FIELD SCREENING OF WATER QUALITY, BOTTOM SEDIMENT, AND BIOTA ASSOCIATED WITH THE EMERY AND SCOFIELD PROJECT AREAS, CENTRAL UTAH, 1994

By Doyle Stephens, U.S. Geological Survey; and Bruce Waddell, Kristi DuBois, and Elise Peterson, U.S. Fish and Wildlife Service

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 96-4298

U.S. GEOLOGICAL SURVEY,
U.S. FISH AND WILDLIFE SERVICE,
BUREAU OF RECLAMATION, and
BUREAU OF INDIAN AFFAIRS

Salt Lake City, Utah
1997

U.S. DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
acre	4,047	square meter
acre-foot (acre-ft)	1,233	cubic meter
acre-foot per year (acre-ft/yr)	0.00003907	cubic meter per second
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
ton	0.907	metric ton

Water temperature is reported 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—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Chemical concentration and water temperature are reported only in metric units. Chemical concentration in water is reported 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 greater than 7,000 milligrams per liter. One thousand micrograms per liter is equivalent to 1 milligram per liter. Radioactivity is expressed in picocuries per liter (pCi/L), 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 reported in micrograms per gram (µg/g), which is equal to parts per million (ppm), or micrograms per kilogram (µg/kg), which is equal to parts per billion (ppb). Specific conductance is reported in microsiemens per centimeter at 25 degrees Celsius (µS/cm).

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ABSTRACT

Field screening of water quality, bottom sediment, and biota was done by the U.S. Geological Survey during 1994 at sites in the Emery and Scofield Project areas of central Utah to determine if irrigation or project mitigation water delivered by the U.S. Department of the Interior caused harmful effects to fish and wildlife resources or to human health. Water quality in the Emery Project area was generally poorer than in the Scofield Project area, although source water from Joes Valley Reservoir was excellent. Water in some subsurface drains contained a selenium concentration as high as 16 µg/L, and the concentration in an open channel receiving subsurface drainage was 46 µg/L. Water flowing into Desert Lake Waterfowl Management Area contained amounts of dissolved solids, uranium, and selenium that are potentially hazardous to biota. Concentrations of selenium and uranium entering Tamarisk Lake at the management area exceeded values known to have adverse effects on waterbirds. The quality of source water in the Scofield Project area was excellent, but deteriorated slightly in the downstream parts of the area as the water accumulated boron, selenium, and salinity.

Selenium concentrations were elevated above the toxicity-threshold value of 3 µg/g in such dietary items as invertebrates and fish at Desert Lake Waterfowl Management Area, Dutchmans and Olsen Reservoirs, the Price River, and Soldier Creek. The high concentrations of selenium in dietary items resulted in concentrations of selenium in eggs of insect- and fish-eating birds that exceeded the toxicity threshold at Desert Lake Waterfowl Management Area and were greater than normal background concentrations at Olsen Reservoir. Adverse effects at Desert Lake Waterfowl Management Area may be more pronounced in the initial impoundments such as Tamarisk Lake, where concentrations for all coot eggs collected in 1988, all duck and grebe eggs collected in 1990, and all avocet eggs collected in 1994 exceeded the toxicity threshold for waterbird production.

Selenium contamination of water with resultant adverse effects on biota appears limited to Desert Lake Waterfowl Management Area and Olsen Reservoir. Both are located within the Price River drainage but the contamination is caused primarily by water from the Emery Project. Boron, uranium, and dissolved salts also may be adversely affecting biota at these sites.

INTRODUCTION

Background

Studies by the U.S. Fish and Wildlife Service (USFWS) in the Western United States have related mortality, embryo teratogenesis, and reproductive failures of aquatic birds and fish to high concentrations of selenium in irrigation drainage. These effects were observed in 1983 at the Kesterson National Wildlife Refuge in western San Joaquin Valley, California, where drainage water was impounded.

In response to widespread concern about the general nature and extent of contaminant problems associated with irrigation drainage, the U.S. Department of the Interior (DOI) developed the Irrigation Drainage

Program (currently called the National Irrigation Water Quality Program or NIWQP) in 1985 and formed the interbureau Task Group on Irrigation Drainage to address water-quality problems related to irrigation drainage for which DOI may be responsible. Subsequently, 39 areas that warranted reconnaissance-level or field-screening study were identified. The study areas relate to four areas of DOI responsibility: (1) irrigation or drainage facilities constructed or managed by the DOI; (2) National Wildlife Refuges managed by the DOI that receive irrigation drainage; (3) other migratory-bird or endangered-species management areas that receive water from DOI-funded projects; and (4) public and private drinking water supplies that may be affected by drainwater from DOI irrigation facilities.

The discovery of the effects of selenium on the health of biota has led to more than a decade of scientific investigation regarding the quality of irrigation water and its potential harmful effects on humans, fish, and wildlife (Feltz and others, 1991; Peterson and Nebeker, 1992). Selenium concentrations that exceeded the water-quality criterion for the protection of aquatic life (U.S. Environmental Protection Agency, 1987) were detected in surface and subsurface drainage from irrigated land (Feltz and Engberg, 1994), and arsenic, heavy metals, and pesticide residues have been detected in numerous areas of the Western United States that receive irrigation drainage. Concentrations can become toxic where naturally occurring selenium and associated constituents are leached from soil and underlying geologic formations by irrigation water and are accumulated by processes of evaporation and bioaccumulation. Wetlands and closed-basin ponds are particularly susceptible sites.

Sampling done within the Emery Project area by the U.S. Geological Survey (USGS) and the USFWS at Desert Lake Waterfowl Management Area (WMA) in 1988 and 1990 found selenium concentration in the inflow water to be as high as 12 µg/L. Samples of bottom sediment from ponds contained low but detectable concentrations of DDT and DDE, and waterbird eggs contained selenium concentrations as high as 22.6 µg/g (dry weight) (Waddell and Coyner, 1990; Waddell and Stephensen, 1992).

Historical water-quality data for the San Rafael River near its confluence with the Green River show selenium concentrations as high as 5 µg/L, with concentrations in one tributary (Muddy Creek) as high as 16 µg/L. Concentrations of selenium in water from Spring Canyon Creek in the Scofield Project area have been as high as 21 µg/L, and in the Price River near its confluence with the Green River, concentrations have been as high as 12 µg/L. On the basis of results of the historical data and recent investigations, the quality of irrigation water in the Emery and Scofield Project areas became a subject of concern.

Purpose and Scope

This report documents the results of a field-screening study of the physical and chemical conditions associated with a water supply developed for the Emery and Scofield Projects by the DOI. Physical and chemical data are presented for water, bottom sediment, and biota believed to be representative of the irrigated and wetland areas within the irrigation project areas. Data collected during this study will enable the DOI to determine if irrigation or mitigation water delivered by the project causes, or has the potential to cause, significant harmful effects to fish and wildlife resources in Desert Lake WMA, Huntington North Reservoir, or wetland or riparian areas receiving project water.

General Description of the Projects and Areas

The Emery Project area, located in Emery County, east-central Utah, was authorized in 1956 as one of the initial projects of the Colorado River Storage Project, and the Bureau of Reclamation (BOR) began construction in 1963. Principal features of the project area are Joes Valley Reservoir located on the Wasatch Plateau 17 mi west of Huntington, Swasey Diversion Dam near Castle Dale, Huntington North Reservoir near Huntington, and Cottonwood Creek-Huntington Canal (figs. 1 and 2). The project provides 28,100 acre-ft of water annually for irrigation of 14,171 acres. Water impounded in Joes Valley Reservoir is delivered via Huntington and Cottonwood Creeks and Cottonwood Creek-Huntington Canal for agricultural use on the east slope of the Wasatch Plateau. Some of the water discharged from the northern part of the project flows through subsurface drains and canals to the 2,600-acre Desert Lake WMA, managed by the Utah Department of Natural Resources, Division of Wildlife Resources, and eventually to the Price River (fig. 2). Part of the mitigation for the Emery Project involved transfer of additional water rights to the State for use at Desert Lake WMA. Water from the south part of the Emery Project discharges to the San Rafael River. Initial project plans included 24 mi of subsurface drains, but only about two-thirds of these were constructed

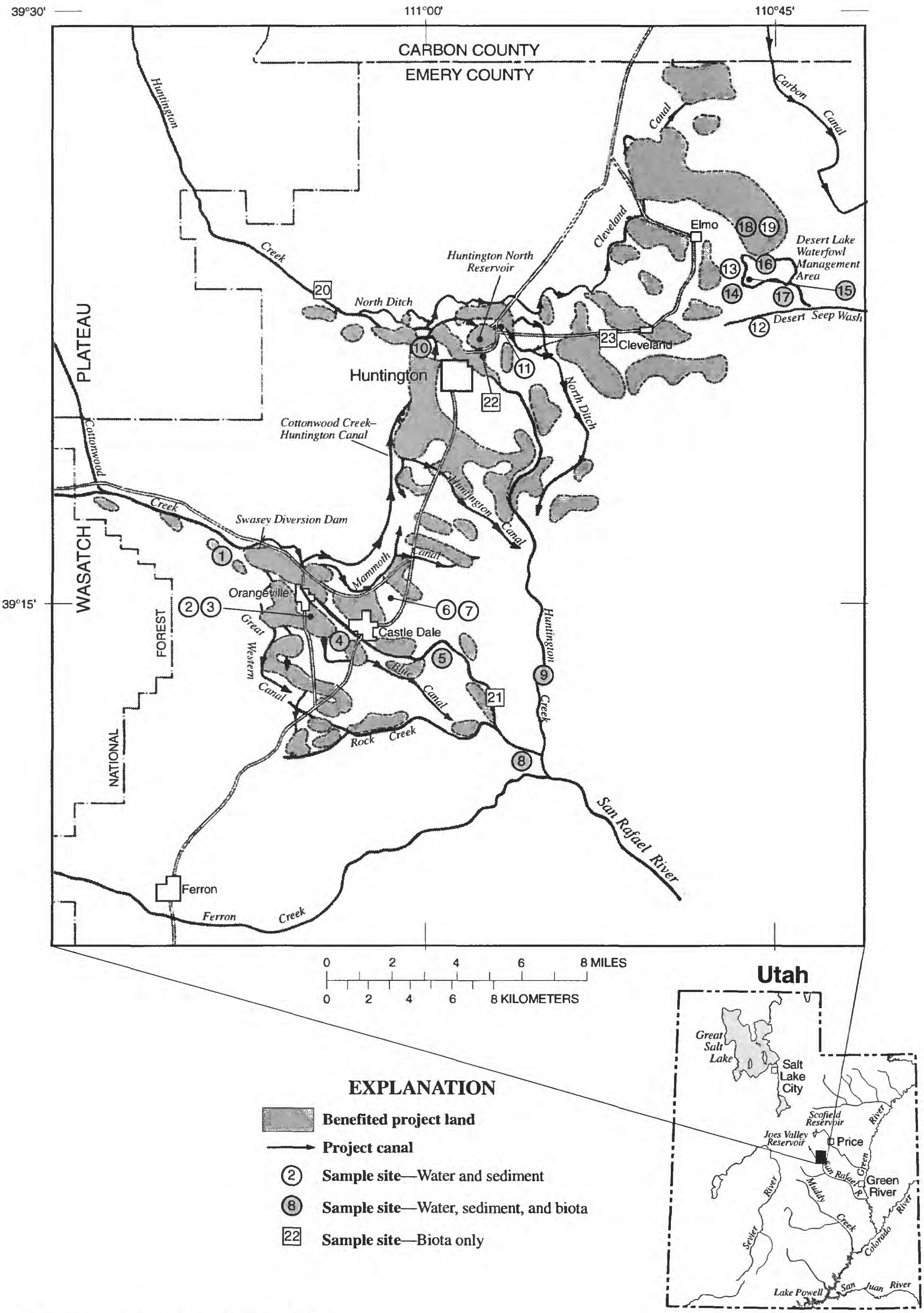

Figure 1. Emery Project area, Utah.

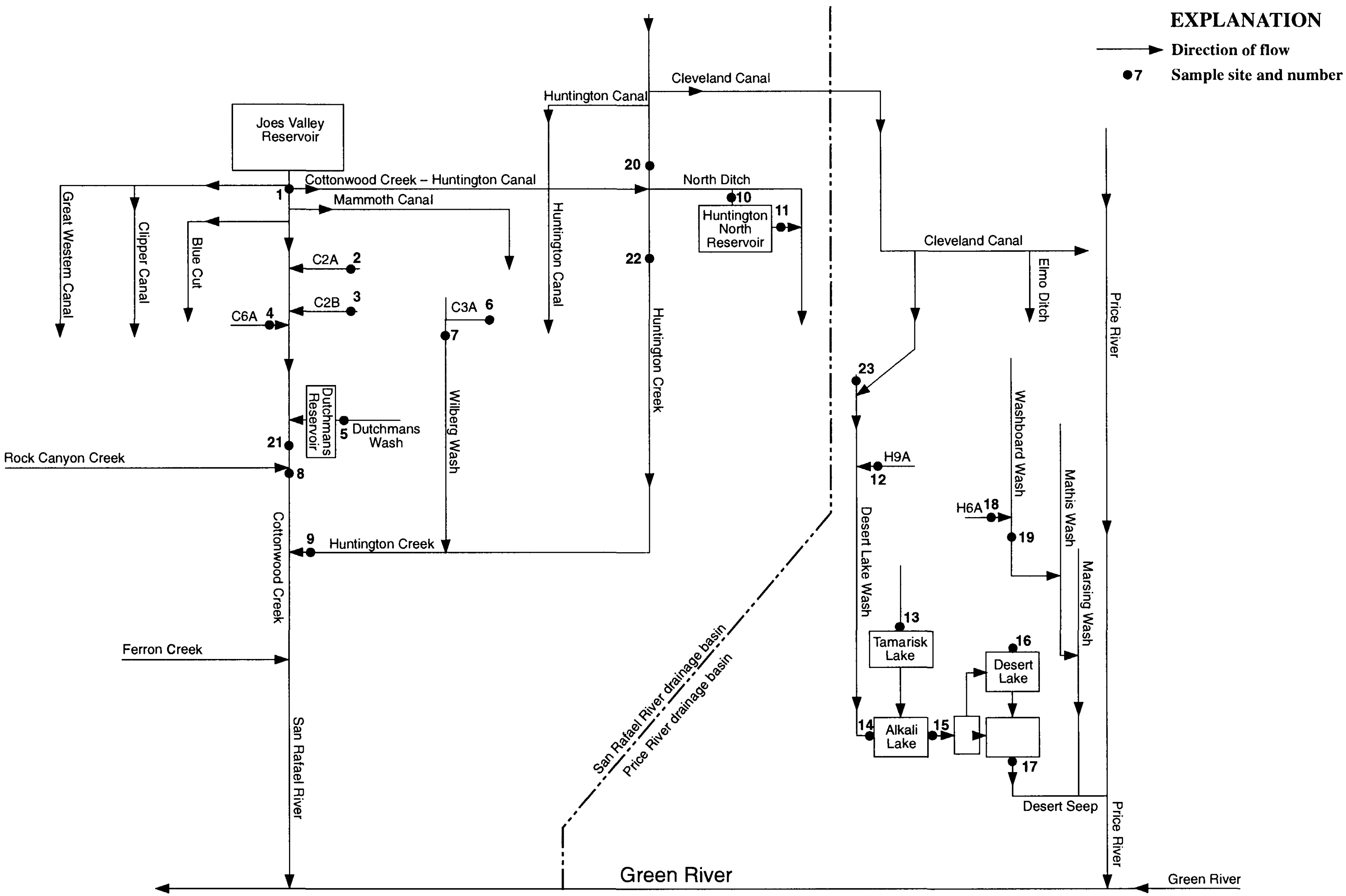

Figure 2. Schematic diagram of water-delivery system and sample sites, Emery Project, Utah.

(Clark Whitlock, oral commun., Bureau of Reclamation, 1994).

The Scofield Project area, located in central Utah at the headwaters of the Price River, extends to the Price and Helper areas north of the Emery Project (fig. 3). A generalized schematic diagram of the Scofield irrigation project is shown in figure 4. The project was authorized in 1943 under the Water Conservation and Utilization Act and was constructed during 1943-46 by the BOR. Operation of the project was transferred from BOR to the Carbon Water Conservancy District in 1949. The principal feature is Scofield Reservoir, located 20 mi northwest of Price, which was enlarged in 1946 to provide 65,800 acre-ft of irrigation and municipal water for 26,000 acres of land in the Price-Helper-Spring Glen areas. Water is discharged from Scofield Reservoir to the Price River and is distributed by several ditches, the Price-Wellington Canal, and Carbon Canal. Irrigation return and local drainage are collected in natural channels and discharge back into the Price River, which discharges into the Green River. Only four to six subsurface drains are associated with the project, and they were installed as on-farm projects by the Natural Resources Conservation Service (formerly called the Soil Conservation Service).

There are no State or Federal waterfowl management areas within the Scofield Project. However, some endangered species of fish (as well as two candidate species, flannelmouth sucker and roundtail chub) have been found in the lower Price River, and critical habitat for all threatened and endangered fish in the upper Colorado River drainage includes all of the Green River below the confluence with the Price River. Additionally, the Castle Gate and Book Cliffs areas are known wintering areas for bald eagles, which may feed on organisms in streams in the project areas.

Soils and Geology

Soils in the project areas are derived from several formations that crop out in the area, including the Summerville Formation, Entrada Sandstone, and Morrison Formation, and are classified as "seleniferous" by Rosenfeld and Beath (1964). A local equivalent of the Mancos Shale, the Indianola Formation, is present in the valley floor. Soil types derived from seleniferous formations include the Libbings, Chipeta, Persayo, Billings, and Killpack. Soil evaporites are a persistent source of salinity in the Scofield and Emery project areas, and both areas are included in the Price-San Rafael Rivers Unit of the Upper Colorado Salinity Control Project, which began in 1993.

Historical Irrigation-Drainage Problems

Water-quality data from the discharge to Desert Lake WMA were collected in 1988 by the USGS and the USFWS (table 1). Selenium concentrations ranged from 4 to 12 µg/L (number of samples, n=4). Samples of bottom sediment from two ponds contained low but measurable concentrations of DDT (0.1 µg/kg, dry weight) and DDE (0.2 µg/kg). Samples of coot eggs taken from Tamarisk Lake contained selenium concentrations that exceeded the toxicity-threshold value of 8 µg/g, dry weight (Skorupa and Ohlendorf, 1991), and ranged from 9.6 to 16.9 µg/g (dry weight) with a geometric mean of 13.4 µg/g (n=5). The mean concentration in eggs from several ponds located downstream of Tamarisk Lake was 5.4 µg/g (n=5). No deformities were noted in one egg that was incubated to a stage of growth where deformities would be observable. Selenium concentration in composite samples of carp, Utah chub, and green sunfish ranged from 6 to 15.7 µg/g, dry weight (n=6). Most biota contained selenium concentrations that exceeded 8 µg/g in waterbird eggs and 6 µg/g in warm-water fish, which are believed to be minimum concentrations at which toxicity may occur (Waddell and Coyner, 1990).

In 1990, waterbird eggs sampled by USFWS from Tamarisk Lake at Desert Lake WMA contained selenium concentrations that ranged from 6.84 to 22.6 µg/g (dry weight, n=7). Two American coot eggs had a geometric mean of 6.96 µg/g, but all other waterbird eggs contained concentrations high enough to impair reproduction (Waddell and Stephensen, 1992).

Water-quality data for the San Rafael River near its confluence with the Green River indicate that selenium concentration ranges from less than 1 to 5 µg/L with a mean of 2 µg/L (n=17, for 1975-86). Much of the selenium likely originates in small drainages such as Muddy Creek, which has a concentration ranging from 3 to 16 µg/L with a mean of 9.3 µg/L (n=9, 1975-87).

In the Scofield Project area, water quality in streams at high altitude is good but deteriorates as the water flows toward the Green River. Dissolved solids and selenium are the principal contaminants. Scofield Reservoir occasionally is subject to algal blooms caused by high phosphorus concentrations, and manganese concentrations within the hypolimnion often exceed drinking water standards (Stephens and others,

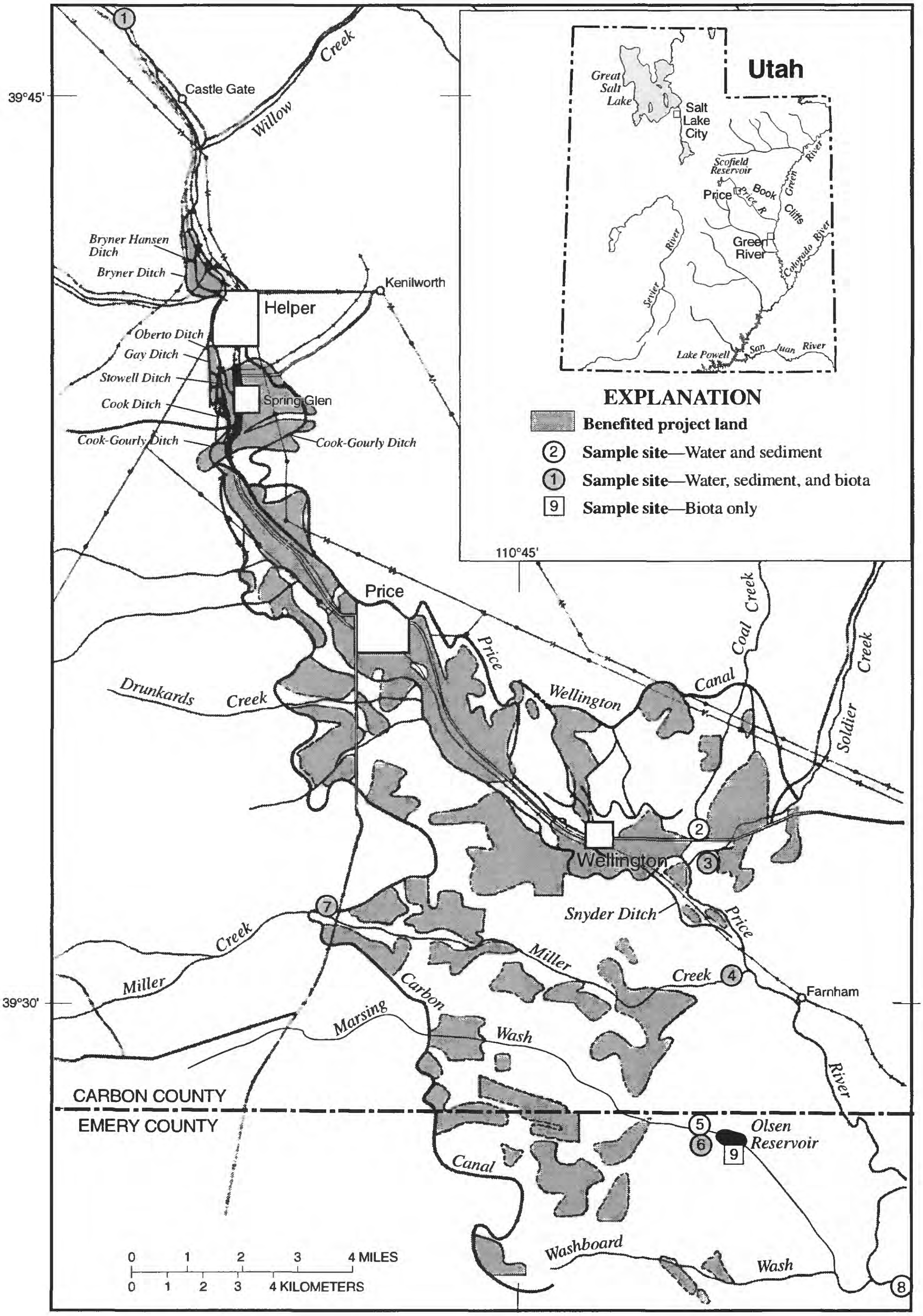

Figure 3. Scofield Project area, Utah.

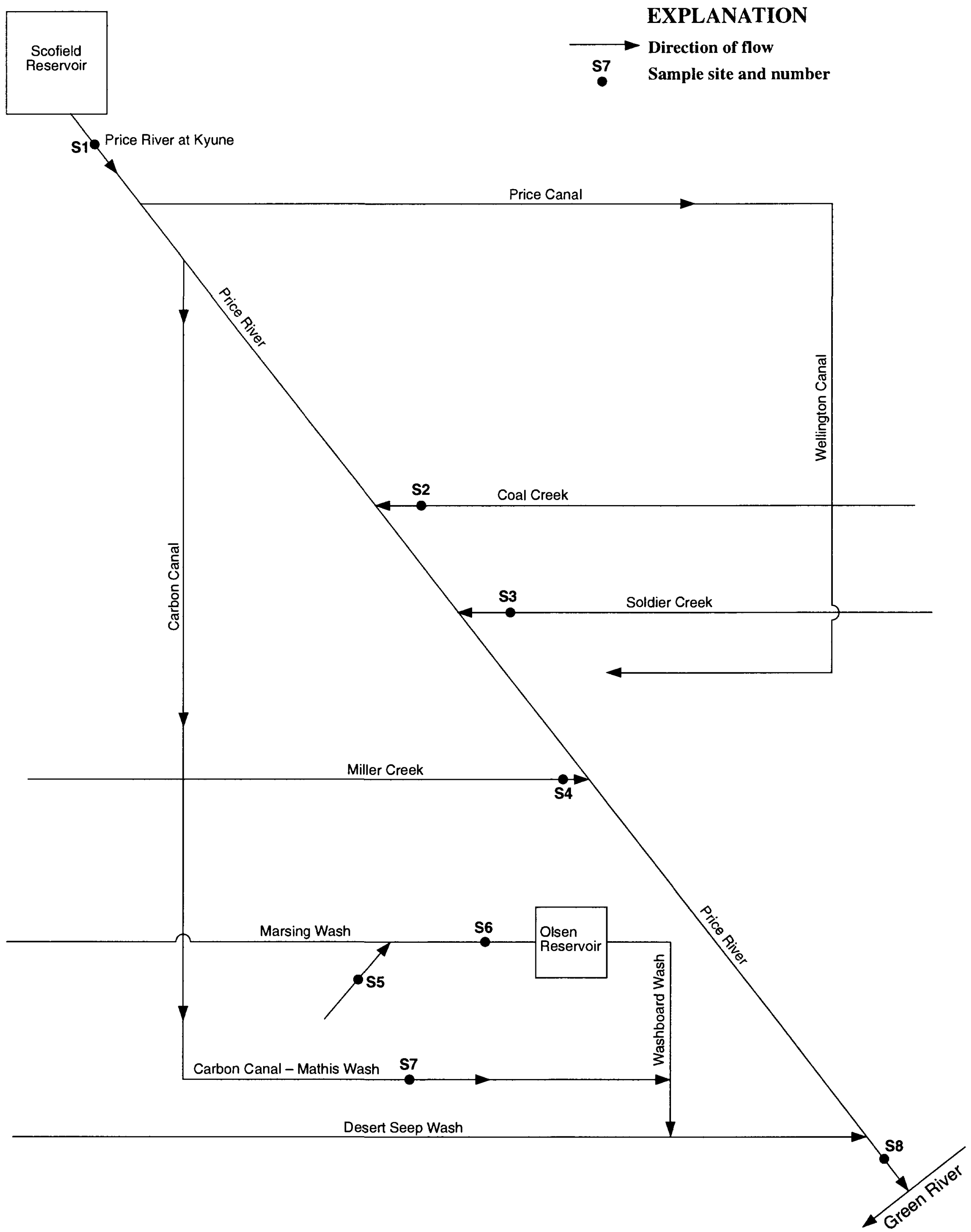

Figure 4. Schematic diagram of water-delivery system and sample sites, Scofield Project, Utah.

Table 1. Physical properties and concentration of inorganic constituents in water discharging into Desert Lake Waterfowl Management Area, Utah, April 1988

[mg/L, milligrams per liter; <, less than; —, no data; µS/cm, microsiemens per centimeter at 25 degrees Celsius; µg/L, micrograms per liter]

Property or constituent	Unit	Desert Lake Wash		Timothy Wash	
		April 18	April 23	April 18	April 23
Alkalinity	mg/L	415	317	538	310
Specific conductance	µS/cm	7,730	4,870	10,200	5,070
Total residual dissolved solids	mg/L	7,510	4,800	10,500	4,510
pH	standard unit	7.9	8.0	8.0	8.0
NO_2+NO_3, dissolved	mg/L	1.70	<.1	—	.990
Hardness ($CaCO_3$)	mg/L	3,100	2,000	4,100	1,700
Calcium, dissolved	mg/L	440	320	400	240
Magnesium, dissolved	mg/L	490	290	760	260
Sodium, dissolved	mg/L	1,100	640	1,700	800
Sodium absorption ratio	ratio	9	6	12	9
Potassium, dissolved	mg/L	13	13	13	11
Chloride, dissolved	mg/L	67	45	120	48
Sulfate, dissolved	mg/L	4,800	2,900	6,900	2,900
Arsenic, dissolved	µg/L	1	1	1	1
Boron, dissolved	µg/L	610	470	780	360
Cadmium, dissolved	µg/L	<1	<1	<1	<1
Chromium, dissolved	µg/L	1	<1	<1	<1
Copper, dissolved	µg/L	1	2	2	2
Lead, dissolved	µg/L	<5	<5	<5	<5
Mercury, dissolved	µg/L	<.1	<.1	<.1	<.1
Molybdenum, dissolved	µg/L	4	2	6	4
Selenium, dissolved	µg/L	6	4	7	12
Vanadium, dissolved	µg/L	5	3	8	12
Zinc, dissolved	µg/L	20	10	10	20

1996) but these conditions are not the result of irrigation tailwater or drainwater. Concentrations of selenium in water from Spring Canyon Creek near Helper range from 11 to 21 µg/L (n=11, 1976-80), 3 to 7 µg/L (n=3, 1975-76) in the Price River at Wellington, and less than 1 to 12 µg/L (n=30, 1975-93) in the Price River just upstream of the confluence with the Green River.

Irrigation and Drainage Systems

The Scofield and Emery Projects consist of a mixture of private and project conveyance structures, and project water commonly is exchanged for and commingled with private water throughout the systems. Generalized schematic diagrams of major features for each project are shown in figures 2 and 4. (Small canals and laterals are not shown.) Water from the Scofield Project remains within the drainage basin for the Price River, but some water from the Emery Project is exchanged for Huntington Creek water and is delivered by the northern extension of the Cleveland Canal into the Price River basin. Part of the Emery Project water is therefore used as source water for Desert Lake WMA, which eventually discharges into the Price River.

An unpublished BOR drainage document, dated 1979, lists 58 subsurface irrigation drains originally planned for the project, but most of these were never completed. Data collected by BOR on major-ion concentrations in the drainwater indicate that only 18 drains may have been completed. The status of drains located during this study is listed in the following table. In many instances, drains were clustered in an area and only one was selected for sampling for the screening study. The drains were constructed using 8- to 12-inch-diameter corrugated plastic pipe with slots.

Drain identification	Status
H1	very little discharge on May 26, not sampled
H6A	sampled
H9A	sampled
H9C	very little discharge on May 25, not sampled
H10A	could not locate
H15A	very little discharge on May 25, not sampled
H15B	dry on May 25
H15C	collapsed and plugged
H17A	dry on June 15
C2A	sampled
C2B	sampled
C3A	sampled
C6A	sampled
C8A	collapsed, buried
C11A	collapsed, buried

Water Supply to Desert Lake Waterfowl Management Area

Because the amount of water delivered to Desert Lake WMA is often insufficient to maintain ponds for waterfowl production, discussion of the water rights and the delivery system is warranted. Desert Lake WMA was expanded in 1967 as mitigation for upland and wetland wildlife habitat lost by construction of the Joes Valley Reservoir component of the Emery Project (K.L. Rose, U.S. Fish and Wildlife Service, written commun., 1979). Although there are three historical water rights, one with a priority of 1888, the only right actually delivering water is for 2,200 acre-ft in Sand, Feeder, and Desert Lake Washes and is held by the Utah Division of Wildlife Resources (DWR). According to a water-rights specialist with the USFWS, "Basically, lands east of the Cleveland Canal have contributed substantial return flows to Desert Lake WMA. The BOR Emery Project has impacted the return flows to Desert Lake, as additional new irrigation shares are sold and new lands are developed, return flows decrease," (D. Schmidt, U.S. Fish and Wildlife Service, written commun., 1991). The DWR water right is located at the end of the Cleveland Canal, and because of conveyance losses, additional demands for water, and general drought conditions, the WMA only obtains a small part of the 2,200-acre-ft right.

The actual amount of water provided under the mitigation that expanded Desert Lake WMA is harder to identify. Originally, the open-water area was to be 2,000 acres, which would require 12,000 to 13,000 acre-ft of water annually. Harold Crane, director of the Utah Fish and Game Division, thought the sources would be (1) increased irrigation return discharge from project lands, (2) increased irrigation surplus in the form of carrier discharges that could be impounded by increasing the capacity of Desert Lake, (3) natural runoff and drainage from the watershed, (4) active storage in Huntington North Reservoir, and (5) limited water rights acquired along with some of the private lands (written commun., 1962).

A letter to Region 2 Director of the USFWS implied that the BOR estimated that 5,000 acre-ft/yr of drainage water would be available to the Desert Lake mitigation project through the Cleveland Drain (now the H9A, -B, -C drains). An additional 3,500 acre-ft could be obtained by diversion of Elmo Creek into Desert Lake. Both of these sources were regarded as very salty, and additional freshwater would be needed (William Godby, U.S. Fish and Wildlife Service, written commun., 1965). Godby summed up his 1965 visit to the area as follows, "It appears that the ultimate development of the Desert Lake Project will be governed by the Bureau of Reclamation's decision whether or not to provide the 2,500 acre-ft of water for wildlife proposed from the Huntington North Reservoir. At this time, Reclamation has stated that water is available for municipal and industrial purposes and that water is not available for the waterfowl management area." Subsequently, the BOR constructed a pipeline, funded through drought relief programs, that is capable of delivering 1 ft^3/s from Huntington North Reservoir via the Cleveland Canal. It first operated (at about 45 percent capacity because of the drought) in 1994 (Harold Weaver, Desert Lake Waterfowl Management Area, oral commun., 1994).

During 1994, water entered the wetland complex at Desert Lake Wash from the south branch of Cleveland Canal; at the main body of Desert Lake from the south branch of Cleveland Canal; and at Tamarisk Lake from Elmo Ditch.

Location of Sampling Sites

Sampling sites in the Emery and Scofield Projects are listed in table 2 and are shown in figures 1 to 4. Sites in the Scofield Project are identified by an "S" prefix. In general, the water-sampling sites were

Table 2. Sampling sites in the Emery and Scofield Project areas, Utah

["S" prefix indicates Scofield Project sites]

Site identification: See figures 1 to 4

Site number	Site name	Site identification
	Emery Project area (figures 1 and 2)	
1	Cottonwood Creek at Swasey Diversion	391524111062900
2	C2A drain near Orangeville	391442110025501
3	C2B drain near Orangeville	391442110025502
4	C6A drain to Cottonwood Creek	391249111015800
5	Dutchmans Wash Reservoir—northwest side	391307110575300
6	C3A drain to Wilberg Wash	391518110590600
7	Wilberg Wash downstream of C3A drain	391518110590601
8	Cottonwood Creek below confluence with Rock Creek	390947110560300
9	Huntington Creek above San Rafael River	391300110550000
10	Inflow to Huntington North Reservoir	392118110572000
11	Outflow of Huntington North Reservoir	392034110562900
12	H9A drain near Cleveland sewage lagoons	392057110494700
13	Inflow to Tamarisk Lake-west side	392154110481500
14	Desert Lake Wash at Desert Lake perimeter road	392128110471101
15	Alkali Lake at Desert Lake Waterfowl Management Area	392144110470500
16	Desert Lake near northwest side	392235110471400
17	Desert Lake outflow to Desert Seep Wash	392144110460801
18	H6A Drain to Washboard Wash near Elmo	392343110460100
19	Washboard Wash downstream of H6A drain	392343110460101
20	Huntington Creek above North Ditch diversion	3921291110145
21	Cottonwood Creek above Rock Creek	3901491164258
22	Huntington Creek near Huntington sewage lagoons	3918561105524
23	North Ditch (Desert Lake Wash) near Cleveland	3920431105311
	Scofield Project area (figures 3 and 4)	
S1	Price River at Kyune	394936110565600
S2	Coal Creek at U.S. Highway 6	393233110415700
S3	Soldier Creek at confluence with Price River	393233110411100
S4	Miller Creek above confluence with Price River	393019110413000
S5	Marsing Wash inflow to Olsen Reservoir	392801110430200
S6	Olsen Reservoir inflow, 1 mile due west of reservoir	392747110432700
S7	Carbon Canal-Mathis Wash	392608110463600
S8	Price River below Desert Seep Wash	392527110374700
S9	Olsen Reservoir, main body	3927411104156

chosen to determine trace-element concentrations in inflow from project or natural stream water, in flow through representative subsurface drains, and in outflow from project lands. Sites for sediment sampling represent a subset of the water-quality sites in areas where water enters waterfowl habitat, such as Desert Lake WMA. Sites where biota were sampled were chosen on an "as available" basis but generally consisted of areas associated with the primary sites and areas of impounded water and riparian zones. Water samples were collected in May after the start of the irrigation season and again in August or September when water use for irrigation was greatest. Samples of biota were collected primarily during June and July. Bottom sediment was collected during August and September.

Collection and Analysis of Water and Bottom Sediment

Water samples were collected and analyzed using a modification of the trace-element protocol developed by the USGS. Where water was sampled from wide streams or sources not known to be well mixed, a DH48-TM sampler (U.S. Geological Survey, 1977, p. 3-20) was employed with equal-width depth-integrated procedures. Field measurements of discharge, water temperature, dissolved oxygen, pH, and specific conductance were made at the time water samples were taken. Samples were filtered in the field using 0.45-micrometer porosity cartridge filters, acidified with nitric acid where necessary, and submitted to the USGS National Water-Quality Laboratory in Arvada, Colorado, for analysis of major ions, trace elements, and uranium. Quality-control (blank samples) analyses available for the cartridge filters indicated that concentrations of trace elements in extractions from the filters were less than analytical reporting levels.

Water samples for quality control consisted of equipment field blanks (table 3) and a single sample replicate. With the exception of the June 15 field blank, concentrations of trace elements were generally less than the reporting limit. The June 15 blank consisted of locally produced deionized water that was of poorer quality than the "reagent" water used for blanks analyzed in May and September. However, selenium, the element of primary concern in this study, was not detected in any of the equipment field blanks. Results of the replicate sample analysis for the August 23 sample from the inflow to Tamarisk Lake were within 10 percent for major ions and within 4 percent for trace elements.

Eleven samples of bottom sediment were collected using a BMH 53 sampler (U.S. Geological Survey, 1977, p. 3-37), composited from five cores but not sieved in the field, and submitted to the USGS Geochemical Laboratory for sieving and analysis of the less-than-63-micrometer fraction using Inductively Coupled Plasma analysis for trace elements. Selenium was analyzed separately using total digestion and hydride-generation atomic absorption, and mercury was analyzed using digestion and cold-vapor analysis. Ten samples of bottom sediment were analyzed to determine the extent of organochlorine contamination associated with past drainage from the agricultural areas. The sediment collected for analysis of organochlorine compounds was sieved to select the less-than-2-millimeter fraction, placed in cleansed and baked glass jars, and submitted to the USGS National Water-Quality Laboratory for analysis.

Collection and Analysis of Biological Samples

Samples of aquatic plants, aquatic invertebrates, fish, bird livers, and bird eggs were collected during May, June, and July 1994. Biota samples were collected at most study sites. However, most of the samples were collected at three pond units within the study area: Desert Lake WMA (managed by Utah DWR), Olsen Reservoir, and Dutchmans Reservoir (both managed by the Bureau of Land Management (BLM)).

Aquatic plants were collected as whole, composite samples and stored in plastic bags. Invertebrate samples were collected by kick-netting in running water, or with light traps (Espinosa and Clark, 1972) and sweep-netting in standing water. Invertebrate samples were sorted by taxa with forceps when sufficient biomass was available; otherwise, samples were composited. Fish (minnows) and crayfish were collected opportunistically by sweep-netting and were placed in either acid-cleansed jars or plastic bags. Bird eggs were collected from nests, measured, and opened with a scalpel. The contents were examined to determine embryo presence, age, and condition, and then were placed into sample jars. No adult birds were intentionally collected; however, livers were obtained from one American coot, which was found dead as a result of an illegal shooting, and from two pied-billed grebes, which were caught accidentally in a gill net set to collect fish.

All forceps, pans, scalpels, and other small instruments used to process samples were rinsed first

Table 3. Concentration of elements determined in equipment field blanks during sampling of the Emery and Scofield Project

[mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than; —, no data]

Date	Solids, residue at 180°C, dissolved (mg/L)	Hardness, as $CaCO_3$ (mg/L)	Alkalinity, as $CaCO_3$ (mg/L)	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Potassium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Chloride, dissolved (mg/L)	Fluoride, dissolved (mg/L)	Sulfate, dissolved (mg/L)
[1]May 26	<1	0	1.1	0.09	0.02	<0.10	<0.20	<0.10	<0.10	<0.10
[2]June 15	70	12	40	1.0	2.3	16	2.6	3.0	<.10	12
[1]September 14	<1	—	1.8	<.02	<.01	<.10	<.20	<.10	<.10	<.10

[1]Source of blank: Water free of inorganic constituents, supplied by U.S. Geological Survey Laboratory, Ocala, Florida.
[2]Source of blank: Deionized water produced at U.S. Geological Survey office in Salt Lake City, Utah.

with a 10-percent solution of nitric acid, then with acetone, and lastly with deionized water. Samples were either stored in acid-cleansed glass jars or in plastic bags. Samples were placed on dry ice in the field and kept frozen until shipped to the laboratory for chemical analysis. All analyses were done at Geochemical and Environmental Research Group in College Station, Texas, under contract with the USFWS. Samples were analyzed for arsenic and selenium by hydride-generation-atomic-absorption spectroscopy (AAS), for mercury by cold-vapor AAS, and for other trace elements by inductively coupled plasma atomic-emission spectroscopy. Several samples were analyzed for organochlorine pesticide residues. The analytical procedure for pesticides consisted of solvent extraction and analysis using electron-capture gas chromatography.

Laboratory quality control was assured through the Patuxent Analytical Control Facility (PACF) in Laurel, Maryland. The precision and accuracy of laboratory analyses were confirmed with procedural blanks, duplicate analyses, test recoveries of spiked material, and reference-material analyses. Interlaboratory tests among USFWS and contract analytical laboratories also were part of the PACF quality-assurance review.

Evaluation of Data

Concentrations of constituents and elements in water were evaluated using Utah Water Quality Standards for Class C protection (aquatic wildlife) and Environmental Protection Agency (EPA) and Utah Class A criteria and standards for drinking-water protection (Scofield Project includes public water supply). There is no State water-quality standard established to protect aquatic wildlife from uranium; however, the concentration of dissolved uranium, in µg/L, can be expressed as an estimate of alpha radiation, in picocuries per liter (pCi/L), by multiplying by 0.68. The State standard for alpha radiation to protect aquatic wildlife is 15 pCi/L. As there are no State or EPA criteria for boron relative to wildlife protection, the California criterion of 500 µg/L to protect aquatic organisms from irrigation returns into marine embayments was used.

A summary of criteria for selenium effects on biota is presented in table 4. In general, during the last 10 years the concentration criteria have been lowered compared to the criteria summarized by Lemly and Smith (1987).

RESULTS OF THE SCREENING STUDY

Water-Quality Data

Water-quality data for sites sampled during the 1994 screening study are shown in table 5 (at back of report). The quality of source water in the Scofield Project (Price River at Kyune) was excellent but deteriorated slightly in downstream parts of the project as salts, boron, and some selenium were leached from local soils. Water sampled from the downstream reaches of Coal and Miller Creeks contained selenium concentrations of 4 to 6 µg/L, and boron concentrations in Miller Creek exceeded 500 µg/L. The single sample of combined inflow from Marsing Wash entering Olsen Reservoir, a heavily used waterfowl area, contained 670 µg/L boron but only 2 µg/L selenium. Olsen Reservoir drains to Washboard Wash, which discharges into Desert Seep Wash and then into the Price River. Most of the water entering the Price River through Desert Seep Wash is believed to be from the Emery Project. During water years 1990-94, selenium in water discharged to the Green River from the Price River (as

Date	Arsenic, dis-solved (µg/L)	Boron, dis-solved (µg/L)	Cadmium, dis-solved (µg/L)	Chro-mium, dis-solved (µg/L)	Copper, dis-solved (µg/L)	Lead, dis-solved (µg/L)	Mercury, dis-solved (µg/L)	Molyb-denum, dis-solved (µg/L)	Sele-nium, dis-solved (µg/L)	Vana-dium, dis-solved (µg/L)	Zinc, dis-solved (µg/L)	Uranium, natural, dis-solved (µg/L)
[1]May 26	<1	<10	<1.0	<1	<1	<1	<.1	<1	<1	<1	<3	<0.40
[2]June 15	<1	40	<1.0	<1	<1	<1	<.1	<1	<1	<1	57	<.40
[1]September 14	<1	10	<1.0	<1	4	<1	<.1	<1	<1	<1	<3	<.40

measured at Woodside, 35 mi southeast of Price), ranged from less than 1 to 7 µg/L with a median of 2 µg/L. There did not appear to be any other water-quality problems associated with irrigation water from the Scofield Project.

Water quality at sites in the Emery Project was generally poorer than in the Scofield Project. Source water from Joes Valley Reservoir, as measured in Cottonwood Creek at the Swasey Diversion, was excellent and suitable for all uses. Water quality of subsurface drains (C2A, C2B, C6A) located at higher altitudes on the system was generally acceptable for wildlife and fishery uses. Water quality at drains located at lower altitudes on the system, in pediment soils farther from the mountains, was generally poor and not suitable for wildlife, waterfowl, or fishery use. The concentration of selenium in drain C3A, which discharges to Wilberg Wash, was 12 µg/L in June, and discharge was less than 0.1 ft^3/s. The drain was dry during the September sampling, but water in Wilberg Wash immediately downstream of the drain contained 46 µg/L of selenium, which was the highest concentration measured during the screening study. Drain C3A services several small fields and only discharges when irrigation water is applied to those fields.

Water from drain H6A, which discharges to upper Washboard Wash and eventually into Olsen Reservoir in the Price River drainage, contained a selenium concentration of 16 µg/L and a dissolved uranium concentration of 68 µg/L in May. The drain was not flowing when visited on August 23, but water in Washboard Wash near the drain outfall contained 20 µg/L selenium, 48 µg/L dissolved uranium, and 900 µg/L dissolved boron. The selenium concentration in Huntington Creek above the confluence with the San Rafael River was slightly higher than the toxicity-threshold value of 2 µg/L on September 12.

High concentrations of dissolved solids in water at Desert Lake WMA create management problems for the area. Water flowing into Desert Lake WMA through Desert Lake Wash and through Timothy Wash into Tamarisk Lake had a specific conductance of 5,000 µS/cm or greater (dissolved-solids concentrations in excess of 4,700 mg/L) on both dates sampled. As the source water is routed through several impoundments, evaporative concentration greatly increases the existing salinity and creates problems for young waterfowl inhabiting the wetlands. Saline water is hazardous primarily to ducklings because adults can excrete salts through the nasal glands. Mitcham and Wobeser (1988) reported that ducklings given naturally saline water with a specific conductance of 7,720 µS/cm grew poorly during a 14-day experiment, and 60 percent of ducklings given water with a specific conductance of 20,000 µS/cm died. The mean weight gain of ducklings exposed to water with a specific conductance of 10,000 µS/cm for 9 days was only 23 to 38 percent of the gain reported for ducklings not exposed to saline water (Swanson and others, 1984). Swanson and others (1988) reported that water with a specific conductance of 17,000 µS/cm or greater caused statistically significant slower growth rates than nonsaline water. The lower limit for no effect was not determined.

In addition to high concentrations of dissolved solids, water in Desert Lake Wash contained more than 500 µg/L of boron and 4 µg/L of selenium. On May 26, the concentration of selenium entering Tamarisk Lake was 13 µg/L; dissolved uranium, expressed as alpha radiation, was 27 pCi/L. Concentrations of these elements exceed levels known to have adverse effects on

Table 4. Criteria for effects of selenium on fish and wildlife

[µg/L, micrograms per liter; <, less than; >, greater than; mg/kg, milligrams per kilogram; µg/g, micrograms per gram]

Medium	No effect[1]	Level of concern[2]	Toxicity threshold[3]
Water, µg/L (total recoverable)	<1	1-2	[6]>2
Sediment, mg/kg (dry weight)	<2	[7]4	>4
Dietary[4] µg/g (dry weight)	<2	2-3	[8]>3
Waterbird eggs[5], µg/g (dry weight)	<3	[8]3-[9]8	>8
Warm water fish, µg/g (dry weight, whole body)	<3	[8]4	>4
Cold water fish, µg/g (dry weight, whole body)	<2	[8]4	>4

[1]Selenium concentrations less than this criterion in various media do not appear to be related to any discernible adverse effects on fish and wildlife and are typical of background concentrations in environments not impacted by selenium.

[2]Selenium concentrations at this criterion in various media rarely appear to be related to any discernible adverse effects on fish and wildlife but are elevated above typical background concentrations.

[3]Selenium concentrations exceeding this criterion in various media appear to be related to adverse effects on some fish and wildlife species, such as increased risk of teratogenesis and embryo mortality.

[4]Dietary criteria are on an average daily exposure basis.

[5]Waterbird criteria are based on population mean.

[6]Peterson and Nebeker (1992).

[7]Lemly and Smith (1987).

[8]Lemly (1993).

[9]Skorupa and Ohlendorf (1991).

waterfowl. Concentrations of selenium and uranium entering Tamarisk Lake were less than levels known to have adverse effects when sampled on August 23, 1994, but this may have been because of a large amount of fresher irrigation water supplied to the area in August. Specific conductance and concentrations of selenium and boron measured in 1994 were similar to those measured in 1988 (table 1), indicating a continuing problem with the quality of water supplied to the area. The natural channel into Tamarisk Lake is Timothy Wash, a shallow draw draining Poison Spring Bench 6 mi north of Huntington. The bench was named in 1877 by settlers who found spring water in the area to be too "alkaline" (contained considerable salt and selenium) to be used for stock water.

Water flows through several impoundments in the Desert Lake complex and is discharged to Desert Seep Wash or into an irrigation canal near the wash. Typically, concentrations of dissolved solids in water discharged from the last pond in the complex are much higher than in the inflows. Dissolved solids in the outflow to Desert Seep Wash were 8,370 and 13,200 mg/L and boron was 760 and 1,100 µg/L in the May and August sampling, respectively. Harold Weaver, the WMA area manager, stated that source water was always very salty, and the discharge from the Desert Lake WMA was so salty that farmers downstream would not use the water for anything other than irrigation of alfalfa.

While the conservative salts increase in concentration as they move through Desert Lake WMA, some of the nonconservative elements such as selenium are biologically removed from the water. Selenium concentrations in the discharge from the WMA were only 1 and 2 µg/L in the May and August sampling, respectively. The concentration of selenium in Alkali Lake, which is an initial impoundment at the WMA, was only 2 µg/L in June, but the specific conductance was 8,150 µS/cm. Concentrations of elements and salt in Desert Lake (also called pond 6) do not exceed standards or criteria established to protect waterfowl and fishery use. The sources of salts and toxic trace elements entering the Desert Lake WMA are irrigation return discharge and some subsurface drainage from the Emery Project via the Cleveland Canal and associated laterals. The generally better water quality measured in Desert Lake is the result of fresher water from Elmo Ditch (a lateral of Cleveland Canal) that discharged directly into Desert Lake during August.

Additional poor-quality water from the Emery Project enters Olsen Reservoir in the Price River drainage. It is likely that some of the boron and possibly selenium entering Olsen Reservoir from Marsing Wash comes from drainwater from the three drains of the H6 drain series that discharges to Washboard Wash, then to Mathis Wash, and then Marsing Wash. The Carbon Canal (Scofield Project) also may discharge to Marsing Wash.

Generally, most of the Emery Project drainwater and irrigation tailwater discharges to the San Rafael River. There are only 17 determinations of selenium concentrations in water from the San Rafael River near the confluence with the Green River, and these were made between 1975 and 1986. During this period, the selenium concentration ranged from less than 1 to 5 μg/L with a median of 2 μg/L. During the same period, boron concentrations ranged from 100 to 550 μg/L and dissolved solids from 789 to 4,990 mg/L.

Bottom-Sediment Data

Concentrations of major and trace elements in bottom sediment from 11 sites in both project areas are presented in table 6 (at back of report). Concentrations of these elements in the bottom sediment were all within the observed range for soils in the Piceance and Uinta Basins as reported by Tidball and Severson (1982). These values generally indicate that biologically significant contamination from trace elements is not present in the bottom sediment from the sampled sites. Separate sediment samples were submitted for mercury and selenium determinations using methods with lower reporting limits; however, all but three samples were destroyed during laboratory digestion and preparation.

Concentrations of chlorinated-hydrocarbon compounds in bottom sediment from 10 of the sites where samples were analyzed for inorganic constituents are presented in table 7 (at back of report). Concentrations of each of the 17 chlorinated-hydrocarbon compounds were generally less than the reporting level for each compound at all sites except Olsen Reservoir, where bottom sediment from the inflow channel contained a DDE concentration of 0.3 μg/kg.

Biological Data

Wildlife Observations

Dutchmans Reservoir (Emery Project area)

Dutchmans Reservoir is a small irrigation reservoir of about 15 acres located on BLM land 3 mi east of Castle Dale. The reservoir receives irrigation runoff from agricultural land at the head of Dutchmans Wash and irrigation water through Mammoth Canal. Saline seeps were widespread in Dutchmans Wash upstream from the reservoir. Dutchmans Reservoir retained water throughout the nesting season in 1994 and provided nesting and feeding habitat for waterfowl and shorebirds.

Nine nests were located, including four American coot, two pied-billed grebe, one ruddy duck, one cinnamon teal, and one black-necked stilt or American avocet (uncertain identification) nest. Nesting success appeared to be good; however, one pied-billed grebe and two American coot hatchlings were found dead next to their nests. No deformities were observed in these hatchlings or in embryos collected for analysis. Several broods were observed, including American coot and pied-billed grebe.

Several dead adult birds were found in Dutchmans Reservoir, including one yellow-headed blackbird, one ruddy duck, one pied-billed grebe, and one American coot. Most appear to have been illegally shot with a small-caliber rifle. The liver was collected from the American coot, but other carcasses were too decomposed for samples.

Olsen Reservoir (Scofield Project area)

Olsen Reservoir is an irrigation reservoir of about 30 acres located on BLM land southeast of Wellington. It receives irrigation water and irrigation drainage and provides nesting and feeding habitat for waterfowl and shorebirds during spring and early summer. By late June 1994, the reservoir had been drained for irrigation, limiting waterbird production.

Four black-crowned night-heron nests were located and monitored. All appeared to have failed for unknown reasons. One dead black-crowned night-heron hatchling was collected from a nest with two live eggs. The hatchling appeared normal and may have died from investigator-induced heat stress. One dead American coot chick was observed and had no apparent abnormalities. Olsen Reservoir had many ducks, coots, grebes, and shorebirds in April and early May. However, the reservoir was drained completely by late June. Several broods were observed in mid-June, including northern shoveler, redhead, and American coot. These broods probably did not survive the low water conditions.

Desert Lake Waterfowl Management Area (Emery Project area)

Desert Lake WMA consists of 2,621 acres of which 544 acres are managed as open water. At the time of this study in 1994, drought had reduced the open-water area to 375 acres. Nests located at Desert Lake Pond 4 (Alkali Lake) included four American avocet and two black-crowned night heron. Two pied-billed grebes (probably a mated pair) died when they were accidently caught in gill nets set for fish collection in Pond 4. The livers of both grebes were collected for chemical analysis. Two American avocet nests and one black-necked stilt nest were located by the main lake (Pond 6). No abnormal embryos or chicks were observed. Broods observed included several American coot and western/Clark's grebe broods in Pond 4 and one American avocet brood by the main lake (Pond 6). Numerous Canada goose broods feed on grassy areas along the north end of the main lake. Several adult birds, including a snowy egret, black-crowned night heron, and pied-billed grebe, were observed dead from unknown causes.

Only one American avocet nest was located at Tamarisk Lake. However, several broods were observed, including two American avocet, two gadwall, one mallard, and one unidentified dabbling duck. No abnormal embryos or chicks were observed.

Huntington Lake (Emery Project area)

Huntington Lake, also called Huntington North Reservoir, has limited wetland habitat for migratory birds. High water levels are maintained and the shoreline provides little waterbird habitat. Heavy recreational use also may limit nesting by migratory birds. No biological samples were collected from Huntington Lake.

Biological Tissue Analyses

Collection of biota in 1994 included 17 invertebrate samples, 21 plant samples, 12 composite fish (small fish or minnow) samples, 18 bird eggs, 3 bird livers, and 1 whole-body chick. Bird egg samples consisted of five American avocet, five American coot, six black-crowned night heron, one ruddy duck, and one unidentified duck egg (probably redhead).

Concentrations of trace elements in the biota samples are presented in tables 8 through 11 at the back of this report. Concentrations of trace elements in biota, other than boron and selenium, were generally less than threshold values that are harmful to wildlife. Boron concentrations were large (>30 µg/g, dry weight) in 10 aquatic plant samples and exceeded 1,000 µg/g, dry weight (1,157 µg/g), in a Ruppia sample from Desert Lake Pond 6 (historic Desert Lake) (table 8, at back of report). Mallards fed 1,000 µg/g dietary boron laid eggs that had significantly lower hatching success, and ducklings fed 30 µg/g dietary boron experienced decreased growth rates (Smith and Anders, 1989; Hoffman and others, 1990). Boron concentrations in aquatic invertebrates and fish were less than 30 µg/g, dry weight (tables 9 and 10, at back of report). Boron concentrations exceeded 3 µg/g, dry weight, in eight waterbird eggs, indicative of potential adverse effects on waterbird reproduction (Smith and Anders, 1989). There was no geographic consistency to the higher boron concentrations. Boron concentration was elevated in aquatic plant samples collected from all Desert Lake WMA sites, Huntington Creek, and Cottonwood Creek (table 8, at back of report), and from eggs collected primarily at Dutchmans Reservoir and Olsen Reservoir (table 11, at back of report).

Selenium concentrations were greater than the dietary-toxicity threshold value of 3 µg/g in a sample of Ruppia from Desert Lake Pond 6 (7.35 µg/g, dry weight), a green algae sample from Middle Huntington Creek (8.01 µg/g, dry weight), and an aquatic plant from North Ditch (3.35 µg/g). Plant samples from Olsen Reservoir (one of two samples) and Tamarisk Lake (one of three samples) had selenium concentrations of potential risk (level of concern of 2 to 3 µg/g) for bird diets (table 8, at back of report). Selenium concentrations in other aquatic plant samples were less than dietary levels known to be harmful to birds.

Selenium concentrations in aquatic invertebrates exceeded the dietary-toxicity threshold for birds at the terminal pond at Desert Lake (Pond 0), Desert Lake Wash, Dutchmans Reservoir, all but one of the Huntington sites, Olsen Reservoir, Price River, Soldier Creek, and Tamarisk Lake (table 9, at back of report). A sample consisting of adult predaceous diving beetles (Coleoptera) from Olsen Reservoir contained 29 µg/g, dry weight selenium. This is nearly 10 times the dietary toxicity-threshold value of 3 µg/g.

Selenium concentrations were greater than the toxicity-threshold value of 4 µg/g in all fish samples. Fish from Tamarisk Lake, Desert Lake Pond 4 (Alkali Lake), and Desert Lake Wash had highest selenium concentrations, all exceeding 13 µg/g (table 10, at back of report). Selenium concentrations in all fish samples exceeded the 85th percentile concentrations for whole fish collected by the National Contaminant Biomonitoring Program (NCBP) between 1976 and 1984 (Schmitt and Brumbaugh, 1990). Selenium in two fish samples (Desert Lake Pond 4 and Tamarisk Lake) exceeded the 1976-84 maximum NCBP selenium concentration of 14.6 µg/g, dry weight.

Ten of the 18 waterbird eggs collected (table 11, at back of report) had selenium concentrations within the level of concern for waterbird eggs (3-8 µg/g), and 6 exceeded the toxicity-threshold value of 8 µg/g. Selenium in the eight waterbird eggs collected from the Desert Lake complex ranged from 6.65 µg/g, dry weight, to 14.6 µg/g, dry weight, with five above the toxicity threshold (table 11, at back of report). Four black-crowned night-heron eggs collected from Olsen Reservoir contained selenium concentrations ranging from 5.76 µg/g to 7.55 µg/g (dry weight). Most waterbird eggs collected from Dutchmans Reservoir contained low selenium concentrations, with only two in the range of level of concern for waterbird eggs, and one pied-billed grebe that exceeded the toxicity threshold.

Selenium concentrations in livers from two adult pied-billed grebes (table 11, at back of report) collected from Pond 4 (Alkali Lake) of Desert Lake on June 30 greatly exceeded the 10 µg/g dry-weight concentrations found in the livers of mallards that experienced impaired reproduction from a diet with a high selenium concentration (Heinz and others, 1989). The male grebe (selenium concentration =72.5 µg/g) was molting and flightless, and the female grebe (57.6 µg/g) had an egg forming in the oviduct, indicating that these birds were probably a resident breeding pair rather than transient birds. Therefore, the selenium concentrations may be indicative of local conditions at Desert Lake WMA. The selenium concentration also was high in the pied-billed grebe egg collected on May 10 from Dutchmans Reservoir (12.9 µg/g, dry weight). However, the early collection date and comparatively low selenium concentrations in American coot eggs from Dutchmans Reservoir indicate that the female grebe may have accumulated the selenium elsewhere and had recently moved to this area.

Analyses for organochlorine pesticides and polychlorinated biphenyls (PCBs) were done on three bird egg samples from Desert Lake WMA, one bird egg from Olsen Reservoir, two bird eggs from Dutchmans Reservoir, two composite longnose dace samples from Huntington Creek and one longnose dace sample from Soldier Creek. Concentrations of most organochlorine compounds were either less than laboratory detection limits or were detected in amounts less than levels of concern (table 12, at back of report). However, large levels of pp-DDE were detected in an American avocet egg from Desert Lake Pond 4 (4.31 µg/g, wet weight) and in a black-crowned night-heron egg from Olsen Reservoir (12.20 µg/g, wet weight). Blus (1982) considered DDE concentrations higher than 3 µg/g, wet weight (12 µg/g, dry weight) in eggs to be indicative of impaired reproduction in brown pelicans (*Pelicanus occidentalis*).

Fourteen PCB conjugers or conjuger groups were detected in some samples at concentrations slightly greater than detection limits (table 13, at back of report). All other PCB concentrations were less than 0.02 µg/g, wet weight.

DISCUSSION AND CONCLUSIONS

Generally, selenium is the primary element of concern in samples of water and biota from the Emery and Scofield Project areas. In the Emery Project, concentrations of selenium exceeded the State wildlife standard in water from Drain C3A (12 µg/L) and its receiving channel, Wilberg Wash (46 µg/L), inflow to Tamarisk Lake (13 µg/L), Drain H6A (16 µg/L), and Washboard Wash (20 µg/L) (fig. 5). Concentrations of selenium in water did not exceed 6 µg/L in the Scofield Project but were greater than the State standard of 5 µg/L for wildlife protection in samples collected during May and June from Miller Creek and Coal Creek (fig. 6). Concentrations of selenium exceeded the toxicity-threshold value of 2 µg/L, known to be toxic to some species of fish and wildlife (Lemly, 1993), in the Price River downstream of Desert Seep Wash, Miller Creek near the confluence with the Price River, and in Coal Creek at U.S. Highway 6 (fig. 6).

Values for specific conductance (a measure of dissolved solids) were high at Desert Lake WMA and ranged from inflows with 4,950 µS/cm to the discharge from the terminal pond with 12,200 µS/cm. Values higher than 7,720 µS/cm have been associated with

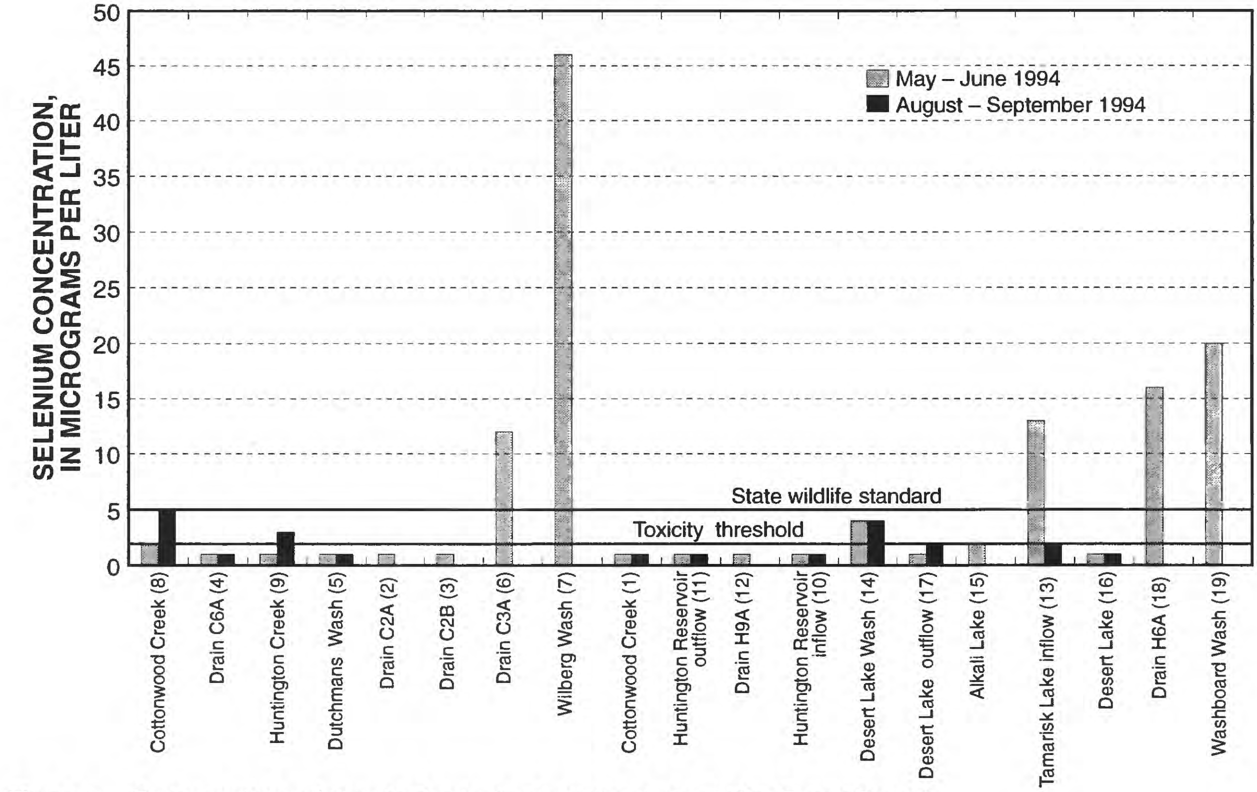

Figure 5. Concentrations of dissolved selenium in water at sites in the Emery Project, Utah. Numbers in parentheses refer to figures 1 and 2.

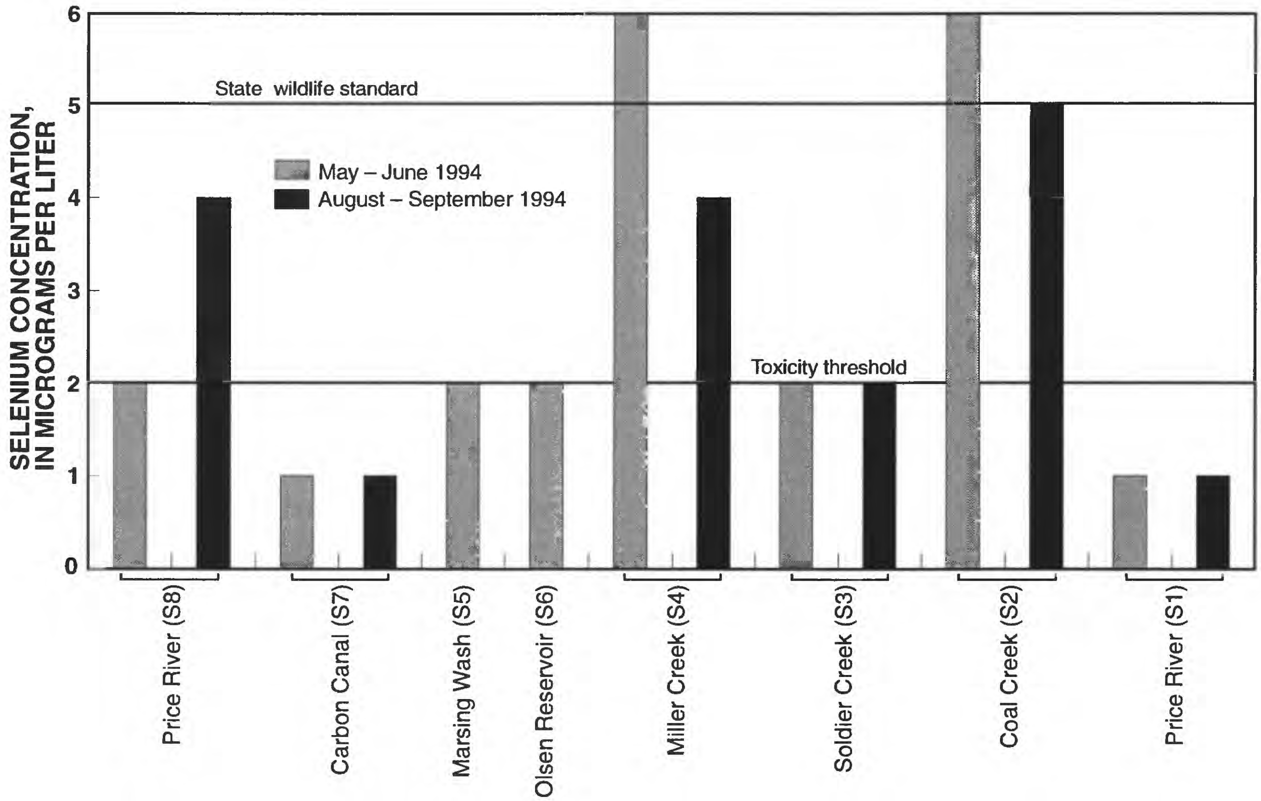

Figure 6. Concentrations of dissolved selenium in water at sites in the Scofield Project, Utah. Numbers in parentheses refer to figures 3 and 4.

poor growth in ducklings under laboratory conditions. Water from several sites in the Emery Project also contained high concentrations of dissolved uranium, but these sites were not always coincident with sites that had high concentrations of selenium. Uranium concentrations exceeded the drinking water criterion of 35 µg/L in the inflow to Tamarisk Lake, Drain H6A, and Washboard Wash. When expressed as alpha radiation activity, for which there is a State wildlife standard of 15 pCi/L, there were exceedances at Desert Lake Wash, the outflow from Desert Lake to Desert Seep Wash, inflow to Tamarisk Lake, Drain H6A, and Washboard Wash (fig. 7). These sites represent sources to the large wetland areas at Desert Lake WMA and Olsen Reservoir.

Selenium concentrations exceeded the dietary toxicity-threshold value of 3 µg/g for invertebrates and fish at Dutchmans Reservoir, Desert Lake WMA and Olsen Reservoir (fig. 8). The concentration in some plants from Desert Lake WMA also was of concern. High selenium concentrations in dietary items resulted in concentrations of selenium in eggs of insect- and fish-eating birds that exceeded the toxicity-threshold value of 8 µg/g for waterbird eggs at Desert Lake WMA and the level of concern of 3 µg/g for waterbird eggs at Olsen Reservoir and Dutchmans Reservoir (fig. 9). Although the present study was not designed to follow nesting success and no deformed embryos were found, data collected in 1994 from Desert Lake WMA indicate that selenium may be adversely affecting production of grebes, herons, and avocets. Concentrations of selenium found in waterbird eggs in 1994 are similar in magnitude to those found in American coot eggs in 1988 (fig. 10). Adverse effects may be more pronounced in the initial impoundments such as Tamarisk Lake, where data for all American coot eggs collected in 1988, all duck and grebe eggs collected in 1990, and all avocet eggs collected in 1994 exceeded the toxicity threshold for waterbird production (fig. 11). No American coots were observed using Tamarisk Lake in 1994, and it is unknown if this was a result of poor habitat conditions or the presence of contaminants. Although no quantitative data were collected on waterbird production in 1994, Desert Lake WMA appeared to have low numbers of waterbird broods relative to the quantity and quality of habitat available. Waterfowl productivity at Desert Lake WMA is limited not only by the poor quality of the delivered water, which is made worse by evaporation, but also by an insufficient amount of water to support the existing open-water acreage and associated habitat.

Although water depletion is probably the primary factor that limits waterbird production at Olsen Reservoir, high concentrations of selenium in samples of the biota (8.17 µg/g in fish to 29 µg/g in diving beetles) indicate that selenium may be contributing to the low numbers of birds produced. Concentrations of selenium in samples of some invertebrates, American coots, and ducks collected at Dutchmans Reservoir in the Emery Project area were within a level of concern but did not exceed the toxicity threshold, except in a single pied-billed grebe. Selenium concentrations in the remainder of the Emery-Scofield Project areas were generally below toxicity thresholds for birds.

Selenium contamination of water with resultant adverse effects on biota appears to be limited to Desert Lake WMA and Olsen Reservoir. Both are located within the Price River drainage, but the contamination is caused primarily by water from the Emery Project. The most severe contamination by selenium is at Desert Lake WMA and adverse effects on waterfowl are likely intensified by the low volume of suitable water available to the area. A solution to the contaminant problem may be to provide additional fresh water to the area during the spring and summer. Boron, uranium, and dissolved salts also may be adversely affecting biota at these sites.

The Emery and Scofield Projects deliver water to some areas that have a high potential for salt leaching. This problem is being addressed by the Colorado River Salinity Control Program, which completed the final Environmental Impact Statement (EIS) in December 1993 (U.S. Department of the Interior, U.S. Department of Agriculture, 1993). This salinity-control project is awaiting Congressional legislation and funding; timing for partial or full implementation is not known. The goal of the project is to reduce salt loading to the Colorado River system by 161,000 tons annually by using a combination of on-farm irrigation-improvement features and off-farm lining of canals or replacement with pipe, and elimination of winter stock water in project canals. No additional water will be provided by the project. The greatest ecological effect of the project will be loss of wetlands and upland game habitat that was previously supported by water from leaky canals and stock ponds and overwatering. The off-farm work with canals and piped laterals is being done by the BOR and the on-farm improvements by the Natural Resources Conservation Service (NRCS). Mitigation for habitat loss by the BOR program will consist of development of 330 acres of wetlands, which will be given to the Utah DWR for management. Mitigation

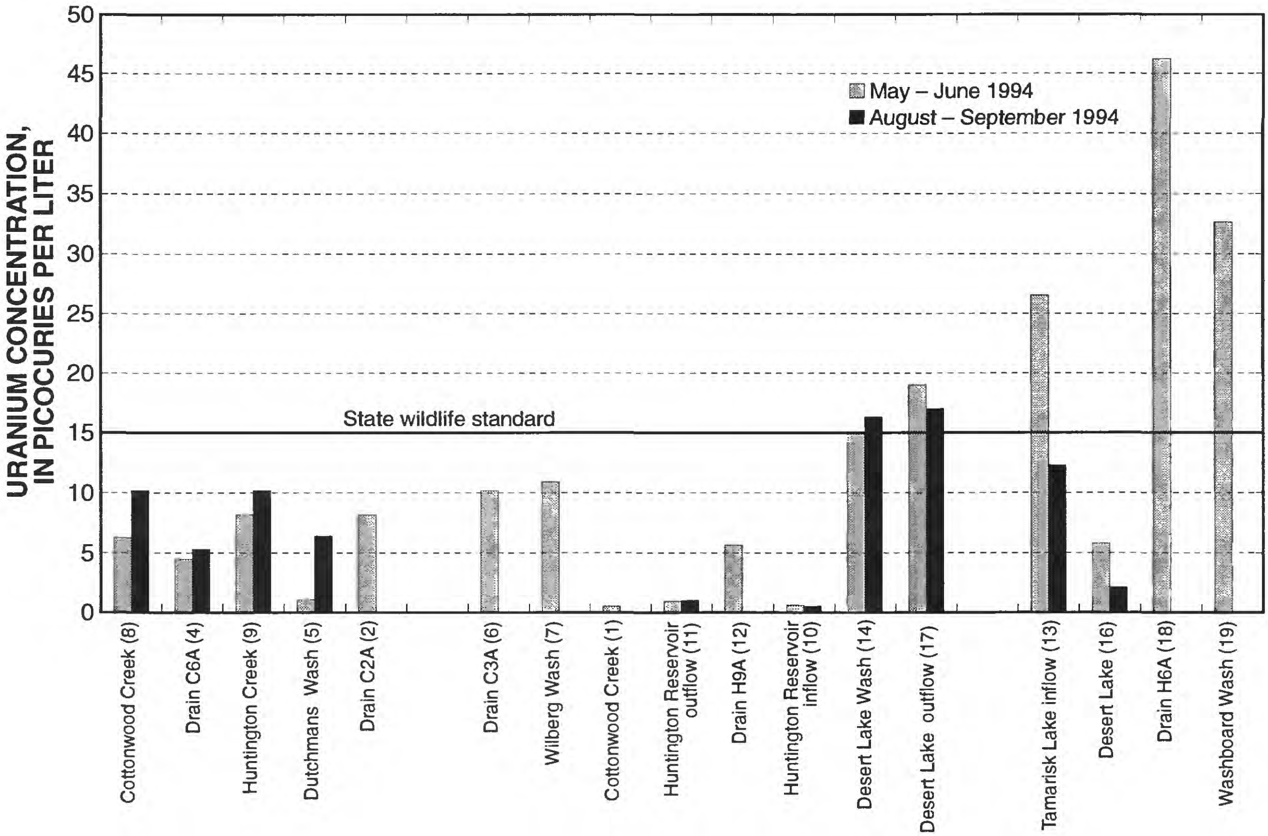

Figure 7. Concentrations of uranium expressed as alpha radiation in water at sites in the Emery Project, Utah. Numbers in parentheses refer to figures 1 and 2.

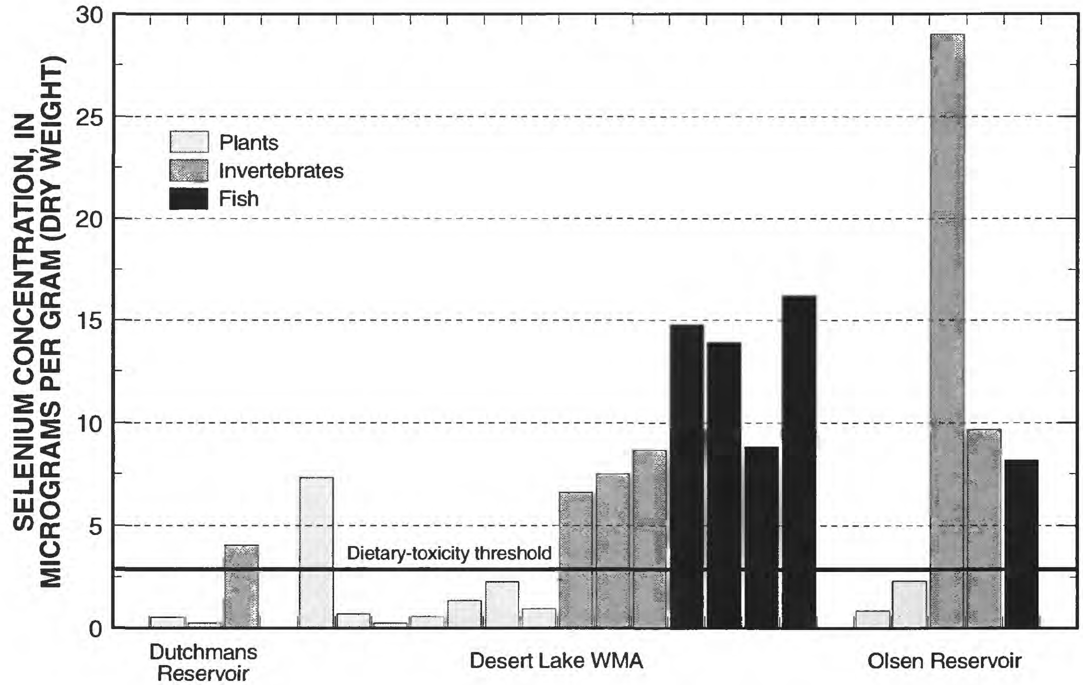

Figure 8. Concentrations of selenium in composite samples of aquatic plants, invertebrates, and small fish collected from Dutchmans Reservoir, Desert Lake Wildlife Management Area (WMA), and Olsen Reservoir in 1994.

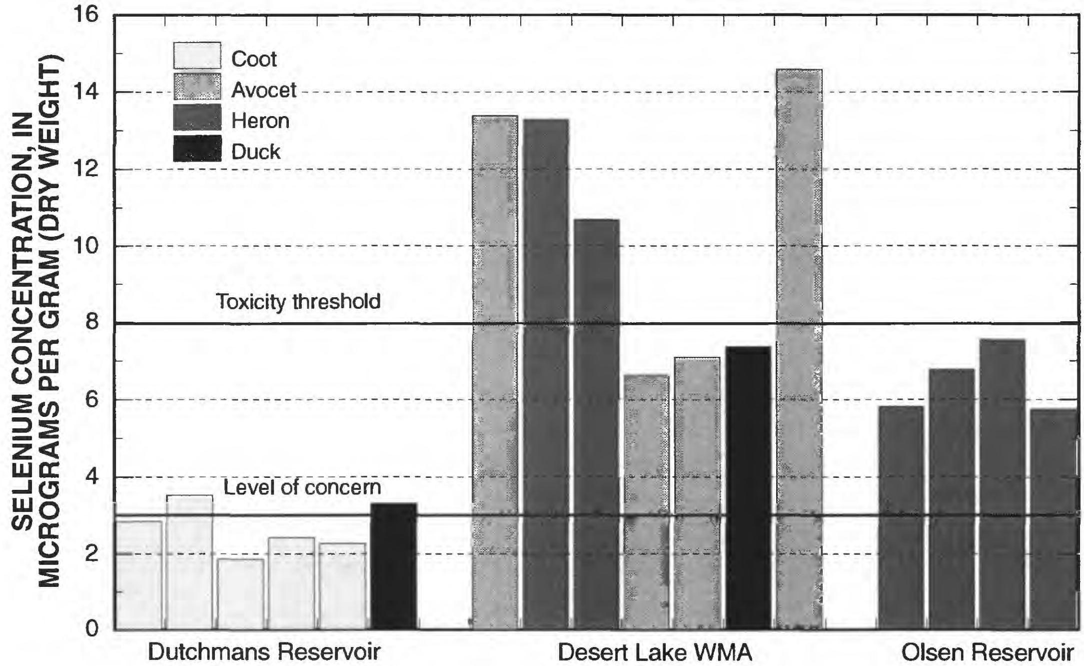

Figure 9. Concentrations of selenium in waterbird eggs collected from Dutchmans Reservoir, Desert Lake Wildlife Management Area (WMA), and Olsen Reservoir in 1994.

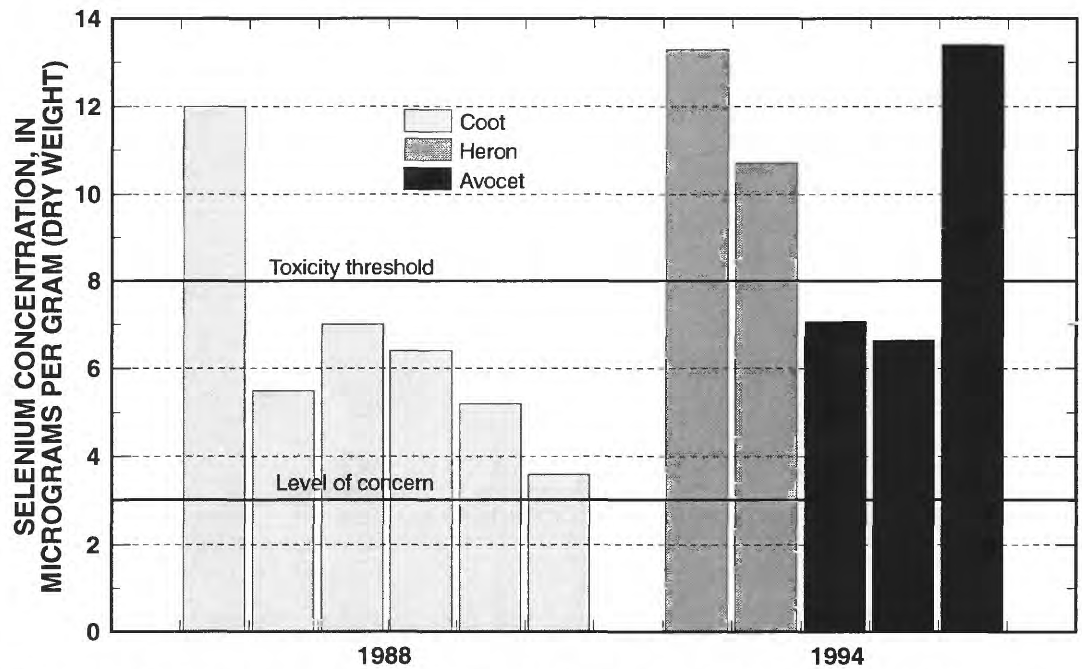

Figure 10. Concentrations of selenium in waterbird eggs collected from Desert Lake Ponds 1-4 and Pond 6 in 1988 and 1994.

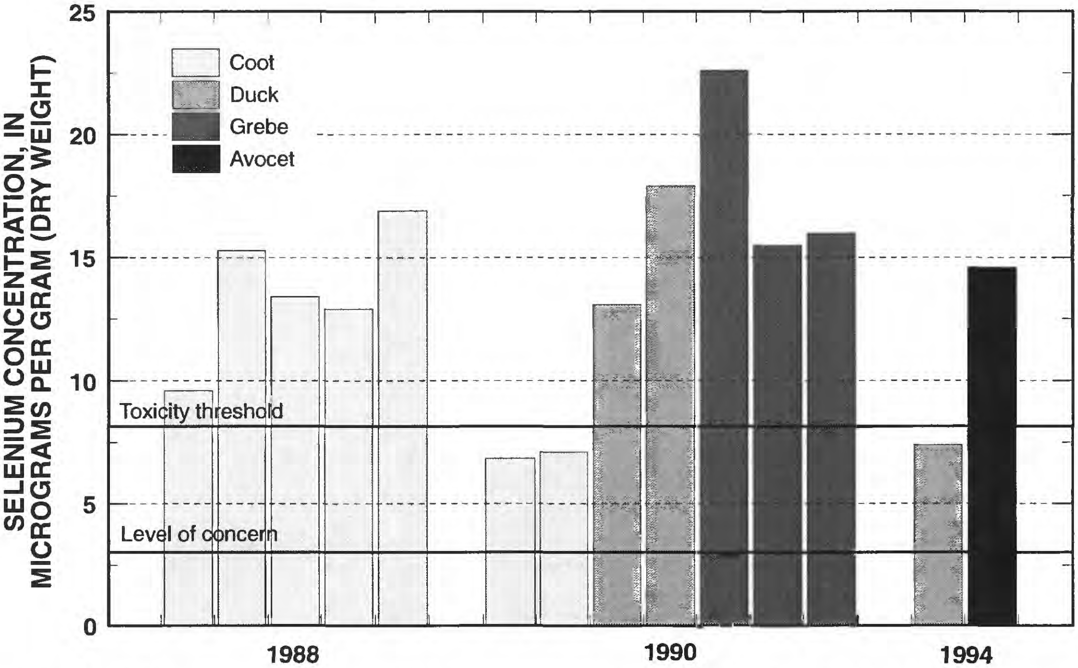

Figure 11. Concentrations of selenium in waterbird eggs collected from Tamarisk Lake at Desert Lake Waterfowl Management Area (WMA) in 1988, 1990, and 1994.

for NRCS projects is voluntary at the level of the landowner.

If fully implemented, the project could have a minor effect on the following features investigated by this screening study:

Desert Lake WMA—The project would eliminate the Cleveland 4-b section (Elmo Ditch) of the north branch of Cleveland Canal that delivers project water to Desert Lake. The canal would be replaced with a piped lateral which could result in greater water availability and improved water quality from this source to the WMA, although specific mention of project effects on the WMA were not discussed in the EIS. There is no mention of closing any of the BOR subsurface drains in the Emery Project.

Olsen Reservoir—The salinity control project does not improve any of the main canals such as Carbon Canal, which supplies this reservoir. Because the Carbon Canal sits topographically high on the system, replacement of smaller laterals with pipe should not affect the water quality in the Carbon Canal (which is typically of good quality). Replacement of the Carbon 25A and B laterals with pipe and completion of on-farm improvements within the drainage area for Marsing Wash could reduce the volume of water entering the Wash (and subsequently Olsen Reservoir), and improve the water quality. However, less water entering the reservoir could result in a decrease of available habitat. Marsing Wash inflow (1.4 ft^3/s) to the reservoir in May 1994 contained 5,250 mg/L of dissolved solids and 2 µg/L selenium.

Dutchmans Reservoir—The irrigation reservoir receives water from the Center Ditch diversion (also termed Cottonwood 2B) from Mammoth Canal. The Cottonwood 2B is scheduled for elimination by replacement with Castle Dale Number 2 off-farm lateral. If seepage from and into the open canal is reduced, salt loading to Dutchmans Reservoir and the selenium contamination problem should be reduced. Elimination of winter water deliveries from Mammoth Canal could reduce some seepage of salt and selenium that may enter the wash, but it is unlikely that winter water ever was released directly into Dutchmans Wash.

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Table 5. Physical properties and concentration of selected elements and constituents in water samples from sites in the Emery and Scofield Project areas of central Utah during 1994

[ft^3/s, cubic feet per second; deg. °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than; —, no data]

Station number	Station name	Date	Time	Discharge (ft^3/s)	Temperature, water (°C)	Specific conduct (µS/cm)	pH, water (standard units)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)	Solids, residue at 180 °C, dissolved (mg/L)	Hardness, total (mg/L as $CaCO_3$)	Alkalinity, lab (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)
390947110560300	Cottonwood Creek below confluence	05-25-94	1240	13	19.0	3,100	8.2	8.6	115	2,560	1,100	325	210	140
	with Rock Canyon Creek	09-13-94	0930	8.6	13.0	4,000	8.1	8.0	93	3,460	1,100	302	210	140
391249111015800	C6A Drain to Cottonwood Creek	05-25-94	1420	.14	10.0	1,420	7.3	7.4	81	978	670	418	170	60
		09-12-94	1535	.06	13.0	1,500	7.7	7.0	81	1,130	780	376	200	68
391300110550000	Huntington Creek above confluence	05-25-94	1030	6.7	17.0	3,880	8.0	8.2	105	3,390	1,300	309	240	180
	with San Rafael River	09-12-94	1430	6.1	19.5	3,550	7.5	8.5	114	3,170	1,100	276	210	140
391307110575300	Dutchmans Reservoir, northwest side	05-25-94	0940	4.0	16.0	810	7.9	7.6	95	494	290	236	51	39
		09-12-94	1355	—	18.0	1,430	8.1	—	—	1,050	510	254	91	69
391442110025501	Drain C2A near Orangeville	09-12-94	1630	.01	16.0	3,300	7.3	—	—	2,860	1,100	422	220	130
391442110025502	Drain C2B near Orangeville[1]	09-12-94	1645	.01	16.0	4,300	7.2	—	—	—	—	—	—	—
391518110590600	Drain C3A	06-15-94	1330	.02	14.0	2,250	7.1	2.5	30	1,750	860	406	180	100
391518110590601	Wilberg Wash below Drain C3A at Highway 10	09-14-94	1250	.09	17.0	6,800	8.0	12.0	157	6,000	1,500	338	240	230
391524111062900	Cottonwood Creek at Swasey	06-15-94	1230	—	13.0	410	8.2	8.8	104	214	210	190	46	22
	Diversion	09-14-94	1145	44	13.0	410	8.4	8.8	104	199	190	186	43	21
392034110562900	Outflow of Huntington North	05-26-94	0920	17	14.5	650	8.2	8.4	102	384	280	179	60	32
	Reservoir	09-14-94	1330	18	20.0	650	8.3	8.0	109	396	260	159	49	34
392057110494700	H9A Drain to Desert Lake Wash near Cleveland Lagoons	05-26-94	1120	.02	12.0	1,320	7.3	—	—	924	630	339	150	61
392118110572000	Inflow to Huntington North	06-15-94	1530	—	—	410	8.2	—	—	220	210	192	45	23
	Reservoir	09-14-94	1400	—	17.0	430	8.5	8.4	107	227	200	181	43	22
392128110471101	Desert Lake Wash at Desert	05-26-94	1330	2.0	19.5	4,950	8.3	14.8	201	4,760	2,000	286	330	290
	Lake perimeter road	08-24-94	1030	.90	15.5	5,200	8.0	8.3	103	5,170	2,000	284	340	290
392144110460801	Desert Lake discharge to	05-26-94	1410	1.7	23.0	8,300	8.5	8.5	125	8,370	2,800	240	310	490
	Desert Seep Wash	08-24-94	1120	1.7	23.0	12,200	9.0	7.8	115	13,200	4,400	132	390	820
392144110470500	Alkali Lake	06-16-94	1145	—	18.0	8,150	9.1	11.0	148	—	—	—	—	—

Table 5. Physical properties and concentration of selected elements and constituents in water samples from sites in the Emery and Scofield Project areas of central Utah during 1994—Continued

Station number	Date	Potassium, dissolved (mg/L as K)	Sodium, dissolved (mg/L as Na)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Sulfate, dissolved (mg/L as SO_4)	Arsenic, dissolved (µg/L as As)	Boron, dissolved (µg/L as B)	Cadmium, dissolved (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)	Copper, dissolved (µg/L as Cu)	Lead, dissolved (µg/L as Pb)	Mercury, dissolved (µg/L as Hg)	Molybdenum, dissolved (µg/L as Mo)	Selenium, dissolved (µg/L as Se)	Vanadium, dissolved (µg/L as V)	Zinc, dissolved (µg/L as Zn)	Uranium, natural, dissolved (µg/L as U)
390947110560300	05-25-94	7.9	390	50	0.40	1,400	1	410	<1.0	<1	<1	<1	<0.1	2	2	2	<10	9.2
	09-13-94	9.8	550	53	.30	2,000	<1	570	<1.0	<1	1	<1	<.1	<1	5	2	<10	15
391249111015800	05-25-94	2.4	62	14	.50	380	<1	140	<1.0	<1	2	<1	<.1	1	<1	<1	5	6.6
	09-12-94	2.4	72	15	.50	510	<1	200	<1.0	<1	<1	<1	<.1	<1	<1	<1	<3	7.8
391300110550000	05-25-94	9.5	520	47	.30	2,000	<1	330	<1.0	<1	<1	<1	<.1	2	1	2	<10	12
	09-12-94	9.5	460	35	.20	1,800	<1	300	<1.0	<1	<1	<1	<.1	2	3	2	<10	15
391307110575300	05-25-94	2.2	61	5.7	.20	180	<1	70	<1.0	<1	1	<1	<.1	1	<1	<1	<3	1.6
	09-12-94	5.6	120	14	.20	520	1	120	<1.0	<1	<1	<1	<.1	1	<1	<1	4	9.4
391442110025501	09-12-94	5.9	400	33	.60	1,500	<1	300	<1.0	1	<1	<1	<.1	<1	<1	1	<10	12
391442110025502	09-12-94	—	—	—	—	—	—	—	—	—	—	—	—	—	<1	—	—	—
391518110590600	06-15-94	7.4	240	29	.60	860	1	200	<1.0	<1	8	<1	<.1	4	12	3	<10	15
391518110590601	09-14-94	10	1,200	120	.30	3,600	<1	300	<1.0	1	1	<1	<.1	<1	46	3	<10	16
391524111062900	06-15-94	.90	9.1	3.2	.10	20	<1	20	<1.0	<1	<1	<1	<.1	1	<1	<1	<3	.80
	09-14-94	.90	8.7	3.4	.10	19	1	20	<1.0	<1	<1	<1	<.1	<1	<1	<1	<3	<.40
392034110562900	05-26-94	1.9	25	23	.10	120	<1	90	<1.0	<1	1	<1	<.1	<1	<1	<1	<3	1.4
	09-14-94	2.2	28	23	.10	140	<1	100	<1.0	<1	<1	<1	<.1	<1	<1	<1	<3	1.5
392057110494700	05-26-94	5.7	45	24	.60	380	<1	160	<1.0	<1	3	<1	<.1	3	1	2	<3	8.3
392118110572000	06-15-94	.80	10	3.5	.10	23	<1	10	<1.0	<1	<1	<1	<.1	1	<1	1	7	.90
	09-14-94	.90	11	4.4	.10	31	1	30	<1.0	<1	<1	<1	<.1	<1	<1	<1	<3	.80
392128110471101	05-26-94	12	620	44	.20	2,900	<1	560	<1.0	<1	1	<1	<.1	2	4	2	10	22
	08-24-94	14	670	48	.20	3,000	<1	520	<1.0	1	1	<1	<.1	1	4	2	<10	24
392144110460801	05-26-94	20	1,400	97	.40	5,400	<1	760	<1.0	<1	<1	<1	<.1	4	1	3	20	28
	08-24-94	34	2,300	150	.50	8,600	2	1,100	<1.0	<1	1	<1	.3	3	2	6	<10	25
392144110470500	06-16-94	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—

Table 5. Physical properties and concentration of selected elements and constituents in water samples from sites in the Emery and Scofield Project areas of central Utah during 1994—Continued

Station number	Station name	Date	Time	Discharge (ft^3/s)	Temperature, water (°C)	Specific conduct (µS/cm)	pH, water (standard units)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)	Solids, residue at 180 °C, dissolved (mg/L)	Hardness, total (mg/L as $CaCO_3$)	Alkalinity, lab (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)
392154110481500	Inflow to west side Tamarisk Lake at Desert Lake Waterfowl Management Area	05-26-94	1530	1.1	24.0	7,300	8.5	—	—	6,900	2,100	331	230	360
		08-23-94	1515	.41	23.0	5,850	8.3	14.4	208	5,260	1,800	302	270	270
		08-23-94	1516[2]	—	—	5,850	8.3	—	—	5,360	1,600	272	260	240
392235110471400	Desert Lake near northwest side	06-16-94	1115	—	22.0	2,400	7.8	—	—	1,820	710	322	120	100
		08-24-94	0900	—	14.5	980	7.7	7.0	84	641	360	235	82	38
392343110460100	H6A Drain to Washboard Wash near Elmo	05-26-94	1030	.02	12.0	3,900	7.3	—	—	3,360	1,400	421	240	200
392343110460101	Washboard Wash at Drain H6A near Elmo	08-23-94	1620	1.0	23.0	7,900	8.3	15.0	218	7,660	2,500	298	370	380
392527110374700	Price River below Desert Seep Wash	06-14-94	1645	18	26.0	2,950	8.8	10.6	162	2,420	890	156	140	130
		08-22-94	1510	22	25.0	3,150	8.2	8.7	129	2,580	1,000	265	190	130
392608110463600	Carbon Canal–Mathis Wash	06-15-94	0845	2.8	16.0	480	8.2	7.4	93	284	220	179	53	22
		09-14-94	1515	2.1	18.0	600	8.4	9.2	120	369	250	171	54	28
392747110432700	Marsing Wash inflow to Olsen Reservoir	05-24-94	1725	1.4	26.0	3,600	8.7	7.3	111	1,960	700	247	120	98
392801110430200	Combined inflow to Olsen Reservoir (Marsing Wash)	08-23-94	1210	.30	14.5	5,800	8.1	6.2	75	5,250	1,800	359	280	270
393019110413000	Miller Creek above confluence with Price River	05-24-94	1530	3.6	27.5	4,500	8.3	8.2	129	4,310	1,800	264	310	240
		08-23-94	1015	2.3	16.0	4,200	8.2	9.3	115	4,220	1,500	231	290	200
393233110411100	Soldier Creek at confluence with Price River	06-16-94	0845	.87	13.0	2,900	8.1	9.1	106	2,360	1,100	290	210	140
		08-23-94	0900	1.4	14.0	1,900	8.1	8.6	101	1,480	650	255	130	79
393233110415700	Coal Creek at UT 6	06-16-94	0800	1.3	13.0	3,750	8.1	8.7	101	3,180	1,200	271	210	170
		08-22-94	1700	1.6	27.0	3,350	8.4	8.0	124	2,830	1,000	197	160	150
394936110565600	Price River at Kyune	06-14-94	1245	164	17.0	420	8.4	8.0	108	235	200	177	54	17
		09-14-94	1130	50	12.0	375	8.4	9.2	110	203	160	145	37	16

Table 5. Physical properties and concentration of selected elements and constituents in water samples from sites in the Emery and Scofield Project areas of central Utah during 1994—Continued

Station number	Date	Potassium, dissolved (mg/L as K)	Sodium, dissolved (mg/L as Na)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Sulfate, dissolved (mg/L as SO_4)	Arsenic, dissolved (µg/L as As)	Boron, dissolved (µg/L as B)	Cadmium, dissolved (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)	Copper, dissolved (µg/L as Cu)	Lead, dissolved (µg/L as Pb)	Mercury, dissolved (µg/L as Hg)	Molybdenum, dissolved (µg/L as Mo)	Selenium, dissolved (µg/L as Se)	Vanadium, dissolved (µg/L as V)	Zinc, dissolved (µg/L as Zn)	Uranium, natural, dissolved (µg/L as U)
392154110481500	05-26-94	17	1,400	98	0.40	4,500	1	500	<1.0	<1	3	<1	<0.1	7	13	5	20	39
	08-23-94	16	790	53	.20	3,200	<1	670	<1.0	1	2	<1	.1	1	2	3	<10	18
	08-23-94	17	900	52	.20	3,200	<1	640	<1.0	1	<1	<1	<.1	<1	2	2	<10	—
392235110471400	06-16-94	1.8	330	9.4	.60	1,000	<1	290	<1.0	<1	1	<1	<.1	1	<1	<1	<10	8.5
	08-24-94	1.6	70	13	.20	270	<1	90	<1.0	<1	<1	<1	<.1	<1	<1	<1	<3	3.1
392343110460100	05-26-94	6.3	520	100	1.0	1,900	<1	410	<1.0	<1	10	<1	<.1	4	16	3	20	68
392343110460101	08-23-94	19	1,300	74	.20	4,800	<1	900	<1.0	1	1	<1	<.1	2	20	3	<10	48
392527110374700	06-14-94	7.0	380	70	.20	1,400	<1	310	<1.0	<1	<1	<1	<.1	2	2	2	<10	10
	08-22-94	9.4	400	89	.30	1,500	1	410	<1.0	<1	<1	<1	<.1	1	4	3	<10	13
392608110463600	06-15-94	1.9	17	11	.20	59	<1	50	<1.0	<1	<1	<1	<.1	1	<1	<1	<3	1.1
	09-14-94	2.1	27	17	.20	120	1	110	<1.0	<1	<1	<1	<.1	<1	<1	<1	<3	1.5
392747110432700	05-24-94	9.4	360	28	.30	1,100	2	310	<1.0	<1	2	<1	<.1	2	2	3	<10	8.2
392801110430200	08-23-94	16	870	50	.30	3,100	2	670	<1.0	2	1	<1	<.1	<1	2	3	<10	17
393019110413000	05-24-94	11	610	85	.20	2,600	<1	520	<1.0	<1	1	<1	<.1	2	6	2	10	23
	08-23-94	11	580	69	.20	2,500	<1	570	<1.0	<1	2	<1	<.1	<1	4	2	<10	20
393233110411100	06-16-94	5.0	330	54	.40	1,300	<1	270	<1.0	<1	<1	<1	<.1	2	2	1	<10	14
	08-23-94	4.9	180	38	.30	760	1	190	<1.0	<1	1	<1	<.1	1	<2	2	<3	8.1
393233110415700	06-16-94	7.1	510	51	.30	1,900	<1	30	<1.0	<1	<1	<1	<.1	3	6	2	<10	12
	08-22-94	8.9	440	48	.30	1,700	<1	330	<1.0	<1	1	<1	<.1	2	5	2	<10	11
394936110565600	06-14-94	1.7	11	7.8	.10	31	<1	40	<1.0	<1	<1	<1	<.1	<1	<1	1	<3	.80
	09-14-94	1.2	11	8.1	.10	30	2	40	<1.0	<1	1	<1	<.1	<1	<1	1	6	.70

[1]Analytical determination only for dissolved selenium.

[2]Replicate analysis for sample collected at 1515 hours.

Table 6. Concentration of selected inorganic elements in the less-than-63-micron fraction of bottom-sediment samples from the Emery and Scofield Project areas of central Utah during 1994

[Concentrations reported in percent or µg/g, micrograms per gram (dry weight); <, less than; —, no data]

Station number	Station name	Date	Aluminum (percent)	Iron (percent)	Calcium (percent)	Magnesium (percent)	Phosphorus (percent)	Potassium (percent)
392144110460801	Desert Lake discharge to Desert Seep Wash	08-24-94	4.3	1.6	4.0	1.2	0.11	1.4
393019110413000	Miller Creek above confluence with Price River	08-23-94	4.5	1.7	5.7	1.6	.11	1.5
392128110471101	Desert Lake Wash at Desert Lake perimeter road	08-24-94	4.5	1.7	7.6	1.9	.12	1.6
392154110481500	Inflow to west side Tamarisk Lake at Desert Lake	08-23-94	4.3	1.6	8.2	1.6	.11	1.5
392235110471400	Desert Lake near northwest side	08-24-94	5.0	2.6	5.7	1.4	.09	1.6
393233110415700	Coal Creek at U.S. Highway 6	08-22-94	3.0	1.3	5.1	1.5	.10	1.2
393233110411100	Soldier Creek at confluence with Price River	08-23-94	5.1	1.9	5.1	1.6	.11	1.7
392527110374700	Price River below Desert Seep Wash	08-22-94	4.7	1.8	8.0	1.7	.11	1.6
392343110460101	Washboard Wash at Drain H6A near Elmo	08-23-94	3.2	1.4	6.7	1.5	.10	1.3
392801110430200	Combined inflow to Olsen Reservoir (Marsing Wash)	08-23-94	5.6	2.2	5.9	1.6	.13	1.8
391518110590601	Wilberg Wash below Drain C3A	09-13-94	2.8	1.1	6.3	2.1	.07	.96

Station number	Date	Sodium (percent)	Arsenic (µg/g)	Barium (µg/g)	Beryllium (µg/g)	Bismuth (µg/g)	Cadmium (µg/g)	Cerium (µg/g)	Cobalt (µg/g)	Chromium (µg/g)	Copper (µg/g)	Europium (µg/g)	Gallium (µg/g)
392144110460801	08-24-94	0.56	<10	370	1	<10	<2	46	6	42	11	<2	9
393019110413000	08-23-94	.32	<10	320	1	<10	<2	42	7	53	12	<2	10
392128110471101	08-24-94	.46	<10	310	1	<10	<2	42	6	54	12	<2	10
392154110481500	08-23-94	.53	<10	340	1	<10	<2	36	7	46	13	<2	10
392235110471400	08-24-94	.68	11	400	1	<10	<2	43	10	50	22	<2	11
393233110415700	08-22-94	.44	<10	350	<1	<10	<2	28	5	35	10	<2	6
393233110411100	08-23-94	.43	<10	350	1	<10	<2	45	7	58	13	<2	11
392527110374700	08-22-94	.41	<10	350	1	<10	<2	44	7	51	13	<2	11
392343110460101	08-23-94	.39	<10	370	<1	<10	<2	33	5	39	8	<2	7
392801110430200	08-23-94	.49	<10	410	1	<10	<2	46	8	58	19	<2	13
391518110590601	09-13-94	.22	<10	210	<1	<10	<2	29	5	36	8	<2	6

Station number	Date	Gold (µg/g)	Holmium (µg/g)	Lanthanum (µg/g)	Lead (µg/g)	Lithium (µg/g)	Manganese (µg/g)	Mercury[1] (µg/g)	Molybdenum (µg/g)	Neodymium (µg/g)	Nickel (µg/g)	Niobium (µg/g)	Scandium (µg/g)
392144110460801	08-24-94	<8	<4	26	12	34	170	0.02	<2	22	16	10	5
393019110413000	08-23-94	<8	<4	25	10	35	210	—	<2	20	17	12	6
392128110471101	08-24-94	<8	<4	25	12	35	300	.07	<2	22	18	11	6
392154110481500	08-23-94	<8	<4	21	12	35	330	—	<2	19	19	10	6
392235110471400	08-24-94	<8	<4	25	22	42	260	—	16	22	28	8	7
393233110415700	08-22-94	<8	<4	17	10	21	180	.04	<2	15	12	7	4
393233110411100	08-23-94	<8	<4	27	13	38	220	—	<2	24	19	13	7
392527110374700	08-22-94	<8	<4	26	11	34	280	—	<2	22	16	12	7
392343110460101	08-23-94	<8	<4	20	12	24	190	—	<2	18	15	8	5
392801110430200	08-23-94	<8	<4	27	16	43	250	—	<2	23	27	13	8
391518110590601	09-13-94	<8	<4	17	9	23	140	—	<2	13	13	8	4

Station number	Date	Selenium[1] (µg/g)	Silver (µg/g)	Strontium (µg/g)	Tantalum (µg/g)	Thorium (µg/g)	Tin (µg/g)	Titanium (percent)	Uranium (µg/g)	Vanadium (µg/g)	Ytterbium (µg/g)	Yttrium (µg/g)	Zinc (µg/g)
392144110460801	08-24-94	<1	<2	180	<40	7	<5	0.16	<100	56	1	15	57
393019110413000	08-23-94	—	<4	190	<40	8	<5	.17	<100	61	1	15	57
392128110471101	08-24-94	<1	<4	260	<40	8	<5	.17	<100	63	2	17	64
392154110481500	08-23-94	—	<4	380	<40	8	<5	.15	<100	66	1	14	63
392235110471400	08-24-94	—	<4	230	<40	8	<5	.18	<100	83	2	15	83
393233110415700	08-22-94	<1	<2	150	<40	5	<5	.11	<100	42	1	12	45
393233110411100	08-23-94	—	<4	170	<40	8	<5	.19	<100	72	2	16	69
392527110374700	08-22-94	—	<4	290	<40	8	<5	.18	<100	61	1	16	57
392343110460101	08-23-94	—	<4	190	<40	5	<5	.12	<100	45	1	13	48
392801110430200	08-23-94	—	<4	220	<40	9	<5	.20	<100	99	2	16	90
391518110590601	09-13-94	—	<2	110	<40	5	<5	.11	<100	40	2	10	38

[1]Only three samples were analyzed for mercury by cold-vapor method and selenium by hydride-generation method. Other samples were destroyed in laboratory preparation.

Table 7. Concentration of selected chlorinated hydrocarbon compounds in the less-than-2-millimeter fraction of bottom

[Concentrations reported in µg/kg, micrograms per kilogram (dry weight); <, less than; —, no data]

Station number	Station name	Date	Aldrin, total in bottom material (µg/kg)	Chlordane, total in bottom material (µg/kg)	DDT, total in bottom material (µg/kg)	DDD, total in bottom material (µg/kg)	DDE, total in bottom material (µg/kg)	Dieldrin, total in bottom material (µg/kg)	Endosulfan, total in bottom material (µg/kg)
392144110460801	Desert Lake discharge to Desert Seep Wash	08-24-94	<0.1	<1.0	<0.1	<0.1	<0.1	<0.8	<0.1
393019110413000	Miller Creek above confluence with Price River	08-23-94	<.1	<1.0	<.1	<.1	<.1	<.8	<.1
392128110471101	Desert Lake Wash at Desert Lake perimeter road	08-24-94	<.1	<1.0	<.1	<.1	<.1	<.8	<.1
392154110481500	Inflow to west side Tamarisk Lake at Desert Lake Waterfowl Management Area	08-23-94	.1	<1.0	<.1	<.1	<.1	<.8	<.1
392235110471400	Desert Lake near northwest site	08-24-94	<.1	<1.0	<.1	<.1	<.1	<.8	<.1
393233110415700	Coal Creek at U.S. Highway 6	08-22-94	<.1	<1.0	<.1	<.1	<.1	<.8	<.1
393233110411100	Soldier Creek at confluence with Price River	08-23-94	<.1	<1.0	<.1	<.1	<.1	<.8	<.1
392527110374700	Price River below Desert Seep Wash	08-22-94	<.1	<1.0	<.1	<.1	<.1	<.4	<.1
392343110460101	Washboard Wash at Drain H6A near Elmo	08-23-94	<.1	<1.0	<.1	<.1	<.1	<.8	<.1
392801110430200	Combined inflow to Olsen Reservoir (Marsing Wash)	08-23-94	<.1	<1.0	<.1	<.1	.3	<.4	<.1

sediment from sites in the Emery and Scofield Project areas of central Utah during 1994

Station number	Date	Endrin, total in bottom material (μg/kg)	Hepta-chlor, total in bottom material (μg/kg)	Hepta-chlor epoxide, total in bottom material (μg/kg)	Lindane, total in bottom material (μg/kg)	Methoxy-chlor, total in bottom material (μg/kg)	Mirex, total in bottom material (μg/kg)	Perthane, total in bottom material (μg/kg)	PCB, total in bottom material (μg/kg)	PCN, total in bottom material (μg/kg)	Toxa-phene, total in bottom material (μg/kg)
392144110460801	08-24-94	<0.1	<0.1	<0.1	<0.1	<0.8	<0.1	—	<1	<1	<10
393019110413000	08-23-94	<.1	<.1	<.1	<.1	<.8	<.1	—	<1	<1	<10
392128110471101	08-24-94	<.1	<.1	<.1	<.1	<.8	<.1	—	<1	<1	<10
392154110481500	08-23-94	<.1	<.1	<.1	<.1	<.8	<.1	—	<1	<1	<10
392235110471400	08-24-94	<.1	<.1	<.1	<.1	<.8	<.1	—	<1	<1	<10
393233110415700	08-22-94	<.1	<.1	<.1	<.1	<.8	<.1	—	<1	<1	<10
393233110411100	08-23-94	<.1	<.1	<.1	<.1	<.8	<.1	—	<1	<1	<10
392527110374700	08-22-94	<.1	<.1	<.1	<.1	<4.0	<.1	<1.00	<1	<1	<10
392343110460101	08-23-94	<.1	<.1	<.1	<.1	<.8	<.1	—	<1	<1	<10
392801110430200	08-23-94	<.1	<.1	<.1	<.1	<4.0	<.1	<1.00	<1	<1	<10

Table 8. Trace-element concentration in aquatic plants from the Emery and Scofield Project areas of central Utah in 1994

[Concentrations reported in µg/g, micrograms per gram (dry weight); number in parentheses is site number from table 2; see figs. 1 and 3 for site location;

Location	Site number	Species	Percent moisture	Aluminum	Arsenic	Boron	Barium	Beryllium	Cadmium	Chromium	Copper
C6 Drain	(4)	Watercress	89.8	8,727	2.1	15	39	0.45	0.35	11	27
C6 Drain	(4)	Cattail	89.6	632	<.5	15	14	<.1	<.1	1.6	4.5
Carbon Canal	(S7)	Cattail	86.6	837	<.5	14	26	.1	<.1	1.8	4.1
Cottonwood Creek	(21)	*Chara*	85.5	7,802	2.5	180	40	.42	.16	7.9	5.2
Desert Lake Pond 6	(16)	*Ruppia maritima*	91.4	15,127	5.4	1,160	42	.72	<.1	12	9.9
Desert Lake Pond 6	(16)	Cattail	88.0	39	<.5	36	1.7	<.1	<.1	1.1	4.0
Desert Lake Seep	(17)	*Ruppia maritima*	78.2	4,399	.63	107	34	.2	.54	8.6	3.9
Desert Lake Wash	(23)	*Ruppia maritima*	84.1	2,835	1.1	294	31	.17	.14	7.6	5.2
Dutchmans Reservoir	(5)	Aquatic plant	88.2	401	.7	20	40	<.1	<.1	4.1	9.3
Dutchmans Reservoir	(5)	Aquatic plant	87.0	2,258	.7	24	86	.11	<.1	5.9	6.3
Huntington Lower	(9)	Potamogeton	87.9	4,615	1.7	297	22	.26	.3	5.2	15.0
Huntington Middle Creek	(23)	Green algae	84.8	23,704	6.6	20	101	2.0	.18	26	80
Huntington Middle Creek	(22)	*Chara*	81.4	6,530	.59	12	56	.32	<.1	13	2.6
Miller Creek	(S4)	*Chara*	72.0	8,331	2.0	12	105	.41	<.1	14	4.1
North Ditch	(20)	Aquatic plant	86.2	2,145	<.5	12	29	.11	<.1	9.5	2.8
Olsen Reservoir	(S9)	*Chara*	77.8	1,729	1.8	10	91	.12	<.1	11	2.0
Olsen Reservoir inflow	(S6)	Aquatic plant	74.0	1,776	5.2	14	18	<.1	<.1	.7	5.2
Tamarisk Lake	(13)	Green algae	82.6	19,828	4.6	53	58	.9	.25	18	7.5
Tamarisk Lake	(13)	*Chara*	90.7	12,918	4.4	83	68	.55	.13	15	4.9
Tamarisk Lake	(13)	*Ruppia maritima*	73.6	22,924	6.0	86	108	1.1	.26	23	10.0
Washboard Wash	(19)	*Ruppia maritima*	83.0	12,878	2.9	170	64	.58	.18	9.5	9.3

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Location	Site number	Iron	Mercury	Magne- sium	Manga- nese	Molyb- denum	Nickel	Lead	Sele- nium	Stron- tium	Vana- dium	Zinc
C6 Drain	(4)	5,042	<0.1	6,978	558	<2	6.4	5.5	<.5	126	13	73
C6 Drain	(4)	353	<.1	3,937	794	<2	1.2	.7	<.5	107	1.0	28
Carbon Canal	(S7)	865	<.1	3,661	347	<2	1.6	1.1	<.5	66	2.0	29
Cottonwood Creek	(21)	4,711	<.1	6,638	750	<2	6.2	4.1	1.6	305	12	37
Desert Lake Pond 6	(16)	10,928	<.1	19,420	682	<2	28	3.7	7.4	317	28	45
Desert Lake Pond 6	(16)	74	<.1	5,680	231	<2	.5	<.5	.7	84	<.5	30
Desert Lake Seep	(17)	2,299	<.1	9,555	613	<2	6.0	1.0	<.5	2,150	4.1	72
Desert Lake Wash	(23)	1,524	<.1	11,577	570	<2	6.0	.8	.58	816	6.0	31
Dutchmans Reservoir	(5)	539	<.1	5,957	387	4.28	4.5	.5	.54	959	1.0	49
Dutchmans Reservoir	(5)	1,259	<.1	5,138	620	<2	4.4	.6	<.5	1,068	3.1	29
Huntington Lower	(9)	5,599	<.1	8,715	444	<2	3.9	1.9	.77	321	7.7	39
Huntington Middle Creek	(22)	45,139	<.1	16,523	305	<2	19	7.9	8.0	242	36	46
Huntington Middle Creek	(22)	3,698	<.1	8,631	433	<2	4.7	1.0	<.5	1,762	8.4	17
Miller Creek	(S4)	3,914	<.1	9,677	769	<2	7.3	1.6	<.5	1,284	11	20
North Ditch	(20)	1,191	<.1	5,724	540	<2	14	.6	3.4	4,258	3.6	12
Olsen Reservoir	(S9)	1,342	<.1	7,031	1,412	<2	3.1	.7	2.3	2,155	3.8	13
Olsen Reservoir inflow	(S6)	3,375	<.1	2,087	143	<2	2.4	1.2	.85	28	4.1	34
Tamarisk Lake	(13)	9,764	<.1	11,770	303	<2	12	4.5	1.4	282	32	38
Tamarisk Lake	(13)	5,164	<.1	18,631	742	<2	12	2.4	2.3	1,885	20	30
Tamarisk Lake	(13)	13,476	<.1	11,635	329	<2	13	7.6	.95	742	39	62
Washboard Wash	(19)	5,998	<.1	10,373	1,021	<2	12	4.0	.93	556	20	47

Table 9. Trace-element concentration in aquatic invertebrates from the Emery and Scofield Project areas of central Utah in

[Concentrations reported in µg/g, micrograms per gram (dry weight); number in parentheses is site number from table 2; see figs. 1 and 3 for site location;

Location	Site number	Species	Percent moisture	Aluminum	Arsenic	Boron	Barium	Beryllium	Cadmium	Chromium	Copper
Cottonwood Creek	(21)	Crayfish	83.7	1,009	1.4	13	28	<0.1	<0.1	5.9	55
Cottonwood Creek	(21)	Crayfish	79.6	633	1.4	23	18	<.1	<.1	6.5	114
Cottonwood Creek	(21)	Mixed invertebrates	84.5	3,287	1.2	7.1	19	.16	.13	3.1	15
Cottonwood Creek	(21)	Mixed invertebrates	79.5	1,126	1.9	9.2	13	<.1	.10	3.8	52
Cottonwood/Swasey	(1)	Diptera	86.1	12,384	6.5	21	106	.71	.13	18	13
Cottonwood/Swasey	(1)	Mixed invertebrates	86.1	3,680	3.7	6.6	46	.2	.24	4.5	26
Cottonwood/Swasey	(1)	Stone flies	77.7	2,408	2.6	8.2	31	.15	<.1	2.5	23
Desert Lake Pond	(17)	Mixed invertebrates	84.3	123	<.5	5.5	<1	<.1	.13	<.5	19
Desert Lake Wash	(23)	Mixed invertebrates	84.7	2,309	.79	11	9.7	.13	<.1	3.4	13
Dutchmans Reservoir	(5)	Mixed invertebrates	84.2	1,242	<.5	4.1	5.7	<.1	.14	1.6	23
Huntington Lower	(9)	Mixed invertebrates	81.6	2,567	1.5	13	14	.15	.20	4.8	14
Huntington Middle Creek	(22)	Crayfish	79.1	1,172	1.2	7.4	12	<.1	<.1	9.5	54
Huntington Middle Creek	(22)	Mixed invertebrates	78.8	2,013	1.1	11	8.1	.11	<.1	3.4	10
Huntington Upper	(20)	Mixed invertebrates	86.6	4,540	1.4	13	28	.24	.33	6.4	15
Miller Creek	(S4)	Mixed invertebrates	83.8	2,111	.81	13	11	.12	<.1	2.5	11
Olsen Reservoir	(S9)	Diving beetles	81.0	56	<.5	3.9	<1	<.1	<.1	<.5	19
Olsen Reservoir	(S9)	Mixed invertebrates	85.4	99	<.5	7.8	1.5	<.1	.15	<.5	14
Price River	(S1)	Mixed invertebrates	83.8	1,843	1.6	<2	25	<.1	.30	1.3	32.0
Soldier Creek	(S3)	Mixed invertebrates	86.5	2,934	.63	5.2	23	.13	.30	2.5	21.0
Tamarisk Lake	(13)	Mixed invertebrates	82.0	411	.83	11	8	<.1	<.1	<.5	11

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Location	Site number	Iron	Mercury	Magnesium	Manganese	Molybdenum	Nickel	Lead	Selenium	Strontium	Vanadium	Zinc
Cottonwood Creek	(21)	491	0.12	2,938	64	<2	1.3	<.5	1.8	560	0.9	63
Cottonwood Creek	(21)	357	.13	2,678	52	<2	1.4	<.5	1.2	467	1.4	82
Cottonwood Creek	(21)	2,225	<.1	2,443	354	<2	2.8	1.03	1.3	72	5.4	81
Cottonwood Creek	(21)	779	.15	2,290	69	<2	.7	<.5	2.3	242	.8	113
Cottonwood/Swasey	(1)	6,556	<.1	9,320	358	<2	10	4.5	1.1	74	18	58.0
Cottonwood/Swasey	(1)	1,930	.12	2,788	425	<2	2.7	1.3	2.5	30	4.6	141
Cottonwood/Swasey	(1)	1,224	.19	3,291	181	<2	1.7	.74	2.0	32	2.9	175
Desert Lake	(17)	147	<.1	3,511	23	<2	<.5	<.5	7.5	43	<.5	123
Desert Lake Wash	(23)	1,153	<.1	2,730	72	<2	2.3	.60	6.6	66	4.0	94
Dutchmans Reservoir	(5)	573	<.1	1,626	21	<2	1.3	<.5	4.1	26	1.7	117
Huntington Lower	(9)	2,850	<.1	2,239	317	<2	2.7	1.6	4.2	83	4.9	92
Huntington Middle Creek	(22)	1,091	<.1	2,870	79	<2	2.5	<.5	1.3	631	2.6	52
Huntington Middle Creek	(22)	2,392	<.1	1,705	130	<2	2.4	.85	3.1	63	3.6	66
Huntington Upper	(20)	2,387	<.1	3,106	94	<2	5.2	2.2	5.1	22	7.1	104
Miller Creek	(S4)	1,028	<.1	1,966	146	<2	3.3	.64	2.6	79	3.5	66
Olsen Reservoir	(S9)	114	<.1	1,444	67	<2	.6	<.5	29	22	<.5	80
Olsen Reservoir	(S9)	207	.12	2,227	22	<2	.7	<.5	9.7	35	<.5	123
Price River	(S1)	1,173	<.1	2,037	108	<2	1.5	.82	3.3	29	3.3	164
Soldier Creek	(S3)	1,699	<.1	2,993	89	<2	1.9	.93	7.6	47	5.2	112
Tamarisk Lake	(13)	231	<.1	2,564	24	<2	.8	<.5	8.7	19	.8	61

Table 10. Trace-element concentration in fish from the Emery and Scofield Project areas of central Utah in 1994

[Concentrations reported in µg/g, micrograms per gram (dry weight); number in parentheses is site number from table 2; see figs. 1 and 3 for site location;

Location	Site number	Species	Percent moisture	Aluminum	Arsenic	Boron	Barium	Beryllium	Cadmium	Chromium	Copper
Desert Lake Pond 4	(15)	Small fish	69.4	26	0.75	6.9	<1	<0.1	<0.1	3.5	5.1
Desert Lake Wash	(23)	Utah chub	74.3	106	<.5	<2	1.0	<.1	<.1	15	6.3
Desert Seep	(17)	Utah chub	73.4	51	<.5	<2	<1	<.1	<.1	10	4.3
Huntington Lower	(9)	Longnose dace	70.7	98	<.5	<2	1.5	<.1	<.1	7.2	2.6
Huntington Middle Creek	(22)	Longnose dace	76.9	301	<.5	2.0	2.1	<.1	<.1	13	3.1
Olsen Reservoir inflow	(S6)	Small fish	75.0	247	<.5	3.2	3.0	<.1	<.1	16	6.6
Soldier Creek	(S3)	Longnose dace	72	80	<.5	4.1	5.1	<.1	<.1	5.7	17.9
Soldier Creek	(S3)	Longnose dace	73.8	68	<.5	4.2	3.5	<.1	<.1	16	2.9
Tamarisk Lake	(13)	Small fish	81.4	256	<.5	12.4	3.5	<.1	<.1	2.5	6.6

Table 11. Trace-element concentration in bird egg, nestling, and liver samples from the Emery and Scofield Project areas of

[Concentrations reported in µg/g, micrograms per gram (dry weight); number in parentheses is site number from table 2; see figs. 1 and 3 for site location;

Location	Site number	Species	Percent moisture	Aluminum	Arsenic	Boron	Barium	Beryllium	Cadmium	Chromium	Copper
Desert Lake Pond 4	(15)	American avocet egg	72.2	12	1.2	3.7	<1	<0.1	<0.1	1.9	2.0
Desert Lake Pond 4	(15)	American avocet egg	75.4	9.6	.54	2.3	<1	<.1	<.1	<.5	2.5
Desert Lake Pond 4	(15)	Black-crowned night-heron egg	80.4	9.8	<.5	<2	<1	<.1	<.1	<.5	4.4
Desert Lake Pond 4	(15)	Black-crowned night-heron egg	81.5	8.4	<.5	<2	<1	<.1	<.1	.7	5.5
Desert Lake Pond 6	(15)	American avocet egg	78.8	<5	<.5	3.5	<1	<.1	<.1	.56	3.1
Desert Lake Pond 6	(16)	American avocet egg	71.2	<5	<.5	3.8	<1	<.1	<.1	<.5	3.9
Dutchmans Reservoir	(5)	American coot egg	78.2	10	<.5	7.7	1.1	<.1	<.1	11	3.6
Dutchmans Reservoir	(5)	American coot egg	73.6	<5	<.5	3.2	1.1	<.1	<.1	6.7	3.3
Dutchmans Reservoir	(5)	American coot egg	74.6	<5	<.5	<2	<1	<.1	<.1	<.5	2.1
Dutchmans Reservoir	(5)	American coot egg	75.4	<5	<.5	<2	2.8	<.1	<.1	<.5	3.0
Dutchmans Reservoir	(5)	Pied-bill grebe egg	80.2	<5	<.5	<2	<1	<.1	<.1	<.5	3.2
Dutchmans Reservoir	(5)	Ruddy duck egg	68.7	<5	<.5	<2	3.1	<.1	<.1	<.5	2.2
Olsen Reservoir	(S9)	Black-crowned night-heron egg	80.5	<5	<.5	4.2	<1	<.1	<.1	7.6	6.1
Olsen Reservoir	(S9)	Black-crowned night-heron egg	81.5	<5	<.5	6.4	<1	<.1	<.1	<.5	3.4
Olsen Reservoir	(S9)	Black-crowned night-heron egg	82.1	<5	<.5	3.2	1.4	<.1	<.1	11	5.8
Olsen Reservoir	(S9)	Black-crowned night-heron egg	81.7	<5	<.5	<2	<1	<.1	<.1	<.5	4.8
Olsen Reservoir	(S9)	Black-crowned night-heron chick	82.9	57	<.5	2.8	2.8	<.1	<.1	1	5.0
Tamarisk Lake	(13)	American avocet egg	60.7	<5	<.5	<2	<1	<.1	<.1	2.9	1.9
Tamarisk Lake	(13)	Unknown species egg	67.3	<5	<.5	<2	1.2	<.1	<.1	<.5	3.2
Desert Lake Pond 4	(15)	Pied-bill grebe liver	71.9	10	1	2.6	<1	<.1	1.99	<.5	16
Desert Lake Pond 4	(15)	Pied-bill grebe liver	72.1	10	1.2	<2	<1	<.1	.213	<.5	21
Dutchmans Reservoir	(5)	American coot liver	69.6	7.1	.60	23	<1	<.1	.233	<.5	15

<, less than]

Location	Site number	Iron	Mercury	Magne-sium	Manga-nese	Molyb-denum	Nickel	Lead	Sele-nium	Stron-tium	Vana-dium	Zinc
Desert Lake Pond 4	(15)	57	<0.1	1,287	8	<2	1.21	<0.5	14.8	114	<0.5	177
Desert Lake Wash	(23)	151	<.1	1,234	8	<2	8.3	<.5	13.9	102	<.5	139
Desert Seep	(17)	99	<.1	1,305	7	<2	6.3	<.5	8.8	89	<.5	140
Huntington Lower	(9)	290	.19	1,136	12	<2	3.8	<.5	5.9	135	<.5	145
Huntington Middle Creek	(22)	371	.21	1,271	15	2	8.2	<.5	5.5	104	.8	151
Olsen Reservoir inflow	(S6)	248	.11	1,312	13	<2	11	<.5	8.2	90	<.5	152
Soldier Creek	(S3)	111	.23	1,174	10	<2	<.5	<.5	6.4	136	<.5	137
Soldier Creek	(S3)	148	.21	1,117	9	2.5	10	<.5	7.1	116	<.5	116
Tamarisk Lake	(13)	332	<.1	2,826	113	<2	<.5	<.5	16	119	<.5	149

central Utah in 1994

<, less than]

Location	Site number	Iron	Mercury	Magne-sium	Manga-nese	Molyb-denum	Nickel	Lead	Sele-nium	Stron-tium	Vana-dium	Zinc
Desert Lake Pond 4	(15)	152	0.16	338	1.9	<2	1.67	<0.5	6.7	10	<0.5	45
Desert Lake Pond 4	(15)	89	<.1	360	1.7	<2	<.5	<.5	7.1	9	<.5	43
Desert Lake Pond 4	(15)	87	.75	390	1.7	<2	<.5	<.5	13.3	2	<.5	43
Desert Lake Pond 4	(15)	106	.78	437	1.4	<2	<.5	<.5	11	3	<.5	54
Desert Lake Pond 6	(16)	132	<.1	409	2.5	<2	<.5	<.5	10	9	<.5	53
Desert Lake Pond 6	(16)	87	.37	306	1.9	<2	<.5	<.5	13	15	<.5	46
Dutchmans Reservoir	(5)	205	<.1	673	2.1	2.1	8.6	<.5	3.5	75	<.5	84
Dutchmans Reservoir	(5)	149	<.1	626	3.2	<2	4.6	<.5	2.3	51	<.5	69
Dutchmans Reservoir	(5)	72	<.1	448	<1	<2	<.5	<.5	1.9	17	<.5	54
Dutchmans Reservoir	(5)	114	.28	475	1.3	<2	<.5	<.5	2.4	22	<.5	60
Dutchmans Reservoir	(5)	37	.32	466	<1	<2	.55	<.5	13	4	<.5	32
Dutchmans Reservoir	(5)	109	<.1	303	1.5	<2	.77	<.5	3.3	11	<.5	48
Olsen Reservoir	(S9)	152	.52	501	1.7	2.5	6.3	<.5	5.8	3	<.5	47
Olsen Reservoir	(S9)	83	1.7	507	3.3	<2	<.5	<.5	6.8	6	<.5	47
Olsen Reservoir	(S9)	139	2.0	428	3.1	3.0	8.8	<.5	7.5	4	<.5	61.7
Olsen Reservoir	(S9)	78	.89	337	<1	<2	<.5	<.5	5.8	2	<.5	34
Olsen Reservoir	(S9)	182	2.2	715	3.7	<2	<.5	<.5	5.6	31	<.5	80
Tamarisk Lake	(13)	144	.22	324	1	<2	3.0	<.5	15	13	<.5	44
Tamarisk Lake	(13)	97	.21	328	<1	<2	<.5	<.5	7.4	9	<.5	52
Desert Lake Pond 4	(15)	2,989	14.8	702	11	<2	<.5	<.5	58	<.5	<.5	120
Desert Lake Pond 4	(15)	3,387	1.5	593	14	<2	<.5	<.5	73	<.5	<.5	80
Dutchmans Reservoir	(5)	1,403	.11	498	7.4	<2	<.5	<.5	2.9	1.5	0.94	65

Table 12. Concentration of organochlorine compounds in waterbird eggs and whole-body longnose dace samples collected

[Concentration reported in µg/g, micrograms per gram (wet weight); number in parentheses is site number from table 2; see figs. 1 and 3 for site location; HCB, hexachlorobenzene; Heptac, heptachlor; hept-e, heptachlor epoxide; op-DDD, ortho-para-dichloro-diphenyl-dichloro-ethane; op-DDE, diphenyl-dichloro-ethane; pp-DDE, para-para-dichloro-diphenyl-ethane; pp-DDT, para-para-dichloro-diphenyl; PCB-TOT, PCB Totals; tr-nona,

Location	Site number	Species	Percent moisture	Percent lipid	Aldrin	alpBHC	a-chlo	b-BHC	cn-chl	d-BHC	Dieldrin	Endrin	g-BHC	g-chlo
Bird eggs														
Desert Lake Pond 4	(15)	Black-crowned night heron	82.8	4.8	<0.01	<0.01	<0.01	0.04	<0.01	<0.01	<1.00	<0.01	<0.01	<0.01
Desert Lake Pond 4	(15)	American avocet	77.9	7.2	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Desert Lake Pond 6	(16)	American avocet	73.7	10.3	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Olsen Reservoir	(S9)	Black-crowned night heron	83.7	3.2	<.01	<.01	<.01	.19	<.01	<.01	<.01	<.01	<.01	<.01
Dutchmans Reservoir	(5)	American coot	77.7	5.6	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Dutchmans Reservoir	(5)	Ruddy duck	72.2	10.6	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Whole-body fish														
Huntington Creek Middle	(22)	Longnose dace	82.6	3.8	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Huntington Creek Lower	(9)	Longnose dace	75.1	7.3	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002
Soldier Creek	(S3)	Longnose dace	73.5	6.0	<.002	<.002	<.002	<.002	<.002	<.002	.004	<.002	<.002	<.002

Table 13. Concentration of polychlorinated biphenyls (PCBs) in waterbird eggs and whole-body longnose dace samples

[Concentration reported in µg/g, micrograms per gram (wet weight); number in parentheses is site number from table 2; see figs. 1 and 3 for site location;

Location	Site number	Species	Percent moisture	PCB 49	PCB 66	PCB 82	PCB 87	PCB 110/77
Bird eggs								
Desert Lake Pond 4	(15)	American avocet	82.8	0.01	<0.015	<0.015	<0.015	<0.015
Desert Lake Pond 4	(15)	American avocet	77.9	.01	<.013	<.013	<.013	<.013
Desert Lake Pond 6	(16)	American avocet	73.7	.02	<.017	<.017	<.017	<.017
Olsen Reservoir	(S9)	Black-crowned night heron	83.7	.02	<.016	.017	<.016	<.016
Dutchmans Reservoir	(5)	American coot	77.7	.02	<.017	<.017	<.017	<.017
Dutchmans Reservoir	(5)	Ruddy duck	72.2	.01	<.013	<.013	<.013	<.013
Whole-body fish								
Huntington Creek Middle	(22)	Longnose dace	82.6	.002	<.002	<.002	<.002	<.002
Huntington Creek Lower	(9)	Longnose dace	75.1	.002	<.002	<.002	<.002	<.002
Soldier Creek	(S3)	Longnose dace	73.5	.004	.004	<.002	.005	.007

from the Emery and Scofield Project areas of central Utah in 1994

alpBHC, alpha BHC; a-chlo, alpha chlordane; b-BHC, beta BHC; cn-chl, c-nonachlor; d-BHC, delta BHC; g-BHC, gamma BHC; g-chlo, gamma BHC; ortho-para-dichloro-diphenyl-ethane; op-DDT, ortho-para-dichloro-diphenyl-trichloro-ethane; oxychl, oxychlordane; pp-DDD, para-para-dichloro-tertiary nonachlor; <, less than]

Location	Site number	HCB	Heptac	hept-e	Mirex	op-DDD	op-DDE	op-DDT	oxychl	pp-DDD	pp-DDE	pp-DDT	PCB-TOT	tr-nona
Bird eggs														
Desert Lake Pond 4	(15)	<0.015	<0.016	<0.016	<0.016	<0.016	<0.016	<0.016	<0.016	<0.016	4.31	0.032	0.259	<0.0167
Desert Lake Pond 4	(15)	<.013	<.013	<.013	<.013	<.013	<.013	<.013	<.013	<.013	.279	<.013	.182	<.013
Desert Lake Pond 6	(16)	<.017	<.017	<.017	<.017	<.017	<.017	<.017	<.017	<.017	.762	.026	.114	<.017
Olsen Reservoir	(S9)	<.016	<.016	<.016	<.016	<.016	<.016	<.016	<.016	<.016	12.2	<.016	.249	<.016
Dutchmans Reservoir	(5)	<.017	<.017	<.017	<.017	<.017	<.017	<.017	<.017	<.017	.059	<.017	.083	<.017
Dutchmans Reservoir	(5)	<.013	<.013	<.013	<.013	<.013	<.013	<.013	<.013	<.013	.122	<.013	.063	<.013
Whole-body fish														
Huntington Creek Middle	(22)	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	.003	<.002	.013	<.002
Huntington Creek Lower	(9)	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	.006	<.002	.010	<.002
Soldier Creek	(S3)	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	.019	<.002	.083	.002

collected from the Emery and Scofield Project areas of central Utah in 1994

<, less than]

Location	Site number	PCB 118/108/149	PCB 138	PCB 149	PCB 153	PCB 56/171	PCB 172	PCB 180	PCB 187/182	PCB 194
Bird eggs										
Desert Lake Pond 4	(15)	<0.015	0.045	<0.015	0.036	<0.015	<0.015	0 .045	0 .021	<0.015
Desert Lake Pond 4	(15)	.021	.029	<.013	<.013	<.013	.017	<.013	.028	.013
Desert Lake Pond 6	(16)	<.017	<.017	<.017	<.017	<.017	.019	<.017	<.017	<.017
Olsen Reservoir	(S9)	<.016	.040	<.016	.019	<.016	.017	.044	<.016	<.016
Dutchmans Reservoir	(5)	<.017	<.017	<.017	<.017	<.017	.019	<.017	<.017	<.017
Dutchmans Reservoir	(5)	<.013	<.013	<.013	<.013	<.013	<.013	<.013	<.013	<.013
Whole-body fish										
Huntington Creek Middle	(22)	<.002	<.002	<.002	<.002	<.002	<.002	.004	<.002	<.002
Huntington Creek Lower	(9)	<.002	<.002	<.002	<.002	<.002	.002	.002	<.002	<.002
Soldier Creek	(S3)	.008	.010	.004	.016	.002	.002	<.002	.003	.002