrams per kilogram)
Turtle Lake	2.4 to 54	<0.1 to 6.0
New Rockford	2.5 to 70	<0.1 to 3.5
Harvey Pumping	1.0 to 9.7	<0.1 to 5.4
Lincoln Valley	2.0 to 9.9	<0.1 to 0.7

Average arsenic, iron, manganese, and selenium concentrations in the Turtle Lake irrigation area soils generally increase with depth through the topsoil, oxidized soil, and transition soil but decrease in the reduced soil at the bottom of the sampled horizons, possibly because the elements were leached downward by percolating water. Although these constituents would be strongly adsorbed onto soil particles, net downward movement through the soil column probably occurs over time. Arsenic is soluble in the reduced part of the aquifer and, therefore, would partition into the pore water, leaving smaller concentrations in the reduced area of the soil horizon. Average arsenic, iron, and manganese concentrations in the New Rockford irrigation area soils follow the same pattern as in the Turtle Lake irrigation area, but selenium concentrations do not show a clear pattern of variation with depth. In the Harvey Pumping and Lincoln Valley irrigation area soils, arsenic and selenium concentrations do not appear to vary systematically with depth.

No correlation is shown between arsenic and selenium concentrations in soils and arsenic and selenium concentrations in soil extracts from the Turtle Lake, New Rockford, Harvey Pumping, and Lincoln Valley irrigation areas, indicating that, based on conditions of laboratory soil-water extraction experiments, trace-element concentrations in soils are not good predictors of trace-element concentrations in irrigation return flow. The average percentages of arsenic and selenium in soil extracts compared to the total concentrations in soils from the Turtle Lake, New Rockford, Harvey Pumping, and Lincoln Valley irrigation areas are given in the following table:

	Average percent of arsenic and selenium in 1:5 soil-to-water extractions compared to total concentration in soil	
Irrigation area	Arsenic	Selenium
Turtle Lake	0.2	1.8
New Rockford	.2	1.2
Harvey Pumping	1.8	7.0
Lincoln Valley	<.1	12

A total of 52 ground-water samples were collected and analyzed for inorganic constituents and organic carbon. The water underlying each irrigation area was characterized, and major water types are given in the following table:

Irrigation area	Water type
Turtle Lake	Calcium bicarbonate to sodium calcium sulfate bicarbonate
New Rockford	Calcium bicarbonate to calcium magnesium sulfate bicarbonate
Harvey Pumping	Calcium bicarbonate
Lincoln Valley	Calcium bicarbonate to sodium magnesium sulfate
LaMoure	Calcium bicarbonate sulfate to sodium bicarbonate sulfate

Analysis of the data by use of the equilibrium model WATEQ4F indicates that water in the irrigation areas was saturated or undersaturated with respect to particular minerals as follows:

Irrigation area	Saturated	Undersaturated
Turtle Lake	Aragonite, calcite, dolomite, and iron-oxide minerals	Gypsum
New Rockford	Iron-oxide minerals	Aragonite, calcite, dolomite, and gypsum
Harvey Pumping	Iron-oxide minerals	Aragonite, calcite, dolomite, and gypsum
Lincoln Valley	Aragonite, calcite, dolomite, and iron-oxide minerals	Gypsum
LaMoure	Aragonite, calcite, dolomite, and iron-oxide minerals	Gypsum

Arsenic concentrations in ground water generally were larger in the deep part of the aquifers underlying the Turtle Lake and New Rockford irrigation areas than in the shallow part of the aquifers. In the shallow part of the aquifers, where oxidizing conditions prevail, arsenic is in the +5 oxidation state and is strongly adsorbed to soil particles. In the deep part of the aquifers, where reducing conditions prevail, arsenic is in the more mobile +3 oxidation state. Arsenic concentrations in the deep part of the aquifers ranged from less than 1 microgram per liter to 27 micrograms per liter. All concentrations were less than the maximum contaminant level of 50 micrograms per liter for drinking water.

Selenium is more mobile in the oxidized state. All concentrations larger than the minimum reporting level were in the shallow oxidized part of the aquifers. Selenium concentrations ranged from less than 1 microgram per liter to 4 micrograms per liter. All concentrations were less than the maximum contaminant level of 50 micrograms per liter for drinking water.

Arsenic and selenium concentrations in irrigation areas of the GDU were compared to arsenic and selenium concentrations in other irrigation areas in the western United States. Median arsenic and selenium concentrations in irrigation areas of the GDU were less than the maximum contaminant level for drinking water for both constituents. Median arsenic and selenium concentrations in other irrigation areas in the western United States were much larger than the concentrations in irrigation areas of the GDU. Problems resulting from arsenic and selenium concentrations in return flow from irrigation areas of the GDU are unlikely.

REFERENCES

Baedecker, P.A., ed., 1987, Methods for geochemical analysis: U.S. Geological Survey Bulletin 1770, 125 p.

Ball, J.W., and Nordstrom, D.K., 1991, User's manual for WATEQ4F, with revised thermodynamic data base and test cases for calculating specification of major, trace, and redox elements in natural waters: U.S. Geological Survey Open-File Report 91-183, 189 p.

Bluemle, J.P., 1965, Geology and ground water resources of Eddy and Foster Counties, North Dakota, Part I, Geology: North Dakota Geological Survey Bulletin 44 and North Dakota State Water Conservation Commission County Ground Water Studies 5, 66 p.

———1971, Geology of McLean County, North Dakota: North Dakota Geological Survey Bulletin 60, pt. I, and North Dakota State Water Commission County Ground Water Studies 19, pt. I, 65 p.

———1981, Geology of Sheridan County, North Dakota: North Dakota Geological Survey Bulletin 75, pt. I, and North Dakota State Water Commission County Groundwater Studies 32, pt. I, 59 p.

Bluemle, J.P., Faigle, G.A., Kresl, R.J., and Reid, J.R., 1967, Geology and ground water resources of Wells County, Part I, Geology: North Dakota Geological Survey Bulletin 51 and North Dakota State Water Commission County Ground Water Studies 12, 39 p.

Brockmann, L.C., Evenson, E.E., Strum, J.F., Anderson, T.C., Jr., Freymiller, W.F., Weiser, P.K., and Howey, R.L., 1979, Soil survey of McLean County, North Dakota: U.S. Department of Agriculture, Soil Conservation Service, 218 p., 174 maps.

Butler, D.L., Kreuger, R.P., Campbell-Osmundson, Barbara, Thompson, A.L., Formea, J.J., and Wickman, D.W., 1992, Reconnaissance investigation of water quality, bottom sediment, and biota associated with irrigation drainage in the Pine River project area, southern Ute Indian Reservation, southwestern Colorado and northwestern New Mexico, 1988-89: U.S. Geological Survey Water-Resources Investigations Report 92-4188, 105 p.

Butler, D.L., Kreuger, R.P., Campbell-Osmundson, Barbara, Thompson, A.L., and McCall, S.K., 1991, Reconnaissance investigation of water quality, bottom sediment, and biota associated with irrigation drainage in the Gunnison and Uncompaghre River Basins and at Sweitzer Lake, west-central Colorado, 1988-89: U.S. Geological Survey Water-Resources Investigations Report 91-4103, 99 p.

Butler, D.L., Wright, W.G., Hahn, D.A., Kreuger, R.P., and Campbell-Osmundson, Barbara, 1994, Physical, chemical, and biological data for detailed study of irrigation drainage in the Uncomphagre project area in the Grand Valley, west-central Colorado, 1991-92: U.S. Geological Survey Water-Resources Investigations Report 94-4110, 146 p.

Deveral, S.J., Gilliom, R.J., Fujii, Roger, Izbicki, J.A., and Fields, T.C., 1984, Areal distribution of selenium and other inorganic constituents in shallow ground water of the San Luis drain service area, San Joaquin Valley, California; A preliminary study: U.S. Geological Survey Water-Resources Investigations Report 84-4319, 67 p.

Farnsworth, R.K., Thompson, E.S., and Peck, E.L., 1982, Evaporation atlas for the contiguous 48 United States: National Oceanic and Atmospheric Administration Technical Report NWS 33, 26 p.

Fishman, M.J., and Friedman, L.C., eds., 1989, Methods for determination of inorganic substances in water and fluvial sediments (3rd ed.): U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A1, 545 p.

Freeze, R.A., and Cherry, J.A., 1979, Groundwater: Englewood Cliffs, New Jersey, Prentice-Hall, Inc., 604 p.

Fujii, Roger, Deveral, S.J., and Hatfield, D.B., 1988, Distribution of selenium in soils of agricultural fields, western San Joaquin Valley, California: Soil Science Society of America Journal, v. 52, no. 5, p. 1274-1283.

Gilliom, R.J., and others, 1989, Preliminary assessment of sources, distribution, and mobility of selenium in the San Joaquin Valley, California: U.S. Geological Survey Water-Resources Investigations Report 88-4186, 129 p.

Goolsby, D.A., Severson, R.C., Wilson, S.A., and Webber, Kurt, 1989, Geochemistry of soils and shallow ground water, with emphasis on arsenic and selenium, in part of the Garrison Diversion Unit, North Dakota, 1985-87: U.S. Geological Survey Water-Resources Investigations Report 89-4104, 132 p.

Hach Company, 1988, Procedures manual, DR/2000 spectrophotometer: 438 p.

Helsel, D.R., and Cohn, T.A., 1988, Estimation of descriptive statistics for multiply censored water quality data: Water Resources Research, v. 24, no. 12, p. 1997-2004.

Hoffman, R.J., Hallock, R.J., Rowe, T.G., Lico, M.S., Burge, H.L., and Thompson, S.P., 1989, Reconnaissance investigation of water quality, bottom sediment, and biota associated with irrigation drainage in and near Stillwater Wildlife Management Area, Nevada, 1986-87: U.S. Geological Survey Water-Resources Investigations Report 89-4105, 150 p.

Izbicki, J.A., 1984, Chemical quality of water at 14 sites near Kesterson National Wildlife Refuge, Fresno and Merced Counties, California: U.S. Geological Survey Open-File Report 84-582, 9 p.

Jacobs, L.W., ed., 1989, Selenium in agriculture and the environment: Soil Science Society of America, Special Publication 23, 233 p.

Knapton, J.R., Jones, W.E., and Sutphin, J.W., 1988, Reconnaissance investigations of water quality, bottom sediment, and biota associated with irrigation drainage in the Sun River area, west-central Montana, 1986-87: U.S. Geological Survey Water-Resources Investigations Report 87-4244, 77 p.

McNeal, J.M., and Balestrieri, L.S., 1989, Geochemistry and occurrence of selenium; An overview, *in* Jacobs, L.W., ed., Selenium in agriculture and the environment: Soil Science Society of America Special Publication 23, p. 1-13.

North Dakota Department of Health, 1994, Public water supply systems in North Dakota, chapter 33-17-01: Bismarck, North Dakota, 43 p.

North Dakota Geological Survey [n.d.], Generalized glacial map of North Dakota: Miscellaneous map no. 9, 1 sheet.

Ohlendorf, H.M., Hothem, R.L., Bunck, C.M., Aldrich, T.W., and Moore, J.F., 1986, Relationships between selenium concentrations, *in* Transactions of the North American Wildlife and Natural Resources Conference, 51st, Reno, Nevada: p. 330-342.

Peltz, L.A., and Waddell, Bruce, 1991, Physical, chemical, and biological data for detailed study of irrigation drainage in the Middle Green River Basin, Utah, 1988-89, with selected data for 1982-87: U.S. Geological Survey Water-Resources Investigations Report 91-4530, 213 p.

Peterson, D.A., Jones, W.E., and Morton, A.G., 1988, Reconnaissance investigation of water quality, bottom sediment, and biota associated with irrigation drainage in the Kendrick Reclamation project area, Wyoming, 1986-87: U.S. Geological Survey Water-Resources Investigations Report 87-4255, 57 p.

Presser, T.S., and Barnes, Ivan, 1985, Dissolved constituents including selenium in waters in the vicinity of Kesterson National Wildlife Refuge and the West Grassland, Fresno and Merced Counties, California: U.S. Geological Survey Water-Resources Investigations Report 85-4220, 73 p.

Rinella, F.A., and Schuler, C.A., 1991, Reconnaissance investigation of water quality, bottom sediment, and biota associated with irrigation drainage in the Malheur National Wildlife Refuge, Harney County, Oregon, 1988-89: U.S. Geological Survey Water-Resources Investigations Report 91-4085, 106 p.

Rowe, T.G., Lico, M.S., Hallock, R.J., Maest, A.S., and Hoffman, R.J., 1991, Physical, chemical, and biological data for detailed study of irrigation drainage in and near Stillwater, Fernley, and Humbolt Wildlife Management Areas and Carson Lake, west-central Nevada, 1987-89: U.S. Geological Survey Water-Resources Investigations 91-185, 199 p.

See, R.B., Peterson, D.A., and Ramirez, Pedro, 1991, Physical, chemical, and biological data for the detailed study of irrigation drainage in the Kendrick Reclamation project area, Wyoming, 1988-90: U.S. Geological Survey Water-Resources Investigations Report 91-533, 272 p.

Seiler, R.L., 1995, Prediction of areas where irrigation drainage may induce selenium contamination of water: Journal of Environmental Quality, v. 24, p. 973-979.

Seiler, R.L., Ekechukwu, G.A., and Hallock, R.J., 1993, Reconnaissance investigation of water quality, bottom sediment, and biota associated with irrigation drainage in and near Humbolt Wildlife Management Area, Nevada, 1990-91: U.S. Geological Survey Water-Resources Investigations Report 93-4072, 115 p.

Shaver, R.B., and Schuh, W.M., 1990, Feasibility of artificial recharge to the Oakes aquifer, southeastern North Dakota--Hydrology of the Oakes aquifer: North Dakota State Water Commission Water Resources Investigation 5, 11 plates, 123 p.

Stephens, D.W., Waddell, Bruce, and Miller, J.B., 1988, Reconnaissance investigation of water quality, bottom sediment, and biota associated with irrigation drainage in the Middle Green River Basin, Utah, 1986-87: U.S. Geological Survey Water-Resources Investigations Report 88-4011, 70 p.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data and Information Service, 1982, Monthly normals of temperature, precipitation, and heating and cooling degree days 1951-80, North Dakota: Asheville, North Carolina, Climatography of the United States, No. 81 (by State), unpaginated.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Environmental Satellite Data and Information Service, 1989-91, Climatological data, North Dakota, Annual summaries, 1988-90: Asheville, North Carolina, v. 97-99, no. 13, unpaginated.

U.S. Environmental Protection Agency, 1986, Quality criteria for water 1986: Office of Water Regulations and Standards, Washington, D.C., EPA 440/5-86-001, unpaginated.

Welch, A.H., Lico, M.S., and Hughes, J.L., 1988, Arsenic in ground water of the western United States: Ground Water, v. 26, no. 3, p. 333-347.

Wershaw, R.L., Fishman, M.J., Grabbe, R.R., and Lowe, L.E., eds., 1987, Methods for the determination of organic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A3, 80 p.

Wright, M.R., and Sweeney, M.D., 1977, Soil survey of Eddy County and parts of Benson and Nelson Counties, North Dakota: U.S. Department of Agriculture, Soil Conservation Service, 202 p., 70 maps.

Supplement 1. Methods of analysis and minimum reporting levels for soil samples

[ICAP/OES, inductively-coupled argon plasma/optical emission spectroscopy; HG/AAS, hydride generation/atomic absorption spectroscopy; mg/kg, milligrams per kilogram; CV/AAS, cold vapor/atomic absorption spectroscopy]

Constituent	Method of analysis	Minimum reporting level	Unit of measure
Aluminum	ICAP/OES	0.01	Percent
Arsenic	HG/AAS	.2	mg/kg
Barium	ICAP/OES	1	mg/kg
Beryllium	ICAP/OES	1	mg/kg
Bismuth	ICAP/OES	10	mg/kg
Cadmium	ICAP/OES	2	mg/kg
Calcium	ICAP/OES	.01	Percent
Cerium	ICAP/OES	1	mg/kg
Chromium	ICAP/OES	1	mg/kg
Cobalt	ICAP/OES	1	mg/kg
Copper	ICAP/OES	1	mg/kg
Europium	ICAP/OES	2	mg/kg
Gallium	ICAP/OES	1	mg/kg
Gold	ICAP/OES	8	mg/kg
Holmium	ICAP/OES	4	mg/kg
Iron	ICAP/OES	.01	Percent
Lanthanum	ICAP/OES	1	mg/kg
Lead	ICAP/OES	1	mg/kg
Lithium	ICAP/OES	1	mg/kg
Magnesium	ICAP/OES	.01	Percent
Manganese	ICAP/OES	1	mg/kg
Mercury	CV/AAS	.02	mg/kg
Molybdenum	ICAP/OES	2	mg/kg
Neodymium	ICAP/OES	1	mg/kg
Nickel	ICAP/OES	1	mg/kg
Niobium	ICAP/OES	4	mg/kg
Phosphorus	ICAP/OES	.01	Percent
Potassium	ICAP/OES	.01	Percent
Scandium	ICAP/OES	1	mg/kg
Selenium	HG/AAS	.1	mg/kg
Silver	ICAP/OES	2	mg/kg
Sodium	ICAP/OES	.01	Percent
Strontium	ICAP/OES	1	mg/kg
Sulfur	Combustion	.01	Percent
Tantalum	ICAP/OES	40	mg/kg
Thorium	ICAP/OES	1	mg/kg
Tin	ICAP/OES	10	mg/kg
Titanium	ICAP/OES	.01	Percent
Uranium	ICAP/OES	100	mg/kg
Vanadium	ICAP/OES	1	mg/kg
Ytterbium	ICAP/OES	1	mg/kg
Yttrium	ICAP/OES	1	mg/kg
Zinc	ICAP/OES	1	mg/kg

Supplement 2. Methods of analysis and minimum reporting levels for extracts from a 1:5 soil-to-water extraction conducted on soil samples

[ICAP/OES, inductively-coupled argon plasma/optical emission spectroscopy; mg/kg, milligrams per kilogram; HG/AAS, hydride generation/atomic absorption spectroscopy; µg/kg, micrograms per kilogram]

Constituent	Method of analysis	Minimum reporting level	Unit of measure
Aluminum	ICAP/OES	5	mg/kg
Antimony	ICAP/OES	.5	mg/kg
Arsenic	HG/AAS	2	µg/kg
Barium	ICAP/OES	.1	mg/kg
Beryllium	ICAP/OES	.1	mg/kg
Bismuth	ICAP/OES	1	mg/kg
Boron	ICAP/OES	.5	mg/kg
Cadmium	ICAP/OES	.2	mg/kg
Calcium	ICAP/OES	1	mg/kg
Cerium	ICAP/OES	.4	mg/kg
Chromium	ICAP/OES	.1	mg/kg
Cobalt	ICAP/OES	.1	mg/kg
Copper	ICAP/OES	.1	mg/kg
Iron	ICAP/OES	5	mg/kg
Lanthanum	ICAP/OES	.2	mg/kg
Lead	ICAP/OES	.4	mg/kg
Lithium	ICAP/OES	.2	mg/kg
Magnesium	ICAP/OES	1	mg/kg
Manganese	ICAP/OES	.4	mg/kg
Molybdenum	ICAP/OES	.2	mg/kg
Nickel	ICAP/OES	.2	mg/kg
Phosphorus	ICAP/OES	5	mg/kg
Potassium	ICAP/OES	1	mg/kg
Selenium	HG/AAS	1	µg/kg
Silicon	ICAP/OES	10	mg/kg
Silver	ICAP/OES	.2	mg/kg
Sodium	ICAP/OES	1	mg/kg
Strontium	ICAP/OES	.2	mg/kg
Thorium	ICAP/OES	.4	mg/kg
Tin	ICAP/OES	.5	mg/kg
Titanium	ICAP/OES	5	mg/kg
Vanadium	ICAP/OES	.2	mg/kg
Wolfram	ICAP/OES	.5	mg/kg
Yttrium	ICAP/OES	.2	mg/kg
Zinc	ICAP/OES	.2	mg/kg
Zirconium	ICAP/OES	.2	mg/kg

Supplement 3. Methods of analysis and minimum reporting levels for water samples

[AA, atomic absorption; mg/L, milligrams per liter; IC, ion-exchange chromatography; MB,ASF, molybdate blue, automated-segmented flow, colorimetric; D,ASF, diazotization, automated-segmented flow, colorimetric; CRD,ASF, cadmium reduction, diazotization, automated-segmented flow, colorimetric; SH,ASF, salicylate-hypochloric, automated-segmented flow, colorimetric; PPMB,ASF, phosphomolybdate, automated-segmented flow, colorimetric; AA,H, atomic absorption, hydride; µg/L, micrograms per liter; DCP, direct-current plasma; CVAA, cold vapor atomic absorption spectroscopy; GFAA, graphite furnace atomic adsorption; WO, wet oxidation]

Constituent	Method of analysis	Minimum reporting level
Calcium, dissolved	AA	0.1 mg/L
Magnesium, dissolved	AA	0.1 mg/L
Sodium, dissolved	AA	0.1 mg/L
Potassium, dissolved	AA	0.1 mg/L
Sulfate, dissolved	IC	0.1 mg/L
Chloride, dissolved	IC	1 mg/L
Fluoride, dissolved	IC	0.1 mg/L
Silica, dissolved	MB,ASF	0.1 mg/L
Nitrite, dissolved	D,ASF	0.001 mg/L as N
Nitrite plus nitrate, dissolved	CRD,ASF	0.01 mg/L as N
Ammonia, dissolved	SH,ASF	0.01 mg/L as N
Orthophosphorus, dissolved	PPMB,ASF	0.01 mg/L as P
Arsenic, dissolved	AA,H	1 µg/L
Boron, dissolved	DCP	10 µg/L
Iron, dissolved	AA	3 µg/L as Fe
Lithium, dissolved	AA	10 µg/L
Manganese, dissolved	AA	10 µg/L
Mercury, dissolved	CVAA	0.1 µg/L
Molybdenum, dissolved	GFAA	1 µg/L
Selenium, dissolved	AA,H	1 µg/L
Strontium, dissolved	AA	10 µg/L
Organic carbon, dissolved	WO	0.1 mg/L

Supplement 4. Chemical analyses of soils in the Turtle Lake irrigation area

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Date	Latitude-longitude identification number	Township-range identification number	Horizon sampled (feet below land surface)	Aluminum (percent)	Arsenic (mg/kg)	Barium (mg/kg)
81-123A	7-17-90	473325100580202	147-081-14BBD2	0 to 2	4.99	6.2	732
				2 to 6.5	4.07	5.1	664
				6.5 to 10.5	4.03	10	731
				10.5 to 14	3.58	9.2	551
				14 to 18	5.64	4.1	597
81-129A	7-19-90	473246100582102	147-081-15DDD2	0 to 2	4.71	6.0	634
				2 to 5.5	4.35	10	687
				5.5 to 10	4.74	18	776
				10 to 14	4.27	16	805
				14 to 18	4.48	13	765
81-130A	7-17-90	473305100582102	147-081-15DAA2	0 to 3	4.47	7.1	648
				3 to 4	3.61	6.4	515
				4 to 7	4.31	10	733
				7 to 10	4.37	13	729
				10 to 14	3.90	26	1,030
				14 to 19	4.30	26	1,250
87-148	7-19-90	473509100535301	147-080-05BAD	0 to 2	5.22	5.2	696
				2 to 5.5	4.12	7.9	604
				5.5 to 14	3.93	8.6	688
				14 to 17	3.90	10	678
				17 to 23	3.65	8.9	568
87-153	7-18-90	473758100561902	148-081-13DCC	0 to 1	5.36	5.7	669
				1 to 3	3.57	4.7	523
				3 to 8	3.91	5.8	598
				8 to 13.5	3.79	6.1	653
				13.5 to 18	3.56	11	892
				18 to 21	3.96	10	766
				21 to 23	4.27	16	1,250

Supplement 4. Chemical analyses of soils in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Beryllium (mg/kg)	Bismuth (mg/kg)	Cadmium (mg/kg)	Calcium (percent)	Cerium (mg/kg)	Chromium (mg/kg)	Cobalt (mg/kg)	Copper (mg/kg)
81-123A	0 to 2	1	<10	<2	1.49	59	49	14	17
	2 to 6.5	<1	<10	<2	9.96	59	47	14	12
	6.5 to 10.5	1	<10	<2	9.41	48	50	14	19
	10.5 to 14	1	<10	<2	10.6	47	42	13	18
	14 to 18	1	<10	<2	4.77	43	61	12	22
81-129A	0 to 2	1	<10	2	6.16	51	49	12	14
	2 to 5.5	<1	<10	<2	8.69	46	49	16	12
	5.5 to 10	1	<10	<2	7.66	65	63	21	19
	10 to 14	2	<10	<2	7.11	53	83	23	83
	14 to 18	1	<10	<2	6.44	51	72	18	44
81-130A	0 to 3	1	<10	<2	2.94	46	42	11	16
	3 to 4	1	<10	<2	13.8	41	35	10	11
	4 to 7	1	<10	<2	6.58	49	42	12	13
	7 to 10	1	<10	<2	6.78	47	53	12	9
	10 to 14	1	<10	<2	10.2	48	52	18	20
	14 to 19	1	<10	<2	6.06	57	46	21	37
87-148	0 to 2	1	<10	<2	1.19	60	60	10	12
	2 to 5.5	1	<10	<2	8.08	52	57	14	19
	5.5 to 14	<1	<10	<2	6.23	76	81	12	9
	14 to 17	1	<10	<2	7.60	73	65	17	10
	17 to 23	<1	<10	<2	9.34	58	66	23	7
87-153	0 to 1	1	<10	<2	1.07	57	53	10	14
	1 to 3	<1	<10	<2	14.2	54	42	8	12
	3 to 8	<1	<10	<2	5.28	60	36	8	6
	8 to 13.5	<1	<10	<2	5.50	53	39	9	6
	13.5 to 18	<1	<10	<2	8.45	106	62	17	11
	18 to 21	1	<10	<2	6.71	43	44	15	14
	21 to 23	2	<10	<2	6.37	63	66	15	17

Supplement 4. Chemical analyses of soils in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Europium (mg/kg)	Gallium (mg/kg)	Gold (mg/kg)	Holmium (mg/kg)	Iron (percent)	Lanthanum (mg/kg)	Lead (mg/kg)	Lithium (mg/kg)
81-123A	0 to 2	<2	14	<8	<4	2.75	33	16	18
	2 to 6.5	<2	13	<8	<4	2.69	32	24	18
	6.5 to 10.5	<2	13	<8	<4	3.72	27	23	22
	10.5 to 14	<2	11	<8	<4	3.05	27	26	17
	14 to 18	<2	13	<8	<4	2.67	27	12	30
81-129A	0 to 2	<2	11	<8	<4	2.19	30	13	20
	2 to 5.5	<2	12	<8	<4	2.78	26	15	17
	5.5 to 10	<2	14	<8	<4	3.74	37	19	22
	10 to 14	<2	15	<8	<4	3.94	29	45	23
	14 to 18	<2	12	<8	<4	4.03	30	40	21
81-130A	0 to 3	<2	12	<8	<4	2.22	26	12	16
	3 to 4	<2	10	<8	<4	1.64	24	8	14
	4 to 7	<2	10	<8	<4	2.62	30	27	16
	7 to 10	<2	10	<8	<4	2.77	27	46	16
	10 to 14	<2	13	<8	<4	3.46	29	51	18
	14 to 19	<2	15	<8	<4	4.22	32	19	18
87-148	0 to 2	<2	12	<8	<4	2.38	35	13	17
	2 to 5.5	<2	12	<8	<4	2.54	30	12	19
	5.5 to 14	<2	10	<8	<4	2.77	42	49	15
	14 to 17	<2	11	<8	<4	2.87	40	17	15
	17 to 23	<2	11	<8	<4	2.72	32	17	15
87-153	0 to 1	<2	12	<8	<4	2.60	35	13	18
	1 to 3	<2	9	<8	<4	2.11	32	8	15
	3 to 8	<2	8	<8	<4	1.93	36	13	12
	8 to 13.5	<2	10	<8	<4	1.79	28	18	12
	13.5 to 18	<2	10	<8	<4	3.40	57	26	14
	18 to 21	<2	10	<8	<4	2.49	26	20	15
	21 to 23	<2	11	<8	<4	3.26	35	15	14

Supplement 4. Chemical analyses of soils in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Magnesium (percent)	Manganese (mg/kg)	Mercury (mg/kg)	Molybdenum (mg/kg)	Neodymium (mg/kg)	Nickel (mg/kg)	Niobium (mg/kg)	Phosphorus (percent)
81-123A	0 to 2	0.80	1,710	0.04	<2	29	28	6	0.08
	2 to 6.5	2.36	1,060	.04	<2	29	24	<4	.08
	6.5 to 10.5	3.35	1,840	.06	<2	23	31	5	.07
	10.5 to 14	3.99	1,830	.06	<2	21	28	5	.08
	14 to 18	2.05	688	.04	3	23	33	10	.07
81-129A	0 to 2	1.26	844	.02	<2	23	27	5	.09
	2 to 5.5	3.10	1,780	.02	<2	21	29	<4	.07
	5.5 to 10	2.50	2,640	.06	<2	28	41	<4	.09
	10 to 14	2.02	2,840	.18	<2	24	59	9	.10
	14 to 18	2.06	1,560	.12	<2	24	40	8	.09
81-130A	0 to 3	.82	1,510	.04	<2	23	24	6	.10
	3 to 4	1.15	1,050	.04	<2	21	25	5	.07
	4 to 7	1.61	1,010	.04	2	25	25	<4	.08
	7 to 10	2.33	975	.04	<2	22	22	<4	.07
	10 to 14	3.32	3,080	.08	4	23	36	<4	.07
	14 to 19	1.93	4,140	.16	2	27	42	6	.08
87-148	0 to 2	.62	917	.02	<2	28	25	5	.07
	2 to 5.5	2.12	1,870	.04	<2	24	37	<4	.06
	5.5 to 14	2.02	969	.04	<2	31	26	<4	.05
	14 to 17	2.41	2,210	.02	<2	31	30	<4	.06
	17 to 23	2.92	1,830	.02	<2	26	32	<4	.07
87-153	0 to 1	.61	796	.04	<2	27	20	7	.07
	1 to 3	1.63	745	.04	<2	27	20	<4	.10
	3 to 8	1.62	567	.02	<2	26	16	<4	.05
	8 to 13.5	1.86	640	.02	<2	25	21	<4	.07
	13.5 to 18	2.80	1,640	.04	4	46	27	<4	.05
	18 to 21	2.22	1,300	.04	2	20	35	8	.07
	21 to 23	2.07	842	.12	3	26	50	15	.07

Supplement 4. Chemical analyses of soils in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Potassium (percent)	Scandium (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)	Sodium (percent)	Strontium (mg/kg)	Sulfur (percent)	Tantalum (mg/kg)
81-123A	0 to 2	1.59	8	0.4	<2	0.99	168	0.06	<40
	2 to 6.5	1.19	7	<.1	<2	1.15	228	<.05	<40
	6.5 to 10.5	1.19	7	.3	<2	1.03	210	<.05	<40
	10.5 to 14	1.14	6	1.2	<2	.91	185	<.05	<40
	14 to 18	1.67	9	.7	<2	.83	168	.24	<40
81-129A	0 to 2	1.40	6	.2	<2	1.06	237	<.05	<40
	2 to 5.5	1.33	6	.1	<2	1.35	255	<.05	<40
	5.5 to 10	1.36	8	.2	<2	1.24	254	<.05	<40
	10 to 14	1.07	9	2.4	<2	.89	323	.11	<40
	14 to 18	1.24	8	2.7	<2	1.07	284	.05	<40
81-130A	0 to 3	1.49	7	.6	<2	.91	160	.05	<40
	3 to 4	1.07	5	.2	<2	.81	218	<.05	<40
	4 to 7	1.35	6	.2	<2	1.23	270	<.05	<40
	7 to 10	1.38	7	.2	<2	1.34	255	<.05	<40
	10 to 14	1.25	6	.4	<2	1.01	229	<.05	<40
	14 to 19	1.27	7	6.0	<2	1.09	256	<.05	<40
87-148	0 to 2	1.59	7	.3	<2	1.11	180	<.05	<40
	2 to 5.5	1.20	6	.3	<2	.92	199	<.05	<40
	5.5 to 14	1.20	6	<.1	<2	1.02	200	<.05	<40
	14 to 17	1.18	6	.2	<2	1.04	214	<.05	<40
	17 to 23	1.09	6	.2	<2	.92	209	<.05	<40
87-153	0 to 1	1.61	8	.4	<2	1.02	162	<.05	<40
	1 to 3	1.07	6	.4	<2	.81	175	<.05	<40
	3 to 8	1.26	6	<.1	<2	1.21	206	<.05	<40
	8 to 13.5	1.22	6	<.1	<2	1.18	206	<.05	<40
	13.5 to 18	1.06	7	.2	<2	.87	198	<.05	<40
	18 to 21	1.21	6	.2	<2	.97	204	<.05	<40
	21 to 23	1.21	8	1.1	<2	1.23	258	<.05	<40

Supplement 4. Chemical analyses of soils in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Thorium (mg/kg)	Tin (mg/kg)	Titanium (percent)	Uranium (mg/kg)	Vanadium (mg/kg)	Ytterbium (mg/kg)	Yttrium (mg/kg)	Zinc (mg/kg)
81-123A	0 to 2	10	<10	0.23	<100	70	2	19	82
	2 to 6.5	9	<10	.22	<100	69	2	15	46
	6.5 to 10.5	9	<10	.19	<100	73	2	13	54
	10.5 to 14	8	<10	.16	<100	63	1	12	48
	14 to 18	9	<10	.23	<100	106	2	15	73
81-129A	0 to 2	7	<10	.19	<100	63	2	16	60
	2 to 5.5	6	<10	.15	<100	54	1	14	41
	5.5 to 10	10	<10	.20	<100	74	2	17	59
	10 to 14	8	<10	.24	<100	76	3	25	67
	14 to 18	7	<10	.24	<100	75	2	20	63
81-130A	0 to 3	8	<10	.20	<100	66	2	16	74
	3 to 4	6	<10	.16	<100	62	1	12	37
	4 to 7	11	<10	.19	<100	60	2	16	47
	7 to 10	7	<10	.17	<100	58	2	14	41
	10 to 14	8	<10	.17	<100	64	1	14	53
	14 to 19	10	<10	.22	<100	69	2	20	56
87-148	0 to 2	9	<10	.22	<100	73	2	18	67
	2 to 5.5	8	<10	.18	<100	79	2	15	53
	5.5 to 14	12	<10	.20	<100	76	2	17	49
	14 to 17	12	<10	.20	<100	75	2	17	48
	17 to 23	9	<10	.19	<100	79	2	16	52
87-153	0 to 1	10	<10	.26	<100	72	2	19	80
	1 to 3	9	<10	.21	<100	58	1	13	37
	3 to 8	11	<10	.18	<100	49	2	14	36
	8 to 13.5	8	<10	.19	<100	48	1	15	36
	13.5 to 18	19	<10	.24	<100	88	2	21	51
	18 to 21	5	<10	.21	<100	76	2	16	49
	21 to 23	12	<10	.34	<100	78	2	21	48

Supplement 4. Chemical analyses of soils in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Date	Latitude-longitude identification number	Township-range identification number	Horizon sampled (feet below land surface)	Aluminum (percent)	Arsenic (mg/kg)	Barium (mg/kg)
87-155	7-18-90	473850100573802	148-081-11DCC	0 to 2	4.76	5.4	602
				2 to 5.5	4.49	5.6	622
				5.5 to 8	4.63	7.2	702
				8 to 13	4.25	11	737
				13 to 18	4.00	8.5	669
87-158	7-18-90	473823100582002	148-081-15ADD	0 to 2	5.60	9.6	708
				2 to 9	3.90	18	725
				9 to 17	4.26	13	784
				17 to 23	4.05	6.0	683
87-159	7-19-90	473817100585102	148-081-15DBB	0 to 0.5	5.23	12	645
				0.5 to 2.5	5.02	14	842
				2.5 to 7.5	4.46	18	739
				7.5 to 11.5	3.66	14	770
				11.5 to 17	4.13	6.9	665
				17 to 18	4.95	6.0	557
87-164A	7-18-90	473733100593902	148-081-21ADD2	0 to 3	5.04	6.0	659
				3 to 8	3.75	8.7	597
				8 to 12.5	3.70	12	644
				12.5 to 15	4.20	9.8	893
				15 to 17	4.07	5.5	1,000
				17 to 18	3.99	6.7	929
87-165A	7-19-90	473707100562702	148-081-24CBB2	0 to 2	5.19	6.6	646
				2 to 3	3.76	5.6	631
				3 to 8	3.94	5.2	749
				8 to 12	3.61	7.1	702
				12 to 16.5	3.72	13	1,010
				16.5 to 18	3.37	54	8,850

Supplement 4. Chemical analyses of soils in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Beryllium (mg/kg)	Bismuth (mg/kg)	Cadmium (mg/kg)	Calcium (percent)	Cerium (mg/kg)	Chromium (mg/kg)	Cobalt (mg/kg)	Copper (mg/kg)
87-155	0 to 2	1	<10	<2	1.42	59	57	9	15
	2 to 5.5	1	<10	<2	5.51	66	56	9	9
	5.5 to 8	<1	<10	<2	4.40	52	47	8	9
	8 to 13	1	<10	<2	8.13	58	62	13	14
	13 to 18	<1	<10	<2	6.77	54	50	11	10
87-158	0 to 2	1	<10	<2	1.27	53	55	11	17
	2 to 9	1	<10	<2	10.6	47	155	18	26
	9 to 17	1	<10	<2	8.13	60	91	17	22
	17 to 23	<1	<10	2	5.56	75	52	9	6
87-159	0 to 0.5	1	<10	<2	1.88	49	55	11	16
	0.5 to 2.5	1	<10	<2	10.2	54	59	18	19
	2.5 to 7.5	1	<10	<2	8.68	44	68	18	22
	7.5 to 11.5	<1	<10	<2	8.64	56	75	14	14
	11.5 to 17	<1	<10	<2	6.40	60	50	11	7
	17 to 18	1	<10	<2	4.64	52	54	12	17
87-164A	0 to 3	1	<10	<2	1.29	57	46	12	18
	3 to 8	<1	<10	<2	10.5	51	39	13	12
	8 to 12.5	<1	<10	<2	10.0	37	47	15	10
	12.5 to 15	1	<10	<2	5.47	42	41	14	18
	15 to 17	1	<10	<2	5.62	67	54	16	14
	17 to 18	1	<10	<2	7.00	41	42	18	15
87-165A	0 to 2	1	<10	<2	1.90	57	58	11	18
	2 to 3	1	<10	<2	14.9	50	50	13	16
	3 to 8	<1	<10	<2	6.05	70	56	12	8
	8 to 12	<1	<10	<2	9.34	76	77	14	8
	12 to 16.5	<1	<10	<2	9.01	85	110	19	8
	16.5 to 18	<1	<10	<2	9.72	49	56	53	17

Supplement 4. Chemical analyses of soils in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Europium (mg/kg)	Gallium (mg/kg)	Gold (mg/kg)	Holmium (mg/kg)	Iron (percent)	Lanthanum (mg/kg)	Lead (mg/kg)	Lithium (mg/kg)
87-155	0 to 2	<2	11	<8	<4	2.48	35	13	17
	2 to 5.5	<2	11	<8	<4	2.50	37	15	17
	5.5 to 8	<2	9	<8	<4	2.07	30	14	14
	8 to 13	<2	11	<8	<4	3.10	32	39	19
	13 to 18	<2	10	<8	<4	2.31	31	14	14
87-158	0 to 2	<2	13	<8	<4	2.93	34	16	19
	2 to 9	<2	12	<8	<4	4.35	28	434	20
	9 to 17	<2	13	<8	<4	3.74	34	85	20
	17 to 23	<2	10	<8	<4	2.33	42	13	12
87-159	0 to 0.5	<2	12	<8	<4	3.03	31	16	19
	0.5 to 2.5	<2	15	<8	<4	4.44	31	15	24
	2.5 to 7.5	<2	12	<8	<4	4.39	25	74	22
	7.5 to 11.5	<2	10	<8	<4	2.93	32	143	16
	11.5 to 17	<2	10	<8	<4	2.61	35	15	14
	17 to 18	<2	11	<8	<4	2.58	30	14	19
87-164A	0 to 3	<2	12	<8	<4	2.55	35	13	17
	3 to 8	<2	11	<8	<4	2.74	28	15	16
	8 to 12.5	<2	10	<8	<4	2.92	21	53	16
	12.5 to 15	<2	9	<8	<4	2.55	26	16	15
	15 to 17	<2	10	<8	<4	3.64	38	17	14
	17 to 18	<2	11	<8	<4	3.49	24	23	15
87-165A	0 to 2	<2	12	<8	<4	2.75	34	13	19
	2 to 3	<2	11	<8	<4	2.61	28	12	19
	3 to 8	<2	9	<8	<4	2.11	39	14	14
	8 to 12	<2	10	<8	<4	3.06	41	35	13
	12 to 16.5	<2	16	<8	<4	4.30	47	20	14
	16.5 to 18	<2	44	<8	<4	3.48	28	14	16

Supplement 4. Chemical analyses of soils in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Magnesium (percent)	Manganese (mg/kg)	Mercury (mg/kg)	Molybdenum (mg/kg)	Neodymium (mg/kg)	Nickel (mg/kg)	Niobium (mg/kg)	Phosphorus (percent)
87-155	0 to 2	0.82	759	0.04	<2	28	21	8	0.10
	2 to 5.5	2.00	821	<.02	<2	28	21	<4	.05
	5.5 to 8	1.94	514	.02	<2	23	16	<4	.06
	8 to 13	2.69	1,200	.04	<2	26	27	<4	.07
	13 to 18	2.18	1,010	.02	<2	24	24	<4	.06
87-158	0 to 2	.82	993	.04	<2	27	23	8	.09
	2 to 9	3.59	2,060	.08	7	23	42	<4	.08
	9 to 17	2.74	1,820	.06	<2	28	41	9	.09
	17 to 23	1.79	884	<.02	<2	34	21	<4	.05
87-159	0 to 0.5	1.09	964	.04	<2	26	26	7	.11
	0.5 to 2.5	2.93	1,580	.08	<2	27	37	6	.09
	2.5 to 7.5	2.85	2,060	.08	3	21	37	<4	.09
	7.5 to 11.5	2.89	1,810	.04	3	24	25	<4	.07
	11.5 to 17	2.12	817	.04	<2	28	22	<4	.06
	17 to 18	1.73	565	.04	<2	26	19	<4	.07
87-164A	0 to 3	.67	1,050	.04	<2	28	24	7	.10
	3 to 8	3.21	1,070	.04	<2	24	20	<4	.07
	8 to 12.5	3.73	1,440	.06	<2	18	27	<4	.07
	12.5 to 15	1.91	657	.10	<2	21	34	7	.06
	15 to 17	1.81	1,020	.10	<2	30	28	6	.07
	17 to 18	2.38	1,590	.08	<2	20	32	5	.07
87-165A	0 to 2	1.00	954	.04	<2	28	27	9	.10
	2 to 3	2.83	1,370	.04	<2	23	27	6	.11
	3 to 8	1.84	821	.04	<2	32	29	<4	.06
	8 to 12	2.95	1,570	.02	<2	32	27	<4	.06
	12 to 16.5	2.93	4,460	.04	3	36	53	<4	.04
	16.5 to 18	3.58	45,300	.04	39	24	117	6	.09

Supplement 4. Chemical analyses of soils in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Potassium (percent)	Scandium (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)	Sodium (percent)	Strontium (mg/kg)	Sulfur (percent)	Tantalum (mg/kg)
87-155	0 to 2	1.47	7	0.6	<2	0.86	143	<0.05	<40
	2 to 5.5	1.36	6	<.1	<2	1.17	209	<.05	<40
	5.5 to 8	1.44	6	<.1	<2	1.37	234	<.05	<40
	8 to 13	1.27	7	.2	<2	1.04	213	<.05	<40
	13 to 18	1.25	5	.2	<2	1.16	225	<.05	<40
87-158	0 to 2	1.61	9	.5	<2	.94	150	<.05	<40
	2 to 9	1.13	7	.3	<2	.99	209	<.05	<40
	9 to 17	1.23	8	.3	<2	1.04	220	<.05	<40
	17 to 23	1.29	6	.2	<2	1.22	228	<.05	<40
87-159	0 to 0.5	1.62	8	.6	<2	.95	153	<.05	<40
	0.5 to 2.5	1.09	8	.3	<2	1.38	264	.06	<40
	2.5 to 7.5	1.21	8	.3	<2	1.14	232	<.05	<40
	7.5 to 11.5	1.19	6	.2	<2	.95	198	<.05	<40
	11.5 to 17	1.24	7	<.1	<2	1.14	219	<.05	<40
	17 to 18	1.43	8	.3	<2	1.05	196	<.05	<40
87-164A	0 to 3	1.61	7	.4	<2	1.07	184	<.05	<40
	3 to 8	1.23	6	.2	<2	1.02	212	<.05	<40
	8 to 12.5	1.17	6	.1	<2	1.04	208	<.05	<40
	12.5 to 15	1.32	6	2.5	<2	1.16	226	<.05	<40
	15 to 17	1.23	7	1.1	<2	1.19	226	.53	<40
	17 to 18	1.25	6	.9	<2	1.11	218	.46	<40
87-165A	0 to 2	1.54	8	.6	<2	.89	152	.05	<40
	2 to 3	1.06	7	.3	<2	.80	195	<.05	<40
	3 to 8	1.20	6	<.1	<2	1.15	230	<.05	<40
	8 to 12	1.04	7	.1	<2	1.07	249	<.05	<40
	12 to 16.5	1.03	7	.2	<2	1.00	228	<.05	<40
	16.5 to 18	.96	6	.2	<2	.78	209	<.05	<40

Supplement 4. Chemical analyses of soils in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Thorium (mg/kg)	Tin (mg/kg)	Titanium (percent)	Uranium (mg/kg)	Vanadium (mg/kg)	Ytterbium (mg/kg)	Yttrium (mg/kg)	Zinc (mg/kg)
87-155	0 to 2	9	<10	0.23	<100	69	2	18	78
	2 to 5.5	10	<10	.18	<100	67	2	16	44
	5.5 to 8	7	<10	.19	<100	53	1	15	37
	8 to 13	10	<10	.17	<100	72	2	16	50
	13 to 18	7	<10	.17	<100	60	1	15	37
87-158	0 to 2	12	<10	.24	<100	73	2	19	95
	2 to 9	7	<10	.20	<100	70	2	14	62
	9 to 17	10	<10	.26	<100	76	2	18	62
	17 to 23	13	<10	.20	<100	63	2	18	36
87-159	0 to 0.5	9	<10	.24	<100	72	2	19	81
	0.5 to 2.5	10	<10	.29	<100	78	2	15	68
	2.5 to 7.5	7	<10	.23	<100	74	2	14	65
	7.5 to 11.5	8	<10	.17	<100	60	2	14	47
	11.5 to 17	10	<10	.21	<100	69	2	17	43
	17 to 18	9	<10	.24	<100	84	2	17	55
87-164A	0 to 3	11	<10	.21	<100	65	2	19	81
	3 to 8	9	<10	.15	<100	60	1	13	41
	8 to 12.5	5	<10	.15	<100	57	1	12	47
	12.5 to 15	7	<10	.17	<100	59	2	18	51
	15 to 17	10	<10	.29	<100	70	2	18	50
	17 to 18	6	<10	.20	<100	64	2	15	55
87-165A	0 to 2	10	<10	.22	<100	76	2	20	87
	2 to 3	8	<10	.18	<100	63	1	14	53
	3 to 8	10	<10	.22	<100	65	2	17	42
	8 to 12	11	<10	.22	<100	70	2	18	42
	12 to 16.5	15	<10	.29	<100	94	2	18	52
	16.5 to 18	22	<10	.18	<100	86	2	19	75

Supplement 4. Chemical analyses of soils in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Date	Latitude-longitude identification number	Township-range identification number	Horizon sampled (feet below land surface)	Aluminum (percent)	Arsenic (mg/kg)	Barium (mg/kg)
87-166A	7-18-90	473707100573402	148-081-23DCC2	1 to 4	3.75	19	470
				4 to 7	3.63	12	669
				7 to 9	3.48	16	783
				9 to 15	3.45	9.6	868
				15 to 18	4.98	4.8	653
87-177	7-16-90	473424100553801	147-080-07BBB	0 to 3	4.86	5.3	678
				3 to 4	3.36	5.0	554
				4 to 9.5	3.67	12	545
				9.5 to 13	3.69	19	1,380
				13 to 15	2.78	7.6	1,110
				15 to 19	5.59	3.1	687
87-184	7-17-90	473305100553801	147-080-18CBB	0 to 2.5	5.31	6.4	671
				2.5 to 5	4.18	8.6	609
				5 to 9.5	4.03	8.8	620
				9.5 to 14.5	4.42	11	637
				14.5 to 19	3.81	11	888
				19 to 23	3.16	10	612
87-186	7-16-90	473404100480701	147-080-12ADD	0 to 3	4.89	2.4	673
				3 to 5	5.91	3.4	669
				5 to 7	5.47	24	585
				7 to 8	4.97	9.5	542
				8 to 13	4.06	19	248
				13 to 18	4.01	21	154
90-1	7-18-90	473635100581302	148-081-26CBB2	0 to 1	4.03	4.7	604
				1 to 4	3.79	4.7	656
				4 to 6	4.49	19	530
				6 to 9	3.73	52	1,350
				9 to 17	5.62	5.6	647

Supplement 4. Chemical analyses of soils in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Beryllium (mg/kg)	Bismuth (mg/kg)	Cadmium (mg/kg)	Calcium (percent)	Cerium (mg/kg)	Chromium (mg/kg)	Cobalt (mg/kg)	Copper (mg/kg)
87-166A	1 to 4	<1	<10	<2	13.2	53	54	13	16
	4 to 7	<1	<10	<2	12.7	44	48	14	16
	7 to 9	1	<10	<2	11.3	45	43	15	22
	9 to 15	1	<10	<2	10.0	50	42	14	22
	15 to 18	1	<10	<2	3.93	46	49	12	11
87-177	0 to 3	1	<10	<2	1.15	63	48	11	15
	3 to 4	<1	<10	<2	14.4	44	30	9	11
	4 to 9.5	1	<10	<2	11.6	39	48	12	17
	9.5 to 13	1	<10	<2	9.19	45	49	15	23
	13 to 15	1	<10	<2	11.8	30	36	11	8
	15 to 19	1	<10	<2	5.18	51	62	12	22
87-184	0 to 2.5	2	<10	<2	1.70	55	55	13	20
	2.5 to 5	1	<10	<2	6.44	40	53	17	15
	5 to 9.5	1	<10	<2	6.89	54	60	18	16
	9.5 to 14.5	1	<10	<2	6.55	55	50	17	20
	14.5 to 19	1	<10	<2	8.76	55	52	13	13
	19 to 23	<1	<10	<2	11.3	39	36	17	15
87-186	0 to 3	1	<10	<2	1.17	61	48	13	17
	3 to 5	2	<10	<2	1.21	97	90	12	9
	5 to 7	2	<10	<2	1.01	66	70	18	25
	7 to 8	1	<10	<2	2.34	55	54	15	18
	8 to 13	1	<10	<2	4.99	52	52	23	17
	13 to 18	1	<10	<2	6.45	40	48	18	15
90-1	0 to 1	1	<10	<2	3.41	44	38	9	17
	1 to 4	<1	<10	<2	11.5	47	36	8	12
	4 to 6	1	<10	<2	7.56	55	58	12	9
	6 to 9	1	<10	<2	7.40	46	45	22	12
	9 to 17	1	<10	<2	5.11	46	61	12	20

Supplement 4. Chemical analyses of soils in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Europium (mg/kg)	Gallium (mg/kg)	Gold (mg/kg)	Holmium (mg/kg)	Iron (percent)	Lanthanum (mg/kg)	Lead (mg/kg)	Lithium (mg/kg)
87-166A	1 to 4	<2	11	<8	<4	3.51	29	11	22
	4 to 7	<2	13	<8	<4	3.11	27	28	19
	7 to 9	<2	14	<8	<4	3.13	24	24	18
	9 to 15	<2	13	<8	<4	2.42	28	18	17
	15 to 18	<2	10	<8	<4	2.42	28	12	17
87-177	0 to 3	<2	12	<8	<4	2.57	35	15	16
	3 to 4	<2	10	<8	<4	1.80	25	11	12
	4 to 9.5	<2	11	<8	<4	3.27	24	27	21
	9.5 to 13	<2	20	<8	<4	5.18	26	20	21
	13 to 15	<2	15	<8	<4	7.03	18	15	17
	15 to 19	<2	14	<8	<4	2.61	30	14	32
87-184	0 to 2.5	<2	13	<8	<4	2.89	34	17	20
	2.5 to 5	<2	13	<8	<4	2.82	24	18	21
	5 to 9.5	<2	13	<8	<4	2.71	32	49	21
	9.5 to 14.5	<2	14	<8	<4	3.34	30	21	21
	14.5 to 19	<2	12	<8	<4	3.07	32	18	18
	19 to 23	<2	17	<8	<4	2.43	21	15	17
87-186	0 to 3	<2	10	<8	<4	2.13	36	16	18
	3 to 5	<2	15	<8	<4	3.30	53	20	27
	5 to 7	<2	13	<8	<4	7.33	37	25	23
	7 to 8	<2	12	<8	<4	3.88	31	19	22
	8 to 13	<2	10	<8	<4	5.79	31	21	21
	13 to 18	<2	11	<8	<4	5.39	25	17	19
90-1	0 to 1	<2	10	<8	<4	2.07	26	14	17
	1 to 4	<2	10	<8	<4	1.88	26	8	18
	4 to 6	<2	11	<8	<4	3.61	30	12	22
	6 to 9	<2	15	<8	<4	5.21	25	14	17
	9 to 17	<2	13	<8	<4	2.64	27	14	30

Supplement 4. Chemical analyses of soils in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Magnesium (percent)	Manganese (mg/kg)	Mercury (mg/kg)	Molybdenum (mg/kg)	Neodymium (mg/kg)	Nickel (mg/kg)	Niobium (mg/kg)	Phosphorus (percent)
87-166A	1 to 4	3.83	1,240	0.04	<2	28	35	<4	0.10
	4 to 7	4.30	3,010	.08	3	22	31	6	.08
	7 to 9	3.90	3,360	.10	<2	20	34	<4	.07
	9 to 15	3.23	3,080	.08	<2	25	30	5	.06
	15 to 18	1.48	711	.04	<2	20	27	8	.06
87-177	0 to 3	.60	1,010	.04	<2	30	26	8	.08
	3 to 4	1.02	838	.04	<2	21	23	<4	.07
	4 to 9.5	2.25	1,410	.08	<2	19	31	6	.08
	9.5 to 13	2.04	6,360	.10	8	22	36	7	.10
	13 to 15	3.20	4,320	.04	5	14	21	4	.12
	15 to 19	2.18	851	.06	<2	25	33	9	.06
87-184	0 to 2.5	.90	1,180	.04	<2	27	29	8	.09
	2.5 to 5	2.35	1,740	.08	<2	19	42	5	.06
	5 to 9.5	2.66	2,250	.06	<2	20	45	<4	.06
	9.5 to 14.5	2.34	1,750	.06	<2	24	43	<4	.09
	14.5 to 19	3.00	1,520	.06	<2	26	27	5	.07
	19 to 23	4.14	5,670	.06	3	19	43	<4	.06
87-186	0 to 3	.73	236	.02	<2	30	23	8	.06
	3 to 5	.98	348	.04	<2	45	34	8	.08
	5 to 7	.84	387	.10	9	32	57	8	.09
	7 to 8	1.38	378	.04	8	28	38	8	.06
	8 to 13	2.49	753	.10	6	25	58	8	.06
	13 to 18	1.92	1,100	.10	7	19	45	9	.07
90-1	0 to 1	1.08	1,100	.04	<2	20	21	6	.12
	1 to 4	1.71	586	.02	<2	24	17	4	.08
	4 to 6	3.09	459	.06	<2	24	30	<4	.06
	6 to 9	2.98	4,810	.14	6	27	46	<4	.07
	9 to 17	2.32	796	.04	<2	24	30	8	.06

Supplement 4. Chemical analyses of soils in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Potassium (percent)	Scandium (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)	Sodium (percent)	Strontium (mg/kg)	Sulfur (percent)	Tantalum (mg/kg)
87-166A	1 to 4	1.08	8	0.2	<2	0.92	194	<0.05	<40
	4 to 7	1.07	7	.2	<2	.94	197	<.05	<40
	7 to 9	1.08	7	.2	<2	.67	170	<.05	<40
	9 to 15	1.07	7	2.3	<2	.73	184	<.05	<40
	15 to 18	1.45	7	.4	<2	1.30	226	.25	<40
87-177	0 to 3	1.61	7	.3	<2	1.07	182	<.05	<40
	3 to 4	1.04	5	.1	<2	.91	210	<.05	<40
	4 to 9.5	1.10	7	<.1	<2	.88	235	<.05	<40
	9.5 to 13	1.10	8	.2	<2	.84	246	<.05	<40
	13 to 15	.88	6	.2	<2	.57	179	<.05	<40
	15 to 19	1.64	9	.8	<2	.82	174	.26	<40
87-184	0 to 2.5	1.61	8	.5	<2	.87	147	<.05	<40
	2.5 to 5	1.18	8	.1	<2	.64	144	<.05	<40
	5 to 9.5	1.11	7	.1	<2	.85	190	<.05	<40
	9.5 to 14.5	1.20	8	.2	<2	1.05	232	<.05	<40
	14.5 to 19	1.13	7	.2	<2	.88	221	<.05	<40
	19 to 23	.97	5	.1	<2	.75	207	<.05	<40
87-186	0 to 3	1.66	8	.3	<2	.95	164	<.05	<40
	3 to 5	1.79	12	<.1	<2	1.26	206	<.05	<40
	5 to 7	1.58	10	.9	<2	1.05	177	.07	<40
	7 to 8	1.44	8	1.4	<2	.96	167	2.14	<40
	8 to 13	1.22	8	1.8	<2	.81	148	3.73	<40
	13 to 18	1.25	7	1.3	<2	.92	178	3.48	<40
90-1	0 to 1	1.39	6	.8	<2	.77	171	.07	<40
	1 to 4	1.17	6	.4	<2	.79	276	<.05	<40
	4 to 6	1.16	10	<.1	<2	.75	159	<.05	<40
	6 to 9	1.10	7	.5	<2	.81	174	<.05	<40
	9 to 17	1.66	9	.7	<2	.82	169	.25	<40

Supplement 4. Chemical analyses of soils in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Thorium (mg/kg)	Tin (mg/kg)	Titanium (percent)	Uranium (mg/kg)	Vanadium (mg/kg)	Ytterbium (mg/kg)	Yttrium (mg/kg)	Zinc (mg/kg)
87-166A	1 to 4	9	<10	0.21	<100	63	2	14	53
	4 to 7	8	<10	.20	<100	61	1	12	48
	7 to 9	7	<10	.17	<100	80	2	14	53
	9 to 15	10	<10	.17	<100	79	2	16	50
	15 to 18	7	<10	.24	<100	65	2	15	51
87-177	0 to 3	12	<10	.23	<100	66	2	19	65
	3 to 4	6	<10	.16	<100	48	1	12	28
	4 to 9.5	6	<10	.18	<100	78	2	15	56
	9.5 to 13	7	<10	.21	<100	96	2	20	60
	13 to 15	5	<10	.11	<100	74	2	13	46
	15 to 19	8	<10	.24	<100	111	2	16	72
87-184	0 to 2.5	8	<10	.22	<100	81	2	20	99
	2.5 to 5	5	<10	.18	<100	123	2	14	63
	5 to 9.5	4	<10	.19	<100	101	2	14	57
	9.5 to 14.5	7	<10	.23	<100	91	2	16	62
	14.5 to 19	10	<10	.19	<100	86	2	14	46
	19 to 23	7	<10	.12	<100	68	1	12	48
87-186	0 to 3	11	<10	.22	<100	64	2	19	96
	3 to 5	14	<10	.32	<100	126	3	26	86
	5 to 7	12	<10	.25	<100	133	3	22	108
	7 to 8	9	<10	.22	<100	89	2	18	107
	8 to 13	8	<10	.20	<100	99	2	15	76
	13 to 18	5	<10	.20	<100	78	2	14	65
90-1	0 to 1	9	<10	.16	<100	55	1	13	91
	1 to 4	8	<10	.17	<100	51	2	13	61
	4 to 6	7	<10	.19	<100	112	2	16	66
	6 to 9	13	<10	.18	<100	78	2	17	58
	9 to 17	10	<10	.22	<100	106	2	16	72

Supplement 4. Chemical analyses of soils in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Date	Latitude-longitude identification number	Township-range identification number	Horizon sampled (feet below land surface)	Aluminum (percent)	Arsenic (mg/kg)	Barium (mg/kg)
OW-48A	7-17-90	473331100553802	147-080-18BBB2	0 to 2	4.94	6.6	650
				2 to 5	3.58	8.7	691
				5 to 7.5	3.62	10	635
				7.5 to 11.5	3.59	10	637
				11.5 to 14	3.77	9.7	1,040
				14 to 18	3.84	12	944

Supplement 4. Chemical analyses of soils in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Beryllium (mg/kg)	Bismuth (mg/kg)	Cadmium (mg/kg)	Calcium (percent)	Cerium (mg/kg)	Chromium (mg/kg)	Cobalt (mg/kg)	Copper (mg/kg)
OW-48A	0 to 2	1	<10	<2	2.32	49	50	13	24
	2 to 5	<1	<10	<2	11.2	45	49	14	14
	5 to 7.5	<1	<10	<2	9.66	54	50	15	12
	7.5 to 11.5	1	<10	<2	9.17	51	47	17	39
	11.5 to 14	1	<10	<2	8.50	53	43	25	17
	14 to 18	1	<10	<2	8.90	44	46	22	19

Supplement 4. Chemical analyses of soils in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Europium (mg/kg)	Gallium (mg/kg)	Gold (mg/kg)	Holmium (mg/kg)	Iron (percent)	Lanthanum (mg/kg)	Lead (mg/kg)	Lithium (mg/kg)
OW-48A	0 to 2	<2	12	<8	<4	2.79	30	19	19
	2 to 5	<2	12	<8	<4	2.83	26	40	19
	5 to 7.5	<2	12	<8	<4	2.77	32	28	17
	7.5 to 11.5	<2	12	<8	<4	2.93	28	25	18
	11.5 to 14	<2	17	<8	<4	3.06	29	21	21
	14 to 18	<2	15	<8	<4	3.33	25	20	20

Supplement 4. Chemical analyses of soils in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Magnesium (percent)	Manganese (mg/kg)	Mercury (mg/kg)	Molybdenum (mg/kg)	Neodymium (mg/kg)	Nickel (mg/kg)	Niobium (mg/kg)	Phosphorus (percent)
OW-48A	0 to 2	1.06	1,310	0.06	<2	25	29	9	0.10
	2 to 5	3.27	1,830	.06	<2	22	33	5	.06
	5 to 7.5	3.24	1,500	.06	<2	25	31	5	.06
	7.5 to 11.5	3.26	1,580	.08	<2	24	41	9	.07
	11.5 to 14	3.21	4,730	.08	3	24	39	5	.07
	14 to 18	3.20	3,740	.08	<2	20	37	5	.07

Supplement 4. Chemical analyses of soils in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Potassium (percent)	Scandium (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)	Sodium (percent)	Strontium (mg/kg)	Sulfur (percent)	Tantalum (mg/kg)
OW-48A	0 to 2	1.59	8	0.5	<2	0.86	145	<0.05	<40
	2 to 5	1.12	7	.1	<2	.75	184	<.05	<40
	5 to 7.5	1.11	7	.1	<2	.83	195	<.05	<40
	7.5 to 11.5	1.06	6	.4	<2	.82	204	<.05	<40
	11.5 to 14	1.08	7	.4	<2	.72	182	<.05	<40
	14 to 18	1.13	7	.5	<2	.75	189	<.05	<40

Supplement 4. Chemical analyses of soils in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Thorium (mg/kg)	Tin (mg/kg)	Titanium (percent)	Uranium (mg/kg)	Vanadium (mg/kg)	Ytterbium (mg/kg)	Yttrium (mg/kg)	Zinc (mg/kg)
OW-48A	0 to 2	8	<10	0.21	<100	78	2	18	95
	2 to 5	8	<10	.18	<100	85	1	13	48
	5 to 7.5	11	<10	.19	<100	86	2	14	48
	7.5 to 11.5	8	<10	.21	<100	81	2	17	52
	11.5 to 14	9	<10	.17	<100	100	2	14	55
	14 to 18	7	<10	.17	<100	93	2	13	56

Supplement 5. Chemical analyses of soil horizons in the Turtle Lake irrigation area

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Date	Latitude-longitude identification number	Township-range identification number	Soil series[1]	Horizon sampled	Aluminum (percent)	Arsenic (mg/kg)	Barium (mg/kg)
81-123A	7-17-90	473325100580202	147-081-14BBD2	Unknown	Topsoil	4.99	6.2	732
					Oxidized	3.91	7.9	653
					Transition	5.64	4.1	597
81-129A	7-19-90	473246100582102	147-081-15DDD2	Manning	Topsoil	4.71	6.0	634
					Oxidized	4.47	15	737
81-130A	7-17-90	473305100582102	147-081-15DAA2	Manning	Topsoil	4.47	7.1	648
					Oxidized	4.24	11	700
					Transition	4.12	26	1,150
87-148	7-19-90	473509100535301	147-080-05BAD	Unknown	Topsoil	5.22	5.2	696
					Oxidized	3.88	8.8	638
87-153	7-18-90	473758100561902	148-081-13DCC	Manning	Topsoil	5.36	5.7	669
					Oxidized	3.82	8.3	747
87-155	7-18-90	473850100573802	148-081-11DCC	Manning	Topsoil	4.76	5.4	602
					Oxidized	4.28	8.4	685
87-158	7-18-90	473823100582002	148-081-15ADD	Manning	Topsoil	5.60	9.6	708
					Oxidized	4.08	13	735
87-159	7-19-90	473817100585102	148-081-15DBB	Wabek	Topsoil	5.23	12	645
					Oxidized	4.22	13	734
					Transition	4.95	6.0	557
87-164A	7-18-90	473733100593902	148-081-21ADD2	Russo	Topsoil	5.04	6.0	659
					Oxidized	3.73	10	620
					Transition	4.20	9.8	893
					Reduced	4.04	5.9	976
87-165A	7-19-90	473707100562702	148-081-24CBB2	Wabek	Topsoil	5.19	6.6	646
					Oxidized	3.73	12	1,560

Supplement 5. Chemical analyses of soil horizons in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled	Beryllium (mg/kg)	Bismuth (mg/kg)	Cadmium (mg/kg)	Calcium (percent)	Cerium (mg/kg)	Chromium (mg/kg)	Cobalt (mg/kg)	Copper (mg/kg)
81-123A	Topsoil	1	<10	<2	1.49	59	49	14	17
	Oxidized	1	<10	<2	9.96	52	47	14	16
	Transition	1	<10	<2	4.77	43	61	12	22
81-129A	Topsoil	1	<10	2	6.16	51	49	12	14
	Oxidized	1	<10	<2	7.44	54	67	20	40
81-130A	Topsoil	1	<10	<2	2.94	46	42	11	16
	Oxidized	1	<10	<2	7.70	47	46	12	11
	Transition	1	<10	<2	7.90	53	49	20	29
87-148	Topsoil	1	<10	<2	1.19	60	60	10	12
	Oxidized	<1	<10	<2	7.62	66	70	16	10
87-153	Topsoil	1	<10	<2	1.07	57	53	10	14
	Oxidized	<1	<10	<2	7.09	65	46	12	10
87-155	Topsoil	1	<10	<2	1.42	59	57	9	15
	Oxidized	<1	<10	<2	6.55	58	55	11	11
87-158	Topsoil	1	<10	<2	1.27	53	55	11	17
	Oxidized	1	<10	<2	8.22	60	101	15	19
87-159	Topsoil	1	<10	<2	1.88	49	55	11	16
	Oxidized	<1	<10	<2	8.09	53	63	15	15
	Transition	1	<10	<2	4.64	52	54	12	17
87-164A	Topsoil	1	<10	<2	1.29	57	46	12	18
	Oxidized	<1	<10	<2	10.3	44	43	14	11
	Transition	1	<10	<2	5.47	42	41	14	18
	Reduced	1	<10	<2	6.08	58	50	17	14
87-165A	Topsoil	1	<10	<2	1.90	57	58	11	18
	Oxidized	<1	<10	<2	8.50	73	94	18	9

Supplement 5. Chemical analyses of soil horizons in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled	Europium (mg/kg)	Gallium (mg/kg)	Gold (mg/kg)	Holmium (mg/kg)	Iron (percent)	Lanthanum (mg/kg)	Lead (mg/kg)	Lithium (mg/kg)
81-123A	Topsoil	<2	14	<8	<4	2.75	33	16	18
	Oxidized	<2	12	<8	<4	3.14	29	24	19
	Transition	<2	13	<8	<4	2.67	27	12	30
81-129A	Topsoil	<2	11	<8	<4	2.19	30	13	20
	Oxidized	<2	13	<8	<4	3.65	31	30	21
81-130A	Topsoil	<2	12	<8	<4	2.22	26	12	16
	Oxidized	<2	10	<8	<4	2.54	28	32	16
	Transition	<2	14	<8	<4	3.88	31	33	18
87-148	Topsoil	<2	12	<8	<4	2.38	35	13	17
	Oxidized	<2	11	<8	<4	2.73	37	27	16
87-153	Topsoil	<2	12	<8	<4	2.60	35	13	18
	Oxidized	<2	10	<8	<4	2.41	36	18	13
87-155	Topsoil	<2	11	<8	<4	2.48	35	13	17
	Oxidized	<2	10	<8	<4	2.56	32	22	16
87-158	Topsoil	<2	13	<8	<4	2.93	34	16	19
	Oxidized	<2	12	<8	<4	3.54	34	181	18
87-159	Topsoil	<2	12	<8	<4	3.03	31	16	19
	Oxidized	<2	11	<8	<4	3.45	31	64	18
	Transition	<2	11	<8	<4	2.58	30	14	19
87-164A	Topsoil	<2	12	<8	<4	2.55	35	13	17
	Oxidized	<2	11	<8	<4	2.83	25	33	16
	Transition	<2	9	<8	<4	2.55	26	16	15
	Reduced	<2	10	<8	<4	3.59	33	19	14
87-165A	Topsoil	<2	12	<8	<4	2.75	34	13	19
	Oxidized	<2	15	<8	<4	2.80	40	21	14

Supplement 5. Chemical analyses of soil horizons in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled	Magnesium (percent)	Manganese (mg/kg)	Mercury (mg/kg)	Molybdenum (mg/kg)	Neodymium (mg/kg)	Nickel (mg/kg)	Niobium (mg/kg)	Phosphorus (percent)
81-123A	Topsoil	0.80	1,710	0.04	<2	29	28	6	0.08
	Oxidized	3.17	1,540	.05	<2	25	28	5	.08
	Transition	2.05	688	.04	3	23	33	10	.07
81-129A	Topsoil	1.26	844	.02	<2	23	27	5	.09
	Oxidized	2.40	2,230	.10	<2	24	43	6	.09
81-130A	Topsoil	.82	1,510	.04	<2	23	24	6	.10
	Oxidized	1.85	1,000	.04	<2	23	24	<4	.07
	Transition	2.55	3,670	.12	3	25	39	5	.08
87-148	Topsoil	.62	917	.02	<2	28	25	5	.07
	Oxidized	2.35	1,540	.03	<2	28	30	<4	.06
87-153	Topsoil	.61	796	.04	<2	27	20	7	.07
	Oxidized	2.05	1,140	.04	3	29	26	6	.06
87-155	Topsoil	.82	759	.04	<2	28	21	8	.10
	Oxidized	2.26	951	.03	<2	25	23	<4	.06
87-158	Topsoil	.82	993	.04	<2	27	23	8	.09
	Oxidized	2.75	1,630	.06	4	28	36	5	.08
87-159	Topsoil	1.09	964	.04	<2	26	26	7	.11
	Oxidized	2.63	1,530	.06	3	25	29	4	.08
	Transition	1.73	565	.04	<2	26	19	<4	.07
87-164A	Topsoil	.67	1,050	.04	<2	28	24	7	.10
	Oxidized	3.46	1,240	.05	<2	21	23	<4	.07
	Transition	1.91	657	.10	<2	21	34	7	.06
	Reduced	2.00	1,210	.09	<2	27	29	6	.07
87-165A	Topsoil	1.00	954	.04	<2	28	27	9	.10
	Oxidized	2.65	6,240	.04	6	32	43	4	.06

Supplement 5. Chemical analyses of soil horizons in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled	Potassium (percent)	Scandium (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)	Sodium (percent)	Strontium (mg/kg)	Sulfur (percent)	Tantalum (mg/kg)
81-123A	Topsoil	1.59	8	0.4	<2	0.99	168	0.06	<40
	Oxidized	1.18	7	.5	<2	1.04	209	<.05	<40
	Transition	1.67	9	.7	<2	.83	168	.24	<40
81-129A	Topsoil	1.40	6	.2	<2	1.06	237	<.05	<40
	Oxidized	1.25	8	1.4	<2	1.13	279	.07	<40
81-130A	Topsoil	1.49	7	.6	<2	.91	160	.05	<40
	Oxidized	1.32	6	.2	<2	1.22	256	<.05	<40
	Transition	1.26	7	3.5	<2	1.05	244	<.05	<40
87-148	Topsoil	1.59	7	.3	<2	1.11	180	<.05	<40
	Oxidized	1.17	6	.2	<2	.98	204	<.05	<40
87-153	Topsoil	1.61	8	.4	<2	1.02	162	<.05	<40
	Oxidized	1.18	6	.3	<2	1.07	206	<.05	<40
87-155	Topsoil	1.47	7	.6	<2	.86	143	<.05	<40
	Oxidized	1.31	6	.2	<2	1.16	219	<.05	<40
87-158	Topsoil	1.61	9	.5	<2	.94	150	<.05	<40
	Oxidized	1.21	7	.3	<2	1.07	219	<.05	<40
87-159	Topsoil	1.62	8	.6	<2	.95	153	<.05	<40
	Oxidized	1.20	7	.2	<2	1.12	223	<.05	<40
	Transition	1.43	8	.3	<2	1.05	196	<.05	<40
87-164A	Topsoil	1.61	7	.4	<2	1.07	184	<.05	<40
	Oxidized	1.20	6	.2	<2	1.03	210	<.05	<40
	Transition	1.32	6	2.5	<2	1.16	226	<.05	<40
	Reduced	1.24	7	1.0	<2	1.16	223	.51	<40
87-165A	Topsoil	1.54	8	.6	<2	.89	152	.05	<40
	Oxidized	1.08	7	.1	<2	1.03	230	<.05	<40

Supplement 5. Chemical analyses of soil horizons in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled	Thorium (mg/kg)	Tin (mg/kg)	Titanium (percent)	Uranium (mg/kg)	Vanadium (mg/kg)	Ytterbium (mg/kg)	Yttrium (mg/kg)	Zinc (mg/kg)
81-123A	Topsoil	10	<10	0.23	<100	70	2	19	82
	Oxidized	9	<10	.19	<100	69	2	13	49
	Transition	9	<10	.23	<100	106	2	15	73
81-129A	Topsoil	7	<10	.19	<100	63	2	16	60
	Oxidized	8	<10	.21	<100	70	2	19	58
81-130A	Topsoil	8	<10	.20	<100	66	2	16	74
	Oxidized	9	<10	.18	<100	59	2	15	43
	Transition	9	<10	.20	<100	67	2	17	55
87-148	Topsoil	9	<10	.22	<100	73	2	18	67
	Oxidized	10	<10	.19	<100	77	2	16	50
87-153	Topsoil	10	<10	.26	<100	72	2	19	80
	Oxidized	11	<10	.22	<100	64	2	17	42
87-155	Topsoil	9	<10	.23	<100	69	2	18	78
	Oxidized	9	<10	.18	<100	64	2	16	43
87-158	Topsoil	12	<10	.24	<100	73	2	19	95
	Oxidized	10	<10	.22	<100	70	2	17	55
87-159	Topsoil	9	<10	.24	<100	72	2	19	81
	Oxidized	9	<10	.22	<100	69	2	15	54
	Transition	9	<10	.24	<100	84	2	17	55
87-164A	Topsoil	11	<10	.21	<100	65	2	19	81
	Oxidized	8	<10	.15	<100	59	1	13	44
	Transition	7	<10	.17	<100	59	2	18	51
	Reduced	7	<10	.26	<100	68	2	17	52
87-165A	Topsoil	10	<10	.22	<100	76	2	20	87
	Oxidized	13	<10	.23	<100	76	2	18	49

Supplement 5. Chemical analyses of soil horizons in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Date	Latitude-longitude identification number	Township-range identification number	Soil series[1]	Horizon sampled	Aluminum (percent)	Arsenic (mg/kg)	Barium (mg/kg)
87-166A	7-18-90	473707100573402	148-081-23DCC2	Divide	Topsoil	3.75	19	470
					Oxidized	3.57	14	715
					Transition	3.45	9.6	868
					Reduced	4.98	4.8	653
87-177	7-16-90	473424100553801	147-080-07BBB	Russo	Topsoil	4.86	5.3	678
					Oxidized	3.65	14	838
					Transition	2.78	7.6	1,110
					Reduced	5.59	3.1	687
87-184	7-17-90	473305100553801	147-080-18CBB	Russo	Topsoil	5.31	6.4	671
					Oxidized	4.11	9.8	697
					Transition	3.16	10	612
87-186	7-16-90	473404100480701	147-080-12ADD	Tonka	Topsoil	4.89	2.4	673
					Oxidized	5.91	3.4	669
					Transition	5.47	24	585
					Reduced	4.12	19	232
90-1	7-18-90	473635100581302	148-081-26CBB2	Vallens	Topsoil	4.03	4.7	604
					Oxidized	4.07	10	606
					Transition	3.73	52	1,350
					Reduced	5.62	5.6	647
OW-48A	7-17-90	473331100553802	147-080-18BBB2	Manning	Topsoil	4.94	6.6	650
					Oxidized	3.63	9.6	734
					Transition	3.84	12	944

Supplement 5. Chemical analyses of soil horizons in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled	Beryllium (mg/kg)	Bismuth (mg/kg)	Cadmium (mg/kg)	Calcium (percent)	Cerium (mg/kg)	Chromium (mg/kg)	Cobalt (mg/kg)	Copper (mg/kg)
87-166A	Topsoil	<1	<10	<2	13.2	53	54	13	16
	Oxidized	<1	<10	<2	12.1	44	46	14	18
	Transition	1	<10	<2	10.0	50	42	14	22
	Reduced	1	<10	<2	3.93	46	49	12	11
87-177	Topsoil	1	<10	<2	1.15	63	48	11	15
	Oxidized	1	<10	<2	11.0	42	47	13	19
	Transition	1	<10	<2	11.8	30	36	11	8
	Reduced	1	<10	<2	5.18	51	62	12	22
87-184	Topsoil	2	<10	<2	1.70	55	55	13	20
	Oxidized	1	<10	<2	7.22	52	54	16	16
	Transition	<1	<10	<2	11.3	39	36	17	15
87-186	Topsoil	1	<10	<2	1.17	61	48	13	17
	Oxidized	2	<10	<2	1.21	97	90	12	9
	Transition	2	<10	<2	1.01	66	70	18	25
	Reduced	1	<10	<2	5.41	47	50	20	16
90-1	Topsoil	1	<10	<2	3.41	44	38	9	17
	Oxidized	<1	<10	<2	9.92	50	45	10	11
	Transition	1	<10	<2	7.40	46	45	22	12
	Reduced	1	<10	<2	5.11	46	61	12	20
OW-48A	Topsoil	1	<10	<2	2.32	49	50	13	24
	Oxidized	<1	<10	<2	9.64	51	47	18	23
	Transition	1	<10	<2	8.90	44	46	22	19

Supplement 5. Chemical analyses of soil horizons in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled	Europium (mg/kg)	Gallium (mg/kg)	Gold (mg/kg)	Holmium (mg/kg)	Iron (percent)	Lanthanum (mg/kg)	Lead (mg/kg)	Lithium (mg/kg)
87-166A	Topsoil	<2	11	<8	<4	3.51	29	11	22
	Oxidized	<2	13	<8	<4	3.12	26	26	19
	Transition	<2	13	<8	<4	2.42	28	18	17
	Reduced	<2	10	<8	<4	2.42	28	12	17
87-177	Topsoil	<2	12	<8	<4	2.57	35	15	16
	Oxidized	<2	14	<8	<4	3.79	25	23	20
	Transition	<2	15	<8	<4	7.03	18	15	17
	Reduced	<2	14	<8	<4	2.61	30	14	32
87-184	Topsoil	<2	13	<8	<4	2.89	34	17	20
	Oxidized	<2	13	<8	<4	3.02	30	30	20
	Transition	<2	17	<8	<4	2.43	21	15	17
87-186	Topsoil	<2	10	<8	<4	2.13	36	16	18
	Oxidized	<2	15	<8	<4	3.30	53	20	27
	Transition	<2	13	<8	<4	7.33	37	25	23
	Reduced	<2	11	<8	<4	5.43	28	19	20
90-1	Topsoil	<2	10	<8	<4	2.07	26	14	17
	Oxidized	<2	10	<8	<4	1.88	26	8	18
	Transition	<2	15	<8	<4	5.21	25	14	17
	Reduced	<2	13	<8	<4	2.64	27	14	30
OW-48A	Topsoil	<2	12	<8	<4	2.79	30	19	19
	Oxidized	<2	13	<8	<4	2.90	29	29	19
	Transition	<2	15	<8	<4	3.33	25	20	20

Supplement 5. Chemical analyses of soil horizons in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled	Magnesium (percent)	Manganese (mg/kg)	Mercury (mg/kg)	Molybdenum (mg/kg)	Neodymium (mg/kg)	Nickel (mg/kg)	Niobium (mg/kg)	Phosphorus (percent)
87-166A	Topsoil	3.83	1,240	0.04	<2	28	35	<4	0.10
	Oxidized	4.14	3,150	.09	2	21	32	5	.08
	Transition	3.23	3,080	.08	<2	25	30	5	.06
	Reduced	1.48	711	.04	<2	20	27	8	.06
87-177	Topsoil	.60	1,010	.04	<2	30	26	8	.08
	Oxidized	2.05	3,080	.08	4	20	32	6	.09
	Transition	3.20	4,320	.04	5	14	21	4	.12
	Reduced	2.18	851	.06	<2	25	33	9	.06
87-184	Topsoil	.90	1,180	.04	<2	27	29	8	.09
	Oxidized	2.61	1,820	.06	<2	23	39	4	.07
	Transition	4.14	5,670	.06	3	19	43	<4	.06
87-186	Topsoil	.73	236	.02	<2	30	23	8	.06
	Oxidized	.98	348	.04	<2	45	34	8	.08
	Transition	.84	387	.10	9	32	57	8	.09
	Reduced	2.13	877	.09	7	23	50	8	.06
90-1	Topsoil	1.08	1,100	.04	<2	20	21	6	.12
	Oxidized	2.26	535	.04	<2	24	22	<4	.07
	Transition	2.98	4,810	.14	6	27	46	<4	.07
	Reduced	2.32	796	.04	<2	24	30	8	.06
OW-48A	Topsoil	1.06	1,310	.06	<2	25	29	9	.10
	Oxidized	3.25	2,280	.07	<2	24	37	6	.07
	Transition	3.20	3,740	.08	<2	20	37	5	.07

Supplement 5. Chemical analyses of soil horizons in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled	Potassium (percent)	Scandium (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)	Sodium (percent)	Strontium (mg/kg)	Sulfur (percent)	Tantalum (mg/kg)
87-166A	Topsoil	1.08	8	0.2	<2	0.92	194	<0.05	<40
	Oxidized	1.07	7	.2	<2	.83	186	<.05	<40
	Transition	1.07	7	2.3	<2	.73	184	<.05	<40
	Reduced	1.45	7	.4	<2	1.30	226	.25	<40
87-177	Topsoil	1.61	7	.3	<2	1.07	182	<.05	<40
	Oxidized	1.09	7	.1	<2	.87	236	<.05	<40
	Transition	.88	6	.2	<2	.57	179	<.05	<40
	Reduced	1.64	9	.8	<2	.82	174	.26	<40
87-184	Topsoil	1.61	8	.5	<2	.87	147	<.05	<40
	Oxidized	1.15	7	.2	<2	.89	204	<.05	<40
	Transition	.97	5	.1	<2	.75	207	<.05	<40
87-186	Topsoil	1.66	8	.3	<2	.95	164	<.05	<40
	Oxidized	1.79	12	<.1	<2	1.26	206	<.05	<40
	Transition	1.58	10	.9	<2	1.05	177	.07	<40
	Reduced	1.25	8	1.5	<2	.87	163	3.47	<40
90-1	Topsoil	1.39	6	.8	<2	.77	171	.07	<40
	Oxidized	1.17	8	.3	<2	.77	229	<.05	<40
	Transition	1.10	7	.5	<2	.81	174	<.05	<40
	Reduced	1.66	9	.7	<2	.82	169	.25	<40
OW-48A	Topsoil	1.59	8	.5	<2	.86	145	<.05	<40
	Oxidized	1.09	7	.3	<2	.78	193	<.05	<40
	Transition	1.13	7	.5	<2	.75	189	<.05	<40

Supplement 5. Chemical analyses of soil horizons in the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled	Thorium (mg/kg)	Tin (mg/kg)	Titanium (percent)	Uranium (mg/kg)	Vanadium (mg/kg)	Ytterbium (mg/kg)	Yttrium (mg/kg)	Zinc (mg/kg)
87-166A	Topsoil	9	<10	0.21	<100	63	2	14	53
	Oxidized	8	<10	.19	<100	69	1	13	50
	Transition	10	<10	.17	<100	79	2	16	50
	Reduced	7	<10	.24	<100	65	2	15	51
87-177	Topsoil	12	<10	.23	<100	66	2	19	65
	Oxidized	6	<10	.19	<100	81	2	16	55
	Transition	5	<10	.11	<100	74	2	13	46
	Reduced	8	<10	.24	<100	111	2	16	72
87-184	Topsoil	8	<10	.22	<100	81	2	20	99
	Oxidized	7	<10	.20	<100	97	2	15	56
	Transition	7	<10	.12	<100	68	1	12	48
87-186	Topsoil	11	<10	.22	<100	64	2	19	96
	Oxidized	14	<10	.32	<100	126	3	26	86
	Transition	12	<10	.25	<100	133	3	22	108
	Reduced	7	<10	.20	<100	89	2	15	74
90-1	Topsoil	9	<10	.16	<100	55	1	13	91
	Oxidized	8	<10	.18	<100	75	2	14	63
	Transition	13	<10	.18	<100	78	2	17	58
	Reduced	10	<10	.22	<100	106	2	16	72
OW-48A	Topsoil	8	<10	.21	<100	78	2	18	95
	Oxidized	9	<10	.19	<100	87	2	15	51
	Transition	7	<10	.17	<100	93	2	13	56

[1]Brockmann and others, 1979.

Supplement 6. Results of analysis of variance on ranked soils data for the Turtle Lake irrigation area

[Null hypothesis A, the median constituent concentrations in each soil horizon are equal; null hypothesis B, the median constituent concentrations in each soil series are equal; null hypothesis C, the median constituent concentrations in each soil horizon within each soil series are equal]

Constituent	Acceptance or rejection of null hypothesis		
	Null hypothesis A	Null hypothesis B	Null hypothesis C
Aluminum	**REJECT**	**REJECT**	**REJECT**
Arsenic	**REJECT**	**REJECT**	**REJECT**
Barium	**REJECT**	Accept	**REJECT**
Beryllium	**REJECT**	Accept	Accept
Bismuth	Accept	Accept	Accept
Cadmium	Accept	Accept	Accept
Calcium	**REJECT**	**REJECT**	**REJECT**
Cerium	**REJECT**	**REJECT**	Accept
Chromium	Accept	**REJECT**	Accept
Cobalt	**REJECT**	Accept	Accept
Copper	Accept	Accept	Accept
Europium	Accept	Accept	Accept
Gallium	Accept	Accept	Accept
Gold	Accept	Accept	Accept
Holmium	Accept	Accept	Accept
Iron	Accept	Accept	Accept
Lanthanum	**REJECT**	**REJECT**	Accept
Lead	**REJECT**	**REJECT**	**REJECT**
Lithium	Accept	Accept	Accept
Magnesium	**REJECT**	**REJECT**	**REJECT**
Manganese	**REJECT**	**REJECT**	Accept
Mercury	**REJECT**	Accept	Accept
Molybdenum	**REJECT**	Accept	Accept
Neodymium	**REJECT**	**REJECT**	**REJECT**
Nickel	**REJECT**	Accept	Accept
Niobium	**REJECT**	Accept	Accept
Phosphorus	**REJECT**	Accept	Accept
Potassium	**REJECT**	**REJECT**	**REJECT**
Scandium	Accept	**REJECT**	Accept
Selenium	**REJECT**	Accept	Accept
Silver	Accept	Accept	Accept
Sodium	Accept	Accept	Accept
Strontium	**REJECT**	Accept	Accept
Sulfur	**REJECT**	Accept	Accept
Tantalum	Accept	Accept	Accept
Thorium	Accept	**REJECT**	Accept
Tin	Accept	Accept	Accept
Titanium	**REJECT**	**REJECT**	**REJECT**
Uranium	Accept	Accept	Accept
Vanadium	Accept	Accept	Accept
Ytterbium	Accept	**REJECT**	**REJECT**
Yttrium	**REJECT**	**REJECT**	Accept
Zinc	**REJECT**	**REJECT**	Accept

Supplement 7. Chemical analyses of soil extracts from the Turtle Lake irrigation area

[mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram; <, less than]

Identification number	Date	Latitude-longitude identification number	Township-range identification number	Horizon sampled (feet below land surface)	Aluminum (mg/kg)	Antimony (mg/kg)	Arsenic (µg/kg)	Barium (mg/kg)
81-123A	7-17-90	473325100580202	147-081-14BBD2	10.5 to 14	<5	<0.5	7	<0.1
				14 to 18	<5	<.5	7	.5
81-129A	7-19-90	473246100582102	147-081-15DDD2	10 to 14	<5	<.5	<10	.1
81-130A	7-17-90	473305100582102	147-081-15DAA2	0 to 3	<5	<.5	10	.3
				14 to 19	<5	<.5	7	.2
87-153	7-18-90	473758100561902	148-081-13DCC	21 to 23	<5	<.5	<10	.5
87-155	7-18-90	473850100573802	148-081-11DCC	0 to 2	<5	<.5	34	.3
87-159	7-19-90	473817100585102	148-081-15DBB	0 to 0.5	<5	<.5	37	.3
87-164A	7-18-90	473733100593902	148-081-21ADD2	12.5 to 15	<5	<.5	36	.3
				15 to 17	<5	<.5	<10	.6
				17 to 18	<5	<.5	<10	.4
87-165A	7-19-90	473707100562702	148-081-24CBB2	0 to 2	<5	<.5	34	.3
87-177	7-16-90	473424100553801	147-080-07BBB	15 to 19	<5	<.5	8	.6
87-186	7-16-90	473404100480701	147-080-12ADD	5 to 7	<5	<.5	<2	.1
				7 to 8	<5	<.5	<2	.4
				8 to 13	<5	<.5	<2	.3
				13 to 18	<5	<.5	<2	.4
90-1	7-18-90	473635100581302	148-081-26CBB2	0 to 1	<5	<.5	37	.5
				9 to 17	20	<.5	<10	.8

Supplement 7. Chemical analyses of soil extracts from the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Beryllium (mg/kg)	Bismuth (mg/kg)	Boron (mg/kg)	Cadmium (mg/kg)	Calcium (mg/kg)	Cerium (mg/kg)	Chromium (mg/kg)	Cobalt (mg/kg)
81-123A	10.5 to 14	<0.1	<1	<0.5	<0.2	74	<0.4	<0.1	<0.1
	14 to 18	<.1	<1	<.5	<.2	260	<.4	<.1	<.1
81-129A	10 to 14	<.1	<1	.9	<.2	110	<.4	<.1	<.1
81-130A	0 to 3	<.1	<1	<.5	<.2	210	<.4	<.1	<.1
	14 to 19	<.1	<1	<.5	<.2	110	<.4	<.1	<.1
87-153	21 to 23	<.1	<1	<.5	<.2	110	<.4	<.1	<.1
87-155	0 to 2	<.1	<1	<.5	<.2	190	<.4	<.1	<.1
87-159	0 to 0.5	<.1	<1	<.5	<.2	160	<.4	<.1	<.1
87-164A	12.5 to 15	<.1	<1	<.5	<.2	100	<.4	<.1	<.1
	15 to 17	<.1	<1	.5	<.2	290	<.4	<.1	<.1
	17 to 18	<.1	<1	<.5	<.2	520	<.4	<.1	<.1
87-165A	0 to 2	<.1	<1	<.5	<.2	210	<.4	<.1	<.1
87-177	15 to 19	<.1	<1	<.5	<.2	250	<.4	<.1	<.1
87-186	5 to 7	<.1	<1	<.5	<.2	140	<.4	<.1	<.1
	7 to 8	<.1	<1	1	<.2	2,900	<.4	<.1	.3
	8 to 13	<.1	<1	<.5	<.2	3,200	<.4	<.1	.2
	13 to 18	<.1	<1	<.5	<.2	2,200	<.4	<.1	<.1
90-1	0 to 1	<.1	<1	.6	<.2	240	<.4	<.1	<.1
	9 to 17	<.1	<1	<.5	<.2	280	<.4	<.1	<.1

Supplement 7. Chemical analyses of soil extracts from the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Copper (mg/kg)	Iron (mg/kg)	Lanthanum (mg/kg)	Lead (mg/kg)	Lithium (mg/kg)	Magnesium (mg/kg)	Manganese (mg/kg)	Molybdenum (mg/kg)
81-123A	10.5 to 14	<0.1	<5	<0.2	<0.4	<0.2	30	<0.4	<0.2
	14 to 18	<.1	<5	<.2	<.4	.3	65	.4	.4
81-129A	10 to 14	<.1	<5	<.2	<.4	<.2	50	<.4	<.2
81-130A	0 to 3	<.1	<5	<.2	<.4	<.2	30	<.4	<.2
	14 to 19	<.1	<5	<.2	<.4	<.2	40	<.4	<.2
87-153	21 to 23	<.1	<5	<.2	<.4	<.2	40	<.4	<.2
87-155	0 to 2	<.1	<5	<.2	<.4	<.2	50	<.4	<.2
87-159	0 to 0.5	<.1	<5	<.2	<.4	<.2	50	<.4	<.2
87-164A	12.5 to 15	<.1	<5	<.2	<.4	<.2	40	<.4	<.2
	15 to 17	<.1	<5	<.2	<.4	<.2	81	.7	<.2
	17 to 18	<.1	<5	<.2	<.4	<.2	130	1	<.2
87-165A	0 to 2	<.1	<5	<.2	<.4	<.2	50	<.4	<.2
87-177	15 to 19	<.1	<5	<.2	<.4	.3	62	.7	.4
87-186	5 to 7	<.1	<5	<.2	<.4	<.2	80	<.4	.3
	7 to 8	<.1	<5	<.2	<.4	.3	1,600	20	<.2
	8 to 13	<.1	<5	<.2	<.4	.2	1,200	20	<.2
	13 to 18	<.1	<5	<.2	<.4	.2	410	20	.2
90-1	0 to 1	<.1	<5	<.2	<.4	<.2	77	<.4	<.2
	9 to 17	<.1	10	<.2	<.4	.3	57	.7	.3

Supplement 7. Chemical analyses of soil extracts from the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Nickel (mg/kg)	Phosphorus (mg/kg)	Potassium (mg/kg)	Selenium (µg/kg)	Silicon (mg/kg)	Silver (mg/kg)	Sodium (mg/kg)	Strontium (mg/kg)
81-123A	10.5 to 14	<0.2	<5	20	<1	40	<0.2	130	<0.2
	14 to 18	<.2	<5	98	25	40	<.2	50	.9
81-129A	10 to 14	<.2	<5	20	8	59	<.2	150	1
81-130A	0 to 3	<.2	<5	58	3	72	<.2	10	.3
	14 to 19	<.2	<5	30	3	40	<.2	54	.7
87-153	21 to 23	<.2	<5	20	8	62	<.2	20	.3
87-155	0 to 2	<.2	<5	30	15	69	<.2	8	.3
87-159	0 to 0.5	<.2	<5	40	13	65	<.2	6	.3
87-164A	12.5 to 15	<.2	<5	20	18	57	<.2	20	.4
	15 to 17	<.2	<5	40	44	40	<.2	20	.7
	17 to 18	<.2	<5	40	33	40	<.2	30	1
87-165A	0 to 2	<.2	<5	20	15	59	<.2	7	.3
87-177	15 to 19	<.2	<5	89	18	40	<.2	30	.7
87-186	5 to 7	<.2	<5	61	9	54	<.2	60	.5
	7 to 8	<.2	<5	120	8	30	<.2	65	6
	8 to 13	.4	<5	120	9	40	<.2	70	5
	13 to 18	<.2	<5	110	4	30	<.2	50	4
90-1	0 to 1	<.2	<5	140	20	99	<.2	20	.8
	9 to 17	<.2	<5	100	55	50	<.2	40	1

Supplement 7. Chemical analyses of soil extracts from the Turtle Lake irrigation area—Continued

[mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Thorium (mg/kg)	Tin (mg/kg)	Titanium (mg/kg)	Vanadium (mg/kg)	Wolfram (mg/kg)	Yttrium (mg/kg)	Zinc (mg/kg)	Zirconium (mg/kg)
81-123A	10.5 to 14	<0.4	<0.5	<5	<0.2	<0.5	<0.2	<0.2	<0.2
	14 to 18	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
81-129A	10 to 14	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
81-130A	0 to 3	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
	14 to 19	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
87-153	21 to 23	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
87-155	0 to 2	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
87-159	0 to 0.5	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
87-164A	12.5 to 15	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
	15 to 17	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
	17 to 18	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
87-165A	0 to 2	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
87-177	15 to 19	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
87-186	5 to 7	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
	7 to 8	<.4	<.5	<5	<.2	<.5	<.2	.7	<.2
	8 to 13	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
	13 to 18	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
90-1	0 to 1	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
	9 to 17	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2

Supplement 8. Chemical analyses of water from wells in the Turtle Lake irrigation area

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; mg/L, milligrams per liter; IT, incremental titration; <, less than; µg/L, micrograms per liter]

Identification number	Date	Latitude-longitude identification number	Township-range identification number	Altitude of screen bottom (feet)	Water-level elevation (feet)	Type of well	Specific conductance (µS/cm)	pH (standard units)
81-123A	9-13-90	473325100580202	147-081-14BBD2	1,831.3	1,834.3	Shallow	1,040	7.44
81-129A	9-18-90	473246100582102	147-081-15DDD2	1,818.8	1,821.8	Shallow	690	7.73
81-130A	9-18-90	473305100582102	147-081-15DAA2	1,823.0	1,826.7	Shallow	690	7.63
87-148	9-13-90	473509100535301	147-080-05BAD	1,840.2	1,845.0	Deep	750	7.52
87-164	9-19-90	473733100593901	148-081-21ADD1	1,829.7	1,837.9	Deep	590	7.10
87-164A	9-19-90	473733100593902	148-081-21ADD2	1,834.2	1,837.9	Shallow	560	7.45
87-165	9-18-90	473707100562701	148-081-24CBB1	1,832.2	1,847.7	Deep	560	7.41
87-165A	9-18-90	473707100562702	148-081-24CBB2	1,846.2	1,847.7	Shallow	630	7.45
87-166	9-21-90	473707100573401	148-081-23DCC1	1,821.1	1,846.3	Deep	518	7.49
87-166A	9-21-90	473707100573402	148-081-23DCC2	1,841.0	1,846.3	Shallow	346	8.01
87-177	9-12-90	473424100553801	147-080-07BBB	1,842.7	1,846.2	Shallow	870	7.29
87-184	9-13-90	473305100553801	147-080-18CBB	1,835.4	1,838.6	Shallow	720	7.79
87-186	9-12-90	473404100480701	147-080-12ADD	1,830.3	1,843.2	Deep	990	7.22
90-1	9-19-90	473635100581302	148-081-26CBB2	1,834.0	1,838.4	Shallow	510	7.87
OW-48A	9-12-90	473331100553802	147-080-18BBB2	1,837.1	1,840.5	Shallow	442	7.99

Supplement 8. Chemical analyses of water from wells in the Turtle Lake irrigation area—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; mg/L, milligrams per liter; IT, incremental titration; <, less than; µg/L, micrograms per liter]

Identification number	Date	Temperature, water (deg C)	Oxygen, dissolved (mg/L)	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Potassium, dissolved (mg/L)	Carbonate, dissolved, IT-field (mg/L as CO_3)	Bicarbonate, dissolved IT-field (mg/L as HCO_3)	Sulfate, dissolved (mg/L as SO_4)	Sulfide, dissolved (mg/L as S)
81-123A	9-13-90	14.6	0.19	76	34	120	4.5	0	342	300	0.001
81-129A	9-18-90	14.8	5.4	47	27	65	2.6	0	365	24	.003
81-130A	9-18-90	14.3	2.2	64	36	39	3.3	0	325	85	.006
87-148	9-13-90	10.9	1.9	97	38	11	3.1	0	337	36	.003
87-164	9-19-90	14.7	.18	78	30	11	3.6	0	322	67	.004
87-164A	9-19-90	16.0	3.9	64	31	8.6	3.1	0	251	30	.010
87-165	9-18-90	11.8	.14	77	27	9.2	3.9	0	308	58	.003
87-165A	9-18-90	14.2	1.4	82	32	6.6	4.0	0	304	42	.009
87-166	9-21-90	8.3	.28	78	26	10	3.1	0	314	75	.003
87-166A	9-21-90	12.4	.37	49	11	.7	13	0	164	55	<.001
87-177	9-12-90	19.6	.37	130	39	17	4.6	0	410	190	.007
87-184	9-13-90	12.3	2.8	70	51	8.4	2.5	0	273	80	.006
87-186	9-12-90	10.3	.08	110	50	35	11	0	576	76	.005
90-1	9-19-90	21.4	5.3	69	22	8.2	1.4	0	256	57	.007
OW-48A	9-12-90	18.6	.45	37	36	2.9	1.1	0	271	19	.006

Supplement 8. Chemical analyses of water from wells in the Turtle Lake irrigation area—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; mg/L, milligrams per liter; IT, incremental titration; <, less than; µg/L, micrograms per liter]

Identification number	Date	Chloride, dissolved (mg/L)	Fluoride, dissolved (mg/L as SiO_2)	Silica dissolved (mg/L)	Nitrite, dissolved (mg/L as N)	Nitrite plus nitrate, dissolved (mg/L as N)	Ammonia, dissolved (mg/L as N)	Orthophosphorus, dissolved (mg/L as P)	Arsenic, dissolved (µg/L)	Boron, dissolved (µg/L)
81-123A	9-13-90	15	0.5	25	0.003	0.05	0.01	0.01	1	210
81-129A	9-18-90	3.9	.2	26	.026	15	<.01	<.01	<1	300
81-130A	9-18-90	6.0	<.1	27	.026	.06	.04	<.01	1	180
87-148	9-13-90	4.3	.2	26	.001	.04	<.01	.09	2	70
87-164	9-19-90	5.6	<.1	20	.002	.04	.03	<.01	1	60
87-164A	9-19-90	4.0	.1	30	.002	18	.01	<.01	<1	90
87-165	9-18-90	4.0	<.1	28	.002	.03	.05	<.01	4	40
87-165A	9-18-90	4.1	<.1	28	.013	.03	.01	.01	1	40
87-166	9-21-90	11	<.1	27	<.001	<.01	.20	.02	27	70
87-166A	9-21-90	4.4	<.1	20	<.001	<.01	.38	<.01	1	20
87-177	9-12-90	8.7	.2	32	.002	.10	.05	<.01	<1	50
87-184	9-13-90	12	.2	28	.001	22	<.01	<.01	<1	50
87-186	9-12-90	4.7	.2	23	.001	<.01	.05	<.01	4	50
90-1	9-19-90	2.7	<.1	26	.023	1.1	.02	<.01	<1	50
OW-48A	9-12-90	2.6	.2	29	.035	12	<.01	<.01	1	30

Supplement 8. Chemical analyses of water from wells in the Turtle Lake irrigation area—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; mg/L, milligrams per liter; IT, incremental titration; <, less than; µg/L, micrograms per liter]

Identification number	Date	Iron, dissolved (µg/L as Fe)	Ferrous iron, dissolved (µg/L as Fe)	Lithium, dissolved (µg/L)	Manganese, dissolved (µg/L)	Mercury, dissolved (µg/L)	Molybdenum, dissolved (µg/L)	Selenium, dissolved (µg/L)	Strontium, dissolved (µg/L)	Organic carbon, dissolved (mg/L)
81-123A	9-13-90	5	10	62	210	<0.1	2	<1	110	2.6
81-129A	9-18-90	<3	10	45	27	<.1	3	1	390	3.2
81-130A	9-18-90	<3	<10	35	110	<.1	<1	1	430	2.0
87-148	9-13-90	<3	10	15	<1	<.1	<1	2	99	1.9
87-164	9-19-90	61	80	21	620	<.1	<1	<1	220	2.9
87-164A	9-19-90	<3	<10	18	1	<.1	<1	3	230	2.3
87-165	9-18-90	310	310	17	290	<.1	<1	<1	220	1.4
87-165A	9-18-90	<3	10	14	1	<.1	<1	<1	140	1.7
87-166	9-21-90	970	1,040	22	630	<.1	4	<1	340	3.2
87-166A	9-21-90	37	40	4	2,600	<.1	3	<1	91	3.3
87-177	9-12-90	44	40	25	1,400	<.1	2	<1	290	5.9
87-184	9-13-90	<3	<10	21	<1	<.1	2	2	290	1.9
87-186	9-12-90	800	770	48	180	<.1	2	<1	390	3.7
90-1	9-19-90	4	<10	17	580	.1	4	<1	160	2.7
OW-48A	9-12-90	9	<10	10	4	<.1	5	<1	110	2.1

Supplement 9. Results of Wilcoxon's rank sum tests between the shallow and deep parts of the aquifer underlying the Turtle Lake irrigation area

[Null hypothesis: the median constituent concentrations for the shallow and deep wells are equal]

Constituent	Acceptance or rejection of null hypothesis
Specific conductance	Accept
pH	**REJECT**
Temperature, water	**REJECT**
Oxygen, dissolved	**REJECT**
Calcium, dissolved	**REJECT**
Magnesium, dissolved	Accept
Sodium, dissolved	Accept
Potassium, dissolved	Accept
Bicarbonate, dissolved	Accept
Sulfate, dissolved	Accept
Chloride, dissolved	Accept
Fluoride, dissolved	Accept
Silica, dissolved	Accept
Nitrite, dissolved	**REJECT**
Nitrite plus nitrate, dissolved	**REJECT**
Ammonia, dissolved	Accept
Orthophosphorus, dissolved	Accept
Arsenic, dissolved	**REJECT**
Boron, dissolved	Accept
Iron, dissolved	**REJECT**
Lithium, dissolved	Accept
Manganese, dissolved	Accept
Mercury, dissolved	Accept
Molybdenum, dissolved	Accept
Selenium, dissolved	Accept
Strontium, dissolved	Accept
Organic carbon, dissolved	Accept

Supplement 10. Chemical analyses of soils in the New Rockford irrigation area

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Date	Latitude-longitude identification number	Township-range identification number	Horizon sampled (feet below land surface)	Aluminum (percent)	Arsenic (mg/kg)	Barium (mg/kg)
NR23C	7-11-90	474628099010304	150-065-29CCC4	0 to 1	2.34	3.0	415
				1 to 2.5	2.34	4.1	391
				2.5 to 4	4.46	4.8	587
				4 to 7	3.39	37	1,540
				7 to 11	4.34	11	588
				11 to 15	4.36	8.9	973
				15 to 18	4.22	12	316
NR32	7-13-90	474302099123803	149-067-14CCC3	0 to 2	4.74	5.7	651
				2 to 3	4.60	7.1	676
				3 to 7.5	4.59	13	685
				7.5 to 9.5	4.46	15	708
				9.5 to 14	3.88	26	716
				14 to 18	6.09	4.4	778
NR45	7-12-90	474209099060201	149-066-22CCD1	0 to 1	5.10	6.6	680
				1 to 3	5.13	10	702
				3 to 7.5	5.25	9.7	765
				7.5 to 10.5	5.13	6.8	829
				10.5 to 13	4.93	4.4	728
NR55	7-12-90	474505099042601	149-066-02CAA1	0 to 2	4.64	3.3	687
				2 to 3	5.22	6.4	738
				3 to 9	4.39	5.8	635
				9 to 11	4.82	4.8	710
				11 to 13	4.84	6.8	1,030
				13 to 14	5.02	4.3	740
NR68	7-12-90	474412099023001	149-066-12DAA1	0 to 1	5.05	4.2	673
				1 to 2.5	3.72	5.1	605
				2.5 to 4	5.00	10	737
				4 to 5.5	5.75	5.4	872
				5.5 to 9	5.32	10	969

Supplement 10. Chemical analyses of soils in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Beryllium (mg/kg)	Bismuth (mg/kg)	Cadmium (mg/kg)	Calcium (percent)	Cerium (mg/kg)	Chromium (mg/kg)	Cobalt (mg/kg)	Copper (mg/kg)
NR23C	0 to 1	<1	<10	<2	14.8	25	23	5	10
	1 to 2.5	<1	<10	<2	21.6	28	26	5	8
	2.5 to 4	1	<10	<2	7.64	63	50	12	7
	4 to 7	1	<10	<2	12.4	42	40	18	14
	7 to 11	1	<10	<2	7.76	46	66	16	18
	11 to 15	1	<10	<2	6.87	51	58	16	15
	15 to 18	1	<10	<2	6.71	55	52	15	14
NR32	0 to 2	1	<10	<2	1.36	49	46	11	17
	2 to 3	1	<10	<2	8.47	52	47	13	22
	3 to 7.5	1	<10	<2	8.45	45	60	26	21
	7.5 to 9.5	1	<10	<2	9.41	66	57	26	23
	9.5 to 14	1	<10	<2	10.7	56	49	32	30
	14 to 18	1	<10	<2	3.71	49	66	13	21
NR45	0 to 1	1	<10	<2	1.12	48	50	11	17
	1 to 3	1	<10	<2	5.59	60	53	20	16
	3 to 7.5	1	<10	<2	4.45	67	60	16	10
	7.5 to 10.5	1	<10	<2	5.02	47	53	19	14
	10.5 to 13	1	<10	<2	3.28	45	44	9	13
NR55	0 to 2	1	<10	<2	1.47	46	46	10	14
	2 to 3	1	<10	<2	2.70	49	48	9	11
	3 to 9	1	<10	<2	4.86	83	48	10	8
	9 to 11	1	<10	<2	4.62	69	55	18	8
	11 to 13	1	<10	<2	5.58	47	52	17	17
	13 to 14	1	<10	<2	3.34	45	47	11	7
NR68	0 to 1	1	<10	<2	1.40	58	50	11	11
	1 to 2.5	<1	<10	<2	12.4	40	37	8	9
	2.5 to 4	1	<10	<2	4.97	52	47	14	11
	4 to 5.5	2	<10	<2	3.37	48	51	16	18
	5.5 to 9	1	<10	<2	4.70	55	44	19	15

Supplement 10. Chemical analyses of soils in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Europium (mg/kg)	Gallium (mg/kg)	Gold (mg/kg)	Holmium (mg/kg)	Iron (percent)	Lanthanum (mg/kg)	Lead (mg/kg)	Lithium (mg/kg)
NR23C	0 to 1	<2	6	<8	<4	1.10	15	9	24
	1 to 2.5	<2	5	<8	<4	1.32	16	7	20
	2.5 to 4	<2	11	<8	<4	2.50	34	14	23
	4 to 7	<2	16	<8	<4	4.45	24	38	18
	7 to 11	<2	13	<8	<4	3.86	27	50	20
	11 to 15	<2	12	<8	<4	3.50	29	37	19
	15 to 18	<2	11	<8	<4	3.70	30	19	16
NR32	0 to 2	<2	12	<8	<4	2.43	30	14	18
	2 to 3	<2	12	<8	<4	2.62	32	15	21
	3 to 7.5	<2	13	<8	<4	4.00	27	31	22
	7.5 to 9.5	<2	14	<8	<4	4.13	35	25	23
	9.5 to 14	<2	16	<8	<4	4.75	30	22	18
	14 to 18	<2	15	<8	<4	2.91	28	16	33
NR45	0 to 1	<2	13	<8	<4	2.64	31	16	21
	1 to 3	<2	13	<8	<4	3.35	34	17	22
	3 to 7.5	<2	12	<8	<4	2.75	37	15	17
	7.5 to 10.5	<2	14	<8	<4	2.69	27	19	19
	10.5 to 13	<2	11	<8	<4	2.04	25	14	22
NR55	0 to 2	<2	11	<8	<4	2.03	27	14	18
	2 to 3	<2	11	<8	<4	1.78	28	13	20
	3 to 9	<2	10	<8	<4	2.54	43	16	14
	9 to 11	<2	11	<8	<4	2.58	36	17	17
	11 to 13	<2	12	<8	<4	2.66	27	18	18
	13 to 14	<2	11	<8	<4	2.30	26	12	16
NR68	0 to 1	<2	12	<8	<4	2.36	33	13	19
	1 to 2.5	<2	8	<8	<4	1.61	24	11	20
	2.5 to 4	<2	13	<8	<4	2.53	28	21	19
	4 to 5.5	<2	14	<8	<4	2.33	27	20	21
	5.5 to 9	<2	16	<8	<4	2.78	30	19	19

Supplement 10. Chemical analyses of soils in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Magnesium (percent)	Manganese (mg/kg)	Mercury (mg/kg)	Molybdenum (mg/kg)	Neodymium (mg/kg)	Nickel (mg/kg)	Niobium (mg/kg)	Phosphorus (percent)
NR23C	0 to 1	3.37	510	0.02	<2	13	11	5	0.10
	1 to 2.5	1.86	392	<.02	<2	15	12	4	.07
	2.5 to 4	2.58	952	.04	<2	28	23	<4	.05
	4 to 7	3.28	5,960	.04	12	22	35	<4	.08
	7 to 11	2.61	1,850	.04	<2	23	35	4	.07
	11 to 15	2.41	1,480	.04	<2	25	37	<4	.07
	15 to 18	2.20	1,510	.04	<2	24	40	<4	.07
NR32	0 to 2	.68	969	.04	<2	25	25	7	.10
	2 to 3	1.64	886	.08	<2	26	31	6	.11
	3 to 7.5	3.08	1,490	.06	<2	22	46	5	.07
	7.5 to 9.5	2.77	2,070	.08	<2	29	54	<4	.06
	9.5 to 14	3.09	3,800	.08	3	26	61	5	.08
	14 to 18	1.71	580	.06	<2	24	34	8	.07
NR45	0 to 1	.62	797	.06	<2	26	27	8	.10
	1 to 3	2.69	1,240	.08	<2	29	50	<4	.08
	3 to 7.5	1.44	723	.08	<2	31	37	<4	.06
	7.5 to 10.5	1.95	1,510	.08	<2	18	42	8	.06
	10.5 to 13	1.38	426	.04	<2	22	23	6	.07
NR55	0 to 2	.86	920	.02	<2	22	18	6	.06
	2 to 3	1.56	309	.02	<2	24	22	<4	.07
	3 to 9	2.12	782	.02	<2	37	24	<4	.06
	9 to 11	2.06	576	.02	<2	31	30	<4	.05
	11 to 13	2.02	1,310	.04	<2	23	48	<4	.06
	13 to 14	1.11	580	<.02	<2	22	27	<4	.06
NR68	0 to 1	.74	724	.02	<2	27	25	6	.05
	1 to 2.5	2.44	381	.02	<2	19	20	<4	.05
	2.5 to 4	1.74	761	.04	<2	24	32	<4	.06
	4 to 5.5	1.37	819	.06	<2	22	37	7	.05
	5.5 to 9	1.69	2,800	.06	2	27	39	4	.06

Supplement 10. Chemical analyses of soils in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Potassium (percent)	Scandium (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)	Sodium (percent)	Strontium (mg/kg)	Sulfur (percent)	Tantalum (mg/kg)
NR23C	0 to 1	0.87	3	0.9	<2	0.59	408	0.11	<40
	1 to 2.5	.81	4	.3	<2	.55	420	.06	<40
	2.5 to 4	1.42	7	<.1	<2	1.05	213	<.05	<40
	4 to 7	1.11	6	.4	<2	.75	206	<.05	<40
	7 to 11	1.39	8	1.2	<2	1.02	225	.53	<40
	11 to 15	1.39	8	.6	<2	1.07	225	.54	<40
	15 to 18	1.38	7	.6	<2	1.18	242	.67	<40
NR32	0 to 2	1.56	7	.5	<2	.94	169	<.05	<40
	2 to 3	1.35	8	.4	<2	.97	207	<.05	<40
	3 to 7.5	1.31	9	.2	<2	1.12	251	<.05	<40
	7.5 to 9.5	1.26	9	.2	<2	1.09	237	<.05	<40
	9.5 to 14	1.16	7	1.0	<2	1.01	237	<.05	<40
	14 to 18	1.78	10	.6	<2	1.06	217	.24	<40
NR45	0 to 1	1.67	8	.5	<2	.94	164	<.05	<40
	1 to 3	1.57	9	.2	<2	1.20	227	<.05	<40
	3 to 7.5	1.37	8	<.1	<2	1.54	307	<.05	<40
	7.5 to 10.5	1.43	7	.7	<2	1.40	282	<.05	<40
	10.5 to 13	1.61	7	.3	<2	1.23	217	.18	<40
NR55	0 to 2	1.61	6	.3	<2	1.11	187	.05	<40
	2 to 3	1.60	7	<.1	<2	1.35	217	<.05	<40
	3 to 9	1.33	7	.1	<2	1.39	244	<.05	<40
	9 to 11	1.40	7	.2	<2	1.36	251	<.05	<40
	11 to 13	1.37	7	.9	<2	1.31	257	<.05	<40
	13 to 14	1.39	7	.5	<2	1.61	295	.16	<40
NR68	0 to 1	1.61	7	.2	<2	1.18	212	<.05	<40
	1 to 2.5	1.17	5	.1	<2	.96	332	<.05	<40
	2.5 to 4	1.47	7	.2	<2	1.46	290	<.05	<40
	4 to 5.5	1.66	8	.8	<2	1.55	319	<.05	<40
	5.5 to 9	1.55	7	.9	<2	1.53	316	<.05	<40

Supplement 10. Chemical analyses of soils in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Thorium (mg/kg)	Tin (mg/kg)	Titanium (percent)	Uranium (mg/kg)	Vanadium (mg/kg)	Ytterbium (mg/kg)	Yttrium (mg/kg)	Zinc (mg/kg)
NR23C	0 to 1	<4	<10	0.10	<100	32	<1	7	64
	1 to 2.5	5	<10	.10	<100	32	<1	7	34
	2.5 to 4	9	<10	.16	<100	80	2	16	47
	4 to 7	8	<10	.13	<100	70	2	15	56
	7 to 11	9	<10	.21	<100	84	2	15	53
	11 to 15	12	<10	.21	<100	80	2	16	51
	15 to 18	8	<10	.21	<100	69	2	15	61
NR32	0 to 2	8	<10	.21	<100	64	2	18	75
	2 to 3	9	<10	.23	<100	69	2	17	53
	3 to 7.5	6	<10	.21	<100	77	2	16	69
	7.5 to 9.5	8	<10	.18	<100	85	2	16	74
	9.5 to 14	10	<10	.18	<100	71	2	16	68
	14 to 18	7	<10	.25	<100	105	2	17	68
NR45	0 to 1	8	<10	.22	<100	70	2	19	83
	1 to 3	10	<10	.21	<100	77	2	18	60
	3 to 7.5	12	<10	.30	<100	72	2	18	55
	7.5 to 10.5	<4	<10	.22	<100	69	2	15	60
	10.5 to 13	7	<10	.21	<100	65	2	15	48
NR55	0 to 2	8	<10	.19	<100	58	2	15	74
	2 to 3	7	<10	.19	<100	71	2	16	44
	3 to 9	17	<10	.26	<100	62	2	20	41
	9 to 11	12	<10	.21	<100	71	2	16	60
	11 to 13	7	<10	.22	<100	81	2	16	58
	13 to 14	7	<10	.26	<100	61	2	16	45
NR68	0 to 1	9	<10	.22	<100	64	2	17	66
	1 to 2.5	6	<10	.12	<100	54	2	12	30
	2.5 to 4	7	<10	.19	<100	68	2	15	49
	4 to 5.5	6	<10	.21	<100	76	2	16	58
	5.5 to 9	9	<10	.19	<100	67	2	17	54

Supplement 10. Chemical analyses of soils in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Date	Latitude-longitude identification number	Township-range identification number	Horizon sampled (feet below land surface)	Aluminum (percent)	Arsenic (mg/kg)	Barium (mg/kg)
NR75A	7-12-90	474714099014202	150-065-30ABB2	0 to 2	4.57	5.3	645
				2 to 4	4.43	5.3	617
				4 to 9.5	4.03	10	595
				9.5 to 13	3.97	8.1	736
				13 to 16	5.30	2.9	992
				16 to 18.5	5.86	5.1	306
NR79A	7-10-90	474621098583502	150-065-33AAA2	0 to 1.5	4.55	3.9	596
				1.5 to 4	3.87	2.7	412
				4 to 9	4.07	4.4	437
				9 to 11	4.01	6.1	570
				11 to 13	4.65	6.6	696
				13 to 17	5.68	4.6	931
				17 to 18	4.72	3.7	774
NR86A	7-11-90	474647098571702	150-065-27DAA2	0 to 2	4.64	5.5	673
				2 to 3.5	5.29	3.3	674
				3.5 to 6	4.21	3.9	517
				6 to 8	3.65	4.2	440
				8 to 12	3.93	6.2	485
				12 to 14	3.99	6.0	601
				14 to 15.5	3.84	3.6	526
				15.5 to 18	3.73	4.8	485
NR89A	7-10-90	474505098572102	149-065-03DAA2	0 to 2	4.23	4.0	668
				2 to 7	3.81	2.7	406
				7 to 9	4.25	5.1	468
				9 to 11.5	4.40	3.1	580
				11.5 to 13	4.24	4.5	570
				13 to 18	4.54	6.5	576

Supplement 10. Chemical analyses of soils in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Beryllium (mg/kg)	Bismuth (mg/kg)	Cadmium (mg/kg)	Calcium (percent)	Cerium (mg/kg)	Chromium (mg/kg)	Cobalt (mg/kg)	Copper (mg/kg)
NR75A	0 to 2	1	<10	<2	1.70	53	48	10	15
	2 to 4	1	<10	<2	6.54	62	57	15	20
	4 to 9.5	<1	<10	<2	8.15	77	51	11	7
	9.5 to 13	2	<10	<2	5.54	83	71	14	129
	13 to 16	2	<10	<2	2.18	75	80	14	59
	16 to 18.5	2	<10	<2	2.03	62	82	25	35
NR79A	0 to 1.5	1	<10	<2	1.08	48	52	11	17
	1.5 to 4	1	<10	<2	5.36	45	53	15	16
	4 to 9	1	<10	<2	2.66	47	63	18	16
	9 to 11	1	<10	<2	3.46	50	60	20	24
	11 to 13	1	<10	<2	3.87	61	51	15	12
	13 to 17	1	<10	<2	3.81	48	59	11	14
	17 to 18	1	<10	<2	3.42	54	42	9	8
NR86A	0 to 2	1	<10	<2	1.18	45	47	10	14
	2 to 3.5	1	<10	<2	.96	60	63	13	14
	3.5 to 6	1	<10	<2	4.70	67	63	15	15
	6 to 8	1	<10	<2	8.39	40	51	13	14
	8 to 12	1	<10	<2	6.59	52	51	13	13
	12 to 14	1	<10	<2	5.80	56	52	24	18
	14 to 15.5	1	<10	<2	6.09	47	50	18	20
	15.5 to 18	1	<10	<2	7.15	45	51	25	24
NR89A	0 to 2	<1	<10	<2	3.04	59	40	12	8
	2 to 7	1	<10	<2	5.75	44	52	13	15
	7 to 9	1	<10	<2	4.15	47	52	20	17
	9 to 11.5	1	<10	<2	3.94	47	36	10	9
	11.5 to 13	1	<10	<2	4.41	51	46	18	14
	13 to 18	1	<10	<2	1.23	47	51	11	19

Supplement 10. Chemical analyses of soils in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Europium (mg/kg)	Gallium (mg/kg)	Gold (mg/kg)	Holmium (mg/kg)	Iron (percent)	Lanthanum (mg/kg)	Lead (mg/kg)	Lithium (mg/kg)
NR75A	0 to 2	<2	11	<8	<4	2.09	30	14	16
	2 to 4	<2	12	<8	<4	2.25	35	15	19
	4 to 9.5	<2	10	<8	<4	2.66	40	24	13
	9.5 to 13	<2	13	<8	<4	3.31	44	37	17
	13 to 16	<2	14	<8	<4	2.84	40	22	24
	16 to 18.5	<2	15	<8	<4	3.75	33	19	31
NR79A	0 to 1.5	<2	11	<8	<4	2.16	29	15	17
	1.5 to 4	<2	12	<8	<4	1.98	25	13	25
	4 to 9	<2	14	<8	<4	2.17	26	27	27
	9 to 11	<2	16	<8	<4	2.27	26	25	25
	11 to 13	<2	12	<8	<4	2.24	31	18	18
	13 to 17	<2	13	<8	<4	2.36	28	12	26
	17 to 18	<2	10	<8	<4	1.89	30	12	16
NR86A	0 to 2	<2	11	<8	<4	1.94	26	13	14
	2 to 3.5	<2	13	<8	<4	2.53	35	14	20
	3.5 to 6	<2	12	<8	<4	2.34	38	16	22
	6 to 8	<2	11	<8	<4	1.99	23	13	21
	8 to 12	<2	11	<8	<4	2.22	30	17	18
	12 to 14	<2	15	<8	<4	2.34	31	18	21
	14 to 15.5	<2	14	<8	<4	2.10	26	18	22
	15.5 to 18	<2	16	<8	<4	2.55	25	19	23
NR89A	0 to 2	<2	10	<8	<4	1.90	34	15	14
	2 to 7	<2	14	<8	<4	1.98	25	18	26
	7 to 9	<2	13	<8	<4	2.10	26	20	23
	9 to 11.5	<2	11	<8	<4	1.45	26	13	14
	11.5 to 13	<2	13	<8	<4	1.90	29	19	18
	13 to 18	<2	13	<8	<4	2.21	29	14	17

Supplement 10. Chemical analyses of soils in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Magnesium (percent)	Manganese (mg/kg)	Mercury (mg/kg)	Molybdenum (mg/kg)	Neodymium (mg/kg)	Nickel (mg/kg)	Niobium (mg/kg)	Phosphorus (percent)
NR75A	0 to 2	0.58	959	0.02	<2	25	21	5	0.07
	2 to 4	1.00	1,850	.06	<2	31	46	<4	.08
	4 to 9.5	2.87	1,050	.02	<2	35	24	<4	.06
	9.5 to 13	2.16	1,410	.32	<2	38	59	14	.08
	13 to 16	1.07	1,540	.16	<2	35	56	10	.07
	16 to 18.5	1.26	694	.06	<2	28	55	10	.06
NR79A	0 to 1.5	.59	1,340	.06	<2	24	26	6	.08
	1.5 to 4	1.20	2,260	.04	<2	22	44	<4	.04
	4 to 9	1.42	2,600	.04	<2	23	45	<4	.03
	9 to 11	1.60	4,560	.08	<2	22	52	<4	.04
	11 to 13	1.51	1,900	.04	<2	26	48	<4	.05
	13 to 17	1.69	498	.04	<2	24	29	5	.07
	17 to 18	1.22	433	.02	<2	25	21	<4	.06
NR86A	0 to 2	.50	1,110	.04	<2	22	22	6	.07
	2 to 3.5	.64	1,140	.04	<2	31	27	<4	.06
	3.5 to 6	1.52	1,710	.06	<2	29	34	<4	.05
	6 to 8	1.58	1,610	.04	<2	19	34	<4	.04
	8 to 12	1.90	1,040	.04	<2	25	28	<4	.05
	12 to 14	2.28	3,880	.06	<2	27	56	<4	.05
	14 to 15.5	2.62	3,370	.06	<2	22	49	<4	.04
	15.5 to 18	3.06	5,190	.06	<2	20	65	<4	.05
NR89A	0 to 2	1.05	576	.04	<2	28	25	4	.07
	2 to 7	1.97	2,840	.06	<2	18	32	6	.04
	7 to 9	1.77	2,030	.06	<2	23	37	6	.05
	9 to 11.5	1.41	745	.02	<2	25	27	<4	.06
	11.5 to 13	1.50	2,400	.04	<2	24	46	5	.06
	13 to 18	.64	1,230	.06	<2	28	24	7	.07

Supplement 10. Chemical analyses of soils in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Potassium (percent)	Scandium (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)	Sodium (percent)	Strontium (mg/kg)	Sulfur (percent)	Tantalum (mg/kg)
NR75A	0 to 2	1.48	7	0.3	<2	1.02	176	<0.05	<40
	2 to 4	1.23	7	.2	<2	.90	168	<.05	<40
	4 to 9.5	1.22	6	.2	<2	1.28	241	<.05	<40
	9.5 to 13	1.07	9	.8	<2	.88	201	.07	<40
	13 to 16	1.39	10	.9	<2	.94	188	.07	<40
	16 to 18.5	1.50	11	1.1	<2	.90	172	.76	<40
NR79A	0 to 1.5	1.41	7	.5	<2	.81	139	<.05	<40
	1.5 to 4	.96	7	.1	<2	.35	95	<.05	<40
	4 to 9	1.06	7	<.1	<2	.36	99	<.05	<40
	9 to 11	1.11	7	.1	<2	.45	115	<.05	<40
	11 to 13	1.31	7	.2	<2	1.14	225	<.05	<40
	13 to 17	1.66	8	.4	<2	1.36	261	.21	<40
	17 to 18	1.45	6	.2	<2	1.44	260	.16	<40
NR86A	0 to 2	1.41	7	.4	<2	1.10	201	<.05	<40
	2 to 3.5	1.50	8	.2	<2	1.00	174	<.05	<40
	3.5 to 6	1.13	7	.1	<2	.67	140	<.05	<40
	6 to 8	.92	6	<.1	<2	.45	116	<.05	<40
	8 to 12	1.06	7	<.1	<2	.84	181	<.05	<40
	12 to 14	1.08	7	.2	<2	.69	154	<.05	<40
	14 to 15.5	1.09	6	.2	<2	.60	138	<.05	<40
	15.5 to 18	1.05	6	3.5	<2	.57	138	<.05	<40
NR89A	0 to 2	1.42	5	.4	<2	1.31	212	<.05	<40
	2 to 7	.99	7	<.1	<2	.36	107	<.05	<40
	7 to 9	1.19	7	.6	<2	.68	149	<.05	<40
	9 to 11.5	1.42	5	.6	<2	1.37	247	<.05	<40
	11.5 to 13	1.31	6	3.1	<2	1.09	208	<.05	<40
	13 to 18	1.41	7	2.1	<2	.85	147	.38	<40

Supplement 10. Chemical analyses of soils in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Thorium (mg/kg)	Tin (mg/kg)	Titanium (percent)	Uranium (mg/kg)	Vanadium (mg/kg)	Ytterbium (mg/kg)	Yttrium (mg/kg)	Zinc (mg/kg)
NR75A	0 to 2	9	<10	0.20	<100	66	2	16	69
	2 to 4	11	<10	.20	<100	98	2	19	49
	4 to 9.5	13	<10	.18	<100	58	2	16	36
	9.5 to 13	13	<10	.31	<100	76	5	41	76
	13 to 16	12	<10	.28	<100	116	3	29	88
	16 to 18.5	12	<10	.30	<100	163	2	19	101
NR79A	0 to 1.5	8	<10	.20	<100	79	2	17	88
	1.5 to 4	7	<10	.15	<100	139	2	14	63
	4 to 9	8	<10	.16	<100	152	2	14	73
	9 to 11	9	<10	.18	<100	138	2	15	74
	11 to 13	10	<10	.19	<100	81	2	16	59
	13 to 17	8	<10	.25	<100	77	2	16	6
	17 to 18	11	<10	.21	<100	54	2	15	39
NR86A	0 to 2	8	<10	.21	<100	66	2	16	75
	2 to 3.5	10	<10	.23	<100	97	2	21	75
	3.5 to 6	10	<10	.17	<100	121	2	17	59
	6 to 8	7	<10	.15	<100	122	2	13	56
	8 to 12	8	<10	.20	<100	101	2	16	57
	12 to 14	9	<10	.20	<100	117	2	15	70
	14 to 15.5	8	<10	.14	<100	114	2	13	69
	15.5 to 18	9	<10	.14	<100	114	2	14	84
NR89A	0 to 2	10	<10	.20	<100	56	2	15	45
	2 to 7	4	<10	.14	<100	136	1	14	58
	7 to 9	7	<10	.16	<100	126	2	15	69
	9 to 11.5	6	<10	.15	<100	59	2	14	46
	11.5 to 13	7	<10	.16	<100	84	1	15	62
	13 to 18	9	<10	.19	<100	77	2	17	88

Supplement 10. Chemical analyses of soils in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Date	Latitude-longitude identification number	Township-range identification number	Horizon sampled (feet below land surface)	Aluminum (percent)	Arsenic (mg/kg)	Barium (mg/kg)
NR104A	7-10-90	474353098560402	149-065-11DDD2	0 to 1	4.53	3.7	574
				1 to 4	4.81	10	540
				4 to 7.5	4.62	5.8	557
				7.5 to 9.5	4.24	38	482
				9.5 to 13	4.14	70	298
				13 to 18	4.25	8.0	623
NR121A	7-11-90	474628098544002	150-065-25DDD2	2 to 3	4.58	4.4	615
				3 to 8	4.16	8.0	494
				8 to 9	4.92	4.7	717
				9 to 12.5	4.52	8.7	684
				12.5 to 15.5	4.54	7.6	703
				15.5 to 18	3.63	50	2,310
				18 to 23	4.29	13	689
NR152A	7-10-90	474347098533002	149-064-18AAA2	0 to 1	4.85	3.8	651
				1 to 3.5	4.91	2.5	532
				3.5 to 4.5	4.19	3.7	499
				4.5 to 12	3.92	5.9	505
				12 to 16	4.69	5.3	604
				16 to 17	3.55	15	1,130
				17 to 18	4.80	7.0	793
NR161A	7-09-90	474347098513402	149-064-16BAA2	0 to 1	4.88	4.5	534
				1 to 3.5	4.02	4.5	409
				3.5 to 7	3.97	7.1	420
				7 to 11	3.66	19	917
				11 to 13	3.47	61	2,530
				13 to 18	4.08	12	689

Supplement 10. Chemical analyses of soils in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Beryllium (mg/kg)	Bismuth (mg/kg)	Cadmium (mg/kg)	Calcium (percent)	Cerium (mg/kg)	Chromium (mg/kg)	Cobalt (mg/kg)	Copper (mg/kg)
NR104A	0 to 1	1	<10	<2	1.16	55	54	14	17
	1 to 4	2	<10	<2	.99	61	71	25	16
	4 to 7.5	1	<10	<2	.95	86	76	26	26
	7.5 to 9.5	1	<10	<2	3.08	54	59	42	21
	9.5 to 13	1	<10	<2	4.48	43	51	22	19
	13 to 18	1	<10	<2	3.64	47	54	21	18
NR121A	2 to 3	1	<10	<2	3.22	55	46	9	7
	3 to 8	1	<10	<2	5.59	46	70	16	18
	8 to 9	1	<10	<2	3.37	38	40	9	8
	9 to 12.5	1	<10	<2	4.35	46	53	14	11
	12.5 to 15.5	1	<10	<2	4.63	56	48	16	12
	15.5 to 18	1	<10	<2	6.76	50	44	129	16
	18 to 23	1	<10	<2	6.25	57	50	24	17
NR152A	0 to 1	1	<10	<2	.95	51	55	12	17
	1 to 3.5	2	<10	<2	.76	55	76	22	15
	3.5 to 4.5	1	<10	<2	3.11	53	57	21	15
	4.5 to 12	1	<10	<2	5.48	53	57	19	15
	12 to 16	1	<10	<2	2.90	72	62	22	24
	16 to 17	1	<10	<2	11.5	52	49	25	14
	17 to 18	1	<10	<2	6.21	58	62	21	24
NR161A	0 to 1	1	<10	<2	1.42	47	57	12	20
	1 to 3.5	1	<10	<2	6.31	40	54	14	18
	3.5 to 7	1	<10	<2	4.25	42	59	16	18
	7 to 11	1	<10	<2	5.24	50	53	24	30
	11 to 13	1	<10	<2	5.99	46	49	35	31
	13 to 18	1	<10	<2	3.51	51	61	20	21

Supplement 10. Chemical analyses of soils in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Europium (mg/kg)	Gallium (mg/kg)	Gold (mg/kg)	Holmium (mg/kg)	Iron (percent)	Lanthanum (mg/kg)	Lead (mg/kg)	Lithium (mg/kg)
NR104A	0 to 1	<2	12	<8	<4	2.22	31	15	18
	1 to 4	<2	16	<8	<4	3.11	34	12	28
	4 to 7.5	<2	16	<8	<4	2.71	48	34	25
	7.5 to 9.5	<2	12	<8	<4	2.70	29	22	24
	9.5 to 13	<2	10	<8	<4	3.10	24	17	22
	13 to 18	<2	14	<8	<4	2.52	25	20	24
NR121A	2 to 3	<2	11	<8	<4	1.88	32	12	13
	3 to 8	<2	13	<8	<4	2.61	26	59	25
	8 to 9	<2	10	<8	<4	1.66	23	16	15
	9 to 12.5	<2	11	<8	<4	2.31	26	24	16
	12.5 to 15.5	<2	12	<8	<4	2.26	31	26	18
	15.5 to 18	<2	23	<8	<4	4.02	28	21	20
	18 to 23	<2	12	<8	<4	2.68	31	18	20
NR152A	0 to 1	<2	13	<8	<4	2.32	32	17	18
	1 to 3.5	<2	16	<8	<4	2.78	34	17	28
	3.5 to 4.5	<2	14	<8	<4	2.51	30	20	24
	4.5 to 12	<2	13	<8	<4	2.55	29	23	22
	12 to 16	<2	14	<8	<4	2.76	40	20	26
	16 to 17	<2	18	<8	<4	2.62	28	18	22
	17 to 18	<2	15	<8	<4	4.47	33	18	28
NR161A	0 to 1	<2	14	<8	<4	2.54	31	14	20
	1 to 3.5	<2	13	<8	<4	2.31	23	17	25
	3.5 to 7	<2	14	<8	<4	2.53	23	30	27
	7 to 11	<2	23	<8	<4	2.77	27	30	26
	11 to 13	<2	32	<8	<4	2.86	25	24	24
	13 to 18	<2	16	<8	<4	2.80	29	20	28

Supplement 10. Chemical analyses of soils in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Magnesium (percent)	Manganese (mg/kg)	Mercury (mg/kg)	Molybdenum (mg/kg)	Neodymium (mg/kg)	Nickel (mg/kg)	Niobium (mg/kg)	Phosphorus (percent)
NR104A	0 to 1	0.68	1,530	0.04	<2	29	31	8	0.06
	1 to 4	.88	2,990	.08	<2	30	62	7	.06
	4 to 7.5	.81	2,860	.08	<2	42	64	6	.06
	7.5 to 9.5	1.80	645	.06	<2	28	103	8	.05
	9.5 to 13	1.33	938	.04	11	21	49	8	.06
	13 to 18	1.34	2,380	.04	<2	24	47	4	.05
NR121A	2 to 3	1.11	601	.02	<2	28	21	4	.07
	3 to 8	2.25	2,000	.06	2	23	44	6	.05
	8 to 9	1.15	551	.04	<2	17	20	4	.06
	9 to 12.5	1.54	1,180	.04	<2	23	29	<4	.06
	12.5 to 15.5	1.65	1,390	.04	<2	25	33	<4	.05
	15.5 to 18	2.42	11,200	.06	9	24	88	<4	.07
	18 to 23	2.39	1,500	.04	<2	27	45	<4	.05
NR152A	0 to 1	.56	1,340	.06	<2	30	25	7	.08
	1 to 3.5	.83	2,800	.06	<2	32	42	7	.05
	3.5 to 4.5	1.67	2,770	.08	<2	26	44	6	.05
	4.5 to 12	2.25	2,310	.06	<2	26	44	6	.05
	12 to 16	1.56	2,190	.06	<2	35	59	8	.05
	16 to 17	3.73	5,690	.08	<2	25	64	5	.04
	17 to 18	1.69	1,580	.08	<2	28	41	7	.07
NR161A	0 to 1	.84	1,630	.06	<2	28	28	8	.10
	1 to 3.5	2.21	2,030	.06	<2	21	35	4	.06
	3.5 to 7	1.89	2,280	.06	<2	22	45	5	.04
	7 to 11	2.39	10,500	.08	4	26	71	5	.04
	11 to 13	2.29	23,100	.08	14	23	76	5	.04
	13 to 18	1.54	3,440	.06	<2	25	56	7	.04

Supplement 10. Chemical analyses of soils in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Potassium (percent)	Scandium (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)	Sodium (percent)	Strontium (mg/kg)	Sulfur (percent)	Tantalum (mg/kg)
NR104A	0 to 1	1.43	7	0.3	<2	0.79	139	<0.05	<40
	1 to 4	1.34	9	<.1	<2	.57	116	<.05	<40
	4 to 7.5	1.29	9	.2	<2	.54	130	<.05	<40
	7.5 to 9.5	1.22	7	2.6	<2	.72	140	.81	<40
	9.5 to 13	1.27	6	1.0	<2	.84	163	1.35	<40
	13 to 18	1.23	7	.3	<2	.75	166	.17	<40
NR121A	2 to 3	1.33	6	<.1	<2	1.48	265	<.05	<40
	3 to 8	1.15	7	.1	<2	.65	151	<.05	<40
	8 to 9	1.53	5	<.1	<2	1.53	276	<.05	<40
	9 to 12.5	1.40	6	.1	<2	1.31	252	<.05	<40
	12.5 to 15.5	1.41	6	<.1	<2	1.17	235	<.05	<40
	15.5 to 18	1.06	6	.2	<2	.65	169	<.05	<40
	18 to 23	1.22	7	1.1	<2	.92	202	<.05	<40
NR152A	0 to 1	1.55	7	.3	<2	.91	149	<.05	<40
	1 to 3.5	1.29	9	.2	<2	.49	103	<.05	<40
	3.5 to 4.5	1.20	7	<.1	<2	.59	123	<.05	<40
	4.5 to 12	1.13	7	.2	<2	.63	137	<.05	<40
	12 to 16	1.25	8	.2	<2	.70	148	<.05	<40
	16 to 17	.98	7	1.1	<2	.55	167	<.05	<40
	17 to 18	1.25	9	2.4	<2	.87	209	.38	<40
NR161A	0 to 1	1.41	8	.6	<2	.79	133	.05	<40
	1 to 3.5	1.07	7	.2	<2	.54	121	<.05	<40
	3.5 to 7	1.07	7	.1	<2	.41	110	<.05	<40
	7 to 11	1.00	6	.1	<2	.39	123	<.05	<40
	11 to 13	.97	6	.3	<2	.37	240	<.05	<40
	13 to 18	1.10	7	1.4	<2	.45	134	.40	<40

Supplement 10. Chemical analyses of soils in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Thorium (mg/kg)	Tin (mg/kg)	Titanium (percent)	Uranium (mg/kg)	Vanadium (mg/kg)	Ytterbium (mg/kg)	Yttrium (mg/kg)	Zinc (mg/kg)
NR104A	0 to 1	9	<10	0.21	<100	87	2	18	98
	1 to 4	11	<10	.22	<100	165	2	20	90
	4 to 7.5	16	<10	.25	<100	151	3	24	86
	7.5 to 9.5	10	<10	.21	<100	128	2	17	75
	9.5 to 13	6	<10	.18	<100	102	2	15	66
	13 to 18	8	<10	.19	<100	124	2	15	81
NR121A	2 to 3	8	<10	.23	<100	58	2	16	40
	3 to 8	7	<10	.16	<100	122	2	14	66
	8 to 9	4	<10	.17	<100	57	2	14	46
	9 to 12.5	11	<10	.20	<100	68	2	14	48
	12.5 to 15.5	9	<10	.19	<100	80	2	15	50
	15.5 to 18	12	<10	.15	<100	118	2	18	85
	18 to 23	11	<10	.18	<100	95	2	15	58
NR152A	0 to 1	9	<10	.21	<100	85	2	18	94
	1 to 3.5	12	<10	.21	<100	161	2	20	74
	3.5 to 4.5	8	<10	.18	<100	131	2	16	70
	4.5 to 12	9	<10	.19	<100	120	2	15	65
	12 to 16	11	<10	.24	<100	140	2	18	102
	16 to 17	11	<10	.15	<100	94	1	13	66
	17 to 18	13	<10	.26	<100	114	2	18	77
NR161A	0 to 1	8	<10	.19	<100	95	2	20	92
	1 to 3.5	7	<10	.15	<100	124	2	14	64
	3.5 to 7	8	<10	.15	<100	139	2	13	67
	7 to 11	11	<10	.15	<100	131	2	14	90
	11 to 13	13	<10	.13	<100	131	2	17	105
	13 to 18	9	<10	.18	<100	147	2	15	87

Supplement 10. Chemical analyses of soils in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Date	Latitude-longitude identification number	Township-range identification number	Horizon sampled (feet below land surface)	Aluminum (percent)	Arsenic (mg/kg)	Barium (mg/kg)
NR172A	7-10-90	474235098535902	149-064-19ACC2	0 to 2.5	4.56	4.0	584
				2.5 to 5	4.22	5.2	508
				5 to 8.5	3.86	8.4	520
				8.5 to 13	3.93	8.4	459
				13 to 17.5	4.20	4.7	721
NR211A	7-11-90	474117098493902	149-064-27DDD2	0 to 2	4.35	5.3	606
				2 to 3	5.41	4.3	643
				3 to 5.5	3.56	4.2	470
				5.5 to 7	4.09	8.3	578
				7 to 12	4.04	19	1,080
				12 to 14	4.21	9.6	643
				14 to 18	4.13	8.9	590

Supplement 10. Chemical analyses of soils in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Beryllium (mg/kg)	Bismuth (mg/kg)	Cadmium (mg/kg)	Calcium (percent)	Cerium (mg/kg)	Chromium (mg/kg)	Cobalt (mg/kg)	Copper (mg/kg)
NR172A	0 to 2.5	1	<10	<2	1.09	55	52	14	17
	2.5 to 5	1	<10	<2	4.31	45	56	21	16
	5 to 8.5	1	<10	<2	6.84	46	56	21	17
	8.5 to 13	1	<10	<2	5.71	53	58	26	29
	13 to 17.5	1	<10	<2	3.09	48	59	19	21
NR211A	0 to 2	1	<10	<2	1.25	59	49	15	21
	2 to 3	2	<10	<2	1.21	66	68	20	15
	3 to 5.5	1	<10	<2	12.8	46	45	17	16
	5.5 to 7	1	<10	<2	5.74	50	59	23	17
	7 to 12	1	<10	<2	6.93	51	62	28	22
	12 to 14	1	<10	<2	4.79	50	65	25	21
	14 to 18	1	<10	<2	4.13	76	57	14	11

Supplement 10. Chemical analyses of soils in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Europium (mg/kg)	Gallium (mg/kg)	Gold (mg/kg)	Holmium (mg/kg)	Iron (percent)	Lanthanum (mg/kg)	Lead (mg/kg)	Lithium (mg/kg)
NR172A	0 to 2.5	<2	13	<8	<4	2.41	32	17	18
	2.5 to 5	<2	15	<8	<4	2.47	25	21	27
	5 to 8.5	<2	15	<8	<4	2.62	24	32	25
	8.5 to 13	<2	15	<8	<4	2.97	27	29	26
	13 to 17.5	<2	14	<8	<4	2.90	27	24	27
NR211A	0 to 2	<2	13	<8	<4	2.34	32	19	16
	2 to 3	<2	16	<8	<4	3.21	39	18	23
	3 to 5.5	<2	12	<8	<4	2.06	27	15	20
	5.5 to 7	<2	14	<8	<4	2.62	27	18	26
	7 to 12	<2	21	<8	<4	3.76	27	37	25
	12 to 14	<2	14	<8	<4	3.06	29	38	29
	14 to 18	<2	12	<8	<4	3.09	42	22	17

Supplement 10. Chemical analyses of soils in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Magnesium (percent)	Manganese (mg/kg)	Mercury (mg/kg)	Molybdenum (mg/kg)	Neodymium (mg/kg)	Nickel (mg/kg)	Niobium (mg/kg)	Phosphorus (percent)
NR172A	0 to 2.5	0.65	1,660	0.06	<2	29	30	8	0.06
	2.5 to 5	1.87	2,890	.06	<2	22	53	6	.04
	5 to 8.5	2.85	3,410	.06	<2	22	47	5	.04
	8.5 to 13	2.36	3,330	.08	<2	25	59	7	.05
	13 to 17.5	1.26	1,970	.08	<2	23	43	7	.05
NR211A	0 to 2	.60	1,930	.08	<2	30	34	7	.09
	2 to 3	.89	2,080	.08	<2	36	49	6	.05
	3 to 5.5	1.77	2,170	.08	<2	24	39	6	.06
	5.5 to 7	2.14	2,810	.06	<2	24	48	5	.04
	7 to 12	2.37	7,470	.08	4	24	70	5	.05
	12 to 14	1.47	2,100	.06	2	26	66	7	.05
	14 to 18	1.21	1,340	.06	<2	35	32	5	.07

Supplement 10. Chemical analyses of soils in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Potassium (percent)	Scandium (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)	Sodium (percent)	Strontium (mg/kg)	Sulfur (percent)	Tantalum (mg/kg)
NR172A	0 to 2.5	1.34	7	0.4	<2	0.76	134	<0.05	<40
	2.5 to 5	1.09	7	<.1	<2	.59	133	<.05	<40
	5 to 8.5	1.03	7	.2	<2	.58	135	<.05	<40
	8.5 to 13	1.03	7	1.8	<2	.50	123	<.05	<40
	13 to 17.5	1.15	7	1.3	<2	.53	133	.36	<40
NR211A	0 to 2	1.39	7	.6	<2	.78	137	<.05	<40
	2 to 3	1.55	9	.3	<2	.86	146	<.05	<40
	3 to 5.5	.94	6	.2	<2	.55	134	<.05	<40
	5.5 to 7	1.05	7	<.1	<2	.48	123	<.05	<40
	7 to 12	1.10	8	.4	<2	.56	147	<.05	<40
	12 to 14	1.17	7	1.1	<2	.48	128	.62	<40
	14 to 18	1.29	7	.6	<2	1.14	206	.55	<40

Supplement 10. Chemical analyses of soils in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Thorium (mg/kg)	Tin (mg/kg)	Titanium (percent)	Uranium (mg/kg)	Vanadium (mg/kg)	Ytterbium (mg/kg)	Yttrium (mg/kg)	Zinc (mg/kg)
NR172A	0 to 2.5	9	<10	0.20	<100	86	2	19	91
	2.5 to 5	8	<10	.17	<100	134	2	14	69
	5 to 8.5	7	<10	.16	<100	117	1	13	72
	8.5 to 13	11	<10	.18	<100	131	2	15	79
	13 to 17.5	8	<10	.18	<100	144	2	14	70
NR211A	0 to 2	10	<10	.19	<100	80	2	17	102
	2 to 3	12	<10	.24	<100	117	2	24	93
	3 to 5.5	8	<10	.14	<100	95	2	15	53
	5.5 to 7	8	<10	.17	<100	137	2	14	74
	7 to 12	9	<10	.18	<100	121	2	17	85
	12 to 14	10	<10	.17	<100	146	2	15	108
	14 to 18	13	<10	.28	<100	80	2	18	63

Supplement 11. Chemical analyses of soil horizons in the New Rockford irrigation area

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Date	Latitude-longitude identification number	Township-range identification number	Soil series[1]	Horizon sampled	Aluminum (percent)	Arsenic (mg/kg)	Barium (mg/kg)
NR23C	7-11-90	474628099010304	150-065-29CCC4	Marysland	Topsoil	2.34	3.0	415
					Oxidized	3.40	4.5	489
					Transition	3.39	37	1,540
					Reduced	4.31	10	654
NR32	7-13-90	474302099123803	149-067-14CCC3	Arvilla	Topsoil	4.74	5.7	651
					Oxidized	4.56	13	690
					Transition	3.88	26	716
					Reduced	6.09	4.4	778
NR45	7-12-90	474209099060201	149-066-22CCD1	Arvilla	Topsoil	5.10	6.6	680
					Oxidized	5.21	9.8	746
					Transition	5.13	6.8	829
					Reduced	4.93	4.4	728
NR55	7-12-90	474505099042601	149-066-02CAA1	Kensal	Topsoil	4.64	3.3	687
					Oxidized	4.51	5.9	650
					Transition	4.82	4.8	710
					Reduced	4.90	6.0	933
NR68	7-12-90	474412099023001	149-066-12DAA1	Wyndmere	Topsoil	5.05	4.2	673
					Oxidized	4.36	7.6	671
					Transition	5.75	5.4	872
					Reduced	5.32	10	969
NR75A	7-12-90	474714099014202	150-065-30ABB2	Binford	Topsoil	4.57	5.3	645
					Oxidized	4.14	8.7	601
					Transition	3.97	8.1	736
					Reduced	5.55	3.9	680
NR79A	7-10-90	474621098583502	150-065-33AAA2	Brantford	Topsoil	4.55	3.9	596
					Oxidized	4.00	3.8	429
					Transition	4.33	6.4	633
					Reduced	5.49	4.4	900

Supplement 11. Chemical analyses of soil horizons in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled	Beryllium (mg/kg)	Bismuth (mg/kg)	Cadmium (mg/kg)	Calcium (percent)	Cerium (mg/kg)	Chromium (mg/kg)	Cobalt (mg/kg)	Copper (mg/kg)
NR23C	Topsoil	<1	<10	<2	14.8	25	23	5	10
	Oxidized	<1	<10	<2	14.6	46	38	9	8
	Transition	1	<10	<2	12.4	42	40	18	14
	Reduced	1	<10	<2	7.15	50	59	16	16
NR32	Topsoil	1	<10	<2	1.36	49	46	11	17
	Oxidized	1	<10	<2	8.71	52	57	24	22
	Transition	1	<10	<2	10.7	56	49	32	30
	Reduced	1	<10	<2	3.71	49	66	13	21
NR45	Topsoil	1	<10	<2	1.12	48	50	11	17
	Oxidized	1	<10	<2	4.80	65	58	17	12
	Transition	1	<10	<2	5.02	47	53	19	14
	Reduced	1	<10	<2	3.28	45	44	9	13
NR55	Topsoil	1	<10	<2	1.47	46	46	10	14
	Oxidized	1	<10	<2	4.55	78	48	10	8
	Transition	1	<10	<2	4.62	69	55	18	8
	Reduced	1	<10	<2	4.83	46	50	15	14
NR68	Topsoil	1	<10	<2	1.40	58	50	11	11
	Oxidized	<1	<10	<2	8.69	46	42	11	10
	Transition	2	<10	<2	3.37	48	51	16	18
	Reduced	1	<10	<2	4.70	55	44	19	15
NR75A	Topsoil	1	<10	<2	1.70	53	48	10	15
	Oxidized	<1	<10	<2	7.72	73	53	12	10
	Transition	2	<10	<2	5.54	83	71	14	129
	Reduced	2	<10	<2	2.11	69	81	19	48
NR79A	Topsoil	1	<10	<2	1.08	48	52	11	17
	Oxidized	1	<10	<2	3.56	46	60	17	16
	Transition	1	<10	<2	3.67	56	56	18	18
	Reduced	1	<10	<2	3.73	49	56	11	13

Supplement 11. Chemical analyses of soil horizons in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled	Europium (mg/kg)	Gallium (mg/kg)	Gold (mg/kg)	Holmium (mg/kg)	Iron (percent)	Lanthanum (mg/kg)	Lead (mg/kg)	Lithium (mg/kg)
NR23C	Topsoil	<2	6	<8	<4	1.10	15	9	24
	Oxidized	<2	8	<8	<4	1.91	25	11	22
	Transition	<2	16	<8	<4	4.45	24	38	18
	Reduced	<2	12	<8	<4	3.69	29	37	19
NR32	Topsoil	<2	12	<8	<4	2.43	30	14	18
	Oxidized	<2	13	<8	<4	3.85	30	27	22
	Transition	<2	16	<8	<4	4.75	30	22	18
	Reduced	<2	15	<8	<4	2.91	28	16	33
NR45	Topsoil	<2	13	<8	<4	2.64	31	16	21
	Oxidized	<2	12	<8	<4	2.93	36	16	19
	Transition	<2	14	<8	<4	2.69	27	19	19
	Reduced	<2	11	<8	<4	2.04	25	14	22
NR55	Topsoil	<2	11	<8	<4	2.03	27	14	18
	Oxidized	<2	10	<8	<4	2.43	41	16	15
	Transition	<2	11	<8	<4	2.58	36	17	17
	Reduced	<2	12	<8	<4	2.54	27	16	17
NR68	Topsoil	<2	12	<8	<4	2.36	33	13	19
	Oxidized	<2	11	<8	<4	2.07	26	16	20
	Transition	<2	14	<8	<4	2.33	27	20	21
	Reduced	<2	16	<8	<4	2.78	30	19	19
NR75A	Topsoil	<2	11	<8	<4	2.09	30	14	16
	Oxidized	<2	11	<8	<4	2.55	39	22	15
	Transition	<2	13	<8	<4	3.31	44	37	17
	Reduced	<2	14	<8	<4	3.25	37	21	27
NR79A	Topsoil	<2	11	<8	<4	2.16	29	15	17
	Oxidized	<2	13	<8	<4	2.11	26	22	26
	Transition	<2	14	<8	<4	2.26	29	22	22
	Reduced	<2	12	<8	<4	2.27	28	12	24

Supplement 11. Chemical analyses of soil horizons in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled	Magnesium (percent)	Manganese (mg/kg)	Mercury (mg/kg)	Molybdenum (mg/kg)	Neodymium (mg/kg)	Nickel (mg/kg)	Niobium (mg/kg)	Phosphorus (percent)
NR23C	Topsoil	3.37	510	0.02	<2	13	11	5	0.10
	Oxidized	2.22	672	.03	<2	22	18	<4	.06
	Transition	3.28	5,960	.04	12	22	35	<4	.08
	Reduced	2.43	1,620	.04	<2	24	37	<4	.07
NR32	Topsoil	.68	969	.04	<2	25	25	7	.10
	Oxidized	2.81	1,560	.07	<2	24	46	5	.07
	Transition	3.09	3,800	.08	3	26	61	5	.08
	Reduced	1.71	580	.06	<2	24	34	8	.07
NR45	Topsoil	.62	797	.06	<2	26	27	8	.10
	Oxidized	1.82	882	.08	<2	30	41	<4	.07
	Transition	1.95	1,510	.08	<2	18	42	8	.06
	Reduced	1.38	426	.04	<2	22	23	6	.07
NR55	Topsoil	.86	920	.02	<2	22	18	6	.06
	Oxidized	2.04	714	.02	<2	35	24	<4	.06
	Transition	2.06	576	.02	<2	31	30	<4	.05
	Reduced	1.72	1,070	.03	<2	23	41	<4	.06
NR68	Topsoil	.74	724	.02	<2	27	25	6	.05
	Oxidized	2.09	571	.03	<2	22	27	<4	.06
	Transition	1.37	819	.06	<2	22	37	7	.05
	Reduced	1.69	2,800	.06	2	27	39	4	.06
NR75A	Topsoil	.58	959	.02	<2	25	21	5	.07
	Oxidized	2.37	1,260	.03	<2	34	30	<4	.07
	Transition	2.16	1,410	.32	<2	38	59	14	.08
	Reduced	1.16	1,160	.11	<2	32	56	10	.07
NR79A	Topsoil	.59	1,340	.06	<2	24	26	6	.08
	Oxidized	1.35	2,490	.04	<2	23	45	<4	.03
	Transition	1.56	3,230	.06	<2	24	50	<4	.05
	Reduced	1.60	485	.04	<2	24	27	5	.07

Supplement 11. Chemical analyses of soil horizons in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled	Potassium (percent)	Scandium (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)	Sodium (percent)	Strontium (mg/kg)	Sulfur (percent)	Tantalum (mg/kg)
NR23C	Topsoil	0.87	3	0.9	<2	0.59	408	0.11	<40
	Oxidized	1.12	6	.2	<2	.80	317	.05	<40
	Transition	1.11	6	.4	<2	.75	206	<.05	<40
	Reduced	1.39	8	.8	<2	1.08	230	.57	<40
NR32	Topsoil	1.56	7	.5	<2	.94	169	<.05	<40
	Oxidized	1.30	9	.2	<2	1.09	241	<.05	<40
	Transition	1.16	7	1.0	<2	1.01	237	<.05	<40
	Reduced	1.78	10	.6	<2	1.06	217	.24	<40
NR45	Topsoil	1.67	8	.5	<2	.94	164	<.05	<40
	Oxidized	1.43	8	.1	<2	1.44	282	<.05	<40
	Transition	1.43	7	.7	<2	1.40	282	<.05	<40
	Reduced	1.61	7	.3	<2	1.23	217	.18	<40
NR55	Topsoil	1.61	6	.3	<2	1.11	187	.05	<40
	Oxidized	1.37	7	<.1	<2	1.38	240	<.05	<40
	Transition	1.40	7	.2	<2	1.36	251	<.05	<40
	Reduced	1.38	7	.8	<2	1.41	270	.09	<40
NR68	Topsoil	1.61	7	.2	<2	1.18	212	<.05	<40
	Oxidized	1.32	6	.2	<2	1.21	933	<.05	<40
	Transition	1.66	8	.8	<2	1.55	319	<.05	<40
	Reduced	1.55	7	.9	<2	1.53	316	<.05	<40
NR75A	Topsoil	1.48	7	.3	<2	1.02	176	<.05	<40
	Oxidized	1.22	6	.2	<2	1.18	222	<.05	<40
	Transition	1.07	9	.8	<2	.88	201	.07	<40
	Reduced	1.44	11	1.0	<2	.92	181	.38	<40
NR79A	Topsoil	1.41	7	.5	<2	.81	139	<.05	<40
	Oxidized	1.03	7	<.1	<2	.36	98	<.05	<40
	Transition	1.21	7	.2	<2	.80	170	<.05	<40
	Reduced	1.62	8	.4	<2	1.38	261	.20	<40

Supplement 11. Chemical analyses of soil horizons in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled	Thorium (mg/kg)	Tin (mg/kg)	Titanium (percent)	Uranium (mg/kg)	Vanadium (mg/kg)	Ytterbium (mg/kg)	Yttrium (mg/kg)	Zinc (mg/kg)
NR23C	Topsoil	<4	<10	0.10	<100	32	<1	7	64
	Oxidized	7	<10	.13	<100	56	1	12	41
	Transition	8	<10	.13	<100	70	2	15	56
	Reduced	10	<10	.21	<100	78	2	15	54
NR32	Topsoil	8	<10	.21	<100	64	2	18	75
	Oxidized	7	<10	.20	<100	78	2	16	68
	Transition	10	<10	.18	<100	71	2	16	68
	Reduced	7	<10	.25	<100	105	2	17	68
NR45	Topsoil	8	<10	.22	<100	70	2	19	83
	Oxidized	11	<10	.27	<100	74	2	18	57
	Transition	<4	<10	.22	<100	69	2	15	60
	Reduced	7	<10	.21	<100	65	2	15	48
NR55	Topsoil	8	<10	.19	<100	58	2	15	74
	Oxidized	16	<10	.25	<100	63	2	19	41
	Transition	12	<10	.21	<100	71	2	16	60
	Reduced	7	<10	.23	<100	74	2	16	54
NR68	Topsoil	9	<10	.22	<100	64	2	17	66
	Oxidized	7	<10	.16	<100	61	2	14	40
	Transition	6	<10	.21	<100	76	2	16	58
	Reduced	9	<10	.19	<100	67	2	17	54
NR75A	Topsoil	9	<10	.20	<100	66	2	16	69
	Oxidized	12	<10	.19	<100	69	2	17	39
	Transition	13	<10	.31	<100	76	5	41	76
	Reduced	12	<10	.29	<100	137	3	24	94
NR79A	Topsoil	8	<10	.20	<100	79	2	17	88
	Oxidized	8	<10	.16	<100	148	2	14	70
	Transition	10	<10	.19	<100	110	2	16	67
	Reduced	9	<10	.24	<100	72	2	16	57

Supplement 11. Chemical analyses of soil horizons in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Date	Latitude-longitude identification number	Township-range identification number	Soil series[1]	Horizon sampled	Aluminum (percent)	Arsenic (mg/kg)	Barium (mg/kg)
NR86A	7-11-90	474647098571702	150-065-27DAA2	Edgley	Topsoil	4.64	5.5	673
					Oxidized	4.09	4.8	622
					Transition	3.73	4.8	485
NR89A	7-10-90	474505098572102	149-065-03DAA2	Binford	Topsoil	4.23	4.0	668
					Oxidized	3.81	2.7	406
					Transition	4.25	5.1	468
					Reduced	4.45	5.6	576
NR104A	7-10-90	474353098560402	149-065-11DDD2	Tiffany	Topsoil	4.53	3.7	574
					Oxidized	4.71	7.7	549
					Transition	4.24	38	482
					Reduced	4.20	34	489
NR121A	7-11-90	474628098544002	150-065-25DDD2	Binford	Oxidized	4.43	7.6	615
					Transition	4.07	25	1,230
NR152A	7-10-90	474347098533002	149-064-18AAA2	Binford	Topsoil	4.85	3.8	651
					Oxidized	4.31	5.0	536
					Transition	3.55	15	1,130
					Reduced	4.80	7.0	793
NR161A	7-09-90	474347098513402	149-064-16BAA2	Brantford	Topsoil	4.88	4.5	534
					Oxidized	4.00	6.0	415
					Transition	3.66	19	917
					Reduced	3.91	26	1,220
NR172A	7-10-90	474235098535902	149-064-19ACC2	Binford	Topsoil	4.56	4.0	584
					Oxidized	4.01	7.1	515
					Transition	3.93	8.4	459
					Reduced	4.20	4.7	721

Supplement 11. Chemical analyses of soil horizons in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled	Beryllium (mg/kg)	Bismuth (mg/kg)	Cadmium (mg/kg)	Calcium (percent)	Cerium (mg/kg)	Chromium (mg/kg)	Cobalt (mg/kg)	Copper (mg/kg)
NR86A	Topsoil	1	<10	<2	1.18	45	47	10	14
	Oxidized	1	<10	<2	5.71	54	55	16	15
	Transition	1	<10	<2	7.15	45	51	25	24
NR89A	Topsoil	<1	<10	<2	3.04	59	40	12	8
	Oxidized	1	<10	<2	5.75	44	52	13	15
	Transition	1	<10	<2	4.15	47	52	20	17
	Reduced	1	<10	<2	2.51	48	46	12	15
NR104A	Topsoil	1	<10	<2	1.16	55	54	14	17
	Oxidized	1	<10	<2	.97	74	74	26	21
	Transition	1	<10	<2	3.08	54	59	42	21
	Reduced	1	<10	<2	3.99	45	53	21	18
NR121A	Oxidized	1	<10	<2	4.60	57	57	16	13
	Transition	1	<10	<2	6.42	55	48	59	17
NR152A	Topsoil	1	<10	<2	.95	51	55	12	17
	Oxidized	1	<10	<2	3.85	58	62	20	17
	Transition	1	<10	<2	11.5	52	49	25	14
	Reduced	1	<10	<2	6.21	58	62	21	24
NR161A	Topsoil	1	<10	<2	1.42	47	57	12	20
	Oxidized	1	<10	<2	5.11	41	57	15	18
	Transition	1	<10	<2	5.24	50	53	24	30
	Reduced	1	<10	<2	4.22	50	58	24	24
NR172A	Topsoil	1	<10	<2	1.09	55	52	14	17
	Oxidized	1	<10	<2	5.79	46	56	21	17
	Transition	1	<10	<2	5.71	53	58	26	29
	Reduced	1	<10	<2	3.09	48	59	19	21

Supplement 11. Chemical analyses of soil horizons in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled	Europium (mg/kg)	Gallium (mg/kg)	Gold (mg/kg)	Holmium (mg/kg)	Iron (percent)	Lanthanum (mg/kg)	Lead (mg/kg)	Lithium (mg/kg)
NR86A	Topsoil	<2	11	<8	<4	1.94	26	13	14
	Oxidized	<2	12	<8	<4	2.25	31	16	20
	Transition	<2	16	<8	<4	2.55	25	19	23
NR89A	Topsoil	<2	10	<8	<4	1.90	34	15	14
	Oxidized	<2	14	<8	<4	1.98	25	18	26
	Transition	<2	13	<8	<4	2.10	26	20	23
	Reduced	<2	12	<8	<4	1.95	28	15	16
NR104A	Topsoil	<2	12	<8	<4	2.22	31	15	18
	Oxidized	<2	16	<8	<4	2.89	42	24	26
	Transition	<2	12	<8	<4	2.70	29	22	24
	Reduced	<2	12	<8	<4	2.76	25	19	23
NR121A	Oxidized	<2	12	<8	<4	2.33	26	36	19
	Transition	<2	16	<8	<4	3.13	30	19	20
NR152A	Topsoil	<2	13	<8	<4	2.32	32	17	18
	Oxidized	<2	14	<8	<4	2.64	33	20	24
	Transition	<2	18	<8	<4	2.62	28	18	22
	Reduced	<2	15	<8	<4	4.47	33	18	28
NR161A	Topsoil	<2	14	<8	<4	2.54	31	14	20
	Oxidized	<2	14	<8	<4	2.44	23	25	26
	Transition	<2	23	<8	<4	2.77	27	30	26
	Reduced	<2	21	<8	<4	2.82	28	21	27
NR172A	Topsoil	<2	13	<8	<4	2.41	32	17	18
	Oxidized	<2	15	<8	<4	2.56	24	27	26
	Transition	<2	15	<8	<4	2.97	27	29	26
	Reduced	<2	14	<8	<4	2.90	27	24	27

Supplement 11. Chemical analyses of soil horizons in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled	Magnesium (percent)	Manganese (mg/kg)	Mercury (mg/kg)	Molybdenum (mg/kg)	Neodymium (mg/kg)	Nickel (mg/kg)	Niobium (mg/kg)	Phosphorus (percent)
NR86A	Topsoil	0.50	1,110	0.04	<2	22	22	6	0.07
	Oxidized	1.78	1,940	.05	<2	25	37	<4	.05
	Transition	3.06	5,190	.06	<2	20	65	<4	.05
NR89A	Topsoil	1.05	576	.04	<2	28	25	4	.07
	Oxidized	1.97	2,840	.06	<2	18	32	6	.04
	Transition	1.77	2,030	.06	<2	23	37	6	.05
	Reduced	1.00	1,290	.05	<2	27	29	6	.07
NR104A	Topsoil	.68	1,530	.04	<2	29	31	8	.06
	Oxidized	.84	2,920	.08	<2	36	63	6	.06
	Transition	1.80	645	.06	<2	28	103	8	.05
	Reduced	1.34	1,790	.04	6	23	48	6	.05
NR121A	Oxidized	1.77	1,440	.05	<2	23	34	4	.05
	Transition	2.40	4,730	.05	4	26	59	<4	.06
NR152A	Topsoil	.56	1,340	.06	<2	30	25	7	.08
	Oxidized	1.79	2,390	.06	<2	29	48	7	.05
	Transition	3.73	5,690	.08	<2	25	64	5	.04
	Reduced	1.69	1,580	.08	<2	28	41	7	.07
NR161A	Topsoil	.84	1,630	.06	<2	28	28	8	.10
	Oxidized	2.02	2,180	.06	<2	22	41	5	.05
	Transition	2.39	10,500	.08	4	26	71	5	.04
	Reduced	1.75	9,060	.07	5	24	62	6	.04
NR172A	Topsoil	.65	1,660	.06	<2	29	30	8	.06
	Oxidized	2.44	3,190	.06	<2	22	50	5	.04
	Transition	2.36	3,330	.08	<2	25	59	7	.05
	Reduced	1.26	1,970	.08	<2	23	43	7	.05

Supplement 11. Chemical analyses of soil horizons in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled	Potassium (percent)	Scandium (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)	Sodium (percent)	Strontium (mg/kg)	Sulfur (percent)	Tantalum (mg/kg)
NR86A	Topsoil	1.41	7	0.4	<2	1.10	201	<0.05	<40
	Oxidized	1.11	6	.1	<2	.72	154	<.05	<40
	Transition	1.05	6	3.5	<2	.57	138	<.05	<40
NR89A	Topsoil	1.42	5	.4	<2	1.31	212	<.05	<40
	Oxidized	.99	7	<.1	<2	.36	107	<.05	<40
	Transition	1.19	7	.6	<2	.68	149	<.05	<40
	Reduced	1.40	6	1.9	<2	1.03	185	.23	<40
NR104A	Topsoil	1.43	7	.3	<2	.79	139	<.05	<40
	Oxidized	1.31	9	.2	<2	.55	124	<.05	<40
	Transition	1.22	7	2.6	<2	.72	140	.81	<40
	Reduced	1.25	7	.6	<2	.79	165	.66	<40
NR121A	Oxidized	1.31	6	<.1	<2	1.06	214	<.05	<40
	Transition	1.17	7	.8	<2	.83	191	<.05	<40
NR152A	Topsoil	1.55	7	.3	<2	.91	149	<.05	<40
	Oxidized	1.19	8	.2	<2	.62	133	<.05	<40
	Transition	.98	7	1.1	<2	.55	167	<.05	<40
	Reduced	1.25	9	2.4	<2	.87	209	.38	<40
NR161A	Topsoil	1.41	8	.6	<2	.79	133	.05	<40
	Oxidized	1.07	7	.1	<2	.46	115	<.05	<40
	Transition	1.00	6	.1	<2	.39	123	<.05	<40
	Reduced	1.06	7	1.1	<2	.43	164	.30	<40
NR172A	Topsoil	1.34	7	.4	<2	.76	134	<.05	<40
	Oxidized	1.06	7	.2	<2	.58	134	<.05	<40
	Transition	1.03	7	1.8	<2	.50	123	<.05	<40
	Reduced	1.15	7	1.3	<2	.53	133	.36	<40

Supplement 11. Chemical analyses of soil horizons in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled	Thorium (mg/kg)	Tin (mg/kg)	Titanium (percent)	Uranium (mg/kg)	Vanadium (mg/kg)	Ytterbium (mg/kg)	Yttrium (mg/kg)	Zinc (mg/kg)
NR86A	Topsoil	8	<10	0.21	<100	66	2	16	75
	Oxidized	9	<10	.18	<100	111	2	16	62
	Transition	9	<10	.14	<100	114	2	14	84
NR89A	Topsoil	10	<10	.20	<100	56	2	15	45
	Oxidized	4	<10	.14	<100	136	1	14	58
	Transition	7	<10	.16	<100	126	2	15	69
	Reduced	8	<10	.19	<100	73	2	16	72
NR104A	Topsoil	9	<10	.21	<100	87	2	18	98
	Oxidized	14	<10	.24	<100	157	3	22	88
	Transition	10	<10	.21	<100	128	2	17	75
	Reduced	7	<10	.19	<100	115	2	15	75
NR121A	Oxidized	8	<10	.18	<100	89	2	14	54
	Transition	11	<10	.17	<100	103	2	16	67
NR152A	Topsoil	9	<10	.21	<100	85	2	18	94
	Oxidized	10	<10	.21	<100	133	2	17	77
	Transition	11	<10	.15	<100	94	1	13	66
	Reduced	13	<10	.26	<100	114	2	18	77
NR161A	Topsoil	8	<10	.19	<100	95	2	20	92
	Oxidized	8	<10	.15	<100	133	2	13	66
	Transition	11	<10	.15	<100	131	2	14	90
	Reduced	10	<10	.17	<100	142	2	16	92
NR172A	Topsoil	9	<10	.20	<100	86	2	19	91
	Oxidized	7	<10	.16	<100	124	1	13	71
	Transition	11	<10	.18	<100	131	2	15	79
	Reduced	8	<10	.18	<100	144	2	14	70

Supplement 11. Chemical analyses of soil horizons in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Date	Latitude-longitude identification number	Township-range identification number	Soil series[1]	Horizon sampled	Aluminum (percent)	Arsenic (mg/kg)	Barium (mg/kg)
NR211A	7-11-90	474117098493902	149-064-27DDD2	Arvilla	Topsoil	4.35	5.3	606
					Oxidized	4.09	4.2	519
					Transition	4.05	16	964
					Reduced	4.16	9.1	608

Supplement 11. Chemical analyses of soil horizons in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled	Beryllium (mg/kg)	Bismuth (mg/kg)	Cadmium (mg/kg)	Calcium (percent)	Cerium (mg/kg)	Chromium (mg/kg)	Cobalt (mg/kg)	Copper (mg/kg)
NR211A	Topsoil	1	<10	<2	1.25	59	49	15	21
	Oxidized	1	<10	<2	9.49	52	52	18	20
	Transition	1	<10	<2	6.68	51	61	27	21
	Reduced	1	<10	<2	4.35	67	60	18	14

Supplement 11. Chemical analyses of soil horizons in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled	Europium (mg/kg)	Gallium (mg/kg)	Gold (mg/kg)	Holmium (mg/kg)	Iron (percent)	Lanthanum (mg/kg)	Lead (mg/kg)	Lithium (mg/kg)
NR211A	Topsoil	<2	13	<8	<4	2.34	32	19	16
	Oxidized	<2	13	<8	<4	2.39	30	16	21
	Transition	<2	19	<8	<4	3.50	27	33	25
	Reduced	<2	13	<8	<4	3.08	38	27	21

Supplement 11. Chemical analyses of soil horizons in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled	Magnesium (percent)	Manganese (mg/kg)	Mercury (mg/kg)	Molybdenum (mg/kg)	Neodymium (mg/kg)	Nickel (mg/kg)	Niobium (mg/kg)	Phosphorus (percent)
NR211A	Topsoil	0.60	1,930	0.08	<2	30	34	7	0.09
	Oxidized	1.52	2,140	.08	<2	27	42	6	.06
	Transition	2.32	6,400	.08	3	24	65	5	.05
	Reduced	1.30	1,590	.06	2	32	43	6	.06

Supplement 11. Chemical analyses of soil horizons in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled	Potassium (percent)	Scandium (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)	Sodium (percent)	Strontium (mg/kg)	Sulfur (percent)	Tantalum (mg/kg)
NR211A	Topsoil	1.39	7	0.6	<2	0.78	137	<0.05	<40
	Oxidized	1.11	7	.2	<2	.64	137	<.05	<40
	Transition	1.09	8	.3	<2	.54	141	<.05	<40
	Reduced	1.25	7	.8	<2	.92	180	.57	<40

Supplement 11. Chemical analyses of soil horizons in the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled	Thorium (mg/kg)	Tin (mg/kg)	Titanium (percent)	Uranium (mg/kg)	Vanadium (mg/kg)	Ytterbium (mg/kg)	Yttrium (mg/kg)	Zinc (mg/kg)
NR211A	Topsoil	10	<10	0.19	<100	80	2	17	102
	Oxidized	9	<10	.17	<100	101	2	18	64
	Transition	9	<10	.18	<100	125	2	16	82
	Reduced	12	<10	.24	<100	102	2	17	78

[1]Wright and Sweeney, 1977.

Supplement 12. Results of analysis of variance on ranked soils data for the New Rockford irrigation area

[Null hypothesis A, the median constituent concentrations in each soil horizon are equal; null hypothesis B, the median constituent concentrations in each soil series are equal; null hypothesis C, the median constituent concentrations in each soil horizon within each soil series are equal]

Constituent	Acceptance or rejection of null hypothesis		
	Null hypothesis A	Null hypothesis B	Null hypothesis C
Aluminum	**REJECT**	Accept	Accept
Arsenic	**REJECT**	Accept	Accept
Barium	**REJECT**	**REJECT**	Accept
Beryllium	Accept	Accept	Accept
Bismuth	Accept	Accept	Accept
Cadmium	Accept	Accept	Accept
Calcium	**REJECT**	**REJECT**	**REJECT**
Cerium	Accept	Accept	Accept
Chromium	**REJECT**	Accept	Accept
Cobalt	**REJECT**	Accept	Accept
Copper	Accept	Accept	Accept
Europium	Accept	Accept	Accept
Gallium	**REJECT**	Accept	Accept
Gold	Accept	Accept	Accept
Holmium	Accept	Accept	Accept
Iron	**REJECT**	Accept	Accept
Lanthanum	Accept	Accept	Accept
Lead	**REJECT**	Accept	Accept
Lithium	**REJECT**	Accept	Accept
Magnesium	**REJECT**	**REJECT**	Accept
Manganese	**REJECT**	Accept	Accept
Mercury	**REJECT**	**REJECT**	Accept
Molybdenum	**REJECT**	Accept	Accept
Neodymium	Accept	Accept	Accept
Nickel	**REJECT**	**REJECT**	Accept
Niobium	**REJECT**	**REJECT**	Accept
Phosphorus	**REJECT**	**REJECT**	Accept
Potassium	**REJECT**	**REJECT**	Accept
Scandium	Accept	Accept	Accept
Selenium	**REJECT**	Accept	**REJECT**
Silver	Accept	Accept	Accept
Sodium	Accept	**REJECT**	Accept
Strontium	Accept	**REJECT**	Accept
Sulfur	**REJECT**	**REJECT**	**REJECT**
Tantalum	Accept	Accept	Accept
Thorium	Accept	Accept	Accept
Tin	Accept	Accept	Accept
Titanium	**REJECT**	Accept	Accept
Uranium	Accept	Accept	Accept
Vanadium	**REJECT**	**REJECT**	Accept
Ytterbium	Accept	Accept	Accept
Yttrium	Accept	Accept	Accept
Zinc	**REJECT**	**REJECT**	Accept

Supplement 13. Chemical analyses of soil extracts from the New Rockford irrigation area

[mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram; <, less than]

Identification number	Date	Latitude-longitude identification number	Township-range identification number	Horizon sampled (feet below land surface)	Aluminum (mg/kg)	Antimony (mg/kg)	Arsenic (µg/kg)	Barium (mg/kg)
NR86A	7-11-90	474647098571702	150-065-27DAA2	2 to 3.5	10	<0.5	<10	0.2
				15.5 to 18	<5	<.5	9	<.1
NR89A	7-10-90	474505098572102	149-065-03DAA2	7 to 9	<5	<.5	13	<.1
				9 to 11.5	<5	<.5	15	<.1
				11.5 to 13	<5	<.5	13	<.1
				13 to 18	<5	<.5	11	.7
NR152A	7-10-90	474347098533002	149-064-18AAA2	16 to 17	<5	<.5	19	<.1
				17 to 18	<5	<.5	<2	.6
NR161A	7-09-90	474347098513402	149-064-16BAA2	0 to 1	<5	<.5	<2	.1
				13 to 18	<5	<.5	16	.5
NR172A	7-10-90	474235098535902	149-064-19ACC2	8.5 to 13	<5	<.5	11	<.1
				13 to 17.5	<5	<.5	7	.5
NR211A	7-11-90	474117098493902	149-064-27DDD2	0 to 2	<5	<.5	<2	.4
				12 to 14	<5	<.5	9	.5
				14 to 18	<5	<.5	9	.4

Supplement 13. Chemical analyses of soil extracts from the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Beryllium (mg/kg)	Bismuth (mg/kg)	Boron (mg/kg)	Cadmium (mg/kg)	Calcium (mg/kg)	Cerium (mg/kg)	Chromium (mg/kg)	Cobalt (mg/kg)
NR86A	2 to 3.5	<0.1	<1	<0.5	<0.2	58	<0.4	<0.1	<0.1
	15.5 to 18	<.1	<1	<.5	<.2	87	<.4	<.1	<.1
NR89A	7 to 9	<.1	<1	<.5	<.2	64	<.4	<.1	<.1
	9 to 11.5	<.1	<1	<.5	<.2	40	<.4	<.1	<.1
	11.5 to 13	<.1	<1	<.5	<.2	59	<.4	<.1	<.1
	13 to 18	<.1	<1	<.5	<.2	650	<.4	<.1	<.1
NR152A	16 to 17	<.1	<1	<.5	<.2	90	<.4	<.1	<.1
	17 to 18	<.1	<1	<.5	<.2	440	<.4	<.1	<.1
NR161A	0 to 1	<.1	<1	<.5	<.2	170	<.4	<.1	<.1
	13 to 18	<.1	<1	<.5	<.2	310	<.4	<.1	<.1
NR172A	8.5 to 13	<.1	<1	<.5	<.2	88	<.4	<.1	<.1
	13 to 17.5	<.1	<1	<.5	<.2	450	<.4	<.1	<.1
NR211A	0 to 2	<.1	<1	<.5	<.2	88	<.4	<.1	<.1
	12 to 14	<.1	<1	<.5	<.2	1,800	<.4	<.1	.1
	14 to 18	<.1	<1	<.5	<.2	420	<.4	<.1	<.1

Supplement 13. Chemical analyses of soil extracts from the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Copper (mg/kg)	Iron (mg/kg)	Lanthanum (mg/kg)	Lead (mg/kg)	Lithium (mg/kg)	Magnesium (mg/kg)	Manganese (mg/kg)	Molybdenum (mg/kg)
NR86A	2 to 3.5	<0.1	<5	<0.2	<0.4	<0.2	20	<0.4	<0.2
	15.5 to 18	<.1	<5	<.2	<.4	<.2	20	<.4	<.2
NR89A	7 to 9	<.1	<5	<.2	<.4	<.2	30	<.4	<.2
	9 to 11.5	<.1	<5	<.2	<.4	<.2	20	<.4	<.2
	11.5 to 13	<.1	<5	<.2	<.4	<.2	30	<.4	<.2
	13 to 18	<.1	<5	<.2	<.4	.3	220	2.0	<.2
NR152A	16 to 17	<.1	<5	<.2	<.4	<.2	20	<.4	.3
	17 to 18	<.1	<5	<.2	<.4	.4	120	.7	<.2
NR161A	0 to 1	<.1	<5	<.2	<.4	<.2	40	<.4	<.2
	13 to 18	<.1	<5	<.2	<.4	.3	120	.7	<.2
NR172A	8.5 to 13	<.1	<5	<.2	<.4	<.2	30	<.4	<.2
	13 to 17.5	<.1	<5	<.2	<.4	.3	100	1.0	<.2
NR211A	0 to 2	<.1	10	<.2	<.4	<.2	20	<.4	<.2
	12 to 14	.1	<5	<.2	<.4	.5	300	5.0	.5
	14 to 18	<.1	<5	<.2	<.4	.2	74	.9	<.2

Supplement 13. Chemical analyses of soil extracts from the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Nickel (mg/kg)	Phosphorus (mg/kg)	Potassium (mg/kg)	Selenium (µg/kg)	Silicon (mg/kg)	Silver (mg/kg)	Sodium (mg/kg)	Strontium (mg/kg)
NR86A	2 to 3.5	<0.2	<5	20	6	76	<0.2	20	0.2
	15.5 to 18	<.2	<5	30	<1	89	<.2	20	<.2
NR89A	7 to 9	<.2	<5	20	5	93	<.2	40	<.2
	9 to 11.5	<.2	<5	20	<1	72	<.2	20	<.2
	11.5 to 13	<.2	<5	30	20	91	<.2	40	<.2
	13 to 18	<.2	<5	91	40	86	<.2	96	2.0
NR152A	16 to 17	<.2	<5	30	2	86	<.2	20	<.2
	17 to 18	<.2	<5	85	60	67	<.2	50	.9
NR161A	0 to 1	<.2	<5	40	2	65	<.2	20	.2
	13 to 18	<.2	<5	60	32	97	<.2	170	1.0
NR172A	8.5 to 13	<.2	<5	10	<1	92	<.2	59	<.2
	13 to 17.5	<.2	<5	63	32	77	<.2	100	1.0
NR211A	0 to 2	<.2	<5	55	2	58	<.2	10	.2
	12 to 14	<.2	<5	84	15	78	<.2	80	3.0
	14 to 18	<.2	<5	40	6	54	<.2	30	.7

Supplement 13. Chemical analyses of soil extracts from the New Rockford irrigation area—Continued

[mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Thorium (mg/kg)	Tin (mg/kg)	Titanium (mg/kg)	Vanadium (mg/kg)	Wolfram (mg/kg)	Yttrium (mg/kg)	Zinc (mg/kg)	Zirconium (mg/kg)
NR86A	2 to 3.5	<0.4	<0.5	<5	<0.2	<0.5	<0.2	<0.2	<0.2
	15.5 to 18	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
NR89A	7 to 9	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
	9 to 11.5	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
	11.5 to 13	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
	13 to 18	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
NR152A	16 to 17	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
	17 to 18	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
NR161A	0 to 1	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
	13 to 18	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
NR172A	8.5 to 13	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
	13 to 17.5	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
NR211A	0 to 2	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
	12 to 14	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
	14 to 18	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2

Supplement 14. Chemical analyses of water from wells and a drain in the New Rockford irrigation area

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; mg/L, milligrams per liter; IT, incremental titration; <, less than; µg/L, micrograms per liter; >, greater than; --, no data]

Identification number	Date	Latitude-longitude identification number	Township-range identification number	Altitude of screen bottom (feet)	Altitude of water level (feet)	Type of well	Specific conductance (µS/cm)	pH (standard units)
NR23B	10-18-90	474628099010303	150-065-29CCC3	1,523.1	1,530.1	Deep	585	7.39
NR32	10-16-90	474302099123803	149-067-14CCC3	1,516.2	1,520.7	Shallow	729	7.28
NR45	10-16-90	474209099060201	149-066-22CCD1	1,524.8	1,526.4	Shallow	956	7.13
NR55	10-16-90	474505099042601	149-066-02CAA1	1,525.4	1,529.1	Shallow	1,420	7.33
NR68	10-18-90	474412099023001	149-066-12DAA1	1,521.0	1,524.7	Shallow	1,490	7.28
NR75	10-18-90	474714099014201	150-065-30ABB1	1,527.7	1,535.6	Deep	592	7.07
NR75A	10-18-90	474714099014202	150-065-30ABB2	1,533.4	1,535.6	Shallow	572	7.58
NR79	10-22-90	474621098583501	150-065-33AAA1	1,520.7	1,526.2	Deep	451	7.60
NR79A	10-22-90	474621098583502	150-065-33AAA2	1,523.6	1,526.2	Shallow	425	7.78
NR86	10-22-90	474647098571701	150-065-27DAA1	1,514.1	1,526.1	Deep	464	7.68
NR89	10-19-90	474505098572101	149-065-03DAA1	1,510.5	1,522.1	Deep	603	7.43
NR89A	10-19-90	474505098572102	149-065-03DAA2	1,520.0	1,522.1	Shallow	677	7.61
NR104	10-23-90	474353098560401	149-065-11DDD1	1,500.9	1,516.6	Deep	538	7.50
NR121	10-23-90	474628098544001	150-065-25DDD1	1,510.1	1,517.1	Deep	491	7.70
NR121A	10-23-90	474628098544002	150-065-25DDD2	1,514.5	1,517.1	Shallow	500	7.52
NR152	10-23-90	474347098533001	149-064-18AAA1	1,503.6	1,513.2	Deep	457	7.43
NR152A	10-23-90	474347098533002	149-064-18AAA2	1,510.5	1,513.2	Shallow	426	7.53
NR161	10-24-90	474347098513401	149-064-16BAA1	1,489.3	1,500.3	Deep	807	7.24
NR161A	10-24-90	474347098513402	149-064-16BAA2	1,497.8	1,500.3	Shallow	850	7.27
NR172	10-24-90	474235098535901	149-064-19ACC1	1,501.2	1,512.6	Deep	533	7.40
NR172A	10-24-90	474235098535902	149-064-19ACC2	1,508.2	1,512.6	Shallow	529	7.50
NR211	10-24-90	474117098493901	149-064-27DDD1	1,490.2	1,503.9	Deep	472	7.38
NR211A	10-24-90	474117098493902	149-064-27DDD2	1,499.5	1,503.9	Shallow	577	7.34
Drain	10-16-90	474321099072901	149-066-16CBB	--	--	Shallow	994	7.11

Supplement 14. Chemical analyses of water from wells and a drain in the New Rockford irrigation area—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; mg/L, milligrams per liter; IT, incremental titration; <, less than; µg/L, micrograms per liter; >, greater than; --, no data]

Identification number	Date	Temperature, water (deg C)	Oxygen, dissolved (mg/L)	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Potassium, dissolved (mg/L)	Carbonate, IT-field (mg/L as CO_3)	Bicarbonate, IT-field (mg/L as HCO_3)	Sulfate, dissolved (mg/L as SO_4)	Sulfide, dissolved (mg/L as S)
NR23B	10-18-90	6.4	1.2	75	30	21	5.9	0	339	92	0.011
NR32	10-16-90	10.0	4.0	86	37	18	3.9	0	276	170	.008
NR45	10-16-90	12.2	2.7	110	41	49	6.1	0	444	180	.003
NR55	10-16-90	10.4	1.0	93	82	140	3.9	0	508	420	.006
NR68	10-18-90	9.2	1.2	140	66	110	8.3	0	361	550	<.001
NR75	10-18-90	3.8	.18	87	23	4.8	6.3	0	405	9.4	<.001
NR75A	10-18-90	8.6	1.0	96	21	3.4	3.2	0	347	36	<.001
NR79	10-22-90	13.6	.80	57	18	4.0	2.6	0	195	40	.014
NR79A	10-22-90	11.2	2.1	54	17	3.1	2.4	0	181	27	.039
NR86	10-22-90	16.6	.14	66	20	5.7	2.3	0	210	73	<.001
NR89	10-19-90	5.0	.35	69	27	28	4.8	0	320	75	<.001
NR89A	10-19-90	8.3	.59	68	44	22	5.6	0	356	71	.001
NR104	10-23-90	11.0	.90	62	19	34	3.5	0	278	72	.003
NR121	10-23-90	5.4	1.8	70	21	7.2	2.9	0	254	40	<.001
NR121A	10-23-90	8.0	3.4	70	21	4.4	2.4	0	254	27	.012
NR152	10-23-90	13.9	.44	54	23	16	3.9	0	259	60	.005
NR152A	10-23-90	11.2	6.6	63	20	3.5	1.6	0	225	10	<.001
NR161	10-24-90	3.8	.16	82	40	63	4.9	0	534	66	.019
NR161A	10-24-90	7.1	.86	89	44	66	4.9	0	581	47	<.001
NR172	10-24-90	6.1	.44	71	21	25	3.7	0	288	88	<.001
NR172A	10-24-90	9.9	2.3	71	24	18	1.3	0	268	73	<.001
NR211	10-24-90	9.0	.49	70	20	20	2.5	0	286	53	.010
NR211A	10-24-90	9.9	1.6	88	29	6.5	2.0	0	337	51	<.001
Drain	10-16-90	11.9	1.1	150	51	36	6.6	0	334	390	.004

Supplement 14. Chemical analyses of water from wells and a drain in the New Rockford irrigation area—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; mg/L, milligrams per liter; IT, incremental titration; <, less than; µg/L, micrograms per liter; >, greater than; --, no data]

Identification number	Date	Chloride, dissolved (mg/L)	Fluoride, dissolved (mg/L)	Silica, dissolved (mg/L as SiO_2)	Nitrite, dissolved (mg/L as N)	Nitrite plus nitrate, dissolved (mg/L as N)	Ammonia, dissolved (mg/L as N)	Orthophosphorus, dissolved (mg/L as P)	Arsenic, dissolved (µg/L)	Boron, dissolved (µg/L)
NR23B	10-18-90	7.0	0.2	26	0.002	<0.01	0.07	<0.01	4	60
NR32	10-16-90	11	<.1	25	.002	4.8	<.01	<.01	<1	50
NR45	10-16-90	29	.2	25	.026	2.2	<.01	<.01	<1	60
NR55	10-16-90	37	<.1	22	.005	.02	.01	<.01	1	40
NR68	10-18-90	18	<.1	25	.007	4.5	<.01	<.01	<1	60
NR75	10-18-90	13	.1	28	.010	.10	.19	<.01	5	30
NR75A	10-18-90	11	.1	24	.060	2.3	.02	.02	<1	40
NR79	10-22-90	3.1	.1	29	.002	.07	.01	.07	3	40
NR79A	10-22-90	2.6	.1	29	.038	11	.01	.09	3	30
NR86	10-22-90	2.8	.2	27	<.001	<.01	.02	.02	3	30
NR89	10-19-90	17	.2	32	.003	.01	.19	.03	<1	70
NR89A	10-19-90	15	.3	32	.007	5.4	.01	<.01	2	60
NR104	10-23-90	9.8	.2	26	.002	.14	.12	.03	2	90
NR121	10-23-90	4.9	.1	26	<.001	3.7	.03	.03	3	50
NR121A	10-23-90	4.0	.1	29	<.001	8.4	<.01	.06	3	40
NR152	10-23-90	3.8	.2	28	.003	<.01	.10	.02	3	50
NR152A	10-23-90	2.7	.2	30	.002	12	.03	.05	1	40
NR161	10-24-90	12	.2	34	<.001	<.01	.05	.02	14	140
NR161A	10-24-90	17	.2	35	.012	3.1	<.01	.01	6	140
NR172	10-24-90	9.2	.2	29	<.001	.02	.14	<.01	3	70
NR172A	10-24-90	5.1	.3	29	.004	8.0	<.01	<.01	1	70
NR211	10-24-90	8.7	.2	29	<.001	<.01	.07	<.01	5	60
NR211A	10-24-90	17	.1	30	.003	2.4	.02	<.01	1	40
Drain	10-16-90	19	.2	28	.006	.01	.05	.02	4	60

Supplement 14. Chemical analyses of water from wells and a drain in the New Rockford irrigation area—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; mg/L, milligrams per liter; IT, incremental titration; <, less than; µg/L, micrograms per liter; >, greater than; --, no data]

Identification number	Date	Iron, dissolved (µg/L as Fe)	Ferrous iron, dissolved (µg/L as Fe)	Lithium, dissolved (µg/L)	Manganese, dissolved (µg/L)	Mercury, dissolved (µg/L)	Molybdenum, dissolved (µg/L)	Selenium, dissolved (µg/L)	Strontium, dissolved (µg/L)	Organic carbon, dissolved (mg/L)
NR23B	10-18-90	1,200	1,250	28	270	<0.1	2	<1	220	2.7
NR32	10-16-90	<3	<10	24	43	<.1	<1	<1	270	2.3
NR45	10-16-90	<3	10	26	270	<.1	<1	2	260	7.2
NR55	10-16-90	20	10	48	230	<.1	<1	<1	250	8.6
NR68	10-18-90	4	<10	75	65	<.1	1	4	430	5.1
NR75	10-18-90	4,800	>3,000	8	630	<.1	<1	<1	100	5.5
NR75A	10-18-90	<3	10	12	710	.1	2	<1	160	2.9
NR79	10-22-90	6	10	15	130	.1	<1	<1	100	1.9
NR79A	10-22-90	<3	20	14	820	<.1	<1	<1	77	2.3
NR86	10-22-90	120	160	17	250	<.1	<1	<1	130	1.3
NR89	10-19-90	410	410	16	610	.2	<1	<1	200	3.0
NR89A	10-19-90	4	<10	23	180	.1	<1	4	210	3.4
NR104	10-23-90	25	50	18	590	.1	2	<1	230	2.1
NR121	10-23-90	10	10	15	27	.2	2	<1	150	1.2
NR121A	10-23-90	<3	<10	16	2	<.1	<1	<1	140	1.4
NR152	10-23-90	2,000	2,110	21	270	<.1	<1	<1	170	2.2
NR152A	10-23-90	11	<10	10	35	<.1	<1	<1	78	1.6
NR161	10-24-90	360	390	47	390	.2	<1	<1	330	5.4
NR161A	10-24-90	<3	<10	44	820	.4	2	<1	390	4.2
NR172	10-24-90	2,300	2,380	22	520	<.1	<1	<1	230	2.3
NR172A	10-24-90	16	20	22	440	.1	<1	2	140	2.5
NR211	10-24-90	670	680	16	730	<.1	2	<1	170	2.5
NR211A	10-24-90	<3	<10	24	230	<.1	2	<1	170	2.0
Drain	10-16-90	1,100	1,060	40	440	<.1	<1	<1	410	2.4

Supplement 15. Results of Wilcoxon's rank sum tests between the shallow and deep parts of the aquifer underlying the New Rockford irrigation area

[Null hypothesis: the median constituent concentrations for the shallow and deep wells are equal]

Constituent	Acceptance or rejection of null hypothesis
Specific conductance	Accept
pH	Accept
Temperature, water	Accept
Oxygen, dissolved	**REJECT**
Calcium, dissolved	**REJECT**
Magnesium, dissolved	**REJECT**
Sodium, dissolved	Accept
Potassium, dissolved	Accept
Bicarbonate, dissolved	Accept
Sulfate, dissolved	Accept
Chloride, dissolved	Accept
Fluoride, dissolved	Accept
Silica, dissolved	Accept
Nitrite, dissolved	**REJECT**
Nitrite plus nitrate, dissolved	**REJECT**
Ammonia, dissolved	**REJECT**
Orthophosphorus, dissolved	Accept
Arsenic, dissolved	**REJECT**
Boron, dissolved	Accept
Iron, dissolved	**REJECT**
Lithium, dissolved	Accept
Manganese, dissolved	Accept
Mercury, dissolved	Accept
Molybdenum, dissolved	Accept
Selenium, dissolved	**REJECT**
Strontium, dissolved	Accept
Organic carbon, dissolved	Accept

Supplement 16. Chemical analyses of soils in the Harvey Pumping irrigation area

[mg/kg, milligrams per kilogram; <, less than]

identification number	Date	Latitude-longitude identification number	Township-range identification number	Horizon sampled (feet below land surface)	Aluminum (percent)	Arsenic (mg/kg)	Barium (mg/kg)
HP8	8-07-90	474113099523801	149-072-33AAA1	0 to 1.5	5.50	7.3	669
				1.5 to 6.5	4.72	6.0	888
				6.5 to 11	5.36	6.5	759
				11 to 16	5.37	5.9	763
				16 to 18	4.87	7.2	912
				18 to 21	4.51	1.8	1,230
				21 to 24	5.01	7.8	977
HP21	8-06-90	474146099551301	149-072-30ADD1	0 to 2.5	5.05	4.9	695
				2.5 to 4	5.05	5.5	763
				4 to 8	5.16	9.7	955
				8 to 12	5.19	6.7	814
				12 to 16.5	4.72	4.2	742
				16.5 to 18	5.26	1.0	805
HP26	8-06-90	474139099534601	149-072-28CBB1	0 to 2	5.53	5.4	718
				2 to 4	5.28	7.2	768
				4 to 10	4.75	6.4	750
				10 to 12	5.16	3.3	736
				12 to 15.5	5.01	7.2	842
				15.5 to 17	4.93	5.5	862
				17 to 18	5.41	5.5	846

Supplement 16. Chemical analyses of soils in the Harvey Pumping irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Beryllium (mg/kg)	Bismuth (mg/kg)	Cadmium (mg/kg)	Calcium (percent)	Cerium (mg/kg)	Chromium (mg/kg)	Cobalt (mg/kg)	Copper (mg/kg)
HP8	0 to 1.5	1	<10	<2	1.08	54	57	11	13
	1.5 to 6.5	<1	<10	<2	8.48	44	47	10	12
	6.5 to 11	1	<10	<2	4.02	51	59	11	13
	11 to 16	1	<10	<2	3.80	52	56	11	14
	16 to 18	2	<10	<2	4.13	56	57	16	18
	18 to 21	1	<10	<2	4.47	45	38	15	10
	21 to 24	1	<10	<2	4.17	53	45	12	13
HP21	0 to 2.5	1	<10	<2	1.39	60	51	9	11
	2.5 to 4	1	<10	<2	4.49	51	49	10	8
	4 to 8	1	<10	<2	4.26	58	67	17	10
	8 to 12	1	<10	<2	3.52	50	54	17	8
	12 to 16.5	<1	<10	<2	3.18	60	48	9	4
	16.5 to 18	1	<10	<2	1.77	44	49	8	6
HP26	0 to 2	1	<10	<2	1.03	60	59	9	11
	2 to 4	1	<10	<2	3.70	52	58	12	13
	4 to 10	1	<10	<2	3.26	50	42	10	7
	10 to 12	1	<10	<2	2.87	52	49	9	6
	12 to 15.5	1	<10	<2	3.43	51	52	10	7
	15.5 to 17	1	<10	<2	3.09	74	67	11	8
	17 to 18	1	<10	<2	4.16	50	55	11	16

Supplement 16. Chemical analyses of soils in the Harvey Pumping irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Europium (mg/kg)	Gallium (mg/kg)	Gold (mg/kg)	Holmium (mg/kg)	Iron (percent)	Lanthanum (mg/kg)	Lead (mg/kg)	Lithium (mg/kg)
HP8	0 to 1.5	<2	12	<8	<4	2.35	31	14	20
	1.5 to 6.5	<2	10	<8	<4	1.87	26	12	23
	6.5 to 11	<2	11	<8	<4	2.21	29	28	21
	11 to 16	<2	11	<8	<4	2.16	29	14	21
	16 to 18	<2	12	<8	<4	2.34	32	17	21
	18 to 21	<2	10	<8	<4	2.73	27	12	15
	21 to 24	<2	11	<8	<4	2.33	30	13	20
HP21	0 to 2.5	<2	11	<8	<4	2.03	34	16	15
	2.5 to 4	<2	10	<8	<4	1.84	28	13	15
	4 to 8	<2	12	<8	<4	2.92	32	26	17
	8 to 12	<2	12	<8	<4	2.10	28	20	15
	12 to 16.5	<2	9	<8	<4	1.88	33	10	11
	16.5 to 18	<2	12	<8	<4	1.64	25	10	17
HP26	0 to 2	<2	11	<8	<4	2.23	35	13	19
	2 to 4	<2	12	<8	<4	2.26	30	20	20
	4 to 10	<2	10	<8	<4	1.81	27	19	13
	10 to 12	<2	10	<8	<4	1.65	30	17	14
	12 to 15.5	<2	11	<8	<4	2.19	28	16	14
	15.5 to 17	<2	10	<8	<4	2.61	40	12	15
	17 to 18	<2	11	<8	<4	2.32	28	14	23

Supplement 16. Chemical analyses of soils in the Harvey Pumping irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Magnesium (percent)	Manganese (mg/kg)	Mercury (mg/kg)	Molybdenum (mg/kg)	Neodymium (mg/kg)	Nickel (mg/kg)	Niobium (mg/kg)	Phosphorus (percent)
HP8	0 to 1.5	0.55	544	0.04	<2	26	28	6	0.06
	1.5 to 6.5	2.08	423	.02	<2	21	24	6	.07
	6.5 to 11	1.67	455	.02	<2	24	25	<4	.06
	11 to 16	1.59	487	.04	<2	23	25	<4	.06
	16 to 18	1.66	585	.08	<2	26	45	10	.07
	18 to 21	1.56	1,400	.04	2	21	28	<4	.07
	21 to 24	1.62	648	.04	<2	26	26	4	.07
HP21	0 to 2.5	.52	639	.02	<2	26	17	4	.07
	2.5 to 4	.96	383	.02	<2	23	20	<4	.06
	4 to 8	1.39	784	.04	<2	26	31	<4	.06
	8 to 12	1.28	785	.02	<2	23	32	<4	.05
	12 to 16.5	.96	435	<.02	<2	26	19	<4	.05
	16.5 to 18	.80	166	<.02	<2	19	24	7	.06
HP26	0 to 2	.52	442	.02	<2	29	27	<4	.06
	2 to 4	1.59	616	.02	<2	25	27	<4	.06
	4 to 10	1.26	608	.02	<2	23	22	<4	.06
	10 to 12	.99	293	<.02	<2	23	19	<4	.05
	12 to 15.5	1.18	460	.04	<2	21	24	<4	.06
	15.5 to 17	1.06	505	.02	<2	31	21	6	.07
	17 to 18	1.70	523	.02	<2	23	25	9	.07

Supplement 16. Chemical analyses of soils in the Harvey Pumping irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Potassium (percent)	Scandium (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)	Sodium (percent)	Strontium (mg/kg)	Sulfur (percent)	Tantalum (mg/kg)
HP8	0 to 1.5	1.70	7	0.4	<2	1.19	191	<0.05	<40
	1.5 to 6.5	1.43	6	.3	<2	1.08	292	<.05	<40
	6.5 to 11	1.63	7	.1	<2	1.27	226	<.05	<40
	11 to 16	1.63	7	<.1	<2	1.28	222	<.05	<40
	16 to 18	1.46	9	.3	<2	1.10	216	<.05	<40
	18 to 21	1.40	6	.6	<2	1.35	253	.12	<40
	21 to 24	1.57	7	.4	<2	1.34	246	.21	<40
HP21	0 to 2.5	1.55	6	.3	<2	1.27	216	<.05	<40
	2.5 to 4	1.47	6	<.1	<2	1.40	261	<.05	<40
	4 to 8	1.51	7	.2	<2	1.37	265	<.05	<40
	8 to 12	1.52	6	<.1	<2	1.49	281	<.05	<40
	12 to 16.5	1.33	5	<.1	<2	1.55	280	<.05	<40
	16.5 to 18	1.44	6	5.4	<2	1.34	251	.06	<40
HP26	0 to 2	1.73	7	.2	<2	1.29	210	<.05	<40
	2 to 4	1.64	6	<.1	<2	1.33	236	<.05	<40
	4 to 10	1.50	5	<.1	<2	1.51	261	<.05	<40
	10 to 12	1.53	5	<.1	<2	1.60	285	<.05	<40
	12 to 15.5	1.45	6	.2	<2	1.53	280	<.05	<40
	15.5 to 17	1.42	6	1.6	<2	1.50	274	.24	<40
	17 to 18	1.68	7	.5	<2	1.37	240	.27	<40

Supplement 16. Chemical analyses of soils in the Harvey Pumping irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Thorium (mg/kg)	Tin (mg/kg)	Titanium (percent)	Uranium (mg/kg)	Vanadium (mg/kg)	Ytterbium (mg/kg)	Yttrium (mg/kg)	Zinc (mg/kg)
HP8	0 to 1.5	8	<10	0.22	<100	74	2	18	60
	1.5 to 6.5	6	<10	.18	<100	64	1	13	45
	6.5 to 11	7	<10	.19	<100	73	2	16	56
	11 to 16	7	<10	.20	<100	73	2	16	56
	16 to 18	7	<10	.25	<100	74	3	24	61
	18 to 21	7	<10	.21	<100	70	2	14	49
	21 to 24	10	<10	.23	<100	64	2	15	49
HP21	0 to 2.5	9	<10	.21	<100	59	2	16	64
	2.5 to 4	6	<10	.18	<100	56	1	14	46
	4 to 8	8	<10	.25	<100	70	2	16	64
	8 to 12	6	<10	.20	<100	61	1	14	58
	12 to 16.5	9	<10	.22	<100	49	2	15	37
	16.5 to 18	6	<10	.22	<100	69	1	13	62
HP26	0 to 2	10	<10	.23	<100	71	2	19	57
	2 to 4	7	<10	.21	<100	69	2	16	51
	4 to 10	7	<10	.18	<100	49	1	14	40
	10 to 12	7	<10	.21	<100	54	1	14	45
	12 to 15.5	7	<10	.23	<100	58	2	15	44
	15.5 to 17	14	<10	.37	<100	66	2	17	47
	17 to 18	7	<10	.26	<100	71	2	16	60

Supplement 17. Chemical analyses of soil extracts from the Harvey Pumping irrigation area

[mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram; <, less than]

Identification number	Date	Latitude-longitude identification number	Township-range identification number	Horizon sampled (feet below land surface)	Aluminum (mg/kg)	Antimony (mg/kg)	Arsenic (µg/kg)	Barium (mg/kg)
HP8	8-07-90	474113099523801	149-072-33AAA1	18 to 21	<5	<0.5	<10	0.4
HP21	8-06-90	474146099551301	149-072-30ADD1	16.5 to 18	<5	<.5	42	.4
HP26	8-06-90	474139099534601	149-072-28CBB1	15.5 to 17	<5	<.5	36	.3

Supplement 17. Chemical analyses of soil extracts from the Harvey Pumping irrigation area—Continued

[mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Beryllium (mg/kg)	Bismuth (mg/kg)	Boron (mg/kg)	Cadmium (mg/kg)	Calcium (mg/kg)	Cerium (mg/kg)	Chromium (mg/kg)	Cobalt (mg/kg)
HP8	18 to 21	<0.1	<1	<0.5	<0.2	240	<0.4	<0.1	<0.1
HP21	16.5 to 18	<.1	<1	.6	<.2	97	<.4	<.1	<.1
HP26	15.5 to 17	<.1	<1	<.5	<.2	170	<.4	<.1	<.1

Supplement 17. Chemical analyses of soil extracts from the Harvey Pumping irrigation area—Continued

[mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Copper (mg/kg)	Iron (mg/kg)	Lanthanum (mg/kg)	Lead (mg/kg)	Lithium (mg/kg)	Magnesium (mg/kg)	Manganese (mg/kg)	Molybdenum (mg/kg)
HP8	18 to 21	0.2	<5	<0.2	<0.4	<0.2	59	<0.4	<0.2
HP21	16.5 to 18	<.1	<5	<.2	<.4	<.2	50	<.4	<.2
HP26	15.5 to 17	<.1	<5	<.2	<.4	<.2	40	<.4	<.2

Supplement 17. Chemical analyses of soil extracts from the Harvey Pumping irrigation area—Continued

[mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Nickel (mg/kg)	Phosphorus (mg/kg)	Potassium (mg/kg)	Selenium (µg/kg)	Silicon (mg/kg)	Silver (mg/kg)	Sodium (mg/kg)	Strontium (mg/kg)
HP8	18 to 21	<0.2	<5	40	24	30	<0.2	80	0.5
HP21	16.5 to 18	<.2	<5	40	650	50	<.2	40	.3
HP26	15.5 to 17	<.2	<5	40	80	40	<.2	130	.6

Supplement 17. Chemical analyses of soil extracts from the Harvey Pumping irrigation area—Continued

[mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Thorium (mg/kg)	Tin (mg/kg)	Titanium (mg/kg)	Vanadium (mg/kg)	Wolfram (mg/kg)	Yttrium (mg/kg)	Zinc (mg/kg)	Zirconium (mg/kg)
HP8	18 to 21	<0.4	<0.5	<5	<0.2	<0.5	<0.2	<0.2	<0.2
HP21	16.5 to 18	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
HP26	15.5 to 17	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2

Supplement 18. Chemical analyses of water from wells in the Harvey Pumping irrigation area

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; mg/L, milligrams per liter; IT, incremental titration; <, less than; µg/L, micrograms per liter]

Identification number	Date	Latitude-longitude identification number	Township-range identification number	Altitude of screen bottom (feet)	Altitude of water level (feet)	Type of well	Specific conductance (µS/cm)	pH (standard units)
HP8	9-20-90	474113099523801	149-072-33AAA1	1,599.7	1,604.5	Shallow	1,010	7.26
HP11	9-20-90	474027099534601	149-072-33CCC1	1,600.2	1,607.4	Deep	595	6.69
HP21	10-25-90	474146099551301	149-072-30ADD1	1,599.3	1,603.8	Shallow	544	7.26
HP26	10-25-90	474139099534601	149-072-28CBB1	1,605.6	1,608.7	Shallow	669	7.51

Supplement 18. Chemical analyses of water from wells in the Harvey Pumping irrigation area—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; mg/L, milligrams per liter; IT, incremental titration; <, less than; µg/L, micrograms per liter]

Identification number	Date	Temperature, water (deg C)	Oxygen, dissolved (mg/L)	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Potassium, dissolved (mg/L)	Carbonate, IT-field (mg/L as CO_3)	Bicarbonate, IT-field (mg/L as HCO_3)	Sulfate, dissolved (mg/L as SO_4)	Sulfide, dissolved (mg/L as S)
HP8	9-20-90	10.8	0.90	94	31	80	6.7	0	488	160	0.004
HP11	9-20-90	10.2	.80	73	22	24	3.5	0	278	64	.003
HP21	10-25-90	13.0	.88	65	30	13	1.8	0	315	29	.002
HP26	10-25-90	9.4	.17	60	32	44	13	0	439	27	<.001

Supplement 18. Chemical analyses of water from wells in the Harvey Pumping irrigation area—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; mg/L, milligrams per liter; IT, incremental titration; <, less than; µg/L, micrograms per liter]

Identification number	Date	Chloride, dissolved (mg/L)	Fluoride, dissolved (mg/L)	Silica, dissolved (mg/L as SiO_2)	Nitrite, dissolved (mg/L as N)	Nitrite plus nitrate, dissolved (mg/L as N)	Ammonia, dissolved (mg/L as N)	Orthophosphorus, dissolved (mg/L as P)	Arsenic, dissolved (µg/L)	Boron, dissolved (µg/L)
HP8	9-20-90	8.0	<0.1	24	0.010	0.74	0.10	<0.01	2	80
HP11	9-20-90	6.0	<.1	23	.017	1.1	.03	<.01	1	60
HP21	10-25-90	12	.3	29	.012	5.0	.01	<.01	<1	90
HP26	10-25-90	5.6	.3	23	.006	.04	.02	<.01	<1	140

Supplement 18. Chemical analyses of water from wells in the Harvey Pumping irrigation area—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; mg/L, milligrams per liter; IT, incremental titration; <, less than; µg/L, micrograms per liter]

Identification number	Date	Iron, dissolved (µg/L as Fe)	Ferrous iron, dissolved (µg/L as Fe)	Lithium, dissolved (µg/L)	Manganese, dissolved (µg/L)	Mercury, dissolved (µg/L)	Molybdenum, dissolved (µg/L)	Selenium, dissolved (µg/L)	Strontium, dissolved (µg/L)	Organic carbon, dissolved (mg/L)
HP8	9-20-90	560	560	25	160	<0.1	<1	<1	220	4.1
HP11	9-20-90	<3	10	15	72	.2	<1	1	170	1.9
HP21	10-50-90	<3	<10	20	9	<.1	<1	1	170	2.8
HP26	10-25-90	6	10	27	230	<.1	1	<1	240	3.1

Supplement 19. Chemical analyses of soils in the Lincoln Valley irrigation area

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Date	Latitude-longitude identification number	Township-range identification number	Horizon sampled (feet below land surface)	Aluminum (percent)	Arsenic (mg/kg)	Barium (mg/kg)
LV2B	8-08-90	473940100191002	148-076-02CDD2	0 to 1.5	5.33	7.0	722
				1.5 to 5	5.31	7.9	808
				5 to 10.5	5.57	7.6	881
				10.5 to 14	5.98	7.9	893
				14 to 18	5.30	5.4	698
				18 to 20	5.38	6.5	701
LV4B	8-07-90	474027100190102	149-075-31DDC2	0 to 3	4.74	9.4	752
				3 to 5	4.25	8.9	755
				5 to 8.5	4.45	6.5	703
				8.5 to 15.5	4.41	7.1	723
				15.5 to 19	4.47	7.0	728
				19 to 21.5	4.50	6.6	829
LV40	8-07-90	474027100193001	149-075-31CCC	0 to 2	5.36	6.3	727
				2 to 5	5.13	7.4	778
				5 to 12	5.67	4.9	866
				12 to 20	5.67	8.4	776
				20 to 22	5.17	7.0	712
LV90-1	8-07-90	474027100171402	149-075-32CDD2	0 to 4.5	5.10	7.7	782
				4.5 to 10.5	5.09	9.9	863
				10.5 to 14	5.31	2.0	814

Supplement 19. Chemical analyses of soils in the Lincoln Valley irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Beryllium (mg/kg)	Bismuth (mg/kg)	Cadmium (mg/kg)	Calcium (percent)	Cerium (mg/kg)	Chromium (mg/kg)	Cobalt (mg/kg)	Copper (mg/kg)
LV2B	0 to 1.5	1	<10	<2	1.10	46	47	11	15
	1.5 to 5	1	<10	<2	4.15	44	48	12	13
	5 to 10.5	1	<10	<2	3.93	48	55	12	14
	10.5 to 14	1	<10	<2	2.96	43	57	13	15
	14 to 18	1	<10	<2	4.73	43	53	12	23
	18 to 20	1	<10	<2	4.70	48	55	13	24
LV4B	0 to 3	1	<10	<2	4.15	44	45	13	16
	3 to 5	1	<10	<2	4.16	47	37	12	9
	5 to 8.5	1	<10	<2	4.30	42	38	10	10
	8.5 to 15.5	1	<10	<2	4.28	44	41	11	11
	15.5 to 19	1	<10	<2	4.30	39	38	21	11
	19 to 21.5	1	<10	<2	4.17	44	40	31	11
LV40	0 to 2	1	<10	<2	.89	47	51	12	14
	2 to 5	1	<10	<2	5.24	49	46	11	13
	5 to 12	1	<10	<2	2.57	42	47	10	7
	12 to 20	1	<10	<2	3.68	46	59	14	18
	20 to 22	1	<10	<2	4.44	41	50	12	18
LV90-1	0 to 4.5	1	<10	<2	3.73	47	45	11	12
	4.5 to 10.5	1	<10	<2	3.77	66	48	12	10
	10.5 to 14	1	<10	<2	2.96	55	44	10	8

Supplement 19. Chemical analyses of soils in the Lincoln Valley irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Europium (mg/kg)	Gallium (mg/kg)	Gold (mg/kg)	Holmium (mg/kg)	Iron (percent)	Lanthanum (mg/kg)	Lead (mg/kg)	Lithium (mg/kg)
LV2B	0 to 1.5	<2	11	<8	<4	2.33	27	13	19
	1.5 to 5	<2	11	<8	<4	2.32	26	12	26
	5 to 10.5	<2	12	<8	<4	2.45	27	13	26
	10.5 to 14	<2	12	<8	<4	2.65	25	12	25
	14 to 18	<2	12	<8	<4	2.49	25	15	30
	18 to 20	<2	13	<8	<4	2.68	28	15	31
LV4B	0 to 3	<2	11	<8	<4	2.29	25	13	25
	3 to 5	<2	10	<8	<4	1.96	26	13	17
	5 to 8.5	<2	10	<8	<4	1.78	25	12	18
	8.5 to 15.5	<2	8	<8	<4	1.81	26	17	18
	15.5 to 19	<2	9	<8	<4	1.96	24	12	18
	19 to 21.5	<2	12	<8	<4	1.93	25	13	19
LV40	0 to 2	<2	13	<8	<4	2.37	27	11	18
	2 to 5	<2	11	<8	<4	2.20	28	11	22
	5 to 12	<2	10	<8	<4	1.95	25	11	17
	12 to 20	<2	13	<8	<4	2.83	26	17	24
	20 to 22	<2	11	<8	<4	2.58	24	13	26
LV90-1	0 to 4.5	<2	11	<8	<4	2.14	28	12	24
	4.5 to 10.5	<2	12	<8	<4	2.50	35	13	20
	10.5 to 14	<2	11	<8	<4	2.26	32	11	17

Supplement 19. Chemical analyses of soils in the Lincoln Valley irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Magnesium (percent)	Manganese (mg/kg)	Mercury (mg/kg)	Molybdenum (mg/kg)	Neodymium (mg/kg)	Nickel (mg/kg)	Niobium (mg/kg)	Phosphorus (percent)
LV2B	0 to 1.5	0.59	601	0.02	<2	23	24	6	0.07
	1.5 to 5	1.75	495	.02	<2	21	28	<4	.07
	5 to 10.5	1.42	510	.04	<2	23	30	<4	.07
	10.5 to 14	1.46	427	.04	<2	21	29	5	.07
	14 to 18	2.27	542	.06	<2	22	32	8	.07
	18 to 20	2.27	647	.06	<2	25	34	8	.07
LV4B	0 to 3	1.72	583	.08	<2	22	28	7	.07
	3 to 5	1.64	549	.04	<2	22	24	<4	.06
	5 to 8.5	1.87	333	.04	<2	21	25	<4	.06
	8.5 to 15.5	1.89	378	.04	<2	19	24	<4	.06
	15.5 to 19	1.93	1,020	.04	2	18	30	5	.07
	19 to 21.5	1.89	1,780	.04	<2	21	32	5	.06
LV40	0 to 2	.56	664	.04	<2	23	25	5	.05
	2 to 5	1.67	453	.02	<2	24	26	<4	.06
	5 to 12	1.15	287	.02	2	21	23	6	.07
	12 to 20	1.58	840	.04	<2	22	37	5	.07
	20 to 22	1.99	411	.06	<2	20	33	7	.07
LV90-1	0 to 4.5	1.67	515	.04	<2	23	25	<4	.06
	4.5 to 10.5	1.46	668	.04	<2	30	28	<4	.07
	10.5 to 14	1.17	553	.04	<2	26	27	<4	.06

Supplement 19. Chemical analyses of soils in the Lincoln Valley irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Potassium (percent)	Scandium (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)	Sodium (percent)	Strontium (mg/kg)	Sulfur (percent)	Tantalum (mg/kg)
LV2B	0 to 1.5	1.72	7	0.3	<2	1.14	187	<0.05	<40
	1.5 to 5	1.59	7	.2	<2	1.28	269	<.05	<40
	5 to 10.5	1.63	7	.2	<2	1.35	296	.37	<40
	10.5 to 14	1.72	8	.3	<2	1.44	308	<.05	<40
	14 to 18	1.75	8	.6	<2	.95	169	.51	<40
	18 to 20	1.78	8	.6	<2	.95	168	.50	<40
LV4B	0 to 3	1.53	7	.4	<2	1.08	256	<.05	<40
	3 to 5	1.42	6	.1	<2	1.21	218	<.05	<40
	5 to 8.5	1.51	6	<.1	<2	1.17	199	<.05	<40
	8.5 to 15.5	1.51	5	.2	<2	1.18	200	<.05	<40
	15.5 to 19	1.53	5	.2	<2	1.18	198	<.05	<40
	19 to 21.5	1.52	6	.3	<2	1.16	208	<.05	<40
LV40	0 to 2	1.78	7	.4	<2	1.14	187	<.05	<40
	2 to 5	1.56	7	<.1	<2	1.21	243	<.05	<40
	5 to 12	1.64	6	<.1	<2	1.67	314	<.05	<40
	12 to 20	1.66	8	.5	<2	1.16	219	<.05	<40
	20 to 22	1.65	7	.7	<2	.97	169	.24	<40
LV90-1	0 to 4.5	1.59	7	<.1	<2	1.33	234	<.05	<40
	4.5 to 10.5	1.53	6	<.1	<2	1.45	276	<.05	<40
	10.5 to 14	1.54	6	<.1	<2	1.64	313	<.05	<40

Supplement 19. Chemical analyses of soils in the Lincoln Valley irrigation area—Continued

[mg/kg, milligrams per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Thorium (mg/kg)	Tin (mg/kg)	Titanium (percent)	Uranium (mg/kg)	Vanadium (mg/kg)	Ytterbium (mg/kg)	Yttrium (mg/kg)	Zinc (mg/kg)
LV2B	0 to 1.5	8	<10	0.21	<100	70	2	16	73
	1.5 to 5	6	<10	.22	<100	71	2	15	59
	5 to 10.5	6	<10	.25	<100	74	2	15	63
	10.5 to 14	6	<10	.25	<100	79	2	15	71
	14 to 18	6	<10	.24	<100	81	2	15	83
	18 to 20	8	<10	.27	<100	84	2	16	88
LV4B	0 to 3	7	<10	.22	<100	71	2	15	60
	3 to 5	6	<10	.21	<100	56	2	14	49
	5 to 8.5	5	<10	.18	<100	56	2	14	55
	8.5 to 15.5	<4	<10	.20	<100	57	2	14	55
	15.5 to 19	4	<10	.18	<100	57	1	13	59
	19 to 21.5	6	<10	.19	<100	61	2	14	60
LV40	0 to 2	9	<10	.22	<100	72	2	16	68
	2 to 5	9	<10	.20	<100	69	2	14	55
	5 to 12	6	<10	.24	<100	61	2	14	52
	12 to 20	6	<10	.23	<100	85	2	16	68
	20 to 22	7	<10	.22	<100	78	2	14	78
LV90-1	0 to 4.5	6	<10	.20	<100	67	2	14	54
	4.5 to 10.5	11	<10	.24	<100	65	2	15	55
	10.5 to 14	8	<10	.24	<100	60	2	15	52

Supplement 20. Chemical analyses of soil extracts from the Lincoln Valley irrigation area

[mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram; <, less than]

Identification number	Date	Latitude-longitude identification number	Township-range identification number	Horizon sampled (feet below land surface)	Aluminum (mg/kg)	Antimony (mg/kg)	Arsenic (µg/kg)	Barium (mg/kg)
LV2B	8-08-90	473940100191002	148-076-02CDD2	14 to 18	<5	<0.5	<10	0.2
				18 to 20	<5	<.5	<10	.1
LV40	8-07-90	474027100193001	149-075-31CCC	20 to 22	<5	<.5	<10	.3

Supplement 20. Chemical analyses of soil extracts from the Lincoln Valley irrigation area—Continued

[mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Beryllium (mg/kg)	Bismuth (mg/kg)	Boron (mg/kg)	Cadmium (mg/kg)	Calcium (mg/kg)	Cerium (mg/kg)	Chromium (mg/kg)	Cobalt (mg/kg)
LV2B	14 to 18	<0.1	<1	0.9	<0.2	1,300	<0.4	<0.1	<0.1
	18 to 20	<.1	<1	.7	<.2	670	<.4	<.1	<.1
LV40	20 to 22	<.1	<1	<.5	<.2	340	<.4	<.1	<.1

Supplement 20. Chemical analyses of soil extracts from the Lincoln Valley irrigation area—Continued

[mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Copper (mg/kg)	Iron (mg/kg)	Lanthanum (mg/kg)	Lead (mg/kg)	Lithium (mg/kg)	Magnesium (mg/kg)	Manganese (mg/kg)	Molybdenum (mg/kg)
LV2B	14 to 18	0.2	<5	<0.2	<0.4	0.5	610	4	<0.2
	18 to 20	.2	<5	<.2	<.4	.5	340	2	.2
LV40	20 to 22	.1	<5	<.2	<.4	.3	76	<.4	<.2

Supplement 20. Chemical analyses of soil extracts from the Lincoln Valley irrigation area—Continued

[mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Nickel (mg/kg)	Phosphorus (mg/kg)	Potassium (mg/kg)	Selenium (µg/kg)	Silicon (mg/kg)	Silver (mg/kg)	Sodium (mg/kg)	Strontium (mg/kg)
LV2B	14 to 18	<0.2	<5	97	78	30	<0.2	160	7
	18 to 20	<.2	<5	84	72	30	<.2	210	5
LV40	20 to 22	<.2	<5	73	82	40	<.2	30	1

Supplement 20. Chemical analyses of soil extracts from the Lincoln Valley irrigation area—Continued

[mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram; <, less than]

Identification number	Horizon sampled (feet below land surface)	Thorium (mg/kg)	Tin (mg/kg)	Titanium (mg/kg)	Vanadium (mg/kg)	Wolfram (mg/kg)	Yttrium (mg/kg)	Zinc (mg/kg)	Zirconium (mg/kg)
LV2B	14 to 18	<0.4	<0.5	<5	<0.2	<0.5	<0.2	<0.2	<0.2
	18 to 20	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2
LV40	20 to 22	<.4	<.5	<5	<.2	<.5	<.2	<.2	<.2

Supplement 21. Chemical analyses of water from wells in the Lincoln Valley irrigation area

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; mg/L, milligrams per liter; IT, incremental titration; µg/L, micrograms per liter; <, less than]

Identification number	Date	Latitude-longitude identification number	Township-range identification number	Altitude of screen bottom (feet)	Altitude of water level (feet)	Type of well	Specific conductance (µS/cm)	pH (standard units)
LV4A	9-10-90	474027100190101	149-075-31DDC1	1,736.8	1,748.7	Deep	1,530	7.54
LV4B	9-10-90	474027100190102	149-075-31DDC2	1,744.5	1,747.2	Shallow	1,650	7.87
LV40	9-11-90	474027100193001	149-075-31CCC	1,769.1	1,782.0	Deep	570	8.23
LV90-1	9-11-90	474027100171402	149-075-32CDD2	1,690.8	1,693.3	Shallow	1,690	7.93

Supplement 21. Chemical analyses of water from wells in the Lincoln Valley irrigation area—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; mg/L, milligrams per liter; IT, incremental titration; µg/L, micrograms per liter; <, less than]

Identification number	Date	Temperature, water (deg C)	Oxygen, dissolved (mg/L)	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Potassium, dissolved (mg/L)	Carbonate, IT-field (mg/L as CO_3)	Bicarbonate, IT-field (mg/L as HCO_3)	Sulfate, dissolved (mg/L as SO_4)	Sulfide, dissolved (mg/L as S)
LV4A	9-10-90	12.7	0.27	200	110	13	2.9	0	415	550	0.094
LV4B	9-10-90	17.5	7.8	240	110	13	2.3	0	361	640	.014
LV40	9-11-90	38.0	.62	83	30	1.9	9.7	0	369	22	.005
LV90-1	9-11-90	21.6	8.3	86	150	530	6.5	0	595	1,500	.005

Supplement 21. Chemical analyses of water from wells in the Lincoln Valley irrigation area—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; mg/L, milligrams per liter; IT, incremental titration; µg/L, micrograms per liter; <, less than]

Identification number	Date	Chloride, dissolved (mg/L)	Fluoride, dissolved (mg/L)	Silica, dissolved (mg/L as SiO_2)	Nitrite, dissolved (mg/L as N)	Nitrite plus nitrate, dissolved (mg/L as N)	Ammonia, dissolved (mg/L as N)	Orthophosphorus, dissolved (mg/L as P)	Arsenic, dissolved (µg/L)	Boron, dissolved (µg/L)
LV4A	9-10-90	1.6	0.3	24	0.094	1.3	0.01	<0.01	<1	430
LV4B	9-10-90	1.2	.3	24	.036	1.5	<.01	.01	<1	450
LV40	9-11-90	3.9	.2	15	.002	.02	.1	<.01	<1	40
LV90-1	9-11-90	5.2	.3	25	.285	14	<.01	.01	<1	320

Supplement 21. Chemical analyses of water from wells in the Lincoln Valley irrigation area—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; mg/L, milligrams per liter; IT, incremental titration; µg/L, micrograms per liter; <, less than]

Identification number	Date	Iron, dissolved (µg/L as Fe)	Ferrous iron, dissolved (µg/L as Fe)	Lithium, dissolved (µg/L)	Manganese, dissolved (µg/L)	Mercury, dissolved (µg/L)	Molybdenum, dissolved (µg/L)	Selenium, dissolved (µg/L)	Strontium, dissolved (µg/L)	Organic carbon, dissolved (mg/L)
LV4A	9-10-90	160	190	120	910	<0.1	4	<1	1,400	4.1
LV4B	9-10-90	25	90	110	640	.1	6	<1	1,600	5.3
LV40	9-11-90	7	10	14	780	<.1	2	<1	280	3.4
LV90-1	9-11-90	10	10	340	20	<.1	4	2	1,000	7.9

Supplement 22. Chemical analyses of water from wells in the LaMoure irrigation area

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; mg/L, milligrams per liter; IT, incremental titration; >, greater than; <, less than; µg/L, micrograms per liter; --, no data]

Identification number	Date	Latitude-longitude identification number	Township-range identification number	Specific conductance (µS/cm)	pH (standard units)	Temperature, water (deg C)	Oxygen, dissolved (mg/L)	Calcium, dissolved (mg/L)
NDSWC 6116	11-20-90	462821098230801	135-061-29CCD	1,660	7.72	9.0	0.43	52
NDSWC 6167	11-20-90	465513098324901	140-062-30AAA	1,570	7.43	8.6	.21	100
NDSWC 9215	11-19-90	461939098131901	133-060-15CCC	740	7.48	9.5	.23	92
NDSWC 9476	11-20-90	462420098230801	134-061-21DAA	1,190	7.51	9.7	.31	110
NDSWC 11910	11-19-90	461939098135701	133-060-16DCC	1,130	7.57	10.1	.31	190

Supplement 22. Chemical analyses of water from wells in the LaMoure irrigation area—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; mg/L, milligrams per liter; IT, incremental titration; >, greater than; <, less than; µg/L, micrograms per liter; --, no data]

Identification number	Date	Magnesium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Potassium, dissolved (mg/L)	Carbonate, IT-field (mg/L as CO_3)	Bicarbonate, IT-field (mg/L as HCO_3)	Sulfate, dissolved (mg/L as SO_4)	Sulfide, dissolved (mg/L as S)	Chloride, dissolved (mg/L)	Fluoride, dissolved (mg/L)
NDSWC 6116	11-20-90	23	280	9.5	0	595	180	>0.600	170	0.5
NDSWC 6167	11-20-90	35	170	8.1	0	469	250	.008	140	.4
NDSWC 9215	11-19-90	32	21	4.2	0	305	170	<.001	7.9	.4
NDSWC 9476	11-20-90	38	67	8.0	0	300	300	.036	70	.4
NDSWC 11910	11-19-90	55	16	4.0	0	256	480	.009	18	<.1

Supplement 22. Chemical analyses of water from wells in the LaMoure irrigation area—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; mg/L, milligrams per liter; IT, incremental titration; >, greater than; <, less than; µg/L, micrograms per liter; --, no data]

Identification number	Date	Silica, dissolved (mg/L as SiO_2)	Nitrite, dissolved (mg/L as N)	Nitrite plus nitrate, dissolved (mg/L as N)	Ammonia, dissolved (mg/L as N)	Orthophosphorus, dissolved (mg/L as P)	Arsenic, dissolved (µg/L)	Boron, dissolved (µg/L)	Iron, dissolved (µg/L as Fe)	Ferrous iron, dissolved (µg/L as Fe)
NDSWC 6116	11-20-90	--	0.006	<0.01	2.2	0.14	3	880	880	950
NDSWC 6167	11-20-90	28	.007	<.01	.82	<.01	3	410	3,300	2,950
NDSWC 9215	11-19-90	27	.004	<.01	.30	<.01	12	230	3,300	>3,000
NDSWC 9476	11-20-90	22	.005	<.01	.08	<.01	2	270	7,300	>3,000
NDSWC 11910	11-19-90	25	.007	<.01	.16	<.01	6	100	5,700	>3,000

Supplement 22. Chemical analyses of water from wells in the LaMoure irrigation area—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; mg/L, milligrams per liter; IT, incremental titration; >, greater than; <, less than; µg/L, micrograms per liter; --, no data]

Identification number	Date	Lithium, dissolved (µg/L)	Manganese, dissolved (µg/L)	Mercury, dissolved (µg/L)	Molybdenum, dissolved (µg/L)	Selenium, dissolved (µg/L)	Strontium, dissolved (µg/L)	Organic carbon, dissolved (mg/L)
NDSWC 6116	11-20-90	99	140	<0.1	<1	<1	550	4.0
NDSWC 6167	11-20-90	89	760	<.1	<1	<1	670	3.0
NDSWC 9215	11-19-90	30	410	<.1	2	<1	670	--
NDSWC 9476	11-20-90	77	350	<.1	2	<1	520	1.5
NDSWC 11910	11-19-90	34	2,000	<.1	<1	<1	450	1.6

*U.S.GOVERNMENT PRINTING OFFICE 1996-0-790-301/43000