RECONNAISSANCE INVESTIGATION OF WATER QUALITY, BOTTOM SEDIMENT, AND BIOTA ASSOCIATED WITH IRRIGATION DRAINAGE IN THE MIDDLE GREEN RIVER BASIN, UTAH, 1986-87

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CONVERSION FACTORS

For readers who prefer to use metric (International System) units, conversion factors for inch-pound units used in this report are listed below:

Multiply inch-pound unit	By	To obtain metric units
acre	4,047	square meter
acre-foot	1,233	cubic meter
cubic foot	28.32	liter
cubic foot per second	0.02832	cubic meter per second
foot	0.3048	meter
gallon per minute	3.748	liter per minute
inch	25.40	millimeter
mile	1.609	kilometer
square mile	2.590	square kilometer

Chemical concentration in water is given in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter is a unit expressing the solute per unit volume (liter) of water, and is about the same as parts per million unless concentrations are more than 7,000 milligrams per liter. One thousand micrograms per liter is equivalent to 1 milligram per liter. One million nanograms per liter is equivalent to 1 milligram per liter. Radioactivity is expressed in picocuries per liter which is the amount of radioactive decay producing 2.2 disintegrations per minute in a unit volume (liter) of water. Chemical concentration in sediment and biological tissues is given in milligrams per kilogram or micrograms per gram which are both equal to parts per million.

Water temperature is given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation:

$$F = 1.8\ (°C) + 32.$$

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".

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ABSTRACT

Reconnaissance of wildlife areas in the middle Green River basin of Utah was conducted during 1986 and 1987 to determine whether irrigation drainage has caused, or has the potential to cause significant harmful effects on human health, fish, and wildlife, or may adversely affect the suitability of water for beneficial uses. Studies at Stewart Lake Waterfowl Management Area and Ouray National Wildlife Refuge indicated that concentrations of boron, selenium, and zinc in water, bottom sediment, and biological tissue were sufficiently large to be harmful to fish and wildlife, and to adversely affect beneficial uses of water. Concentrations of most other elements and pesticides in surface water generally were less than established standards with the exception of gross alpha radiation, which exceeded by factors of three to five times the standard of 15 picocuries per liter in water from two of the drains discharging into Stewart Lake.

Selenium is the principal element of concern in both areas. Concentrations of dissolved selenium in irrigation-drain water entering Stewart Lake Waterfowl Management Area ranged from 14 to 140 micrograms per liter and consistently exceeded Utah standards for wildlife protection in water in two of the four drains. Concentrations of boron and zinc exceeded Utah standards only occasionally in the drain waters. Concentrations of total selenium in sediments collected where the drains discharge into the lake were 10 to 85 micrograms per gram. Liver tissue collected from American coots at Stewart Lake Waterfowl Management Area contained concentrations of selenium from 4.9 to 26 micrograms per gram (dry weight), and whole-body samples of carp contained as much as 31 micrograms per gram (dry weight). Concentrations of selenium in <u>Potamogeton</u> and blue-green algae ranged from 2.1 to 27 micrograms per gram.

Concentrations of boron, selenium, and zinc were also measured in water from Ouray National Wildlife Refuge. Generally, both boron and zinc concentrations were within established State of Utah standards for wildlife protection. However, concentrations of selenium in two samples from the North Roadside Pond were 28 and 93 micrograms per liter compared to the State standard which is 50 micrograms per liter. This pond supplies water to the Sheppard Bottom pond complex, where it is supplemented with water from the Green River. The selenium concentration in the terminal pond in the complex was 3 micrograms per gram. Water at one site in the other major pond complex, Leota Bottom, contained a selenium concentration of less than 1 microgram per liter.

Liver tissue of American coots from the North Roadside Pond, which receives irrigation tailwater, contained a geometric-mean concentration of selenium of 32 micrograms per gram (dry weight). This is within the range

reported to cause detrimental effects to waterfowl at Kesterson National Wildlife Refuge in California. Liver tissue from American coots collected in the Leota Bottom area, which receives water primarily from the Green River, contained less than 5 micrograms per gram. Five water-bird eggs collected from the North and South Roadside Ponds contained selenium concentrations of 63 to 120 micrograms per gram (dry weight). The discovery of deformed American-coot embryos resulted in closure of a part of the Ouray National Wildlife Refuge for a short time in 1987.

INTRODUCTION

Background

During the last several years, there has been increasing concern about the quality of irrigation drainage, surface and subsurface water draining irrigated land, and its potential effects on human health, fish, and wildlife. Large concentrations of selenium have been detected in subsurface drainage 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 drainage water 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 has responsibility.

Initially, the Task Group identified 19 locations in 13 states that warranted reconnaissance investigations. These locations relate to three specific areas of DOI responsibilities: (1) irrigation or drainage facilities constructed or managed by the DOI, (2) national wildlife refuges that receive irrigation drainage, 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. These areas are:

Arizona-California: Lower Colorado-Gila River Valley area
California: Salton Sea area
Tulare Lake area
Montana: Sun River Reclamation Project area
Milk River Reclamation Project 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.

Purpose and Scope

This report describes the results of a two-year reconnaissance of irrigation-related contaminants and their effects on wildlife areas within the middle Green River basin. Because the study was a reconnaissance, data were collected to define only the magnitude and extent of contamination and not to describe the processes which were involved.

Acknowledgments

Appreciation is extended to property owners adjacent to Stewart Lake Waterfowl Management Area for allowing access to their lands. Special thanks to Neil Folks and Michael Ottenbacher, Utah Division of Wildlife Resources, and to Keith Hansen, Refuge Manager for the Ouray National Wildlife Refuge, for providing information, personnel, facilities and equipment that greatly aided this study. Electrofishing support was provided by Harold Tyus, Colorado River Fisheries Program, U.S. Fish and Wildlife Service.

STUDY AREA

Location and Wildlife Use

The Green River and its tributaries drain an area of nearly 45,000 square miles in Colorado, Utah, and Wyoming (fig. 1). The middle Green River basin is defined here as the area of about 25,500 square miles that consists of the drainage of the main stem of the Green River and its tributaries located between Flaming Gorge Reservoir on the north and the city of Green River, Utah, on the south (fig. 1). The Browns Park and Ouray National Wildlife Refuges, and the Browns Park, Stewart Lake and Desert Lake Waterfowl Management Areas are located within this area. An additional wildlife area, Pariette Wetlands, managed by the U.S. Bureau of Land Management, is located 8 miles south of the Ouray National Wildlife area. No land is irrigated in the vicinity of the Browns Park National Wildlife Refuge or the Browns Park Waterfowl Management Area. Because geologic maps do not indicate large outcrops of seleniferous material in or near these areas, they were not considered in the initial screening. Data from waterfowl collected in 1985 by the Utah Division of Wildlife Resources indicated concentrations of selenium were insignificant at the Desert Lake Waterfowl Management Area. The study team, therefore, concentrated efforts at the Stewart Lake Waterfowl Management Area, an area reported by the Sacramento Bee newspaper to have a selenium problem. The Ouray National Wildlife Refuge also was selected because of its proximity to the Stewart Lake Waterfowl Management Area and the extensive irrigation within its drainage basin.

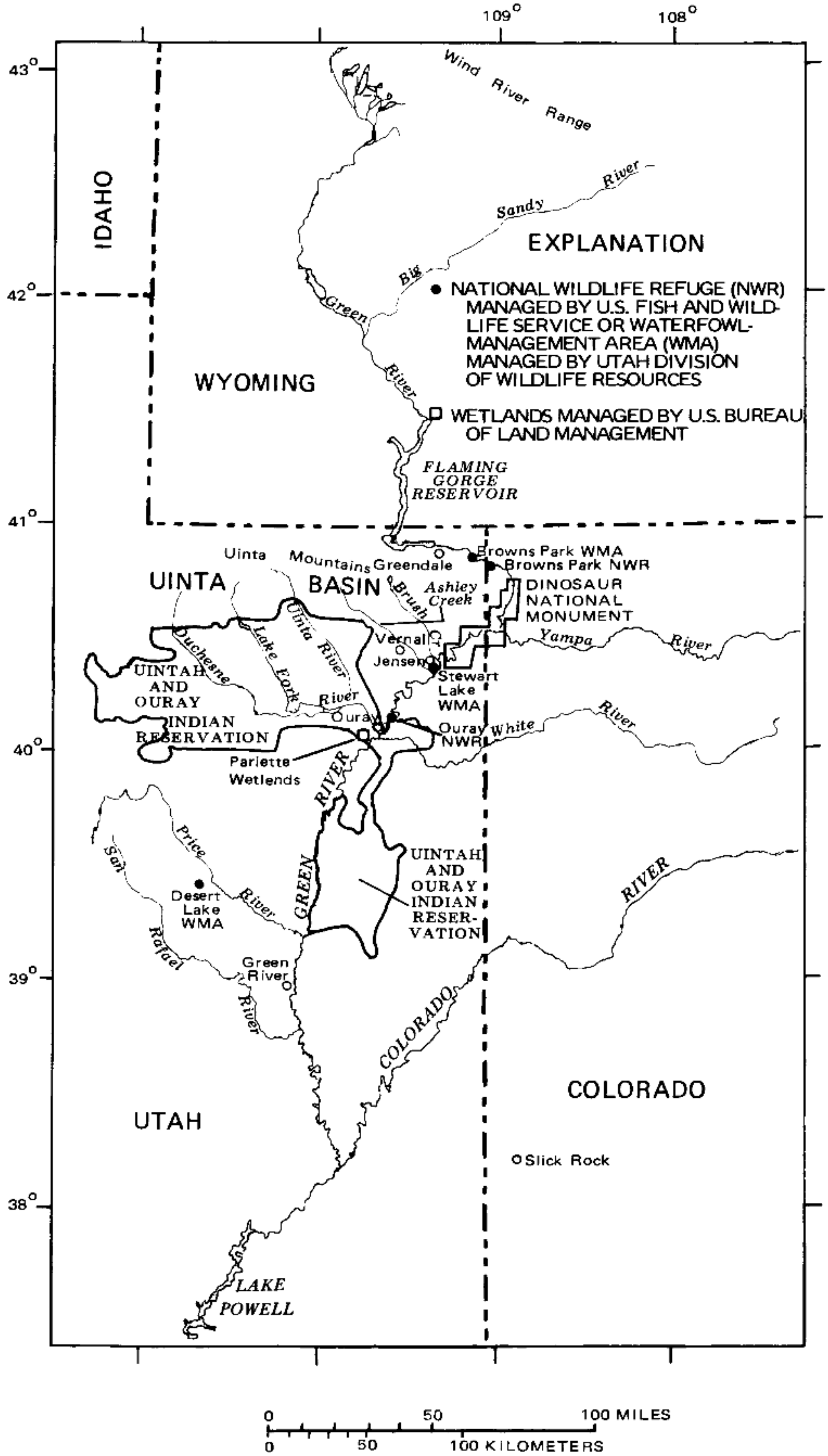


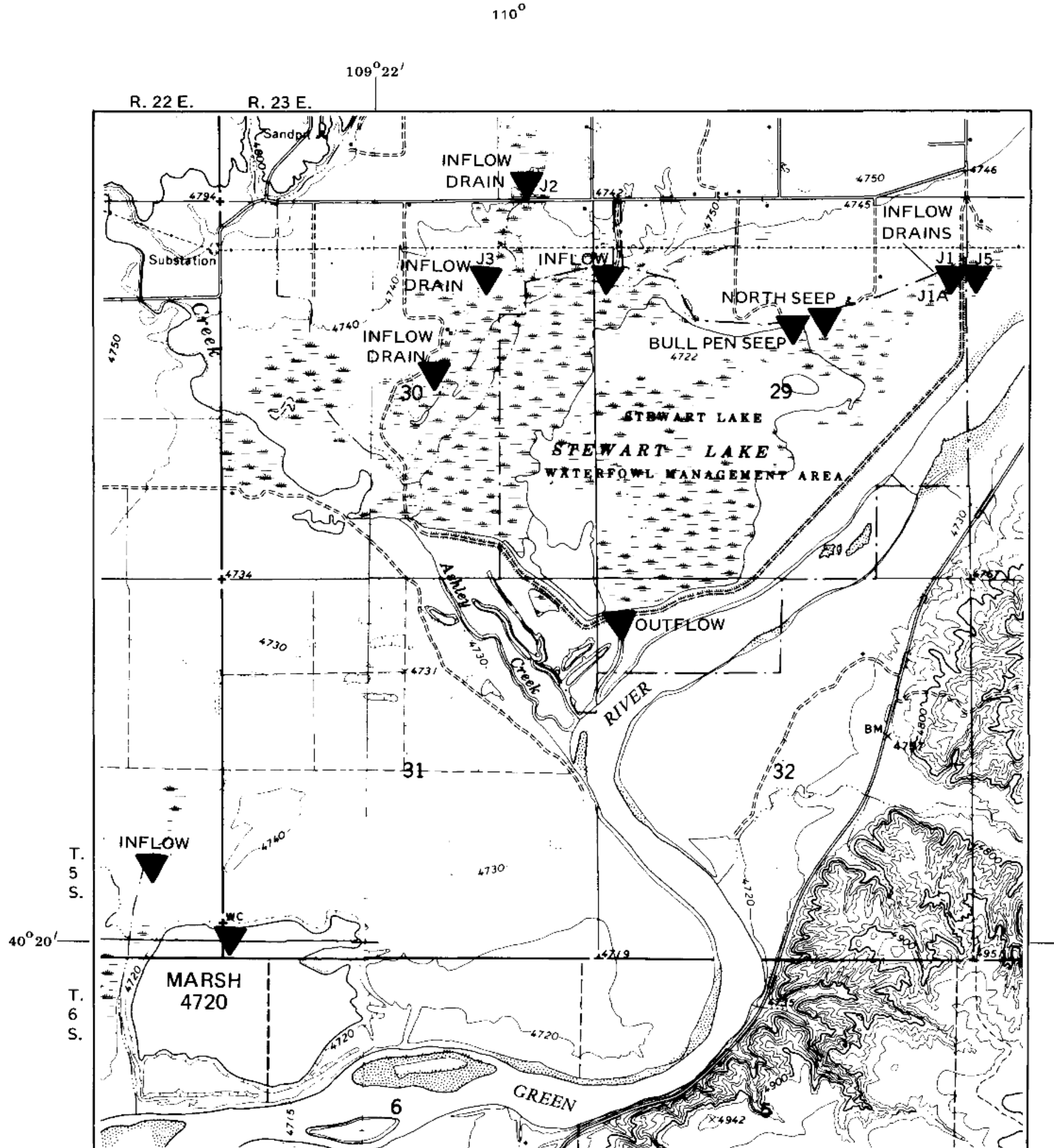
Figure 1.—The Green River and major tributaries, and location of national wildlife refuges, waterfowl-management areas, and managed wetlands within the middle Green River basin.

The Stewart Lake Waterfowl Management Area is located adjacent to the Green River (fig. 2), 12 miles southeast of Vernal, Utah. Stewart Lake has a surface area of about 250 acres and is operated by the Utah Division of Wildlife Resources. The principle sources of surface water to the lake are flows from four ground-water drains with a combined discharge of about 3 cubic feet per second, and a surface channel with a discharge of about 0.5 cubic foot per second. There is little management of the water level in Stewart Lake, but the lake is occasionally flushed when the level of the Green River rises, and river water flows into the lake through road culverts, which happened annually from 1983 to 1986. Waterfowl use is concentrated during migration and the breeding season. Few wildlife-use counts have been made for this management area. About 700-800 American coots, adult and young ducks, and Canada geese formerly used the lake for breeding and nesting during the summer. Waterfowl species nesting here in significant numbers include American coots, mallards, and gadwalls. The Green River provides limited winter habitat for ducks and Canada geese. Three species of endangered fish live in this area of the Green River. A suspected spawning site for Colorado squawfish (Ptychocheilus lucius) exists north of Jensen on the Green River; during high river flows, backwater areas are prime nursery habitat for the squawfish. The other two endangered species present are the humpback chub (Gila cypha) and bonytail chub (G. elegans). A species that is a candidate for being listed as endangered, the razorback sucker (Xyrauchen texanus), also is believed to spawn upstream from the Stewart Lake Waterfowl Management Area in the Green River. The marsh (called marsh 4720 in this report) along the Green River 1 mile south of the Stewart Lake Waterfowl Management Area is leased from private owners by the Utah Department of Natural Resources. This marsh receives irrigation tailwater that is not channeled into subsurface drains.

The Ouray National Wildlife Refuge is located on the Green River 30 miles southwest of Vernal near the town of Ouray, Utah (fig. 3). This refuge has an area of 11,483 acres, which includes 3,500 acres of leased land in the Uintah and Ouray Indian Reservation. The refuge was established in 1961 and is managed by the U.S. Fish and Wildlife Service primarily as waterfowl habitat. The refuge provides migration rest areas and nesting for about 200 species of marsh and water birds and raptors. Bird-use days exceed 1,850,000 annually, primarily by 14 species of ducks. This refuge also is used by migrating whooping cranes, wintering peregrine falcons, and bald eagles. The Green River provides a yearlong habitat for three species of endangered fish (Colorado squawfish, humpback chub, bonytail chub). The refuge is located in a desert environment and relies on flooding or pumping from the Green River or irrigation water derived from runoff from the Uinta Mountains for water supply.

Climate

The low-elevation or basin lands along the middle Green River are arid to semiarid; the climate gradually becomes more humid with increased elevation. The average annual precipitation in the area (1941-70) ranged from less than 8 inches near Ouray, to more than 38 inches in the high west-central part of the Uinta Mountains (Hood and Fields, 1978, p. 9). Storms from the northwest during October through April account for about 60 percent of the average annual precipitation (Fields and Adams, 1975).



Base from Jensen, 1965, 1:24,000 and
Rasmussen Hollow, 1965, 1:24,000

0 1 MILE
0 1 KILOMETER

CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
Datum is sea level

EXPLANATION

INFLOW ▼ DATA-COLLECTION SITE AND NAME—See table 4 for description of sites

Figure 2.—Data-collection sites at Stewart Lake Waterfowl Management Area and a nearby marsh.

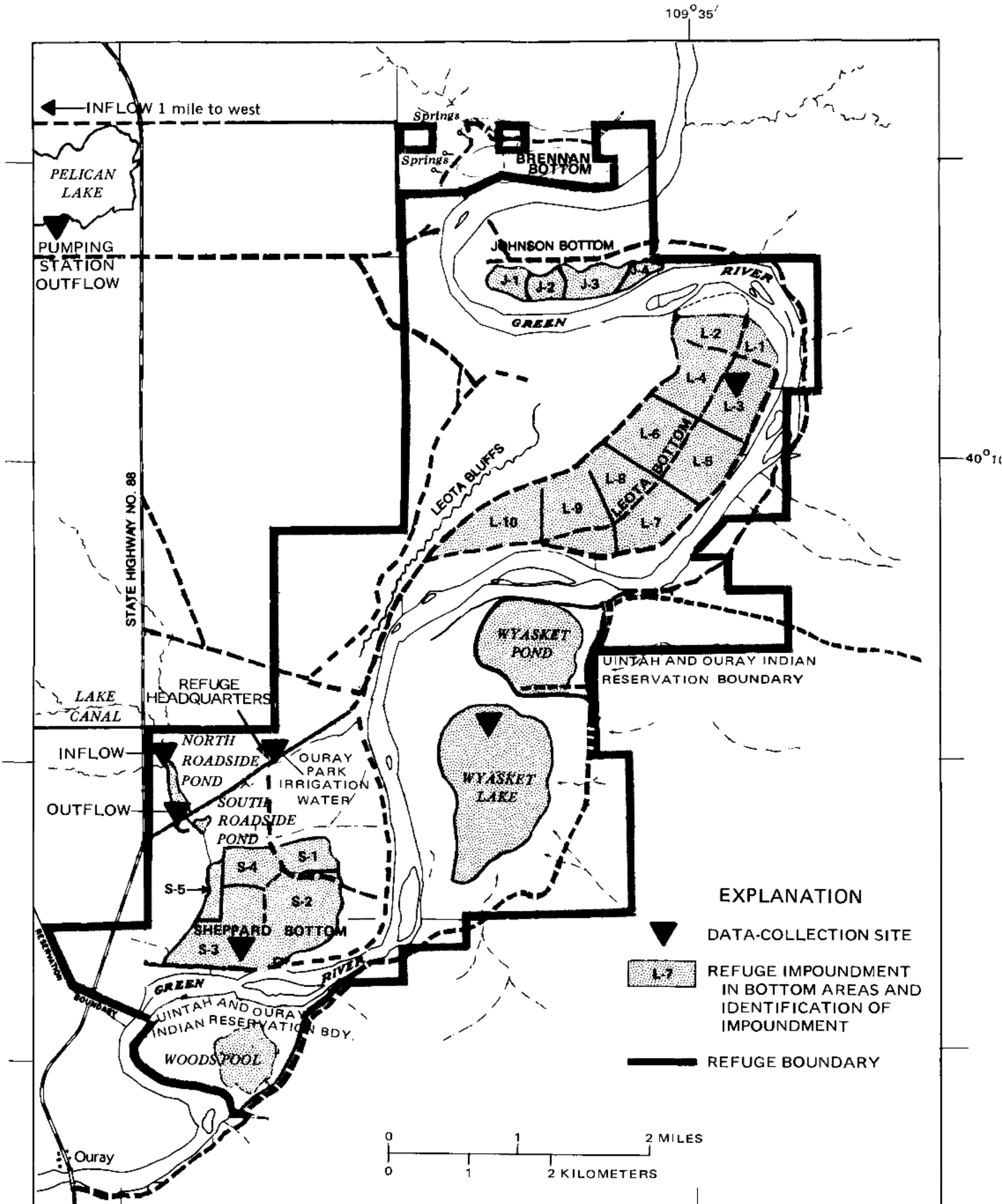


Figure 3.—Data-collection sites at Ouray National Wildlife Refuge and Pelican Lake.

The area has hot summers and cold winters. Wintertime temperatures commonly are less than 0 degree Fahrenheit, and summertime temperatures commonly exceed 90 degrees Fahrenheit. The average annual air temperature for the area (1941-70) ranged from about 48 degrees Fahrenheit at lower elevations to about 15 degrees Fahrenheit at the highest elevations in the mountains (Hood and Fields, 1978, p. 9).

Based on the average annual air temperature, potential evapotranspiration at Ouray is about nine times the average annual precipitation, or about 72 inches (Hood and Fields, 1978, p. 9). Thus, precipitation at the lower elevations is mainly lost by evaporation and transpiration and is not a source of water for streams or ground water recharge, and the precipitation at high elevations, where potential evapotranspiration is less than precipitation, provides surface and ground water for most of the basin.

Geology

Most of the area investigated in this reconnaissance is included in a structural basin called the Uinta Basin (fig. 1). The northern part of the Uinta Basin, an area of about 5,200 square miles in northeastern Utah and northwestern Colorado, extends from about the location of Browns Park National Wildlife Refuge on the northeast, to Ouray on the south and to the headwaters of the Duchesne River on the west. Rocks cropping out in the northern Uinta Basin range in age from Precambrian to Holocene. The exposed section has a composite thickness of about 58,000 feet in the western part of the basin and of about 53,000 feet in the eastern part of the basin (Hood and Fields, 1978, p. 6). The thickness and hydrologic characteristics of the geological units were described by Hood (1976, table 1). Geologic units and the occurrence of selenium within them are summarized in table 1.

The Uinta Basin is underlain by a partly dissected sequence of Tertiary rocks deposited in a subsiding trough with an east-trending axis that parallels the axis of the Uinta Mountains. Intermittent uplift and other structural events not only resulted in large-scale erosion of the rocks of early Tertiary age, but also faulted, fractured, and folded them. Glaciation during Pleistocene time carved the Uinta Mountains to approximately their current form and provided the debris from which the major unconsolidated hydrologic units of Quaternary age are formed.

Seven of the geologic units or their equivalents are considered to be either minor aquifers or to have significant effects on the ground water of the basin. Eight other units or their equivalents are classed as major aquifers. The remaining units have little permeability and either inhibit recharge or deter ground-water movement (Hood and Fields, 1978, p. 8). Some units contain evaporite deposits that greatly degrade the quality of the water moving through them (Hood and Fields, 1978, p. 8). These evaporite deposits, primarily within the Mancos Shale, create the water-quality problems associated with irrigation return flows in the area.

Table 1.—Geologic units that crop out in the northern Uinta Basin with classification of selenium occurrence

[Geologic units adapted from Hood and Fields, 1978, table 1; selenium occurrence from Rosenfeld and Beath, 1964, tables 2-7]

<table>
<tr><th rowspan="2"></th><th rowspan="2">Age</th><th colspan="2">Geologic unit</th></tr>
<tr><th>Western part of basin</th><th>Eastern part of basin</th></tr>
<tr><td rowspan="8">CENOZOIC</td><td rowspan="2">Quaternary</td><td colspan="2">Younger alluvium, gravel surfaces, landslide and talus deposits, and dune sand and other windblown deposits</td></tr>
<tr><td colspan="2">Glacial deposits, alluvium of Pleistocene age, and terrace deposits</td></tr>
<tr><td rowspan="6">Tertiary</td><td colspan="2">Browns Park Formation - Seleniferous in areas</td></tr>
<tr><td>Extrusive igneous rocks</td><td>Absent</td></tr>
<tr><td colspan="2">Duchesne River Formation - Seleniferous in areas</td></tr>
<tr><td colspan="2">Uinta Formation - Seleniferous in areas</td></tr>
<tr><td colspan="2">Green River Formation - Seleniferous in areas</td></tr>
<tr><td colspan="2">Wasatch Formation - Seleniferous in areas</td></tr>
<tr><td rowspan="11">MESOZOIC</td><td rowspan="4">Cretaceous</td><td>Current Creek Formation</td><td>Absent</td></tr>
<tr><td colspan="2">Mesaverde Group</td></tr>
<tr><td colspan="2">Mancos Shale (including Frontier Sandstone Member) - Seleniferous</td></tr>
<tr><td colspan="2">Dakota Sandstone and Cedar Mountain Formation, undivided</td></tr>
<tr><td rowspan="4">Jurassic</td><td colspan="2">Morrison Formation - Seleniferous</td></tr>
<tr><td colspan="2">Curtis Formation - Seleniferous</td></tr>
<tr><td colspan="2">Entrada Sandstone - Seleniferous</td></tr>
<tr><td>Twin Creek Limestone</td><td>Carmel Formation</td></tr>
<tr><td>Jurassic (?) and Triassic (?)</td><td colspan="2">Glen Canyon Sandstone
(Nugget Sandstone of Stokes, 1964) (Navajo Sandstone of Stokes, 1964)</td></tr>
<tr><td rowspan="2">Triassic</td><td colspan="2">Chinle Formation (including Gartra Member) - Seleniferous</td></tr>
<tr><td>Mahogany Formation (Ankareh Formation of Stokes, 1964: Thaynes Formation - Seleniferous Woodside Formation (or Shale)</td><td>Moenkopi Formation - Seleniferous</td></tr>
<tr><td rowspan="6">PALEOZOIC</td><td>Permian</td><td colspan="2">Park City Formation (or Group)</td></tr>
<tr><td>Permian and Pennsylvanian</td><td colspan="2">Weber Quartzite (or Sandstone or Formation)</td></tr>
<tr><td>Pennsylvanian</td><td colspan="2">Morgan Formation</td></tr>
<tr><td>Pennsylvanian and Mississippian</td><td colspan="2">Manning Canyon (?) Shale (of Stokes, 1964) - Seleniferous</td></tr>
<tr><td>Mississippian</td><td>Upper Mississippian rocks, undivided
Lower Mississippian rocks, undivided</td><td>Mississippian rocks, undivided</td></tr>
<tr><td>Cambrian</td><td>Tintic Quartzite</td><td>Lodore Formation</td></tr>
<tr><td rowspan="3"></td><td rowspan="3">Precambrian</td><td>Red Pine Shale of Uinta Mountain Group</td><td>Absent</td></tr>
<tr><td colspan="2">Unnamed quartzite unit of Uinta Mountain Group
(Mutual Formation of Stokes, 1964)</td></tr>
<tr><td>Lower part of the Uinta Mountain Group, undivided</td><td>Absent</td></tr>
</table>

In the Jensen area, the Mancos Shale is more than 5,000 feet thick and is the formation on which the Green River flows in much of the area (Untermann and Untermann, 1954, p. 63, 64). The Mancos consists of gray- and yellow-weathered, soft, calcareous shales of marine origin, containing a few sandstone lenses and nodular calcareous beds. Thin calcareous seams, selenite gypsum, epsomite, and other minerals commonly occur in the Mancos. The shale flattens toward the Jensen syncline, an east-trending syncline that approximately parallels the axis of the basin, and, where exposed, weathers easily. The agricultural lands of the Jensen valley overlie this formation. Where drainage is not well developed, the Mancos Shale supports vegetation consisting chiefly of salt-brush types. Samples of pyrite and marcasite collected from the Mancos Shale near Slick Rock, Colorado, contained an average of 140 micrograms per gram selenium (Coleman and Delevaux, 1957, p. 519). In comparison, the average concentration of selenium in a typical shale is 0.6 micrograms per gram (Drever, 1982, p. 298).

Near the Ouray National Wildlife Refuge, gravel of Quaternary age and alluvial deposits of Holocene age characterize the surficial geology. Fluvial and lake deposits of the Uinta Formation and fluvial sandstone and mudstone of the Duchesne River Formation underlie most of the upland areas and the reach of the Green River between the Stewart Lake Waterfowl Management Area and the Ouray National Wildlife Refuge.

Soils and Agriculture

Agricultural lands near Jensen and the Stewart Lake Waterfowl Management Area are located on upper and lower benches. The soils of these benches were developed on alluvial material of Holocene age that has been modified and reworked by the Green River. The soils have no distinct profile patterns or horizons. Areas of deep, fine-textured soils are commonly close or adjacent to areas of coarse-textured soils or shallow soils overlying gravel mixed with cobbles. The soils are aquic xerofluvent and ustifluvent types, and are slightly to substantially alkaline (Wilson and others, 1975, p. 43). Geochemical data for soils in the area were not available, but soils developed on Mancos Shale 100 miles south of Jensen have total selenium concentrations ranging from 4 to 5.6 micrograms per gram, whereas soils developed on the Morrison Formation near the same area contain 40 to 90 micrograms per gram (Rosenfeld and Beath, 1964, p. 45).

The valley adjacent to Brush Creek is characterized by narrow tracts of arable land that are slightly rolling with moderate slopes. Much of the arable land consists of small alluvial fans deposited at right angles to the major stream course. The soils are developed on alluvial material of Holocene age. They are yellowish-brown, thick, and medium textured except for an occasional clay profile. The fields generally are small and irregularly shaped, resulting in short to moderately long irrigation conveyances. The larger areas of arable land are located near the mouth of Brush Creek.

Soils near the Ouray National Wildlife Refuge are developed on alluvium similar to those near Jensen. However, the typic calciorthid soils near the refuge generally are thick and moderately to substantially alkaline. Surface layers are reddish-yellow and consist of silt and loam. Calcium-carbonate layers occur between depths of 10 and 40 inches. These soils are well drained and surface-water runoff from them is rapid.

The principal agricultural enterprise in both areas is the production of beef cattle, with production of sheep of secondary importance. Irrigated lands are devoted almost exclusively to crops used for feeding livestock during the winter. About 73 percent of the irrigated land is used to grow alfalfa hay or for pasture. Corn silage and small grains also are important crops.

PREVIOUS STUDIES

Occurrence of Selenium in Rocks and Soils

Considerable variation occurs in the distribution of selenium within geologic formations and within soils derived from underlying geologic formations. Rosenfeld and Beath (1964, p. 9) attribute the origin of selenium in Cretaceous deposits to volcanic dust deposited into Cretaceous seas. However, not all seleniferous deposits are associated with volcanic debris. The Manning Canyon Shale of Pennsylvanian and Late Mississippian age near Provo, Utah (120 miles west of Vernal) contains beds that are among the most seleniferous in the western conterminous United States, yet there is no evidence that volcanoes were active in Utah during or immediately preceding the time that these beds were deposited. Rosenfeld and Beath (1964, p. 11) hypothesize that erosion of igneous or seleniferous sedimentary rocks or absorption by marine organisms and subsequent deposition were responsible for the accumulation of selenium in the Manning Canyon Shale.

Selenium, during the decomposition of geologic materials, probably alters to selenite ions that may combine with cobalt, copper, iron, or molybdenum (Rankama and Sahama, 1950, p. 599). Little is actually known about the forms of selenium in the soils that produce toxic vegetation. Trelease and Beath (1949, p. 106) reported that more than one-half of several thousand soil samples tested contained less than 1 microgram per gram selenium and that the maximum content was 100 micrograms per gram. Most of this selenium was believed to occur as ferric selenite, $Fe_2(OH)_4SeO_3$, and is unavailable to plants, but 95 percent of the selenium could be freed by leaching the soils with sulfuric acid. Elemental selenium may be present in exceedingly small concentrations in some soils as certain bacteria, fungi, and algae are capable of reducing selenites and probably selenates to the elemental form. Biological reduction, using bacteria of the genus Clostridium, has recently been reported as an effective means of removing selenium ions from uranium ore under acidic conditions (Kauffman and others, 1986).

In most soils, the water-soluble concentration of selenium is less than 0.1 microgram per gram (Trelease and Beath, 1949, p. 107). Selenium that is available to plants occurs in the soil in organic compounds and as the selenate ion. Organic selenium compounds are released through the decay of plants. The inorganic fraction probably is mostly calcium selenate. The soluble compounds generally are leached out of the surface soil in humid climates, but in arid climates, such as that of the middle Green River basin, they become enriched in the surface soil through the seasonal decay of seleniferous vegetation or by evaporation of the soil water that has moved upward by capillary action or both. It is likely that biological accumulation is the more important of the two processes in Utah. Cannon (1964, p. 55) reported that *Astragalus pattersoni* in southeastern Utah contained 12,000 micrograms per gram selenium (in the plant ash) extracted from soil containing only 8 micrograms per gram selenium. Trelease and Beath (1949) further reported plants bioconcentrating selenium to the following concentrations, in micrograms per gram:

Astragalus bisulcatus	5,530
Stanleya pinnata	1,190
Atriplex nuttallii	300
grasses	23

Trelease and Beath (1949) also mapped areas where seleniferous plants occurred. The middle Green River basin contains several areas characterized by plants containing more than 500 micrograms per gram selenium; species of plants found in the area that concentrate selenium and indicate its presence in the soil are listed in table 2. The genus *Astragalus*, known as locoweed, has 38 to 40 species in Utah. Twenty three of these species grow in the middle Green River basin (Lois Arnow, Utah Herbarium, written commun., 1987). All of the 23 species grow only on seleniferous soils.

Trelease and Beath (1949, p. 146) state that the water-soluble fractions of selenite, selenate, and organic selenium are not equally available to plants. The only reliable method of determining the selenium that can be supplied by the soil is to determine the selenium concentration in the various species of plants growing on the soil.

Aqueous Chemistry of Selenium

Under aerobic or oxidizing conditions, selenium is transported in water in the selenite or selenate forms (oxidation states of +4 and +6) that are readily soluble. Under anaerobic or reducing conditions, selenium can form metal selenides by direct reaction or by substitution for sulfur in metal sulfides. Most of the metal selenides are minimally soluble (Versar Inc., 1979, p. 16-1). Selenium is removed from aqueous solution by adsorption on precipitated hydroxides of iron and manganese, organic matter, and iron sulfides. In reducing environments, such as anaerobic muds, hydrogen selenide may form and escape as a gas. Selenium also may be methylated by organisms and escape as a gas. In the aquatic environment, selenium is taken up as selenate or selenite by plants and incorporated into amino acids, such as cysteine or methionine. Selenate and organic selenium are the forms most available to organisms. It is through the amino-acid protein pathway that selenium bioaccumulates in organisms. The importance of biological processes in cycling selenium in the environment was postulated by Shrift (1964) with confirmation of several of the reduction reactions given by Rosenfeld and Beath (1964, p. 347) and recently by Kauffman and others (1986, p. 244). A comprehensive review of the chemistry of selenium has been written by Zingaro and Cooper (1974).

Table 2.--Plant species growing in the middle Green River basin that are known to be indicators of seleniferous soils

Species	Common name	Elevation (feet)	Period of bloom
Astragalus flavus	Locoweed	2,780-5,580	April-June
Astragalus preussii	do	2,780-6,400	April-May
Astragalus praelongus	do	2,780-7.050	April-July
Astragalus sabulosus	do	4,100-5,090	April-May
Astragalus moencoppensis	do	4,670-6,460	May-June
Astragalus eastwoodiae	do	4,770-5,430	April-May
Astragalus bisulcatus	do	4,790-8,450	May-July
Astragalus asclepiadoides	do	4,800-6,200	May-June
Astragalus racemosus	do	5,360-6,460	May-June
Astragalus hamiltonii	do	5,500-5,900	May-June
Astragalus pattersonii	do	5,760-7,860	May-June
Xylorhiza glabriuscula	Woody aster	[1]4,690	May-June
Xylorhiza fenusta	do	4,000-6,800	May-June
Stanleya pinnata	Prince's plume	3,080-9,100	May-August
Stanleya viridiflora	do	5,080-8,940	July-August

[1]Single observation

Relation of Selenium to Health

The dietary requirements for selenium in most animal species range from 0.05 to 0.20 microgram per gram (Combs and Combs, 1986, p. 510). Selenium toxicity has been reported in livestock consuming feeds containing large concentrations of selenium in the western United States. Forage crops with selenium concentrations of 10 to 30 micrograms per gram (dry weight) may produce toxicity symptoms in cattle (Church and others, 1971). Trelease and Beath (1949) reported "Selenium content has been found to be highly variable over even relatively small areas ... The selenium content in plants shows no relationship to either the total or water soluble selenium in the soil samples ... Water soluble soil selenium varies from 0.05-18.99 micrograms per gram and constitutes from 1.1 to 62.0 percent if the total selenium ... No evidence has been obtained thus far that selenium occurring in water supplies, even in the most seleniferous areas, is sufficient to produce either alkali disease or blind staggers in livestock".

Selenium and arsenic were commonly regarded as toxins during 1930-40. However, from 1960 to the present (1987), these and other trace elements have been determined to be essential and vital in plant and animal nutrition. Recent studies have determined that selenium can decrease the toxic affects of various other trace elements. Selenium and vitamin E have been determined to be antidotes to toxicity caused by arsenic and trace metals, particularly cadmium, lead, mercury, silver, and thallium (Frost, 1981; Whanger, 1981). Dietary supplements of cadmium, cobalt, copper, silver, tellurium, vanadium, and zinc were reported to induce selenium vitamin-E deficiency lesions in birds and pigs in laboratory experiments (Van Vleet and Boon, 1981). In laboratory studies, live animals fed selenium-amended diets were determined to have greater concentrations of trace metals in liver and kidney tissue than a group of animals that died because of metal toxicity. It was speculated that selenium forms inorganic complexes with other trace metals and that these complexes are insoluble and biologically unavailable (Combs and Combs, 1986, p. 243-246).

Water Quality in and near the Stewart Lake Waterfowl Management Area

The U.S. Bureau of Reclamation sampled the water discharging from irrigation drains to the Stewart Lake Waterfowl Management Area and the outflow from the lake from about 1978 to April 1986. The samples were analyzed by the Utah Department of Health Laboratory in Salt Lake City; analyical procedures used generally were those specified by American Public Health Association and others (1985). The extensive analysis of the samples included determination of concentrations of major ions, nutrients, oxygen-demanding substances, suspended solids, trace elements, and common pesticides. Most of the major-ion data indicated that the water was hard and of a sodium sulfate or calcium sulfate type (fig. 4). Summary statistics for nitrate, eight potentially toxic trace elements, and two herbicides are presented in table 3. Maximum concentrations of nitrate exceeded the Utah standard of 18 micrograms per liter only at drain J4. Maximum concentrations of arsenic, cadmium, lead, mercury, selenium, and the two herbicides did not exceed the Utah standards. Maximum concentrations of boron were larger than the Utah standard of 750 micrograms per liter in water from drains J2, J3 and J4, and the outflow. Mean concentrations of boron were larger than the Utah standard at drain J4 and the outflow. The maximum concentration of copper exceeded the Utah standard of 40 micrograms per liter at drain J4. Mean concentrations of zinc did not exceed the Utah standard of 50 micrograms per liter, but maximum concentations in water from all sites exceeded the standard.

Concentrations of selenium in water samples analyzed by the State of Utah were never larger than the Utah standard of 50 micrograms per liter and are considerably less than those determined by the U.S. Geological Survey during the current reconnaissance. Officials from the U.S. Bureau of Reclamation met with Utah Department of Health officials in February 1987 to determine the exact methodology used to determine selenium concentrations. The method currently (1987) in general use involves generation of selenium hydride followed by reduction to selenium and measurement using atomic absorption. No sample-digestion procedure is used prior to analysis. It is not certain, however, if that method has been in use since the initiation of the sampling in 1978. The method used by U.S. Geological Survey utilizes the same general procedure, but requires digestion of the sample using potassium permanganate in a hot acid solution followed by reduction of the selenate to selenite using hydrochloric acid. A final conversion to selenium hydride is made with sodium borohydride. Analysis without digestion does not include organic selenium or that form of selenium present as selenate ion, which potentially may represent a large proportion of the selenium present.

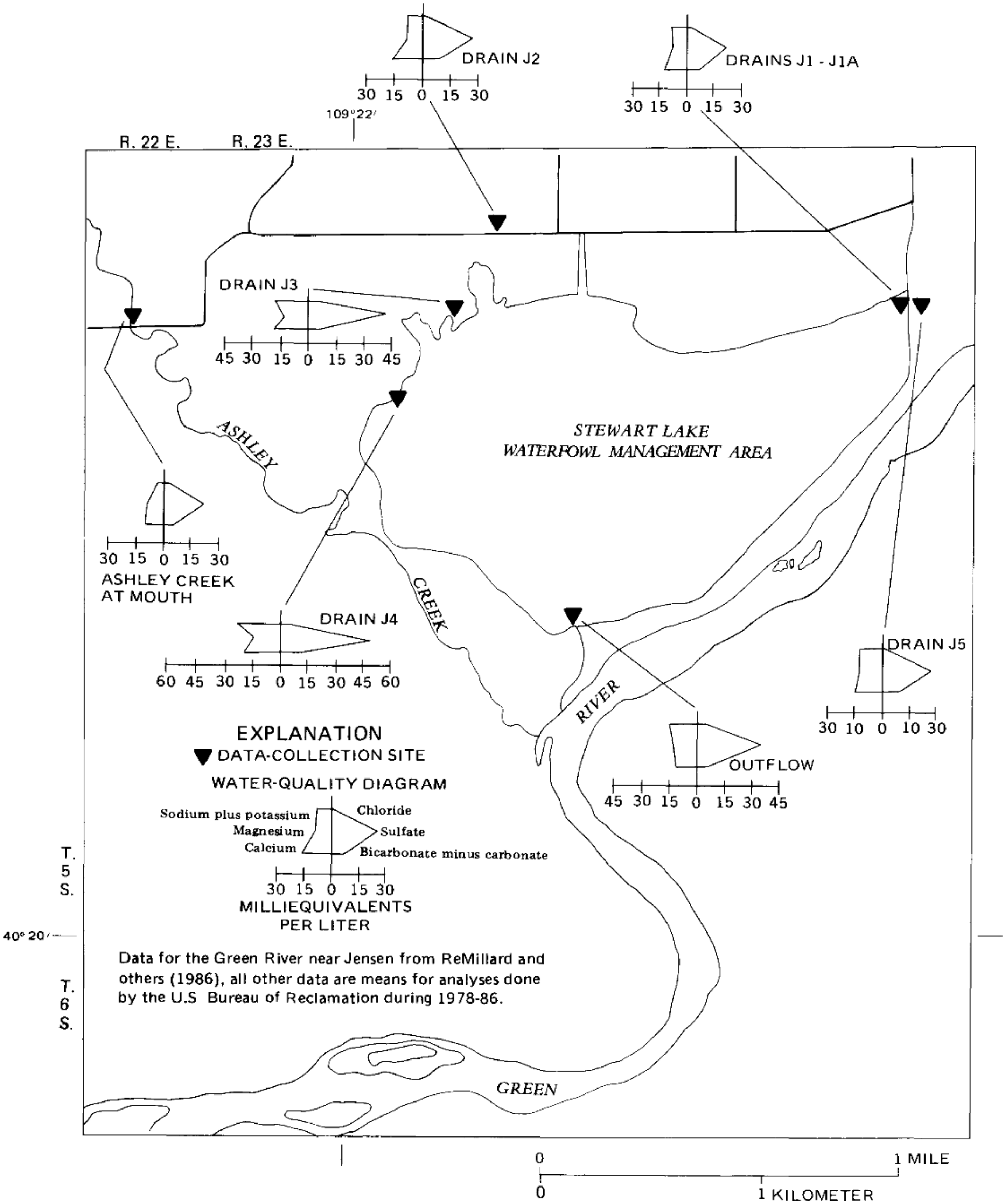


Figure 4.—Concentrations of major ions in surface and drain water in and near the Stewart Lake Waterfowl Management Area.

Table 3.--**Summary of concentrations of nitrate, selected trace elements, and two herbicides in unfiltered water samples from irrigation drainage entering Stewart Lake and in the outflow from the lake, 1978-86**

[Data from U.S. Bureau of Reclamation monitoring done generally monthly or bimonthly.
The standard given in parentheses is that of the Utah Department of Social Services, Division of Health (1983) and is the Utah standard for aquatic-wildlife protection except for boron which is an agricultural standard and the herbicides which are domestic-source standards. Concentrations of selenium likely represent the selenite ion only.
Units: mg/L, milligrams per liter; μg/L, micrograms per liter; ng/L, nanograms per liter]

Sampling Site	Constituent (Utah standard)																	
	Nitrate, as NO_3 mg/L (18)			Arsenic, μg/L (140)			Boron, μg/L (750)			Cadmium, μg/L (16)			Copper, μg/L (40)			Lead, μg/L (200)		
	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.
Drains J1-1A	3.97	0.14	5.35	0.64	0.25	2.24	392	60	662	1.01	0.50	6.00	8.6	2.5	35	9	1	104
Drain J2	3.04	.03	5.75	1.08	.15	6.30	571	60	870	1.02	.15	7.00	7.8	2.5	25	8	1	99
Drain J3	6.24	3.80	17.40	.40	.25	1.00	490	175	805	.66	.50	5.00	8.5	5.0	25	6	3	97
Drain J4	7.47	5.10	37.50	.44	.25	2.00	752	225	1,278	.68	.50	5.00	9.9	5.0	55	7	3	123
Drain J5	1.59	.00	10.16	1.68	.15	5.40	351	85	627	.96	.15	6.00	6.0	2.5	15	8	1	86
Outflow	.17	.00	1.30	1.81	.15	12.20	815	25	2,748	1.01	.15	6.30	7.8	2.5	25	8	1	99

Sampling Site	Constituent (Utah standard)														
	Mercury, μg/L (1)			Selenium μg/L (50)			Zinc μg/L (50)			2,4-D ng/L (100,000)			2,4,5-T ng/L (10,000)		
	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.
Drains J1-1A	0.059	0.007	0.200	0.4	0.2	0.9	23	3	275	288	30	1,400	98	50	200
Drain J2	.055	.007	.460	.6	.2	2.2	28	3	504	157	2	1,800	17	1	100
Drain J3	.060	.050	.100	.9	.2	2.0	16	3	60	164	25	400	101	50	490
Drain J4	.058	.050	.100	.4	.2	1.5	26	3	305	542	25	3,900	348	50	2,400
Drain J5	.049	.005	.230	.7	.2	2.3	20	3	277	130	1	1,000	39	1	300
Outflow	.056	.007	.300	.8	.2	4.4	20	3	216	45	1	500	22	1	100

Data from the U.S. Geological Survey hydrologic station on the Green River near Jensen characterize the water as hard (250 milligrams per liter), with a small sodium-adsorption ratio (less than 3) but generally large percentage of sodium (30 percent). No analyses have been made of trace elements at this site other than boron, which typically is less than 100 micrograms per liter. Trace-element data are available for hydrologic stations upstream and downstream from the study area at the Green River near Greendale (downstream from Flaming Gorge Reservoir) and at the Green River at the city of Green River (ReMillard and others, 1986 and earlier volumes in that series). Generally the water is suitable for all uses, but concentrations of some trace elements, notably zinc, may exceed Utah standards for wildlife protection. Concentrations of boron, selenium, and zinc for the Green River at Greendale and at the city of Green River from 1980 to 1986 are summarized in figure 5.

HYDROLOGIC SETTING

Streamflow

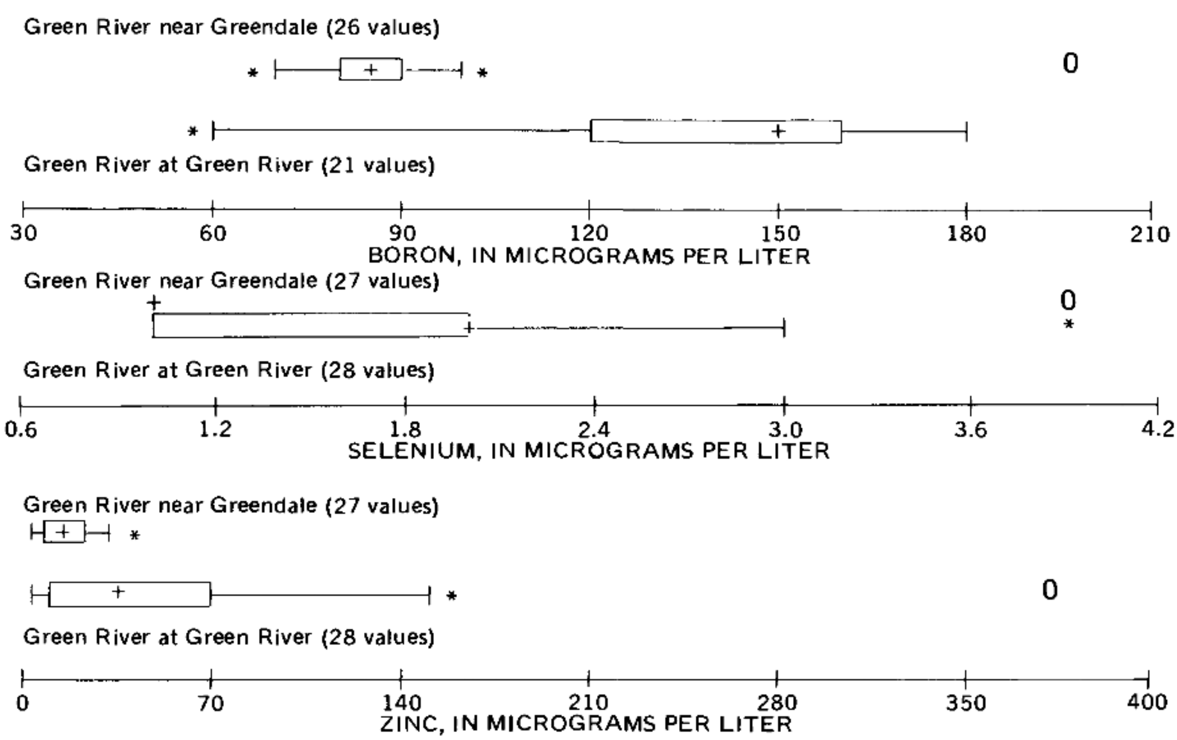
Flow throughout the middle Green River basin was much greater than average from 1983 to 1986, as indicated by the continuous record for the Green River near Jensen (fig. 6). The mean discharge at this site is about 4,500 cubic feet per second for the period of record, water years 1947-86. Annual flooding of the Stewart Lake Waterfowl Management Area in May and June since 1982 is a direct result of the large flows in the Green River in the spring of each year.

Inflow to and Outflow From Stewart Lake

No continuous records of streamflow into or from Stewart Lake are available. Inflow and outflow data for Stewart Lake collected by the U.S. Bureau of Reclamation from the start of the monitoring to April 1986, and the flows measured during reconnaissance in 1986 are summarized in table 4. Once the lake reaches a controlled depth of 3 to 4 feet in early summer, it stabilizes such that the inflow and outflow are equal. The total inflow from the drains generally averages less than 4 cubic feet per second, but it constitutes most of the inflow to the lake. Unmeasured ground-water seepage along the north shore contributes an unknown quantity of flow to the lake. During April 1987, a flow of 0.3 gallon per minute was measured from a pipe draining a field along the north shore. A total flow of 2 to 3 gallons per minute was also estimated to be entering the lake from about six seeps in the same area.

Irrigation and Drainage Near Stewart Lake Waterfowl Management Area

The Jensen Unit of the U.S. Bureau of Reclamation's Central Utah Project provides irrigation water from Red Fleet Reservoir via Brush Creek for about 4,000 acres near the Stewart Lake Waterfowl Management Area (fig. 7). About 90 percent, or 3,600 acres, are supplemental-service areas that receive only a part of their irrigation water from the Jensen Unit. The other 10 percent, or 400 acres, are full-service areas. The full-service areas are in small tracts interspersed among the supplemental service areas. The land served by the



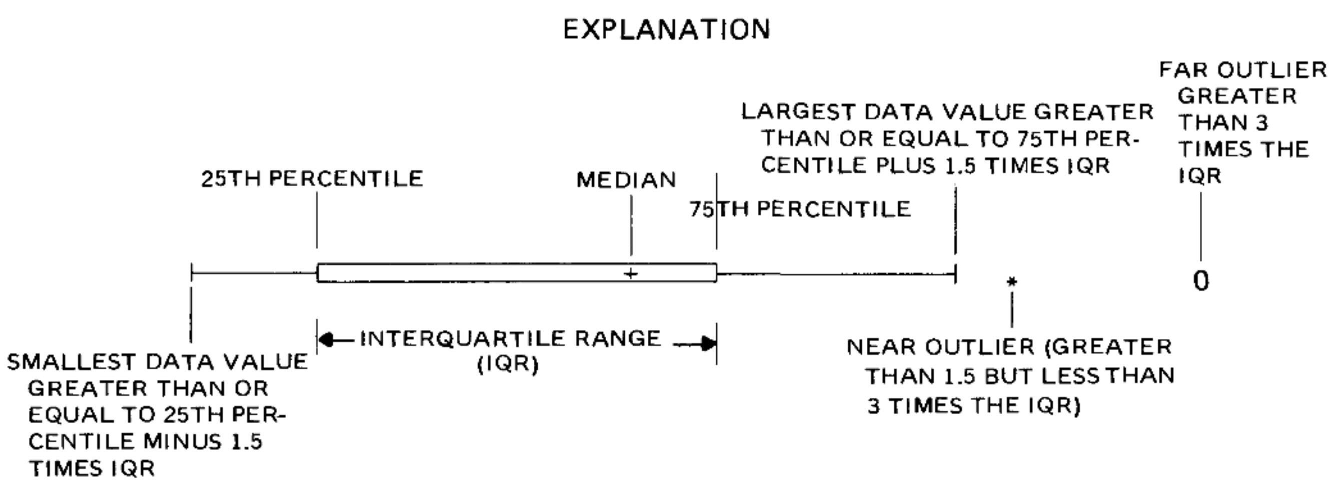


Figure 5.—Boxplots of concentration data for boron, selenium, and zinc in the Green River, 1980-86.

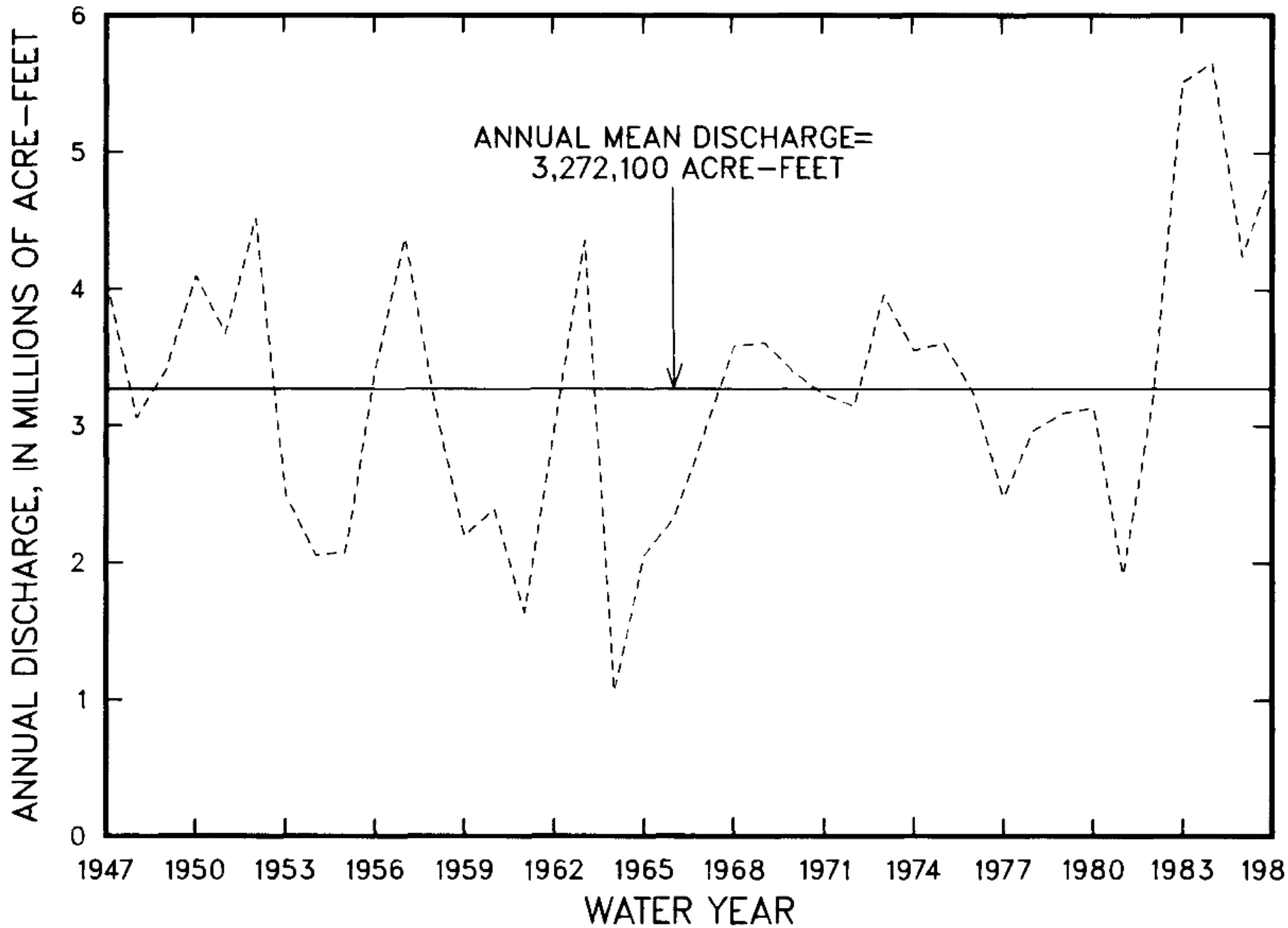


Figure 6.—Annual and annual mean discharge of the Green River near Jensen, Utah, water years 1947-86.

Table 4.—Summary of inflow to and outflow from Stewart Lake 1978-86

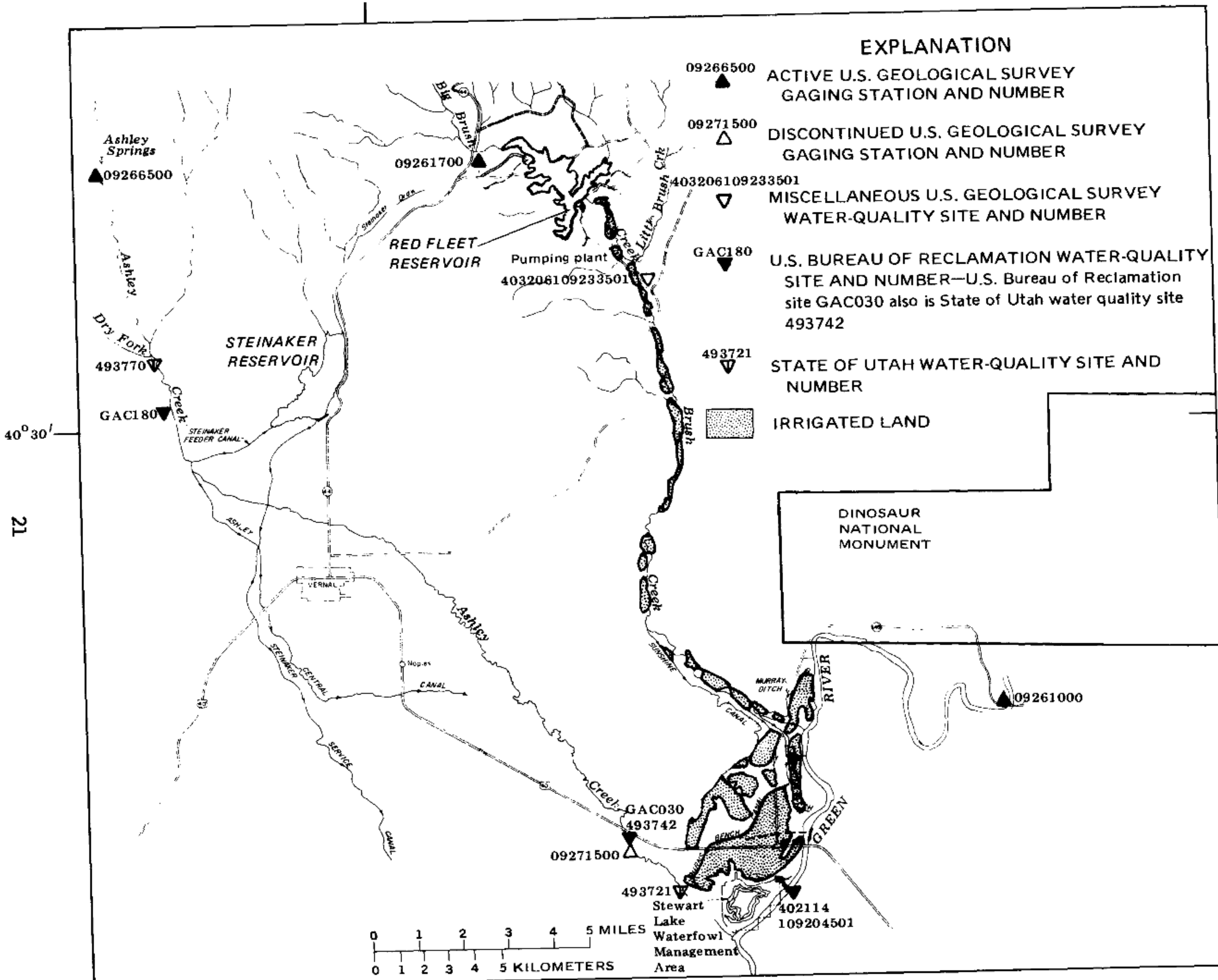
[All flows in cubic feet per second]

	U.S. Bureau of Reclamation data				Data collected during 1986	
Site	Time period	Mean	Minimum	Maximum	June	August
Drains J1-1A	8-80 to 4-86	1.62	0.20	25	2.50	3.40
Drain J2	11-78 to 4-86	.72	.01	2	1.3	1.7
Drain J3	2-81 to 4-86	.52	.06	3.5	.22	.35
Drain J4	2-81 to 4-86	.34	.05	1.1	.2	.58
Drain J5	2-78 to 4-86	.58	.01	2	.39	.1
Outflow	6-78 to 4-86	2.28	.01	27.3	20	1.1

project generally is well leached of soluble salts and is productive. The land that is presently (1987) irrigated has been irrigated on a sustained basis for more than 60 years.

Drainage facilities were installed by the U.S. Bureau of Reclamation from 1974 to 1979. Although there are about 4,000 acres of irrigated lands in the Jensen area, the federally sponsored drainage system involves only about 750 acres, almost all of which are supplemental-service areas. The land that required drains occupies topographic lows near the northern edge of the Stewart Lake Waterfowl Management Area and was either deficient in drainage or was expected to become deficient during the duration of the project. This land is subject to flooding by surface water and subsurface inflow of ground water from land higher on the bench, has an almost flat surface, and has no well developed outlet channels for surface runoff and subsurface drainage. The land, however, is permeable so that artificial drainage is feasible. The Jensen area and the Stewart Lake Waterfowl Management Area after completion of the drainage project are shown in figure 8.

Four ground-water drains, consisting of 8- to 18-inch diameter concrete pipe with bell and spigot unions, discharge to the lake (fig. 9). The unions are designed to provide about a one-eighth inch gap that allows water to percolate into the pipe through the 4-inch gravel pack surrounding it. The drains are at a depth of 8 to 10 feet beneath the surface of the agricultural land north of the lake. Manholes every 1,200 feet provide access to the pipe for cleaning. The total discharge from these drains typically averages about 7 cubic feet per second during summer and 3 cubic feet per second during winter. Drain J5, also known as the Oden drain, is actually a surface-water inlet from a marsh which drains a lowland area between the eastern edge of the lake and the Green River and does not include any buried concrete pipe. It is



Base from U.S. Bureau of Reclamation, Jensen Unit-Utah, 1975, 1:6,500,000

Figure 7.—Gaging stations, water-quality sites, and irrigated land near the Stewart Lake Waterfowl Management Area.

Figure 8.—The Stewart Lake Waterfowl Management
Area in 1981, view to the north.

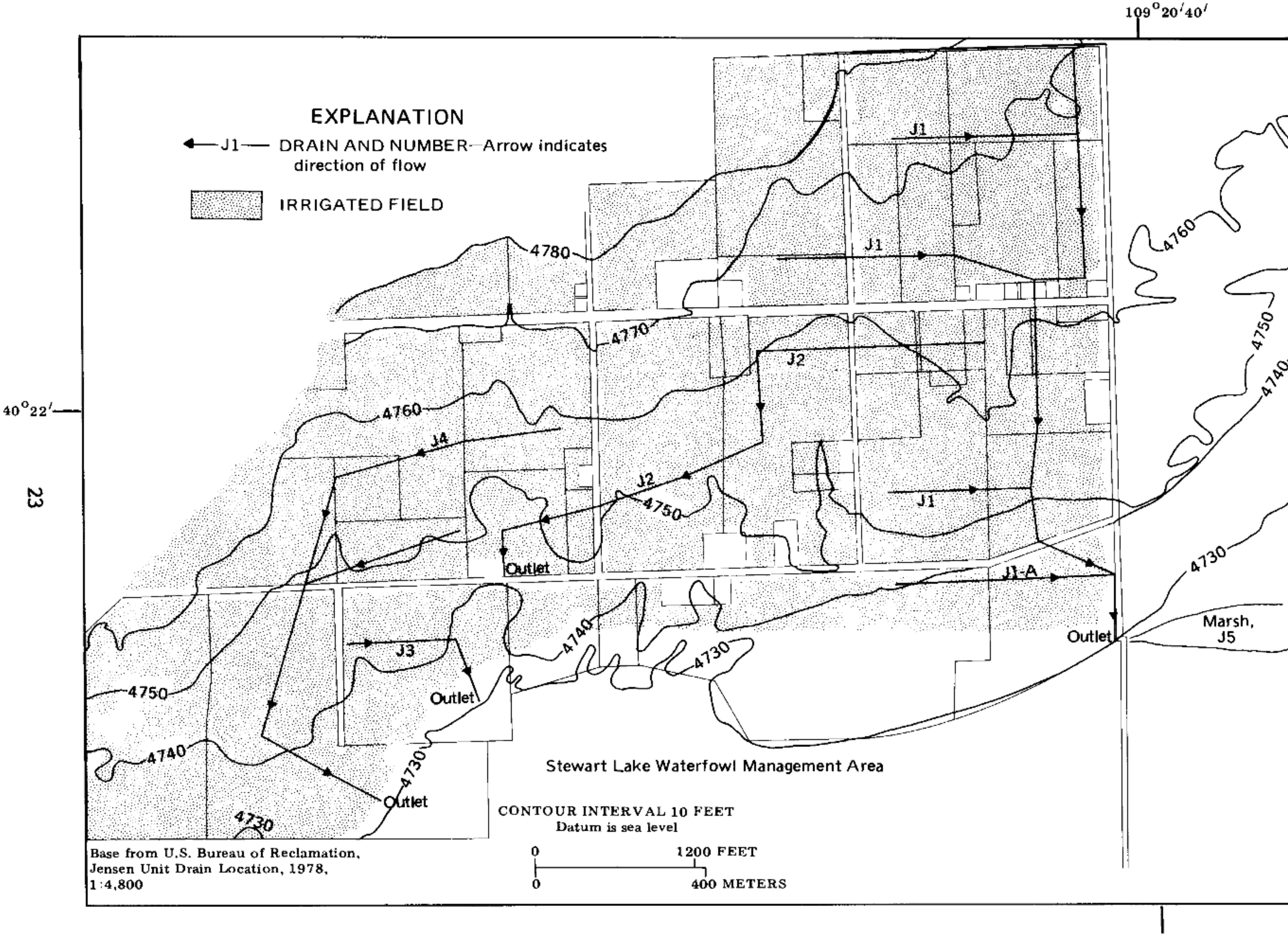


Figure 9.—Major trunk-line ground-water drains in the Jensen area that enter the Stewart Lake Waterfowl Management Area.

not a U.S. Bureau of Reclamation drain. The irrigation season is typically May through September with drainage reaching the lake throughout this period. Outflow from the lake enters the Green River.

Irrigation and Drainage Near Ouray National Wildlife Refuge

Areas northwest of the Ouray National Wildlife Refuge are irrigated extensively using water delivered by the Ouray Park Irrigation Co. No irrigation water is known to be supplied by U.S. Bureau of Reclamation facilities (Leon Meldron, U.S. Bureau of Reclamation, written commun., 1987). About 42,000 acres of land on the Uintah and Ouray Indian Reservation and 11,000 acres of land outside the reservation may receive irrigation water. Much of the return flow typically enters the Green River south of the refuge by way of the Duchesne River. However, water from an undetermined number of acres drains toward Pelican Lake (fig. 3) and the refuge. Water use within the refuge is estimated to be 2,500 acre-feet annually, with 800 acre-feet supplied by the Ouray Park Irrigation Co. and the remainder from the Green River. Irrigation water from the irrigation company enters the refuge through underground pipe and is used south of the refuge headquarters to irrigate grain for waterfowl feeding. Some of the return flow from this irrigated area may enter ponds in the Sheppard Bottom area. Irrigation water from the Lake Canal also enters the draw north of the North and South Roadside Ponds and flows through these ponds into pond S-5 in Sheppard Bottom. From this pond, water enters ponds S-3 and S-4 where it is mixed with water primarily obtained from the Green River. The Johnson Bottom, Leota Bottom, and Wyasket areas receive water almost exclusively from the Green River. The refuge maintains about 2,500 acres in shallow, freshwater-marsh habitat through a series of dikes and gravity flow of water from the Green River. An additional 6,000 acres is unregulated river-bottom lands.

SAMPLE COLLECTION AND ANALYSIS

Sampling Sites

The sampling program was designed to collect information from critical locations at critical times such that maximum likely concentrations of constituents associated with irrigation drainage would be determined. Previous to this study, the U.S. Bureau of Reclamation and the Utah Division of Water Pollution Control established several sampling sites in and near the Stewart Lake Waterfowl Management Area and entered data from these sites in the STORET computer files of the U.S. Environmental Protection Agency. The U.S. Geological Survey maintains several stream-gaging stations in the area which are cross-referenced as STORET stations. Several additional sites were also established specifically for this study. A listing of all sites that were used in this study and their designation in the U.S. Geological Survey, U.S. Bureau of Reclamation and State of Utah systems appears in table 5; the location of each site is shown in figures 2, 3, and 7.

Table 5.--**Data-collection sites**

[Eight-digit U.S. Geological Survey site numbers are hydrologic-station numbers; 15-digit numbers are miscellaneous site numbers based on latitude and longitude.]

Site name	Site number			Latitude	Longitude
	U.S. Geological Survey	U.S. Bureau of Reclamation	State of Utah		
Middle Green River basin north and west of the Stewart Lake Waterfowl Management Area (fig. 7)					
Green River near Jensen	09261000	-	-	40° 24' 34"	109° 14' 05"
Green River above Stewart Lake	402114109204501	-	-	40° 21' 14"	109° 20' 45"
Big Brush Creek above Red Fleet Reservoir	09261700	-	-	40° 35' 20"	109° 27' 53"
Brush Creek below Red Fleet Reservoir	403206109233501	-	-	40° 32' 06"	109° 23' 35"
Ashley Creek near Vernal	09266500	-	-	40° 34' 39"	109° 37' 17"
Ashley Creek at Merkley Park	-	-	493770	40° 31' 32"	109° 35' 57"
Ashley Creek at Highline Canal	-	GAC180	-	40° 30' 41"	109° 35' 38"
Ashley Creek near Jensen	09271500	GAC030	493742	40° 22' 29"	109° 24' 27"
Ashley Creek above confluence with the Green River	-	-	493721	40° 21' 03"	109° 22' 41"
Stewart Lake Waterfowl Management Area and vicinity (fig. 2)					
Inflow drains J1 and J1A	402136109204102	GASL01	-	40° 21' 36"	109° 20' 41"
Inflow drain J2	402146109220301	GASL02	-	40° 21' 46"	109° 22' 03"
Inflow drain J3	402134109221001	GASL03	-	40° 21' 34"	109° 22' 10"
Inflow drain J4	402120109221901	GASL04	-	40° 21' 20"	109° 22' 19"
Inflow drain J5	402136109214601	GASL05	-	40° 21' 36"	109° 21' 46"
Inflow to Stewart Lake	-	GASL06	-	40° 21' 10"	109° 21' 46"
Outflow from Stewart Lake	402146109214501	GASL10	-	40° 20' 46"	109° 21' 45"
North Seep	-	-	-	40° 21' 27"	109° 21' 12"
Bull-Pen Seep	-	-	-	40° 21' 28"	109° 21' 07"
Inflow to marsh 4720 southwest of Stewart Lake	402011109231101	-	-	40° 20' 11"	109° 23' 11"
Marsh 4720 sediment site	-	-	-	40° 20' 02"	109° 22' 55"
Ouray National Wildlife Refuge and vicinity (fig. 3)					
Inflow to North Roadside Pond	400806109390801	-	-	40° 08' 06"	109° 39' 08"
Outflow from North Roadside Pond	400709109385601	-	-	40° 07' 09"	109° 38' 56"
Leota Bottom, pond L-3	401035109340801	-	-	40° 10' 35"	109° 34' 08"
Sheppard Bottom, pond S-3	400658109383001	-	-	40° 06' 58"	109° 38' 30"
Wyasket Lake	400754109363601	-	-	40° 07' 54"	109° 36' 36"
Ouray Park irrigation water at refuge headquarters	400801109383801	-	-	40° 08' 01"	109° 38' 38"
Inflow to Pelican Lake at southwest shore	401147109420401	-	-	40° 11' 47"	109° 42' 04"
Outflow from Pelican Lake at pumping station	400806109390801	-	-	40° 11' 02"	109° 40' 47"

Collection and Analysis of Water Samples

The collection of onsite data and water samples was done using procedures given by the U.S. Geological Survey (1977). Onsite measurements of specific conductance and pH were made using meters that were calibrated prior to use with at least two standards. Dissolved oxygen was measured using a polaragraphic system that was calibrated at the local barometric pressure and temperature. Grab samples of water were collected from most sites because the flow was small and well-mixed. However, samples collected from Ashley Creek were collected using equal-width, depth-integrated methods and a DH-48TM sampler (U.S. Geological Survey, 1977, p. 3-20). Except for water samples collected for pesticide analysis, a churn splitter was used to composite and homogenize samples for each site and then to obtain splits for analyses of various constituents. Grab samples of water for pesticide analysis were collected using hexane rinsed and baked bottles fitted with teflon[1] liners. Water samples that required filtration were filtered at the sampling sites using 0.45-micrometer filters and a plastic filtration unit. Where acid was used to stabilize samples for trace-metal analyses, 1 milliliter of concentrated nitric acid was added per 250 milliliters of sample. This resulted in a final pH of less than 2. Water samples collected for radiochemical analysis were acidified with hydrochloric acid to a pH less than 2.

Analytical determinations of trace elements and pesticides in water and pesticides in bottom sediment were made by the U.S. Geological Survey's laboratory in Denver, Colorado. Trace-element analyses were done using procedures described by Fishman and Friedman (1985). Analyses for all pesticides except carbamates were done using procedures in Wershaw and others (1983). The carbamates were analyzed using direct aqueous injection into a high-performance liquid chromatograph with no preliminary digestion. Radiochemical analyses were performed by a private laboratory under contract to the U.S. Geological Survey using procedures given in Thatcher and Janzer (1977). The constituents of interest and their reporting levels are given in tables 6 and 7.

Analytical determinations of the major ions in water samples were performed by the U.S. Bureau of Reclamation's laboratory in Salt Lake City. Analytical procedures used were those specified by the American Public Health Association and others (1985).

Collection and Analysis of Bottom-Sediment Samples

Samples of bottom sediment were collected near each of the drains entering the Stewart Lake Waterfowl Management Area, the outflow from Stewart Lake, marsh 4720, and Ashley Creek near Jensen using a BMH-53 sampler with a stainless-steel barrel (U.S. Geological Survey, 1977, p. 3-37). Three to four sediment cores were collected in each area from depths of less than 8 inches and usually to a depth at which the underlying clay became uniform in color and compacted. The cores were then homogenized using a stainless-steel spoon and split into three samples. One sample, for trace-element analysis,

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[1]The use of trade names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Table 6.--**Reporting levels for trace elements and radiochemicals determined in water and bottom sediment**

[µg/L, micrograms per liter; pCi/L, picocuries per liter; µg/g, micrograms per gram; — not analyzed]

Constituent	Analytical reporting level	
	Water	Bottom Sediments
Arsenic	1 µg/L	0.1 µg/g
Barium	100 µg/l	1.0 µg/g
Boron	10 µg/L	0.4 µg/g
Cadmium	1 µg/L	2 µg/g
Chromium	10 µg/L	1
Copper	10 µg/L	1 µg/g
Lead	1 µg/L	4 µg/g
Mercury	0.1 µg/L	0.02 µg/g
Molybdenum	1 µg/L	0.2 µg/g
Nickel	1 µg/L	2 µg/g
Selenium	1 µg/L	0.1 µg/g
Silver	1 µg/L	2.0 µg/g
Vanadium	1 µg/L	2.0 µg/g
Zinc	10 µg/L	4 µg/g
Gross alpha (as natural uranium)	0.4 µg/L	--
Gross beta (as cesium-137)	0.4 pCi/L	--
Gross beta (as strontium-90/ ytterbium-90)	0.4 pCi/L	--
Radium-226	0.1 pCi/L	--
Thorium	—	0.2 µg/g
Uranium, natural	0.4 µg/L	0.2 µg/g

was seived to select only the silt and clay fraction (less than 63 micrometers) using a stainless-steel sieve. One nonsieved split also was analyzed for trace elements and the second nonsieved split was analyzed for pesticide residues.

Analytical determinations of trace elements in bottom sediment and bottom materials were performed by the U.S. Geological Survey's geochemistry laboratory in Denver, Colorado. The samples of sediment were air dried, disaggregated, sieved to 230 mesh, and digested with acid prior to analysis. The rigorous digestion procedure included hydrochloric acid, hydrofluoric acid, perchloric acid, and aqua regia. After digestion, the extracts were processed using methods given by Severson and others (1987). Analytical determinations of arsenic, mercury, and selenium were done by atomic-absorption spectroscopy; uranium and thorium by neutron activation; and all others except boron by inductively-coupled plasma analysis. This resulted in determinations that represent total extractable elements. However, boron was extracted using a hot-water method that approximates the biologically available fraction in the sediment. Pesticide determinations were done after extraction with acetone and hexane or acetone and diethyl ether, and procedures given by Wershaw and others (1983).

Table 7.—Reporting levels for pesticides and polychlorinated biphenyls and napthalenes determined in water and bottom sediment

[µg/L, micrograms per liter; µg/kg, micrograms per kilogram; -- not analyzed]

Constituent	Analytical reporting level	
	Water	Bottom Sediments
2,4-D	0.01 µg/L	0.1 µg/kg
2,4-DP	0.01 µg/L	0.1 µg/kg
2,4,5-T	0.01 µg/L	0.1 µg/kg
Aldrin	0.001 µg/L	0.1 µg/kg
Carbofuran	2 µg/L	--
Chlordane	0.1 µg/L	1 µg/kg
DDD	0.001 µg/L	0.1 µg/kg
DDE	0.001 µg/L	0.1 µg/kg
DDT	0.001 µg/L	0.1 µg/kg
Diazinon	0.01 µg/L	0.1 µg/kg
Dieldrin	0.001 µg/L	0.1 µg/kg
Endosulfan	0.001 µg/L	0.1 µg/kg
Endrin	0.01 µg/L	0.1 µg/kg
Ethion	0.01 µg/L	0.1 µg/kg
Heptachlor	0.001 µg/L	0.1 µg/kg
Heptachlor epoxide	0.001 µg/L	0.1 µg/kg
Lindane	0.001 µg/L	0.1 µg/kg
Malathion	0.01 µg/L	0.1 µg/kg
Methomyl	2 µg/L	--
Methoxychlor	0.01 µg/L	0.1 µg/kg
Methyl parathion	0.01 µg/L	0.1 µg/kg
Methyl trithion	0.01 µg/L	0.1 µg/kg
Mirex	0.01 µg/L	0.1 µg/kg
Parathion	0.01 µg/L	0.1 µg/kg
Perthane	0.1 µg/L	1 µg/kg
Propham	2 µg/L	--
Sevin	2 µg/L	--
Silvex	0.01 µg/L	0.1 µg/kg
Toxaphene	1 µg/L	10 µg/kg
Trithion	0.01 µg/L	0.1 µg/kg
Gross PCB	0.1 µg/L	1 µg/kg
Gross PCN	0.1 µg/L	1 µg/kg

Collection and Analysis of Biological Samples

Samples of plants, American coots (Fulica americana), and fish were collected. All samples were collected in late August or early September 1986. Sampling had been planned for June 1986, however, the Green River had topped the retaining dam adjacent to Stewart Lake for about 1 month and flooded the lake. Inflow to the lake from the Green River occurred through mid-June. Coot eggs could not be sampled because little or no nesting occurred due to the high water level. Sampling methods used at the Stewart Lake Waterfowl Management Area were used at all other sites except where specifically indicated.

Three species of plants were collected at two sites in the Stewart Lake Waterfowl Management Area: the northeast section of the lake near drains J1-J1A and J5, and near drain J3. At the first site, filamentous algae, hardstem bullrush (Scirpus acutus), and Potamogeton spp. were collected; blue-green algae, hardstem bullrush and Potamogeton spp. were collected near drain J3. All were composite samples of a plant mass with weight ranging from 19 to 956 grams. Samples consisted of the non-rooted portion, except for the hardstem bullrush which consisted of the entire plant including washed roots. Samples were placed in plastic bags and frozen.

American coots were collected at random in the Stewart Lake Waterfowl Management Area using a shotgun with steel shot. Livers were excised, individually placed in chemically cleaned jars, and frozen. Fish were captured in the Stewart Lake Waterfowl Management Area using electrofishing gear and hook and line. Three composite samples consisting of five fish each, one composite sample consisting of four fish, and one sample consisting of a single fish were collected. Species collected included common carp (Cyprinus carpio), black bullhead (Ictalurus melas), and green sunfish (Lepomis cyanellus). Fish were weighed, measured, double-wrapped in aluminum foil, placed in plastic bags, and frozen.

At marsh 4720, three composite samples of plants were collected consisting of the same species collected at the Stewart Lake Waterfowl Management Area. Three composite samples of two species of fish (two carp and one black bullhead) were collected using gill nets. On the Green River near the outflow of Stewart Lake and the confluence of Ashley Creek, one composite sample consisting of five carp and one composite sample consisting of two flannelmouth suckers (Latostomus latispinnis) were collected. At the Ouray National Wildlife Refuge, 11 coots were collected, 4 from the North Roadside Pond and the remaining 7 from Leota Bottom.

Samples were analyzed at the U.S. Fish and Wildlife Service's Patuxent Analytical Control Facility, Patuxent, Md., or the Environmental Trace Substances Research Center, Columbia, Mo. Concentrations of the following trace elements were determined in the analysis of biological tissues: aluminum, arsenic, barium, beryllium, boron, cadmium, copper, iron, lead, magnesium, manganese, mercury, nickel, selenium, tin, vanadium, and zinc. The analytical procedures consisted of an inductively-coupled plasma scan without preconcentration for most elements. Selenium and arsenic were analyzed by hydride generation, and mercury by the cold-vapor technique. All bird livers and three fish samples were scanned for organochlorine pesticide residues. The analytical procedure for pesticides consisted of solvent extraction and analysis using electron-capture gas chromatography.

CRITERIA AND STANDARDS FOR SELECTED CONSTITUENTS IN WATER

Problem Constituents

Water samples collected during this reconnaissance were analyzed for 14 trace elements, 5 radiochemicals, 30 pesticides, polychlorinated biphenyls and napthalenes, and 13 major ions. Water-quality standards established by the State of Utah and criteria recommended by the Environmental Protection Agency and the National Academy of Sciences were used to identify those constituents considered to be harmful. Evaluation of the data indicated hazards to human health, fish, and wildlife, and to other water uses involved only selenium, uranium, boron, nitrate, and zinc, in order of severity. Subsequent discussion of water quality, therefore, is limited primarily to these constituents.

Selenium

Recognizing both beneficial and detrimental aspects of selenium in the environment, the U.S. Environmental Protection Agency has established a water-quality criterion of 35 micrograms per liter as a 24-hour average for total selenite, and is reviewing a possible criterion of 760 micrograms per liter for selenate to protect freshwater aquatic organisms (U.S. Environmental Protection Agency, 1986a). The State of Utah has established dissolved-selenium standards of 50 micrograms per liter to protect aquatic wildlife and 10 micrograms per liter to protect domestic water supplies (Utah Department of Social Services, Division of Health, 1983). The U.S. Environmental Protection Agency also has established a human-health standard of 10 micrograms per liter in public water supplies. A daily intake of 50 to 60 micrograms of selenium is believed to be adequate for human nutrition (Combs and Combs, 1986, p. 387), and the National Academy of Sciences (1983) recommends a minimum daily intake of 50 micrograms. The average daily intake of selenium by adults in the United States ranges from 60 to 216 micrograms. Combs and Combs (1986, p. 511) reviewed available literature and recommended a maximum safe upper limit of 775 micrograms of selenium (in foods or organic form) per day for humans. Stewart Lake, the Ouray National Wildlife Refuge, and downstream reaches of Ashley and Brush Creeks are protected as Utah class 3B (aquatic wildlife) and class 4 (agricultural) waters. Therefore, the Utah standard of 50 micrograms per liter for dissolved selenium is used in this report.

Uranium

Under natural conditions, plants growing on uranium-bearing material are not affected adversely by uranium and, in many instances, will accumulate several micrograms per gram of uranium in their tissues. Within the drainage basins of the Green and Colorado Rivers, botanical prospecting for uranium has been done using *Astragalus* as an indicator plant (Cannon, 1964). This prospecting is based on the co-occurrence of uranium with selenium, and the requirement of some species of *Astragalus* for seleniferous soils. Uranium, in the oxidation series from UO_2 to UO_3 generally is not toxic to animals when injested, whereas the UO_3 radical, present in such minerals as becquerelite, is quite toxic when ingested (Gough and others, 1979, p. 54). In a study of a stream receiving uranium-mill waste, Mitchum and Moore (1966) reported that uranium concentrations of 5 micrograms per liter did not appear harmful to fish, but that concentrations of 60 to 2,000 micrograms per liter were believed to be toxic to trout. The State of Utah does not have an applicable standard for elemental uranium in water. The National Academy of Sciences (1983) recommends a limit of 35 micrograms per liter in water for human consumption. The Utah standard for uranium activity in water, expressed as gross alpha radiation, is 15 picocuries per liter to protect people and aquatic wildlife.

Boron

Boron is an element required for the growth of plants, but the difference between the amount required and toxic concentrations of boron is small. Although the concentration of total boron in the soil is not a good indicator of the concentration of boron available to plants, the concentration of water-extractable (or dissolved) boron is a good index of availability. Extractable boron in the range of 0.5 to 1 microgram per gram was reported to promote growth of fruit trees, whereas concentrations greater than 2 micrograms per gram caused some phytotoxicity (Sauchelli, 1969). Branson (1976) reported that, based on extracts from soils, the limits for boron tolerance were 5 micrograms per gram for semitolerant crops such as corn, lima beans, and wheat and 10 micrograms per gram for tolerant crops such as alfalfa, beets, and onions. A boron concentration in irrigation water that is greater than 1.1 milligrams per liter, combined with a field application rate of 7 inches per acre or greater has been reported to be toxic to sensitive crops (Bradford, 1966). Most criteria and standards for boron in water have been established to protect agricultural uses; however, the California State Water Resources Control Board (1981) recommends a limit of 500 micrograms per liter of boron to protect fish and wildlife in bay areas receiving irrigation return flows from the San Luis Drain. The U.S. Environmental Protection Agency and the State of Utah have set the standard for boron in irrigation water at 750 micrograms per liter to protect sensitive crops.

Nitrate

Nitrate is a major constituent in plant nutrition and commonly is present in animal wastes. Concentrations of nitrate of 45 milligrams per liter or larger in drinking water may result in methemoglobinemia in young children, therefore, most standards for public water supplies limit nitrate to this concentration or less (U.S. Environmental Protection Agency, 1986b). In rural areas, water from wells and streams may be contaminated with nitrate due to seepage from fertilized cropland, barnyards, or septic tanks. Shallow ground water receiving drainage from fertilized cropland may contain large concentrations of nitrate. Nitrate also is a nutrient that contributes to eutrophication of ponds and lakes. Utah has established a wildlife-protection standard for nitrate in water of 18 milligrams per liter (4 milligrams per liter as nitrogen), which is the standard used in this report.

Zinc

Generally zinc must be present in large concentrations in soil, water, or food to be toxic. Gough and others (1979, p. 56-58) summarized several studies which indicated concentrations of zinc in soils must be at least 0.43 percent (4,300 micrograms per gram) to be toxic to crops. Concentrations of 200 micrograms per gram (dry weight) in leaf tissue of plants are regarded as excessive, but concentrations of at least 20 micrograms per gram are regarded as essential to plant nutrition. Zinc is relatively nontoxic to mammals, with few detrimental effects at concentrations in the diet of less than 500 micrograms per gram. In aquatic environments, zinc is slightly more toxic. Burton and others, (1972) reported bluegills survive zinc concentrations of 5.6 milligrams per liter as Zn^{2+} at 20 degrees Celsius under laboratory conditions. Concentrations of 32 milligrams per liter were lethal. The State of Utah has established a zinc standard of 50 micrograms per liter in water to protect aquatic wildlife.

WATER-QUALITY ANALYSES

Major Ions

Concentrations of major ions in water entering and leaving the Jensen area and the Stewart Lake Waterfowl Management Area, and the Green River near Jensen during 1986 are given in table 8. In general, the water was a sodium- or calcium-sulfate type. Concentrations of sodium, sulfate, and nitrate were consistently large in drains J3 and J4. Concentrations of nitrate in drains J3 and J4 were 22 to 63 percent larger than the Utah aquatic-wildlife standard of 18 milligrams per liter as nitrate. Water entering and leaving the Stewart Lake Waterfowl Management Area and the nearby marsh had considerably larger concentrations of dissolved constituents than did the water in the Green River.

Onsite Measurements and Trace Elements

The results of onsite measurements and trace-element analyses done during this reconnaissance are given in table 9. The analysis of deionized-water blanks (3-megaohm resistivity) that were carried to the sampling sites, filtered, and acidified indicates contamination of samples generally did not occur during the reconnaissance. Concentrations of trace elements detected in the blanks were less than or equal to the reporting level for all elements except for the August 26 sampling when molybdenum and zinc were detected at concentrations 4 and 2 times larger than the lower detection limit of the procedures. The reason for this was not determined. A single duplicate analysis of a sample from drain J3 indicated generally good precision for the selected trace elements that were analyzed.

Specific conductance values of water in the Jensen area generally are quite large because of the large sodium and sulfate concentrations in the water. The pH in the ground water from the drains never varied more than 0.1 unit about a pH of 7.2. Ground water discharging from drains J1 through J4 generally is much cooler than surface water and has little variation in temperature (table 9). Concentrations of dissolved oxygen in the surface

Table 8.--Chemical analyses of water flowing into the Jensen area, water flowing into and out of the Stewart Lake Waterfowl Management Area, and water in the Green River near Jensen during 1986

[The analysis for the Green River was done by the U.S. Geological Survey (ReMillard and others, 1986, p. 70), all others performed by the U.S. Bureau of Reclamation laboratory in Salt Lake City. $CaCO_3$, calcium carbonate; NO_3, nitrate; mg/L, milligrams per liter]

Date	Time	Hardness as $CaCO_3$ (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Sodium adsorption ratio	Potassium (mg/L)	Bicarbonate as $CaCO_3$ (mg/L)
				Ashley Creek near Jensen				
06-24-86	1200	442	101	46	44	0.9	2.9	162
08-27-86	1430	1,086	223	129	122	1.6	5.0	305
				Stewart Lake Waterfowl Management Area				
				Drains J1 and J1A				
06-23-86	1500	925	222	90	151	2.2	4.7	467
08-26-86	1030	932	212	98	173	2.5	5.2	440
				Drain J2				
06-23-86	1700	1,160	293	105	172	2.2	6.4	503
08-26-86	1120	1,019	256	92	142	1.9	5.1	439
				Drain J3				
06-23-86	1745	1,730	396	180	508	5.3	7.8	583
08-26-86	1400	1,601	361	171	474	5.2	7.6	528
08-26-86	duplicate	1,550	342	169	474	5.2	7.6	497
				Drain J4				
06-23-86	1815	1,577	367	161	512	5.6	5.6	563
08-26-86	1545	1,461	330	155	471	5.4	5.8	508
				Drain J5				
06-23-86	1530	457	98	52	86	1.7	5.9	297
08-26-86	0950	596	121	72	123	2.2	6.7	560
				Stewart Lake outflow				
06-24-86	0945	418	97	43	86	1.8	4.1	235
08-27-86	1230	865	173	106	227	3.3	7.5	283
				Inflow to marsh 4720 southwest of Stewart Lake				
08-27-86	1030	1,559	306	194	246	2.7	1 5.6	405
				Green River near Jensen				
08-15-86	1015	236	55	24	53	2.0	2.7	--

Table 8.--Chemical analyses of water flowing into the Jensen area, water flowing into and out of the Stewart Lake Waterfowl Management Area, and water in the Green River near Jensen during 1986--Continued

Date	Time	Carbonate as $CaCO_3$ (mg/L)	Alkalinity as $CaCO_3$ (mg/L)	Sulfate (mg/L)	Chloride (mg/L)	Silica (mg/L)	Dissolved Solids (mg/L)	Nitrate as NO_3 (mg/L)
				Ashley Creek near Jensen				
06-24-86	1200	17.4	161	361	9	9.6	680	6.9
08-27-86	1430	0	250	1,015	23	15.9	1,700	14.9
				Stewart Lake Waterfowl Management Area				
				Drains J1 and J1A				
06-23-86	1500	0	382	840	27	16.4	1,590	11.2
08-26-86	1030	0	361	888	25	18.1	1,650	12.3
				Drain J2				
06-23-86	1700	0	412	1,082	27	17.6	1,970	19.0
08-26-86	1120	0	360	913	24	17.9	1,680	11.9
				Drain J3				
06-23-86	1745	0	478	2,145	103	18.8	3,680	29.4
08-26-86	1400	0	432	1,981	89	19.1	3,390	24.5
08-26-86	duplicate	0	407	1,985	89	19.1	3,360	25.7
				Drain J4				
06-23-86	1815	0	461	2,069	69	17.8	3,510	29.1
08-26-86	1545	0	416	1,880	65	17.7	3,200	23.1
				Drain J5				
06-23-86	1530	12.6	264	367	15	3.5	790	--
08-26-86	0950	0	459	436	20	23.2	1,080	--
				Stewart Lake outflow				
06-24-86	0945	0	193	417	16	6.8	790	--
08-27-86	1230	0	232	1,063	37	3.1	1,760	--
				Inflow to marsh 4720 southwest of Stewart Lake				
08-27-86	1030	0	332	1,579	58	23.2	2,620	--
				Green River near Jensen				
08-15-86	1015	--	151	180	23	4.0	456	<0.1

Table 9.--**Streamflow and selected water-quality properties and constituents determined for water flowing into the Jensen area and into and out of the Stewart Lake Waterfowl Management Area during 1986**

[ft3/s, cubic feet per second; μS/cm, microsiemens per centimeter; mg/L, milligrams per liter; μg/L, micrograms per liter; pCi/L, picocuries per liter; °C, degrees Celsius]

Site	Date	Time	STREAM-FLOW, INSTAN-TANEOUS (ft3/s)	SPE-CIFIC CON-DUCT-ANCE (μS/cm)	PH (STAND-ARD UNITS)	TEMPER-ATURE (°C)	OXYGEN, DIS-SOLVED (mg/L)	OXYGEN, DIS-SOLVED (PER-CENT SATUR-ATION)	ARSENIC DIS-SOLVED (μg/L AS AS)	BARIUM, DIS-SOLVED (μg/L AS BA)	BORON, DIS-SOLVED (μg/L AS B)
Brush Cr. below Red Fleet	08-25-86	1530	80	270	7.60	17.0	9.1	114	1	<100	20
Ashley Cr. near Jensen	06-24-86	1200	129	--	8.30	19.0	8.2	104	1	--	210
	08-27-86	1430	30	2,020	8.30	25.0	9.2	132	2	100	630
Stewart Lake Waterfowl Management Area											
Drains J1 and J1A	06-23-86	1500	2.5	--	7.20	13.0	6.5	72	<1	--	450
	08-26-86	1030	3.4	2,300	7.20	14.5	4.4	51	2	100	519
Drain J2	06-23-86	1700	1.3	--	7.20	12.0	4.4	48	<1	--	570
	08-26-86	1120	1.7	2,420	7.10	14.0	3.2	37	1	<100	540
Drain J3	06-23-86	1745	0.22	--	7.20	12.0	5.3	58	<1	--	1,200
	08-26-86	1400	.35	3,600	7.10	13.0	4.8	55	1	<100	1,100
Duplicate	08-26-86	1400	--	--	--	--	--	--	1	<100	1,100
Drain J4	06-23-86	1815	0.2	--	7.30	11.0	7.0	74	<1	--	1,000
	08-26-86	1545	.58	3,400	7.20	13.5	5.9	68	1	<100	1,000
Drain J5	06-23-86	1530	0.39	--	8.30	31.0	12.9	205	2	200	210
	08-26-86	0950	.1	1,950	7.40	14.5	3.9	45	2	100	310
Stewart Lake outflow	06-24-86	0945	20	--	7.80	24.0	6.0	85	2	--	260
	08-27-86	1230	1.1	2,230	7.90	25.0	7.0	101	2	200	620
Marsh 4720	08-27-86	1030	2.6	3,180	7.60	18.0	5.4	68	3	100	910
Deionized-water blank	06-23-86	--	--	--	--	--	--	--	<1	<100	20
Deionized-water blank	08-26-86	--	--	--	--	--	--	--	<1	<100	20

Table 9.--**Streamflow and selected water-quality properties and constituents determined for water flowing into the Jensen area and into and out of the Stewart Lake Waterfowl Management Area during 1986--Continued**

Site	Date	CADMIUM DIS-SOLVED (µg/L AS CD)	CHRO-MIUM, DIS-SOLVED (µg/L AS CR)	COPPER, DIS-SOLVED (µg/L AS CU)	LEAD, DIS-SOLVED (µg/L AS PB)	MERCURY DIS-SOLVED (µg/L AS HG)	MOLYB-DENUM, DIS-SOLVED (µg/L AS MO)	NICKEL, DIS-SOLVED (µg/L AS NI)	SELE-NIUM, DIS-SOLVED (µg/L AS SE)	SILVER, DIS-SOLVED (µg/L AS AG)	VANA-DIUM, DIS-SOLVED (µg/L AS V)
Brush Cr. below Red Fleet	08-25-86	<1	<10	<10	<5	<0.1	2	3	<1	<1	1
Ashley Cr. near Jensen	06-24-86	<1	<10	<10	<5	<0.1	2	2	25	<1	2
	08-27-86	<1	<10	10	<5	<.1	5	4	59	<1	2
Stewart Lake Waterfowl Management Area											
Drains J1 and J1A	06-23-86	<1	<10	<10	<5	<0.1	2	3	31	<1	<1
	08-26-86	<1	<10	10	<5	<.1	1	5	26	<1	<1
Drain J2	06-23-86	<1	<10	<10	<5	<0.1	3	5	42	<1	<1
	08-26-86	<1	<10	10	<5	<.1	4	8	30	<1	1
Drain J3	06-23-86	<1	<10	<10	<5	<0.1	3	8	140	<1	<1
	08-26-86	<1	<10	20	<5	<.1	6	9	110	<1	2
Duplicate	08-26-86	<1	<10	20	<5	<.1	8	8	110	<1	2
Drain J4	06-23-86	<1	<10	<10	<5	<0.1	3	2	97	<1	<1
	08-26-86	<1	<10	10	<5	<.1	4	3	77	<1	1
Drain J5	06-23-86	<1	<10	<10	<5	<0.1	1	2	4	<1	1
	08-26-86	<1	<10	10	10	<5	<0.1	2	4	1	2
Stewart Lake outflow	06-24-86	<1	<10	<10	<5	<0.1	2	3	7	<1	2
	08-27-86	<1	<10	10	<5	<.1	7	3	7	<1	1
Marsh 4720	08-27-86	<1	<10	10	<5	<0.1	8	3	31	<1	5
Deionized-water blank	06-23-86	<1	<10	<10	<5	<0.1	<1	1	<1	<1	<1
Deionized-water blank	08-26-86	<1	<10	<10	<5	<0.1	4	2	<1	<1	<1

Table 9.--Streamflow and selected water-quality properties and constituents determined for water flowing into the Jensen area and into and out of the Stewart Lake Waterfowl Management Area during 1986--Continued

Site	Date	ZINC, DIS-SOLVED (μg/L AS ZN)	GROSS ALPHA, DIS-SOLVED (μg/L AS U-NAT)	GROSS ALPHA, DIS-SOLVED (pCi/L AS U-NAT)	GROSS ALPHA, SUSP. TOTAL (μg/L AS U-NAT)	GROSS BETA, DIS-SOLVED (pCi/L AS CS-137)	GROSS BETA, SUSP. TOTAL (pCi/L AS CS-137)	GROSS BETA, DIS-SOLVED (pCi/L AS SR/YT-90)	GROSS BETA, SUSP. TOTAL (pCi/L AS SR/YT-90)	RA-226, DIS-SOLVED, PLAN-CHET COUNT (pCi/L)	URANIUM NATURAL DIS-SOLVED (μg/L)
Brush Cr. below Red Fleet	08-25-86	20	1.1	0.7	0.4	2.1	0.4	1.6	0.4	0.2	0.6
Ashley Cr. near Jensen	06-24-86	10	15	10.2	1.5	6.2	3.5	4.6	3.3	0.3	12
	08-27-86	20	23	15.6	1.2	26	6.2	18	6.2	.2	33
Stewart Lake Waterfowl Management Area											
Drains J1 and J1A	06-23-86	10	26	17.7	0.6	14	0.5	8.6	0.5	0.2	30
	08-26-86	20	16	10.9	.4	33	.4	21	0.4	.2	42
Drain J2	06-23-86	10	30	20.4	0.6	14	0.5	8.6	0.5	0.1	35
	08-26-86	20	--	--	--	--	--	--	--	--	--
Drain J3	06-23-86	10	109	74.1	0.8	10	0.5	6.5	0.5	0.1	61
	08-26-86	40	61	41.4	.4	53	.8	34	.8	.2	73
Duplicate	08-26-86	20	--	--	--	--	--	--	--	--	--
Drain J4	06-23-86	10	63	42.8	0.6	7.3	1.3	4.9	1.2	0.2	53
	08-26-86	30	56	38.1	.4	45	0.4	28	0.4	.2	59
Drain J5	06-23-86	<10	9.5	6.5	<0.8	7.3	0.6	5.5	0.6	<0.2	9.3
	08-26-86	10	7.5	5.1	<.4	15	.6	7.5	0.6	.2	5.0
Stewart Lake outflow	06-24-86	10	11	7.5	3.1	8.2	4.4	5.9	4.0	0.4	12
	08-27-86	70	26	17.7	1.2	25	3.0	17	2.9	.1	37
Marsh 4720	08-27-86	60	17	11.6	1.1	45	4.4	29	4.4	0.4	54
Deionized-water blank	06-23-86	<10	3.6	2.5	<0.6	1.4	<0.5	1.2	<0.6	<0.1	<0.4
Deionized-water blank	08-26-86	20	3.6	2.5	<0.6	1.4	<0.5	1.2	<0.6	<0.1	<0.4

water generally are near saturation except for drain J5, which drains surface water from a wetland with abundant vegetation. Dissolved oxygen at this site varies considerably depending on the intensity of solar radiation. Concentrations of dissolved oxygen in ground water discharging from drains J1 through J4 were always less than 75 percent saturation and were typically about 50 percent.

Data for Brush Creek represent the quality of irrigation water as it enters the Jensen area. Based on a single analysis, the water is suitable for irrigation. Water in Ashley Creek consists of return flows from irrigation and other uses by the time it enters the Jensen area. Additional data on concentrations of boron, selenium, and zinc in the Green River, Ashley Creek near Jensen, flows into and out of Stewart Lake, and in the area of Ouray National Wildlife Refuge were determined in April 1987 prior to the start of the irrigation season and during irrigation in June or August. The data (table 10) indicate concentrations of selenium greater than 50 micrograms per liter are commonly found in water from drains J3 and J4. In addition, concentrations of selenium in the other drains entering Stewart Lake and in ground water entering the lake on the north shore were much larger than in the Green River upstream from the Stewart Lake Waterfowl Management Area.

Of the constituents for which data were collected in 1986-87, only nitrate, boron, selenium, zinc, and uranium (as total alpha activity) are present in concentrations that exceeded Utah standards (tables 8, 9 and 10). Results from the reconnaissance study in the middle Green River basin for boron, selenium, and zinc in water are summarized in figures 10-12. Concentrations of boron and selenium in water from drains J3 and J4 in the Stewart Lake Waterfowl Management Area exceeded the Utah standards of 750 micrograms per liter for boron and 50 micrograms per liter for selenium in all samples. Concentrations of zinc, although somewhat large in water from these drains, did not exceed the standard of 50 micrograms per liter. Concentrations of zinc did exceed the standard in one sample of the outflow from Stewart Lake and in marsh 4720. Concentrations of selenium in water from Ashley Creek near Jensen exceeded the standard in the August samples in 1986 and 1987.

Table 10.—**Concentrations of boron, selenium, and zinc in water samples from the Green River upstream from Stewart Lake, Ashley Creek near Jensen, drains and seepage to Stewart Lake Waterfowl Management Area, outflow from Stewart Lake, sites at Ouray National Wildlife Refuge, and inflow to and outflow from Pelican Lake during 1987**

[µg/L, micrograms per liter]

Site	Date	Boron (µg/L)	Selenium (µg/L)	Zinc (µg/L)
Green River upstream from Stewart Lake	04-01-87	80	3	10
Ashley Creek near Jensen	08-11-87	600	73	10
Stewart Lake Waterfowl Management Area				
Drains J1 and J1A	04-03-87	—	14	10
do	08-11-87	590	34	10
Drain J2	04-03-87	680	34	20
do	08-11-87	560	34	10
Drain J3	04-03-87	820	62	30
do	08-11-87	950	88	10
Drain J4	04-03-87	—	94	50
do	08-11-87	960	84	10
North seep	04-03-87	330	8	20
Bullpen seep	04-03-87	280	17	10
Outflow from Stewart Lake	04-03-87	490	6	20
do	08-11-87	780	10	10
Ouray National Wildlife Refuge				
Inflow to North Roadside Pond	06-01-87	250	17	10
Outflow from North Roadside Pond	04-02-87	—	93	10
do	06-01-87	280	28	30
do	08-12-87	260	9	5
Leota Bottom, pond L-3	04-03-87	160	<1	10
do	08-13-87	210	<1	6
Sheppard Bottom, pond S-3	04-02-87	360	3	20
Sheppard Bottom, pond S-5	08-12-87	510	2	10
Wyasket Lake	04-02-87	—	<1	20
Well near refuge headquarters	04-02-87	70	<1	70
Ouray Park irrigation water at refuge headquarters	06-02-87	160	<1	10
Inflow to Pelican Lake	06-02-87	120	<1	20
Outflow from Pelican Lake	06-02-87	150	<1	20

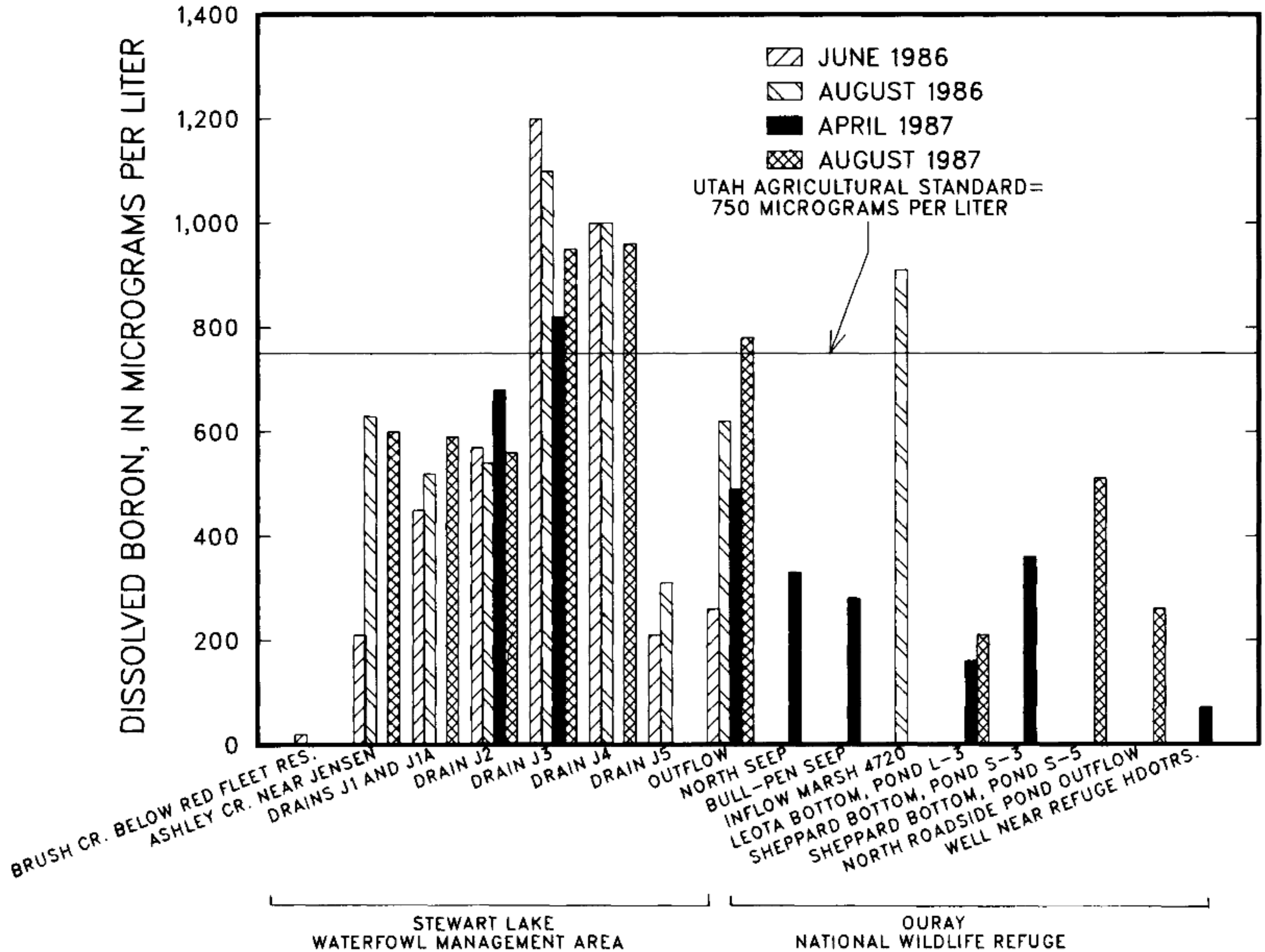

Figure 10.—Concentrations of dissolved boron in water samples from sites in the middle Green River basin, 1986-87.

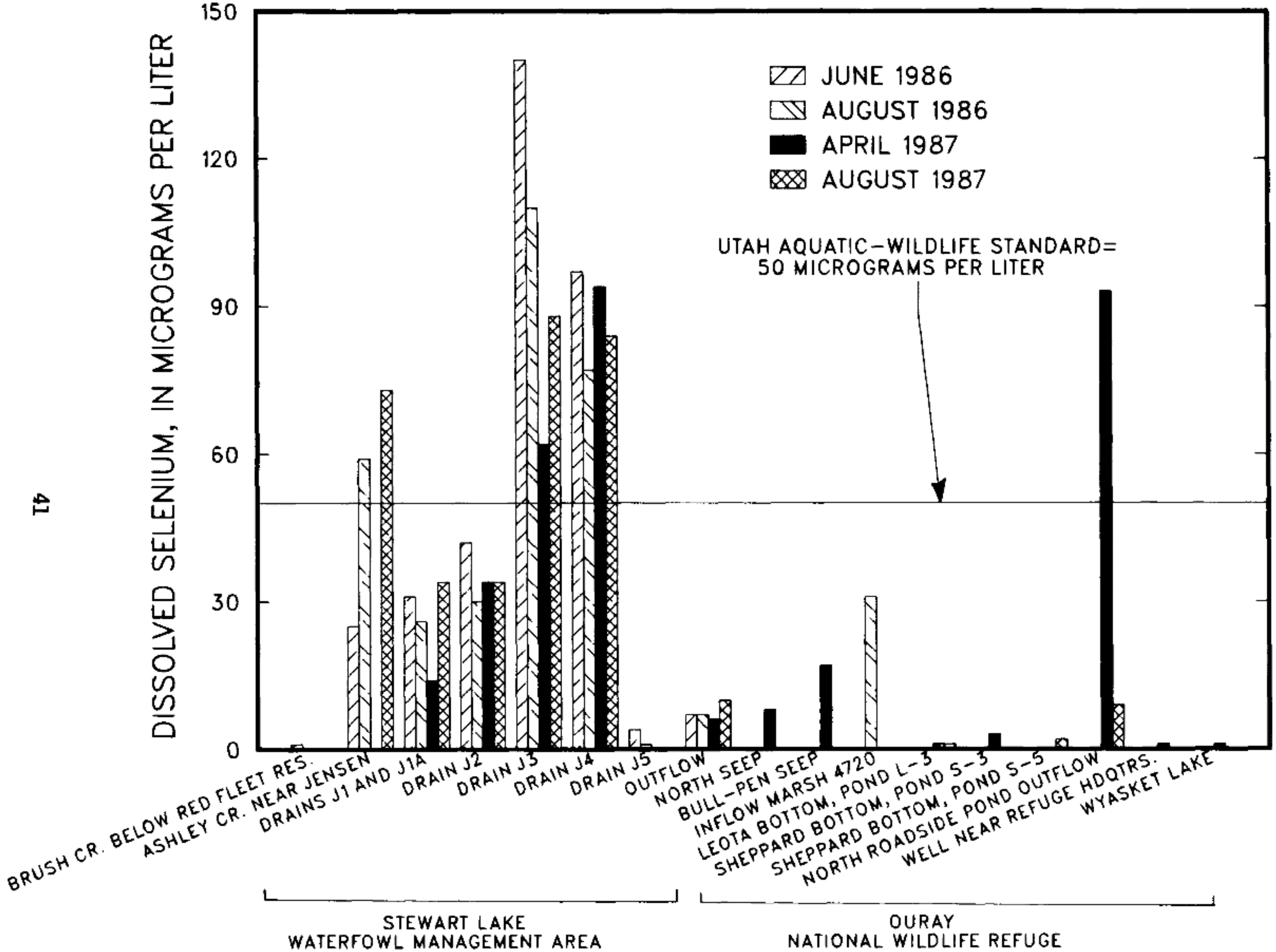

Figure 11.–Concentrations of dissolved selenium in water samples from sites in the middle Green River basin, 1986-87.

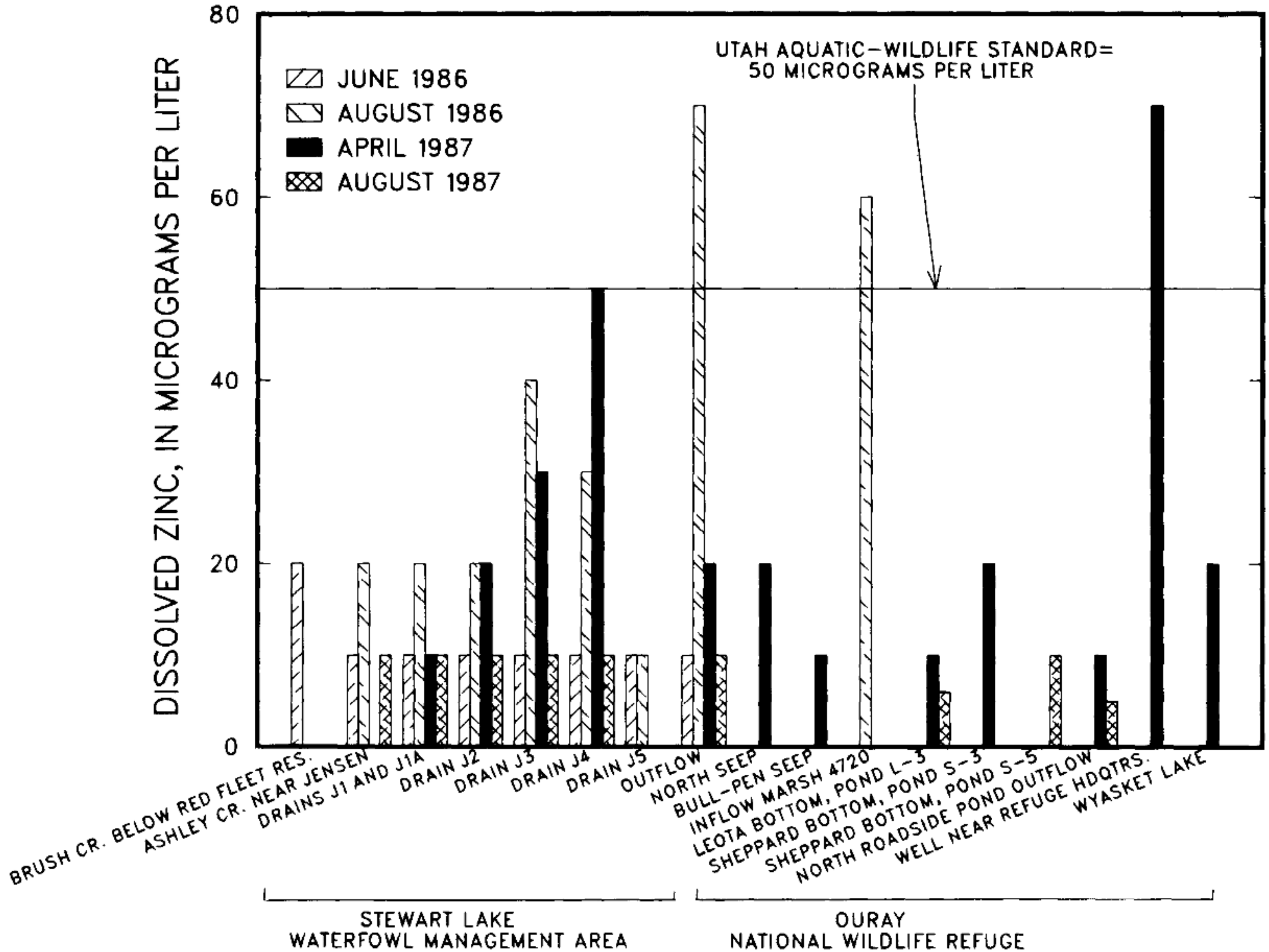

Figure 12.—Concentrations of dissolved zinc in water samples from sites in the middle Green River basin, 1986-87.

Although the concentrations of selenium in drains J3 and J4 are considerably larger than those in drains J1, J1A, and J2, the flows from drains J3 and J4 are quite small. When mean flows and mean concentrations of selenium are used to calculate a daily load of selenium, the combined load from drains J1, J1A, and J2, which had only moderately large concentrations, is nearly twice the combined load from drains J3 and J4, which had large concentrations. Based on the mean for samples collected in 1986, the total estimated load of selenium to the Stewart Lake Waterfowl Management Area is about 0.5 kilogram per day, of which 97 percent enters in ground water from four drains as indicated below:

Drain	Daily load of selenium, in grams
J1-1A	206
J2	132
J3	88
J4	83
J5 (surface water)	15

This reconnaissance was conducted and water samples were collected during unusually wet years when flows were large and water from the Green River flooded Stewart Lake Waterfowl Management area. This flooding has diluted the concentrations of trace elements in the management area considerably. The recent large flows in the Green River have also diluted the potentially large concentrations of trace elements in the outflow from Stewart Lake and from Ashley Creek at their confluences with the Green River, and reduced the effect on the Green River. For example, Ashley Creek contained a selenium concentration of 25 micrograms per liter and had a discharge of 129 cubic feet per second in April 1986 (table 9). This constituted a daily load of nearly 8 kilograms of selenium discharged to the Green River from Ashley Creek. However, the average daily discharge of the Green River near Jensen for that month was about 900 million cubic feet (ReMillard and others, 1986, p. 68), which diluted the selenium contribution of Ashley Creek to about 0.3 microgram per liter in the Green River.

Based on results of a single water sample, marsh 4720 southwest of the Stewart Lake Waterfowl Management Area had concentrations of boron and zinc that exceeded the Utah agricultural and aquatic-wildlife standards respectively. The selenium concentration of 31 micrograms per liter did not exceed the State standard for aquatic wildlife.

Concentrations of uranium in all of the drains except drain J5 were equal to or larger than the criteria of 35 micrograms per liter for human consumption recommended by the National Academy of Sciences (1983) on at least one sampling date. Concentrations of uranium, expressed as gross alpha radiation, also exceeded the Utah aquatic-wildlife standard of 15 picocuries per liter in water from all drains except drain J5. Gross alpha activity in water from drains J3 and J4 was nearly 3 to 5 times greater than the Utah standard. The concentration of uranium and the alpha activity of the sample exceeded the National Academy of Science's criterion and the Utah standard in the single water sample from marsh 4720. Large concentrations of uranium in water in the middle Green River basin are not unusual because many of the shale and sandstone beds in the area contain uranium deposits.

Concentrations of selected pesticides and polychlorinated biphenyls (PCB) and polychlorinated napthalenes (PCN) in water in the area of the Stewart Lake Waterfowl Management Area are given in table 11. Analyses were done for these specific compounds because they represent the majority of pesticides used in the area. No analyses were done for pesticides in water at the Ouray National Wildlife Refuge. All reported concentrations were less than or about the reporting levels of the analytical methods. Samples for pesticide residue analysis were collected in August 1986 during major water, sediment, and biological sampling. Although pesticide application occurs throughout the growing season, it is likely that most application occurs earlier in the year.

At the Ouray National Wildlife Refuge, concentrations of selenium were determined in water from the two major water sources utilized at the refuge. Ponds in the Leota Bottom and Wyasket areas primarily receive water from the Green River, which likely has a selenium concentration of about 3 micrograms per liter (table 10). The North Roadside Pond receives irrigation return flows and shallow ground water from the direction of Pelican Lake. The selenium concentration in the discharge from the North Roadside Pond is 9 to 93 micrograms per liter. Water flows from the North and South Roadside Ponds into the Sheppard Bottom pond complex where it is mixed with water pumped from the Green River. This dilution results in selenium concentrations in ponds of the Sheppard Bottom of 2 to 3 micrograms per liter (table 10). Concentrations of boron, where measured in the refuge area, were less than the State standard of 750 micrograms per liter (table 10). A single water sample from the newly constructed well used to provide water for a fish-rearing pond, contained less than 1 microgram per liter of selenium, but contained 70 micrograms per liter of zinc. The galvanized well casing possibly was the source of zinc. This shallow well (55 feet deep) may yield water from the alluvium of the Green River.

TRACE ELEMENTS AND RADIONUCLIDES ANALYSES IN BOTTOM SEDIMENTS

Analytical results for trace elements and radionuclides in the bottom sediments collected in or near the Stewart Lake Waterfowl Management Area, and the range in values that represents the 95-percent confidence interval for the same constituents for a variety of soils from the Piceance Basin in Colorado and the Uinta Basin in Utah (Tidball and Severson, 1982) are given in table 12. These data are total concentrations for each element except for boron, which represents only the hot-water extractable fraction. A single sediment sample was collected within 10 feet of the discharge point of drains J1, J1A, and J5. The concentrations of most trace elements in the sediments are not outside the range for soils analyzed from the Piceance and Uinta Basins reported by Tidball and Severson (1982). However, selenium and uranium are notably enriched in the sediments of the Stewart Lake Waterfowl Management Area. Selenium and uranium are common trace elements in shale underlying the middle Green River drainage. Selenium concentration in bottom sediments

Table 11.--**Concentrations of selected pesticides and polychlorinated biphenyls and polychlorinated napthalenes in nonfiltered water samples collected in the area of the Stewart Lake Waterfowl Management Area during 1986**

[All concentrations in micrograms per liter]

Site	Date	Aldrin	Chlordane	DDD	DDE	DDT	Dieldrin	Endosulfan	Endrin
Ashley Cr. nr. Jensen	08-28-86	<0.001	<0.1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Drains J1 and J1A	08-28-86	<.001	<.1	<.001	<.001	<.001	<.001	<.001	<.001
Drain J2	08-28-86	<.001	<.1	<.001	<.001	<.001	<.001	<.001	<.001
Drain J3	08-28-86	<.001	<.1	<.001	<.001	<.001	<.001	<.001	<.001
Drain J4	08-28-86	<.001	<.1	<.001	<.001	<.001	<.001	<.001	<.001
Drain J5	08-28-86	<.001	<.1	<.001	<.001	<.001	<.001	<.001	<.001
Stewart Outflow	08-28-86	<.001	<.1	<.001	<.001	<.001	<.001	<.001	<.001
Marsh 4720	08-28-86	<.001	<.1	<.001	<.001	<.001	<.001	<.001	<.001

Site	Date	Heptachlor	Heptachlor Epoxide	Lindane	Methoxychlor	Mirex	PCN	Perthane	PCB
Ashley Cr. nr. Jensen	08-28-86	<0.001	<0.001	<0.001	<0.01	<0.01	<0.1	<0.1	<0.1
Drains J1 and J1A	08-28-86	<.001	<.001	<.001	<.01	<.01	<.1	<.1	<.1
Drain J2	08-28-86	<.001	<.001	<.001	<.01	<.01	<.1	<.1	<.1
Drain J3	08-28-86	<.001	<.001	<.001	<.01	<.01	<.1	<.1	<.1
Drain J4	08-28-86	<.001	<.001	<.001	<.01	<.01	<.1	<.1	<.1
Drain J5	08-28-86	<.001	<.001	<.001	<.01	<.01	<.1	<.1	<.1
Stewart Outflow	08-28-86	<.001	<.001	<.001	<.01	<.01	<.1	<.1	<.1
Marsh 4720	08-28-86	<.001	<.001	<.001	<.01	<.01	<.1	<.1	<.1

Site	Date	Toxaphene	Diazinon	Ethion	Malathion	Methyl Parathion	Methyl Trithion	Parathion	Total Trithion	2,4-D
Ashley Cr. nr. Jensen	08-28-86	<1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.05
Drains J1 and J1A	08-28-86	<1	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Drain J2	08-28-86	<1	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Drain J3	08-28-86	<1	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Drain J4	08-28-86	<1	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Drain J5	08-28-86	<1	<.01	<.01	<.01	<.01	<.01	<.01	<.01	.01
Stewart Outflow	08-28-86	<1	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Marsh 4720	08-28-86	<1	<.01	<.01	<.01	<.01	<.01	<.01	<.01	.04

Table 11.--Concentrations of selected pesticides and polychlorinated biphenyls and polychlorinated napthalenes in nonfiltered water samples collected in the area of the Stewart Lake Waterfowl Management Area during 1986--Continued

Site	Date	2 4-DP	2,4,5-T	Dicamba	Picloram	Silvex	Ametryne	Atrazine	Cyanazine	Prometryne
Ashley Cr. nr. Jensen	08-28-86	<0.01	<0.01	0.01	0.01	<0.01	<0.1	0.1	<0.1	<0.1
Drains J1 and J1A	08-28-86	<.01	<.01	<.01	.01	<.01	<.1	.1	<.1	<.1
Drain J2	08-28-86	<.01	<.01	<.01	<.01	<.01	<.1	<.1	<.1	<.1
Drain J3	08-28-86	<.01	<.01	<.01	.02	<.01	<.1	<.1	<.1	<.1
Drain J4	08-28-86	<.01	<.01	.01	.01	<.01	<.1	.1	<.1	<.1
Drain J5	08-28-86	<.01	<.01	.02	<.01	<.01	<.1	<.1	<.1	<.1
Stewart Outflow	08-28-86	<.01	<.01	.02	.01	<.01	<.1	<.1	<.1	<.1
Marsh 4720	08-28-86	<.01	<.01	.03	.01	<.01	<.1	<.1	<.1	<.1

Site	Date	Prometone	Propazine	Simazine	Simetryne	Carbaryl	Carbofuran	Methomyl	Propham
Ashley Cr. nr. Jensen	08-28-86	0.1	<0.1	<0.1	<0.1	<2.0	<3.4	<2.5	<2.0
Drains J1 and J1A	08-28-86	.1	<.1	<.1	<.1	<2.0	<3.4	<2.5	<2.0
Drain J2	08-28-86	<.1	<.1	<.1	<.1	<2.0	<3.4	<2.5	<2.0
Drain J3	08-28-86	<.1	<.1	<.1	<.1	<2.0	<3.4	<7.8	<5.7
Drain J4	08-28-86	<.1	<.1	<.1	<.1	<2.0	<3.4	<7.8	<5.7
Drain J5	08-28-86	.1	<.1	<.1	<.1	<2.0	<3.4	<2.5	<2.0
Stewart Outflow	08-28-86	<.1	<.1	<.1	<.1	<2.0	<3.4	<2.5	<2.0
Marsh 4720	08-28-86	<.1	<.1	<.1	<.1	<2.0	<3.4	<2.5	<2.0

is greatly enriched compared to the range representing the 95-percent confidence interval of 0.01 to 0.58 micrograms per gram reported for soils of the Piceance and Uinta Basins (Tidball and Severson, 1982).

Concentrations of selenium were largest in the bottom sediments near where drains J3 (48 micrograms per gram) and J4 (85 micrograms per gram) discharge to Stewart Lake. The selenium concentrations in the water from these drains also were large. Bottom sediment at the outflow from Stewart Lake contained only 5.1 micrograms per gram. The large concentrations in bottom sediments near the drains and smaller concentrations in bottom sediments at the outlet indicate that the lake may be a sink for selenium. Concentrations of uranium in the bottom sediments at all sites were similar to or greater than the maximum concentration of 5.2 micrograms per gram for the range reported for soils in the Piceance and Uinta Basins (Tidball and Severson, 1982). The enrichment in uranium is particularly evident in sediments near drains J2, J3, and J4. Concentrations of uranium in water samples collected from these drains ranged from 35 to 73 micrograms per liter (table 9).

The concentrations of selected major and trace elements in bottom sediments collected in the Stewart Lake Waterfowl Management Area (table 13) generally are within the range representing the 95-percent confidence interval for the same elements in soils as reported by Tidball and Severson (1982). The concentration of aluminum in bottom sediment from marsh 4720 near the management area was slightly larger than the maximum concentration for the range in soils, whereas concentrations of aluminum in bottom sediments at all other sites were within the upper range for aluminum. The calcium concentration of 13 micrograms per gram in bottom sediments from near the discharge point of drain J3 was considerably larger than that at any other site, and was larger than the maximum concentration for the range in soils reported by Tidball and Severson (1982).

BIOTA-TISSUE ANALYSES

A search for American coot nests on the Stewart Lake Waterfowl Management Area on June 16, 1986 failed to locate any nests or broods of birds. Less than 24 water-birds were observed, primarily American coots, redheads, and western grebes. Included in the species observed were one double-crested cormorant and two black-crowned night herons. The observed fish population consisted of bullheads, carp, channel catfish, and some unidentified minnows. Few insects, such as dragonflies, and few snails were present. The lake level had been about 30 inches higher earlier in the spring, and was still 8 to 10 inches higher than normal. The widely-fluctuating water levels probably either prevented nesting or destroyed nests built by American coots. All collections of biological samples were deferred for 2 months to allow the water levels to stabilize as much as possible and yet permit sampling of resident American coots.

Table 12.--**Concentrations of trace elements and radionuclides in the less than 63-micrometer fraction of bottom-sediment samples collected in 1986 from Ashley Creek, near outlet of drains flowing into the Stewart Lake Management Area, outflow from Stewart Lake, and marsh 4720 compared with the 95-percent confidence interval for soils in the Piceance Basin, Colorado, and Uinta Basin, Utah**

[Values are for total concentrations except for boron, which is hot-water extractable and is 10-80 percent of the total extractable; μg/g, micrograms per gram]

Trace element or radionuclide	Concentrations at indicated sample locations (μg/g)							
	Ashley Cr.	Drains J1, J1A and J5	Drain J2	Drain J3	Drain J4	Outflow	Marsh 4720	Soils in Piceance[1] and Uinta Basins[2]
Arsenic	7.4	3.4	5.5	2.5	4.8	9.2	7.7	3.5 - 25
Barium	490	530	530	390	470	660	480	640 - 2,250
Beryllium	1	1	1	1	1	2	2	1.1 - 5.3
Boron	3.7	2.4	2.5	4.3	5.2	2.2	5.2	---
Cadmium	<2	<2	<2	<2	<2	<2	<2	---
Cerium	45	53	52	41	48	68	58	25 - 110
Chromium	71	60	61	61	64	62	140	27 - 94
Cobalt	7	8	8	7	8	9	9	4.4 - 12
Copper	16	23	17	19	21	22	18	9.5 - 95
Gallium	11	11	13	11	13	14	15	8.6 - 26
Lanthanum	25	28	27	21	27	37	33	29 - 52
Lead	15	15	17	14	14	19	20	4.5 - 32
Lithium	35	31	38	39	42	38	51	14 - 100
Mercury	0.03	0.02	0.03	0.02	<0.02	0.02	0.03	0.016 - 0.046
Molybdenum	<2	<2	<2	<2	<2	<2	2	2.7 - 12
Neodymium	22	23	24	17	22	32	28	---
Nickel	25	21	26	25	27	24	27	9.9 - 40
Niobium	7	6	5	5	7	9	8	---
Scandium	6	7	8	8	7	8	9	5.5 - 11
Selenium	7.1	10	12	48	85	5.1	4.2	0.01 - 0.58
Strontium	330	510	310	800	430	320	380	190 - 740
Thorium	5.9	<5.2	<6	<8.3	<6.7	12	<4.7	5.5 - 16
Uranium	5.5	7.72	11.2	18.6	14.2	9.18	7.22	2.4 - 5.2
Vanadium	120	65	110	99	99	73	110	40 - 120
Ytterbium	2	2	2	2	2	2	2	1.4 - 4.6
Yttrium	17	16	18	14	16	19	19	11 - 29
Zinc	71	75	75	74	70	72	84	33 - 110

[1] The Piceance Basin, Colorado, is 80 miles southeast of the study area
[2] Data from Tidball and Severson (1982).

Table 13.--Concentrations of selected major and trace elements in the less than 63-micrometer fraction of bottom sediment samples from Ashley Creek, near outlet of drains flowing into the Stewart Lake Waterfowl Management Area, outflow from Stewart Lake, and marsh 4720 compared with the 95-percent confidence interval for soils in the Piceance Basin, Colorado, and Uinta Basin, Utah

Element	Concentrations at indicated sample locations (percent by weight)							
	Ashley Cr.	Drains J1, J1A and J5	Drain J2	Drain J3	Drain J4	Outflow	Marsh 4720	Soils in Piceance[1] and Uinta Basins[2]
Calcium	8.0	9.3	7.1	13.0	8.3	4.7	6.6	0.001 - 11
Magnesium	1.9	1.4	1.6	1.5	1.8	1.4	1.9	0.45 - 3.9
Potassium	1.7	1.6	1.7	1.6	1.8	2.0	1.8	1.2 - 3
Sodium	0.40	0.68	0.56	0.43	0.46	0.71	0.44	0.14 - 2.1
Phosphorus	0.10	0.11	0.11	0.10	0.09	0.71	0.10	---
Aluminum	4.6	4.9	5.5	5.0	5.2	5.7	6.1	3.4 - 5.8
Iron	1.8	1.9	2.1	1.8	2.0	2.5	2.4	1 - 3
Titanium	0.19	0.20	0.21	0.17	0.20	0.25	0.24	0.21 - 0.33

[1] The Piceance Basin, Colorado, is 80 miles southeast of the study area
[2] Data from Tidball and Severson (1982).

Concentrations of trace elements in the biological samples are given in tables 14, 15 and 16. The concentrations are expressed in dry weight in order to be comparable both within and between different taxa. Comparison with other toxicological data can require expression of the data in terms of wet weight, which can be obtained by multiplying the dry-weight concentration by the factor (1 minus the percentage of moisture content expressed as a decimal). For example, the aluminum concentration of Potamogeton collected from the area of drains J1, J1A, and J5 was 8,800 micrograms per gram dry weight, and the percentage of moisture content of the sample was 90.55. This is equivalent to a wet-weight concentration of 832 micrograms per gram [8,800 x (1 - 0.9055)].

The concentrations of inorganic trace elements in tissues, other than boron, selenium, and zinc were not large enough to be harmful to humans or wildlife (tables 14, 15, 16). Undoubtedly, selenium is the principal element in the biota that might be harmful. Concentrations of aluminum in plant tissues were larger than typical concentrations measured in other studies described in the literature. Concentrations of both cadmium and copper in some samples were larger than analytical detection limits, but are not at concentrations likely to be harmful. Arsenic, beryllium, cadmium, lead, mercury, nickel, and vanadium in tissues generally were at concentrations less than analytical detection limits without preconcentration of samples. Concentrations of barium, magnesium, manganese, and tin were greater than the reporting level. However, the relation between the concentrations in tissues and their effects on the biota are not well known. No analyses were done on biological tissues for uranium, even though the concentration of uranium in several water samples exceeded Utah standards for aquatic-wildlife protection.

Table 14.--**Concentrations of selected trace elements in whole-plant samples collected from the middle Green River basin during 1986**

[Concentrations in micrograms per gram (dry weight) and can be expressed as wet weight by multiplying the dry-weight concentration by a factor (1 minus percentage of moisture content expressed as a decimal). Where all values are less than (<), no mean is given; for individual less-than values, one-half of the value was used to calculate the mean]

Organism	Site	Percentage of moisture content	Arsenic	Aluminum	Barium	Beryllium	Boron
Blue-green algae	Drain J3	76.33	2.3	16,000	81	< 0.40	27
do	Marsh 4720	70.47	5.4	2,400	67	< 0.33	9.3
Geometric mean		--	3.5	6,197	74	--	15.8
Range		--	2.3-5.4	2,400-16,000	67-81	--	9.3-27
Filamentous algae	Drains J1, J1A, and J5	83.92	3.7	5,600	72	< 0.62	< 12
Hardstem bullrush	Drains J1, J1A, and J5	85.22	0.39	1,800	22	< 0.68	24
do	Drain J3	78.27	<0.22	250	<4.5	< 0.45	53
do	Marsh 4720	76.60	1.9	3,000	28	< 0.43	46
Geometric mean		--	.43	1,100	11.1	--	39
Range		--	<0.22-1.9	250-3,000	<4.5-28	--	24-56
Potamogeton	Drains J1, J1A, and J5	90.55	4.1	8,800	79	< 1.00	58.0
do	Drain J3	85.68	4.4	9,200	65	< 0.68	190
do	Marsh 4720	92.11	4.5	4,900	63	< 1.2	540
Geometric mean		--	4.3	7,348	69	--	181
Range		--	4.1-4.5	4,900-9,200	63-79	--	58-540

Organism	Site	Cadmium	Copper	Iron	Lead	Magnesium	Manganese
Blue-green algae	Drain J3	<0.4	10	8,100	1.0	11,000	390
do	Marsh 4720	1.1	6.7	15,000	2.7	11,000	330
Geometric mean		0.5	8.2	11,023	1.6	11,000	359
Range		<0.4-1.1	6.7-10	8,100-15,000	1.0-2.7	11,000	330-390
Filamentous algae	Drains J1, J1A, and J5	7.5	11	4,900	<1.2	6,200	1,100
Hardstem bullrush	Drains J1, J1A, and J5	<0.68	13	1,300	<1.4	2,300	280
do	Drain J3	<0.45	1.9	2,900	<0.9	1,900	620
do	Marsh 4720	<0.43	9.4	2,100	<0.85	3,300	660
Geometric mean		--	6.1	1,731	--	2,434	486
Range		--	1.9-13	1,300-2,900	--	1,900-3,300	280-660
Potamogeton	Drains J1, J1A, and J5	<1.0	19.0	8,800	<2.1	7,500	350.0
do	Drain J3	<0.68	8.6	4,600	<1.4	8,500	4,100
do	Marsh 4720	<1.2	9.0	6,300	<2.4	11,000	1,900
Geometric mean		--	11.4	6,342	--	8,884	1,397
Range		--	8.6-19.0	4,600-8,800	--	7,500-11,000	350-4,100

Organism	Site	Mercury	Nickel	Selenium	Tin	Vanadium	Zinc
Blue-green algae	Drain J3	< 0.20	4.6	24	20	35	40
do	Marsh 4720	< 0.16	9.1	2.1	380	32	30
Geometric mean		--	6.5	7.1	87	33	35
Range		--	4.6-9.1	2.1-24	20-380	32-35	30-40
Filamentous algae	Drains J1, J1A, and J5	< 0.28	16	0.49	120	15	75
Hardstem bullrush	Drains J1, J1A, and J5	< 0.33	<6.8	1.2	32	3	14
do	Drain J3	< 0.23	<4.5	7.2	<9	<1.4	34
do	Marsh 4720	< 0.18	<4.3	1.2	18	5.7	11
Geometric mean		--	--	2.2	14	2.3	17.4
Range		--	--	1.2-7.2	<9-32	<1.4-5.7	11-34
Potamogeton	Drains J1, J1A, J5	< 0.49	<10.0	13.00	210.0	25.0	50
do	Drain J3	< 0.34	< 6.8	21	110	30	34
do	Marsh 4720	< 0.59	<12	27	160	19	63
Geometric mean		--	--	19.5	154.6	24.2	47
Range		--	--	13-27	110-210	19-30	34-50

Table 15.--**Concentrations of selected trace elements in American-coot liver samples collected from the middle Green River basin**

[Concentrations in micrograms per gram (dry weight) and can be expressed as wet weight by multiplying the dry-weight concentration by a factor (1 minus percentage of moisture content expressed as a decimal). Where all values are less than (<), no mean is given; for individual less-than values, one-half of the value was used to calculate the mean]

Site	Percentage of moisture content	Arsenic	Aluminum	Barium	Beryllium	Boron
Stewart Lake Waterfowl	75.00	< 0.15	19	<3.8	< 0.38	15
Management Area	75.75	0.5	21	<3.9	< 0.39	13
	76.31	0.21	25	<4.1	< 0.41	<8.2
	71.53	0.27	9.6	<3.4	< 0.34	6.7
	71.14	0.28	17	<4.9	< 0.49	12
	72.85	< 0.25	36	<6.6	< 0.66	29
Geometric mean	--	.21	19.7	--	--	11.1
Range	--	<0.15-0.28	9.6-36	--	--	6.7-29
Ouray National Wildlife	72.65	0.16	28	<3.6	< 0.36	8.8
Refuge--Leota Bottom	74.56	0.44	17	<3.8	< 0.38	< 7.6
Pond L-3	72.7	.35	<5	0.2	< 0.1	<2
	69.3	.1	<5	.1	< 0.1	<2
	72.2	.26	<5	.1	< 0.1	2
	72.2	.2	<5	9.7	< 0.1	<2
	71.9	.1	<5	.1	< 0.1	<2
Geometric mean	--	0.20	--	0.5	--	1.8
Range	--	0.1-0.44	--	0.1-9.7	--	<2-8.8
Ouray National Wildlife	77.73	< 0.18	96	<4.4	< 0.44	38
Refuge--North Roadside	75.34	< 0.17	54	<4.0	< 0.40	34
Pond	76.19	< 0.18	46	<4.0	< 0.40	27
	73.87	< 0.15	39	<3.8	< 0.38	26
Geometric mean	--	--	62	--	--	31
Range	--	--	39-96	--	--	26-38

Site	Cadmium	Copper	Iron	Lead	Magnesium	Manganese
Stewart Lake Waterfowl	<0.38	44	3,100	<0.76	960	8.4
Management Area	<0.39	23	360	<0.78	770	7.1
	<0.41	24	3,600	<0.82	800	17
	2.1	21	15,000	<0.68	960	19
	0.97	31	5,300	<0.97	700	17
	1.3	26	1,200	<1.3	540	12
Geometric mean	0.52	27	2,695	--	774	12.6
Range	<0.38-2.1	21-44	360-15,000	--	540-960	7.1-19
Ouray National Wildlife	0.36	12	2,300	<0.73	650	8.8
Refuge--Leota Bottom	0.45	17	6,800	<0.76	670	9.1
Pond L-3	<0.2	10	2,850	<4	691	8.1
	<0.2	9.7	2,340	<4	612	6.0
	0.2	35.3	1,730	<4	640	9.8
	<0.2	24	620	<4	615	13
	<0.2	12	4,890	<4	723	14
Geometric mean	0.16	15.4	2,461	--	656	9.5
Range	<0.2.45	9.7-35.3	620-6,800	--	612-723	6.0-14
Ouray National Wildlife	<0.44	18	760	<0.88	640	7.7
Refuge--North Roadside	<0.4	44	1,800	<0.80	610	7.9
Pond	<0.4	14	1,700	<0.80	660	10
	<0.38	9.8	2,100	<0.75	530	9.8
Geometric mean	--	18.2	1,487	--	608	8.8
Range	--	9.8-44	760-2,100	--	530-660	7.7-10

Table 15.--**Concentrations of selected trace elements in American-coot** liver **samples collected from the middle Green River basin**--Continued

Site	Mercury	Nickel	Selenium	Tin	Vanadium	Zinc
Stewart Lake Waterfowl Management Area	<0.19	<3.8	7.1	<7.6	<1.1	180
	1.30	<3.9	26	7.7	<1.2	120
	0.49	<4.1	16	82	<1.2	110
	<0.17	<3.4	4.9	370	<1.0	130
	1.30	<4.9	8.8	130	<1.5	210
	<0.34	<6.6	8.6	26	<2.0	140
Geometric mean	.32		10.2	38.0	--	144
Range	<0.17-1.3		4.9-26	<7.6-370	--	110-210
Ouray National Wildlife Refuge--Leota Bottom Pond L-3	<0.17	<3.6	4.8	55	<1.1	73
	0.19	<3.8	3.4	160	<1.1	110
	0.264	<0.8	3.3		<0.2	152
	0.16	<0.8	2.6		<0.2	124
	0.233	<0.8	2.1		<0.2	141
	0.202	<0.8	2.0		<0.2	136
	0.235	<0.8	2.5		<0.2	138
Geometric mean	0.188	--	2.8	93.8	--	121
Range	<0.17-0.264	--	2.0-4.8	55-160	--	73-152
Ouray National Wildlife Refuge--North Roadside Pond	0.21	<4.4	27	8.8	<1.3	110
	0.19	<4.0	25	40	<1.2	140
	<0.18	<4.0	43	30	<1.2	96
	<0.16	<3.8	36	50	<1.1	67
Geometric mean	0.13	--	32	27	--	100
Range	<0.16-0.21	--	25-43	8.8-50	--	67-140

Table 16.--**Concentrations of selected trace elements in composite whole-fish samples collected from the middle Green River basin**

[Concentrations in micrograms per gram (dry weight) and can be expressed as wet weight by multiplying the dry-weight concentration by a factor (1 minus percentage of moisture content expressed as a decimal). Where all values are less than (<), no mean is given; for individual less-than values, one-half of the value was used to calculate the mean]

Organism	Site	Mean Length (millimeters)	Mean Weight (grams)	Percentage of moisture content	Arsenic	Aluminum	Barium	Beryllium
Black bullhead	Stewart Lake, north side	183	82	79.05	<0.21	320	17	< 0.47
	Stewart Lake, south side	171	72	80.15	<0.23	950	20	< 0.48
	Marsh 4720	183	96	81.98	<0.23	160	< 5.5	< 0.55
Geometric mean					--	365	9.8	--
Range					--	160-950	<5.5-20	--
Common carp	Stewart Lake, north side	334	480	78.36	0.22	500	18	< 0.45
	Stewart Lake, south side	227	328	79.84	<0.19	280	11	< 0.49
	Green River nr Stewart Lake	329	514	77.07	<0.22	240	13	< 0.42
	Marsh 4720	323	408	79.96	<0.23	170	6.7	< 0.49
	Marsh 4720	312	418	80.85	<0.21	160	< 5.1	< 0.51
Geometric mean				--	.12	247	8.5	--
Range				--	<0.19-0.22	160-500	<5.1-18	--
Flannelmouth sucker	Green River nr Stewart Lake	483	910	75.96	<0.17	160	< 4.0	< 0.40
Green sunfish	Stewart Lake, south side	100	100	77.25	<0.21	42	< 4.3	< 0.43

Organism	Site	Boron	Cadmium	Copper	Iron	Lead	Magnesium	Manganese
Black bullhead	Stewart Lake, north side	< 9.4	<0.47	1.5	880	<0.94	2,300	18
	Stewart Lake, south side	< 9.5	<0.48	5.3	1,300	<0.95	2,200	22
	Marsh 4720	<11	<0.55	< 0.55	910	<1.1	1,800	14
Geometric mean		--	--	1.30	1,013	--	2,088	18
Range		--	--	<0.55-5.3	880-1,300	--	1,800-2,300	14-22
Common carp	Stewart Lake, north side	23	<0.45	3.1	340	<0.90	2,400	22
	Stewart Lake, south side	< 9.8	<0.49	3.5	920	<0.98	2,000	22
	Green River nr Stewart Lake	< 8.4	<0.42	4.4	450	<0.84	2,000	18
	Marsh 4720	< 9.7	<0.49	2.5	730	<0.97	2,100	9.7
	Marsh 4720	<10	<0.51	< 0.51	1,000	<1	1,900	8.9
Geometric mean		6.4	--	2.00	634	--	2,073	15.0
Range		<8.4-23	--	<0.51-4.4	340-1,000	--	1,900-2,400	8.9-22
Flannelmouth sucker	Green River nr Stewart Lake	< 8.1	<0.40	< 0.40	740	<0.81	1,300	13
Green sunfish	Stewart Lake, south side	< 8.6	<0.43	< 0.43	440	<0.86	1,500	47

Organism	Site	Mercury	Nickel	Selenium	Tin	Vanadium	Zinc
Black bullhead	Stewart Lake, north side	<0.20	<4.7	19	<9.4	<1.4	68
	Stewart Lake, south side	<0.25	<4.8	16	15	<1.4	72
	Marsh 4720	0.24	<5.5	7	<11	<1.6	81
Geometric mean		.14	--	13	7.3	--	73
Range		<0.20-0.25	--	7-19	<9.4-15	--	68-81
Common carp	Stewart Lake, north side	<0.22	<4.5	31	<9	<1.4	200
	Stewart Lake, south side	<0.20	<4.9	23	<9.8	<1.5	250
	Green River nr Stewart Lake	0.24	<4.2	10	<8.4	<1.3	190
	Marsh 4720	<0.24	<4.9	19	<9.7	<1.5	190
	Marsh 4720	<0.24	<5.1	21	<10	<1.5	190
Geometric mean		.13	--	20	--	--	203
Range		<0.20-0.24	--	10-31	--	--	190-250
Flannelmouth sucker	Green River nr Stewart Lake	0.95	<4.0	3.1	<8.1	<1.2	40
Green sunfish	Stewart Lake, south side	<0.21	4.9	26	<8.6	<1.3	100

Selenium

Stewart Lake Waterfowl Management Area

Concentrations of selenium in the plant samples from Stewart Lake (table 14) generally correlate quite well with the concentrations in water samples. All genera collected near drain J3 had larger concentrations of selenium than did genera collected near drains J1, J1A, and J5. The concentrations in algae and Potamogeton spp. near drain J3 were within the range of concentrations reported for algae and rooted plants at Kesterson National Wildlife Refuge although they were less than the mean concentrations (Ohlendorf and others, 1986). Larger concentrations of selenium were measured in hardstem bullrush collected near drain J3 than in hardstem bullrush collected near drains J1, J1A, and J5, but concentrations were small at both sites. The emergent-plant community appeared to have a low diversity of species and generally poor growth at Stewart Lake. Concentrations of selenium in Potamogeton at drains J1, J1A, J5, and J3 and in blue-green algae at drain J3 were up to 2.4 times greater than the value of 10 micrograms per gram (as selenomethionine) that has been demonstrated experimentally to cause increased teratogenic effects and decreased duckling survival (Heinz and others, 1987). Ducklings feeding at site J3 would likely have reduced growth rates.

A total of six American coots were collected at the Stewart Lake Waterfowl Management Area between August 27 and September 3, 1986. These probably were premigration birds, however, how much of the summer they may have spent at the management area is not known. The six birds represented a significant proportion of the total number of birds on the lake during the collection period. Selenium concentrations in the livers had a geometric mean of 10.2 micrograms per gram dry weight, and range of 4.9 to 26 micrograms per gram dry weight (table 15). The concentration of 26 micrograms per gram in one of the livers from American coots collected at the Stewart Lake Waterfowl Management Area was within the range measured at the Kesterson National Wildlife Refuge, where waterfowl deformities were documented and associated with selenium contamination. The livers of five American coots collected in 1985 from the Stewart Lake Waterfowl Management Area by the Utah Division of Wildlife Resources had selenium concentrations with a range of 8.6 to 17.3 micrograms per gram dry weight and a geometric mean of 12.0 micrograms per gram dry weight. This mean is considerably larger than the geometric mean of 5.5 micrograms per gram for selenium concentrations in 20 livers of American coots collected at five waterfowl areas elsewhere in Utah in 1985.

Fish samples from the Stewart Lake Waterfowl Management Area consisted of composite samples, which were generally collected near the drains and the lake outlet (summary of the lengths and weights of fish in each composite sample is presented in table 16). Composite whole-fish samples of five bullheads and five carp collected on the north side of Stewart Lake, where most of the water enters, had selenium concentrations of 19 and 31 micrograms per gram dry weight, respectively. Samples of four bullheads, five carp, and one green sunfish collected on the south side of the lake, closer to the outlet, had selenium concentrations of 16, 23, and 26 micrograms per gram dry weight, respectively. Two of the fish samples contained concentrations of selenium that were within the range of 25 to 45 micrograms per gram dry weight that has been associated with reproductive failures in bluegills (Gillespie and Bauman, 1986); all measured concentrations, when converted to wet weight, were larger than the 2 micrograms per gram wet-weight concentration that reportedly may cause toxic effects in fish (Bauman and May, 1984). Some or all of these fish possibly entered the Stewart Lake Waterfowl Management Area during flooding of the Green River. In this case, the 2 or 3 months that elapsed after flooding may not have allowed adequate time for tissue residues to have stabilized and, therefore, these may be conservative concentrations. Selenium concentrations in water near the outlet of the lake were similar (7 micrograms per liter) in both April and in August.

The biological conditions that would have existed in the Stewart Lake Waterfowl Management Area in 1986 in the absence of flooding are not known. Even with substantial dilution of the lake water by the Green River, selenium concentrations near several of the drains were similar to concentrations known to cause toxic conditions. Few waterfowl were nesting on Stewart Lake in 1986; therefore, evaluation of effects of elevated selenium concentrations on waterfowl populations could not be assessed directly. The effects on fish also are equally uncertain. At least one composite sample of five carp contained concentrations of selenium known to cause reproductive failure in bluegills (Gillespie and Bauman, 1986). The effect these concentrations have had on carp reproduction was not determined. Some schools of young-of-the-year fish were observed in 1986. It is unknown if these fish were offspring of uncontaminated, gravid adults introduced into the Stewart Lake Waterfowl Management Area by flooding of the Green River or of resident fish. It is unknown what effects may be occurring to fish-eating birds feeding at the Stewart Lake Waterfowl Management Area. Fish in Stewart Lake have large concentrations of selenium in their tissues. It is likely that double-crested cormorants, raptors and other animals occupying higher trophic levels that feed substantially at Stewart Lake have a diet containing exceedingly large concentrations of selenium.

Marsh 4720

Concentrations of trace elements in the biological samples from this marsh are given in tables 14-16. The marsh also was flooded in 1986 by water from the Green River and nesting by waterfowl was presumed to be reduced at this location. Several broods of Canada geese were observed using this marsh earlier in the year. In late August, the marsh was surveyed for American coots, but only six were observed. The sample of Potamogeton spp. (pondweed) was collected in the inlet channel within 100 meters of the marsh. The algae and hardstem bullrush were collected in the marsh near the inlet where the water sample was collected. The Potamogeton spp. contained a concentration of selenium that was twice as large as has been documented experimentally to cause reduced duckling survival and teratogenic effects (Heinz and others, 1987). Three composite samples, each consisting of five fish, were analyzed but none of these were predatory fish. Two of the samples consisted of carp, which had selenium concentrations of 19 and 21 micrograms per gram dry weight; the third consisted of black bullheads containing 7 micrograms per gram dry weight. The impacts on the health and reproduction of the species sampled are unknown.

Green River Near Stewart Lake Waterfowl Management Area

Two composite samples of fish were collected from the Green River adjacent to the Stewart Lake Waterfowl Management Area on August 26, 1986: one composite sample of five carp, and one composite sample of two flannelmouth suckers. The carp contained 10 micrograms per gram selenium dry weight. This is about 2.5 times the maximum concentration reported by the U.S. Fish and Wildlife Service's National Contaminant Biomonitoring Program (NCBP) for 1978 or 1980 for carp samples collected from the Green River near Ouray, 30 river miles downstream; and nearly 4 times the concentration for a carp sample collected during the 1984 NCBP sampling (unpublished data). In comparison, the selenium concentration of 3.1 micrograms per gram dry weight in the flannelmouth suckers appears relatively small.

Water samples were not collected from the Green River concurrent with the fish sampling, so the concentration of selenium in the water is not known. However, concentrations in the Green River at Green River, 160 river miles downstream, are typically 2 to 3 micrograms per liter. Because three endangered species of fish and one candidate species live in the Green River, concentrations of selenium in water in the Green River are of concern. Areal and seasonal variations in the concentration of selenium along the Green River and whether they represent ambient or irrigation-induced variations, are unknown.

Ouray National Wildlife Refuge

A total of 11 American coots from two different areas of the Ouray National Wildlife Refuge were collected and analyzed in 1986. Liver samples from these birds had selenium concentrations ranging from 2.0 to 43 micrograms per gram dry weight (table 15). Seven of the 11 American coots were collected from the Leota Bottom area, which receives water from the Green River. Liver tissue from these birds contained concentrations of selenium of less than 5 micrograms per gram. Four of the 11 American coots were collected from the North Roadside Pond, which receives irrigation water from Pelican Lake and shallow ground water. Selenium concentrations in the livers of these birds ranged from 25 to 43 micrograms per gram dry weight and had a geometric mean of 32 micrograms per gram dry weight. The mean for American-coot livers collected from the Kesterson National Wildlife Refuge, where large selenium concentrations were shown to harm waterfowl, was 37.2 micrograms per gram dry weight with a range of 21 to 63 micrograms per gram dry weight (Ohlendorf and others, 1986).

Heinz and others (1987) reported that 11 of 12 mallards died when fed a diet containing 100 micrograms per gram selenium as sodium selenite. The livers of these ducks had mean concentrations of 5.6 (females) and 8.3 (males) micrograms per gram wet weight. The liver of a single male mallard which died after it was fed a diet containing 25 micrograms per gram had a selenium concentration of 6.1 micrograms per gram wet weight. Expressed as wet weight, the range of selenium concentrations for livers from the four American coots collected from the North Roadside Pond at the Ouray National Wildlife Refuge was 5.9 to 10 micrograms per gram.

Table 17.—**Concentrations of selenium in eggs collected from the North and South Roadside Ponds at the Ouray National Wildlife Refuge during summer 1987**

[µg/g, micrograms per gram]

Waterfowl	Status of egg	Selenium (µg/g) Wet weight	Selenium (µg/g) Dry weight
American coot	Deformed embryo	15	65
American coot	No development	13	79
American coot	No development	15	120
American coot	Dead embryo, cause unknown	11	63
Pied-billed grebe	Dead embryo	15	63

Data in table 17 indicate that waterfowl in parts of the Ouray National Wildlife Refuge could have been experiencing reproductive and developmental problems in 1986. Studies of nesting success of American coots on the refuge were completed in 1987 by the U.S. Fish and Wildlife Service. One nest on the North Roadside Pond contained deformed embryos. An egg from this nest and from four other nests from this pond and the nearby South Roadside Pond were analyzed for inorganic residues. None of the eggs would have produced young (table 17). One egg came from a nest that had been destroyed. The concentrations of most trace elements were within the range recognized as safe. However, the concentrations of selenium in the eggs were extremely large, ranging from 63 to 120 micrograms per gram dry weight (table 17). These concentrations are comparable to, or larger than, those reported to cause teratogenic effects and reduced survival of ducklings (Patuxent Wildlife Research Center, 1986), and nearly 3 times greater than concentrations reported as harmful by Heinz and others (1987). The mean and the range of concentrations are larger than those reported for eggs collected at the Kesterson National Wildlife Refuge (Olendorf and others, 1986).

The combination of large concentrations of selenium in water, American-coot livers, and egg contents, and the finding of deformed waterbird embryos resulted in closure of the Roadside Ponds and Sheppard Bottom areas to public use in August 1987. The total area affected was about 10 percent of the refuge. As the affected areas had not been open to fishing or hunting, refuge management reopened the areas to uses exclusive of fishing and hunting the following month.

Table 18.--Comparison of concentrations of trace elements in fish tissue collected nationwide for the National Contaminant Biomonitoring Program with concentrations in fish collected in the Green River near Vernal during 1980-81

[Concentrations in micrograms per gram wet weight]

Element	National Contaminant Biomonitoring Program		Mean, Green River near Vernal
	Mean	85th Percentile	
Arsenic	0.14	0.22	0.11
Cadmium	0.03	0.06	0.1
Copper	0.68	0.90	0.09
Lead	0.17	0.25	0.14
Mercury	0.11	0.18	0.14
Selenium	0.47	0.71	1.10
Zinc	23.82	40.09	40.7

The geometric mean for selenium concentrations in all fish samples collected during the reconnaissance study was 3.1 micrograms per gram wet weight. This concentration exceeded the largest concentration for any single sample collected in the United States during the 1980-81 sampling for the NCBP (Lowe and others, 1985), and was slightly less than the most concentrated sample collected during 1978-79 for the NCBP. The geometric mean for fish from the study area was greater than six times the national mean for 1980-81.

Mean concentrations of seven trace elements measured in freshwater fish samples collected at 112 sites throughout the United States during the 1980-81 NCBP survey are listed in table 18 where they are compared to the mean concentrations measured in fish sampled from the station called Green River near Vernal, Utah, an NCBP station, situated about 1 to 2 river miles downstream from the Ouray National Wildlife Refuge. The concentration larger than that in 85 percent of the samples (the 85th percentile) of the 112 nationwide stations also is listed in table 18. These data indicate that mean tissue concentrations of not only selenium, but also of cadmium and zinc are considerably greater in fish from the Green River than the means for the nationwide samples. Mean concentrations in fish from the Green River also are greater than the 85th-percentile values for nationwide data. However, an interrelation of selenium to trace elements as reported by Frost (1981) and Van Vleet and Boon (1981), and summarized by Combs and Combs (1986, p. 242-248) has not been determined for the middle Green River basin.

Boron

Concentrations of boron in American coots from Stewart Lake and North Roadside Pond at the Ouray National Wildlife Refuge (table 15) were in the range of concentrations measured in the livers of mallards experimentally given feed containing 1,000 micrograms per gram boron (as boric acid). This resulted in reduced hatching success and survival of ducklings (Patuxent Wildlife Research Center, 1986). However, the cause and effect relation for wild birds is unproven because no references were found for toxic effects of boron in livers of wild birds and because the relation of boron in natural foods to boric acid in experimental diets is unknown. Concentrations of boron in American-coot livers collected from North Roadside Pond were substantially larger than in American-coot livers collected from Leota Bottom.

In plants, the largest concentrations of boron were in Potamogeton collected from three sites (table 14). At marsh 4720, Potamogeton was determined to have a boron concentration of 540 micrograms per gram dry weight. Boron appeared to accumulate in the Potamogeton, with concentrations ranging from 190 to 540 micrograms per gram dry weight. These concentrations are somewhat greater than boron concentrations of 141 and 170 micrograms per gram dry weight for two species of Potamogeton in Pennsylvania reported by Adams and others (1973). All other plant samples had boron concentrations that were less than what may be potentially toxic when compared to the boron concentration of 1,000 micrograms per gram in the feed cited earlier.

Boron concentrations in the five eggs from North and South Roadside Ponds at the Ouray National Wildlife Refuge were less than the analytical reporting level. However, the reporting levels were within the range associated with reduced duckling growth and decreased survival reported by Patuxent Wildlife Research Center (1986) in mallards.

Zinc

Concentrations of zinc in source-water samples from the study area were greater than the Utah standard of 50 micrograms per liter established to protect aquatic wildlife. Biological accumulation of zinc appears to be common in plants, fish, and birds from the Stewart Lake Waterfowl Management Area, but its significance is unknown. The geometric mean for plants was 33.3 micrograms per gram dry weight compared to 22.4 micrograms per gram dry weight reported for plants at the Kesterson National Wildlife Refuge. These concentrations are slightly less than the smallest concentration of the typical range of 52 to 447 micrograms per gram dry weight reported for aquatic plants by Adams and others (1973), but are similar to the median concentrations of 19 to 122 micrograms per gram dry weight measured in various algal groups by Martin and Knauer (1973).

The geometric mean of zinc concentrations in 10 fish samples from the study area was 24.9 micrograms per gram wet weight, compared to 23.8 micrograms per gram wet weight measured in the NCBP samples (Lowe and others, 1985). Common carp tend to concentrate zinc more than other fish species, and 5 of 10 samples from the middle Green River basin were carp which resulted in a larger mean. The mean zinc concentration for other species of fish of 14.7 micrograms per gram wet weight was similar to the mean of 17.7 micrograms per gram wet weight for fish samples collected under the NCBP (Lowe and others, 1985).

The mean concentration of zinc of 30 micrograms per gram wet weight in American-coot livers from the Stewart Lake Waterfowl Management Area was larger than the smallest concentration of 20 micrograms per gram wet weight measured in Texas, but was less than the range of geometric means in livers collected from American coots living at a control site (33.1 micrograms per gram wet weight) and at powerplant sites (68.3 micrograms per gram wet weight) reported by White and others (1986).

Because of the possible interaction of selenium and other elements, the concentrations of zinc in American coots from the middle Green River basin were compared to those in American coots from the Kesterson National Wildlife Refuge where selenium has been determined to cause reproductive failures in birds. The mean concentration of 118 micrograms per gram dry weight of zinc in American-coot livers from the Stewart Lake Waterfowl Management Area was similar to the mean of 105 micrograms per gram dry weight in American coot livers from the Kesterson National Wildlife Refuge (Ohlendorf and others, 1986).

Aluminum

No standard has been established in Utah for aluminum in water to protect aquatic wildlife. Aluminum is not generally regarded as a problem element in water except under conditions of acidification, such as when precipitation is acidic and aluminum suspended in surface water may be mobilized in the dissolved form. Under these conditions, dissolved aluminum at a concentration of 1,500 micrograms per liter has been reported to cause growth problems and death in rainbow trout (Everhart and Freeman, 1973). Concentrations of aluminum in water were not measured as part of this study. However, concentrations of dissolved aluminum in the Green River at Green River, Utah, never exceeded 30 micrograms per liter during 1982-86, and usually were less than 10 micrograms per liter. A single analysis of 540 micrograms per liter was reported for Big Brush Creek at Kaler Hollow (located 40 miles north of Stewart Lake) in August 1976.

The large concentrations of aluminum (as much as 16,000 micrograms per gram dry weight measured in plant tissues from Stewart Lake Waterfowl Management Area (table 14) demonstrate the tendency for aquatic plants and particularly algae to concentrate aluminum in plant tissue. Concentrations in the study area are generally greater than representative concentrations from other areas. Martin and Knauer (1973) reported that marine algae contain a maximum aluminum concentration of 2,850 micrograms per gram dry weight. Riley and Roth (1971) determined that, for 15 species of marine algae grown in enriched media, the maximum aluminum concentration was 400 micrograms per gram dry weight. They also noted that as the concentration of other trace elements increased in the media (and in the algae), the concentration of aluminum decreased in the algal tissue. Concentrations of aluminum in *Potamogeton* and several other submersed and floating aquatic plants are commonly large. Adams and others (1973) reported that concentrations of aluminum in these plants generally were greater than the maximum detection limit for their analytical procedure of 1,100 micrograms per gram dry weight. The ecological significance of three relatively large aluminum concentrations of 8,800, 9,200, and 16,000 micrograms per gram dry weight in plant tissues from the Stewart Lake area is not known. Likewise, concentrations of aluminum in American-coot livers collected from the North Roadside Pond were larger than concentrations in those collected from the Stewart Lake Waterfowl Management Area and were considerably larger than concentrations in American-coot livers collected at Leota Bottom (table 15), but the significance of these concentrations of aluminum is unknown.

Cadmium

As discussed previously, concentrations of cadmium in fish samples from the Green River were found to exceed the concentration that was greater than 85 percent of concentrations for all stations in the NCBP (Lowe and others, 1985). During the reconnaissance of the middle Green River basin, concentrations in 24 of the 31 biological samples analyzed were less than reporting levels. The largest concentration was 7.5 micrograms per gram dry weight in an algal sample from Stewart Lake.

Copper

Concentrations of copper measured in water samples from the study area did not exceed the Utah standard established to protect aquatic wildlife. Concentrations of copper in rooted plants from the Stewart Lake area (table 14) were about twice those measured at the Kesterson National Wildlife Refuge, but were similar to the single concentration of 14 micrograms per gram dry weight reported for Volta Wildlife Area in Ohlendorf and others (1986, p. 58). Concentrations in American-coot livers from the Stewart Lake Waterfowl Management Area and the Ouray National Wildlife Refuge had a geometric mean of 21.4 micrograms per gram dry weight and ranged from 9.7 to 44 micrograms per gram dry weight (table 15). White and others (1986) concluded that concentrations as large as 9.4 micrograms per gram wet weight were biologically insignificant in their study in Texas. For comparison, the largest wet-weight concentration measured in American coot livers from the middle Green River basin was 11 micrograms per gram. Concentrations of less than 0.4 to 5.3 micrograms per gram dry weight measured in fish from the Stewart Lake Waterfowl Management Area generally were less than the range of 5.2 to 8.4 micrograms per gram dry weight measured at the Volta Wildlife Area or at the Kesterson National Wildlife Refuge in mosquitofish (Ohlendorf and others, 1986).

Pesticides and Polychlorinated Biphenyl Residues

Scans for organochlorine residues and polychlorinated biphenyl residues were done on 4 American-coot livers and 1 composite carp sample from the Stewart Lake Waterfowl Management Area, 1 composite carp sample from the Green River, 1 composite carp sample from marsh 4720, and 6 American-coot livers from the Ouray National Wildlife Refuge (table 19). All concentrations were less than reporting levels. These concentrations compare favorably with data from fish collected from the Green River at Ouray by the U.S. Fish and Wildlife Service under the National Pesticide Monitoring Program (Schmitt and others, 1983, p. 20).

Table 19.--**Concentrations of selected pesticides and polychlorinated biphenyls in American-coot-liver and composite whole-body-carp samples collected from the middle Green River basin during 1986**

[Concentrations in micrograms per gram (dry weight), and can be expressed as wet weight by multiplying the dry-weight concentration by a factor (1 minus percentage of moisture content expressed as a decimal)]

Site	Percentage of moisture content	Percent lipid	cis-Chlordane	p,p'-DDD	p,p'-DDE	p,p'-DDT	Dieldrin
			American coot				
Stewart Lake Waterfowl Management Area	75.00	2.06	<0.080	<0.080	<0.080	<0.080	<0.080
	75.75	1.35	<.040	<.040	<.040	<.040	<.040
	76.31	.99	<.042	<.042	<.042	<.042	<.042
	71.53	2.79	<.12	<.12	<.12	<.12	<.12
Ouray National Wildlife Refuge							
Leota Bottom Pond L-3	72.65	1.83	<0.060	<0.060	<0.060	<0.060	<0.060
	74.56	1.97	<.065	<.065	<.065	<.065	<.065
North Roadside Pond	77.73	0.66	<0.45	<0.45	<0.45	<0.45	<0.45
	75.34	.61	<.45	<.45	<.45	<.45	<.45
	76.19	1.16	<.43	<.43	<.43	<.43	<.43
	73.87	.62	<.43	<.43	<.43	<.43	<.43
			Carp				
Stewart Lake, North Side	75.00	2.73	<0.46	<0.46	<0.46	<0.46	<0.46
Green River nr. Stewart Lake	75.75	3.13	<.43	<.43	<.43	<.43	<.43
Marsh 4720	76.31	1.30	<.49	<.49	<.49	<.49	<.49

Site	Endrin	Heptachlor epoxide	cis-Nonachlor	trans-Nonachlor	Oxychlordane	Polychlorinated biphenyl-1254	Toxaphene
			American coot				
Stewart Lake Waterfowl Management Area	<0.080	<0.080	<0.080	<0.080	<0.080	<0.80	<4.0
	<.040	<.040	<.040	<.040	<.040	<.40	<2.0
	<.042	<.042	<.042	<.042	<.042	<.42	<2.1
	<.12	<.12	<.12	<.12	<.12	<1.2	<5.9
Ouray National Wildlife Refuge							
Leota Bottom Pond L-3	<0.060	<0.060	<0.060	<0.060	<0.060	<0.60	<3.0
	<.065	<.065	<.065	<.065	<.065	<.65	<3.2
North Roadside Pond	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<2.2
	<.45	<.45	<.45	<.45	<.45	<.45	<2.2
	<.43	<.43	<.43	<.43	<.43	<.43	<2.1
	<.43	<.43	<.43	<.43	<.43	<.43	<2.1
			Carp				
Stewart Lake, North Side	<0.46	<0.46	<0.46	<0.46	<0.46	<0.46	<2.3
Green River nr. Stewart Lake	<.43	<.43	<.43	<.43	<.43	<.43	<2.2
Marsh 4720	<.49	<.49	<.49	<.49	<.49	<.49	<2.5

SUMMARY

This report details the results of a reconnaissance study to assess the effects of irrigation drainage on water quality and the biota of the Stewart Lake Waterfowl Management Area and a nearby marsh near Jensen, Utah, and at the Ouray National Wildlife Refuge located 30 river miles south of Stewart Lake. This reconnaissance is one of nine reconnaissance-level studies conducted during 1986-87 that investigated the potential effects of irrigation drainage on human health, fish, and wildlife, or other water uses in areas in the western United States. The reconnaissance studies were done by DOI teams comprised of scientists from the U.S. Geological Survey, the U.S. Fish and Wildlife Service and the U.S. Bureau of Reclamation.

The climate and geology of the area are conducive to salinity and drainage problems. The area is characterized by hot summers and little precipitation, and is underlain by marine and freshwater sedimentary deposits. These deposits contain considerable quantities of boron, selenium, and uranium that may be leached and transported by water. In addition to this naturally occurring process, irrigation increases leaching of salts derived from these deposits and re-use of the water and subsequent concentration of the salts. The discharge of water containing large concentrations of some trace elements into a wildlife area may then result in decreased reproduction and increased deformities of the biota.

Drains were installed from 1974 to 1979 on 750 acres of land in the Jensen area north of the Stewart Lake Waterfowl Management Area to remove shallow ground water accumulated by irrigation and to open areas with a shallow water table to cultivation. The drains typically have flows of less than 4 cubic feet per second, but they constitute the major source of inflow into the Stewart Lake Waterfowl Management Area except when the Green River overflows into the management area. Monitoring of water quality by the U.S. Bureau of Reclamation since the completion of the drains in 1979 at times has detected: (1) large concentrations of boron in water from drains J2, J3, and J4 and the lake outflow; (2) large concentrations of copper in water from drain J4; (3) large concentrations of nitrate in water from drains J3 and J4; and (4) large concentrations of zinc in water from all drains. Concentrations of selenium in drain water were small, probably because the analytical procedure determined only a portion of the total selenium. Analyses indicated that there was little contamination of the drain water by pesticides.

The 1986-87 reconnaissance study was conducted during part of a 4-year period when the Stewart Lake Waterfowl Management Area was flooded annually by the Green River. Consequently, the data represent a period of dilution and flushing of water in the management area and, therefore, portray only conditions occurring at high flows. Water in Brush Creek entering the Jensen area had concentrations of major and trace elements within applicable agricultural and aquatic-wildlife standards. Water in Ashley Creek, which receives some irrigation return flows and discharges to the Green River near Stewart Lake, had selenium concentrations of 25 to 73 micrograms per liter. The largest selenium concentration in the creek occurred during August when water flow was greatly decreased and the proportion of return flows was largest.

Selenium is the principal constituent of concern in water at all areas included in this reconnaissance. Samples of water from four irrigation drains discharging to the Stewart Lake Waterfowl Management Area contained considerable quantities of selenium, ranging from 14 to 140 micrograms per liter. Concentrations in water from drains J1, J1A, and J2 did not exceed 42 micrograms per liter, but water from drains J3 and J4 commonly had concentrations greater than 62 micrograms per liter. The combined load of selenium discharged to the Stewart Lake Waterfowl Management Area from all measured sources was estimated to be 0.5 kilogram per day, with 97 percent of the load contributed by water from the ground water drains.

Water from marsh 4720 southwest of the Stewart Lake Waterfowl Management Area contained concentrations of boron and zinc that exceeded State standards for agriculture and aquatic wildlife. The selenium concentration of 31 micrograms per liter, while not larger than the State standard or U.S. Environmental Protection Agency criterion, probably is potentially hazardous.

Water samples from the Ouray National Wildlife Refuge were analyzed only for selenium, boron, and zinc. Concentrations of selenium in the two principal water sources for the refuge differed considerably. The Green River supplies water to the Leota Bottom area and supplies most of the water used in the Sheppard Bottom area. The selenium concentration in water from the Green River ranged from less than 1 to 3 micrograms per liter. Water supplied to the North Roadside Pond is irrigation return flow and some shallow ground water. Water in the North Roadside Pond had selenium concentrations of 9 to 93 micrograms per liter; the larger concentration is nearly twice the permissable Utah standard for aquatic wildlife. This water is mixed with water from the Green River to supply ponds in Sheppard Bottom; this dilution results in a selenium concentration of 3 micrograms per liter in that area. Concentrations of boron in water from the North Roadside Pond did not exceed 360 micrograms per liter; only one water sample from the Ouray National Wildlife Refuge had a concentration of zinc greater than the Utah standard of 50 micrograms per liter.

Concentrations of trace elements in bottom sediments from Ashley Creek near Jensen were typical of concentrations in soils in the Piceance Basin of Colorado and the Uinta Basin of Utah except for selenium, at a concentration of 7.1 micrograms per gram, which was more than 10 times as much in the bottom sediments from Ashley Creek as in the soils. Selenium was enriched even more in bottom sediments collected from near the discharge points of the drains in the Stewart Lake Waterfowl Management Area. Concentrations near drains J1, J1A, J2, and J5 did not exceed 12 micrograms per gram, but bottom sediments near drains J3 and J4 contained 48 and 85 micrograms per gram which is 83 to 147 times the concentrations normal in soils in the area. Bottom sediments from near the outflow of the lake and from marsh 4720 had selenium concentrations of almost 5 micrograms per gram. The larger concentrations of selenium in bottom sediments near the drains and the smaller in sediment concentration near the outflow may indicate the lake is a sink for selenium. In addition to selenium, concentrations of uranium in bottom sediments near drains J3 and J4 were three to seven times as much as in soils in the area.

Flooding of the Stewart Lake Waterfowl Management Area by the Green River decreased the number of nesting sites for waterfowl during the critical spring nesting season of 1986. In addition, few organisms such as dragonflies, other insects, and snails appeared to be present in 1986. The decreased populations of biota greatly complicated the collection and interpretation of the biological data. Concentrations of most trace elements in plant tissues such as Potamogeton, algae, and hardstem bullrush generally were within measured ranges from areas believed to represent normal background conditions. Concentrations of selenium in plants collected near drain J3 however, were notably larger—twice as large as in plants collected in the vicinity of drains J1, J1A, and J5. The largest concentration of selenium in plant tissue was 27 micrograms per gram dry weight in Potamogeton collected at marsh 4720 southwest of the lake.

Selenium concentrations also were relatively large in livers of American coots collected at the Stewart Lake Waterfowl Management Area, ranging from 4.9 to 26 micrograms per gram dry weight. The mean of 10.2 micrograms per gram was about twice that of concentrations in livers of 20 American coots collected at five other waterfowl areas in Utah in 1985. Some of the livers contained selenium concentrations that were within the range reported to cause reproductive failures in experiments with controlled diets. The largest concentration measured at the Stewart Lake Waterfowl Management Area was within the range of concentrations measured at the Kesterson National Wildlife Refuge, where selenium contamination from irrigation drainage was initially documented.

Concentrations of selenium in composite fish samples from the Stewart Lake Waterfowl Management Area ranged from 16 to 31 micrograms per gram, and tended to be larger in fish collected near the north shore where most of the water enters Stewart Lake. Two of the fish samples contained selenium concentrations of 26 and 31 micrograms per gram dry weight; these concentrations are similar to the concentration that has been associated with reproductive failure in bluegills. All concentrations were larger than the concentration at which toxic effects may occur (2 micrograms per gram wet weight).

Selenium concentrations of 19 and 21 micrograms per gram dry weight in carp collected from marsh 4720 were about the same as the smallest selenium concentration in carp samples from Stewart Lake. The concentration in a composite sample of black bullheads from the marsh was only about one-half of that in bullheads from Stewart Lake. A composite sample of carp collected from the Green River adjacent to the Stewart Lake Waterfowl Management Area contained 10 micrograms per gram dry weight, which was 2.5 to 4 times the maximum concentration reported for carp collected 30 miles downriver near Ouray by the National Contaminant Biomonitoring Program in 1978, 1980, and 1984. However, the flannelmouth suckers collected from the Green River near the Stewart Lake Waterfowl Management Area contained only 3.1 micrograms per gram dry weight.

Concentrations of selenium in American-coot livers collected from two sites at the Ouray National Wildlife Refuge correlated well with selenium concentrations measured in the water. American coots collected in the Leota Bottom area of the refuge that receives water from the Green River and had concentrations of selenium in water of less than 1 microgram per liter, had concentrations of selenium in their livers ranging from 2 to 4.8 micrograms per gram dry weight. Concentrations in livers from American coots collected at the North Roadside Pond that receives irrigation water and groundwater were larger, ranging from 25 to 43 micrograms per gram dry weight. Selenium concentrations in water samples from the North Roadside Pond were also larger—from 9 to 93 micrograms per liter. Deformed American-coot embryos were discovered at the North Roadside Pond; selenium concentrations in five eggs from the North and South Roadside Ponds ranged from 63 to 120 micrograms per gram dry weight. These findings resulted in closure of a part of the refuge during August 1987.

Plants collected from the Stewart Lake Waterfowl Management Area and marsh 4720 contained greater than average concentrations of aluminum, boron, copper, and zinc. However, the effects of these concentrations are not known. Concentrations of aluminum in the fish samples were largest in the black bullheads collected from Stewart Lake.

Concentrations of boron generally were small in fish tissue, but were as large as 38 micrograms per gram dry weight in the livers of American coots collected from the North Roadside Pond at the Ouray National Wildlife Refuge. These concentrations were within a range of concentrations of boron in ducklings that had decreased survival rates during studies of the effects of excessive boron in feed. Concentrations of zinc appeared to be large in fish tissues and American-coot livers from the Stewart Lake Waterfowl Management Area and in American-coot livers from the Ouray National Wildlife Refuge. The mean concentration for 10 fish samples was 24.9 micrograms per gram dry weight, which was slightly larger than the mean reported for fish collected during the National Contaminant Biomonitoring Program. This difference may be because a large proportion of the samples consisted of carp, which preferentially accumulate zinc. There were no significant differences in concentrations of zinc in American-coot livers collected at the Stewart Lake Waterfowl Management Area and at two sites at the Ouray National Wildlife Refuge.

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