RECONNAISSANCE INVESTIGATION OF WATER QUALITY, BOTTOM SEDIMENT, AND BIOTA ASSOCIATED WITH IRRIGATION DRAINAGE IN THE SUN RIVER AREA, WEST-CENTRAL MONTANA, 1986-87

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CONVERSION FACTORS

The following factors may be used to convert inch-pound units published herein to metric (International System) units.

Multiply inch-pound unit	By	To obtain metric unit
acre	4.047	square meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot	0.3048	meter
inch	25.40	millimeter
mile	1.609	kilometer
ton (short)	0.9072	megagram

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) by the equation:

$$°C = 5/9\ (°F - 32)$$

Temperature in °C can be converted to °F by the equation:

$$°F = 9/5\ (°C) + 32$$

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Mean Sea Level of 1929."

Trace-constituent concentrations in bottom sediment are reported as weight per unit of weight, or micrograms per gram (μg/g). The results are equivalent to units of parts per million.

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ABSTRACT

During the past several years, concern by the U.S. Department of the Interior has been increasing about the quality of irrigation drainage and its potential effects on the health of humans, fish, and wildlife. The Sun River area was selected for a reconnaissance investigation of irrigation drainage because sufficient information existed to indicate that potential problems of a toxic nature might exist. The purpose of the report is to describe concentrations of selected inorganic and organic constituents in water, bottom sediment, and biota and to compare the analytical results to various criteria and baseline information.

The area of study included the Sun River Irrigation Project, Freezeout Lake Game Management Area, and Benton Lake National Wildlife Refuge. Water, bottom sediment, and biota were sampled at selected sites and analyzed for inorganic and organic constituents that could be toxic at large concentrations. Although selenium was of primary concern, other trace elements and selected pesticides also were analyzed.

Some water-quality problems have been prevalent for many years in the Sun River Irrigation Project, including the Sun River and Muddy Creek. However, during this study, most sampling sites were free of concentrations of toxic constituents that are in excess of established criteria and standards. There was little change in arsenic, boron, mercury, and selenium concentrations in fish and invertebrates at Sun River sampling sites upstream and downstream from the irrigation project. Presently, the most serious threat within the irrigation project appears to be from nitrate in ground water. Water from some wells contains nitrate concentration in excess of drinking-water standards (10 milligrams per liter) established for the State of Montana.

Freezeout Lake Game Management Area and Benton Lake National Wildlife Refuge had sampling sites where concentrations of toxic constituents in water, bottom sediment, and biota were moderately to considerably larger than established criteria and standards. The largest selenium concentrations in water and bottom sediment were from seeps that surround Benton Lake, with maximum concentrations of 580 micrograms per liter in water and 6.7 micrograms per gram in bottom sediment. Selenium was detected in most biological samples. Several eared-grebe livers from Freezeout Lake and several coot livers and eggs from Benton Lake had selenium concentrations indicative of contamination.

Water from the irrigation project supplied to the Freezeout Lake and Benton Lake areas has dissolved-solids concentrations in the range of 500 to 700 milligrams per liter and trace elements only slightly larger than concentrations measured in the source water from the Sun River. No hydrologic connection is apparent between the water used for irrigation and the seeps sampled in this study. Irrigation drainage, natural basin runoff, and water from the seeps all contribute dissolved constituents to the lakes. To determine the relative proportions of constituents conveyed into the lakes by all sources, a study of the water budget would be necessary.

INTRODUCTION

Background

During the past several years, concern has been increasing about the quality of irrigation drainage, both surface and subsurface water draining irrigated land, and its potential effects on humans, fish, and wildlife. Large concentrations of selenium have been detected in subsurface drainage water from irrigated land in the western part of the San Joaquin Valley in California. In 1983, incidences of mortality, birth defects, and reproductive failures in waterfowl were discovered by the U.S. Fish and Wildlife Service at the Kesterson National Wildlife Refuge in the western San Joaquin Valley, where irrigation drainage was impounded. In addition, potentially toxic trace elements and pesticide residues have been detected in other areas in western States that receive irrigation drainage.

Because of concerns expressed by the U.S. Congress, the Department of the Interior (DOI) initiated a program in late 1985 to identify the nature and extent of water-quality problems induced by irrigation drainage that might exist in the western States. In October 1985, an interbureau group known as the "Task Group on Irrigation Drainage" was formed within the DOI. The Task Group subsequently prepared a comprehensive plan for reviewing irrigation-drainage concerns for which the DOI may have responsibility.

The DOI developed a management strategy and the Task Group prepared a comprehensive plan for reviewing irrigation-drainage concerns. Initially, the Task Group identified 19 locations in 13 States that warranted reconnaissance investigations. These locations relate to three areas of DOI responsibility: (1) irrigation or drainage facilities constructed or managed by the DOI, (2) national wildlife refuges managed by the DOI, and (3) other migratory-bird or endangered-species management areas that receive water from DOI-funded projects.

Nine of the 19 locations were selected for initiation of reconnaissance investigations in 1986. The areas are:

Arizona-California: Lower Colorado-Gila River Valley area
California: Salton Sea area
Tulare Lake area
Montana: Sun River area
Milk River area
Nevada: Stillwater Wildlife Management area
Texas: Lower Rio Grande-Laguna Atascosa National Wildlife Refuge area
Utah: Middle Green River Basin area
Wyoming: Kendrick Reclamation Project area

Each reconnaissance investigation was conducted by interbureau field teams composed of a scientist from the U.S. Geological Survey as team leader, with additional Geological Survey, U.S. Fish and Wildlife Service, and U.S. Bureau of Reclamation scientists representing several different disciplines. The investigations were directed toward determining whether irrigation drainage: (1) has caused or has the potential to cause significant harmful effects on human health, fish, and wildlife, or (2) may adversely affect the suitability of water for other beneficial uses.

This report describes the results of the reconnaissance investigation of the Sun River area. The Sun River area was selected for investigation because sufficient information existed to indicate that trace elements with concentrations large enough to be toxic might be present. The Sacramento (Calif.) Bee newspaper (September 8, 1985) reported a selenium concentration[1] of 7.5 μg/g from a mud sample collected at the Benton Lake National Wildlife Refuge. Subsequent samples collected at several sites by the U.S. Fish and Wildlife Service and analyzed by a private laboratory had selenium concentrations that were both larger and smaller than that reported by the Sacramento Bee. These samples indicated that selenium may be a major concern on this refuge.

Nonconsumptive irrigation waters on the Greenfields Bench of the Sun River area percolate to perched aquifers that are the source of water for many individual domestic wells and one large community well that serves feeder lines for distribution of water off the bench in Cascade, Chouteau, and Teton Counties. Because of the large values of permeability and the perched hydrologic setting, the aquifers underlying the Greenfields Bench are susceptible to contamination resulting from irrigation and farming practices. Previous investigations have detected substantial concentrations of nitrate (as nitrogen) and traces of organic-compound residues in water from domestic wells in the area.

Purpose and Scope

The purpose of this report is to describe concentrations of selected inorganic and organic constituents in water, bottom sediment, and biota and to compare the analytical results to various guidelines and baseline information. Information from the report is intended to help the Department of the Interior determine

[1]Reported as 7.5 parts per million.

whether irrigation drainage has caused or has the potential to cause harmful effects on humans, fish, and wildlife or has impaired the suitability of the water for beneficial use.

Thirty-one sampling sites selected within the three subunits of the study area included streams, ponds, lakes, seeps, and aquifers. Onsite work was conducted during the spring and summer of 1986. Samples of water and bottom sediment were collected by personnel of the U.S. Geological Survey and biota samples were collected by personnel of the U.S. Fish and Wildlife Service. Sample analyses were performed by laboratories of the respective agencies.

Acknowledgments

The authors acknowledge with appreciation the many individuals who assisted in the study. Particular thanks are given to Robert Pearson and his staff at Benton Lake National Wildlife Refuge for assistance in sample collection and for providing information about the refuge. Donald Childress of the Montana Department of Fish, Wildlife and Parks and other members of that Department provided much support in sample collection at Freezeout Lake Game Management Area and in the Sun River. Supplemental information was provided by several sources, especially the Water Quality Bureau of the Montana Department of Health and Environmental Sciences. Marvin Miller of the Montana Bureau of Mines and Geology and John Larson of the Montana Department of Agriculture were especially helpful in supplying information. Special thanks are extended to the various laboratories for processing the many samples that created overload conditions.

GENERAL DESCRIPTION OF STUDY AREA

Location

The Sun River study area is located primarily in Teton and Cascade Counties of west-central Montana. Headwaters of the Sun River form along the eastern slopes of the Rocky Mountains from which the river flows easterly to its confluence with the Missouri River at the city of Great Falls. Most of the study area lies north of the river, with less than 15 percent of the area being south of the river. The investigation was concerned with three separate areas (fig. 1) that are directly affected by irrigation practices and drainage. The three areas of study are: (1) The Sun River Irrigation Project, which consists of the Greenfields and Fort Shaw Divisions and includes the Sun River, irrigation canals and drains, domestic wells, community supplies, and Muddy Creek; (2) the Freezeout Lake Game Management Area -- A State waterfowl refuge that is located adjacent to the Greenfields Bench and receives drainage water from the irrigation project and periodically releases brackish water to the Teton River; and (3) the Benton Lake National Wildlife Refuge -- A closed basin that is managed for waterfowl and receives almost all of its water from Lake Creek, which receives water pumped from Muddy Creek.

Characteristics and History

Sun River Irrigation Project

The Sun River Irrigation Project was authorized by the Secretary of the Interior on February 26, 1906. Construction of the Fort Shaw Division began in May 1907; the first water was delivered in 1909. Construction of the Greenfields Division began in 1913; the first water was delivered in 1920. The main storage structure, Gibson Dam, was constructed during 1922-29.

The Fort Shaw Division is operated by the Fort Shaw Irrigation District and the Greenfields Division is operated by the Greenfields Irrigation District. The 91,000 acres of irrigated land is divided into about 600 farms. Principal crops are wheat, oats, barley, alfalfa, silage, and pasture. Gibson, Pishkun, and Willow Creek Reservoirs are used for boating and fishing. Swimming, camping, and picnicking are available during the summer. In 1985, recreational use of the reservoirs was 55,500 visitor days.

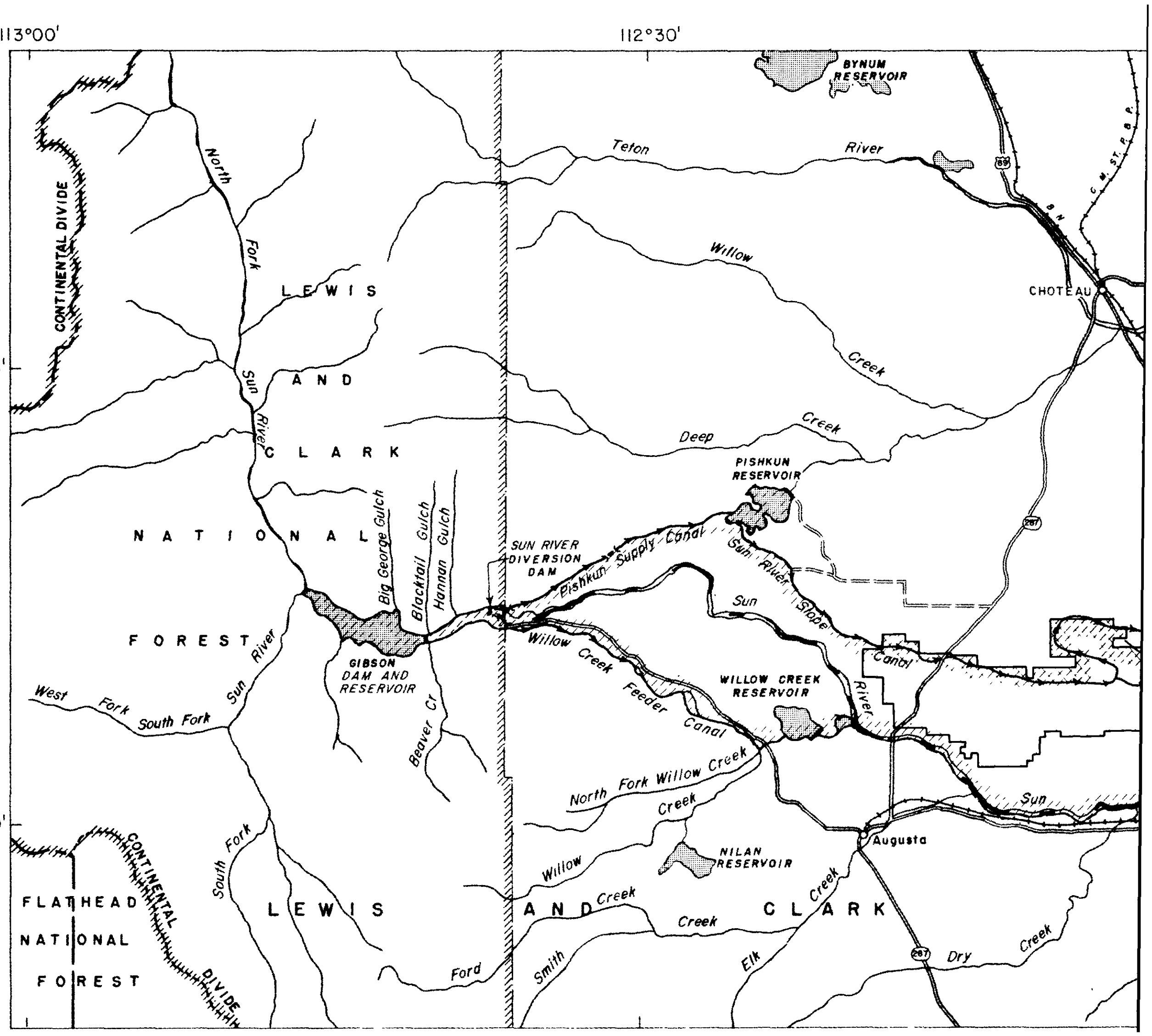
The Montana Department of Fish, Wildlife and Parks manages the fishery of the Sun River. The Sun River upstream from Muddy Creek supports a fair fish population, whereas downstream from Muddy Creek the fishery is considered poor. In addition to the effect of Muddy Creek, the Sun River is affected by diversions during the irrigation season.

Freezeout Lake Game Management Area

Freezeout Lake Game Management Area, established in 1952, contains 12,000 acres, equally divided into wetlands and uplands. The wetlands consist of six marsh units and a main lake (Freezeout Lake). The uplands support native grasslands, seeded grasses, legumes, and small-grain crops. Principal wildlife species are waterfowl and a large variety of marsh and water birds.

The game management area is owned by the State of Montana, except for 435 acres of main lake bottom that is entitled to the U.S. Fish and Wildlife Service, and about 6,000 acres entitled to the U.S. Bureau of Reclamation. The Montana Department of Fish, Wildlife and Parks manages the entire area. Public-use activities include birdwatching, waterfowl hunting, and fur trapping. Water supply for the area is from the Bureau of Reclamation's Sun River Irrigation Project (delivered through the Greenfields Division), saline seeps on nonirrigated farmland, natural runoff (mostly from non-irrigated farmland and rangeland), and irrigation drainage. Water is managed by manipulating the water levels in the marsh units before the water moves into Freezeout Lake. Discharge of water from Freezeout Lake through Priest Butte Lakes into the Teton River occurs during high runoff. The uplands are managed to provide cover for nesting waterfowl and some small-grain food plots for wildlife. Surrounding private lands are farmed for small-grain crops.

In the past, yellow perch, black crappie, and largemouth bass have been stocked in Priest Butte Lakes. However, none of these species have reproduced, perhaps as a result of large dissolved-solids concentrations (Bill Hill, Montana Department of Fish, Wildlife and Parks, oral commun., 1987). Fishkills that have included some of the aforementioned species and white suckers have occurred in the summer. The fishkills have been attributed to oxygen depletion under stratified conditions and accompanying algal blooms. However, some unknown factor other than oxygen depletion was suspected of killing white suckers during the summer of 1985.



Base modified from U.S. Bureau of Reclamation, 1973

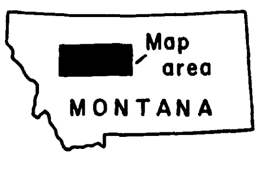
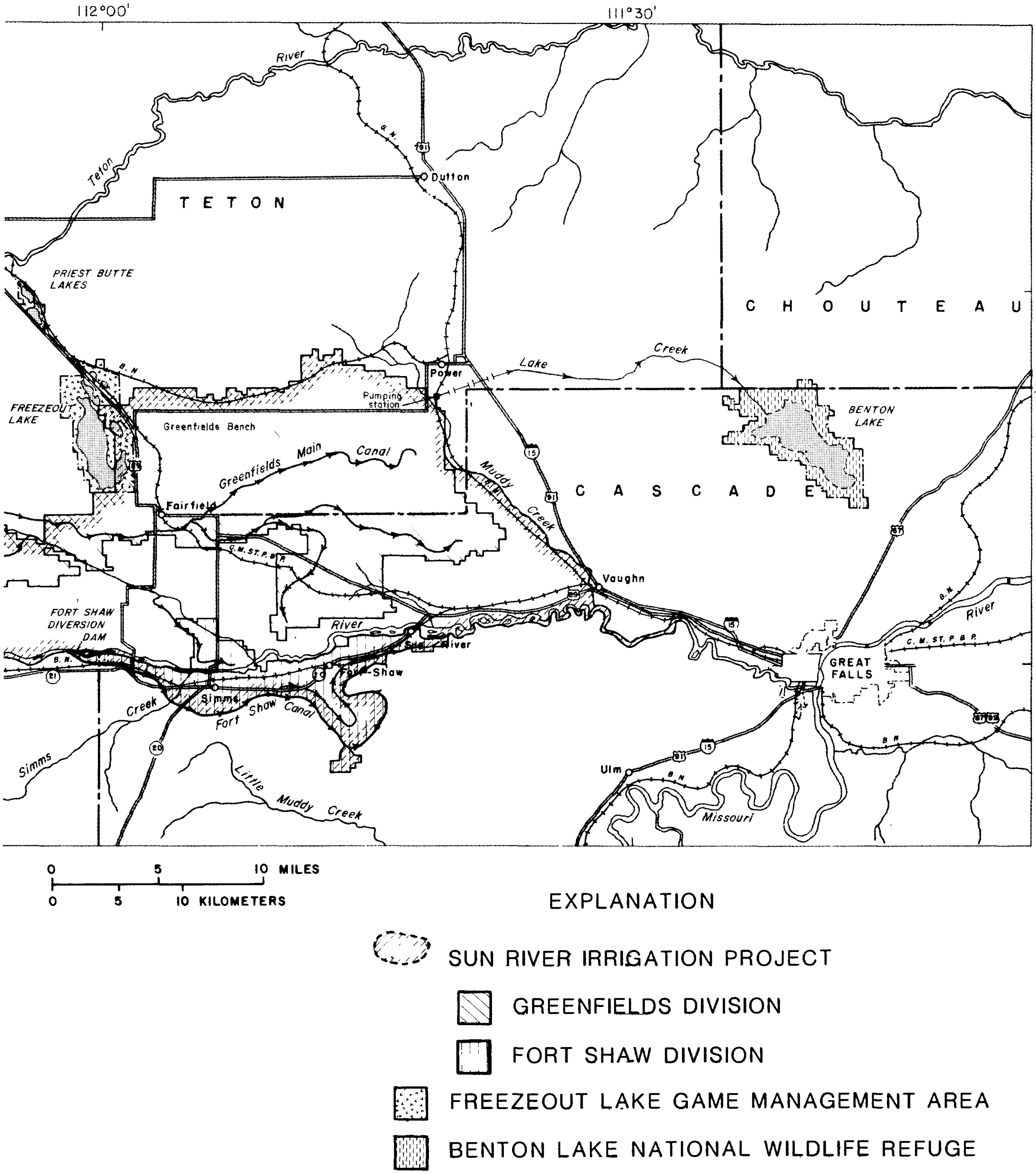


Figure 1.--Location



of study areas.

Waterfowl mortality has occurred frequently for several years at the Freezeout Lake Game Management Area. Although the cause of each waterfowl-mortality episode has not been determined, periodic analyses of dead birds indicate that the major cause of mortality is avian botulism. Snow geese also have died occasionally during spring migration. Laboratory analysis indicated that the cause of death was fowl cholera.

No bird deformities have been noted at either Freezeout Lake or Priest Butte Lakes. However, as far as is known, no investigation has specifically focused on abnormal embryos or deformed birds. Several waterfowl-nesting investigations conducted in the game management area have provided no indication of egg-hatchability problems.

Benton Lake National Wildlife Refuge

The Benton Lake National Wildlife Refuge, which was established in 1929 for waterfowl production and habitat for migrating birds, consists of 12,400 acres--6,800 acres in uplands and 5,600 acres in saline marsh. The refuge is a closed water system with no outlet. Refuge uplands support primarily native and seeded grasses, with surrounding lands planted with small-grain crops. Principal wildlife species are waterfowl (Canada geese and ducks) and a variety of marsh and water birds. Water related public-use activities are limited to birdwatching and waterfowl hunting.

The Benton Lake National Wildlife Refuge obtains most of its water by pumpage from Muddy Creek, which contains a large proportion of irrigation drainage from May to September. Muddy Creek collects irrigation drainage from the Greenfields Division of the Sun River Irrigation Project. Other water sources contributing to the refuge are saline seeps, drains from surrounding nonirrigated farms, and surface runoff from the surrounding nonirrigated farms and rangeland. Because the refuge is a closed water system, the marsh area is divided into separate units that are periodically flooded in alternate years. This operation results in about one-half of the marsh area being dry at any one time. In this way, the water can be managed more effectively to decrease salinity and control botulism in waterfowl, if it should occur. Because there is no surface outlet, salts and other contaminants are concentrated in the water.

Waterfowl mortality is a rather common occurrence at Benton Lake National Wildlife Refuge. Most of the mortality episodes have been confirmed by laboratory analysis to be caused by avian botulism. Some bird mortality on the refuge has also been attributed to lead poisoning from ingestion of lead shot. Usually, mortality from lead poisoning involves a few birds that are found in widely separated areas. A few eared grebes die almost every year on the refuge; these deaths (mainly young-of-the-year birds) may be due to drowning after the birds become entangled in dense algal mats and macrophytic growth. However, such drowning has not been confirmed.

Waterfowl-nesting surveys conducted regularly on the refuge have provided no indication of egg-hatchability problems. However, no investigations have been conducted for the explicit purpose of detecting deformed or abnormal embryos, nor have any investigtions been made to systematically check the refuge for deformed or abnormally developed birds. If a significant number of bird deformities were occurring on the refuge, the problem probably would have been observed by personnel working on the refuge during the spring, summer, and autumn.

Climate

Climate of the area is affected by the Rocky Mountains to the west and the plains to the east; thus, weather patterns are variable. Harsh winters in the plains are frequently modified by "chinook winds" that result from warm air masses moving down the east slope of the Rocky Mountains. These chinook winds commonly produce midwinter runoff from melting snow. During the winter, subzero temperatures are common. Summer temperatures commonly surpass 80 °F. The average annual temperature is 44 °F and the freeze-free period averages 130 days (National Oceanic and Atmospheric Administration, 1982).

Annual precipitation is about 12 inches per year and annual class-A pan evaporation, as estimated by the National Weather Service, is 57 inches. About 80 percent of the annual precipitation falls from April through September. Lowland snowmelt commonly occurs before April. Rainstorms generally contribute significant percentages of the annual precipitation and account for intense runoff.

Climatic conditions are suitable for nonirrigated farming in this part of Montana. The Sun River Irrigation Project has been responsible for converting a substantial part of the area to irrigated farming.

Geology and Water-Yielding Units

Pleistocene glaciation and related processes affected much of the present geology of the study area. Reports by Alden (1932) and Maughan (1961) describe the local geology and physiography.

Sedimentary rocks of Cretaceous age are exposed throughout the study area, principally on the steep slopes of dissected terrain and on the upland surface east of Muddy Creek near Benton Lake. Terraces underlain by gravel form much of the upland surface west of Muddy Creek throughout the Greenfields Bench area. Glacial-lacustrine deposits occur at the land surface principally within the Sun River and Muddy Creek valleys. Moraine deposits are present throughout the study area.

Present physiography was formed principally during Pleistocene time, a period of extensive glacial activity. Prior to Pleistocene time, erosion left a nearly level plain consisting of the Cretaceous Blackleaf Formation of the Colorado Group. Periods of stream erosion followed by periods of gravel deposition continued into late Pleistocene time when present valleys of the Sun River and Muddy Creek were formed, and mantles of glacial till were deposited. Glacial Lake Great Falls existed during the Pleistocene Epoch and accounted for widespread lacustrine deposits throughout the area.

In areas of the Greenfields Division and Freezeout Lake, water contained in permeable zones below the Colorado Group contains large concentrations of dissolved constituents and is infrequently used. Prior to the Sun River Irrigation Project, the supply of water in the gravel underlying the terraces and overlying the shale of the Colorado Group was limited, and domestic water commonly was hauled.

The geohydrology of the area has been artifically modified by irrigation and farming (fig. 2). Flood irrigation has been common, although recently some sprinkler systems have been installed. The soil profile and unconsolidated gravel beneath the terraces readily transmit excess irrigation water and leakage from the network of unlined canals to the top of the almost impermeable shale of the Colorado Group. This recharge has resulted in perched aquifers with artificially high water tables that presently (1987) are a source of water for domestic use. The shallow ground-water system discharges into downgradient drains and at hillside seeps in dissected drainages.

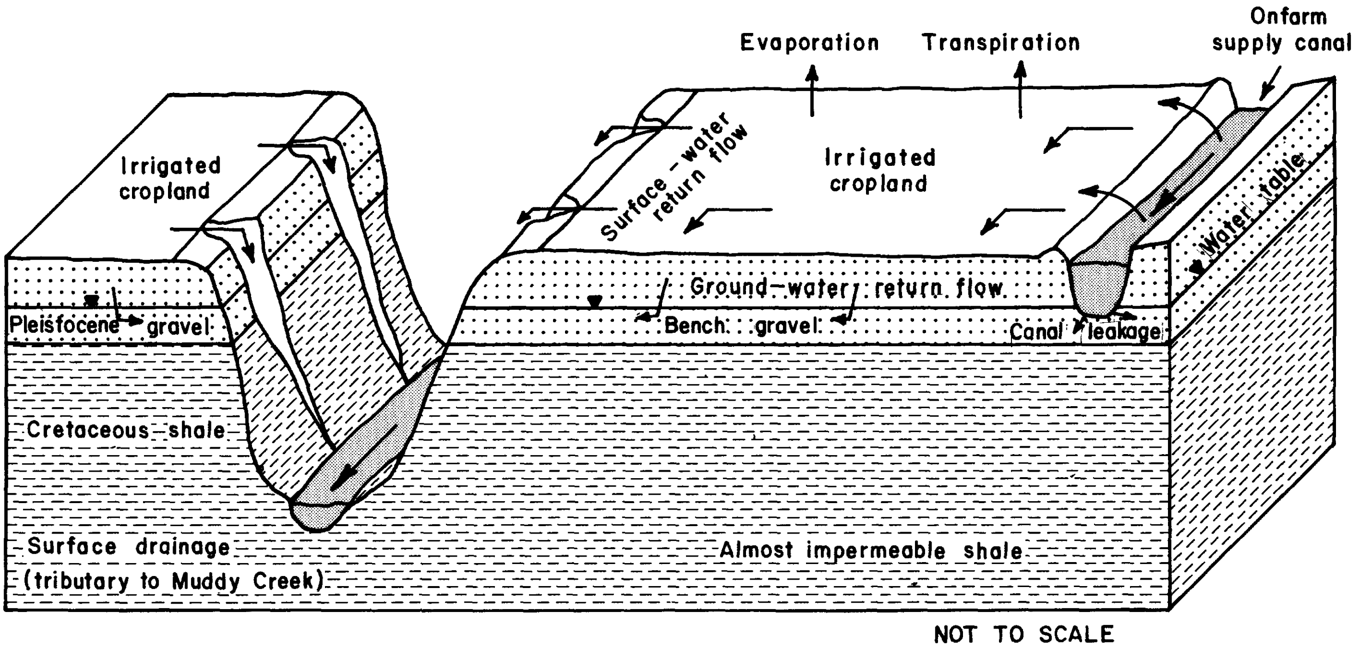


Figure 2.--Schematic diagram showing hydrogeology of the Greenfields Division.

Soils

In general, soils of the irrigable area vary considerably, ranging from gravelly and sandy loams to light clays. The predominant soil types are loam, silt loam, and gravelly silt loam of alluvial or glacial-lacustrine origin.

The dominant soil series of the Greenfields Division is Caleborolls-Calciorthids, which is fine and loamy, deep, and well-drained and calcareous throughout. A transition in soil type occurs from the irrigation project to Benton Lake. Soils in the Benton Lake area are mapped as Argiborolls consisting of a deep profile, predominantly clay, that originated from glacial till and lacustrine sediments (Montagne and others, 1982).

Most soils, specifically those east of the project, have been derived from shale of the Cretaceous Colorado Group or parent material that initially was part of the group. Information from studies of saline seeps in the northern Great Plains of Montana indicates that soils derived from shale of the Colorado Group are a source of trace elements such as selenium (Williams and others, 1940).

HYDROLOGIC SETTING

Principal hydrologic features of the Sun River Irrigation Project are Gibson Dam and Reservoir, Willow Creek Reservoir, Pishkun Reservoir, Sun River Diversion Dam, Fort Shaw Diversion Dam, two supply canals, and six irrigation canals. The project uses the water of the Sun River and its tributaries, stored and regulated by Gibson, Pishkun, and Willow Creek Reservoirs, for storage, diversion, and movement of water in the project as shown in figure 3. Water stored in Gibson Reservoir is released into the Sun River for diversion downstream into the Pishkun Supply Canal or into the Fort Shaw Canal. The Pishkun Supply Canal, which begins at the Sun River Diversion Dam, conveys water to Pishkun Reservoir. Water released from Pishkun Reservoir enters the Sun River Slope Canal, which branches into several main canals for distribution to about 81,000 acres in the Greenfields Division. The Willow Creek Feeder Canal, which branches from the Pishkun Supply Canal and empties into Willow Creek, conveys water to Willow Creek Reservoir. Storage in Willow Creek Reservoir is returned to the Sun River. Water for about 10,000 acres in the Fort Shaw Division is diverted directly from the river at the Fort Shaw Diversion Dam into the Fort Shaw Canal.

Wastewater and return flows are channeled to the Sun River, Muddy Creek, and Freezeout Lake. Return flows into Muddy Creek have caused substantial sediment problems. These flows have been decreased in recent years owing to completion of a Project Rehabilitation and Betterment Program, more efficient project management, and intensive onfarm water-conservation efforts. Muddy Creek is a source of domestic water for the town of Power.

The Greenfields Division provides most of the water supply to the Freezeout Lake Game Management Area through direct delivery and drainwater collection. Other water sources for Freezeout Lake include seeps and local runoff.

The major source of water for the Benton Lake National Wildlife Refuge is Muddy Creek, which conveys drainage water from the Greenfields Division. Water is pumped from Muddy Creek to Lake Creek, which supplies the refuge. Other water sources for the Benton Lake National Wildlife Refuge include seeps and local runoff.

PREVIOUS INVESTIGATIONS

Several environmental investigations conducted in the Sun River basin provide supplementary information to the current reconnaissance investigation. The results of those investigations are summarized below.

Water Quality of Streams

The U.S. Geological Survey has operated streamflow-gaging stations, measured suspended sediment, and monitored water quality at selected sites within the Sun River area for many years. Data are published in a series of reports for each water year (U.S. Geological Survey, issued annually). Some important sites of data collection are:

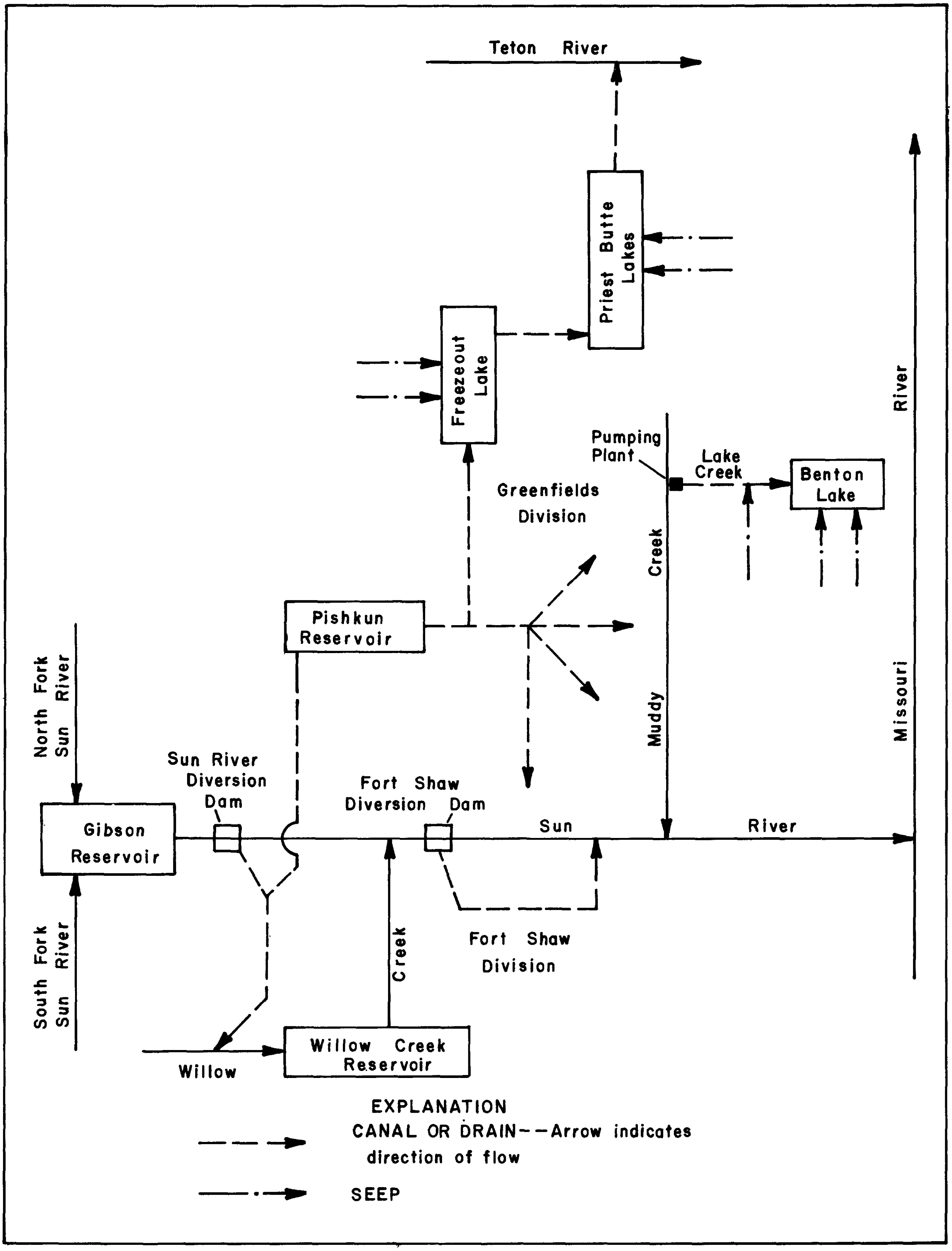


Figure 3.--Schematic diagram showing storage, diversions, and movement of water.

Station No.	Station name
06080900	Sun River below diversion dam, near Augusta
06088300	Muddy Creek near Vaughn
06088500	Muddy Creek at Vaughn
06089000	Sun River near Vaughn

Water in the Sun River near the Sun River Diversion Dam has a range in specific conductance of about 150 to 450 μS/cm (microsiemens per centimeter at 25 °Celsius), with an annual average of about 300 μS/cm. However, during the irrigation season and periods of reservoir filling, the average specific conductance is about 200 μS/cm and the water is a calcium magnesium bicarbonate type.

In the Sun River at the eastern end of the project downstream from Muddy Creek, specific conductance is larger and more variable than upstream. Minimum and maximum values for 16 years of daily record are 214 and 2,610 μS/m. Throughout the irrigation season, values generally range from 300 to 700 μS/cm. Sodium and sulfate constitute larger percentages of the respective cations and anions than at upstream stations.

Much of the increase in specific conductance in the Sun River is attributable to inflow from Muddy Creek, where 12 years of daily conductance record indicate a range of 470 to 5,400 μS/cm. During the irrigation seasons, the average is about 700 μS/cm.

Daily suspended-sediment concentrations for 11 years of record near the mouth of Muddy Creek range from 11 to 21,000 mg/L (milligrams per liter). Annual suspended-sediment loads transported into the Sun River range from 70,000 to 378,000 tons.

Salinity of Freezeout Lake

During 1980-82 the Water Quality Bureau of the Montana Department of Health and Environmental Sciences conducted a study on the Freezeout Lake-Priest Butte Lakes system to: (1) Predict water-quality changes in the system in the event that a surge relief canal is constructed to divert surplus water in the Greenfields Main Canal away from Muddy Creek, and (2) to estimate channel erosion of the Teton River as a result of the increased flow (Loren Bahls, Montana Department of Health and Environmental Sciences, written commun., 1983). During the study, considerable water-quality data were collected from inflows and outflows and within the Freezeout Lake Game Management Area. Analytical determinations generally were for common ions, ammonia, specific conductance, and pH.

Several drains convey inflow water to the Freezeout Lake Game Management Area. At each of the inflow points, samples were collected and specific conductance was measured from 4 to 9 times. Average specific conductance was calculated for each inflow. The averages for the six inflows to Freezeout Lake and one inflow to Pond 1 ranged from 832 to 4,900 μS/cm. Specific conductance of 31 samples collected at the outflow from Freezeout Lake ranged from 3,000 to 8,500 μS/cm and averaged

4,700 µS/cm. Specific conductance of 16 samples collected from the outflow of Priest Butte Lakes ranged from 3,600 to 7,000 µS/cm and averaged 5,770 µS/cm. The largest specific conductance of any inflow water was from a seep flowing into the southeast end of Priest Butte Lakes, where values for six samples ranged from 29,700 to 39,500 µS/cm. Concurrent water discharge was not listed for any of the sampling sites.

Nitrate in Ground Water

A short-term appraisal of water quality in the Greenfields Division was made in 1980 by the Water Quality Bureau of the Montana Department of Health and Environmental Sciences (Walther, 1981) in response to conditions thought to be causing large concentrations of nitrate in ground water. Of concern was the domestic use of water for about 700 wells in the division. Twenty-four wells were selected for sampling and some were sampled as many as 15 times during the 8-month study.

Nitrate concentrations ranged from 0.01 to 37 mg/L as nitrogen in the 392 samples analyzed. The largest difference in a water from a single well was 35 mg/L during a 4-week period and the smallest difference was 0.5 mg/L during nearly 8 months. In 8 of the 24 wells sampled, nitrate concentrations exceeded the primary drinking-water standard of 10 mg/L as nitrogen established for the State of Montana (Montana Department of Health and Environmental Sciences, 1986).

Pesticides in Ground Water

During 1984, the Environmental Management Division of the Montana Department of Agriculture, under a grant from the U.S. Environmental Protection Agency, conducted a ground-water sampling program (John Larson, Montana Department of Agriculture, written commun., 1985) for pesticides in three distinct agriculture production areas of Montana. One of the areas selected was the Greenfields Division, where 12 domestic wells were sampled. Sampling sites were selected on the basis of permeable soils, high water tables, irrigation, and a history of pesticide use. The wells ranged in depth from 14 to 120 feet below land surface, with the median depth being 20 feet.

Water from wells in the Greenfields Division had detectable concentrations of pesticides. Small concentrations of 2,4-D, MCPA, Dicamba, and Picloram were detected in samples from 7 of the 12 wells. The maximum concentrations detected were 0.39 µg/L (micrograms per liter) of 2,4-D, 5.5 µg/L of MCPA, 3.0 µg/L of Dicamba, and 1.1 µg/L of Picloram.

Saline Seeps

Saline seeps in nonirrigated agricultural areas in eastern Montana were studied jointly by the Montana Bureau of Mines and Geology and the Montana Department of Health and Environmental Sciences (Miller and others, 1980). Of the many surface-water and shallow-ground-water samples collected and analyzed for trace elements, some were collected in and near the study area. The following is a summary of the analytical results from the nonirrigated farming area around Great Falls:

Trace element	Number of samples	Concentration, in micrograms per liter [<, less than] Minimum	Maxmimum	Median
Arsenic	33	<2.0	4.3	<2.0
Boron	33	120	2,900	930
Cadmium	17	<10	90	20
Chromium	33	<10	220	<10
Copper	33	<10	350	20
Lead	33	<50	1,300	70
Nickel	33	<10	3,500	30
Selenium	31	<2	1,600	8.3
Zinc	31	<10	7,300	60

Biology of the Lower Sun River

The physical characteristics of the Sun River downstream from Muddy Creek are markedly affected by water discharged from Muddy Creek during the irrigation season. Several studies have demonstrated the degree and extent of effects on aquatic life in the Sun River due to Muddy Creek. Ingman and others (1984) evaluated the effects of Muddy Creek discharge on periphyton and macroinvertebrate communities. Several variables (chlorophyll *a* to pheophytin *a* ratios, rate of chlorophyll *a* accrual, rate of biomass accrual, autotrophic index, Shannon's index, equitability, and others) were used to measure differences upstream and downstream from Muddy Creek. Although some of the measures were unreliable (biological diversity), the data generally demonstrated that water from Muddy Creek enriched the Sun River with organic and inorganic nutrients, impaired the physiological condition of attached algae, and substantially decreased the number of macroinvertebrate organisms. Much of the adverse effect occurred in the first several miles downstream from Muddy Creek. However, during low-flow situations, the effect may extend downstream to the Missouri River. Ingman and others (1984) concluded that it is unlikely the Sun River could support a good fishery for the first 2 miles downstream from Muddy Creek.

SAMPLE COLLECTION AND ANALYSIS

Objectives

Most previous studies of irrigation drainage have been concerned with salts and nutrients. Only recently has there been widespread recognition that serious water-quality problems can result from the presence of many trace elements as well as a large number of pesticides. Trace elements and pesticides in large concentrations can create acute and chronic toxicity problems in humans, fish, and wildlife. Although selenium was initially identified as the primary contaminant of concern because of problems caused at the Kesterson National Wildlife Refuge in California, other toxic constituents also contribute to contaminant problems.

To maintain consistency, a standard list of constituents for water, bottom sediment, and biota was selected for analysis in all Department of the Interior irrigation-drainage investigations. Some additional constituents were analyzed in water samples collected during the present study. Water hardness was measured, because a criterion for toxicity of many trace elements is based on hardness. Previous investigations had indicated that nitrate contamination was present and salinity was a concern. Therefore, analyses for nitrate and dissolved solids were included. Onsite measurements made at the time of sampling were for pH, specific conductance, temperature, and water discharge (where appropriate). Pesticides selected for analysis in water and bottom-sediment samples were limited to those commonly used in the study area.

An objective of the biological investigation was to select an organism or group of organisms that represented diet items of either fish or migratory birds. Further, a basic goal was to achieve consistency if possible from site to site in the kind of organisms sampled so that various areas could be compared. However, consistency could not always be achieved because of differences in habitat and, for invertebrates, because of insufficient numbers of organisms to achieve an adequate biomass for analysis. When deviations were necessary, however, the biota finally selected represented a known diet item for consumer organisms (either fish or migratory birds). Although diet items were selected, no intent was made to establish food-chain relations. Maintaining consistency in the group of invertebrates sampled at various sites was thought to outweigh varying the taxa of organisms collected from site to site based on a different species of consumer organism.

Onsite measurements and constituents analyzed in water, bottom sediment, and biota are listed in table 1. Physical properties, hardness, dissolved solids, nitrite plus nitrate, trace elements, and radiochemicals are identified in the table as core variables. Pesticides are identified separately.

Sampling Sites

Sampling sites were selected to permit comparison of concentrations of constituents throughout different parts of the study area. Inflow water from irrigation diversions serves as a control in assessment of background quality of water entering the area. Water and bottom sediment were sampled where contaminants are most likely to accumulate or occur in the greatest concentrations (for example, lake bottoms, saline seeps, and shallow ground water).

Several considerations were used in selecting the biota sampling sites. These include knowledge of previous data that indicated potentially contaminated sites, knowledge of the refuge manager and persons familiar with the various areas, relations of the site to irrigation water inflow and outflow, and availability of biota.

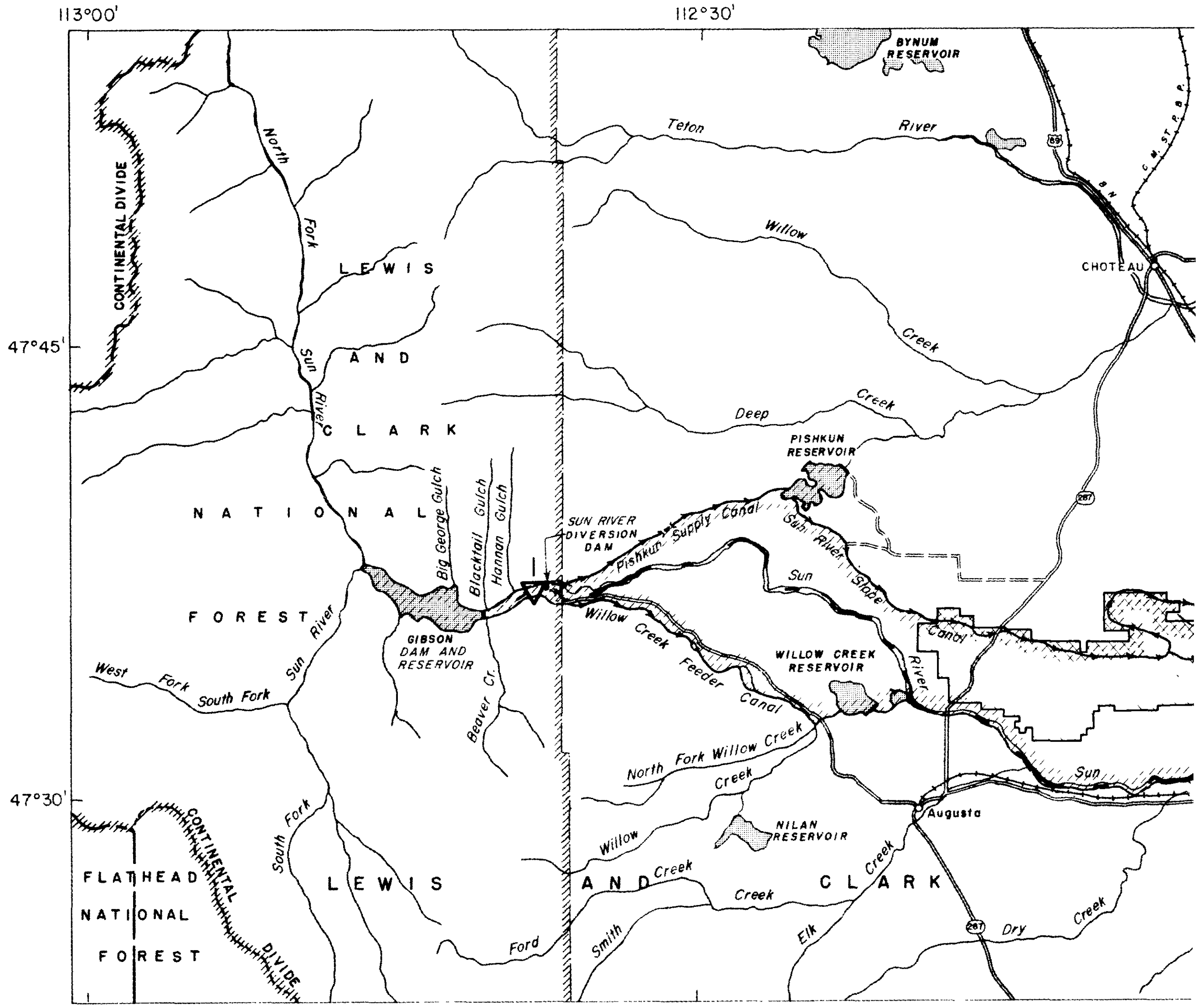
The location and type of sampling sites are shown for the Sun River Irrigation Project (fig. 4), the Freezeout Lake Game Management Area (fig. 5), and the Benton Lake National Wildlife Refuge (fig. 6). Sampling sites, schedules of collection, and sample type are listed in tables 2 and 3.

Table 1.--*Physical properties and constituents analyzed in samples of water, bottom sediment, and biota*

[est., estimated]

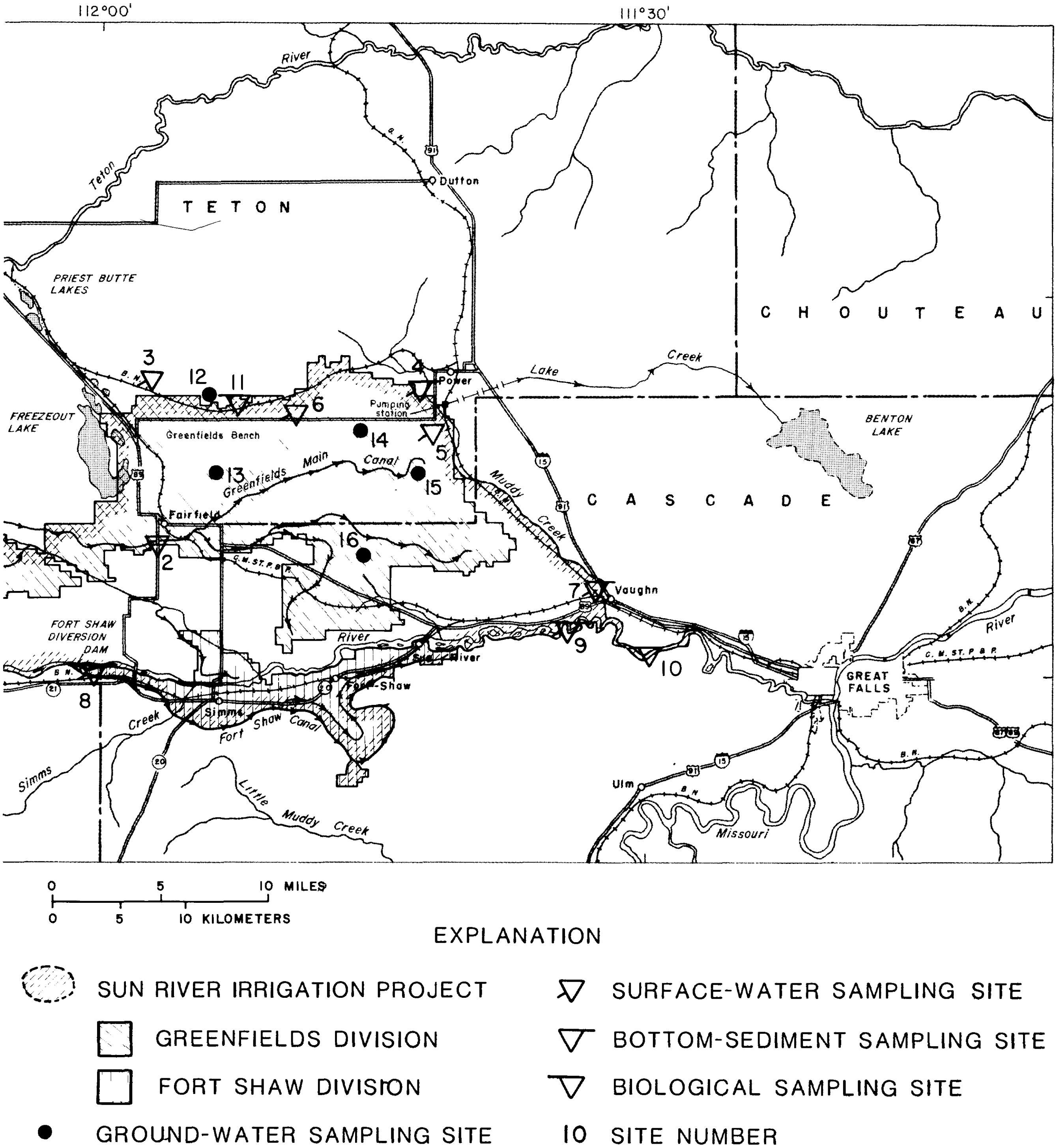
Water		Bottom sediment		Biota[1]	
Core variables[2]	Pesticides[1,3]	Core variables[3]	Pesticides[1,3]	Core variables[3]	Pesticides[3]
Discharge[1]	Picloram	Arsenic	Picloram	Aluminum	p,p'-DDT
Specific conductance	Dicamba	Barium	Dicamba	Arsenic	p,p'-DDE
pH	2,4-D	Boron	2,4-D	Barium	p,p'-DDD
Temperature	2,4,5-T	Cadmium	2,4,5-T	Beryllium	PCB-1248
Hardness	2,4-DP	Chromium	2,4-DP	Boron	PCB-1254 (est.)
Dissolved solids	Silvex	Copper	Silvex	Cadmium	Oxychlordane
Nitrite plus nitrate[1]		Lead		Chromium	cis-Chlordane
Arsenic		Mercury		Copper	trans-Chlordane
Barium		Molybdenum		Iron	cis-Nonachlor
Boron		Nickel		Lead	trans-Nonachlor
Cadmium		Selenium		Magnesium	Dieldrin
Chromium		Silver		Manganese	Endrin
Copper		Vanadium		Mercury	Heptachlor epoxide
Lead		Zinc		Molybdenum	
Mercury		Uranium		Nickel	
Molybdenum				Selenium	
Nickel				Strontium	
Selenium				Tin	
Silver				Vanadium	
Vanadium				Zinc	
Zinc					
Gross alpha					
Gross beta					
Radium-226					
Uranium					

[1]Measured for selected samples.
[2]Concentrations reported as dissolved.
[3]Concentrations reported as total.



Base modified from U.S. Bureau of Reclamation, 1973

Figure 4.--Location and type of sampling sites



in the Sun River Irrigation Project.

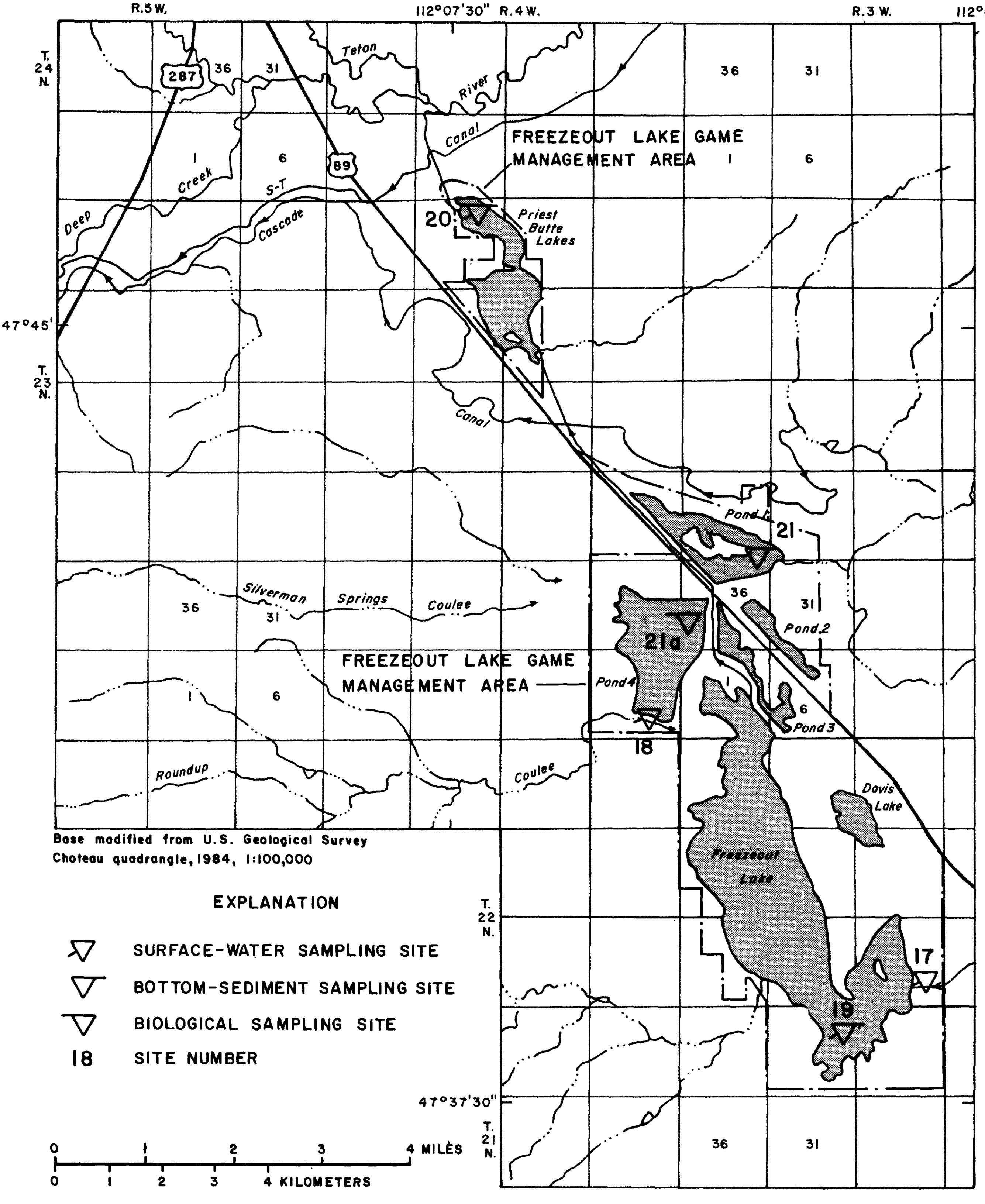


Figure 5.--Location and type of sampling sites in the Freezeout Lake Game Management Area.

Sampling and Analytical Methods

Samples were collected during critical periods, which generally occur during mid- to late summer after irrigation drainage has moved through the system and biological productivity is at a maximum. Sampling schedules account for timing of irrigation diversion, lag time of surface return flows, certain life-cycle stages of growth in biota, and coordination with application of agricultural chemicals.

Water samples were collected and processed onsite in accordance with methods given by Knapton (1985). In flowing water, such as streams and canals, the sample was a composite of depth-integrated subsamples collected at several vertical sections across the stream. Samples from lakes and ponds were collected near mid-depth. Because of the physical nature of the seeps, sampling methods varied. Methods were modified to obtain the most representative sample of each seep. As part of quality control, about 10 percent of all water samples were duplicates.

Bottom-sediment samples were collected using samplers designed by the Federal Inter-Agency Sedimentation Project and using methods outlined by the U.S. Geological Survey (1977). Each bottom-sediment sample submitted to the laboratory was a composite of several subsamples, all collected near the designated site. Composite samples were not sieved onsite but were dry sieved in the laboratory through a 0.0625-millimeter mesh screen using procedures described by Severson and others (1987).

Map sites are designated for biota samples. However, the mobility and nature of biota make these sites approximate.

Standard equipment and techniques were used for collecting the biota samples. Fish were collected using electroshocking equipment, gill nets, and seine or sweep nets; pond invertebrates were collected with a sweep net; stream invertebrates were collected with a kick screen; aquatic vascular plants were uprooted with a tile spade; and filamentous algae were collected by hand-picking (using forceps). Birds were shot using steel shot and the livers removed using stainless-steel dissecting equipment. Collecting apparatus was routinely cleaned between sampling sites and dissecting equipment vigorously cleaned prior to removal of each bird liver. For bird-egg samples, one egg was removed from individual nests until the desirable number (generally five) was obtained.

Although birds were always present in the sample-collection areas, any bird observations were incidental to the main objective. Consequently, there was no plan of study designed to specifically observe individuals or groups of birds for deformities or signs of abnormal behavior. Neither were searches for dead or deformed birds conducted along the shoreline of the marshes or adjacent areas.

Onsite quality control consisted of assuring that the samples were representative of the trophic level and free of extraneous matter such as sediment and unrepresentative biota. Except for bird eggs, all samples were frozen onsite and maintained in this condition until they were analyzed at the laboratory. Because the study was a screening survey and only a selected number of samples could be analyzed, no duplicate samples were collected.

With the exception of the Sun River sampling, selection of the sampling periods was based on availability of young-of-the-year birds and bird eggs. An attempt was made to collect young-of-the-year birds as late in the pre-fledgling stage as pos-

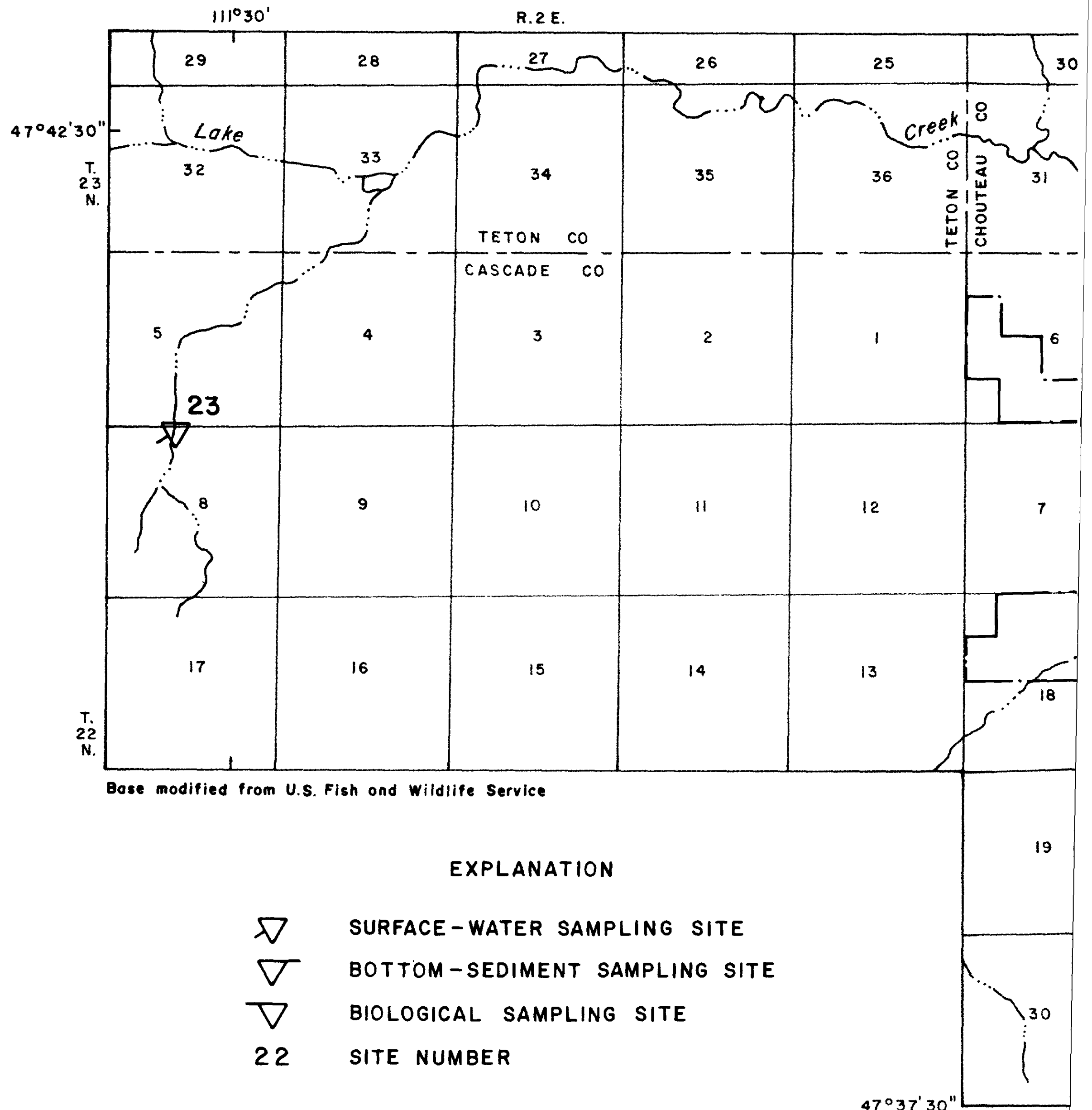
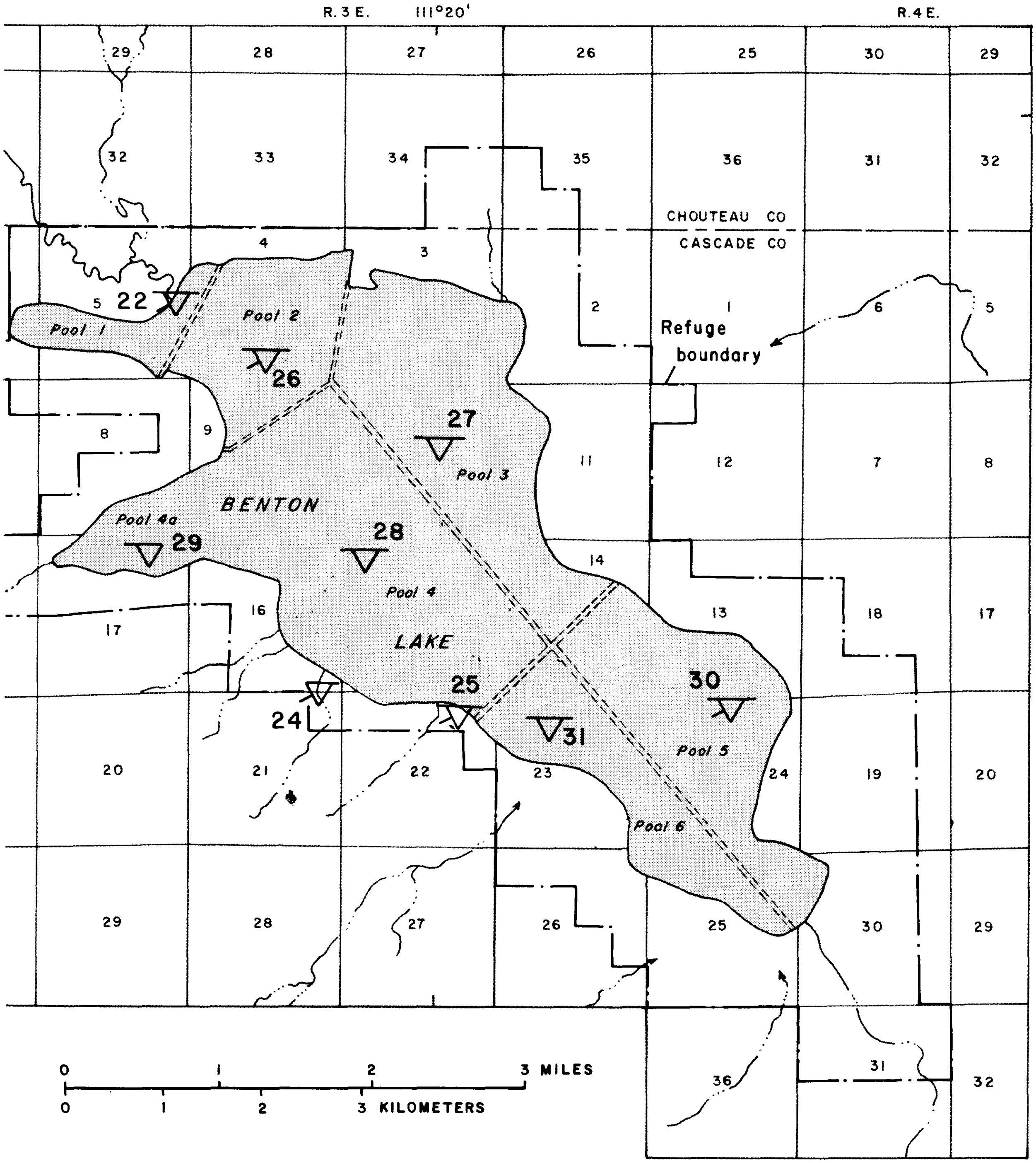


Figure 6.--Location and type of sampling sites in the



Benton Lake National Wildlife Refuge.

Table 2.--*Sampling sites and sampling plan for water, bottom sediment, and biota*

[Core variables and pesticides identified in table 1. X, data collected; -, data not collected]

Site No. (figs. 4-6)	Site name	Station No.	Schedule	Water: Core variables	Water: Pesticides	Bottom sediment: Core variables	Bottom sediment: Pesticides	Biota: Core variables	Biota: Pesticides
			Sun River Irrigation Project						
1	Gibson Diversion Dam (control)	473705112413501	Spring	X	-	-	-	-	-
2	Greenfields Main Canal	473601111582201	Spring	X	-	-	-	-	-
3	North Supply Ditch	474134112003001	Spring	X	-	-	-	-	-
4	Muddy Creek near Power	474247111432201	Mid-summer	X	X	X	X	-	-
			Late summer	X	-	-	-	-	-
5	Spring Coulee	473945111421201	Mid-summer	X	X	-	-	-	-
			Late summer	X	-	-	-	-	-
6	Thompson Drain	474100111481801	Summer	X	-	-	-	-	-
7	Muddy Creek at Vaughn	06088500	Mid-summer	X	-	X	-	-	-
			Late summer	X	-	-	-	-	-
8	Sun River-Fort Shaw Diversion Dam	473009111594501	Summer	X	-	-	-	X	X
9	Sun River below Fort Shaw irrigated lands	473208111430001	Summer	X	-	X	-	X	X
10	Sun River below Muddy Creek	473342111323301	Summer	-	-	-	-	X	X
11	Site not sampled	-	-	-	-	-	-	-	-
12	Tri-County water-supply well	474100111564501	Summer	X	-	-	-	-	-
13	Domestic well	474059111442701	Summer	X	X	-	-	-	-
14	Domestic well	473826111480501	Summer	X	X	-	-	-	-
15	Domestic well	473550111465801	Summer	X	X	-	-	-	-
16	Domestic well	473242111471701	Summer	X	X	-	-	-	-

Table 2.--*Sampling sites and sampling plan for water, bottom sediment, and biota*--Continued

Site No. (figs. 4-6)	Site name	Station No.	Schedule	Water: Core variables	Water: Pesticides	Bottom sediment: Core variables	Bottom sediment: Pesticides	Biota: Core variables	Biota: Pesticides
	Freezeout Lake Game Management Area								
17	Irrigation drain (east)	473750112004501	Summer	X	-	-	-	-	-
18	Saline seep (west)	474112112053401	Spring	X	-	-	-	-	-
19	Freezeout Lake (south end)	473825112013001	Summer	X	X	X	X	-	-
20	Priest Butte Lakes (north pond)	474450112070001	Summer	X	-	X	-	X	X
21	Pond 1[1]	474240112030001	Summer	-	-	X	-	-	-
21a	Pond 4	474200112034001	Spring	-	-	-	-	X	X
			Summer	-	-	-	-	X	X
	Benton Lake National Wildlife Refuge								
22	Lake Creek at mouth	474135111221501	Spring	-	-	-	-	X	X
			Summer	X	X	X	X	X	X
23	Seep drain ditch	474101111303201	Spring	X	-	-	-	-	-
24	Seep (sec. 16)	473917111210001	Spring	X	-	X	-	-	-
25	Seep (sec. 22)	473908111194501	Spring	X	-	X	-	X	-
			Summer	-	-	-	-	X	-
26	Benton Lake (Pool 2)	474110111212001	Spring	-	-	-	-	X	X
			Summer	X	-	X	-	X	X
27	Benton Lake (Pool 3)	474045111200001	Summer	-	-	X	-	X	-
28	Benton Lake (Pool 4)	474010111202501	Spring	-	-	-	-	X	X
			Summer	-	-	X	-	X	X
29	Benton Lake (Pool 4A)	474120111225501	Spring	-	-	-	-	X	-
30	Benton Lake (Pool 5)	473910111180001	Summer	X	-	X	-	X	-
31	Benton Lake (Pool 6)	473855111184001	Summer	-	-	X	-	X	-

[1]Although Pond 1 was initially designated as the sampling site, young-of-the-year birds were not present; thus, biota samples were collected from Pond 4.

Table 3.- *Detailed sampling plan for divisions of biota*

[Core variables (C) and pesticides (P) identified in table 1.
X, data collected; -, no data collected]

Site No. (figs. 4-6)	Site	Schedule	Fish C	Fish P	Invertebrates C	Plants: Aquatic vascular C	Plants: Filamentous algae C	Birds: Livers C	Birds: Livers P	Birds: Eggs C	Birds: Eggs P
	Sun River Irrigation Project										
8	Sun River-Fort Shaw diversion	Summer	X	X	X	-	-	-	-	-	-
9	Sun River below Fort Shaw irrigation lands	Summer	X	X	X	-	-	-	-	-	-
10	Sun River below Muddy Creek	Summer	X	X	X	-	-	-	-	-	-
	Freezeout Lake Game Management Area										
20	Priest Butte Lakes (north pond)	Summer	X	X	X	X	-	-	-	-	-
21a	Pond 4	Spring	-	-	-	-	-	-	-	X	X
		Summer	X	X	X	X	X	X	X	-	-
	Benton Lake National Wildlife Refuge										
22	Lake Creek at mouth	Spring	-	-	-	-	-	-	-	X	X
		Summer	-	-	X	X	X	X	X	-	-
25	Seep (sec. 22)	Spring	-	-	-	-	-	-	-	X	-
		Summer	-	-	X	-	-	-	-	-	-
26	Benton Lake (Pool 2)	Spring			-	-	-	-	-	X	X
		Summer	X	X	X	X	X	X	X	-	-
27	Benton Lake (Pool 3)	Summer	-	-	X	X	-	-	-	-	-
28	Benton Lake (Pool 4)	Spring	-	-	-	-	-	-	-	X	X
		Summer	-	-	X	X	-	X	X	-	-
29	Benton Lake (Pool 4a)	Spring	-	-	-	-	-	-	-	X	-
30	Benton Lake (Pool 5)	Summer	-	-	X	-	-	-	-	-	-
31	Benton Lake (Pool 6)	Summer	-	-	X	-	-	-	-	-	-

sible. This stage would allow maximum exposure of young birds to any contaminant present and add some degree of certainty to the likelihood that any contaminant detected in bird livers also exists in the particular habitat. Consequently, most birds were collected in late July. All bird-egg samples were obtained during early June.

Fish, invertebrates, aquatic vascular plants, and filamentous algae were collected from late July through August. Fish and invertebrate samples from the Sun

River were collected near mid-August. Fish from Freezeout Lake and Priest Butte Lakes were collected in July.

Young-of-the-year American coot and American avocet were the primary age class and bird species designated for collection of liver and egg samples. Based on the literature, bird liver was determined to be the best overall organ to use for a general metal analysis scan, even though other organs may have been better indicators for specific chemical variables (such as kidney for cadmium and bone for lead). Because young-of-the-year birds generally are confined to a given local area until flight stage, the chemicals detected in their tissue can be assumed to have been obtained from the food and water in the area where they were reared.

For a screening survey, it was deemed unnecessary to identify organisms to a finer taxanomic classification than that easily determined by macroscopic features. Several easily identifiable invertebrate groups (damselfly and dragonfly naiads), however, were combined to achieve adequate biomass for analysis. Growth characteristics and collection sites for the filamentous-algae samples were typical of those for green algae (Chlorophyta), although some samples may have contained some filamentous blue-green algae (Cyanophyta).

After onsite processing, the water samples were sent to the U.S. Geological Survey's water-quality laboratory in Arvada, Colorado, for analysis. Analyses were performed using procedures described by Fishman and Friedman (1985) for inorganic constituents and Wershaw and others (1987) for pesticides. Bottom-sediment samples were analyzed by the U.S. Geological Survey's geochemistry laboratory in Denver, Colorado, using procedures described in Severson and others (1987). All biota samples were analyzed at the U.S. Fish and Wildlife Service Patuxent Analytical Control Facility, in Laurel, Maryland.

DISCUSSION OF RESULTS

Water Quality

Analytical results of water are discussed according to the three subunits of the study area. The Sun River Irrigation Project is further divided according to surface water and ground water. Onsite measurements and analytical results for all water samples are listed in table 15 (at back of the report). A statistical summary of the same data is given in table 4. Selected criteria established by the State of Montana for beneficial use of water, with the number of times the criteria values were exceeded, are identified in table 5. Where possible, data are compared to the State of Montana's criteria; where not possible, data are compared to other criteria. Emphasis is placed on values and concentrations that surpass criteria and background data, with little or no discussion given to values and concentrations considered to be at a safe level.

Concentrations of selected trace elements analyzed from water at all sampling sites are shown in figures 7-12. Where more than one sample was collected (sites 4, 5, 7), the largest analytical concentration is given in the figures. In all instances, the differences between the concentrations of similar trace elements from the same sites were insignificant.

Table 4.--*Statistical summary of water-quality data*

[Units are micrograms per liter unless otherwise noted. Symbols: µS/cm, microsiemens per centimeter at 25 °Celsius; mg/L, milligrams per liter; pCi/L, picocuries per liter; <, less than analytical detection limit; --, no data]

	Sun River Irrigation Project							
	Surface water				Ground water			
Variable	Number of samples	Minimum	Maximum	Median	Number of samples	Minimum	Maximum	Median
Specific conductance, µS/cm	12	220	755	630	5	420	950	670
pH, units	12	7.6	8.8	8.4	5	7.3	7.6	7.5
Hardness, mg/L	12	110	340	295	5	220	410	340
Dissolved solids, mg/L	12	124	496	291	5	228	547	353
Nitrite plus nitrate, mg/L	--	--	--	--	5	.46	6.4	4.1
Arsenic	12	<1	2	1	5	<1	2	1
Barium	12	76	110	93	5	86	120	110
Boron	12	<10	140	120	5	40	250	170
Cadmium	12	<1	<1	<1	5	<1	<1	<1
Chromium	12	<10	<10	<10	5	<10	<10	<10
Copper	12	<10	<10	<10	5	<10	10	<10
Lead	12	<1	<5	<5	5	<5	<5	<5
Mercury	11	<.1	<.1	<.1	5	<.1	<.1	<.1
Molybdenum	12	<1	5	2	5	3	8	3
Nickel	12	<1	2	<1	5	<1	3	1
Selenium	12	<1	2	1	5	<1	5	2
Silver	12	<1	<1	<1	5	<1	<1	<1
Vanadium	12	<1	7	3	5	3	11	7
Zinc	12	<3	30	10	5	7	67	44
Gross alpha	9	2.7	11	6.9	5	2.8	9.6	8.2
Radium-226, pCi/L	9	<.1	.3	.2	5	<.1	.2	.1
Uranium	9	1.5	8.2	5.2	5	3.1	18	14
Picloram	2	<.01	<.01	--	5	<.01	<.01	<.01
Dicamba	2	<.02	.01	--	5	<.01	<.01	<.01
2,4-D	2	<.01	.04	--	5	<.01	<.01	<.01
2,4,5-T	2	<.01	<.01	--	5	<.01	<.01	<.01
2,4-DP	2	<.01	<.01	--	5	<.01	<.01	<.01
Silvex	2	<.01	<.01	--	5	<.01	<.01	<.01

Table 4.--*Statistical summary of water-quality data*--Continued

Variable	Freezeout Lake Game Management Area				Benton Lake National Wildlife Refuge			
	Number of samples	Mini-mum	Maxi-mum	Med-ian	Number of samples	Mini-mum	Maxi-mum	Med-ian
Specific conductance, mS/cm	4	980	7,900	2,390	5	860	12,000	3,550
pH, units	4	8.4	9.6	9.0	6	4.5	9.8	8.0
Hardness, mg/L	4	320	3,100	590	6	360	17,000	2,000
Dissolved solids, mg/L	4	674	6,750	1,680	6	548	39,300	4,500
Nitrite plus nitrate, mg/L	-	--	--	--	-	--	--	--
Arsenic	4	2	22	9	6	<1	63	2
Barium	4	93	120	<100	5	45	200	100
Boron	4	160	890	445	6	150	2,500	630
Cadmium	4	<1	1	<1	6	<1	660	<1
Chromium	4	<10	<10	<10	6	<10	40	10
Copper	4	<10	30	15	6	<10	80	15
Lead	4	<1	<5	<5	6	<1	5	<5
Mercury	4	<.1	<.1	<.1	6	<.1	.1	<.1
Molybdenum	4	1	9	5	6	<1	5	1
Nickel	4	<1	2	1	6	1	7,000	5
Selenium	4	<1	8	5	6	<1	580	10
Silver	4	<1	<1	<1	6	<1	<1	<1
Vanadium	4	2	6	5	6	3	11	7
Zinc	4	6	20	16	6	6	19,000	55
Gross alpha	2	9.5	20	--	2	5.4	9.3	--
Radium-226, pCi/L	3	<.2	.2	.2	3	<.1	<.2	<.1
Uranium	3	5.0	25	6.9	3	3.5	7.8	4.1
Picloram	1	<.01	<.01	--	1	.01	.01	--
Dicamba	1	.08	.08	--	1	<.01	<.01	--
2,4-D	1	.22	.22	--	1	<.01	<.01	--
2,4,5-T	1	<.01	<.01	--	1	<.01	<.01	--
2,4-DP	1	<.01	<.01	--	1	<.01	<.01	--
Silvex	1	<.01	<.01	--	1	<.01	<.01	--

Table 5.--*Revised water-quality matrix for the State of Montana showing criteria for six beneficial uses*[1] *and number of times critera were exceeded in water sample*

[N, number of samples; C, criteria given by State of Montana; E, number of times criteria were exceeded; units are micrograms per liter unless otherwise noted; µS/cm, microsiemens per centimeter at 25 °Celsius; mg/L, milligrams per liter; --, no data]

		Beneficial use											
		Cold-water aquatic life		Warm-water aquatic life		Public water supplies		Primary-contact recreation		Irri-gation		Livestock watering	
Variable	N	C	E	C	E	C	E	C	E	C	E	C	E
Specific conductance, µS/cm	27	--	--	--	--	--	--	--	--	1,800	7	--	--
pH, units (minumum)	27	6.5	2	6.5	2	6.5	2	6.5	2	4.5	0	--	--
pH, units (maximum)	27	8.5	6	9.0	3	8.5	6	8.5	6	9.0	3	--	--
Dissolved solids, mg/L	27	--	--	--	--	500	12	--	--	1,200	7	10,000	1
Nitrite plus nitrate, mg/L	5	--	--	--	--	10	0	--	--	--	--	100	0
Arsenic	27	440	0	440	0	50	1	--	--	100	0	200	0
Barium	26	--	--	--	--	1,000	0	--	--	--	--	--	--
Boron	27	--	--	--	--	--	--	--	--	750	4	5,000	0
Cadmium	27	[2]3	2	[2]3	2	10	2	--	--	50	1	50	1
Chromium	27	[2]21	1	[2]21	1	50	0	--	--	1,000	0	--	--
Copper	27	[2]12	5	[2]12	5	1,000	0	--	--	5,000	0	50	0
Lead	27	[2]4	1	[2]4	1	50	0	--	--	10,000	0	100	0
Mercury	26	4	0	4	0	2	0	--	--	--	--	10	0
Nickel	27	[2]1,800	2	[2]1,800	2	15	2	--	--	2,000	2	--	--
Selenium	27	260	2	260	2	10	3	--	--	20	2	50	2
Silver	27	4	0	4	0	50	0	--	--	--	--	--	--
Zinc	27	37	6	37	6	5,000	1	--	--	10,000	1	25,000	0

[1]Modified from Montana Department of Health and Environmental Sciences (1986); units have been converted from milligrams per liter to micrograms per liter.

[2]Specific criteria for protection of aquatic life are based on hardness; criteria given are based on water hardness of 100 milligrams per liter.

Sun River Irrigation Project

Surface Water

Water diverted from the Sun River at the upstream end of the project (fig. 4, site 1) to fulfill irrigation needs is of good quality in terms of criteria listed in table 5. Data collected prior to this study indicate that during the irrigation season dissolved-solids concentrations generally range from 100 to 200 mg/L. The chemical character of the water is a calcium magnesium bicarbonate type and

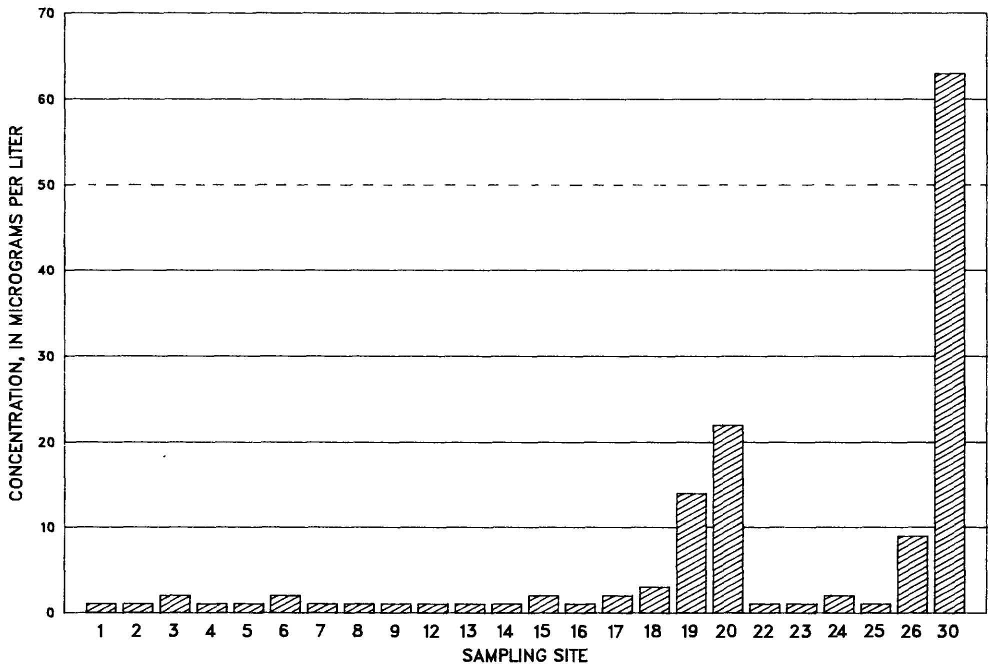


Figure 7.--Concentrations of arsenic in water at sampling sites. The criterion for public water supplies in Montana (dashed line) is 50 micrograms per liter (Montana Department of Health and Environmental Sciences, 1986).

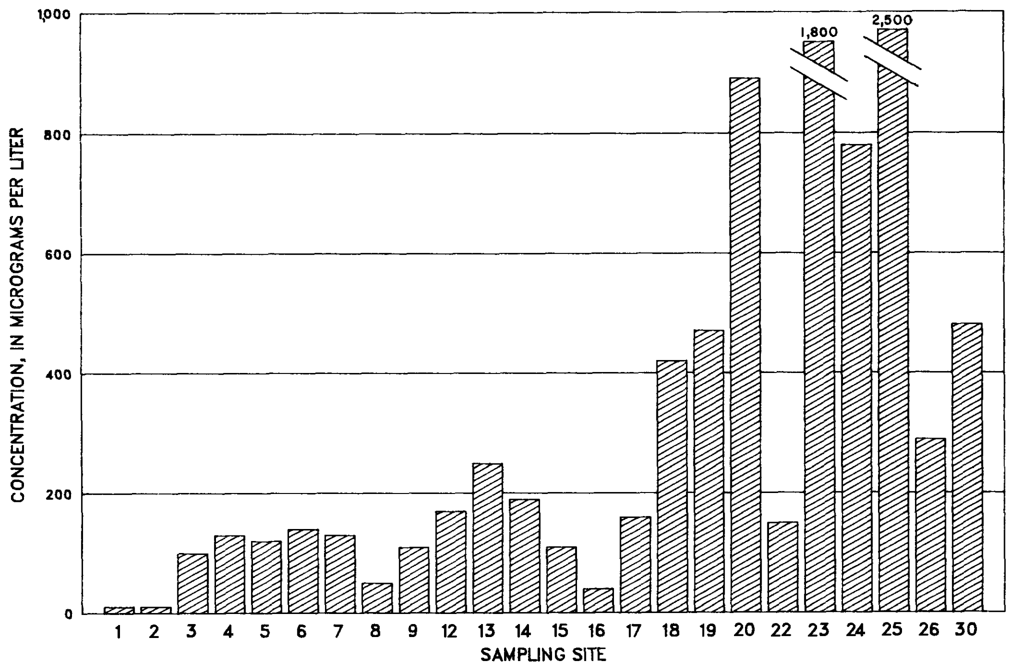


Figure 8.--Concentrations of boron in water at sampling sites. No criterion for boron in public water supplies has been established in Montana.

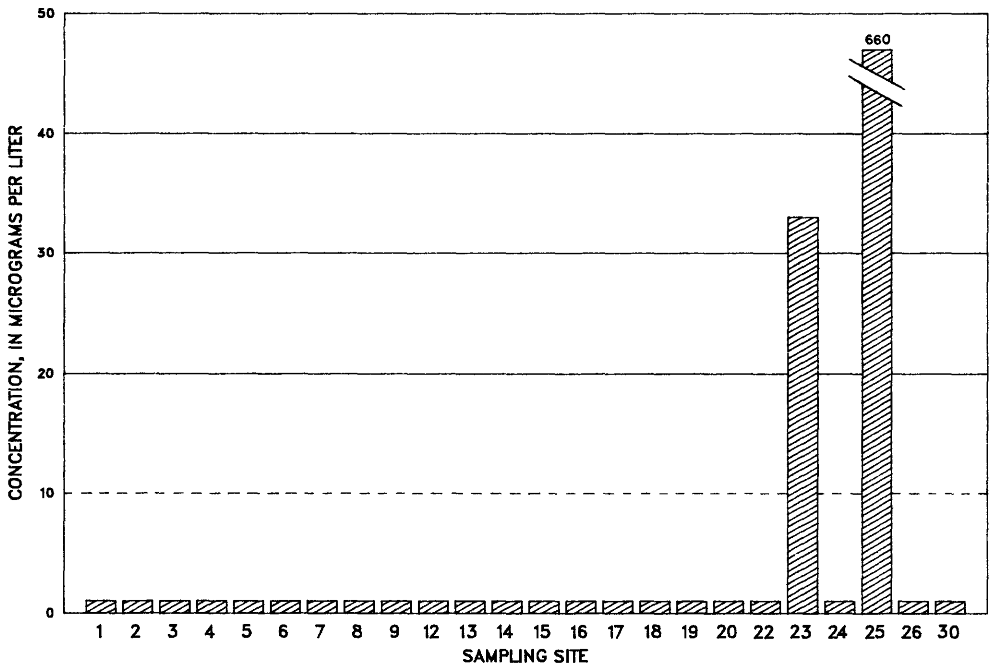


Figure 9.--Concentrations of cadmium in water at sampling sites. The criterion for public water supplies in Montana (dashed line) is 10 micrograms per liter (Montana Department of Health and Environmental Sciences, 1986).

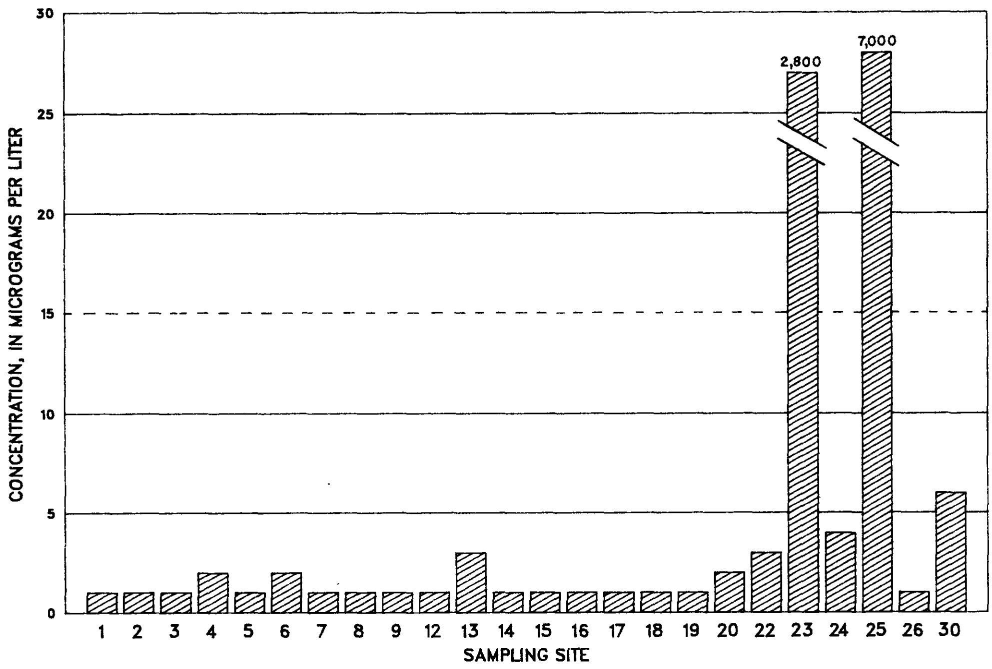


Figure 10.--Concentrations of nickel in water at sampling sites. The criterion for public water supplies in Montana (dashed line) is 15 micrograms per liter (Montana Department of Health and Environmental Sciences, 1986).

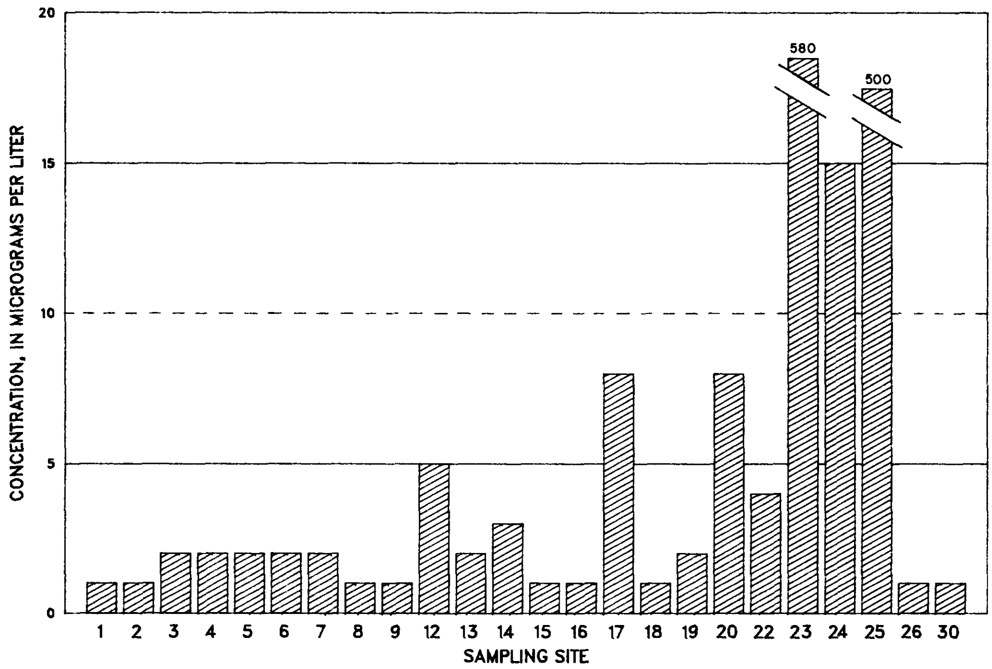


Figure 11.--Concentrations of selenium in water at sampling sites. The criterion for public water supplies in Montana (dashed line) is 10 micrograms per liter (Montana Department of Health and Environmental Sciences, 1986).

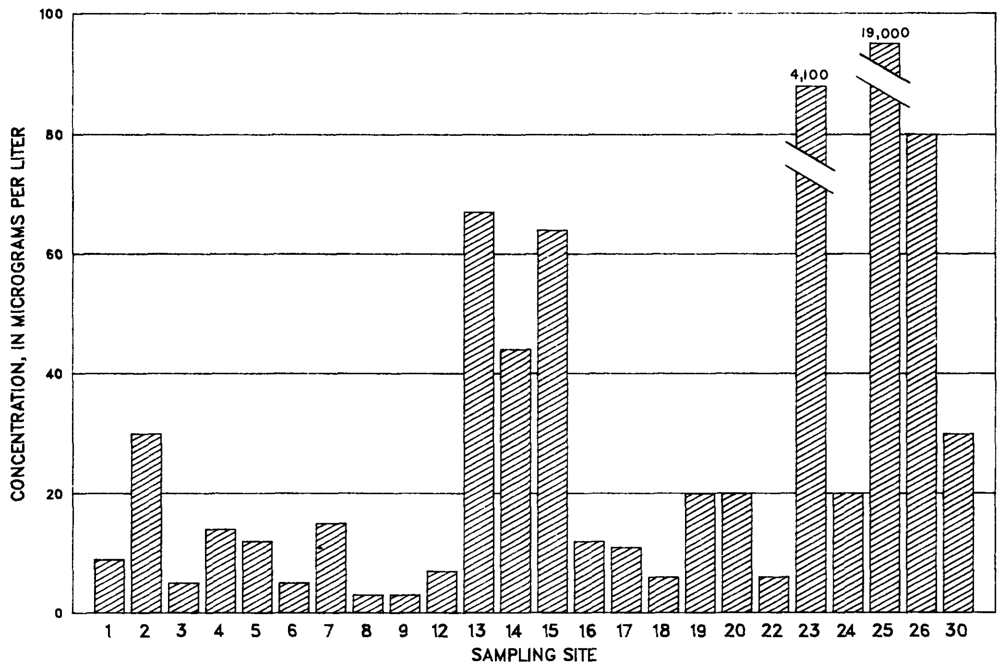


Figure 12.--Concentrations of zinc in water at sampling sites. The criterion for public water supplies in Montana is 5,000 micrograms per liter (Montana Department of Health and Environmental Sciences, 1986).

hardness is about 100 mg/L. Trace-element concentrations are near or less than analytical detection limits (U.S. Geological Survey, issued annually).

At the downstream end of the irrigation project (fig. 4, site 9), dissolved solids in wastewater and surface return flows have 3- to 4-fold increases when compared to water at the initial diversion. Even with the measured increases, dissolved-solids concentrations in the surface-water samples (table 15) did not exceed the criterion of 500 mg/L for public water supplies. However, data from prior investigations indicate that later in the season, when ground water is the major contributor to flow in the Sun River and Muddy Creek, dissolved-solids concentrations are considerably larger (U.S. Geological Survey, issued annually).

Trace-element analyses from samples at the downstream sampling sites had either no increase or slight increases in concentration. Pesticides were analyzed from samples collected at site 4 (Muddy Creek near Power) and site 5 (Spring Coulee). With the exception of 2,4-D, all concentrations were less than or equal to the analytical detection limits. Measurements indicated 2,4-D to be present at site 4 in a concentration of 0.04 μg/L, a concentration slightly larger than the analytical detection limit.

Although concentrations of constituents measured indicated no problems of a toxic nature for surface water at the nine sites sampled, the potential for contamination does exist. Imprudent use of agricultural chemicals, specifically pesticides, could readily contaminate surface water throughout the project, including the Sun River and Muddy Creek. Under such circumstances, the Power community water supply, obtained from Muddy Creek (site 4), could be vulnerable, as could any source that might be used for domestic purposes.

Ground Water

Samples were collected from four domestic wells and the Tri-County water-supply well (site 12) that provides water for about 170 households within Teton, Cascade, and Choteau Counties. Water levels in the wells were shallow, ranging from 4.00 to 10.80 feet below land surface. Dissolved-solids concentrations ranged from 228 to 547 mg/L and hardness ranged from 220 to 410 mg/L. According to Durfor and Becker (1964), water with a hardness of more than 180 mg/L (as $CaCO_3$) is very hard.

A major concern in the Greenfields Division has been contamination of ground water by nitrate commonly used to fertilize crops. Samples from the five wells during the current study had nitrite plus nitrate concentrations that ranged from 0.46 to 6.4 mg/L as nitrogen. Studies by Walther (1981) indicated that 27 percent of 329 samples collected from 24 domestic wells had nitrate concentrations larger than 10 mg/L--the maximum allowable limit for public water supplies (table 5). Walther (1981) indicated that an obvious source of nitrate was fertilizer application to crops and pastures. However, he stated the process might be more complicated than direct leaching to the aquifer.

Examination of trace-element concentrations in samples from the five wells indicated slightly larger concentrations compared to source water from the Sun River. However, all concentrations except that for zinc were substantially less than any listed criteria in table 5. The zinc concentration in ground water from site 13 was 67 µg/L, compared to 37 µg/L for two of the listed criteria. Water from the Tri-County well (site 12) had concentrations of molybdenum of 8 µg/L, selenium of 5 µg/L, and uranium of 18 µg/L. Concentrations of vanadium in well water were 10 µg/L at site 14 and 11 µg/L at site 15.

Because the Environmental Division of the Montana Department of Agriculture had measured detectable concentrations of certain pesticides in ground-water samples from the irrigation district (John Larson, written commun., 1986), samples from the five wells were analyzed for Picloram; Dicamba; 2,4-D; 2,4,5-T; 2,4-DP; and Silvex. In all samples, the pesticide concentrations were less than 0.01 µg/L, which was the detection limit for the analytical procedures.

Freezeout Lake Game Management Area

Water samples were collected at four surface-water sites within the Freezeout Lake Game Management Area. Site 17 is a source of surface return flow to Freezeout Lake from the Sun River Irrigation Project, site 18 is a natural seep west of Freezeout Lake, site 19 is at the south end of Freezeout Lake, and site 20 is at the north end of Priest Butte Lakes.

In terms of dissolved solids and most trace elements, water at the inflow to Freezeout Lake (site 17) had the smallest concentrations of the four sites sampled. However, the selenium concentration of 8 µg/L equaled the largest concentration from the study area, with the exception of seeps in the Benton Lake vicinity. This concentration is slightly less than the 10-µg/L criterion for public water supplies (table 5). The vanadium concentration of 6 µg/L in water from site 17 was the largest of the four sampling sites. However, it was only slightly larger than the median value of 5 µg/L (table 4).

Water samples collected at site 18 had relatively small constituent concentrations when compared to sampled seeps around Benton Lake. Some of the trace-element concentrations were the smallest measured in water from the game management area.

Dissolved-solids concentrations and most other inorganic-constituent concentrations in Freezeout Lake (site 19) were larger than those from inflow water, but less than those measured in Priest Butte Lakes. Freezeout Lake was the only site in the game management area sampled for pesticides and the only site in the study area where pesticide concentrations were substantially larger than detection limits. The concentration of Dicamba was 0.08 µg/L and the concentration of 2,4-D was 0.22 µg/L. Other pesticides in the same sample were less than detectable concentrations.

Water in Priest Butte Lakes generally had larger concentrations of dissolved solids and trace elements than did water from other sampling sites in the game management area. At site 20, the dissolved-solids concentration was 6,750 mg/L. The arsenic concentration was 22 µg/L and the boron concentration was 890 mg/L--more than a 5-fold increase compared to site 17. The uranium concentration in Priest Butte Lakes was 25 µg/L, the largest concentration measured in the study area. This concentration is somewhat smaller than the 35 µg/L given by the National Academy of Sciences (1983) as a maximum recommended uranium concentration for human consumption. Most other trace-element concentrations were small.

Results of the Freezeout Lake salinity study (including Priest Butte Lakes and surrounding area) conducted by the Montana Department of Health and Environmental Sciences during 1980-82 indicate that inflows to Freezeout Lake generally had larger specific-conductance values than were measured during this study. The previous study sampled a larger variety of lake inflows during an extended period. Measurements of specific conductance from the current study in both Freezeout and Priest Butte Lakes were within the range of values for similar sites during the previous study. Six samples collected from a seep at the southeast end of Priest Butte Lakes by the Montana Department of Health and Environmental Sciences had a range in specific conductance of 29,700 to 39,500 μS/cm. This range is indicative that water from site 18, with a specific conductance of 1,700 μS/cm, is not representative of all seeps within the game management area.

Benton Lake National Wildlife Refuge

Water samples were collected at five sites within the Benton Lake National Wildlife Refuge and at one site outside the refuge. Site 22 is on Lake Creek at the inflow to Benton Lake and sites 26 and 30 are locations within the Lake. Sites 24 and 25 are at seeps within the refuge, west of and upgradient from Benton Lake. Site 23, about 5 miles west of the refuge, is on an intermittent tributary that drains into Lake Creek and receives effluent from a system of subsurface drains associated with a large area of nonirrigated farmland; the site is located about 1.5 miles upstream from the confluence with Lake Creek. Because the seeps are natural or related to nonirrigated farmland and are not affected by irrigation water from the Sun River Irrigation Project, lake and seep samples are discussed separately.

Water pumped from Muddy Creek (near site 4) to Benton Lake via Lake Creek (site 22) had about a 40-percent increase in dissolved-solids concentrations between the two locations and an increase in selenium concentration from 2 to 4 μg/L. Most of the other measured constituents showed little change. Increases in dissolved solids and selenium can be attributed to contributions from the Lake Creek drainage.

At the time of sampling, water flowing into Benton Lake at site 22 (mouth of Lake Creek) had a measured discharge of 30 ft^3/s and a dissolved-solids concentration of 548 mg/L. Virtually all flow at this time consisted of diversions from Muddy Creek. Dissolved-solids concentrations were 2,300 mg/L at site 26 and 2,840 mg/L at site 30. The selenium concentration was 4 μg/L at site 22 and less than or equal to the analytical detection limit of 1 μg/L in samples from the other two sites. Most of the other trace elements also had relatively small concentrations when compared to various criteria. An exception was arsenic at site 30, where the concentration was 63 μg/L--the largest arsenic concentration in water measured in the study area (fig. 7). This concentration is about 25 percent larger than the 50-μg/L criterion for public water supplies (table 5).

Water from the two seeps (sites 24 and 25) generally had much larger constituent concentrations than did water from Benton Lake. The seeps presumably are natural, but could have been affected by summer-fallow farming upgradient to the west. Glacial till and shale of the Colorado Group are both present in the area and seeps probably surface near the contact of these formations. Flows were estimated to be less than 0.01 ft^3/s and evaporation likely causes an increase in constituent concentrations. No hydrologic connection was apparent between water being used for irrigation and the seeps.

Dissolved-solids concentrations were 6,790 mg/L at site 24 and 39,300 mg/L at site 25. Site 24 had trace elements in moderate concentrations; site 25 had extremely large concentrations for some trace elements--cadmium, 660 μg/L; nickel, 7,000 μg/L; selenium, 500 μg/L; and zinc, 19,000 μg/L (figs. 7-12). These constituent concentrations far exceeded most available toxicity criteria pertaining to humans and wildlife. Other trace-element concentrations that were moderately large at site 25 were boron, 2,500 μg/L; chromium, 40 μg/L; copper, 80 μg/L; and vanadium, 10 μg/L. Although not necessarily in excess of criteria for public water supplies, all trace-element concentrations, except vanadium, surpassed criteria for some of the uses identified in table 5.

The pH for the sample collected at site 25 was 5.0. The acidic water was probably responsible for dissolution of metals and for maintaining them in solution. Source of the metals is probably the shale of the Colorado Group or soil derived from the shale. Interestingly, with such large concentrations of other trace elements, the arsenic concentration was only equal to the analytical detection limit of 1 μg/L. Because arsenic was present in water throughout the study area, its absence at this site is probably a result of differing geochemical controls.

Sampling site 23 was selected to give an indication of water type that may enter Lake Creek or Benton Lake directly from sources other than irrigation drainage in Muddy Creek. At the time of sampling, stream discharge was 0.3 ft^3/s, with flow decreasing in a downstream direction because of evaporation. The dissolved-solids concentration in the sample collected at site 23 was 6,160 mg/L. The concentration of cadmium was 33 μg/L; nickel, 2,800 μg/L; selenium, 580 μg/L; and zinc, 4,100 μg/L--all significantly in exceedence of one or more criteria (table 5). The pH was 4.5 and arsenic was similar to its occurrence at site 25.

Land use in the drainage basin of Lake Creek and Benton Lake consists predominantly of nonirrigated farming and livestock grazing. Because of the small quantity of precipitation and little relief, runoff is sporadic. Visual observations confirm the accumulation of salts in low-lying areas and in the channels of intermittent streams, including Lake Creek. During runoff, the accumulated salts and other constituents are flushed into Benton Lake directly or indirectly by passage downstream in Lake Creek. The initial runoff during a storm commonly contains large concentrations of dissolved constituents. Water quality improves after the initial flush, particularly during larger storms. Robert Pearson (Refuge Manager, oral commun., 1987) has confirmed this condition by making measurements of specific conductance throughout a season. Pearson notes that water in Lake Creek, when not diluted by pumpage from Muddy Creek, has had measured specific-conductance values of several thousand microsiemens per centimeter compared to values for pumped water from Muddy Creek of 600 to 800 μS/cm. The accumulations of salts and trace elements near site 23 and presumably accumulations from other locations in the drainage basin of Benton Lake are contributions periodically flushed into Benton Lake.

Although trace-element concentrations measured at the three seeps are extremely large, the values may be comparable to other saline seeps (Miller and others, 1980). Cadmium, nickel, and zinc concentrations were somewhat larger than those reported by Miller and others (1980), but other trace elements were within the range of reported concentrations. The three seep samples were collected at the land surface during the summer and evaporation may have been at least partly responsible for the large concentrations. Many of the samples of Miller and others (1980) were from shallow ground water.

The sources of water to Benton Lake are a combination of return flows from the irrigation project that are pumped from Muddy Creek via Lake Creek, precipitation on the Lake, natural runoff, and ground water that enters from surrounding seeps or goes directly into the lake. Because the lake is a sump with no outlet, constituents transported into the lake remain there. To determine the contribution of constituents from each source, a study of the water budget would be necessary.

Bottom Sediment

Bottom-sediment samples were collected at 14 sites within the study area--3 from Sun River Irrigation Project, 3 from Freezeout Lake Game Management Area, and 8 from Benton Lake National Wildlife Refuge. All analytical data from samples of bottom sediments are given in table 16 (at back of the report). A statistical summary of the same data is given in table 6. Because of an absence of trace-element criteria for bottom sediment, analytical results from the study are compared to geochemical baseline information from soils of the western conterminous United

Table 6.--*Statistical summary of selected trace elements from analyses of bottom sediment*

[Concentrations, in micrograms per gram; <, less than analytical detection limits]

	Sun River Irrigation Project				Freezeout Lake Game Management Area				Benton Lake National Wildlife Refuge			
Constituent	Number of samples	Minimum	Maximum	Median	Number of samples	Minimum	Maximum	Median	Number of samples	Minimum	Maximum	Median
Arsenic	3	6.5	8.4	6.8	3	5.3	9.3	5.8	8	7.1	14	8.3
Barium	3	780	990	960	3	690	710	690	8	31	970	845
Boron	3	.9	1.4	1.3	3	2.1	3.9	3.2	8	1.1	6.3	1.9
Cadmium	3	<2	<2	<2	3	<2	<2	<2	8	<2	<2	<2
Chromium	3	47	84	55	3	39	67	51	8	66	130	115
Copper	3	16	24	21	3	13	29	24	8	26	47	42
Lead	3	12	17	15	3	12	20	17	8	9	25	21
Mercury	3	.02	.03	.02	3	<.02	.02	.02	8	.03	.06	.04
Molybdenum	3	<2	<2	<2	3	<2	<2	<2	8	<2	<2	<2
Nickel	3	18	30	20	3	15	25	20	8	26	130	36
Selenium	3	.5	.8	.6	3	.6	3.9	1.0	8	.3	6.7	.9
Silver	3	<2	<2	<2	3	<2	<2	<2	8	<2	<2	<2
Vanadium	3	77	140	82	3	67	110	83	8	100	210	185
Zinc	3	68	98	69	3	55	100	82	8	67	190	125
Uranium	3	<100	<100	<100	3	<100	<100	<100	8	<100	<100	<100

States compiled by the U.S. Geological Survey (Shacklette and Boerngen, 1984); only the constituents analyzed in bottom sediment are included in table 7. The soil-sample population consisted of all natural soils west of the 97th Meridian within the conterminous United States. Samples were collected from the B-horizon or below 8 inches where the B-horizon was undefined. Single samples were collected at about 50-mile intervals.

Little background information is available for pesticides in bottom sediment. Because concentrations of pesticides in bottom sediment in the study area were extremely small, there is little need to make comparisons.

Table 7.--*Geochemical background data for soils from the western conterminous United States*[1]

[Detection ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed; baseline, expected 95-percent range; --, not determined; <, less than]

Trace element	Detection ratio	Micrograms per gram			
		Geometric mean	Geometric deviation	Baseline	Measured range
Arsenic	728:730	5.5	1.98	1.2-22	<0.1-97
Barium	778:778	580	1.72	200-1,700	70-5,000
Boron	506:778	23	1.99	5.8-91	<20-300
Cadmium	--	--	--	--	--
Chromium	778:778	41	2.19	8.5-200	3-2,000
Copper	778:778	21	2.07	4.9-90	2-300
Lead	712:778	17	1.80	5.2-55	<10-700
Mercury	729:733	.046	2.33	.0085-.25	<.01-4.6
Molybdenum	57:774	.85	2.17	.18-4.0	<3-7
Nickel	747:778	15	2.10	3.4-66	<5-700
Selenium	590:733	.23	2.43	.039-1.4	<.1-4.3
Silver	--	--	--	--	--
Vanadium	778:778	70	1.95	18-270	70-500
Zinc	766:766	55	1.79	17-180	10-2,100
Uranium	224:224	2.5	1.45	1.2-5.3	.68-7.9

[1] Modified from Shacklette and Boerngen (1984).

Cadmium, molybdenum, silver, and uranium concentrations from all sites were less than analytical detection limits and the mercury concentration was only slightly larger. Concentrations of boron were less than the geometric mean when compared to soil samples of the western conterminous United States, and lead concentrations were only slightly larger than the mean (table 7). These constituents seem to have little potential for creating toxicity problems.

Bottom-sediment samples from Benton Lake had the largest arsenic concentrations of all sites sampled, with sites 27, 30, and 31 having respective concentrations of 12, 12, and 14 µg/g (table 16). The 14-µg/g concentration is more than double the geometric mean for soil samples of the western conterminous United States (table 7), but less than the maximum (22 µg/g) for baseline values. Site 30 also had the largest arsenic concentration (63 µg/L) of all water samples (table 15).

Barium concentrations were largest in samples from the two Muddy Creek sampling sites, with site 4 (Muddy Creek near Power) having the largest concentration (990 µg/g). This barium concentration is somewhat larger than the geometric mean of 580 µg/g for soil samples, but smaller than the baseline maximum of 1,700 µg/g.

Chromium and copper concentrations in bottom sediment were largest from sampling sites in Benton Lake. Sites 26, 28, and 31 had chromium concentrations of 130 μg/g, and site 30 had a copper concentration of 47 μg/g. The maximum chromium and copper concentrations exceeded the geometric mean for soil samples of the western conterminous United States, but were within the baseline range.

All concentrations of nickel analyzed from bottom sediments were equal to or larger than the geometric mean (15 μg/g) for soil samples of the western conterminous United States. The largest nickel concentration of 130 μg/g was sampled at site 25 (seep near Benton Lake). The nickel concentration in water from site 25 also was extremely large (7,000 μg/L).

Like nickel, the largest concentration of selenium in sediment (6.7 μg/g) was at site 25. Site 20 (Priest Butte Lakes) and site 22 (Lake Creek at mouth) had concentrations of 3.9 μg/g and 2.3 μg/g, respectively. Selenium in five samples collected from the bottom of Benton Lake had a range of 0.3 to 0.9 μg/g, which is comparable to selenium in stream sediment from the Sun River (site 9) and Muddy Creek (sites 4, 7). Soil samples identified in table 7 have a geometric mean concentration for selenium of 0.23 μg/g and a baseline range of 0.039 to 1.4 μg/g.

The large selenium concentrations in sediments from the seep near Benton Lake (site 25) and the mouth of Lake Creek (site 22) generally agree with previous samples reported by the Sacramento Bee and the U.S. Fish and Wildlife Service. The Sacramento Bee reported a concentration of 7.5 μg/g from a sample collected by newspaper representatives (exact sample location was not reported). Bottom-sediment samples collected by the U.S. Fish and Wildlife Service at 10 locations throughout the refuge and analyzed by a private laboratory had selenium concentrations that ranged from less than 2.0 to 10 μg/g.

Vanadium concentrations were largest in samples collected from the bottom of Benton Lake, ranging from 180 to 210 μg/g. All were larger than the geometric mean for soils of the western conterminous United States, but smaller than the maximum for baseline data (table 7).

Zinc concentrations ranged from 55 μg/g at site 20 to 190 μg/g at site 25 (seep near Benton Lake). In comparison, soil data in table 7 indicate that zinc has a geometric mean of 55 μg/g and a baseline range of 17 to 180 μg/g.

The bottom-sediment samples collected at site 4 (Muddy Creek near Power), at site 19 (Freezeout Lake), and at site 22 (Lake Creek at mouth), in addition to being analyzed for trace elements, were analyzed for selected pesticides--Picloram; Dicamba; 2,4-D; 2,4,5-T; 2,4-DP; and Silvex. All concentrations were less than analytical detection limits.

Biota

In natural systems, no universal guidelines have been established for concentrations of trace elements in fish, lower aquatic organisms, or waterfowl that are indicative of various degrees of toxicity. Also, because of the complexity and variability in natural systems, the effects of chemicals on biota in one area are not necessarily the same as those in another area where the biota contain similar concentrations of chemicals. Consequently, information from controlled-diet studies or from other areas can be used only as reference guidelines and inferences as to whether a potentially harmful concentration appears to exist in biota in the area of study.

Because the investigation conducted on the Sun River was a screening survey, it was limited in scope and designed to obtain only a superficial insight into whether certain chemicals exist in biota at concentrations that may indicate contamination. The analytical results for trace elements in biota are tabulated in table 17 on a dry-weight basis and in table 18 on a wet-weight basis (both tables at back of the report). The results presented below are limited primarily to arsenic, boron, mercury, and selenium because of their toxicity to fish and wildlife and the potential for the chemicals to occur at large concentrations in the study area.

Consolidated site information provided an overall perspective of the magnitude and central tendency of arsenic, boron, mercury, and selenium concentrations detected in biota collected during the study (tables 8 and 9). Arsenic concentration was less than analytical detection limits or was small in all biota except plants. The largest arsenic concentration was 130 µg/g dry weight in filamentous algae from Freezeout Lake (Pond 4). Boron occurred in most biota analyzed but was present in much larger concentrations in sago pondweed, an aquatic vascular plant, than in the other organisms sampled. Mercury concentration was less than analytical detection limits in invertebrate and plant samples, and was relatively small in fish, bird livers, and bird eggs.

Table 8.--*Statistical summary of arsenic, boron, mercury, and selenium concentrations (dry weight) in biota*

[Concentrations, in micrograms per gram; LDL, less than analytical detection limits]

Biota	Number of samples	Arsenic			Boron			Mercury			Selenium		
		Minimum	Maximum	Median	Minimum	Maximum	Median	Minimum	Maximum	Median	Minimum	Maximum	Median
Fish													
Brown trout	2	LDL	LDL	LDL	13	100	56.5	0.74	0.83	78	2.5	2.5	2.5
White sucker	3	LDL	LDL	LDL	10	17	11	LDL	.48	LDL	2.2	35	3.8
Yellow perch	2	LDL	LDL	LDL	8.9	24	16.4	LDL	.27	LDL	2.4	48	25.2
Invertebrates													
Crayfish	3	1.9	2.4	2.0	55	75	57	LDL	LDL	LDL	3.0	4.0	3.2
Odonata	8	LDL	2.1	LDL	LDL	120	78	LDL	LDL	LDL	1.8	32	6.0
Hemiptera	5	LDL	.73	LDL	39	300	100	LDL	LDL	LDL	LDL	15	4.9
Plants													
Sago pondweed	6	2.7	34	14.5	230	990	520	LDL	LDL	LDL	.62	2.0	.68
Filamentous algae	3	10	130	29	190	260	230	LDL	LDL	LDL	LDL	2.1	LDL
Bird livers													
Eared grebe	4	LDL	LDL	LDL	LDL	78	LDL	LDL	7.6	.22	36	46	41
Avocet	3	LDL	<.19	LDL	29	79	31	LDL	1.0	.52	2.3	32	28
Coot	8	LDL	.56	.31	15	97	46	LDL	1.1	.28	6.4	28	18
Bird eggs													
Eared grebe	4	LDL	LDL	LDL	LDL	19	13.5	LDL	.62	.34	8.9	18	12.2
Avocet	8	LDL	LDL	LDL	9.2	38	17.5	.23	1.0	.65	2.1	68	5.0
Coot	8	LDL	.26	LDL	LDL	35	10.3	LDL	.65	.26	LDL	7.8	3.9

Table 9.--*Statistical summary of arsenic, boron, mercury, and selenium concentrations (wet weight) in biota*

[Concentrations, in micrograms per gram; LDL, less than analytical detection limits]

Biota	Number of samples	Arsenic Minimum	Arsenic Maximum	Arsenic Median	Boron Minimum	Boron Maximum	Boron Median	Mercury Minimum	Mercury Maximum	Mercury Median	Selenium Minimum	Selenium Maximum	Selenium Median
Fish													
Brown trout	2	LDL	LDL	LDL	3.4	27	15.2	0.20	0.22	0.21	0.65	0.65	0.65
White sucker	3	LDL	LDL	LDL	2.6	4.2	3.1	LDL	.12	LDL	.54	10	.94
Yellow perch	2	LDL	LDL	LDL	2.3	6.5	4.4	LDL	.073	LDL	.65	13	7.82
Invertebrates													
Crayfish	3	0.17	.24	0.17	4.0	7.0	6.5	LDL	LDL	LDL	.27	.39	.28
Odonata	8	LDL	0.092	LDL	LDL	6.1	2.9	LDL	LDL	LDL	.062	.51	.14
Hemiptera	5	LDL	.06	LDL	2.5	6.8	5.9	LDL	LDL	LDL	LDL	1.3	.22
Plants													
Sago pondweed	6	.31	4.1	1.8	23	160	52	LDL	LDL	LDL	.055	.31	.095
Filamentous algae	3	.69	7.6	1.1	9.5	15	11	LDL	LDL	LDL	LDL	.14	LDL
Bird livers													
Eared grebe	4	LDL	LDL	LDL	LDL	26	LDL	LDL	2.5	.059	8.8	13	11
Avocet	3	LDL	LDL	LDL	7.6	19	7.6	LDL	.27	.13	.60	7.8	6.9
Coot	8	LDL	.13	.078	3.8	23	8.0	LDL	.27	.070	1.4	6.4	4.3
Bird eggs													
Eared grebe	4	LDL	LDL	LDL	LDL	3.9	2.8	LDL	.12	.072	1.8	3.9	2.4
Avocet	8	LDL	LDL	LDL	2.5	9.9	4.3	.051	.25	.17	.5	18	1.2
Coot	8	LDL	.068	LDL	LDL	8.1	2.4	LDL	.16	.060	LDL	1.8	1.0

Selenium was detected in all organisms. The largest concentrations generally were in whole-body fish and bird livers.

Fish

Whole-body fish were collected at three sites along the Sun River, at Priest Butte Lakes, at Freezeout Lake, and at Benton Lake National Wildlife Refuge (fig. 4). Along the Sun River, site 8 is just downstream from the Fort Shaw Diversion Dam, site 9 is about 2 river miles upstream from the mouth of Muddy Creek, and site 10 is about 3 river miles downstream from the mouth of Muddy Creek. The sites were selected to bracket the Fort Shaw Irrigation District and to demonstrate any obvious changes in trace-element concentrations in biota downstream from Muddy Creek. The goal to achieve consistency in the predatory and bottom-feeding fish species collected from site to site, however, could not be attained, owing to the variation in habitat conditions and availability of fish. Arsenic, boron, mercury, and selenium concentrations in fish are listed in table 10.

Arsenic

Arsenic concentration was detectable only in the forage-fish sample from site 26 (Benton Lake). However, the 0.088 μg/g wet weight in the forage-fish sample is substantially less than the 2.24 μg/g wet weight measured in whole-body immature bluegills that had poor growth and survival (Gilderhus, 1966). In that same study,

Table 10.--*Arsenic, boron, mercury, and selenium concentrations in whole-body fish*

[Concentrations, in micrograms per gram; LDL, less than analytical detection limits]

Site No. (figs. 4-6)	Biota	Arsenic		Boron		Mercury		Selenium	
		Dry weight	Wet weight	Dry weight	Wet weight	Dry weight	Wet weight	Dry weight	Wet weight
				Sun River					
8	Brown trout (mature)	LDL	LDL	13	3.4	0.83	0.22	2.5	0.65
9	Brown trout (mature)	LDL	LDL	100	27	.74	.20	2.5	.65
9	Carp (mature)	LDL	LDL	15	3.7	.67	.16	2.5	.60
10	White sucker (mature)	LDL	LDL	10	2.6	.48	.12	2.2	.54
10	Yellow perch (mature)	LDL	LDL	24	6.5	.27	.073	2.4	.65
				Priest Butte Lakes					
20	White sucker (mature)	LDL	LDL	11	3.1	LDL	LDL	35	10
20	Yellow perch (mature)	LDL	LDL	8.9	2.3	LDL	LDL	48	13
				Freezeout Lake (Pond 4)					
21a	White sucker (mature)	LDL	LDL	17	4.2	LDL	LDL	3.8	.94
				Benton Lake National Wildlife Refuge					
26	Forage fish	1.5	0.088	LDL	LDL	LDL	LDL	4.9	.29

arsenic residues of about 5.0 μg/g wet weight in adult bluegills were associated with severe weight loss and mortality. However, the growth rates were less when arsenic residues in flesh were between 1.0 and 3.0 μg/g wet weight. Juvenile rainbow trout fed a diet containing 30 μg/g arsenic (dry weight) as sodium arsenite had a substantial decrease in weight gain, had muscle residues of 1.52 μg/g dry weight, and had liver residues of 5.21 μg/g dry weight (Oladimeji and others, 1984). Although different species of fish were used in the controlled studies referenced, it appears that an arsenic concentration in whole-body fish, in general, would need to be about 2.0 to 3.0 μg/g dry weight to induce some form of arsenic-related problem. The maximum asymptotic concentration considered indicative of contaminated water is 0.4 μg/g arsenic wet weight (Moore and Ramamoorthy, 1984). The arsenic concentration in sampled forage fish was considerably less than the arsenic concentration in diet studies that caused problems in fish and less than the concentration indicative of contaminated conditions.

Boron

Boron concentration was less than the analytical detection limit in forage fish from Benton Lake but was detected in all other fish samples. The 100-μg/g dry weight boron concentration in brown trout from site 9 (Sun River) appears to be relatively large compared to the other fish samples. This sample contained fish that were larger than other samples; whether fish size is a factor in the larger boron concentration is unknown.

Also unknown is the significance, if any, of the boron concentrations measured. However, large boron concentrations in water can cause mortality in fish. Juvenile coho salmon exposed to 113,000 μg/L sodium metaborate in freshwater for 283 hours experienced 50 percent mortality (Thompson and others, 1976). Whole-body boron residues in these fish ranged from 224 to 354 μg/g, which is substantially larger than that measured in this investigation. Fifty-percent mortality of rainbow-trout larvae occurred in water with a boron concentration of 27,000 μg/L and a hardness of 49 μg/g, and in water with a boron concentration of 54,000 μg/L and a hardness of 191 μg/g (Birge and Black, 1977).

Mercury

Mercury was detectable only in fish samples from the Sun River. The concentration of mercury in fish from the Sun River is consistent with that measured in fish in several reservoirs in the Missouri River basin. Mercury in whole-body walleye from Oahe Reservoir ranged from 0.19 to 1.70 μg/g wet weight, but in all fish except one, mercury was less than 0.34 μg/g wet weight (U.S. Fish and Wildlife Service, 1985). Phillips and others (1987) measured similar concentrations (less than 0.25 μg/g wet weight) in the muscle of walleye less than about 14 inches in length in several reservoirs in the Missouri River basin. However, mercury concentration in walleye from some reservoirs was less than 0.25 μg/g wet weight for fish longer than about 20 inches.

Selenium

Selenium was detected in all fish samples, ranging in concentration from 2.2 μg/g dry weight in white suckers from the Sun River to 48 μg/g dry weight in yellow perch from Priest Butte Lakes. The data indicate that fish from the Sun River had smaller selenium concentrations than did those from the other sites.

The selenium concentrations in white sucker (35 μg/g dry weight; 10 μg/g wet weight) and in yellow perch (48 μg/g dry weight; 13 μg/g wet weight) from Priest Butte Lakes are larger than that (2 μg/g wet weight) reported by Baumann and May (1984), as possibly having toxic effects on fish. The concentrations also exceed the selenium concentration in adult bluegills (about 6.7 to 9.7 μg/g wet weight) that was associated with a decrease of adult and larval fish in a reservoir in the southeastern United States (Carolina Power and Light, as cited by Gillespie and Baumann, 1986). In a study of whole-body selenium concentration in young carp, Sato and others (1980) reported that fish cultured in water containing 10 μg/g selenium began to die after 7 days and that the selenium concentration of dead fish generally was larger than 10 µg/g wet weight. The selenium concentrations in white sucker and yellow perch from Priest Butte Lakes equal or exceed this concentration.

Although the selenium concentrations are large in several species of fish from Priest Butte Lakes, they are not as large as those measured in carp and white sucker from Sweitzer Lake, Colo., which contained selenium concentrations of 15.8 µg/g wet weight and 19 µg/g wet weight in skeletal muscle, respectively (Birkner, 1978). Fish reproduction and mortality are problems in Sweitzer Lake.

Other Trace Elements

Lead in fish was detected only in brown trout at site 9 (Sun River-Fort Shaw Diversion Dam). The maximum concentrations of barium, copper, molybdenum, vanadium, and zinc in fish were measured in the sample from the Sun River. The remaining trace elements analyzed had maximum concentrations in one of the fish samples from either sites 20, 21a, or 26. Beryllium, cadmium, and tin concentrations in fish were less than the analytical detection limits at all sites.

Pesticides

Except for the carp sample from site 9 (Sun River-Fort Shaw Diversion Dam), which contained a PCB-1248 concentration of 2.0 µg/g wet weight, the organochlorine residues detected in fish were limited to p,p'-DDT, p,p'-DDE, and p,p'-DDD (table 19 at back of the report). The p,p'-DDT concentrations were 0.25 µg/g wet weight in brown trout (site 9), 0.027 µg/g wet weight in white sucker (site 10), and 0.021 µg/g wet weight in yellow perch (site 10). Similar concentrations of p,p'-DDT were measured in fish from sites 20 and 26. At site 9, the p,p'-DDE concentration was 0.022 µg/g wet weight in brown trout and 0.025 µg/g wet weight in carp. The p,p'-DDD concentrations were 0.011 µg/g wet weight in brown trout (site 9) and yellow perch (site 10), and 0.017 µg/g wet weight in carp (site 9). No concentrations of organochlorine residues exceeded the analytical detection limits in fish at site 21a.

Invertebrates

Invertebrate samples collected consisted of crayfish, Odonata, Hemiptera, and chironomids. Arsenic, boron, mercury, and selenium concentrations in invertebrates are listed in table 11.

Arsenic

The range of arsenic concentrations in invertebrates measured during this investigation was rather small (from less than the analytical detection limit to 2.4 µg/g dry weight), considering the different areas and groups of organisms collected. Apparently, in most invertebrate species, there is no evidence of extreme bioaccumulation of arsenic (Moore and Ramamoorthy, 1984).

Brown trout collected at the two upstream sites along the Sun River would be expected to consume some crayfish. Crayfish contained detectable concentrations

Table 11.--*Arsenic, boron, mercury, and selenium concentrations in invertebrates*

[Concentrations, in micrograms per gram; LDL, less than analytical detection limits]

Site No. (figs. 4-6)	Biota	Arsenic		Boron		Mercury		Selenium	
		Dry weight	Wet weight	Dry weight	Wet weight	Dry weight	Wet weight	Dry weight	Wet weight
				Sun River					
8	Crayfish	2.4	0.17	57	4.0	LDL	LDL	4.0	0.28
9	Crayfish	1.9	.24	55	7.0	LDL	LDL	3.0	.39
10	Crayfish	2.0	.17	75	6.5	LDL	LDL	3.2	.27
				Priest Butte Lakes					
20	Odonata	LDL	LDL	LDL	LDL	LDL	LDL	32	.51
20	Hemiptera	.73	.060	65	5.3	LDL	LDL	15	1.3
				Freezeout Lake (Pond 4)					
21a	Odonata	LDL	LDL	120	2.4	LDL	LDL	9.8	.19
21a	Hemiptera	LDL	LDL	150	6.8	LDL	LDL	4.9	.22
				Benton Lake National Wildlife Refuge					
22	Odonata	LDL	LDL	95	3.7	LDL	LDL	9.2	.36
22	Hemiptera	.68	.045	100	6.8	LDL	LDL	6.3	.42
25	Chironomids (larvae)	LDL	LDL	120	2.9	LDL	LDL	12	.29
26	Odonata	LDL	LDL	LDL	LDL	LDL	LDL	9.1	.14
26	Hemiptera	LDL	LDL	39	2.5	LDL	LDL	3.2	.20
27	Odonata	1.0	.054	62	3.2	LDL	LDL	2.9	.15
28	Odonata	1.4	.084	45	2.7	LDL	LDL	2.0	.12
28	Hemiptera	LDL	LDL	300	5.9	LDL	LDL	LDL	LDL
30	Odonata	1.7	.092	110	6.1	LDL	LDL	1.8	.098
31	Odonata	2.1	.068	94	3.1	LDL	LDL	1.9	.062

of arsenic, but no arsenic was detectable in the fish. Likewise, fish from Priest Butte Lakes and Freezeout Lake had no detectable concentrations of arsenic, even though some potential diet items in these areas contained arsenic.

Invertebrates are important diet items to many species of migratory birds. However, it is unlikely that the arsenic concentrations measured in invertebrates from Priest Butte Lakes, Freezeout Lake, and Benton Lake are large enough to pose a significant problem to consumer organisms, particularly if the diet is mixed.

A rather large concentration of arsenic is required to induce mortality of mallards. Arsenic in the diet of mallard ducks at concentrations of 500 μg/g dry weight and 1,000 μg/g dry weight was required to cause 50-percent mortality in 32 days and 6 days, respectively (U.S. Department of the Interior, 1963). Day-old mallards fed 30 μg/g dry weight as sodium arsenate had lighter body weights than control birds at 2 and 5 weeks of age (Patuxent Wildlife Research Center, 1987).

Boron

The boron concentration in the invertebrates is larger than expected, but the significance of the concentration is unknown. At Kesterson National Wildlife Refuge, where boron is a concern, aquatic insects contained boron concentrations ranging from 36 to 54 μg/g dry weight (Ohlendorf and others, 1986). The larger concentration (54 μg/g dry weight) was exceeded in invertebrates at all sites except at site 26, in this investigation.

Mercury

Mercury was not detectable in any of the invertebrate samples. This also was true with other potential diet items (plants) analyzed in the investigation.

Selenium

Selenium exceeded the analytical detection limit in invertebrates at all sampling sites. The significance of the selenium concentrations in invertebrates is unknown. However, mallards fed a diet containing selenium at a concentration of 8 μg/g dry weight had decreased duckling survivial and teratogenic effects (Patuxent Wildlife Research Center, 1987). The selenium concentration in odonates from sites 20, 21a, 22, and 26; in hemipterans from site 20; and in chironomid larvae from site 25 exceeded this diet concentration. Heinz and others (1987) reported that in birds fed a diet containing 10 μg/g selenium dry weight, 18 percent more abnormal embryos were observed than for control birds. Survival of ducklings also was substantially less. At sites 20 and 25, the selenium concentration in invertebrates exceeded 10 μg/g dry weight.

Although selenium concentrations in invertebrates from several sites exceeded those having toxic effects in several diet studies, most birds using the lakes are unlikely to limit their diet solely to invertebrates for any extended time. However, eared grebes and black-necked stilts were two species at Kesterson National Wildlife Refuge that experienced some embryonic mortality; their diet contained only aquatic insects (Ohlendorf and others, 1986).

American coots are common on Benton Lake. Jones (1940) reported adult diets to consist of about 10 percent animal matter, primarily odonates, hemipterans, and coleopterans. However, he determined that animal food comprised nearly one-half of the juvenile diet. For juveniles, hemipterans and coleopterans were the dominant invertebrates eaten. During the first few weeks, coot chicks are fed aquatic invertebrates (Frederickson, 1977). Odonates, dipterans, coleopterans, and hemipterans comprised 21 percent of the juvenile coot diets in southeastern Washington (Fitzner and others, 1980). Fitzner and others (1980) also reported that sago pondweed and filamentous algae occurred at a 20-percent and an 18-percent frequency in juvenile coot diets, respectively. Considering the potential diet composition of juvenile coots reported in the literature and the concentrations measured in potential diet items at Benton Lake, selenium in the diet of juvenile coots at Benton Lake would likely be less than concentrations creating selenium toxicity in controlled-diet studies.

Other Trace Elements

For crayfish samples from the Sun River (sites 8-10), concentrations of all trace elements analyzed except for aluminum, barium, iron, and nickel were smallest at site 9 (downstream from Fort Shaw Division). Concentrations of aluminum, cadmium, chromium, copper, iron, and strontium in crayfish were largest downstream from Muddy Creek (site 10). Barium, nickel, and zinc concentrations in crayfish were largest at the most upstream site (site 8). Cadmium was detected in three samples from the study area; the largest concentration was 2.3 μg/g (dry weight) in crayfish at site 10 (downstream from Muddy Creek).

The largest trace-element concentrations in invertebrates from the entire study area, except for strontium, were measured in samples collected from the Benton Lake National Wildlife Refuge; the strontium concentration in crayfish at site 10 (Sun River) was 39 μg/g. Although it might have been expected from the refuge samples that concentrations would be largest at the mouth of Lake Creek (site 22), this was true only for copper.

Plants

Plants were not collected from the Sun River. For the other sites, arsenic, boron, mercury, and selenium concentrations in plants are listed in table 12.

Arsenic

In this investigation, arsenic concentrations were largest in plants. The range of arsenic concentrations in plants (2.7 to 130 μg/g dry weight), however, was considerably less than that in macrophytes (150 to 3,700 μg/g dry weight) inhabiting lakes in Canada containing mine wastes (Wagemann and others, 1978).

A rather large concentration of arsenic is required to induce mortality of mallards. Arsenic in the diet of mallard ducks at concentrations of 500 μg/g dry weight and 1,000 μg/g dry weight was required to cause 50-percent mortality in 32 days and 6 days, respectively (U.S. Department of the Interior, 1963). Day-old mallards fed 30 μg/g arsenic dry weight as sodium arsenate had lighter body weights than control birds at 2 and 5 weeks of age (Patuxent Wildlife Research Center, 1987). The arsenic concentration (29 μg/g dry weight) in sago pondweed and filamentous algae from site 26 almost equals the 30-μg/g dry weight concentration, and the arsenic concentration of 130 μg/g dry weight in filamentous algae from site 21a considerably exceeds this concentration.

Table 12.--*Arsenic, boron, mercury, and selenium concentrations in plants*

[Concentrations, in micrograms per gram; LDL, less than analytical detection limits]

Site No. (figs. 5 and 6)	Biota	Arsenic Dry weight	Arsenic Wet weight	Boron Dry weight	Boron Wet weight	Mercury Dry weight	Mercury Wet weight	Selenium Dry weight	Selenium Wet weight
				Priest Butte Lakes					
20	Sago pondweed	2.7	0.43	990	160	LDL	LDL	2.0	0.31
				Freezeout Lake (Pond 4)					
21a	Sago pondweed	34	3.0	590	52	LDL	LDL	.63	.055
21a	Filamentous algae	130	7.6	190	11	LDL	LDL	LDL	LDL
				Benton Lake National Wildlife Refuge					
22	Sago pondweed	11	1.1	230	23	LDL	LDL	1.6	.17
22	Filamentous algae	10	.69	230	15	LDL	LDL	2.1	.14
26	Sago pondweed	29	4.1	820	120	LDL	LDL	.66	.093
26	Filamentous algae	29	1.1	260	9.5	LDL	LDL	LDL	LDL
27	Sago pondweed	2.7	.31	450	52	LDL	LDL	.62	.073
28	Sago pondweed	18	2.5	370	50	LDL	LDL	.71	.097

Boron

Like arsenic, the largest concentrations of boron were in plants. Boron concentrations ranged from 190 µg/g dry weight in filamentous algae at site 21a to 990 µg/g dry weight in sago pondweed at site 20.

The significance of boron ingestion on bird reproduction is largely unknown. Boron compounds introduced into bird diets have been determined, however, to cause reproductive problems in mallards. Sago-pondweed samples from sites 20, 21a, 26, 27, and 28 all contained boron concentrations that were between two diet concentrations--300 µg/g, which did not produce significant reproductive effects, and 1,000 µg/g, which lessened hatching success and produced fewer 21-day-old ducklings (Patuxent Wildlife Research Center, 1987). Because the concentration at which results change from nonsignificant to significant has not been defined, the significance, if any, of boron concentrations in plants remains unclear. However, the boron concentrations in sago pondweed at both sites 20 and 26 are only slightly less than the larger concentration. Boron is of concern at Kesterson National Wildlife Refuge because of the concentrations in plants, aquatic insects, and fish.

Boron measured in rooted plants at Kesterson ranged from 270 to 510 µg/g dry weight (Ohlendorf and others, 1986).

Mercury

Mercury was not detected in any of the sago-pondweed or filamentous-algae samples. Accordingly, plants do not appear to be a significant source of mercury.

Selenium

Selenium concentrations in plants were small--2.1 µg/g or less dry weight. This concentration is considerably less than the 8 µg/g selenium dry weight diet that resulted in decreased mallard duckling survival and teratogenic effects (Patuxent Wildlife Research Center, 1987).

Other Trace Elements

Concentrations of copper and molybdenum in sago pondweed were largest at site 21a. Concentrations of aluminum, barium, strontium, vanadium, and zinc in sago pondweed were larger at the mouth of Lake Creek (site 22) than at all other sites. The concentrations of the other trace elements in sago pondweed were largest at sites 26 and 28.

Bird Livers

Livers were obtained from young-of-the-year birds collected from site 21a at Freezeout Lake (Pond 4) and sites 22 and 28 on Benton Lake National Wildlife Refuge. Arsenic, boron, mercury, and selenium concentrations in bird livers are listed in table 13.

Arsenic

Arsenic was not detected in the livers of eared grebes and an avocet from site 21a. Arsenic in avocet livers from sites 22 and 28 also was less than the analytical detection limit, which is consistent with the results from site 21a. Arsenic in one coot liver obtained from site 22 was less than the analytical detection limit. However, arsenic was detectable in all remaining coot livers, ranging from 0.25 µg/g dry weight (0.050 µg/g wet weight) to 0.34 µg/g dry weight (0.089 µg/g wet weight) at site 22, and from 0.25 µg/g dry weight (0.058 µg/g wet weight) to 0.56 µg/g dry weight (0.13 µg/g wet weight) at site 28. Although the sample size is small, there appears to be little difference, if any, between sites 22 and 28. However, both invertebrates and sago pondweed from the two sites had detectable concentrations of arsenic.

Although sago pondweed and filamentous algae from Freezeout Lake (Pond 4) had large concentrations of arsenic, arsenic in invertebrates at the same site was not detectable. Arsenic in eared-grebe and avocet livers also was less than the analytical detection limit at the site. Eared grebes may have been feeding exclusively on invertebrates, which may explain, in part, the difference in the arsenic concentrations in livers of eared grebes and coots between areas.

Table 13.--*Arsenic, boron, mercury, and selenium concentrations in bird livers*

[Concentrations, in micrograms per gram; LDL, less than analytical detection limits]

Site No. (figs. and 5 6)	Biota	Arsenic Dry weight	Arsenic Wet weight	Boron Dry weight	Boron Wet weight	Mercury Dry weight	Mercury Wet weight	Selenium Dry weight	Selenium Wet weight
				Freezeout Lake (Pond 4)					
21a	Eared grebe	LDL	LDL	LDL	LDL	0.22	0.054	36	8.8
21a	Eared grebe	LDL	LDL	33	7.9	LDL	LDL	46	11
21a	Eared grebe	LDL	LDL	LDL	LDL	.23	.059	43	11
21a	Eared grebe	LDL	LDL	78	26	7.6	2.5	39	13
21a	Avocet	LDL	LDL	31	7.6	LDL	LDL	28	6.9
				Benton Lake National Wildlife Refuge					
22	Coot	0.34	0.089	15	3.8	.24	.061	22	5.7
22	Coot	LDL	LDL	19	4.4	.42	.098	20	4.7
22	Coot	.25	.050	41	8.4	LDL	LDL	25	5.2
22	Coot	.28	.072	73	19	.31	.079	16	3.9
22	Avocet	LDL	LDL	79	19	.52	.13	32	7.8
28	Coot	.56	.13	33	7.5	LDL	LDL	16	3.7
28	Coot	.25	.058	51	12	1.1	.27	6.4	1.5
28	Coot	.39	.085	74	16	.85	.19	6.4	1.4
28	Coot	.48	.11	97	23	LDL	LDL	28	6.4
28	Avocet	LDL	LDL	29	7.6	1.0	.27	2.3	.60

There is little information in the literature about arsenic concentrations in bird tissue that are indicative of physiological effect. However, rather large concentrations appear to be required to cause mortality. Livers from two cowbirds that died after being fed a diet containing 22 μg/g copper aceto-arsenite contained 38 and 43 μg/g arsenic dry weight (Wiemeyer and others, 1980). Based on this limited information, and the different species, the significance of the arsenic concentrations measured in coot livers is unclear. However, the concentrations appear to be small and probably are insignificant.

Boron

Boron concentrations in eared-grebe livers from site 21a were variable, ranging from less than the analytical detection limit to 78 μg/g dry weight. Although the sample size is small, the limited results indicate that, within the same species, individuals may have different diet preferences or that perhaps some other factor, such as sex, age, or size, affected intraspecific differences that were apparent for eared grebes.

Boron concentrations in avocet livers from sites 21a, 22, and 28 ranged from 29 μg/g dry weight at site 28 to 79 μg/g dry weight at site 22. The concentration in avocet liver from site 21a (31 μg/g dry weight) was similar to that from site 28.

Boron concentrations ranged from 15 to 73 μg/g dry weight in coot livers from site 22 and from 33 to 97 μg/g dry weight in coot livers from site 28. Invertebrates and plants from both sites contained boron. Concentrations of boron in livers from site 28 appear to be slightly larger overall than those from site 22. However, because of the small sample size and variability of the data, no conclusion regarding differences between the sites can be made.

Boron concentrations in two of the eared-grebe livers from site 21a, two of the coot livers from site 22, and all coot livers from site 28 are within or exceed the range of 23 to 89 μg/g dry weight wherein mallard ducklings had smaller weight gain and decreased survival (Patuxent Wildlife Research Center, 1987). Whether the concentrations measured in mallard-duckling livers would indicate comparable problems in juvenile eared grebes and juvenile coots containing similar concentrations of boron in liver is unknown. Boron in the avocet liver from site 22 (79 μg/g dry weight) was slightly less than the maximum concentratration cited above (89 μg/g dry weight) and the avocet livers from sites 21a and 28 (31 and 29 μg/g dry weight) were slightly more than the minimum concentration (23 μg/g dry weight).

Mercury

Mercury concentrations in bird livers were variable, ranging from less than the analytical detection limit to 7.6 μg/g dry weight (2.5 μg/g wet weight). The latter concentration is considerably larger than the next largest concentration (1.1 μg/g dry weight; 0.27 μg/g wet weight). However, even this maximum concentration appears to be less than concentrations considered to be hazardous. Finley and Stendell (1978) concluded that mercury concentrations in excess of 20 μg/g wet weight in soft tissues should be considered extremely hazardous to passerine birds. The 2.5-μg/g wet weight concentration in the eared-grebe liver also is much less than mercury concentrations (10.23 to 14.46 μg/g wet weight) measured in livers of dead black ducklings that were the offspring of breeding birds fed 3 μg/g methylmercury and maintained on a mash diet containing 3 μg/g mercury (Finley and Stendell, 1978).

Selenium

Selenium was detected in all bird livers. The selenium concentration in eared-grebe livers ranged from 36 to 46 μg/g dry weight, in avocet livers from 2.3 to 32 μg/g dry weight, and in coot livers from 6.4 to 28 μg/g dry weight. Twelve of the 15 livers had selenium concentrations (3.7 to 13 μg/g wet weight) within the range of selenium concentrations measured in livers of mallards (2.6 to 4.0 μg/g wet weight in females and 4.6 to 19 μg/g in males) that had reproductive problems associated with a diet containing 8 μg/g dry weight selenium (Patuxent Wildlife Research Center, 1987). Mallards fed 10 μg/g selenium also produced significantly more abnormal embryos (18.3 percent) than control birds. Livers from affected birds in the experimental study had selenium concentrations ranging from 2.6 to 6.2 μg/g wet weight in females and from 6.1 to 12.0 μg/g wet weight in males (Heinz and others, 1987).

Compared to livers of young-of-the-year coots from Benton Lake (sites 22 and 28), the selenium concentrations in eared-grebe livers from site 21a are larger. This comparison, however, is based on different species, and interspecific differences in uptake of selenium through the diet may be significant.

The concentration of selenium in bird livers in nonselenium-contaminated areas generally is less than 12 to 16 µg/g dry weight, as cited by Ohlendorf and others (1986). If this concentration range also applies to Montana, the data from this investigation would indicate that sites 21a, 22, and 28 perhaps are contaminated with selenium.

Other Trace Elements

Four trace elements only were detected in livers from 1 of the 3 sites: barium was detected in one coot liver from site 22 (1.7 µg/g dry weight), cadmium was detected at site 21a in an eared-grebe liver (1.4 µg/g dry weight), lead was detected in two livers from site 22 (maximum 7.1 µg/g dry weight), and vanadium was detected in an avocet liver at site 21a (0.67 µg/g dry weight). Maximum concentrations (dry weight) of manganese (70 µg/g), molybdenum (13 µg/g), and strontium (2.6 µg/g) were measured in livers from site 21a. Maximum concentrations (dry weight) of aluminum (130 µg/g), chromium (23 µg/g), copper (86 µg/g), nickel (6.3 µg/g), and zinc (250 µg/g) were measured in livers from site 28.

Bird Eggs

Eggs were collected only at sites 21a, 22, 25, 28, and 29. Arsenic, boron, mercury, and selenium concentrations in the eggs are listed in table 14.

Arsenic

Arsenic concentrations larger than the analytical detection limit were detected in 3 of the 20 eggs analyzed. Even in the three eggs, the concentrations were small relative to toxicity data and would not appear to be harmful.

Boron

Boron concentrations in bird eggs varied considerably, ranging from less than the analytical detection limit to 38 µg/g dry weight. Boron in eared-grebe eggs in the study area was about one-half the concentration measured in mallard eggs (26 to 31 µg/g dry weight), which resulted in a substantially lesser hatching success rate and produced fewer 21-day-old ducklings (Patuxent Wildlife Research Center, 1987). However, one avocet egg (site 21a) and one coot egg (site 22) had boron concentrations that exceeded those affecting mallard eggs. Whether similar effects in avocets and coots would occur at the same concentrations that caused toxicity in mallard eggs is unknown.

Table 14.--*Arsenic, boron, mercury, and selenium concentrations in bird eggs*

[Concentrations, in micrograms per gram; LDL, less than analytical detection limits; ND, not determined]

Site No. (figs. 5 and 6)	Biota	Arsenic		Boron		Mercury		Selenium	
		Dry weight	Wet weight	Dry weight	Wet weight	Dry weight	Wet weight	Dry weight	Wet weight
				Freezeout Lake (Pond 4)					
21a	Eared grebe	LDL	LDL	17	3.4	LDL	LDL	8.9	1.8
21a	Eared grebe	LDL	LDL	10	2.1	0.27	0.058	18	3.9
21a	Eared grebe	LDL	LDL	LDL	LDL	.62	.12	15	2.9
21a	Eared grebe	LDL	LDL	19	3.9	.41	.085	9.5	1.9
21a	Avocet	LDL	LDL	9.2	2.5	.78	.21	2.6	.69
21a	Avocet	LDL	LDL	38	9.9	.85	.22	2.8	.73
21a	Avocet	LDL	LDL	ND	ND	.23	.051	4.9	1.1
				Benton Lake National Wildlife Refuge					
22	Coot	LDL	LDL	18	4.3	.19	.044	7.8	1.8
22	Coot	0.25	0.057	35	8.1	.36	.085	5.4	1.3
22	Coot	.25	.068	LDL	LDL	LDL	LDL	4.2	1.1
22	Coot	LDL	LDL	12	2.7	.26	.060	5.2	1.2
22	Avocet	LDL	LDL	14	3.7	.32	.083	4.9	1.3
22	Avocet	LDL	LDL	10	2.5	1.0	.25	7.3	1.8
25	Avocet	LDL	LDL	ND	ND	.52	.13	68	18
28	Coot	.26	.063	9.6	2.3	.25	.060	3.6	.88
28	Coot	LDL	LDL	LDL	LDL	.17	.052	1.0	.31
28	Coot	LDL	LDL	LDL	LDL	.65	.16	1.4	.34
28	Coot	LDL	LDL	11	2.5	.33	.075	LDL	LDL
28	Avocet	LDL	LDL	21	4.9	.86	.20	2.1	.50
29	Avocet	LDL	LDL	21	6.1	.26	.075	5.1	1.5

Mercury

Mercury exceeded the analytical detection limit in all eggs except two. The maximum mercury concentration in the three types of eggs was 0.62 µg/g dry weight (0.12 µg/g wet weight) in an eared-grebe egg from site 21a, 1.0 µg/g dry weight (0.25 µg/g wet weight) in an avocet egg from site 22, and 0.65 µg/g dry weight (0.16 µg/g wet weight) in a coot egg from site 28. These concentrations are considerably less than the mercury concentration (average of 6.14 µg/g mercury wet weight) in black-duck eggs wherein hatching success was decreased (Finley and Stendell, 1978). Mallard hens fed a diet containing 0.5 µg/g mercury produced eggs with a mercury concentration of 1 µg/g wet weight (Heinz, 1975). In the wild, mallard eggs have contained mercury in excess of 1 µg/g wet weight (Heinz, 1975). Mercury concentrations measured in eggs during this investigation are probably within a normally expected range.

Selenium

Selenium was detected in all but one (coot egg from site 28) of the eggs analyzed. Bird eggs from nonselenium-contaminated areas generally are less than 3 to 4 µg/g dry weight (Ohlendorf and others, 1986). The eared-grebe eggs and one of the avocet eggs from site 21a, all coot and avocet eggs from site 22, and the avocet eggs from sites 25 and 29 contained selenium in excess of 4.0 µg/g dry weight. The largest selenium concentration measured in the bird eggs (68 µg/g dry weight), which was about four times the next largest concentration, was in an avocet egg from site 25. However, this egg was a single specimen that evidently had been randomly dropped because no evidence of nests, nest depressions (scoops), or other eggs was observed within the saline-seep area. The egg specimen was analyzed only because of the location of its occurrence. It is unknown whether the female was actively feeding in the area for an extended time, was just moving through the area, or was establishing a nesting site that was not found. Based on the results from samples of other avocet eggs, the selenium concentration measured in this egg could be anomalous owing to some unknown factor.

Eggs produced by mallards fed a diet containing 8 µg/g selenium contained concentrations ranging from 4.9 to 14 µg/g wet weight. In that study, duckling survival was decreased, and teratogenic effects were observed (Patuxent Wildlife Research Center, 1987). Except for the avocet egg from site 25, all eggs in this study contained less than 4.9 µg/g wet weight. However, in another study, the eggs contained selenium concentrations of 2.9 to 5.6 µg/g wet weight and there was a greater incidence of abnormal embryos, and mallard-duckling survivial was decreased (Heinz and others, 1987). Two eared-grebe eggs from site 21a in this study had a selenium concentration that equaled or exceeded the smallest concentration of that range.

Other Trace Elements

Maximum concentrations (dry weight) of chromium (3.6 µg/g), vanadium (7.6 µg/g), and zinc (68 µg/g) were measured in eggs from site 22. Except for barium, maximum concentrations for all other trace elements were measured in eggs from site 21a. Lead was measured in only one eared-grebe egg from site 21a. Beryllium and cadmium were not detected in any eggs.

Pesticides

Egg samples from site 21a (three eared grebe and one avocet), site 22 (three coot and one avocet), and site 28 (three coot and one avocet) were analyzed for organochlorine-pesticide residues (tables 20 and 21 at back of the report). Concentrations of p,p'-DDT in avocet eggs from all three sites were somewhat larger than in eared-grebe or coot eggs. The maximum concentration measured for each species was 0.041 µg/g wet weight in one of the three eared-grebe eggs at site 21a, 0.096 µg/g in the avocet egg from site 22, and 0.034 µg/g in one of the three coot eggs from site 28. Concentrations in three of the coot eggs were less than the analytical detection limit.

All eggs had detectable concentrations of p,p'-DDE. Concentrations in avocet eggs ranged from 0.82 µg/g wet weight at site 21a to 5.7 µg/g wet weight at site 22. Eared-grebe and coot eggs had much smaller concentrations of p,p'-DDE, ranging from 0.10 μg/g wet weight in an eared-grebe egg from site 21a to 0.41 μg/g wet weight in a coot egg from site 22.

Dieldrin, endrin, and heptachlor-epoxide residues were detectable only in avocet eggs. The dieldrin concentration ranged from 0.039 μg/g wet weight (site 28) to 0.18 μg/g wet weight (site 22). Endrin was not detected in eggs from site 21a; the concentration in the avocet egg from site 22 was 0.13 μg/g wet weight and that in the avocet egg from site 28 was 0.016 μg/g wet weight. The heptachlor-epoxide concentration ranged from 0.021 μg/g wet weight at site 21a to 0.058 μg/g wet weight at site 22.

SUMMARY

During the past several years, concern by the DOI has been increasing about the quality of irrigation drainage and its potential effects on the health of humans, fish, and wildlife. The Sun River area was selected for a reconnaissance investigation because information indicated that potential problems of a toxic nature might exist. Samples of water, bottom sediment, and biota were collected from three subunits within the study area--Sun River Irrigation Project, Freezeout Lake Game Management Area, and Benton Lake National Wildlife Refuge.

Specific water-quality problems have been prevalent in the Sun River Irrigation Project, including reaches of the Sun River and Muddy Creek, for many years. However, this investigation determined most sampling sites to be free of concentrations of toxic constituents that are in excess of established criteria and standards. Water flowing into the project has dissolved-solids concentrations that generally are less than 200 mg/L and trace-element concentrations less than or slightly larger than analytical detection limits. At the downstream end of the project, streamflow is a combination of unused canal water and irrigation drainage. Analyses of the water indicated 3- to 4-fold increases in dissolved solids compared to water flowing into the project. Even with the increases, the dissolved-solids concentrations in surface-water samples did not exceed the criterion of 500 mg/L established by the State for public water supplies. Trace elements and other toxic constituents in streamflow were at concentrations considerably less than established criteria.

Both surface and ground water are used within the irrigation project for human and animal consumption and a potential exists for contamination problems. Presently, the most serious threat appears to be from nitrate in ground water. Water from some wells sampled in previous studies contained nitrate concentrations in excess of the established criterion for public water supplies (10 mg/L as nitrogen). Traces of pesticides also have been detected in the ground-water system.

Based on samples from the Sun River, arsenic, boron, mercury, and selenium concentrations in the biota (fish and invertebrates) indicated little change downstream from the irrigated lands associated with the Fort Shaw Division and downstream from Muddy Creek. All constituent concentrations measured were less than concentrations that may be indicative of causing any physiological harm.

Analyses of samples from Freezeout Lake Game Management Area and Benton Lake National Wildlife Refuge indicated concentrations of toxic constituents in water, bottom sediment, and biota that were moderately to considerably larger than established critera. Saline seeps surrounding the lakes (specifically Benton Lake) had

the largest concentrations of toxic constituents, with water and bottom sediment of the lakes having more moderate concentrations. The largest concentrations of selenium in water were 580 μg/L from seeps and 8 μg/L from a nonseep sample. These concentrations can be compared to 10 μg/L, the public-supply criterion for the State of Montana.

No hydrologic connection is apparent between water being used for irrigation and the saline seeps sampled in this investigation. However, the seeps, natural basin runoff, and irrigation return flows all contribute water and dissolved constituents to the lakes. Water from the irrigation project supplied to Freezeout Lake Game Management Area and Benton Lake National Wildlife Refuge has relatively small dissolved-solids concentrations (range of 500 to 700 mg/L) and trace-element concentrations slightly larger than concentrations measured in the source from the Sun River. Conversely, water from seeps and natural basin runoff may have dissolved-solids concentrations of several thousand milligrams per liter and trace-element concentrations considerably in excess of established criteria. To determine the relative proportions of constituents transported into the lakes by all sources, an extensive study of the water budget would be necessary.

The largest concentration of selenium in bottom sediment (6.7 μg/g) was from a seep west of Benton Lake. Samples from Priest Butte Lakes and Lake Creek at the mouth had concentrations of 3.9 and 2.3 μg/g, respectively. These concentrations can be compared to a geometric mean selenium concentrations of 0.23 μg/g for soils in the western conterminous United States and 0.6 μg/g for a bottom sediment sample from the Sun River.

Arsenic and mercury concentrations in biological samples from Freezeout Lake, Priest Butte Lakes, and Benton Lake were not at concentrations believed to be unusual or to be detrimental to fish and wildlife. Boron concentrations in sago pondweed from Freezeout Lake, Priest Butte Lakes, and several sites at Benton Lake were at concentrations that may be a concern for consumer organisms limited to a diet of aquatic vascular plants for an extended time. Except for several bird livers and eggs, boron concentration generally was less than concentrations determined in diet studies to be indicative of boron-related toxicity.

Selenium was detected in most biological samples. Fish, invertebrates, and sago pondweed from Priest Butte Lakes contained the largest concentrations of selenium for these groups in the study area. The large concentrations in fish could be indicative of a potentially adverse situation. Several eared-grebe livers and eggs from Freezeout Lake and several coot livers and eggs from Benton Lake had selenium concentrations indicative of contamination.

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Table 15.--*Onsite measurements and analytical results of water samples*

[Analyses by U.S. Geological Survey. Number in parentheses in column heading is parameter code identification. Abbreviations: ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 °Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter. Symbols: --, no data; <, less than]

Site No. (figs. 4-6)	Date (month, day, year)	Water level, in feet below land surface (72019)	Discharge, instantaneous (ft^3/s) (00061)	Specific conductance, onsite (µS/cm) (00095)	pH, onsite (standard units) (00400)	Temperature, onsite (°C) (00010)	Hardness (mg/L as $CaCO_3$) (00900)	Solids, residue at 180 °C dissolved (mg/L) (70300)
			Sun River Irrigation Project					
1	06-04-86	--	1,510	220	7.6	8.0	110	131
2	06-05-86	--	1,020	220	7.7	12.0	120	124
3	06-04-86	--	5.0	650	8.4	21.5	300	411
4	07-30-86	--	59	660	8.5	10.0	280	399
	09-04-86	--	80	710	8.3	17.0	340	416
5	07-30-86	--	10	610	8.8	17.0	300	350
	09-04-86	--	20	516	8.5	16.0	240	280
6	07-30-86	--	15	650	8.4	16.0	290	390
7	07-30-86	--	310	685	8.4	18.0	310	384
	09-04-86	--	170	725	8.2	14.0	330	496
8	07-31-86	--	150	430	8.1	14.0	210	248
9	07-31-86	--	128	755	8.1	16.0	330	454
12	08-20-86	10.80	--	670	7.6	11.0	340	350
	09-04-86	--	--	--	--	11.0	--	--
13	08-20-86	7.35	--	950	7.3	13.0	390	547
14	08-20-86	10.00	--	940	7.5	13.0	410	521
15	08-20-86	4.55	--	650	7.6	10.5	300	353
16	08-20-86	4.00	--	420	7.5	14.0	220	228
			Freezeout Lake Game Management Area					
17	07-30-86	--	.2	980	9.0	19.5	490	674
18	06-04-86	--	.5	1,700	8.4	25.0	320	1,110
19	08-21-86	--	--	3,080	9.6	16.5	690	2,250
20	08-21-86	--	--	7,900	9.0	16.0	3,100	6,750
			Benton Lake National Wildlife Refuge					
22	08-12-86	--	30	860	8.0	18.0	360	548
23	06-06-86	--	.3	12,000	4.5	15.0	7,800	6,160
24	06-05-86	--	<.01	6,700	8.0	20.0	3,000	6,790
25	06-06-86	--	<.01	--	5.0	17.5	17,000	39,300
26	08-12-86	--	--	2,880	9.8	18.0	950	2,300
30	08-12-86	--	--	3,550	9.1	16.0	1,000	2,840

Table 15.--*Onsite measurements and analytical results of water samples*--Continued

Site No. (figs. 4-6)	Date (month, day, year)	Nitrogen, NO_2+NO_3 dissolved (mg/L as N) (00631)	Arsenic, dissolved (µg/L as As) (01000)	Barium, dissolved (µg/L as Ba) (01005)	Boron, dissolved (µg/L as B) (01020)	Cadmium, dissolved (µg/L as Cd) (01025)	Chromium, dissolved (µg/L as Cr) (01030)	Copper, dissolved (µg/L as Cu) (01040)	Lead, dissolved (µg/L as Pb) (01049)	Mercury, dissolved (µg/L as Hg) (71890)
				Sun River Irrigation Project						
1	06-04-86	--	<1	83	<10	<1	<10	<10	<1	<0.1
2	06-05-86	--	<1	87	10	<1	<10	<10	<1	<.1
3	06-04-86	--	2	95	100	<1	<10	<10	<1	<.1
4	07-30-86	--	1	76	120	<1	<10	<10	<5	<.1
	09-04-86	--	1	99	130	<1	<10	<10	<5	<.1
5	07-30-86	--	1	100	120	<1	<10	<10	<5	<.1
	09-04-86	--	1	95	120	<1	<10	<10	<5	<.1
6	07-30-86	--	2	98	140	<1	<10	<10	<5	<.1
7	07-30-86	--	1	78	110	<1	<10	<10	<5	--
	09-04-86	--	1	85	130	<1	<10	<10	<5	<.1
8	07-31-86	--	<1	110	50	<1	<10	<10	<5	<.1
9	07-31-86	--	1	91	110	<1	<10	<10	<5	<.1
12	08-20-86	4.1	<1	110	170	<1	<10	10	<5	<.1
	09-04-86	--	--	--	--	--	--	--	--	--
13	08-20-86	4.4	1	100	250	<1	<10	10	<5	<.1
14	08-20-86	6.4	1	110	190	<1	<10	<10	<5	<.1
15	08-20-86	3.4	2	86	110	<1	<10	10	<5	<.1
16	08-20-86	.46	1	120	40	<1	<10	<10	<5	<.1
				Freezeout Lake Game Management Area						
17	07-30-86	--	2	120	160	<1	<10	<10	<5	<.1
18	06-04-86	--	3	93	420	<1	<10	<10	<1	<.1
19	08-21-86	--	14	<100	470	1	<10	20	<5	<.1
20	08-21-86	--	22	<100	890	<1	<10	30	<5	<.1
				Benton Lake National Wildlife Refuge						
22	08-12-86	--	1	45	150	<1	<10	<10	5	<.1
23	06-06-86	--	<1	200	1,800	33	20	60	<1	<.1
24	06-05-86	--	2	--	780	<1	10	20	2	<.1
25	06-06-86	--	<1	100	2,500	660	40	80	<5	<.1
26	08-12-86	--	9	<100	290	<1	<10	10	<5	<.1
30	08-12-86	--	63	<100	480	<1	<10	10	<5	.1

Table 15.--*Onsite measurements and analytical results of water samples*--Continued

Site No. (figs. 4-6)	Date (month, day, year)	Molybdenum, dissolved (µg/L as Mo) (01060)	Nickel, dissolved (µg/L as Ni) (01065)	Selenium, dissolved (µg/L as Se) (01145)	Silver, dissolved (µg/L as Ag) (01075)	Vanadium, dissolved (µg/L as V) (01085)	Zinc, dissolved (µg/L as Zn) (01090)	Gross alpha, dissolved (µg/L as U-Nat) (80030)	Gross beta, dissolved (pCi/L as Cs-137) (03515)	Gross beta, dissolved (pCi/L as Yt-90) (80050)
				Sun River Irrigation Project						
1	06-04-86	<1	1	<1	<1	<1	9	--	--	--
2	06-05-86	<1	<1	<1	<1	<1	30	--	--	--
3	06-04-86	1	<1	2	<1	3	5	--	--	--
4	07-30-86	3	<1	2	<1	5	10	8.2	47	36
	09-04-86	5	2	2	<1	3	14	6.6	6.5	5.0
5	07-30-86	2	<1	2	<1	5	5	6.8	5.3	4.2
	09-04-86	2	1	<1	<1	2	12	5.3	4.0	3.1
6	07-30-86	2	2	2	<1	7	5	6.3	7.8	6.0
7	07-30-86	3	<1	2	<1	5	13	11	6.2	4.7
	09-04-86	3	1	1	<1	2	15	6.9	7.0	5.3
8	07-31-86	2	<1	<1	<1	3	<3	2.7	2.8	2.3
9	07-31-86	<1	<1	<1	<1	2	<3	4.0	5.2	3.9
12	08-20-86	8	<1	5	<1	3	7	9.6	7.7	6.2
	09-04-86	--	--	--	--	--	--	--	--	--
13	08-20-86	3	3	2	<1	5	67	8.2	11	8.5
14	08-20-86	3	1	3	<1	10	44	8.8	9.4	7.1
15	08-20-86	6	1	1	<1	11	64	3.1	6.8	5.3
16	08-20-86	3	1	<1	<1	7	12	2.8	3.7	3.1
				Freezeout Lake Game Management Area						
17	07-30-86	1	<1	8	<1	6	11	9.5	7.6	5.7
18	06-04-86	2	1	<1	<1	2	6	--	--	--
19	08-21-86	9	<1	2	<1	4	20	20	11	7.6
20	08-21-86	8	2	8	<1	5	20	--	27	18
				Benton Lake National Wildlife Refuge						
22	08-12-86	4	3	4	<1	5	6	5.4	8.4	6.4
23	06-06-86	<1	2,800	580	<1	6	4,100	--	--	--
24	06-05-86	1	4	15	<1	11	20	--	--	--
25	06-06-86	<1	7,000	500	<1	10	19,000	--	--	--
26	08-12-86	5	1	1	<1	3	80	--	20	11
30	08-12-86	<1	6	<1	<1	8	30	9.3	10	7.7

Table 15.--*Onsite measurements and analytical results of water samples*--Continued

Site No. (figs. 4-6)	Date (month, day, year)	Radium-226, dissolved, planchet count (pCi/L) (09510)	Uranium, natural dissolved (µg/L as U) (22703)	Picloram, (Tordon) (Amdon) total (µg/L) (39720)	Dicamba, (Mediben) (Banvel D) total (µg/L) (82052)	2,4-D, total (µg/L) (39730)	2,4,5-T, total (µg/L) (39740)	2,4-DP, total (µg/L) (82183)	Silvex, total (µg/L) (39760)
			Sun River Irrigation Project						
1	06-04-86	--	--	--	--	--	--	--	--
2	06-05-86	--	--	--	--	--	--	--	--
3	06-04-86	--	--	--	--	--	--	--	--
4	07-30-86	0.2	6.9	<0.01	<0.02	0.04	<0.01	<0.01	<0.01
	09-04-86	.1	8.2	--	--	--	--	--	--
5	07-30-86	.3	4.7	<.01	.01	<.01	<.01	<.01	<.01
	09-04-86	<.1	3.7	--	--	--	--	--	--
6	07-30-86	<.1	6.2	--	--	--	--	--	--
7	07-30-86	.2	5.2	--	--	--	--	--	--
	09-04-86	<.1	5.3	--	--	--	--	--	--
8	07-31-86	.2	1.5	--	--	--	--	--	--
9	07-31-86	.2	2.7	--	--	--	--	--	--
12	08-20-86	.2	18	--	--	--	--	--	--
	09-04-86	--	--	<.01	<.01	<.01	<.01	<.01	<.01
13	08-20-86	<.2	14	<.01	<.01	<.01	<.01	<.01	<.01
14	08-20-86	.2	17	<.01	<.01	<.01	<.01	<.01	<.01
15	08-20-86	.1	8.8	<.01	<.01	<.01	<.01	<.01	<.01
16	08-20-86	<.1	3.1	<.01	<.01	<.01	<.01	<.01	<.01
			Freezeout Lake Game Management Area						
17	07-30-86	.2	5.0	--	--	--	--	--	--
18	06-04-86	--	--	--	--	--	--	--	--
19	08-21-86	.2	6.9	<.01	.08	.22	<.01	<.01	<.01
20	08-21-86	<.2	25	--	--	--	--	--	--
			Benton Lake National Wildlife Refuge						
22	08-12-86	<.2	7.8	.01	<.01	<.01	<.01	<.01	<.01
23	06-06-86	--	--	--	--	--	--	--	--
24	06-05-86	--	--	--	--	--	--	--	--
25	06-06-86	--	--	--	--	--	--	--	--
26	08-12-86	<.1	4.1	--	--	--	--	--	--
30	08-12-86	<.1	3.5	--	--	--	--	--	--

Table 16.--*Analytical results of bottom-sediment samples*

[Analyses by U.S. Geological Survey. Total, total in bottom material; µg/g, micrograms per gram; µg/kg, micrograms per kilogram; <, less than; --, no data]

Site No. (figs. 4-6)	Date (month, day, year)	Time	Arsenic, total (µg/g as As)	Barium, total (µg/g as Ba)	Boron, total (µg/g as B)	Cadmium, total (µg/g as Cd)	Chromium, total (µg/g as Cr)	Copper, total (µg/g as Cu)
			Sun River Irrigation Project					
4	07-30-86	1050	8.4	990	1.4	<2	84	24
7	07-30-86	1730	6.5	960	.9	<2	55	16
9	07-31-86	1000	6.8	780	1.3	<2	47	21
			Freezeout Lake Game Management Area					
19	08-21-86	1000	9.3	690	3.9	<2	51	24
20	08-21-86	1130	5.8	710	3.2	<2	39	13
21	08-21-86	1315	5.3	690	2.1	<2	67	29
			Benton Lake National Wildlife Refuge					
22	08-12-86	1800	7.8	910	2.0	<2	110	35
24	07-31-86	1245	7.1	46	2.3	<2	71	26
25	07-31-86	1215	7.8	31	6.3	<2	66	32
26	08-12-86	1200	9.0	970	1.1	<2	130	42
27	08-12-86	1315	12	700	3.9	<2	110	43
28	08-12-86	1245	8.3	870	1.1	<2	130	40
30	08-12-86	1000	12	820	1.7	<2	120	47
31	08-12-86	1100	14	870	1.4	<2	130	44

Site No. (figs. 4-6)	Lead, total (µg/g as Pb)	Mercury, total (µg/g as Hg)	Molybdenum, total (µg/g as Mo)	Nickel, total (µg/g as Ni)	Selenium, total (µg/g as Se)	Silver, total (µg/g as Ag)	Vanadium, total (µg/g as V)	Zinc, total (µg/g as Zn)	Uranium, natural, total (µg/g as U)
				Sun River Irrigation Project					
4	15	0.03	<2.0	30	0.8	<2	140	98	<100
7	12	.02	<2.0	20	.5	<2	82	68	<100
9	17	.02	<2.0	18	.6	<2	77	69	<100
				Freezeout Lake Game Management Area					
19	17	<.02	<2.0	20	.6	<2	83	82	<100
20	12	<.02	<2.0	15	3.9	<2	67	55	<100
21	20	.02	<2.0	25	1.0	<2	110	100	<100
				Benton Lake National Wildlife Refuge					
22	19	.04	<2.0	51	2.3	<2	180	140	<100
24	11	.03	<2.0	26	1.1	<2	110	67	<100
25	9	.03	<2.0	130	6.7	<2	100	190	<100
26	24	.03	<2.0	35	.8	<2	210	120	<100
27	23	.06	<2.0	34	.9	<2	180	130	<100
28	21	.05	<2.0	35	.5	<2	200	120	<100
30	25	.04	<2.0	37	.6	<2	190	130	<100
31	20	.03	<2.0	39	.3	<2	210	120	<100

Table 16.--*Analytical results of bottom-sediment samples*--Continued

Site No. (figs. 4-6)	Picloram, total (μg/kg)	Dicamba, total dry weight (μg/kg)	2,4-D, total (μg/kg)	2,4,5-T, total (μg/kg)	2,4-DP, total (μg/kg)	Silvex, total (μg/kg)
			Sun River Irrigation Project			
4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
7	--	--	--	--	--	--
9	--	--	--	--	--	--
			Freezeout Lake Game Management Area			
19	<.1	<.1	<.1	<.1	<.1	<.1
20	--	--	--	--	--	--
21	--	--	--	--	--	--
			Benton Lake National Wildlife Refuge			
22	<.1	<.1	<.1	<.1	<.1	<.1
24	--	--	--	--	--	--
25	--	--	--	--	--	--
26	--	--	--	--	--	--
27	--	--	--	--	--	--
28	--	--	--	--	--	--
30	--	--	--	--	--	--
31	--	--	--	--	--	--

Table 17.- *Concentrations (dry weight) of trace elements in biota*

[Analyses by U.S. Fish and Wildlife Service. Concentrations, in micrograms per gram; <, less than; --, no data]

Site No. (figs. 4-6)	Sample type	Taxa	Date (month, day, year)	Aluminum	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium
			Sun River Irrigation Project							
8	Fish	Brown trout	08-19-86	26	<0.17	2.3	<0.35	13	<0.35	<0.35
8	Invertebrates	Crayfish	08-19-86	540	2.4	210	<1.4	57	<1.4	9.5
9	Fish	Brown trout	08-20-86	14	<.17	<.36	<.36	100	<.36	<.36
9	Fish	Carp	08-20-86	120	<.18	8.9	<.40	15	<.40	<.40
9	Liver	Northern pike	08-20-86	12	<.14	<.35	<.35	27	<.35	1.5
9	Invertebrates	Crayfish	08-20-86	680	1.9	100	<.76	55	<.76	3.2
10	Fish	Yellow perch	08-21-86	260	<.18	6.0	<.35	24	<.35	14
10	Fish	White sucker	08-21-86	180	<.16	14	<.40	10	<.40	.56
10	Invertebrates	Crayfish	08-21-86	1,700	2.0	93	<1.1	75	2.3	10
			Freezeout Lake Game Management Area							
20	Liver	White sucker	07-08-86	410	.43	3.5	<.32	7.6	<.32	1.6
20	Fish	Yellow perch	07-08-86	48	<.17	<.37	<.37	8.9	<.37	3.0
20	Fish	White sucker	07-08-86	23	<.16	<.33	<.33	11	<.33	.53
20	Invertebrates	Odonata	07-29-86	260	<2.6	<6.3	<6.3	<130	<6.3	<6.3
20	Invertebrates	Hemiptera	07-29-86	40	.73	<1.2	<1.2	65	<1.2	2.0
20	Plants	Sago pondweed	07-29-86	49	2.7	12	<.62	990	<.62	22
21a	Fish	White sucker	07-08-86	41	<.17	3.2	<.40	17	<.40	.65
21a	Invertebrates	Odonata	07-30-86	630	<2.5	<5.0	<5.0	120	<5.0	<5.0
21a	Invertebrates	Hemiptera	07-30-86	180	<1.0	<2.1	<2.1	150	<2.1	5.0
21a	Plants	Sago pondweed	07-30-86	890	34	27	<1.1	590	<1.1	21
21a	Plants	Filamentous algae	07-30-86	19,000	130	53	<1.7	190	<1.7	16
21a	Liver	Eared grebe	07-31-86	<5.2	<.20	<.52	<.52	<10	<.52	<.52
21a	Liver	Eared grebe	07-31-86	<4.1	<.20	<.41	<.41	33	<.41	<.41
21a	Liver	Eared grebe	07-31-86	8.0	<.19	<.53	<.53	<11	<.53	<.53
21a	Liver	Eared grebe	07-31-86	24	<.15	<.30	<.30	78	1.4	2.5
21a	Liver	Avocet	07-31-86	48	<.29	<.49	<.49	31	<.49	4.5
21a	Egg	Eared grebe	06-06-86	<.50	<.23	.90	<.50	17	<.50	.50
21a	Egg	Eared grebe	06-06-86	6.6	<.21	2.2	<.46	10	<.46	<.46
21a	Egg	Eared grebe	06-06-86	<.50	<.22	1.5	<.50	<9.9	<.50	2.2
21a	Egg	Eared grebe	06-06-86	<.48	<.22	.72	<.48	19	<.48	<.48
21a	Egg	Avocet	06-06-86	<.35	<.18	1.5	<.35	9.2	<.35	<.35
21a	Egg	Avocet	06-06-86	<.38	<.16	3.5	<.38	38	<.38	<.38
21a	Egg	Avocet	06-06-86	--	<.18	--	--	--	--	--

Table 17.--*Concentrations (dry weight) of trace elements in biota*--Continued

Site No. (figs. 4-6)	Copper	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel	Selenium	Strontium	Tin	Vanadium	Zinc
					Sun River Irrigation Project							
8	9.2	62	<0.71	<3.5	0.83	0.43	<0.35	2.5	17	<3.5	<0.35	92
8	51	430	<2.7	59	<.65	<1.4	3.2	4.0	350	<14	<1.4	110
9	7.2	53	4.1	<3.6	.74	<.36	<.36	2.5	4.3	<3.6	<.36	57
9	3.6	170	<.81	7.3	.67	<.40	<.40	2.5	100	<4.0	<.40	320
9	48	1,200	<.70	<3.5	8.0	<.35	.57	7.2	<.35	<3.5	<.35	98
9	27	480	<1.5	39	<.30	2.9	1.4	3.0	200	<7.6	<.76	79
10	2.3	170	<.71	11	.27	<.35	4.2	2.4	56	<3.5	.50	61
10	3.3	210	<.80	14	.48	<.40	<.40	2.2	73	<4.0	.46	46
10	84	1,100	<2.3	68	<.48	<1.1	<1.1	3.2	450	<11	<1.1	98
					Freezeout Lake Game Management Area							
20	5.1	310	<.63	13	<.15	<.32	.44	19	89	<3.2	.47	23
20	.89	53	<.74	19	<.16	<.37	.74	48	290	<3.7	<.37	59
20	1.4	62	<.66	<3.3	<.15	<.33	<.33	35	130	<3.3	<.33	46
20	16	180	<13	<63	<2.9	<6.3	<6.3	32	58	<63	<6.3	99
20	40	120	<2.3	35	<.50	<1.2	<1.2	15	140	<12	<1.2	230
20	2.4	570	<1.2	100	<.31	2.9	7.7	2.0	560	10	1.6	11
21a	2.7	45	<.81	<4.0	<.17	<.40	<.40	3.8	490	<4.0	<.40	43
21a	23	430	<10	<50	<2.3	25	<5.0	9.8	31	<50	<5.0	140
21a	20	220	<4.2	<21	<.85	<2.1	<2.1	4.9	10	<21	<2.1	170
21a	5.5	750	<2.3	89	<.51	25	9.8	.63	64	14	4.3	12
21a	6.3	11,000	<3.3	140	<.79	<1.7	7.3	<.83	210	1,200	22	37
21a	74	610	<1.0	70	.22	<.52	4.8	36	<.52	<5.2	<.52	100
21a	24	470	<.83	11	<.20	<.41	<.41	46	<.41	<4.1	<.41	120
21a	45	400	<1.1	13	.23	3.1	<.53	43	<.53	<5.3	<.53	110
21a	34	2,000	<.60	14	7.6	13	3.3	39	<.30	36	<.30	130
21a	20	1,300	<.97	17	<.30	3.6	1.3	28	2.6	<4.9	.67	170
21a	7.7	180	<1.0	<5.0	<.24	.69	<.50	8.9	14	<5.0	1.2	42
21a	2.2	150	<.92	<4.6	.27	<.46	<.46	18	20	<4.6	.64	58
21a	11	260	1.3	<5.0	.62	.97	.99	15	25	<5.0	<.50	48
21a	9.1	180	<.96	<4.8	.41	<.48	<.48	9.5	12	<4.8	1.5	48
21a	6.3	180	<.70	4.0	.78	.44	<.35	2.6	29	<3.5	2.9	50
21a	6.3	230	<.75	5.7	.85	.58	<.38	2.8	<.38	<3.8	<.38	41
21a	--	--	--	--	.23	--	--	4.9	--	--	--	--

Table 17.--*Concentrations (dry weight) of trace elements in biota*--Continued

Site No. (figs. 4-6)	Sample type	Taxa	Date (month, day, year)	Alu-minum	Arsenic	Barium	Beryl-lium	Boron	Cad-mium	Chro-mium
			Benton Lake National Wildlife Refuge							
22	Inver-tebrates	Odonata	07-23-86	700	<1.0	<2.5	<2.5	95	<2.5	36
22	Inver-tebrates	Hemiptera	07-23-86	170	.68	<1.5	<1.5	100	<1.5	1.6
22	Plants	Sago pondweed	07-23-86	3,000	11	46	<.96	230	<.96	19
22	Plants	Filamentous algae	07-23-86	1,800	10	54	<1.4	230	<1.4	7.1
22	Liver	Coot	07-29-86	59	.34	<.38	<.38	15	<.38	2.4
22	Liver	Coot	07-29-86	56	<.21	<.41	<.41	19	<.41	.55
22	Liver	Coot	07-29-86	12	.25	<.47	<.47	41	<.47	1.6
22	Liver	Coot	07-29-86	42	.28	1.7	<.38	73	<.38	4.6
22	Liver	Avocet	07-29-86	20	<.19	<.39	<.39	79	<.39	5.2
22	Egg	Coot	06-05-86	<.41	<.21	6.4	<.41	18	<.41	<.41
22	Egg	Coot	06-05-86	<.42	.25	3.6	<.42	35	<.42	1.5
22	Egg	Coot	06-05-86	<.36	.25	3.6	<.36	<7.1	<.36	<.36
22	Egg	Coot	06-05-86	<.42	<.20	5.8	<.42	12	<.42	<.42
22	Egg	Avocet	06-05-86	<.38	<.17	4.7	<.38	14	<.38	3.6
22	Egg	Avocet	06-05-86	<.39	<.20	5.4	<.39	10	<.39	<.39
25	Inver-tebrates	Chironomids	07-27-86	2,200	<1.8	<3.8	<3.8	120	<3.8	<3.8
25	Egg	Avocet	06-07-86	--	< .15	--	--	--	--	--
26	Fish	Forage	07-27-86	450	1.5	<1.6	<1.6	<32	<1.6	17
26	Inver-tebrates	Odonata	07-27-86	640	<3.3	<6.3	<6.3	<130	<6.3	<6.3
26	Inver-tebrates	Hemiptera	07-27-86	100	<.67	<1.5	<1.5	39	<1.5	7.3
26	Plants	Sago pondweed	07-27-86	2,200	29	17	<.70	820	<.70	23
26	Plants	Filamentous algae	07-27-86	13,000	29	120	<2.6	260	<2.6	24
27	Inver-tebrates	Odonata	07-28-86	2,300	1.0	<1.9	<1.9	62	<1.9	3.8
27	Plants	Sago pondweed	07-28-86	350	2.7	11	<.83	450	<.83	22
28	Inver-tebrates	Odonata	07-29-86	580	1.4	<1.6	<1.6	45	<1.6	5.8
28	Inver-tebrates	Hemiptera	07-29-86	400	<2.0	<5.0	<5.0	300	<5.0	25
28	Plants	Sago pondweed	07-29-86	900	18	35	<.70	370	<.70	24
28	Liver	Coot	07-30-86	21	.56	<.88	<.88	33	<.88	3.9
28	Liver	Coot	07-30-86	130	.25	<.67	<.67	51	<.67	4.4
28	Liver	Coot	07-30-86	36	.39	<.45	<.45	74	<.45	1.6
28	Liver	Coot	07-30-86	26	.48	<.42	<.42	97	<.42	12
28	Liver	Avocet	07-30-86	12	<.19	<.56	<.56	29	<.56	23
28	Egg	Coot	06-06-86	<.40	.26	10	<.40	9.6	<.40	.66
28	Egg	Coot	06-06-86	1.7	<.15	3.2	<.32	<6.4	<.32	<.32
28	Egg	Coot	06-06-86	.61	<.18	3.7	<.41	<8.1	<.41	1.3
28	Egg	Coot	06-06-86	<.41	<.18	4.1	<.41	11	<.41	<.41
28	Egg	Avocet	06-06-86	<.40	<.19	2.4	<.40	21	<.40	.42
29	Egg	Avocet	06-06-86	<.33	<.16	2.1	<.33	21	.33	.46
30	Inver-tebrates	Odonata	07-28-86	230	1.7	<1.7	<1.7	110	<1.7	22
31	Inver-tebrates	Odonata	07-28-86	310	2.1	<2.9	<2.9	94	<2.9	5.4

Table 17.--*Concentrations (dry weight) of trace elements in biota*--Continued

Site No. (figs. 4-6)	Copper	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel	Selenium	Strontium	Tin	Vanadium	Zinc
						Benton Lake National Wildlife Refuge						
22	21	900	<5.0	26	<1.0	<2.5	14	9.2	18	<25	<2.5	200
22	260	190	<2.9	41	<.76	9.7	<1.5	6.3	19	<15	<1.5	160
22	4.2	9,300	<1.9	620	<.43	<.96	13	1.6	130	170	10	38
22	2.9	1,400	3.1	46	<.62	3.7	16	2.1	230	27	11	12
22	11	110	<.76	11	.24	4.6	.76	22	<.38	17	<.38	180
22	32	200	<.83	8.1	.42	3.6	<.41	20	.50	48	<.41	150
22	4.7	3,300	1.7	9.3	<.22	3.2	.47	25	<.47	110	<.47	110
22	9.9	4,800	7.1	15	.31	3.5	2.1	16	2.3	84	<.38	140
22	17	2,100	<.79	12	.52	2.6	2.3	32	.48	33	<.39	110
22	7.1	130	<.83	<4.1	.19	<.41	<.41	7.8	13	<4.1	2.5	66
22	4.6	120	<.85	<4.2	.36	<.42	.71	5.4	16	<4.2	<.42	68
22	2.5	140	<.71	4.1	<.16	<.36	<.36	4.2	9.3	<3.6	<.36	36
22	6.1	120	<.83	<4.2	.26	<.42	<.42	5.2	17	<4.2	2.2	50
22	5.5	200	<.76	<3.8	.32	<.38	.61	4.9	7.3	<3.8	7.6	44
22	7.1	220	<.79	4.7	1.0	.79	<.39	7.3	10	<3.9	<.39	52
25	10	1,900	<7.7	38	<1.5	<3.8	19	12	16	<38	<3.8	13
25	--	--	--	--	.52	--	--	68	--	--	--	--
26	3.2	390	<3.2	16	<.66	<1.6	5.5	4.9	65	<16	<1.6	130
26	18	490	<13	<63	<2.8	<6.3	<6.3	9.1	16	<63	<6.3	100
26	33	240	<3.0	25	<.62	<1.5	4.5	3.2	22	<15	<1.5	210
26	4.8	10,000	<1.4	210	<.34	2.8	18	.66	130	200	10	34
26	9.5	8,500	7.4	580	<1.1	<2.6	16	<1.3	100	160	<2.6	34
27	16	180	<3.8	<19	<.76	<1.9	<1.9	2.9	15	<19	<1.9	8.5
27	3.0	470	<1.7	420	<.37	2.0	11	.62	75	10	1.6	17
28	19	390	<3.2	74	<.66	<1.6	5.5	2.0	17	<16	<1.6	9.7
28	22	490	<10	50	<2.0	<5.0	18	<2.0	12	<50	<5.0	240
28	1.1	2,300	3.7	1,300	<.33	3.4	11	.71	96	21	2.7	15
28	86	610	<1.8	11	<.44	<.88	1.3	16	1.6	<8.8	<.88	160
28	61	240	<1.3	7.9	1.1	<.67	1.3	6.4	<.67	<6.7	<.67	160
28	24	1,700	<.90	9.9	.85	6.2	.63	6.4	.74	32	<.45	250
28	13	1,100	<.84	18	<.21	5.8	5.0	28	.71	<4.2	<.42	240
28	13	910	<1.1	17	1.0	5.9	6.3	2.3	<.56	<5.6	<.56	100
28	3.4	110	<.80	<4.0	.25	.57	<.40	3.6	14	<4.0	2.7	61
28	3.3	83	<.64	<3.2	.17	.54	<.32	1.0	17	<3.2	<.32	54
28	3.7	150	<.81	<4.1	.65	.44	.76	1.4	7.9	<4.1	.65	59
28	4.2	98	<.82	<4.1	.33	.43	<.41	<.18	11	<4.1	<.41	52
28	6.9	150	<.81	<4.0	.86	<.40	<.40	2.1	12	<4.0	1.9	19
29	3.8	140	<.66	3.6	.26	.59	<.33	5.1	17	<3.3	<.33	57
30	15	340	<3.4	24	<.83	450	10	1.8	22	<17	<1.7	<1.7
31	20	320	<5.9	35	<1.4	46	<2.9	1.9	20	<29	<2.9	100

Table 18.--*Concentrations (wet weight) of trace elements in biota*

[Analyses by U.S. Fish and Wildlife Service. Concentration, in micrograms per gram; <, less than; --, no data]

Site No. (figs. 4-6)	Sample type	Taxa	Date (month, day, year)	Alu-minum	Arsenic	Barium	Beryl-lium	Boron	Cad-mium	Chro-mium
			Sun River Irrigation Project							
8	Fish	Brown trout	08-19-86	7.0	<0.044	0.62	<0.095	3.4	<0.095	<0.095
8	Inver-tebrates	Crayfish	08-19-86	38	.17	15	<.096	4.0	<.096	.67
9	Fish	Brown trout	08-20-86	3.9	<.045	<.097	<.097	27	<.097	<.097
9	Fish	Carp	08-20-86	29	<.044	2.2	<.098	3.7	<.098	<.098
9	Liver	Northern pike	08-20-86	3.3	<.038	<.097	<.097	7.6	<.097	.43
9	Inver-tebrates	Crayfish	08-20-86	88	.24	13	<.098	7.0	<.098	.41
10	Fish	Yellow perch	08-21-86	69	<.048	1.6	<.095	6.5	<.095	3.8
10	Fish	White sucker	08-21-86	46	<.041	3.4	<.10	2.6	<.10	.14
10	Inver-tebrates	Crayfish	08-21-86	150	.17	8.1	<.098	6.5	.20	.88
			Freezeout Lake Game Management Area							
20	Liver	White sucker	07-08-86	130	.13	1.1	<.098	2.3	<.098	.51
20	Fish	Yellow perch	07-08-86	13	<.044	<.097	<.097	2.3	<.097	.77
20	Fish	White sucker	07-08-86	6.8	<.046	<.098	<.098	3.1	<.098	.16
20	Inver-tebrates	Odonata	07-29-86	4.1	<.041	<.099	<.099	<2.0	<.099	<.099
20	Inver-tebrates	Hemiptera	07-29-86	3.2	.060	<.095	<.095	5.3	<.095	.16
20	Plants	Sago pondweed	07-29-86	7.7	.43	1.9	<.098	160	<.098	3.5
21a	Fish	White sucker	07-08-86	10	<.041	.79	<.099	4.2	<.099	.16
21a	Inver-tebrates	Odonata	07-30-86	12	<.049	<.099	<.099	2.4	<.099	<.099
21a	Inver-tebrates	Hemiptera	07-30-86	8.1	<.047	<.095	<.095	6.8	<.095	.23
21a	Plants	Sago pondweed	07-30-86	78	3.0	2.4	<.10	52	<.10	1.9
21a	Plants	Filamentous algae	07-30-86	1,110	7.6	3.1	<.097	11	<.097	.92
21a	Liver	Eared grebe	07-31-86	<1.3	<.050	<.13	<.13	<2.6	<.13	<.13
21a	Liver	Eared grebe	07-31-86	<.99	<.049	<.099	<.099	7.9	<.099	<.099
21a	Liver	Eared grebe	07-31-86	2.1	<.050	<.14	<.14	<2.7	<.14	<.14
21a	Liver	Eared grebe	07-31-86	7.9	<.050	<.098	<.098	26	.45	.83
21a	Liver	Avocet	07-31-86	12	<.071	<.12	<.12	7.6	<.12	1.1
21a	Egg	Eared grebe	06-06-86	<.099	<.046	.18	<.099	3.4	<.099	.099
21a	Egg	Eared grebe	06-06-86	1.4	<.044	.46	<.097	2.1	<.097	<.097
21a	Egg	Eared grebe	06-06-86	<.098	<.043	.29	<.098	<2.0	<.098	.43
21a	Egg	Eared grebe	06-06-86	<.098	<.046	.15	<.098	3.9	<.098	<.098
21a	Egg	Avocet	06-06-86	<.094	<.048	.42	<.094	2.5	<.094	<.094
21a	Egg	Avocet	06-06-86	<.099	<.042	.91	<.099	9.9	<.099	<.099
21a	Egg	Avocet	06-06-86	--	<.040	--	--	--	--	--

Site No. (figs. 4-6)	Copper	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel	Strontium	Tin	Vanadium	Zinc
Sun River Irrigation Project											
8	2.5	17	<0.19	<0.95	0.22	0.11	<0.095	4.5	<0.95	<0.095	25
8	3.7	31	<.19	4.2	<.046	<.096	.23	25	<.96	<.096	7.5
9	1.9	14	1.1	<.97	.20	<.097	<.097	1.1	<.97	<.097	15
9	.88	41	<.20	1.8	.16	<.098	<.098	25	<.98	<.098	78
9	13	330	<.19	<.97	2.2	<.097	.16	<.097	<.97	<.097	27
9	3.5	63	<.20	5.1	<.038	.37	.18	25	<.98	<.098	10
10	.63	46	<.19	3.0	.073	<.095	1.1	15	<.95	.13	16
10	.82	52	<.20	3.4	.12	<.10	<.10	18	<1.0	.11	11
10	7.3	92	<.20	5.9	<.042	<.098	<.098	39	<.98	<.098	8.4
Freezeout Lake Game Management Area											
20	1.6	96	<.20	4.1	<.045	<.098	.14	27	<.98	.15	7.2
20	.23	14	<.19	4.8	<.041	<.097	.19	75	<.97	<.097	15
20	.41	18	<.20	<.98	<.044	<.098	<.098	37	<.98	<.098	14
20	.26	2.8	<.20	<.99	<.045	<.099	<.099	.91	<.99	<.099	1.6
20	3.2	9.7	<.19	2.9	<.041	<.095	<.095	11	<.95	<.095	19
20	.37	91	<.20	16	<.049	.45	1.2	89	1.7	.26	1.8
21a	.65	11	<.20	<.99	<.042	<.099	<.099	120	<.99	<.099	10
21a	.46	8.5	<.20	<.99	<.045	.50	<.099	.61	<.99	<.099	2.8
21a	.93	9.8	<.19	<.95	<.039	<.095	<.095	.45	<.95	<.095	7.9
21a	.48	66	<.20	7.8	<.045	2.2	.86	5.6	1.2	.38	1.0
21a	.37	630	<.19	8.0	<.046	<.097	.43	12	72	1.3	2.1
21a	18	150	<.26	17	.054	<.13	1.2	<.13	<1.3	<.13	26
21a	5.8	110	<.20	2.6	<.049	<.099	<.099	<.099	<.99	<.099	28
21a	12	100	<.27	3.3	.059	.79	<.14	<.14	<1.4	<.14	27
21a	11	670	<.20	4.5	2.5	4.3	1.1	<.098	12	<.098	43
21a	5.0	320	<.24	4.0	<.074	.88	.31	.64	<1.2	.16	43
21a	1.5	36	<.20	<.99	<.048	.14	<.099	2.8	<.99	.24	8.3
21a	.46	31	<.19	<.97	.058	<.097	<.097	4.3	<.97	.14	12
21a	2.1	51	.25	<.98	.12	.19	.20	4.9	<.98	<.098	9.4
21a	1.9	37	<.20	<.98	.085	<.098	<.098	2.4	<.98	.31	9.8
21a	1.7	49	<.19	1.1	.21	.12	<.094	7.7	<.94	.77	13
21a	1.7	61	<.20	1.5	.22	.15	<.099	<.099	<.99	<.099	11
21a	--	--	--	--	.051	--	--	--	--	--	--

Table 18.- *Concentrations (wet weight) of trace elements in biota*--Continued

Site No. (figs. 4-6)	Sample type	Taxa	Date (month, day, year	Aluminum	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium
			Benton Lake National Wildlife Refuge							
22	Invertebrates	Odonata	07-23-86	27	<.039	<.097	<.097	3.7	<.097	1.4
22	Invertebrates	Hemiptera	07-23-86	11	.045	<.097	<.097	6.8	<.097	.10
22	Plants	Sago pondweed	07-23-86	300	1.1	4.7	<.098	23	<.098	2.0
22	Plants	Filamentous algae	07-23-86	120	.69	3.7	<.098	15	<.098	.49
22	Liver	Coot	07-29-86	15	.089	<.099	<.099	3.8	<.099	.63
22	Liver	Coot	07-29-86	13	<.049	<.096	<.096	4.4	<.096	.13
22	Liver	Coot	07-29-86	2.5	.050	<.096	<.096	8.4	<.096	.33
22	Liver	Coot	07-29-86	11	.072	.42	<.097	19	<.097	1.2
22	Liver	Avocet	07-29 86	5.0	<.046	<.096	<.096	19	<.096	1.3
22	Egg	Coot	06-05-86	<.097	<.050	1.5	<.097	4.3	<.097	<.097
22	Egg	Coot	06-05-86	<.099	.057	.85	<.099	8.1	<.099	.36
22	Egg	Coot	06-05-86	<.097	.068	.97	<.097	<1.9	<.097	<.097
22	Egg	Coot	06-05-86	<.095	<.045	1.3	<.095	2.7	<.095	<.095
22	Egg	Avocet	06-05-86	<.098	<.043	1.2	<.098	3.7	<.098	.94
22	Egg	Avocet	06-05-86	<.096	<.049	1.3	<.096	2.5	<.096	<.096
25	Invertebrates	Chironomids	07-27-86	56	<.045	<.097	<.097	2.9	<.097	<.097
25	Egg	Avocet	06-07-86	--	<.040	--	--	--	--	--
26	Fish	Forage	07-27-86	27	.088	<.096	<.096	<1.9	<.096	1.0
26	Invertebrates	Odonata	07-27-86	9.7	<.050	<.095	<.095	<1.9	<.095	<.095
26	Invertebrates	Hemiptera	07-27-86	6.3	<.042	<.095	<.095	2.5	<.095	.46
26	Plants	Sago pondweed	07-27-86	310	4.1	2.4	<.10	120	<.10	3.2
26	Plants	Filamentous algae	07-27-86	470	1.1	4.3	<.097	9.5	<.097	.87
27	Invertebrates	Odonata	07-28-86	120	.054	<.10	<.10	3.2	<.10	.20
27	Plants	Sago pondweed	07-28-86	41	.31	1.2	<.097	52	<.097	2.5
28	Invertebrates	Odonata	07-29-86	35	.084	<.098	<.098	2.7	<.098	.35
28	Invertebrates	Hemiptera	07-29-86	7.8	<.038	<.098	<.098	5.9	<.098	.49
28	Plants	Sago pondweed	07-29-86	120	2.5	4.8	<.097	50	<.097	3.3
28	Liver	Coot	07-30-86	4.8	.13	<.20	<.20	7.5	<.20	.87
28	Liver	Coot	07-30-86	31	.058	<.16	<.16	12	<.16	1.0
28	Liver	Coot	07-30-86	7.9	.085	<.099	<.099	16	<.099	.36
28	Liver	Coot	07-30-86	6.1	.11	<.098	<.098	23	<.098	2.7
28	Liver	Avocet	07-30-86	3.2	<.050	<.15	<.15	7.6	<.15	6.1
28	Egg	Coot	06-06-86	<.097	.063	2.5	<.097	2.3	<.097	.16
28	Egg	Coot	06-06-86	.50	<.045	.97	<.097	<1.9	<.097	<.097
28	Egg	Coot	06-06-86	.15	<.045	.91	<.099	<2.0	<.099	.32
28	Egg	Coot	06-06-86	<.094	<.042	.94	<.094	2.5	<.094	<.094
28	Egg	Avocet	06-06-86	<.095	<.045	.57	<.095	4.9	<.095	.098
29	Egg	Avocet	07-28-86	<.095	<.047	.59	<.095	6.1	<.095	.13
30	Invertebrates	Odonata	07-28-86	13	.092	<.095	<.095	6.1	<.095	1.2
31	Invertebrates	Odonata	07-28-86	10	.068	<.096	<.096	3.1	<.096	.18

Table 18.--*Concentrations (wet weight) of trace elements in biota*--Continued

Site No. (figs. 4-6)	Cop- per	Iron	Lead	Manga- nese	Mer- cury	Molyb- denum	Nickel	Stron- tium	Tin	Vana- dium	Zinc
					Benton Lake National Wildlife Refuge						
22	.82	35	<.19	1.0	<.039	<.097	.54	.70	<.97	<.097	8.0
22	17	12	<.19	2.7	<.050	.64	<.097	1.2	<.97	<.097	11
22	.43	950	<.20	63	<.043	<.098	1.3	13	17	1.0	3.9
22	.20	94	.21	3.1	<.042	.25	1.1	16	1.9	.72	.84
22	3.0	28	<.20	2.8	.061	1.2	.20	<.099	4.4	<.099	48
22	7.5	46	<.19	1.9	.098	.83	<.096	.12	11	<.096	35
22	.96	670	.34	1.9	<.045	.65	.096	<.096	23	<.096	23
22	2.5	1,200	1.8	3.7	.079	.89	.54	.58	21	<.097	35
22	4.2	520	<.19	2.9	.13	.63	.56	.12	8.1	<.096	27
22	1.7	31	<.19	<.97	.044	<.097	<.097	3.1	<.97	.58	16
22	1.1	28	<.20	<.99	.085	<.099	.17	3.8	<.99	<.099	16
22	.67	37	<.19	1.1	<.043	<.097	<.097	2.5	<.97	<.097	9.7
22	1.4	29	<.19	<.95	.060	<.095	<.095	3.8	<.95	.50	11
22	1.4	53	<.20	<.98	.083	<.098	.16	1.9	<.98	2.0	11
22	1.7	54	<.19	1.1	.25	.19	<.096	2.5	<.96	<.096	13
25	.25	48	<.19	.97	<.038	<.097	.48	.41	<.97	<.097	.33
25	--	--	--	--	.13	--	--	--	--	--	--
26	.19	23	<.19	.96	<.040	<.096	.33	3.9	<.96	<.096	7.5
26	.27	7.4	<.19	<.95	<.043	<.095	<.095	.25	<.95	<.095	1.6
26	2.1	15	<.19	1.6	<.039	<.095	.29	1.4	<.95	<.095	13
26	.68	1,500	<.20	30	<.049	.40	2.6	18	28	1.5	4.8
26	.35	310	.27	21	<.039	<.097	.58	3.7	6.0	<.097	1.3
27	.82	9.2	<.20	<1.0	<.039	<.10	<.10	.80	<1.0	<.10	.44
27	.35	54	<.19	49	<.043	.23	1.3	8.7	1.2	.19	1.9
28	1.2	24	<.20	4.5	<.040	<.098	.33	1.0	<.98	<.098	.59
28	.43	9.6	<.20	.98	<.039	<.098	.35	.23	<.98	<.098	4.7
28	.15	310	.50	180	<.045	.46	1.4	13	2.9	.37	2.1
28	19	140	<.40	2.5	<.10	<.20	.30	.37	<2.0	<.20	37
28	14	57	<.31	1.9	.27	<.16	.31	<.16	<1.6	<.16	38
28	5.3	380	<.20	2.2	.19	1.4	.14	.16	6.9	<.099	55
28	2.9	260	<.20	4.1	<.049	1.3	1.2	.17	<.98	<.098	55
28	3.5	240	<.29	4.4	.27	1.5	1.7	<.15	<1.5	<.15	26
28	.83	27	<.19	<.97	.060	.14	<.097	3.5	<.97	.66	15
28	1.0	25	<.19	<.97	.052	.16	<.097	5.0	<.97	<.097	16
28	.91	36	<.20	<.99	.16	.11	.19	1.9	<.99	.16	15
28	.97	23	<.19	<.94	.075	.10	<.094	2.5	<.94	<.094	12
28	1.6	36	<.19	<.95	.20	<.095	<.095	2.8	<.95	.45	4.5
29	1.1	40	<.19	1.0	.075	.17	<.095	4.8	<.95	<.095	16
30	.84	19	<.19	1.3	<.046	25	.55	1.2	<.95	<.095	<.095
31	.65	11	<.19	1.2	<.045	1.5	<.096	.65	<.96	<.096	3.3

Table 19.--*Pesticide residues in fish*

[Analyses by U.S. Fish and Wildlife Service. Concentrations, in micrograms per gram wet weight. Site number shown in parentheses; LDL, less than analytical detection limits; est., estimated]

	Sun River					Priest Butte Lakes		Freezeout Lake (pond 4)	Benton Lake
Pesticide	Brown trout (8)	Brown trout (9)	Carp (9)	White sucker (10)	Yellow perch (10)	White sucker (20)	Yellow perch (20)	White sucker (21a)	Forage fish (26)
p,p'-DDT	LDL	0.025	LDL	0.027	0.021	0.019	0.025	LDL	0.026
p,p'-DDE	0.011	.022	0.025	LDL	LDL	LDL	LDL	LDL	LDL
p,p'-DDD	LDL	.011	.017	LDL	.011	LDL	LDL	LDL	LDL
PCB-1248	LDL	LDL	2.0	LDL	LDL	LDL	LDL	LDL	LDL
PCB-1254 (est.)	LDL	LDL	LDL	LDL	LDL	LDL	LDL	LDL	LDL
Oxychlordane	LDL	LDL	LDL	LDL	LDL	LDL	LDL	LDL	LDL
cis-Chlordane	LDL	LDL	LDL	LDL	LDL	LDL	LDL	LDL	LDL
trans-Chlordane	LDL	LDL	LDL	LDL	LDL	LDL	LDL	LDL	LDL
cis-Nonachlor	LDL	LDL	LDL	LDL	LDL	LDL	LDL	LDL	LDL
trans-Nonachlor	LDL	LDL	LDL	LDL	LDL	LDL	LDL	LDL	LDL
Dieldrin	LDL	LDL	LDL	LDL	LDL	LDL	LDL	LDL	LDL
Endrin	LDL	LDL	LDL	LDL	LDL	LDL	LDL	LDL	LDL
Heptachlor epoxide	LDL	LDL	LDL	LDL	LDL	LDL	LDL	LDL	LDL

Table 20.--*Pesticide residues in eared-grebe and avocet eggs from Freezeout Lake Game Management Area*

[Analyses by U.S. Fish and Wildlife Service. Concentrations, in micrograms per gram wet weight. LDL, less than analytical detection limits; est., estimated; --, not determined]

	Site 21a			
Pesticide	Eared grebe	Eared grebe	Eared grebe	Avocet
p,p'-DDT	--	0.029	0.041	0.061
p,p'-DDE	--	.20	.10	.82
p,p'-DDD	--	LDL	LDL	LDL
PCB-1254 (est.)	LDL	LDL	LDL	LDL
Oxychlordane	LDL	LDL	LDL	LDL
cis-Chlordane	--	LDL	LDL	LDL
trans-Chlordane	--	LDL	LDL	LDL
cis-Nonachlor	--	LDL	LDL	LDL
trans-Nonachlor	--	LDL	LDL	LDL
Dieldrin	--	LDL	LDL	.046
Endrin	--	LDL	LDL	LDL
Heptachlor epoxide	--	LDL	LDL	.021

Table 21.--*Pesticide residues in coot and avocet eggs from Benton Lake National Wildlife Refuge*

[Analyses by U.S. Fish and Wildlife Service. Concentrations, in micrograms per gram wet weight. LDL, less than analytical detection limits; est., estimated]

	Site 22				Site 28			
Pesticide	Coot	Coot	Coot	Avocet	Coot	Coot	Coot	Avocet
p,p'-DDT	0.024	0.026	LDL	0.096	LDL	LDL	0.034	0.075
p,p'-DDE	.16	.15	0.41	5.7	0.21	0.24	.29	3.4
p,p'-DDD	LDL	LDL	LDL	LDL	LDL	LDL	LDL	LDL
PCB-1254 (est.)	LDL	LDL	LDL	LDL	LDL	LDL	LDL	LDL
Oxychlordane	LDL	LDL	LDL	LDL	LDL	LDL	LDL	LDL
cis-Chlordane	LDL	LDL	LDL	LDL	LDL	LDL	LDL	LDL
trans-Chlordane	LDL	LDL	LDL	LDL	LDL	LDL	LDL	LDL
cis-Nonachlor	LDL	LDL	LDL	LDL	LDL	LDL	LDL	LDL
trans-Nonachlor	LDL	LDL	LDL	LDL	LDL	LDL	LDL	LDL
Dieldrin	LDL	LDL	LDL	.18	LDL	LDL	LDL	.039
Endrin	LDL	LDL	LDL	.13	LDL	LDL	LDL	.016
Heptachlor epoxide	LDL	LDL	LDL	.058	LDL	LDL	LDL	.029