Reconnaissance Investigation of Water Quality, Bottom Sediment, and Biota Associated with Irrigation Drainage in and near Humboldt Wildlife Management Area, Churchill and Pershing Counties, Nevada, 1990-91

By Ralph L. Seiler, U.S. Geological Survey, and Geoffrey A. Ekechukwu and Robert J. Hallock, U.S. Fish and Wildlife Service

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"We camped for two days in the neighborhood of the "Sink of the Humboldt." We tried to use the strong alkaline water of the Sink but it would not answer. It was like drinking lye, and not weak lye either. It left a taste in the mouth, bitter and every way execrable, and a burning in the stomach . . . The coffee we made of this water was the meanest compound man has yet invented."

Mark Twain,

Roughing it

"One can get an idea of how it tastes by making a strong solution of tepid water and bitter salts and adding several rotten eggs. Such a mixture would produce about the same effect on the human body as would the water of the sink. Only dire thirst and the knowledge that one would have to walk forty miles before coming to real water could force anyone to take a drink of this diabolical liquid."

Heinrich Lienhard (1846)

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

Multiply	By	To obtain
acre	4,047	square meter (m^2)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
acre-foot per day (acre-ft/d)	0.001233	cubic hectometer per day (hm^3/d)
acre-foot per year (acre-ft/yr)	0.001233	cubic hectometer per year (hm^3/yr)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
foot (ft)	0.3048	meter (m)
inch (in.)	2.54	centimeter (cm)
	25.4	millimeter (mm)
mile (mi)	1.609	kilometer (km)
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
ounce (oz)	28.35	gram (g)
pound (lb)	0.4536	kilogram (kg)

For temperature, degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) by using the formula °F = [1.8(°C)]+32. Degrees Fahrenheit may be converted to degrees Celsius (°C) by using the formula °C = 5/9(°F-32).

ABBREVIATED WATER-QUALITY UNITS

g	(gram)
g/min	(gram per minute)
L	(liter)
µg/g	(microgram per gram)
µg/L	(microgram per liter)
µS/cm	(microsiemens per centimeter at 25 °C)
mm	(millimeter)
mg/kg	(milligram per kilometer)
mg/L	(milligram per liter)
pCi/L	(picocurie per liter)

SEA LEVEL

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

Reconnaissance Investigation of Water Quality, Bottom Sediment, and Biota Associated with Irrigation Drainage in and near Humboldt Wildlife Management Area, Churchill and Pershing Counties, Nevada, 1990-91

By Ralph L. Seiler,[1] Geoffrey A. Ekechukwu,[2] *and* Robert J. Hallock[2]

ABSTRACT

A reconnaissance investigation was begun in 1990 to determine whether the quality of irrigation drainage in and near the Humboldt Wildlife Management Area (WMA), Nevada, has caused or has potential to cause harmful effects on human health or fish and wildlife, or may adversely affect the suitability of water for other beneficial uses.

Samples of surface and ground water, bottom sediment, and biota were collected from sites upstream and downstream from the Lovelock agricultural area. Samples of each of the three media were analyzed for a suite of potentially toxic trace elements, including selenium. Other analyses included radioactive substances; major dissolved constituents and nutrients in water; and pesticide residues in water, bottom sediment, and biota. Water samples were collected three times from March to November 1990, bottom-sediment samples once during low-flow conditions in November 1990, and biological samples during May to July 1990.

Biotoxicity tests to measure the toxicity of water and sediment from reference sites and sites that receive irrigation drain water were conducted using daphnids, fathead-minnow larvae, mysid shrimp, and chironomids as the test organisms. Sites were selected on the basis of the results of onsite specific-conductance measurements of the water and tests that measure the toxicity of the water to a species of marine bacteria.

In areas affected by irrigation drainage, concentrations of the following constituents commonly were found to exceed geochemical baseline values, biological effect levels, or Nevada standards for the protection of aquatic life or for the propagation of wildlife: in water--arsenic, boron, dissolved solids, mercury, molybdenum, sodium, un-ionized ammonia, and possibly selenium; in bottom sediment--arsenic, lithium, molybdenum, and uranium; and in biota--arsenic, boron, chromium, copper, mercury, selenium, and zinc. In the wetlands, selenium appears to be biomagnified. Uranium concentrations were substantially higher at the downstream drain-water sites compared with the upstream reference sites and exceeded drinking-water Maximum Contaminant Levels proposed by the U.S. Environmental Protection Agency; however, surface water is not used for public water supply in the area. Pesticide (DDE and DDD) concentrations in bottom sediment were at the analytical reporting limit, and no pesticides were detected in fish from areas receiving irrigation drain water.

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[1] U.S. Geological Survey
[2] U.S. Fish and Wildlife Service

Biological effects observed during this reconnaissance included reduced insect diversity in sites receiving irrigation drain water and acute toxicity of drain water and sediment to test organisms. Habitat degradation at Humboldt WMA has resulted from reduced water deliveries to the wetlands caused by drought and upstream consumption of water for irrigation. Water and sediment samples from some drains are acutely toxic to fish and insects and may not support food chains essential to some migratory birds.

High concentrations of arsenic in drain water and bottom sediment probably are the result of historical mining activities near Humboldt WMA. High selenium concentrations measured in waterfowl tissue probably are the result of irrigation drainage; however, this investigation did not identify the exposure pathway with certainty.

INTRODUCTION

Background

During the last several years, there has been increasing concern about the quality of irrigation drainage and its potentially harmful effects on human health, fish, and wildlife. Concentrations of selenium greater than those specified for the protection of aquatic life (U.S. Environmental Protection Agency, 1987) have been detected in subsurface drainage from irrigated land in the western San Joaquin Valley in California. In 1983, mortality, birth defects, and reproductive failures in waterfowl were discovered by the U.S. Fish and Wildlife Service at the Kesterson National Wildlife Refuge where San Joaquin Valley irrigation drain water was impounded. In addition, other potentially toxic trace elements and toxic pesticide residues have been detected in other areas in the Western States that receive irrigation drainage.

Because of concerns expressed by the U.S. Congress, the Department of the Interior (DOI) started a program in October 1985 to identify the nature and extent of irrigation-induced water-quality problems in the Western States. The DOI formed an interbureau group known as the "Task Group on Irrigation Drainage." The task group identified study areas that relate to three specific DOI responsibilities: (1) irrigation or drainage facilities constructed or managed by the DOI, (2) national wildlife refuges managed by the DOI, and (3) other migratory-bird or endangered-species management areas that receive water from DOI-funded projects.

Initially, the Task Group identified 19 areas in 13 states that warranted reconnaissance investigation. Nine of these nineteen areas were selected for investigations during 1986-87:

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

Reports for these nine reconnaissance investigations have been published. Based on results of these investigations, four detailed studies began in 1988: Salton Sea Area, Stillwater Wildlife Management Area, Middle Green River Basin, and the Kendrick Reclamation Project Area.

Eleven more reconnaissance investigations were initiated in 1988:

California:	Sacramento Refuge Complex
California-Oregon:	Klamath Basin Refuge Complex
Colorado:	Gunnison River Basin/Grand Valley Project
	Pine River Area
Colorado-Kansas:	Middle Arkansas River Basin
Idaho:	American Falls Reservoir
New Mexico:	Middle Rio Grande and Bosque del Apache National Wildlife Refuge
Oregon:	Malheur National Wildlife Refuge
South Dakota:	Angostura Reclamation Unit
	Belle Fourche Reclamation Project
Wyoming:	Riverton Reclamation Project

Detailed studies for three sites began in 1990-91:

California-Oregon:	Klamath Basin Refuge Complex
Montana:	Sun River Area
Colorado:	Gunnison River Basin/Grand Valley Project

This reconnaissance investigation was one of five initiated in October 1989 and in October 1990:

Oregon-Idaho:	Owyhee-Vale Reclamation Project Areas
Nevada:	Humboldt River Area
Colorado:	Dolores-Ute Mountain Area
New Mexico:	San Juan River Area
Washington:	Columbia River Basin

The reconnaissance investigation of the Humboldt River Area was conducted by an inter-bureau team composed of a scientist from the U.S. Geological Survey as team leader, and additional U.S. Geological Survey, U.S. Fish and Wildlife Service, and U.S. Bureau of Reclamation scientists representing several disciplines.

State and Federal biologists have observed that the Humboldt WMA near Lovelock, Nevada, is an ecosystem in decline. Macroinvertebrate diversity is low, and reptiles and amphibians are very rare in the wetlands. Salt-tolerant vegetation such as muskgrass has replaced pondweed in parts of the wetlands. Bird epizootics in the 1970's and 1980's at the Humboldt WMA killed thousands of birds. The effect of irrigation drainage on water and biota was demonstrated at nearby Stillwater WMA during a reconnaissance investigation of that site (Hoffman and others, 1990). The Humboldt WMA was selected for a reconnaissance investigation, in part, because of its ecological and hydrologic similarity to Stillwater WMA.

As with all the reconnaissance investigations, this study was designed to determine if irrigation drainage (1) has caused or has the potential to cause significant harmful effects on human health, fish, and wildlife, or (2) may adversely affect the suitability of water for other beneficial uses. It included the collection and analysis of physical and chemical data from 11 surface-water sites and 1 shallow ground-water site from March to November 1990. Biological data were collected at 11 surface-water sites.

Purpose and Scope

This report describes the results of the 2-year reconnaissance investigation of irrigation-related contaminants and their effects within and near the Humboldt WMA. The report documents the concentrations of organic and inorganic constituents in water, bottom sediment, and biota in the wildlife areas and relates analytical results to various Federal and State water-quality regulations, criteria and other numerical guidelines, and reference information. The report also documents biological assessment of sites on the Humboldt River, as well as the acute toxicity of water and bottom sediment. To facilitate comparison of data between the similar ecological and hydrologic settings, the presentation of results in this report follows, in general, that used by Hoffman and others (1990) in the reconnaissance investigation at the nearby Stillwater Wildlife Management Area.

Acknowledgments

The authors of this report gratefully acknowledge the following individuals who provided valuable assistance and information during the course of this investigation: Al Tenente, Lovelock; Ben Hodges, Pershing County Water Conservation District, Lovelock; Norman R. Saake, Nevada Department of Wildlife, Fallon.

GENERAL DESCRIPTION OF THE STUDY AREA

Location

Lovelock Valley, about 70 miles northeast of Reno, is in west-central Nevada in the Lovelock Valley hydrographic area (Rush, 1968, plate 1) of the lower Humboldt River Basin (fig. 1). The valley extends southward from Rye Patch Dam on the Humboldt River to the Humboldt Sink (fig. 2). The area is about 45 miles long and 18 miles wide; its total area is about 740 square miles. The principal city in the area is Lovelock, which had a population of 2,330 in 1990.

The Humboldt WMA is located in the Humboldt Sink and covers 36,235 acres; 18,179 acres of this is leased from the U.S. Bureau of Reclamation and 18,056 acres is leased from the Southern Pacific Railroad (Norman A. Saake, Nevada Department of Wildlife, written commun., 1990). The present (1990) wetland area averages about 12,850 acres. The wetland area within the WMA includes Toulon Lake and the upper and lower parts of Humboldt Lake (fig. 2).

In this report, the term "study area" refers to Lovelock Valley, which includes the Humboldt WMA. However, two reference sites on the Humboldt River upstream of Lovelock Valley are also included in the study. These sites were sampled to provide baseline information on biological habitats similar to those found in the Humboldt WMA. They also provided a source of dilution water for aquatic biotoxicity tests.

History of Lovelock Valley

The margins of the Humboldt Sink have been occupied by humans for about 9,000 years (Bard and others, 1979, fig. 17). Granite Point and Ocala and Lovelock Caves near the Humboldt Sink are sites of archeological importance. Bard and others (1979) list and describe numerous archeological investigations done in the Humboldt Sink.

Peter Ogden, an explorer for the Hudson Bay Company, led the first expedition to visit the Humboldt Sink in 1828. The Native American Indians living there described the geography between the Humboldt Sink and Sierra Nevada to him (Bard and others, 1979, p. 13). Joseph Walker led the second and third expeditions into the area in 1833-34.

Between 1841 and 1869, emigrant parties commonly used a section of the Overland Trail that follows the Humboldt River to the Humboldt Sink. Thousands of cattle, oxen, and horses and hundreds of men, women, and children died in this section of the Overland Trail. The Humboldt Sink was the last source of marginally potable water before the Forty-Mile Desert--the feared, barren land between the Humboldt Sink and the Carson or Truckee River. With the completion of the transcontinental railroad in 1869, the misery of the Humboldt River and Sink ended for the emigrants.

The site of Lovelock was initially a station on the overland stage and later a station on the transcontinental railroad. The first permanent settler was James Blake in 1861, followed by George Lovelock and others the next year (Thompson and West, 1881). By 1880, about 400 people inhabited the valley around the town--most engaged in stock-raising and farming.

Agriculture

The Lovelock agricultural area contains about 39,600 acres of irrigable land (fig. 2), of which an average of about 30,860 acres were irrigated between 1968 and 1978 (Water and Power Resources Service, 1981). Alfalfa hay and seed alfalfa are the principal irrigated crops in both acreage and revenue. In Pershing County in 1989, about 30,000 acres of alfalfa produced a crop revenue of $17.4 million (Nevada Agricultural Statistics Service, 1990). The Lovelock agricultural area is by far the largest agricultural area in Pershing County. Much of the hay is used for feeding the large numbers of cattle and sheep brought in from the upper Humboldt Basin and the Central Valley of California (Water and Power Resources Service, 1981).

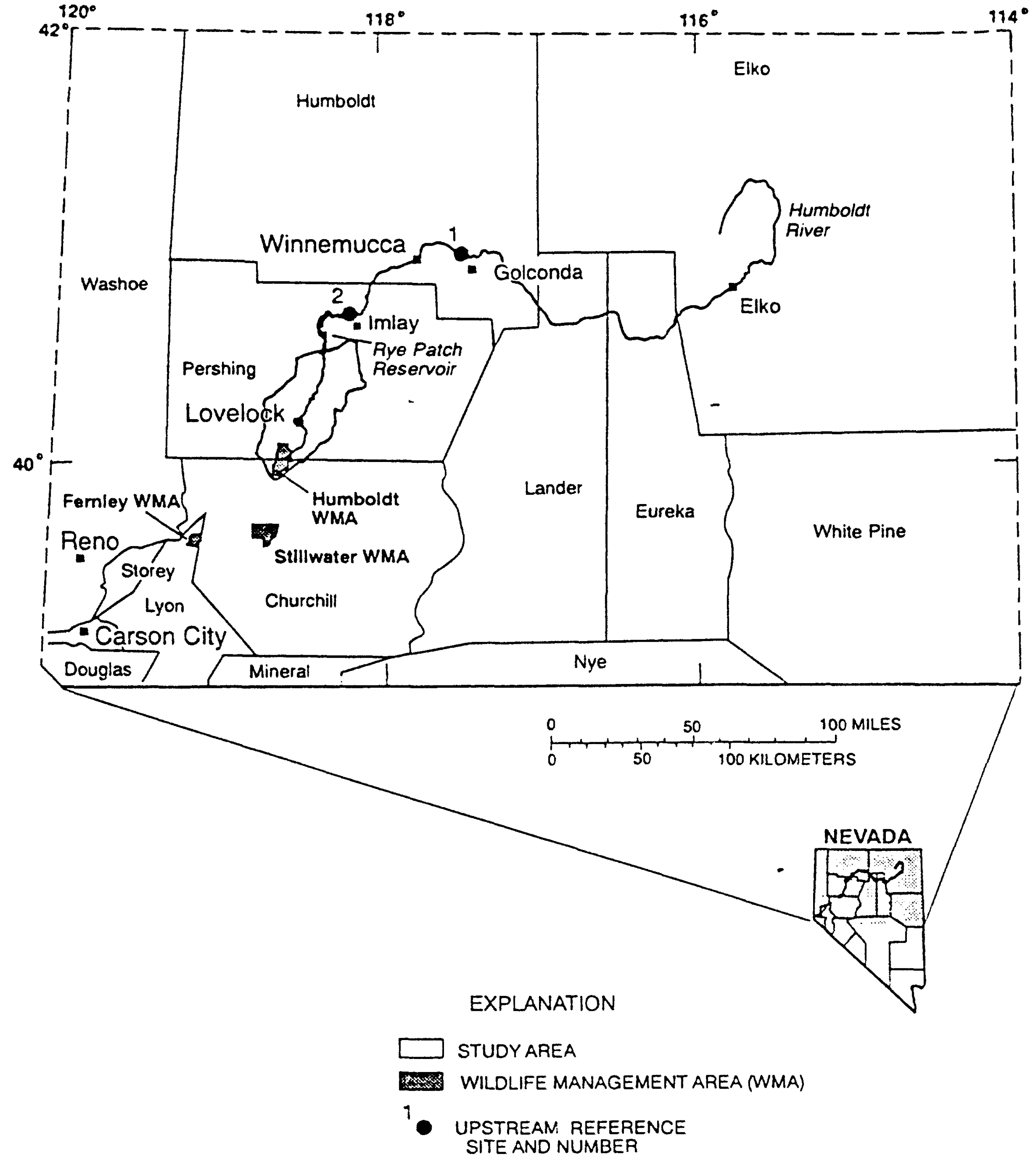


Figure 1. Location of study area, Wildlife Management Areas, and upstream reference sites in relation to Humboldt River and other geographic features in Nevada. For site information, see table 1.

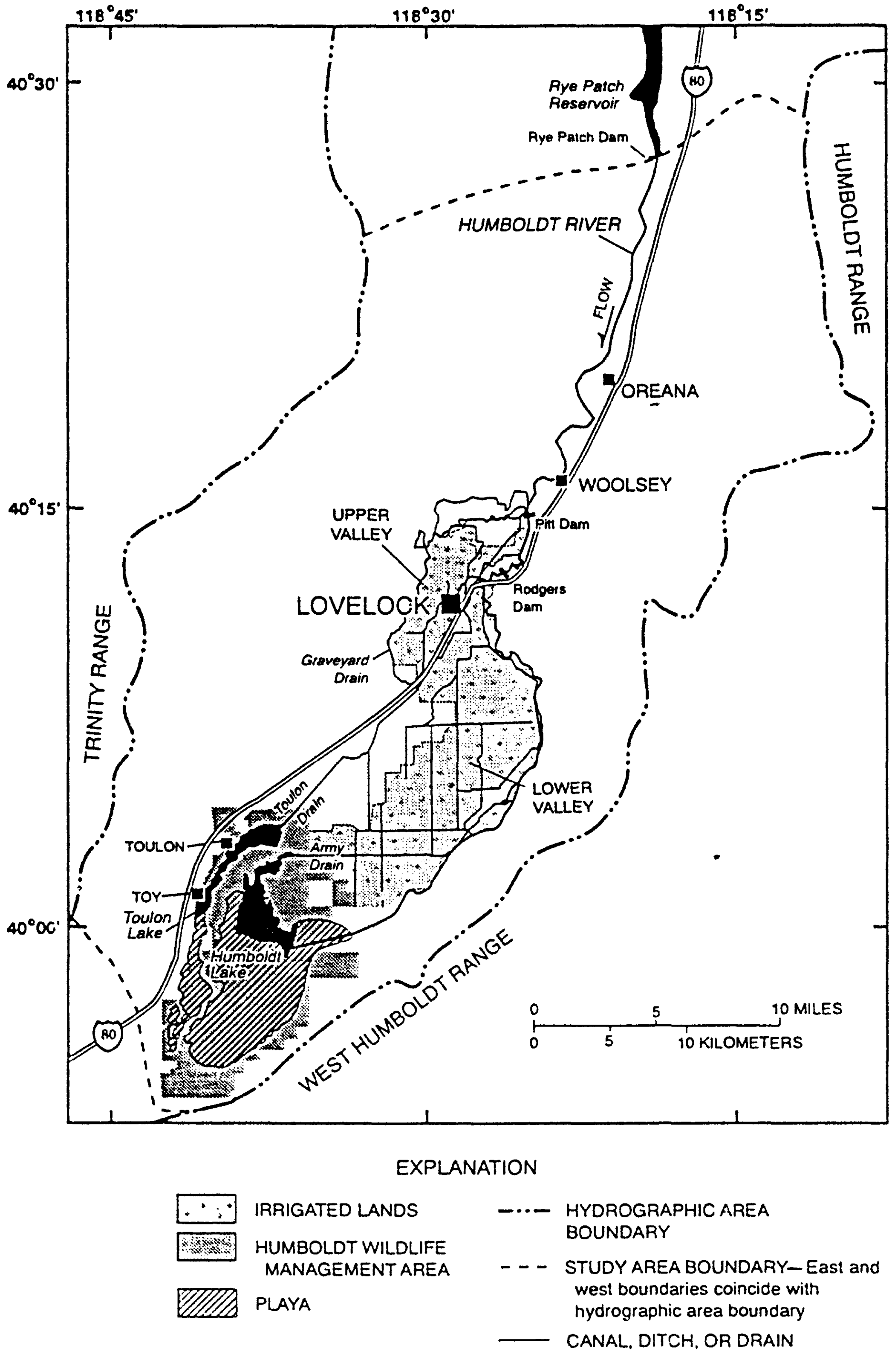


Figure 2. Location of Humboldt Wildlife Management Area and irrigated lands in Upper and Lower Valleys.

Pesticides are not used extensively in the study area. Carbofuran is used to control weevils and aphids. Herbicides, principally 2,4-D, are used to control broadleaf weeds.

Irrigation in the area began with the first settlers in 1862. Storage of irrigation water in the Humboldt River Basin began in 1911 (Water and Power Resources Service, 1981) with the construction by the Lovelock Light and Power Company of the Pitt and Taylor Reservoirs, located about 38 miles north of Lovelock. The U.S. Bureau of Reclamation investigated other potential reservoir sites and in 1933 selected the Rye Patch Dam site, which is 26 miles upstream from Lovelock. Rye Patch Dam is an earth-fill, rock-faced structure that was completed on June 1, 1936. Rye Patch Reservoir has a storage capacity of 213,000 acre-ft of water (Water and Power Resources Service, 1981). The water rights to the Pitt and Taylor Reservoirs were purchased by the Pershing County Water Conservation District in 1945. The reservoirs provide a reserve storage of 35,000 acre-feet of water to support the operation of Rye Patch Reservoir. The operation and maintenance of the Humboldt Project were transferred from the U.S. Bureau of Reclamation to the Pershing County Water Conservation District in January 1941. The first stored water was delivered to the Humboldt Project that same year.

Wetlands

The wetlands in the Humboldt Sink probably were, and continue to be, highly variable in size on an annual basis. Between 1949 and 1973, the combined wetlands within the Humboldt Wildlife Management Area (WMA) averaged about 12,850 acres (Hallock and others, 1981, p. 18). The most common plants in the wetlands include alkali bulrush, cattails, sago pondweed, and muskgrass.

Prior to agricultural development in the region in the late nineteenth century, most of the water of the Humboldt River flowed unregulated to the wetlands. At that time, the Humboldt Sink wetlands probably averaged about 58,000 acres, or about 4.5 times greater than the present (1990) area (Hallock and others, 1981, p. 13). Wetlands were extensive, and the lower valley was a large meadow. Dikes were built along the lower Humboldt River, and wetlands were drained for crops; what was formerly the Big Meadow became the Lower Valley agricultural area.

The Humboldt WMA has three wetlands units: upper Humboldt Lake, lower Humboldt Lake, and Toulon Lake. The water depth in the lakes typically ranges between 2 and 18 inches (Norman A. Saake, Nevada Department of Wildlife, written commun., 1990). The Humboldt Lake has been much deeper at times; soundings in the central part of Humboldt Lake in July 1882 revealed a uniform depth of 12 feet (Russell, 1885).

Toulon Lake is about 4 feet higher than Humboldt Lake and is not directly fed by the Humboldt River. Prior to agricultural development of the area, Toulon Lake was intermittent and filled by spillover from Humboldt Lake. A map of the area made during an archeological exploration of Lovelock Cave in 1924 does not show standing water at the present Toulon Lake (Loud and Harrington, 1929, plate 1). In the late 1930's to early 1940's--prior to the completion of Toulon Drain--it was an alkali playa (Norman A. Saake, Nevada Department of Wildlife, oral commun., 1991).

The wetlands are characterized by wet and dry cycles. In 1846, emigrant James Clyman wrote, "this whole region is now intirely (*sic*) dried up and has the most thirsty appearance of any place I ever witnessed" (Curran, 1982, p. 136). Emigrants writing in 1850 and 1852 described Humboldt Lake as about 5 miles long and 1.5 miles wide, and Horace Greely in 1859 described Humboldt Lake as "A fine sheet of clear water, perhaps fifteen miles in length forty in circumference" (Curran, 1982, p. 136). Russell (1885, p. 66) reports, "In the summer of 1882, Humboldt Lake covered an area of about 20 square miles, did not overflow, and although somewhat alkaline was inhabited by both fish and mollusks, and was sufficiently pure for human use."

The Humboldt WMA was established in 1954 and is managed by the Nevada Department of Wildlife as a feeding and nesting area for migratory birds that use the Pacific flyway. Humboldt WMA is only about 20 air miles north of Stillwater National Wildlife Refuge, and birds from the two areas intermingle. Water-related public uses of Humboldt WMA include waterfowl hunting, birdwatching, and fishing.

Many wildlife species depend on the Humboldt Sink wetlands. Common waterfowl using the area include the Canada goose (*Branta canadensis*), northern pintail duck (*Anas acuta*), mallards (*A. platyrynchos*), and cinnamon teal (*A. cyanoptera*). The white-faced ibis (*Plegadis chihi*), which periodically nests in the Humboldt Sink, is a species of national concern because of its declining population. Threatened and endangered species present include bald eagles (*Haliaeetus leucocephalus*) and peregrine falcons (*Falco peregrinus*). Loud and Harrington (1929) reported that "In spring and summer many thousands of pelicans are to be seen at the lake...."

Between 1969 and 1990, an average of 255 breeding pairs of ducks were in the Humboldt WMA, and the peak recorded was 1,049 breeding pairs (Norman A. Saake, Nevada Department of Wildlife, written commun., 1990). The average annual peak numbers during 1970 to 1989 were 47,722 for coots, 921 for Canada geese, and 11,567 for pintail ducks.

Migratory birds flying along the Pacific flyway through Nevada depend on the wetlands in the Humboldt, Stillwater, and Fernley Wildlife Management Areas (fig. 1) as important sources of water and food. In unusual circumstances, the Humboldt WMA may become the most utilized waterfowl area in Nevada (Hallock and others, 1981). This happened during 1977, when a drought affected the headwaters of the Carson and Truckee Rivers in the Sierra Nevada much more than it affected the headwaters of the Humboldt River in northeastern Nevada.

Indications that habitat degradation is occurring at the Humboldt WMA include the following:

- Migratory-bird epizootics killing thousands of birds (Vega, 1987)
- Changes in the emergent vegetation caused by flooding during the mid-1980's and the subsequent drought; bulrush (*Scirpus acutus and S. poludosus*) and cattail (*Typha sp.*) populations have declined and salt cedar (*Tamarix gallica*) populations have increased; salt cedar now grows on the dry lake bed (Norman A. Saake, Nevada Department of Wildlife, oral commun., 1991)
- Changes in submergent vegetation in upper Humboldt Lake resulting in less sago pondweed (*Potamageton sp.*) and more salt-tolerant species such as muskgrass (*Chara sp.*).
- Lack of species diversity in the wetlands. Reptiles and amphibians are rare in the wetlands; mollusks were reported living in Humboldt Lake in 1882 (Russell, 1885), and Loud and Harrington (1929) identified the mussel and snail shells found there, but no mussels were found living in the Humboldt Sink during 1990.

Climate

Most of western Pershing County is classified as mid-latitude desert with cold winters and hot summers. For the period 1930-52, the average daily minimum temperature at Lovelock in January was 16.6°F, and the average daily maximum in July was 94.7°F (Langan and others, 1965). Both the Sierra Nevada and the Trinity Mountain ranges to the west form a rainshadow that allows little moisture to fall in Lovelock Valley. The average annual precipitation from 1891 to 1989 was 5.48 inches (National Climatic Center, 1989), whereas the average annual evapotranspiration (ET) rate for open water, marshes, meadows, and mudflats in the nearby Stillwater area has been reported to be about 54 inches (Morgan, 1982, p. 33). Average evaporation from open water in Rye Patch Reservoir was reported as 72 inches per year (Langan and others, 1965, p. 82).

Prehistoric Lake Lahontan

Late in the Pleistocene Epoch (14,000 to 12,500 years ago), 8,600 square miles of northwestern Nevada and far eastern California was covered by an inland sea known as Lake Lahontan (Benson and Mifflin, 1986, p. 1). At its maximum extent (altitude, about 4,365 feet), the lake inundated the present-day sites of Lovelock and the Humboldt WMA to a depth of 350-500 feet.

Geology

Lovelock Valley is part of an intermontane basin that is bordered to the west and east by mountains--the Trinity, West Humboldt, and Humboldt Ranges (fig. 2). These mountains are characteristic basin-and-range fault-block masses composed of igneous, sedimentary, and metamorphic rocks (Johnson, 1977).

The valley floor is underlain by unconsolidated and partly consolidated sedimentary deposits of alluvial and lacustrine origin (Bredehoeft, 1963). Near-surface sediments consist of gravel, sand, silt, and clay, with sand- to clay-size particles dominating. The Humboldt Sink playa is underlain by thin beds of fine silty sand, silt, and clayey silt, interbedded with minor evaporate-mineral deposits (Langan and others, 1965).

Sources of Trace-Element Contaminants

The arsenic, boron, mercury, selenium, and uranium content of the soils and underlying sedimentary deposits in the Lovelock area are unknown. The amounts of these elements in soils depend on many factors, one of which is the amount of the element in the parent material. Undoubtedly, some of the sediment deposited in Lake Lahontan in the Lovelock area originated in arsenic-, mercury-, selenium-, and uranium-bearing formations in the Humboldt River Basin.

The Getchell Mine, about 25 miles northeast of Golconda (fig. 1), could recover considerable amounts of arsenic directly from milling its precious metal ores (La Heist, 1964). Samples from inactive gold and silver mines in the Trinity Range have assayed as high as 4.45 percent arsenic (Johnson, 1977, p. 96).

Boron is brought to the earth's surface in igneous deposits and thermal water and accumulates in evaporite deposits in arid basins. Garside and Schilling (1979) present data about several thermal springs and wells along the Humboldt River between Golconda and Lovelock. Although boron data are not available for most of the sites, a spring near Golconda discharges water containing 1,100 µg/L of boron. Accumulation of boron in Nevada marshes is well documented (Smith, 1964), but not in the Humboldt River Basin.

Nevada contains more than 100 mercury mines--many of which are in the Humboldt River Basin (Bailey, 1964). A mine near Imlay (fig. 1) produced 28.6 tons of mercury in 1913-14 (Johnson, 1977, p. 59).

Several selenium deposits are in the Humboldt River Basin (Davidson, 1964, fig. 30). The element is associated with epithermal deposits of antimony in areas near Lovelock and Winnemucca (Davidson, 1964). Thirty-seven samples of kerogen-rich mudstone, siltstone, chert, and dolomitic rocks of Ordovician and Devonian age in central Nevada contained selenium concentrations ranging from 0.2 to 360 mg/kg, with an average of 32 mg/kg (Poole and others, 1979).

Uranium deposits in Nevada have been mapped by Butler (1964). Uranium mines and deposits are most common in the western part of the State, but two uranium deposits have been mapped in Pershing County near Rye Patch Reservoir.

Historical mining activities in the Humboldt Sink may be the source of some of the trace elements now found in the wetlands. Two mills along the west edge of Toulon Lake operated early this century at Toulon and Toy (fig. 2); between 1915 and 1918, both plants milled tungsten from nearby mines in the Trinity mountains (Lincoln, 1923). Later, tungsten milling stopped, and one of the mills was sold and began producing white arsenic in the 1920's, using ore from the Irish Rose mine in Lander County (Lincoln, 1923; La Heist, 1964). During the operation of these mills, the present Toulon Lake was an alkaline playa; tailings could have been deposited or blown into what is now the lake. Additionally, a small spring discharges at the site of the Toy mill and may carry trace elements from tailings into the lake.

HYDROLOGIC SETTING

Lovelock Agricultural Area

Surface Water

Uses of surface water in Lovelock Valley and vicinity include (1) irrigation for agriculture; (2) maintenance of waterfowl and fishery habitats; (3) public recreation, such as hunting, fishing, birdwatching, swimming, boating, and camping. Surface water is not used as a source of drinking water in Lovelock Valley. Irrigation water for the Lovelock area comes from Rye Patch Reservoir, which is fed directly by the Humboldt River (fig. 1). Agricultural land in Lovelock Valley receives water from the U.S. Bureau of Reclamation Humboldt Project, which is operated by the Pershing County Water Conservation District.

Between 1936, when Rye Patch Dam was completed, and 1990, the mean annual release from Rye Patch Reservoir--measured at the Humboldt River below Rye Patch gaging station--has been 183,800 acre-ft per year, and the median discharge has been about 126,000 acre-ft per year (fig. 3). The maximum discharge was 1,452,000 acre-ft in 1984; the discharge along the main stem of the Humboldt River in that year was extraordinary and is considered as greater than a 100-year flood (Moosburner, 1986). The minimum release was 21,150 acre-feet in 1955.

During the 1990 water year,[1] 67,950 acre-feet were released from Rye Patch Reservoir (fig. 3). The data collection for this study took place during a drought; the annual discharge in 1990 has been exceeded in more than 90 percent of the years since completion of the Rye Patch Dam.

From November to the end of March, usually no water is released from Rye Patch Reservoir (fig. 4). During these months, the only water in the drains and river is ground-water inflow and releases from the Lovelock sewage-treatment plant.

Water released for agricultural use or spilled for flood control from Rye Patch Reservoir is routed through the Lovelock agricultural area. A schematic diagram of the flow systems that comprise the Humboldt Project is shown in figure 5. This schematic oversimplifies the true flow system that includes nearly 50 miles of main canals, 100 miles of lateral connecting drains, and 130 miles of open return drains (U.S. Bureau of Reclamation, 1961, p. 2).

The main source of water for Humboldt WMA is agricultural drainage from about 39,600 acres of irrigable lands in Lovelock Valley. Inflows to the Humboldt WMA maintain an average of about 12,850 acres of wetlands[2]. Everett and Rush (1965, table 7) presented a water budget for Lovelock Valley for 1936-61. They estimated the following recharge to the Humboldt Sink:

Source of flow to Humboldt Sink	Amount of flow (acre-ft/yr)
Humboldt River water	51,000
Irrigation drain water	42,000
Ground water from Lovelock Valley	2,000

The flow of irrigation drain water to the sink was estimated by subtracting the estimated consumptive use by irrigated crops from the estimated water applied to the crops. The actual quantity of irrigation return flows that reach the wetlands is not known, because streamflow to the Humboldt and Toulon Lakes is inadequately monitored.

Direct flow of Humboldt River water to the sink only occurs during high flow years; usually all Humboldt River water is used for agriculture, and only irrigation return flow reaches the sink. During operational spills, the water is routed through the canals and drains to Humboldt and Toulon Lakes. These infrequent spills and exceptionally wet years can bring abundant good-quality water to the Humboldt WMA that flushes the wetlands and removes accumulated salts.

[1] The term "water year" refers to the 12-month period October 1 through September 30 during which a complete annual hydrologic cycle normally occurs. The water year is designated by the calendar in which it ends. Thus, the year ending September 30, 1990, is called the "1990 water year."

[2] An interesting note on how the perceived importance of wetlands has changed in the last 25 years is given by Everett and Rush (1965, p. 2) who state, "An average of about 50,000 acre-feet per year of good quality flood water has wasted to the Humboldt Sink."

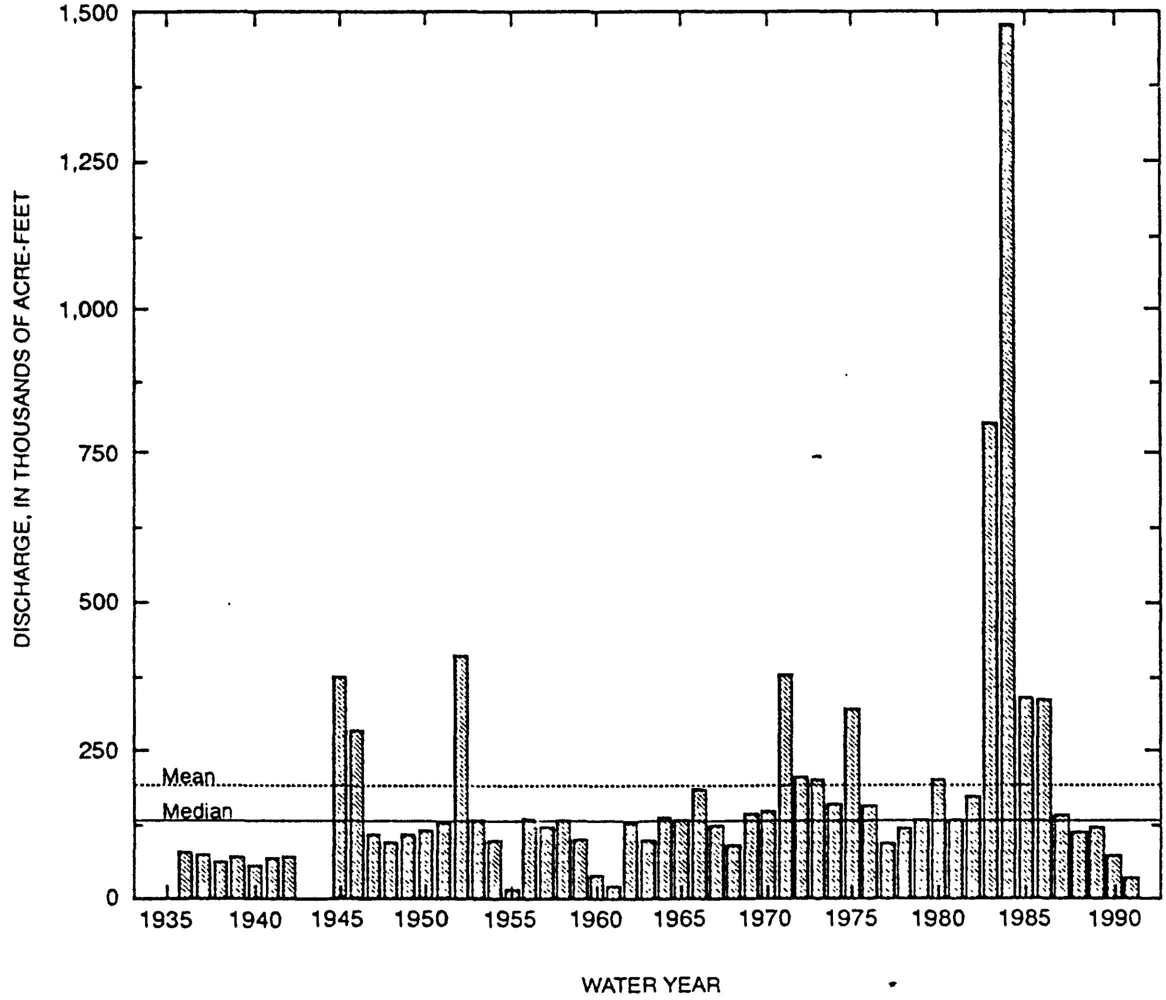


Figure 3. Annual release of water from Rye Patch Reservoir measured at Humboldt River near Rye Patch gaging station (10335000), water years 1936-91. (No data available for 1943-44).

During abnormally high flow years (for example, 1982-84 in fig. 3), the Humboldt Sink overflows into the Carson Sink. During the 1940's, the drainage channel between Humboldt Sink and Carson Sink was dredged to permit larger flows (U.S. Bureau of Reclamation, 1984, p. 1). The water in these closed basins ultimately dissipates by evapotranspiration; thus, the dissolved constituents in the water tend to concentrate over time.

Beginning in December 1951, the U.S. Geological Survey collected water samples for chemical analysis from the Humboldt River at a gaging station immediately below Rye Patch Reservoir (station 10335000). Collection of water-quality samples on a routine basis was discontinued in 1986. The dissolved-solids concentration of the water released from the reservoir varied greatly between 1952 and 1990 (fig. 6). Dissolved-solids concentrations exceeding 1,000 mg/L have been associated with droughts and periods of low discharge from the reservoir. Storage of river water in Rye Patch Reservoir increases the dissolved-solids concentration and changes the chemical composition through evaporation and through dissolution of minerals in the underlying Lake Lahontan sediment. The chemical composition of the water released from the reservoir is predominantly sodium bicarbonate with a median dissolved-solids concentration of 550 mg/L (fig. 7).

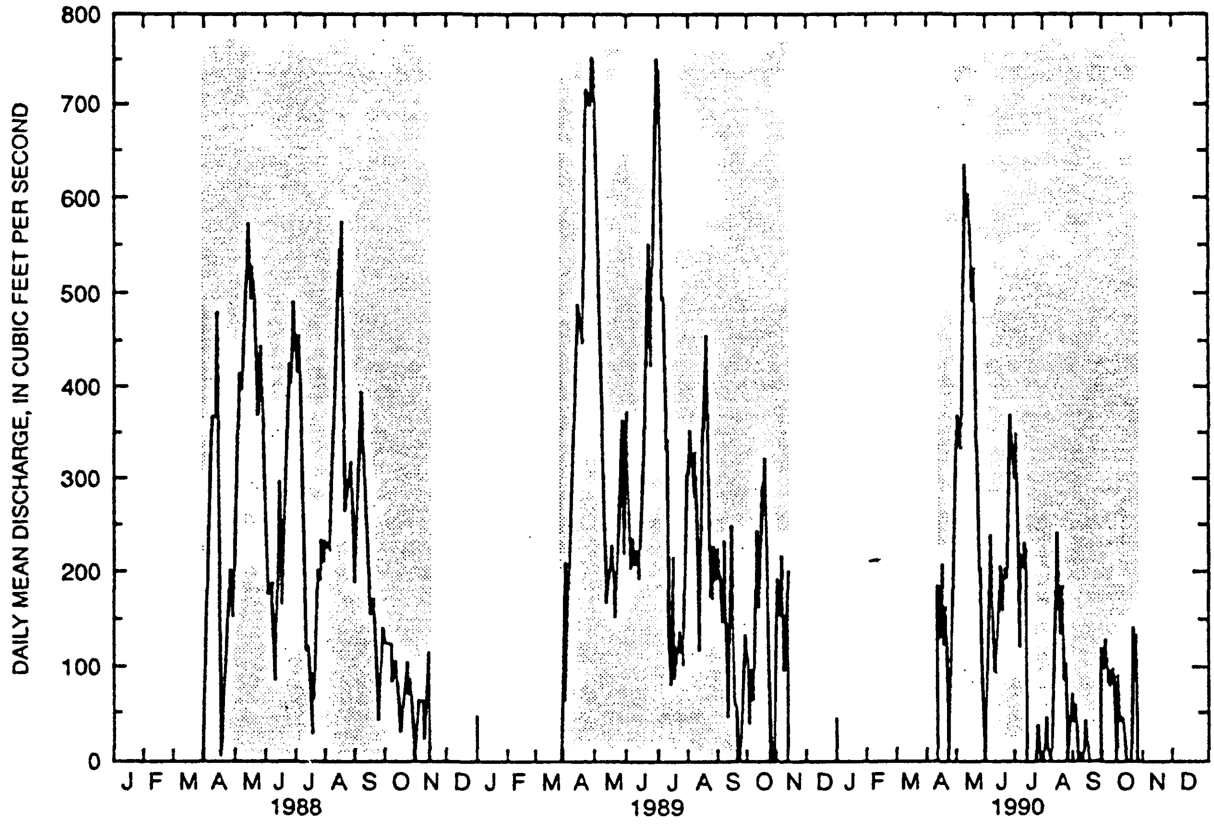


Figure 4. Daily mean release of water from Rye Patch Reservoir measured at Humboldt River near Rye Patch gaging station (10335000), 1988-90. Irrigation season indicated by shading.

The earliest known chemical analysis of water from the Humboldt Sink was made in summer of 1882. Dissolved-solids concentration in the water was about 900 mg/L and the predominant constituents were sodium, chloride, and bicarbonate (Russell, 1885, p. 67). The Humboldt Sink was full at this time, and the lake had a uniform depth of about 12 feet in the central part.

Analyses were made of composite samples from Toulon and Army Drains in 1948 and 1949 by the U.S. Bureau of Reclamation Regional Laboratory (data on file in the offices of Nevada Department of Wildlife, Fallon, Nev.). The dissolved-solids concentrations in Toulon Drain were 2,100 mg/L in 1948 and 1,900 mg/L in 1949; in Army Drain, the concentrations were 4,640 mg/L in 1948 and 4,470 mg/L in 1949. The dominant constituents in all cases were sodium and chloride.

Between 1975 and 1976, chemical analyses were made of water from the Humboldt River near Lovelock (gaging station 1336000; data on file in the offices of Nevada Department of Wildlife, Fallon, Nev.). This site is located downstream of most of the irrigated land and contains mostly irrigation return flow. During times of high discharge, water quality in the Humboldt River below the irrigated areas resembles that of water released from Rye Patch Reservoir (fig. 8). As discharge in the Humboldt River below Lovelock decreases to less than 100 ft^3/s, dissolved-solids concentrations are usually several hundred milligrams per liter greater than in the water being released from Rye Patch Reservoir. The greatest concentrations in the Humboldt River near Lovelock--4,800 and 7,700 mg/L--were measured when discharge was 2-4 ft^3/s. The principal constituents in the water at these low flows were sodium and chloride.

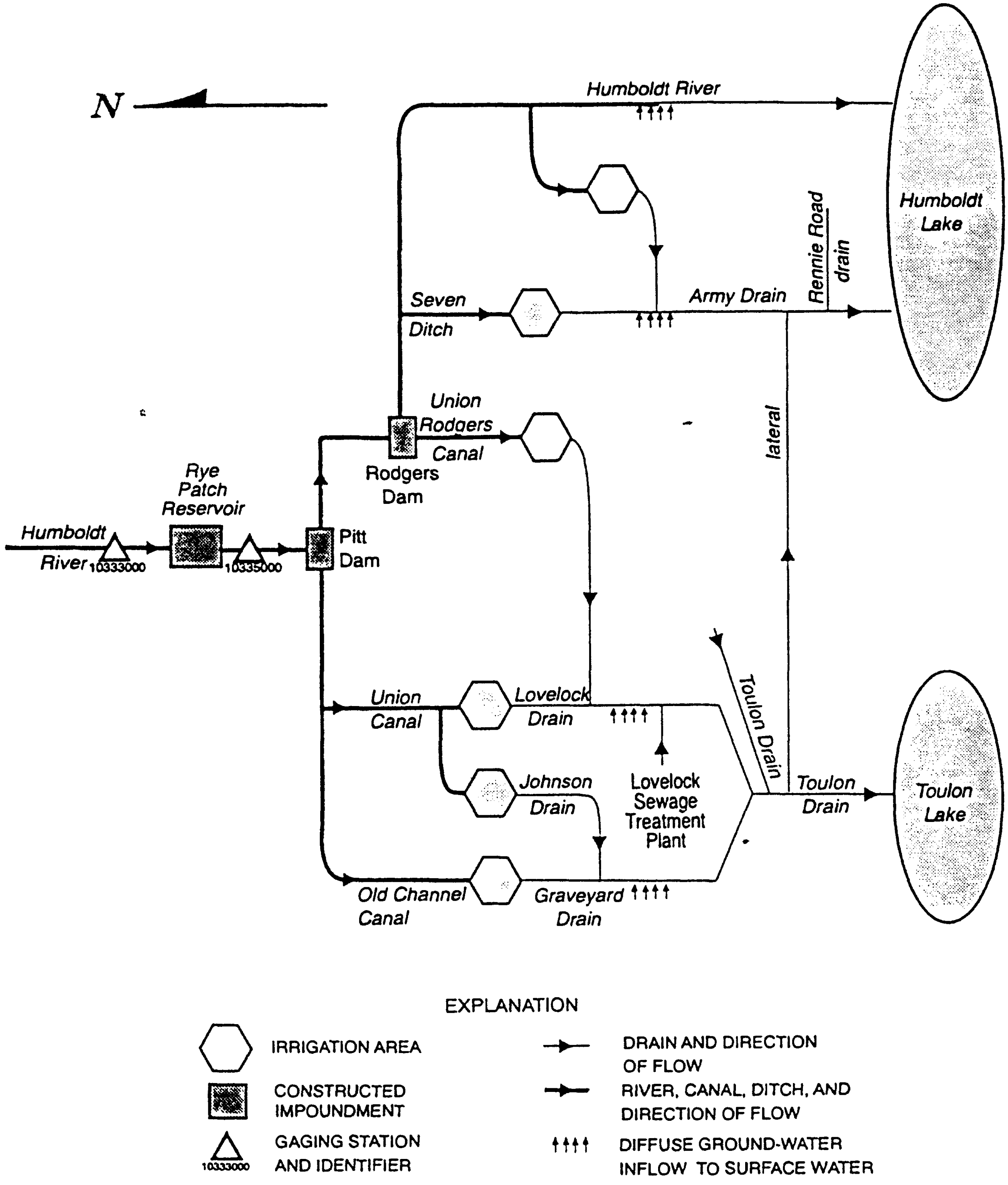


Figure 5. Schematic diagram of the flow system for the U.S. Bureau of Reclamation Humboldt Project.

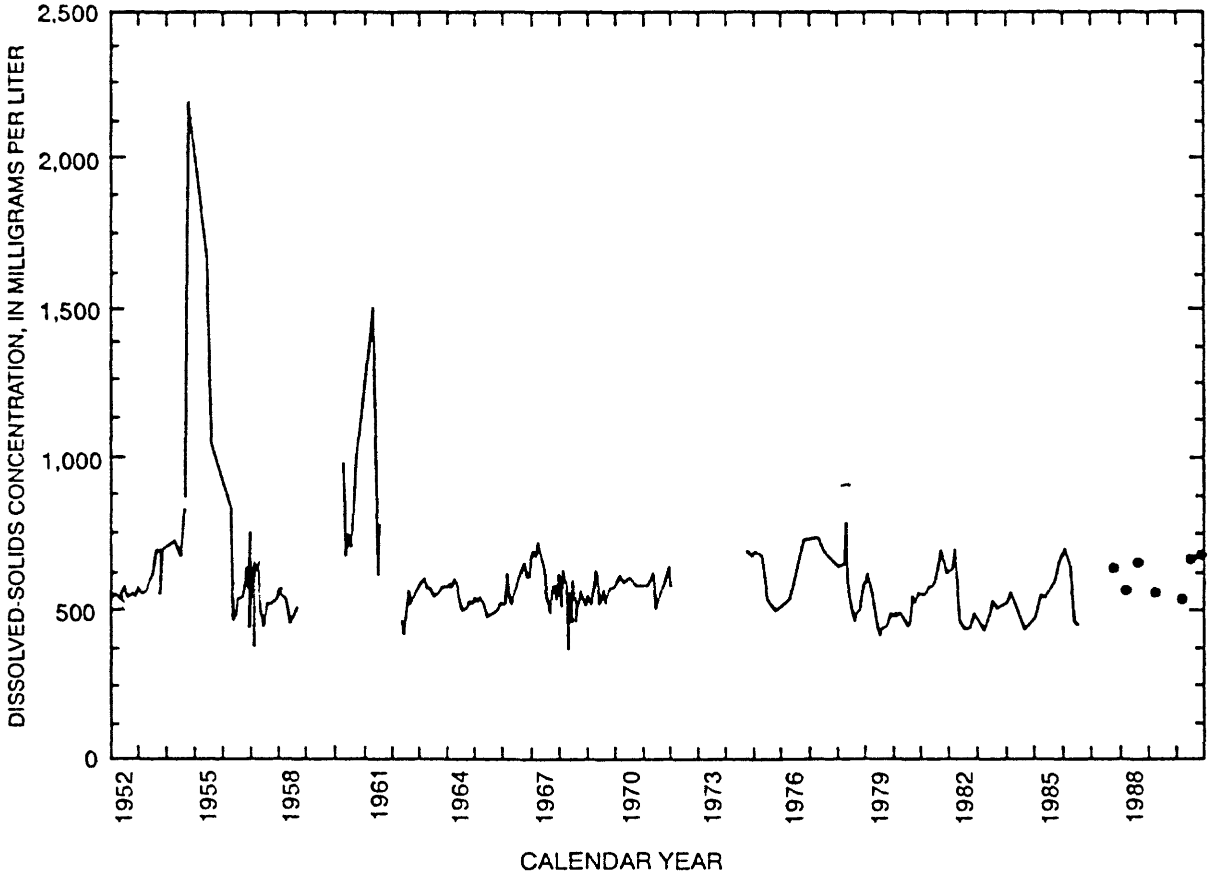


Figure 6. Concentrations of dissolved solids in water released from Rye Patch Reservoir measured at Humboldt River near Rye Patch gaging station (10335000), 1952-86, and at Humboldt River at Upper Valley Road gaging station (10335300), 1987-90. Discontinuities in curve indicate no data.

Ground Water

Both shallow and deep aquifers are present in the Lovelock area (Robinson and Fredericks, 1946). Water in the deep aquifer is under artesian pressure. Recharge to the ground water is primarily infiltration of Humboldt River water and runoff from the surrounding mountains (Robinson and Fredericks, 1946). The water supply for the city of Lovelock is ground water from the Oreana area to the north of Lovelock (fig. 2). Ground water in irrigated areas is not used extensively, and private wells no longer provide drinking water to the residents of Lovelock Valley.

Shallow ground-water levels in the Lovelock agricultural area have risen in some areas and declined in others as a consequence of irrigation, but the amount of change is not known. During the nineteenth century, before the land was developed for agriculture, Lower Valley was called Big Meadows and water levels were undoubtedly higher. Dikes were built along the river to prevent flooding. Open drains, 15-20 feet deep, were dug to drain the soil. In Upper Valley, seepage from the canals, laterals, and irrigated fields has caused water levels to rise. Well owners in the upper valley report that shallow wells go dry when the canals are dry for extended periods.

Seasonal changes in water level in shallow aquifers probably are similar to those in the nearby Fernley and Fallon areas. During the irrigation season in Fernley (mid-March to mid-November), the water level rises and usually reaches a maximum about September. The water level then

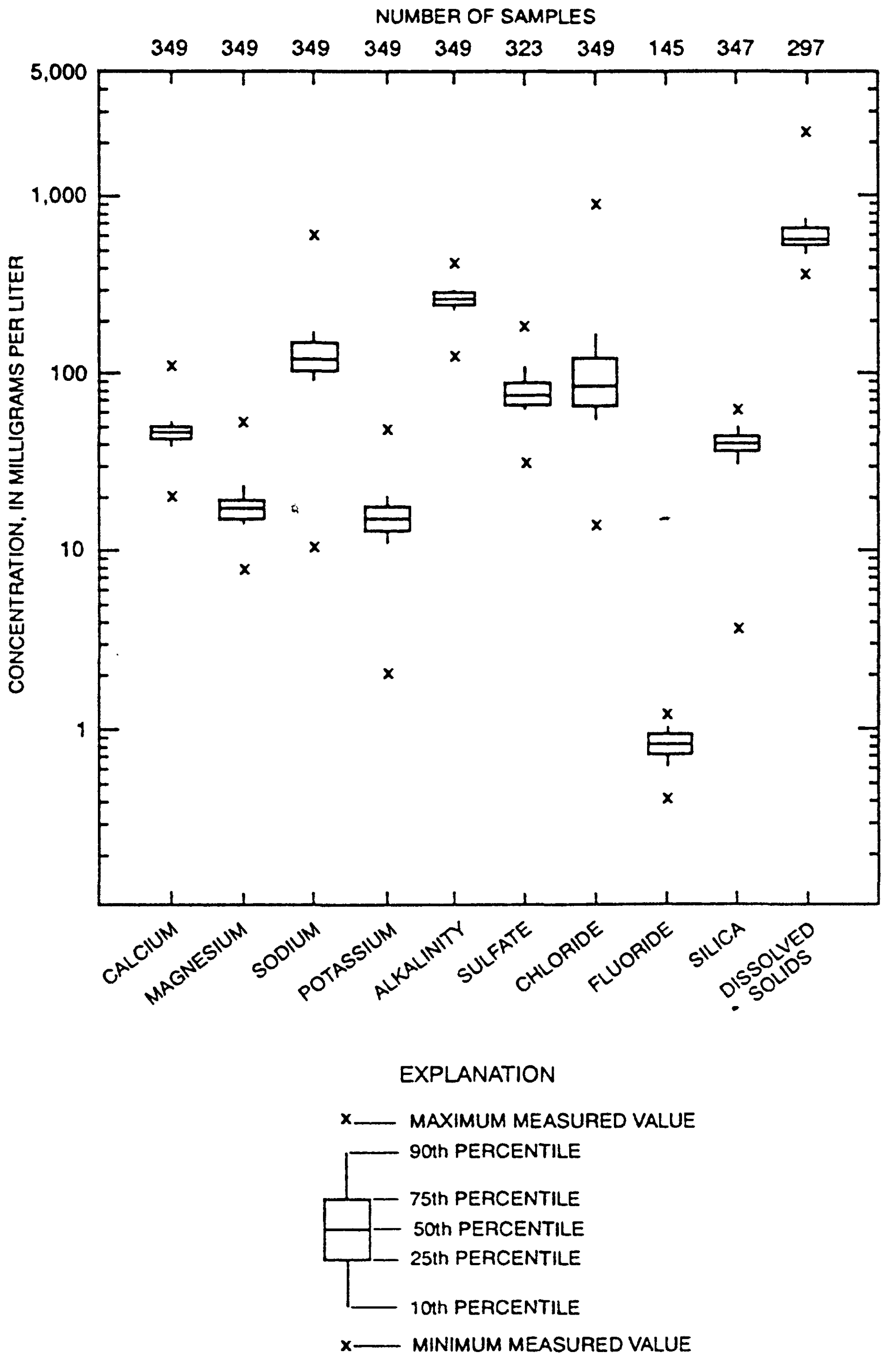


Figure 7. Distribution of major constituents and dissolved-solids concentrations in water released from Rye Patch Reservoir measured at the Humboldt River near Rye Patch gaging station (10335000), 1952-86.

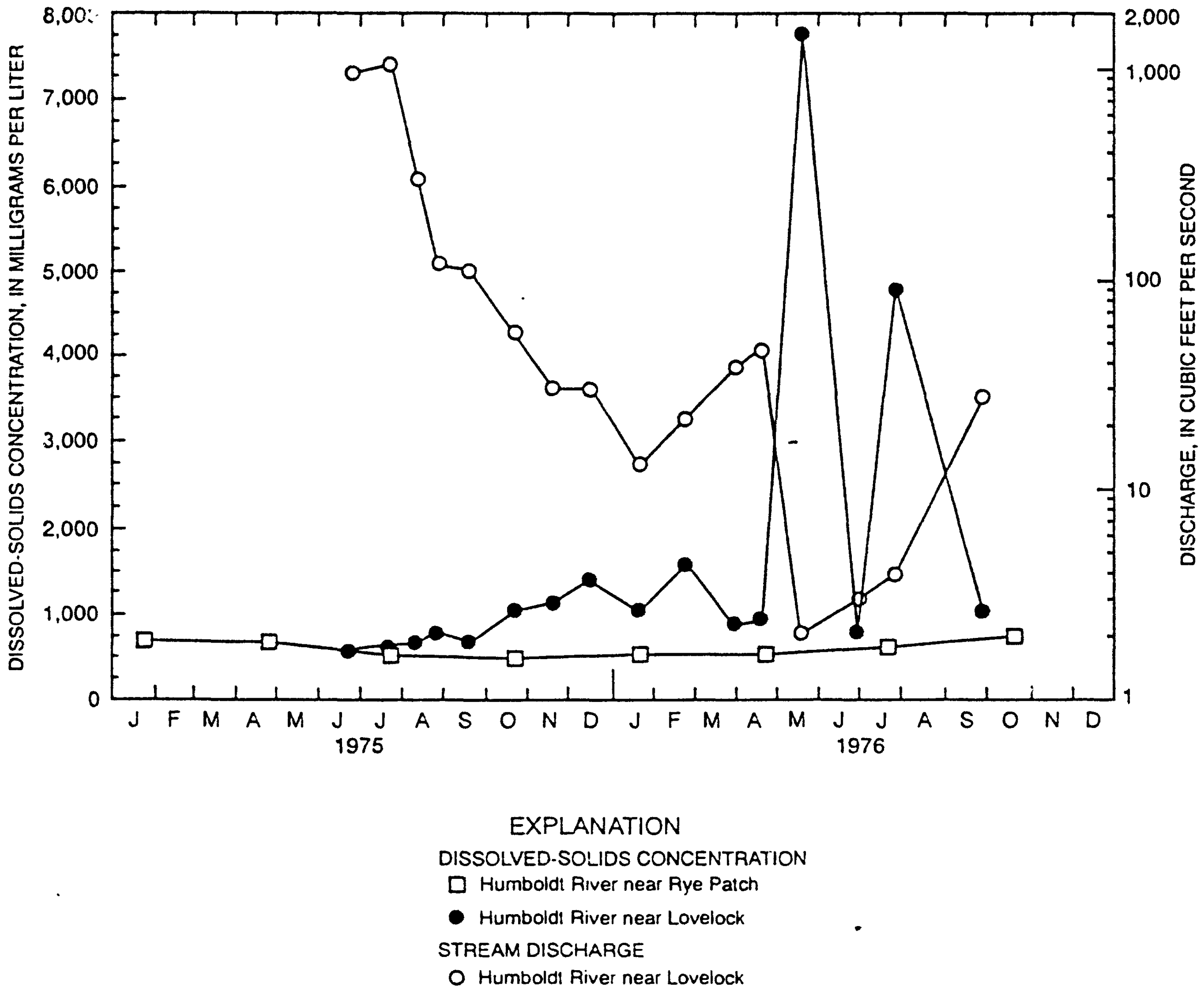


Figure 8. Discharge at Humboldt River near Lovelock gaging station (site 4; fig 10) and relation of dissolved-solids concentrations in water samples from Humboldt River near Rye Patch gaging station and Humboldt River near Lovelock gaging station, 1975-76.

gradually declines during the non-irrigation season and reaches a minimum about April (Sinclair and Loeltz, 1963, p. AA10-AA12). Water levels in shallow wells in an irrigated area south of Fallon show a gradual decrease between November 1984 and April 1985 with an abrupt rise associated with the delivery of irrigation water (Lico and others, 1986).

In Lovelock Valley, the least mineralized ground water is north of Lovelock near Oreana (fig. 2) and the most mineralized water is in the extreme southern end of the valley near Humboldt Lake. In 1946, a deep (432 feet) well near Oreana had a dissolved-solids concentration of 283 mg/L, and in the 1930's, water from shallow (14.5 feet) and deep (212 feet) wells near Humboldt Lake had dissolved-solids concentrations of 2,978 and 3,368 mg/L, respectively (Robinson and Fredericks, 1946). The predominant chemical constituents in water from both these wells were sodium and chloride. Insufficient data are available to characterize changes in water quality with depth in irrigated areas near Lovelock; however, the shallow water is probably less mineralized than the deep water, which has been in contact with the aquifer material longer.

The best quality water in the drains occurs during the irrigation season, when overland runoff of applied water and operational spills--which have relatively low dissolved-solids concentrations--are the principal water sources. For a short time after the irrigation season ends, usually in November, much of the water in the drains is ground-water inflow of recently applied irrigation water. Water in the drains at this time probably is of better quality than right before the irrigation season starts. In February and March, water in the drains originates in deeper parts of the aquifer and probably is of poorer quality because it has been in contact with the aquifer material longer and has had more time to dissolve minerals.

Wetlands

Irrigated land in Lovelock Valley and adjacent wetlands are maintained almost entirely by the Humboldt River. The wetlands obtain water from operational spills or controlled releases from irrigation canals, surface and subsurface agricultural return flow from flood-irrigated land, treated domestic wastewater from Lovelock, and episodic precautionary flood releases from Rye Patch Reservoir. A small spring discharges on the western edge of Toulon Lake near Toy; the source of the water is not known, but it probably originates in the Trinity Mountains to the west.

Large discharges from Rye Patch Reservoir during 1983-86 (fig. 3) were precautionary flood releases because of above-normal precipitation in the headwaters of the Humboldt River. During this period, the Humboldt Sink was full, some agricultural land flooded, and water flowed into the adjacent Carson Sink. Below-average amounts of runoff from the upper Humboldt River Basin during 1987-90 resulted in an almost complete disappearance of standing water in the Humboldt Sink and the near emptying of Rye Patch Reservoir in the summer of 1990. Such wet and dry cycles have occurred in the past.

Pioneers commented on the execrable water in the Humboldt Sink even before Lovelock Valley was settled (see frontispiece). The hydrologic setting alone explains some of the water-quality problems in the wetlands of the Humboldt Sink. The same hydrologic processes operating in the Stillwater WMA (Lico, 1992) also operate in the Humboldt WMA; they are briefly described here. Wetlands in the Stillwater and Humboldt WMA's are terminal; that is, water that flows to them remains there until it is eventually lost to the atmosphere by evapotranspiration. The very high evapotranspiration rates in the irrigated areas and wetlands result in high dissolved-solids concentrations developing in the wetlands, especially during drought years. Similarly, trace elements that accumulate over time in the wetlands can potentially reach toxic concentrations, especially nowadays because agricultural development of the area has resulted in less water reaching the wetlands to dilute the trace elements. Furthermore, application of water to former desert land converted to agricultural use accelerates leaching of soluble minerals (National Research Council, 1989. p. 39), which can increase concentrations of soluble toxic elements in the present wetlands.

PREVIOUS STUDIES

Several reports have described the geohydrology of the Humboldt River Basin, Lovelock Valley, and the Humboldt WMA. Eakin and Lamke (1966) described the hydrology of the entire Humboldt River Basin, and Bredehoeft (1963) described the geology and physical properties of aquifers in the lower Humboldt River Basin. Cohen (1963) described the hydrology of the lower Humboldt River Valley near Winnemucca. Miller and others (1953) presented results of chemical analyses of ground, stream, and spring water used for irrigation in the entire Humboldt River Basin.

The hydrology of Lovelock Valley was described by Everett and Rush (1965), who provided an estimated hydrologic budget for the Humboldt River Valley below Rye Patch Dam. Robinson and Fredericks (1946) described the ground-water system in Lovelock Valley and presented results of chemical analyses of water from several wells.

The effect of irrigation drainage on the nearby Stillwater WMA was investigated recently at both reconnaissance and detailed levels (Hoffman and others, 1990; Rowe and others, 1991; Lico, 1992; Hallock and Hallock, 1993). The reports included data on the occurrence and distribution of potentially toxic chemical constituents in surface water, sediment, and biota in Humboldt WMA.

Timothy G. Rowe (U.S. Geological Survey, written commun., 1989) summarized the findings from the Stillwater reconnaissance investigation and other studies that related to the Humboldt WMA. He concluded that toxic trace elements and dissolved solids may have adverse effects on human health, fish, and wildlife in the Humboldt WMA. The Humboldt WMA was selected for a reconnaissance investigation because of these concerns and because of its ecological and hydrologic similarity to Stillwater WMA.

SAMPLE COLLECTION AND ANALYSIS

Samples were collected at times corresponding to significant irrigation practices in the study area and at times related to significant biological productivity and life-cycle patterns of resident and migratory species. Data collection began in March 1990. Figure 9 shows the times of sample collection and their relation to deliveries of irrigation water. A list of the sites that were used in this study and the rationale for their selection is presented in table 1. The locations of the sites are shown in figures 1 and 10.

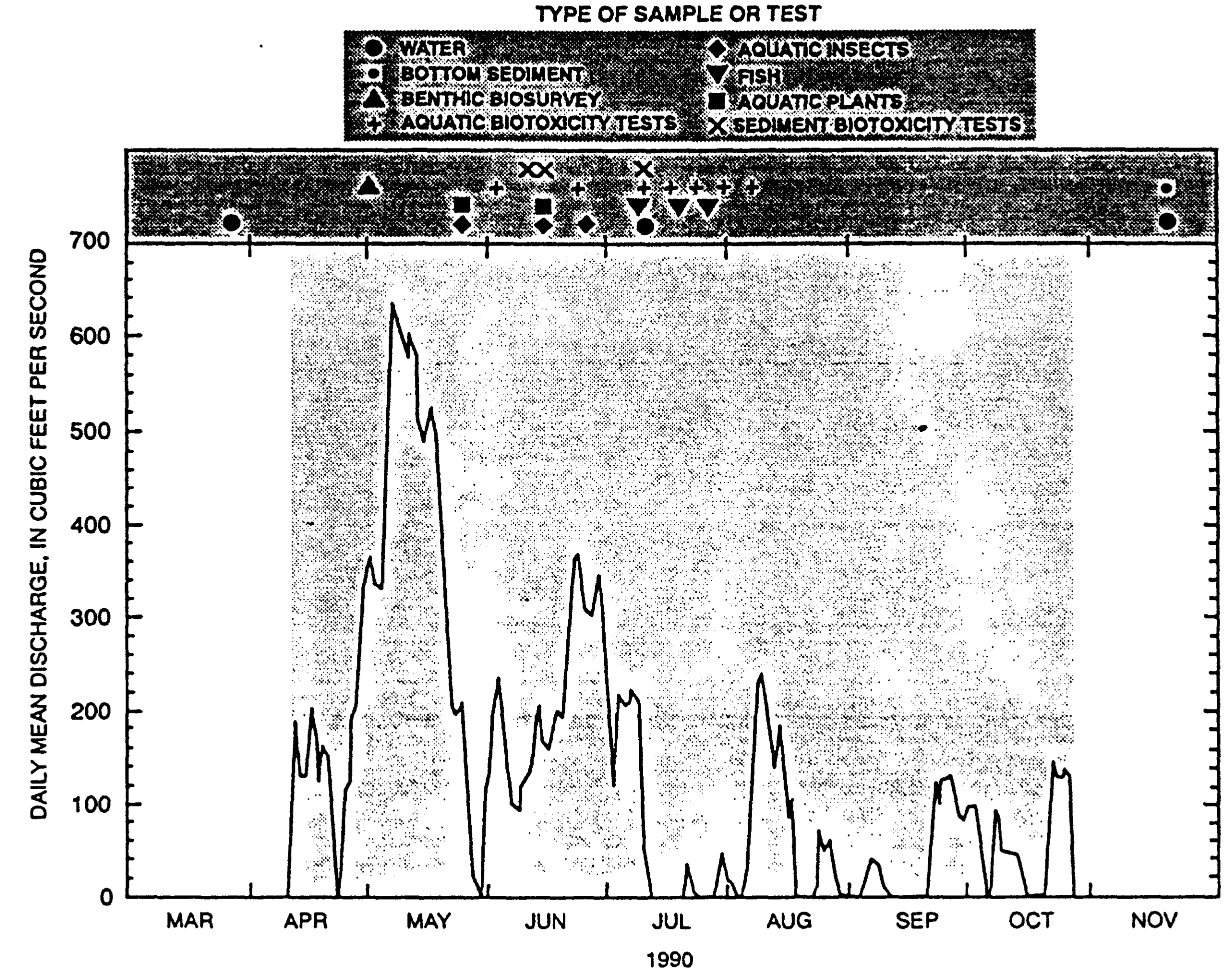
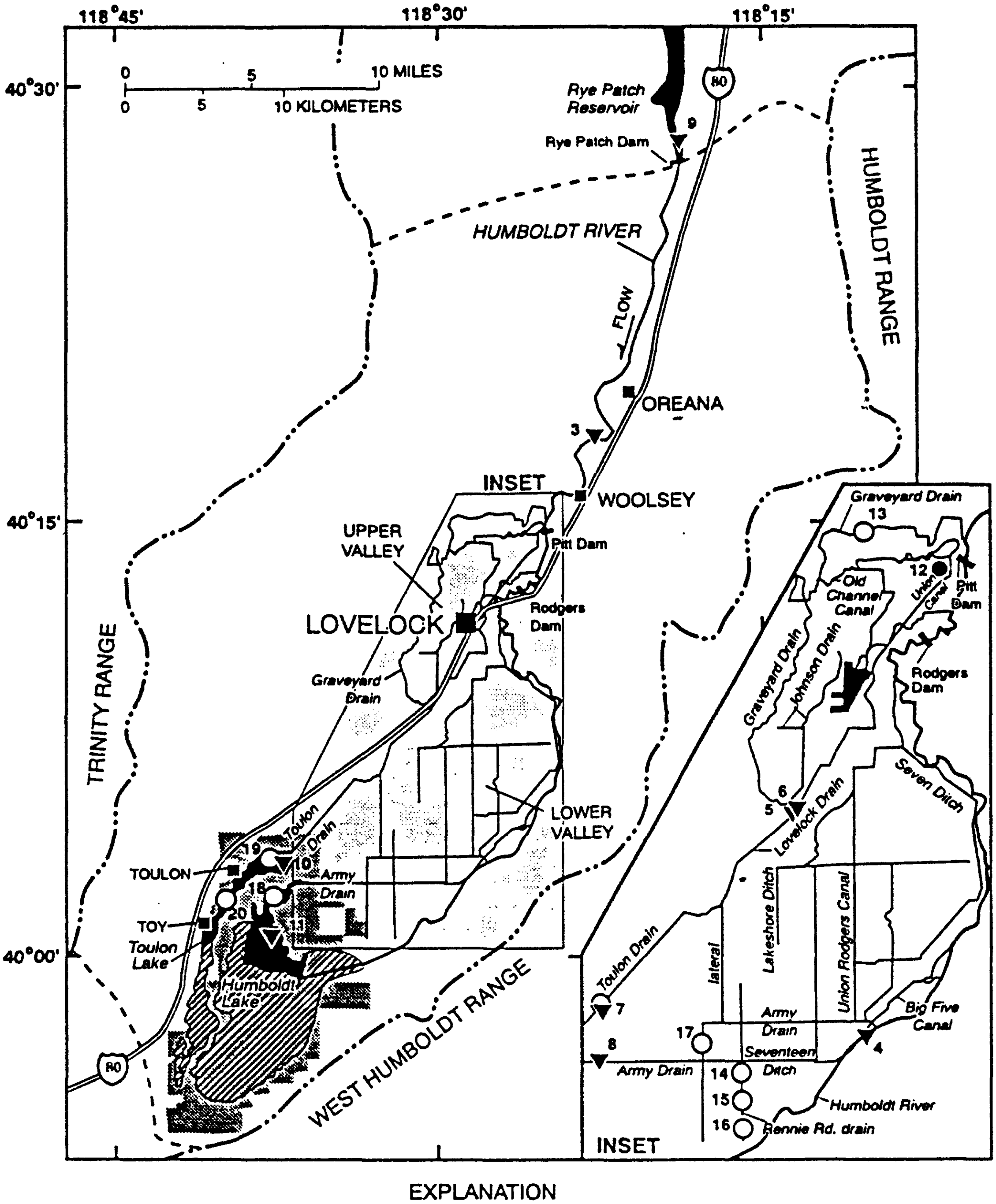


Figure 9. Times of biotoxicity tests and collection of water, bottom sediment, and biological samples relative to changes in daily mean discharge of water from Rye Patch Reservoir; 1990 irrigation season indicated by shading.



EXPLANATION

HUMBOLDT WILDLIFE MANAGEMENT AREA

PLAYA

HYDROGRAPHIC AREA BOUNDARY

STUDY AREA BOUNDARY--East and west boundaries coincide with hydrographic area boundary

CANAL, DITCH, OR DRAIN

SAMPLING SITE AND NUMBER:

12 ● GROUND-WATER SAMPLING SITE

5 ▼ SURFACE-WATER SAMPLING SITE

16 ○ BIOTA SAMPLING SITE

Figure 10. Location of sampling sites for chemical analysis of water and bottom sediment and sampling sites for biotoxicity tests. For site information, see table 1.

Table 1. Sampling sites selected for the collection of water, bottom sediment, and biota in the study area and upstream of the study area, 1990-91

Site No. (figs. 1 and 10)	Site location (in downstream order)	U.S. Geological Survey site identification[a]	Rationale for site selection
CHEMICAL ANALYSIS			
		Reference Sites	
1	Humboldt River near Golconda	10327800	Reference site
2	Humboldt River near Imlay	10333000	Reference site
9	Rye Patch Reservoir	10334500	Reference site; possible source of arsenic and selenium because of storage in Lake Lahontan sediment
3	Humboldt River at Upper Valley Road	10335300	Reference site and initial irrigation input to area; historical data
		Irrigation Drainage Sites	
4	Humboldt River near Lovelock	10336000	High arsenic concentrations; historical data
5	Graveyard Drain at railroad	10335800	Inflow from Upper Valley
6[b]	Lovelock Drain upstream from Graveyard Drain, near Lovelock	10335750	Receives treated sewage effluent from Lovelock
7	Toulon Drain at Derby Field Road	10336035	Inflow containing high arsenic concentrations
8	Army Drain at Iron Bridge	10336040	Inflow containing high arsenic concentrations
10	Toulon Lake (north)	400407118363001	Terminal drainage; wildlife concerns
11	Upper Humboldt Lake	400009118372001	Terminal drainage; wildlife concerns
12	Upper Valley Well	401303118261501	Ground-water quality in irrigated area[c]

Table 1. Sampling sites selected for the collection of water, bottom sediment, and biota in the study area and upstream of the study area, 1990-91--Continued

Site No. (figs. 1 and 10)	Site location (in downstream order)	U.S. Geological Survey site identification[a]	Rationale for site selection
BIOTOXICITY TESTS AND BENTHIC BIOSURVEYS			
		Reference Sites	
1	Humboldt River near Golconda	10327800	Reference site and nearest biological habitat upstream from Lake Lahontan sediments.
2	Humboldt River near Imlay	10333000	Reference site and nearest biological habitat upstream from irrigated areas
		Irrigation Drainage Sites	
13	Graveyard Drain 2	-	High specific conductance and Microtox toxicity[d]
14	Rennie Road drain 1	-	do.
15	Rennie Road drain 2	-	do.
16	Rennie Road drain 3	-	do.
17	Army Drain 2	-	do.
18	Army Drain at inflow to Humboldt Lake	-	do.
7	Toulon Drain at Derby Field Road	10336035	do.
19	Toulon Drain at inflow to Toulon Lake	-	do.
20	Toulon Lake (center)	-	do.

[a] Many sample sites are assigned a unique identification number on the basis of geographic location. The eight-digit numbers are station numbers that follow the "downstream order system": The first two digits, or part number, refers to the drainage basin. The following six digits is the downstream-order number, which is assigned according to the geographic location of the site in the drainage basin; larger number stations are downstream from smaller number stations.

The 15-digit numbers are based on the grid system of latitude and longitude. The first six digits denote degrees, minutes, and seconds of latitude; the next seven digits denote the degrees, minutes and seconds of longitude; the last two digits (assigned sequentially) identify the sites within a 1-second grid. For example, site 400407118363001 is at 40°04'07" latitude and 118°36'30" longitude and is the first site recorded in that 1-second grid.

[b] Only pH, specific conductance, and water temperature were measured at this site.

[c] A shallow well for collecting ground-water samples in Lower Valley could not be located.

[d] Microtox toxicity is explained in section on biotoxicity tests.

Three periods were selected for the collection of water samples:

1. Pre-irrigation season (March): flow in drains is primarily from deeper, more regional parts of the shallow ground-water system; concentrations of dissolved constituents in drain water probably are at their maximum.
2. Mid-irrigation season (July): flow in drains is mixture of overland runoff of applied water, operational-spill water, and inflow from the shallow ground-water system; concentrations of dissolved constituents in drain water probably are at their minimum; late-nesting birds are present and algal productivity is high.
3. Post-irrigation season (November): flow in drains is primarily from shallower parts of the shallow ground-water system.

Measurements made at the time of sample collection included water discharge for surface-water samples, depth to water for ground-water samples, water and air temperature, dissolved oxygen, pH, specific conductance, and alkalinity for all samples.

Bottom-sediment samples were collected in November 1990. Samples from all sites were analyzed for trace elements, and samples from the Toulon and Humboldt Lake sites were analyzed for organic compounds.

The collection of biological samples was difficult. Because of the drought and lack of wetlands, few birds were at the Humboldt WMA during the hunting season, and no new samples of bird tissue were collected. Principal collection of biological samples took place between May and July 1990. Chemical and biological samples collected during 1986-89 from Lovelock Valley were part of the Stillwater reconnaissance investigation and results of analyses were reported by Hoffman and others (1990) and Rowe and others (1991).

All basic data collected are given in tables 12-24 in the Supplemental Data section of this report.

Water Samples

The collection of water samples and measurement of field parameters were done according to the procedures of the U.S. Geological Survey (1977, chapters 1 and 5), Ward and Harr (1990), and Edwards and Glysson (1988). The pH meter was calibrated using pH 7 and 10 buffers. Alkalinity was measured immediately after sample collection by incremental titration of filtered water with 1.60 or 0.160 *N* sulfuric acid (Barnes, 1964). Laboratory analyses of water samples included major dissolved constituents (calcium, magnesium, sodium, potassium, bicarbonate and carbonate, chloride, and sulfate); trace constituents (arsenic, boron, cadmium, chromium, copper, lead, mercury, molybdenum, selenium, uranium, vanadium, and zinc); dissolved-solids residue on evaporation at 180°C; and nutrients (ammonium, nitrite, nitrate, and phosphorus). Analyses of surface and ground water were made by the U.S. Geological Survey National Water-Quality Laboratory in Arvada, Colo., using the methods described by Fishman and Friedman (1989) and Wershaw and others (1987). Hardness and dissolved-solids concentration (sum of constituents) were calculated from the analytical results using equations given by Fishman and Friedman (1989, p. 227 and p. 459-460). Results of these analyses and calculations are shown in tables 12-16 and 19 in the Supplemental Data section.

All the un-ionized ammonia values reported in table 14 were calculated using the equations of Thurston and others (1974), who assumed zero salinity. The presence of dissolved minerals in the water reduces the amount of ammonia that is un-ionized. Un-ionized ammonia values that exceeded the 0.02-mg/L criterion for the propagation of cold-water aquatic life were checked using tables (Skarheim, 1973) that give the fraction of ammonia that is un-ionized as a function of dissolved-solids concentration, pH, and temperature.

Quality-control procedures of the National Water Quality Laboratory are described by Friedman and Erdman (1982) and Jones (1987). The types of trace elements analyzed and their reporting limits are given in table 2. As part of the quality-assurance practices, field blanks were analyzed. Field blanks are volumes of deionized water that are exposed to sampling conditions, treated as samples, and they provide evidence that contaminants are not introduced during sample handling in the field or in the laboratory. Exposure to the water-collecting bottle and churn splitter, filters, chemical preservatives, holding times, and laboratory processing were the same for samples and field blanks.

The field-blank data, listed in table 3, show that nearly all chemical measurements were at or below analytical reporting limits, indicating that trace-element contamination of water samples resulting from sample handling was nonexistent or insignificant.

The methods for computing estimates of summary statistics of trace-element and nutrient data that contain "less-than" values are from Helsel and Cohn (1988).

Bottom-Sediment Samples

Samples of bottom sediment were collected from streams, drains, and areas of deposition in lakes. The samples were collected using either a large stainless-steel spoon or a hand-held piston-type sampler (type US BMH-53; Federal Inter-Agency Sedimentation Project, 1986, p. 97), depending on the composition of the sediment. The bottom sediment was sampled to a depth of 2 to 3.5 inches; usually five to seven equally spaced samples were collected in the cross section of a stream or drain. In the lakes and reservoirs, 10 to 15 randomly spaced samples were collected from within a 400-ft^2 area. The individual samples were composited in a stainless-steel bowl and thoroughly mixed using a stainless-steel spoon. The sample was then put in a pint plastic freezer carton for trace-element analysis.

Samples of bottom sediment were also collected and composited in this manner for organochlorine compound analysis. After being composited, the samples were sieved in the field through a 2-mm stainless-steel sieve, using native water from the site where the sample was collected, stored in pretreated glass jars, and maintained at 4°C until analyzed. Toulon Lake was dry and the organochlorine compound sample from the bottom material was not sieved before being placed in the sample bottle.

Trace-element and percent-carbon analyses of bottom sediment was done by the U.S. Geological Survey Environmental Geochemistry Laboratory in Denver, Colo. The samples were air dried, mechanically disaggregated, and sifted through a sieve into two fractions: less than 62 μm and less than 2 mm. The fractions were then rigorously digested using hydrochloric acid, hydrofluoric acid, perchloric acid, and *aqua regia* (mixture of hydrochloric acid and nitric acid) prior to analysis. After digestion, the extracts were processed using the methods given by Severson and others (1987, p. 3-4). Laboratory determinations of arsenic, mercury, and selenium were done by atomic-absorption spectroscopy (arsenic and selenium by continuous-flow hydride generation and mercury by cold vapor); uranium and thorium by neutron activation; and all others, except boron, by inductively coupled plasma analysis. The rigorous digestion procedures produced total extractable elements rather than biologically available amounts. Boron, however, was extracted using a hot-water method that extracts an amount approximate to the biologically available amount in the sediment. Concentrations are reported in terms of dry weight (table 17 in Supplemental Data section) and the reporting limits are given in table 2.

Pesticide analyses, reported in terms of dry weight, were done by the U.S. Geological Survey National Water-Quality Laboratory in Denver, Colo., using the methods described by Wershaw and others (1987). The results of the analyses are given in table 18 in the Supplemental Data section. The trace elements and pesticides analyzed and the reporting limits are given in table 2.

Biological Samples

Tissues

Biological samples were collected from May to July 1990 as part of this study and from August 1986 to August 1989 as part of the Stillwater investigations. The results of the analyses are given in table 20 in the Supplemental Data section. All results are given in terms of dry weight. The sampling locations are shown in figure 10. Emphasis was on aquatic plants and insects, whole

Table 2. Analytical reporting limits for trace elements, radionuclides, and organochlorine compounds in water, in bottom sediment, and in plant, insect, fish, and bird tissue (modified from Hoffman and others, 1990, tables 4 and 5)

[Abbreviations: µg/g, microgram per gram; µg/L, microgram per liter; pCi/L, picocurie per liter; --, not analyzed]

Constituent	Analytical reporting limit: Water (µg/L, except as indicated)	Bottom sediment (µg/g, dry weight)	Tissue[a] (µg/g, dry weight)
Trace Elements			
Aluminum	10	--	3
Arsenic	1	1	0.05
Barium	100	10	.1
Boron	10	10	5.0
Cadmium	1	1	.2
Chromium	10	1	.2
Copper	10	1	.2
Iron	10	1	--
Lead	1	10	.2
Lithium	1	1	--
Manganese	10	1	--
Mercury	0.1	0.01	.1
Molybdenum	1	.1	.2
Nickel	1	10	.2
Selenium	1	.1	.1
Silver	1	2	--
Vanadium	1	1	.1
Zinc	10	1	1
Radionuclides			
Uranium	0.4	0.2	--
Gross alpha (as uranium)	.4	--	--
Gross beta (as cesium-137)	.4 pCi/L	--	--
Gross beta (as strontium-90/yttrium-90)	.4 pCi/L	--	--
Radium-226	.1 pCi/L	--	--
Thorium	--	.2	--
Organochlorine Compounds			
Aldrin	--	0.1	--
Chlordane	--	1.0	0.01
DDD	--	.1	.01
DDE	--	.1	.01
DDT	--	.1	.01
Dieldrin	--	.1	.01
Endosulfan	--	.1	--
Endrin	--	.1	.01
Heptachlor	--	.1	--
Heptachlor epoxide	--	.1	.01
Lindane	--	.1	--
Methoxychlor	--	.1	--
Mirex	--	.1	--
Nonachlor	--	--	.01
Oxychlordane	--	--	.01
PCB	--	1.0	.1
PCN	--	1.0	--
Perthane	--	1.0	--
Toxaphene	--	10	--

[a] Analytical reporting limits for tissue are based on weight of sample. For trace elements, the sample weight is 5.0 g, dry weight; for organochlorine compounds, it is 10 g, wet weight. For sample weights less than 5 and 10 g, respectively, the reporting limit is larger than that listed in table.

Table 3. Dissolved trace-element concentrations in water from field blanks analyzed for quality assurance

[Symbols: µg/L, microgram per liter; --, not analyzed; <, less than]

Dissolved trace element (µg/L)	Date		
	3-27-90	7-18-90	11-19-90
Arsenic, as As	<1	--	<1
Boron, as B	10	--	<10
Cadmium, as Cd	<1	<0.1	<1
Chromium, as Cr	<5	.6	<1
Copper, as Cu	<10	<.5	1
Lead, as Pb	<10	<.5	<1
Mercury, as Hg	<0.1	<.1	<0.1
Molybdenum, as Mo	<10	1	<1
Selenium, as Se	<1	--	<1
Vanadium, as V	<6	<6	<1
Zinc, as Zn	10	4	<3

fish, livers of adult and juvenile birds, and edible tissue from game birds. Where possible, the same species were collected from each site; however, substitutions were made as necessary.

All biological samples were analyzed by the U.S. Fish and Wildlife Service, Patuxent Analytical Control Facility, Laurel, Md., and their contract laboratories; appropriate quality assurance was documented for each analysis.

Types of laboratory analyses of biological tissue for selected trace elements and pesticide residues and the reporting limits are shown in table 2. The analytical procedures are those described by U.S. Fish and Wildlife Service (1985).

Composite samples of vascular plants and filamentous algae were generally gathered by hand. Plant species and tissues were selected on the basis of availability and speculated use as a wildlife food. An exception was rooted portions of emergents, which required a shovel to extract and extensive rinsing with pond water. Plants were stored in plastic bags, chilled, and frozen as soon as possible. Species included cattail, bulrushes, sago pondweed, muskgrass, unidentified filamentous algae, and an unidentified submerged plant.

Composite insect samples were collected with a kick net. Hemipterans were taken from the water column, placed in nitric acid-washed jars, chilled, and frozen. Dipteran larvae generally were found within detrital masses and near-surface sediment; these were chilled and hand picked over within 1 to 3 days. Cleansed samples were then frozen in nitric acid-washed jars. Minimum sample size for insects was about 0.5 ounce, wet weight. Six insect samples were collected during 1990 and four samples during 1986-87.

Fish were collected with dip nets, seines, or gill nets. Carp (*Cyprinus carpio*) were available in both reference sites and sites affected by irrigation drainage. Where possible, approximately 1-pound, whole fish were taken. In some instances, 4- to 10-ounce fish were taken. During sampling in 1990, game fish were not found in Humboldt WMA but were taken from the Humboldt River near Golconda and Imlay. Fish were wrapped in Saran wrap and placed in Ziploc sealable plastic bags and maintained on ice until they could be frozen.

During July 1990, 37 fish were collected for inorganic analysis, and 15 additional fish were collected for analysis of organochlorine insecticide residues. Five fish samples were collected from

Humboldt Lake and Army Drain during 1986-87 as part of the Stillwater investigation. Reporting limits for organic compounds are shown in table 2.

Fledgling birds were collected with dip nets from an air boat, and adults with shotguns using steel shot. Birds were weighed, stored on ice, and the livers removed in the lab within 2 weeks of collection. A few whole birds were frozen prior to liver removal. Livers were removed with sterile scalpel blades, and rubber gloves were worn throughout the procedure. Acetone and deionized water were used routinely to rinse gloved hands and tools before and after each bird was handled. The samples were labeled and frozen in jars washed with nitric acid. Because stilt livers are relatively small, each sample was composed of livers from two birds. Field notes of each specimen were maintained.

No new bird samples were collected during 1990 as part of this study. Because of drought-related habitat loss, juvenile water birds were not available for collection. All 56 bird tissue samples reported herein were collected during July and August 1986-89 and analyzed as part of the Stillwater investigation. American coots (*Fulica americana*), mallards, shovelers (*Spatula clypeata*), green-winged teal (*Anas carolinensis*), cinnamon teal, redheads (*Aythya americana*), gadwalls (*Anas strepera*), and black-necked stilts (*Himantopus mexicanus*) were collected from Toulon and Humboldt Lakes.

Analysis of tissue from juvenile birds, which had been exposed only to the contaminants in the study area after hatching, was used to address accumulation of contaminants within the study areas. Samples of liver from 22 juvenile American coots and 28 juvenile black-necked stilts were collected in 1986-87.

Eggs from 27 coots and 10 ducks were collected in May 1988 from Toulon Lake and analyzed for trace elements. Embryos in the eggs were visually examined for deformities.

Archived samples of breast muscle from three adult ducks were analyzed to determine if contaminants accumulated in edible portions. The ducks, one adult green-winged teal and two adult shovelers, were collected in 1989 during the hunting season.

Biotoxicity Tests

Synergystic and antagonistic interactions between toxic trace elements can cause the toxicity of water containing a mixture of constituents to be greater or less than the toxicity of the individual constituents. Biotoxicity tests were conducted to obtain information about the actual toxicity of drain water and sediment--information that cannot be obtained from chemical analyses alone.

Site Selection

Water from 34 locations in the study area was screened to select sampling sites for subsequent detailed biotoxicity tests of various invertebrates and fish. The sites were evaluated in the field during May and June 1990 (fig. 9).

The decision whether to conduct biotoxicity tests at a site was based on specific conductance of water and indications of toxicity through Microtox procedure (a test that measures toxicity of the water to a species of marine bacteria). A threshold of 4,500 μS/cm for specific-conductance values was selected. If the specific conductance exceeded 4,500 μS/cm, grab samples of the water were collected and brought back to the laboratory and their toxicity was measured using the Microtox procedure. Although in many areas specific trace-element concentrations are not correlated with specific conductance, Finger and others (1993) concluded that the presence of toxic elements (arsenic, boron, lithium, and molybdenum) was strongly related to the specific conductance of drain water at Stillwater National Wildlife Refuge.

The Microtox procedure is a diagnostic toxicity-testing procedure which uses a freeze-dried culture of a specially developed strain of marine bacteria, *Photobacterium phosphoreum*, as a test organism. The Microtox instrument measures the luminosity of the bacteria before and after they are exposed to a sample of unknown toxicity. The loss of light output is an indicator of the toxicity of the sample.

Exposure time of the bacteria to the sample is an important factor. Some toxic materials act virtually instantaneously, others within 5 minutes, and a few--notably bivalent metals--may require 15 minutes or more to complete their effect. Accordingly, exposure times of 15 and 30 minutes were used in this study.

The Microtox 100-percent assay procedure tests four sample dilutions, of which the highest possible concentration is 91-percent test water. The assay procedure was used to calculate EC_{50} values. The EC_{50} is the median effective concentration of a sample, expressed as percent, causing a 50 percent decrease in light output under defined conditions of exposure time and test temperature. EC_{50} values less than 80 percent can indicate toxicity. As a threshold for subsequent biotoxicity tests, an EC_{50} of 25 percent was selected.

Water-Sample Collection

Water samples were collected as grab samples for biotoxicity tests during the mid-irrigation season in 1990 (fig. 9). Sampling scheduled for the pre-irrigation season in 1991 was cancelled because of the continued drought.

Water samples from each site were collected in 1-L amber glass bottles fitted with Teflon caps. The bottles were washed with Alconox detergent and water, rinsed with tap water, soaked in concentrated nitric acid, and twice rinsed with deionized water. In instances where bottles were suspected to have previously contained organic reagents, they were thoroughly rinsed with either acetone or methanol, again twice rinsed with running deionized water, and allowed to dry in open air. This procedure was used in the preparation of all glassware used in toxicity testing. The water samples were filtered through rinsed cheesecloth to remove debris, aquatic insects, and other organisms that could ingest the test organisms. The filtered sample water was refrigerated until tests were run--within 1 week of collection.

Sediment Collection

Sediment samples were collected with a piston-core sampler. These simple devices, useful in soft mud and muck, consist of a length of thin-wall plastic tubing. The tube was pushed down into the sediment to the desired depth, and the open end was sealed with a rubber or metal stopper. When the entire assembly was withdrawn, the sediment core remained intact because of the suction exerted by the closed air chamber above the sample core.

A syringe was then inserted through the inverted core tube and was carefully pushed up to expel the excess water above the sediment sample. Approximately 2-3 cm of the sediment core was collected from each site and scraped into a plastic container. Although this portion appeared to contain primarily decayed organic matter, there was considerable variation in inorganic content.

Sediment samples were collected randomly from each site until the desired sample size (about 300 g) was gathered. The samples were then stored in the freezer until the test was conducted--usually within 1-2 weeks after collection.

Aquatic Biotoxicity Test Procedures

Aquatic biotoxicity tests were conducted with sample water collected from each site. One-day-old daphnids (*Daphnia magna*), fathead-minnow larvae (*Pimephales promelas*), and newly born (up to 4-day-old) salt-tolerant mysid shrimp (*Mysidopsis bahia*) were used as test organisms, generally following procedures recommended by Peltier and Weber (1985). Tests were prepared in two replicates with 10 organisms per treatment per replicate. Treatments for each replicate consisted of full-strength, undiluted sample water, dilutions of 50 percent, 25 percent, and 12.5 percent, and a control. Thus, a total of 50 organisms were used in each replicate test. Water collected from the reference site (site 1 in fig. 1, Humboldt River near Golconda) was used both as control sample and also as dilution water in aquatic tests. Sample volumes were 100 mL for tests using daphnids and mysids and 600 mL for tests using fathead-minnow larvae. In tests using fathead-minnow larvae, the larvae were put in a glass bowl to acclimate them to laboratory conditions before putting them in the test solutions.

Sample and dilution water were bubbled with air overnight prior to each test to ensure the dissolved-oxygen concentration was at least 40 percent saturation. Before adding the test organisms, temperature, pH, and dissolved oxygen were measured in one beaker of the undiluted sample water and one beaker of the 100 percent dilution water. These parameters were also measured daily before samples were checked for test-organism mortality. The dissolved-oxygen concentration in the sample and dilution water was always more than 40 percent saturation. The tests were run at room temperature in the lab (20°-22.5°C). The pH values ranged from 7.1 to 9.1, which are within the tolerance limits of the organisms.

Biotoxicity tests using daphnids lasted 2 days for acute toxicity tests and 10 days for chronic toxicity tests. Tests using fathead-minnow larvae and mysid shrimp lasted 96 hours. The test organisms were carefully introduced by dropper into each beaker. Care was taken to introduce the daphnids underneath the surface film of the water to avoid air bubbles in the carapace of the organisms. At 24-hour intervals after initial test set-up, the organisms were inspected for mortalities. The number of dead individuals was recorded and percent of cumulative mortalities was calculated and recorded.

At the end of each test, the 100-percent sample water and control samples were preserved with nitric acid and submitted for analysis to the U.S. Fish and Wildlife Service laboratory at the Patuxent Analytical Control Facility, Laurel, Md., or one of its approved contract laboratories.

When high mortality in daphnids or fathead-minnow larvae was observed, additional tests were performed with mysid shrimp--a salt-tolerant species. Biotoxicity tests using mysid shrimp lasted 4 days and were conducted to rule out salinity as the primary cause of death. Tests with mysid shrimp were conducted using the same protocol as tests using daphnids and fathead-minnow larvae; however, synthetic seawater was used instead of water from the reference sites as dilution water and as the reference sample.

The decision was made to use synthetic seawater as dilution water and the control instead of creating a 'synthetic drain water.' Seawater has a different ionic composition from drain water and a higher ionic strength; therefore, creating a synthetic drain water for use as the dilution water would have been preferable. However, because the drains and lakes were rapidly drying up, time was insufficient to do the chemical analysis needed to prepare synthetic drain water. Additionally, the water quality in the drains changes rapidly and the appropriate synthetic drain water for a drain may change week to week.

To prepare synthetic seawater, 124 g of commercially available artificial marine salt was dissolved in 4 L of distilled deionized water. The resultant solution had a specific gravity of 1.020 at 22°C and a salinity of 21 parts per thousand.

Sediment Biotoxicity Test Procedures

Biotoxicity tests were conducted with sediment collected from selected sites to assess the potential toxicity of sediment to benthic invertebrates. The decision of whether to conduct sediment tests was based on the tests of water collected from the site. Toxicity evaluations were conducted with sediment collected from site 15 (Rennie Road drain 2), site 7 (Toulon Drain), site 19 (Toulon Drain at inflow to Toulon Lake), and site 20 (Toulon Lake at center) (see fig. 10).

The tests using second-instar larvae of chironomids (*Chironomus tentans*) lasted 10 days. The biotoxicity tests were performed in accordance with procedures recommended by the American Society for Testing Materials (1988), except that (1) the samples were frozen until used in the toxicity tests, (2) commercially available, 30-mesh, clean, kilned silica sand from Monterey, Calif., was used as control and dilution sediment instead of sediment samples collected from the reference sites. This approach was chosen because of the possibility that historical mining activities in the Humboldt River Basin had contaminated sediment from the reference sites with mercury.

The sediment samples were sieved and frozen until the tests were conducted--usually within 14 days. Before taking an aliquot for the test, sediment samples were warmed to room temperature, sieved through a 10-mesh sieve, and mixed thoroughly. Treatments of each replicate were prepared by adding 20 g of sediment to 100-mL beakers and adding aerated dilution water from the reference site (Humboldt River near Golconda) to the 80-mL mark. Treatments for each replicate included full-strength sediment and serial dilutions of 50 percent, 25 percent, and 12.5 percent using Monterey sand. All treatments were thoroughly mixed by stirring with a glass rod for 1 to 2 minutes and then with a magnetic stirrer.

Tests were prepared in replicates with 10 organisms per replicate. Before adding the test organisms, temperature, pH, dissolved oxygen, and specific conductance were measured in beakers containing the full-strength and control sediments. These parameters were also measured daily when mortality was recorded. The dissolved-oxygen concentrations were above 40 percent saturation throughout the duration of the test. The tests were run at room temperature in the lab (20°-22.5°C). The pH values ranged from 8.4 to 8.9 and were all within tolerance limits of the test organisms.

Egg sacs were purchased from a biological supply company and the chironomids were cultured in the lab. Ten chironomid larvae were carefully introduced by dropper into each of the beakers beneath the surface film of the water. The larvae were gently pushed under the water if they were caught in the surface tension of the water. At 24-hour intervals after initial set-up, the organisms were inspected for mortalities. The number of dead and dying individuals was counted and cumulative mortalities were calculated and recorded.

Benthic Biosurveys

Both diversity and density of benthic invertebrates have been used as indicators of polluted or stressed aquatic habitats (Pratt, 1990). Toxic stress, which may be associated with irrigation drainage, may reduce the number of species and change the species composition from the unstressed condition.

Samples of benthic insects were collected from the reference sites and the sites receiving irrigation drainage to detect biological impairment in the Humboldt River system. The purpose of the benthic biosurvey was to assess the relative severity of effects of agricultural drain water on species abundance and diversity. Assessments were conducted at the Humboldt River near Golconda (site 1), the Humboldt River near Imlay (site 2), the Humboldt River near Lovelock (site 4), the Rennie Road drains (sites 14-16), and Army and Toulon Drains (sites 18 and 19; see fig. 10).

Benthic insects were collected from riffle/run habitats in the river sites, because they provide the most productive habitats in stream systems and include many pollutant-sensitive species (Plafkin and others, 1989). In the drains where riffle/run habitats with gravel were not available, samples were collected from areas that had submerged fixed structures, such as boulders, logs, bridge abutments, and pier pilings. These structures provide suitable habitats for scrappers and filter feeders.

Samples were collected from approximately two 1-m^2 riffle areas per site by capturing organisms dislodged by foot on a fixed nylon net. The samples from the reference sites were composited for subsequent processing, taxonomic classification, and enumeration in the laboratory. Samples were chilled on ice in the field and refrigerated in the laboratory for up to 3 days prior to sorting and enumeration. At times when counting and taxonomic classification were not possible within 3 days, samples were stored in a freezer and subsequently thawed to room temperature prior to counting and identification. The classification of the organisms was limited to the family level. Family-level classifications are valuable in local site inventories of organisms and in evaluation of pollution monitoring programs (Furse and others, 1984).

RESULTS OF THE RECONNAISSANCE INVESTIGATION

Determination of Contaminant Criteria

Beneficial Use

Designated beneficial uses of the Humboldt River from Woolsey to the source of the main stem are listed in the Nevada Environmental Commission's Water Pollution Control Regulations (1991, p. 445-104). They are

- Irrigation
- Watering of livestock
- Recreation involving contact with the water
- Recreation not involving contact with the water
- Industrial supply
- Municipal or domestic supply, or both
- Protection of aquatic life including warm-water fisheries
- Propagation of wildlife

The Humboldt River from Woolsey to Rodgers Dam (fig. 2) is classified by Nevada as Class C. Class C water is defined as being in areas of moderate-to-urban human habitation, where industrial development is present in moderate amounts, agricultural practices are intensive, and where the watershed is considerably altered by human activities. Class C water may contain toxic materials only in such amounts as will not impair receiving water for any beneficial use established for this class. Beneficial uses of Class C water include municipal or domestic supply following complete treatment, protection of aquatic life, propagation of wildlife, and irrigation.

The Humboldt River from Rodgers Dam down to and including the Humboldt Sink is Class D--the lowest possible class. Class D water is defined as being in areas of urban development, highly industrialized, intensively used for agriculture, or a combination of the above and where effluent sources include a multiplicity of waste discharges from the highly altered watershed. Class D water may contain toxic materials only in amounts that will not impair receiving water for any beneficial use established for this class. Beneficial uses of Class D water includes protection of aquatic life, propagation of wildlife, and irrigation.

The water-quality standards and criteria used by the State of Nevada and in this report (table 4) generally are those recommended by the U.S. Environmental Protection Agency in accordance with the Water Pollution Control Act of 1987. Irrigation drainage is not used for municipal or domestic supply; the beneficial-use standard for that category is included in table 4 for comparative purposes only. If a State water-quality standard or criterion was lacking for a particular constituent, information from other published sources was gathered and compared with the data collected as part of this reconnaissance. Data from upstream reference sites that do not receive irrigation drainage were compared to corresponding data from the downstream sites that receive irrigation drainage.

Concern and Effect Levels

Concern and effect levels for fish and wildlife are presented in table 5. *Concern levels* are those which are unusually high compared with background levels and are not associated with known adverse biological effects. They are indicators of potential contaminant exposure in the food chain. The U.S. Fish and Wildlife Service National Contaminant Biomonitoring Program uses the 85th-percentile level to define concern levels in fish for arsenic, copper, mercury, and zinc (Lowe and others, 1985). *Effect levels* are those which can be expected to reduce growth, cause reproductive disorders, kill, or otherwise harm some organism. Some effect levels are based on dietary levels expected to harm higher trophic-level organisms. Data exist for relatively few species, and many effect levels are developed in the laboratory for a particular species under controlled conditions. Because harmful effects may be associated with different residue concentrations in different species, effect levels should not be considered as absolute values but rather as values above which some species under some conditions will be harmed.

Water-quality standards for the protection of aquatic organisms, such as shown in table 4, are not the same as the effect and concern levels in table 5. Effect levels leave no margin of safety for fish and wildlife; water-quality standards, however, include a safety factor to provide a reasonable degree of safety for untested organisms. Depending on when the water-quality standard was developed, the results of a 96-hour bioassay for a particular trace element is multiplied by an arbitrary value of 0.01 (U.S. Environmental Protection Agency, 1976, p. 2) or 0.50 (Stephan and others, 1985, p. 17).

Sediment-Quality Criteria

Sediment-quality criteria (SQC) for selected pesticides depend on the amount of organic carbon in the sediment. The SQC values are interim criteria, not final (U.S. Environmental Protection Agency, 1988). Equations to calculate normalized pesticide concentrations from the measured pesticide concentrations are presented by U.S. Environmental Protection Agency (1988). The normalized pesticide concentration is compared with the SQC values to determine if the criteria have been exceeded. Since the SQC are interim, they are used only as guidelines.

Human-Health Criteria

Criteria based on human-health considerations were obtained from public-health warnings for consumption of fish and duck muscle previously issued in Nevada and California. The criteria are used here only as guidelines.

The California Department of Health Services issued advisories about waterfowl consumption in several areas where selenium in waterfowl muscle may approach or exceed 2.0 µg/g, wet weight (approximately 7.2 µg/g, dry weight) (Fan and others, 1988, p. 544). At this time, the U.S. Food and Drug Administration has not issued a compliance policy guideline for selenium in human food.

Lillebo and others (1988, p. 31) evaluated selenium in whole fish and fish muscle and concluded that residue levels from both media could be considered equivalent. Lillebo and others (1988, p. 38) recommended a public-health-warning action level of 1.0 µg/g selenium, wet weight, in fish muscle. Because the 2.0 µg/g, wet weight (approximately 7.2 µg/g, dry weight) action level is currently in use for waterfowl, this criterion is used to evaluate selenium residue in any edible tissue analyzed for this study.

Surface-Water and Ground-Water Samples

Because of the extended drought, reduced water deliveries during 1990 resulted in Toulon Lake being completely dry during the last half of 1990 and Toulon Drain being dry in November 1990. Water can be diverted from Toulon Drain into Army Drain (fig. 5) to maintain standing water in Humboldt Lake at the expense of Toulon Lake. Less water than normal was delivered during 1990 and deliveries started later and stopped earlier than normal (figs. 4 and 9).

Field measurements and water samples were collected mainly in March, July, and November 1990 to coincide with normal seasonal irrigation patterns in the Lovelock agricultural area. A statistical summary of the field measurements made as part of this investigation and the Stillwater investigation (Hoffman and others, 1990) for the Humboldt WMA is shown in table 6. Data collected for quality assurance are not used in the summary statistics.

The Humboldt River at the two reference sites upstream of Rye Patch Reservoir is relatively fresh water and has a high pH. Specific conductance ranged from 540 to 926 µS/cm and the median conductance was 790 µS/cm. The pH ranged from 8.2 to 8.7 and the median was 8.5.

Storage of Humboldt River water in Rye Patch Reservoir increases the amount of minerals dissolved in the water. Specific conductance of the water in Rye Patch Reservoir was measured during July (1,070 µS/cm) and November 1990 (3,240 µS/cm). Both of these values were greater than the conductance of river water entering the reservoir at Imlay, where the corresponding specific conductances were 653 and 888 µS/cm. The increased mineralization of water in Rye Patch Reservoir is due to dissolution of minerals from Lake Lahontan sediment and concentration by evaporation. The greatest specific conductance was measured in November 1990 after the reservoir had been nearly emptied during the summer. Much of the water in the reservoir at that time may have been highly mineralized water released from bank storage.

Table 4. Nevada water-quality standards and criteria for beneficial uses

[Abbreviations and symbols: µg/L, microgram per liter; mg/L, milligram per liter; pCi/L, picocurie per liter; -, not applicable]

Constituent	Maximum concentration or activity recommended for different beneficial uses[a] (µg/L, except where noted)			
	Municipal or domestic supply	Aquatic life[b]	Irrigation	Watering of livestock
Arsenic (total)	50	40 [c]	100	200
Arsenic (III)				
1 hour	-	360 [d]	-	-
96 hours	-	190 [d]	-	-
Barium	1,000	-	-	-
Boron	-	550	750	5,000
Cadmium	10	-	10	50
1 hour	-	19 [d]	-	-
96 hours	-	3 [d]	-	-
Chromium (total)	50	-	100	1,000
Chromium (VI)				
1 hour	-	16 [d]	-	-
96 hours	-	11 [d]	-	-
Chromium (III)				
1 hour	-	5,400 [d]	-	-
96 hours	-	640 [d]	-	-
Copper	-	-	200	500
1 hour	-	65 [d]	-	-
96 hours	-	39 [d]	-	-
Iron	-	1,000	5,000	-
Lead	50	-	5,000	100
1 hour	-	475 [d]	-	-
96 hours	-	19 [d]	-	-
Manganese	-	-	200	-
Mercury	2	-	-	10
1 hour	-	2.4	-	-
96 hours	-	0.012	-	-
Molybdenum	-	19	-	-
Nickel	13.4	-	200	-
1 hour	-	4,580 [d]	-	-
96 hours	-	510 [d]	-	-
Selenium	10	-	20	50
1 hour	-	20	-	-
96 hours	-	5	-	-
Silver	50	44	-	-
Uranium	20 [e]	-	-	-
Zinc	-	-	2,000	25,000
1 hour	-	380 [d]	-	-
96 hours	-	340 [d]	-	-
Un-ionized ammonia as N	-	0.02 mg/L[f, g]	-	-
Dissolved solids	500/1,000 mg/L[f, h]	-	-	3,000 mg/L[f]
Adjusted gross alpha activity	15 pCi/L[e]	-	-	-

Table 4. Nevada water-quality standards and criteria for beneficial uses--Continued

[a] Except as noted, all values are standards from Nevada Environmental Commission (1991, p. 445-45).

[b] Standards for aquatic life are often given for two exposure times: 1 hour and 96 hours.

[c] The 40-µg/L standard was replaced in 1991 with a standard that depends on the concentration of arsenic (III). Arsenic species were not determined as part of this investigation. The old standard is included here only for comparative purposes, because it was the standard in effect at the time the samples were collected.

[d] Standard calculated according to formula in Nevada Environmental Commission (1991) that incorporates an ambient hardness value. For water that receives irrigation drainage in the Humboldt Wildlife Management Area, a hardness of 400 milligrams per liter was used. See section in text on surface- and ground-water quality.

[e] Standard has been proposed but not promulgated as of 1991 (U.S. Environmental Protection Agency, 1991).

[f] Criteria are from Nevada Environmental Commission (1991, p. 445-20).

[g] The 0.02-mg/L criteria is for the propagation of cold-water aquatic life; a site-specific determination is required for warm-water aquatic life.

[h] 1,000 mg/L is the *secondary maximum contaminant level* (SMCL). SMCL's are based on aesthetic qualities and are enforceable by State. Best available technology is determined by State (Jeffrey A. Fontaine, Nevada Bureau of Consumer Health Protection Services, oral commun., 1989). SMCL's are adopted from National Drinking Water Regulations (U.S. Environmental Protection Agency, 1986, p. 587-590); 500 mg/L is the *secondary preferred standard* (SPS). SPS's must be met unless water of that quality is not available, in which case SMCL's must be met if they exist (Nevada Bureau of Consumer Health Protection Services, 1980, p. 8-9).

Measured specific conductance of the source water for irrigation (at site 3, the Humboldt River at Upper Valley Road near Lovelock) ranged from 863 to 1,120 µS/cm, with a median of 1,040 µS/cm. During the non-irrigation season, flow in the river is low, and perennial flow is supported by ground-water inflow.

Measured streamflow in the drains ranged from 0.01 to 19 ft^3/s. Measured specific conductance in irrigation drain water ranged from 1,520 to 7,900 µS/cm, with a median of 3,180 µS/cm. The measured dissolved-oxygen concentration in drain water ranged from 2.5 to 20 mg/L and usually was supersaturated (median saturation of 123 percent). The water was alkaline; measured pH ranged from 7.8 to 9.6, with a median of 8.5. The drain-water samples had a median hardness of 320 mg/L as $CaCO_3$, and thus are classified as very hard, according to the system presented by Hem (1985, p. 159).

Humboldt and Toulon Lakes are typically warm, shallow (less than 1 foot), turbid, alkaline (pH 8.2 to 9.4), and supersaturated with dissolved oxygen. Measured specific conductance in the lakes ranged from 2,600 to 8,370 µS/cm, with a median of 5,840 µS/cm. The lake samples had a median hardness of 380 mg/L as $CaCO_3$.

A small spring discharges near the western edge of Toulon Lake at the site of the Toy mill and keeps a small area permanently wet. The existence of this spring was unknown during the data-collection phase of this investigation; therefore no sample of the water was collected for chemical analysis. The water was moderately saline with a specific conductance of 8,360 µS/cm in January 1992.

Dissolved Solids

The dissolved-solids concentration of water is important because high concentrations can dehydrate plants and animals. However, high dissolved-solids concentrations are often associated with high values of hardness, and hardness decreases the toxicity of some trace elements to freshwater biota.

Overland runoff of applied water and operational spills are the principal sources of water in the drains during the irrigation season. A bar graph of dissolved solids (fig. 11) shows that at four of the five sites that receive irrigation return flow, the lowest concentrations were measured

Table 5. Concentrations of potentially toxic constituents in water and biota that may adversely affect fish, wildlife, and human health (modified from Hoffman and others, 1990, table 7)

[Sources of data indicated by letter and page number, in parentheses; letters refer to complete citations following table. Abbreviations and symbols: µg/g, microgram per gram; µg/L, microgram per liter; --, data not available]

Constituent	Category[a]	Water (µg/L, except as indicated)	Residue (µg/g, dry weight)				
			Plants	Insects	Fish	Bird liver	Duck muscle
Antimony	Effect	610 (R)	--	--	--	--	
Arsenic	Concern	--	--	--	0.8[b] (K,p.370)	7.2-36[c] (E,p.303)	--
	Effect	40 (B)	--	--	4.7[c] (F,p.295)	36[c] (E,p.303)	--
	Effect, bird diet	--	30 (N,p.12)	30 (N,p.12)	--	--	--
Boron	Effect	200 (A,p.27)	--	--	--	17 (P)	--
	Effect, bird diet	--	100 (N,p.11)	100 (N,p.11)	--	--	--
Chromium	Concern	--	--	--	4.0 (C,p.44)	4.0 (C,p.44)	--
	Effect, duck diet	--	36[c] (G,p.2)	--	--	--	--
Copper	Concern	--	--	--	3.7[b] (K,p.370)	--	--
Mercury	Concern	--	--	--	0.65[b] (K,p.370)	--	--
	Effect	0.26 (Q,p.152)	--	--	4.7[c] (Q,p.153)	4.3[c] (H,p.396)	--
	Effect, bird diet	--	0.47[d] (H,p.395)	0.47[d] (H,p.395)	0.47[d] (H,p.395)	--	--
	Public health advisory	--	--	--	--	--	3.6[c] (S,p.1)
Molybdenum	Effect	1,000 (O,p.31)	--	--	--	--	--
Selenium	Concern	--	--	--	4.0[c,e] (J,p.48)	--	--
	Effect	2.0-5.0 (I,p.9)	--	--	10.0[c,e] (J,p.48)	9.0[f] (I,p.8)	--
	Effect, fish diet	--	5.0 (I,p.9)	5.0 (I,p.9)	5.0 (I,p.9)	--	--
	Effect, bird diet	--	7.0 (P)	7.0 (P)	7.0 (P)	7.0 (P)	--
	Public health advisory	--	--	--	7.2[c,e] (D,p.544)	--	7.2[c] (D,p.544)

Table 5. Concentrations of potentially toxic constituents in water and biota that may adversely affect fish, wildlife, and human health (modified from Hoffman and others, 1990, table 7)--Continued

Constituent	Category[a]	Water (µg/L, except as indicated)	Residue (µg/g, dry weight)				
			Plants	Insects	Fish	Bird liver	Duck muscle
Sodium	Effect	1,500 mg/L (L,p.30)	--	--	--	--	--
Dissolved solids	Effect	4,500 mg/L[g] (M,p.45)	--	--	--	--	--
Zinc	Concern	--	--	--	155[b] (K,p.370)	--	--

[a] Concern levels are those that are unusually high compared with background levels; effect levels are those that can be expected to harm some organism.

[b] Based upon 85th-percentile concentrations for all species. Averaged for the periods 1978-79 and 1980-81 and multiplied by 3.6 to represent dry weight.

[c] Original wet-weight data multiplied by 3.6 to approximate dry weight.

[d] Reported as 0.5 ppm dry weight methylmercury and multiplied by 0.93 to convert methylmercury to total mercury.

[e] Muscle to whole-body ratio for selenium in fish is 1:1 (J, p. 31).

[f] Based on the average liver wet-weight concentrations for female mallards, adjusted for 71-percent moisture.

[g] Based on the effect level of 7,500 microsiemens per centimeter (M, p. 45). Effect level was converted to milligrams per liter using equation 1 in section on Dissolved Solids.

Notes: References used for criteria to categorize contaminant levels in biological samples, water, and human health that are cited in table:

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Table 6. Statistical summary of field measurements for surface-water samples from the study area and upstream sites, 1987-90. For each three-line data group, upper number in parentheses is median concentration, middle numbers indicate range of concentrations, and lower number in parentheses is number of samples

[Abbreviations and symbols: ft^3/s, cubic foot per second; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; --, no value for category]

Site number and name	Water temperature (degrees Celsius)	pH (standard units)	Dissolved oxygen, (mg/L)	Dissolved oxygen saturation (percent)	Specific conductance (µS/cm)	Total alkalinity (mg/L, as $CaCO_3$)	Water discharge (ft^3/s)
Reference Sites							
	(11.5)	(8.5)	(9.7)	(97)	(790)	(235)	(55)
1, 2 Humboldt River	0.5-26.5	8.2-8.7	6.5-12.2	92-103	540-926	226-325	2.0-257
	(9)	(4)	(4)	(4)	(9)	(4)	(9)
	(13.3)	(8.6)	(8.2)	(89)	(2,150)	(319)	
9 Rye Patch Reservoir	4.6-22.1	--	6.9-9.4	86-92	1,070-3,240	--	--
	(2)	(1)	(2)	(2)	(2)	(1)	
	(13.2)	(8.5)	(8.6)	(100)	(1,040)	(205)	(74)
3 Humboldt River	7.0-24.2	8.1-8.7	7.2-11.1	83-100	863-1,120	168-248	0.33-247
	(6)	(6)	(6)	(6)	(6)	(6)	(6)
Irrigation Drainage Sites							
	(16.0)	(8.5)	(10.7)	(123)	(3,180)	(371)	(2.92)
4-8 Drains	4.5-30.1	7.8-9.6	2.5-20.0	31-242	1,520-7,900	286-550	0.01-19
	(23)	(21)	(20)	(20)	(23)	(18)	(21)
	(18.0)	(8.6)	(8.5)	(110)	(5,840)	(346)	
10, 11 Lakes	9.0-36.5	8.2-9.4	6.1-12.3	71-189	2,600-8,370	297-750	--
	(9)	(9)	(8)	(8)	(9)	(9)	

during the irrigation season. The only exception was Army Drain which receives water pumped in from drainage ditches; water quality in Army Drain probably depends on when the sample was collected in relation to times of pumping. At two of four sites receiving irrigation drainage, the concentrations during the pre-irrigation season were higher than during the post-irrigation season.

The drought had little effect on the quality of water entering Lovelock Valley (fig. 6). Of the sites receiving irrigation drainage, Toulon Drain and the Humboldt River near Lovelock showed little change in water quality between March 1988 and March 1990 (fig. 12). For unknown reasons, dissolved-solids concentrations in Army Drain were much higher in the 1988 samples than in 1989 and 1990 samples. Water quality in Toulon Lake deteriorated during this period; shortly after the last measurement in March 1990, the lake went dry.

The concentration of dissolved solids increases in the Humboldt River after storage in Rye Patch Reservoir. The median dissolved-solids concentration in water at the sites upstream from Rye Patch Reservoir (sites 1 and 2 on fig. 1) was 472 mg/L, whereas the median concentration in the Humboldt River at Upper Valley Road (site 3 on fig. 10) was 624 mg/L (fig. 13). Water quality (based on dissolved-solids concentration) changes little between Rye Patch Reservoir and site 3, about 13 miles downstream. The median dissolved-solids concentration at the Humboldt River below Rye Patch gage was 554 mg/L (fig. 7) for 297 analyses between 1952 and 1986.

The median dissolved-solids concentration in drain water (2,210 mg/L) is nearly 3.5 times greater than that of the irrigation source water. Of the sampling sites, Army Drain (site 8 on fig. 10) commonly had the highest concentration of dissolved solids, with a recorded maximum of

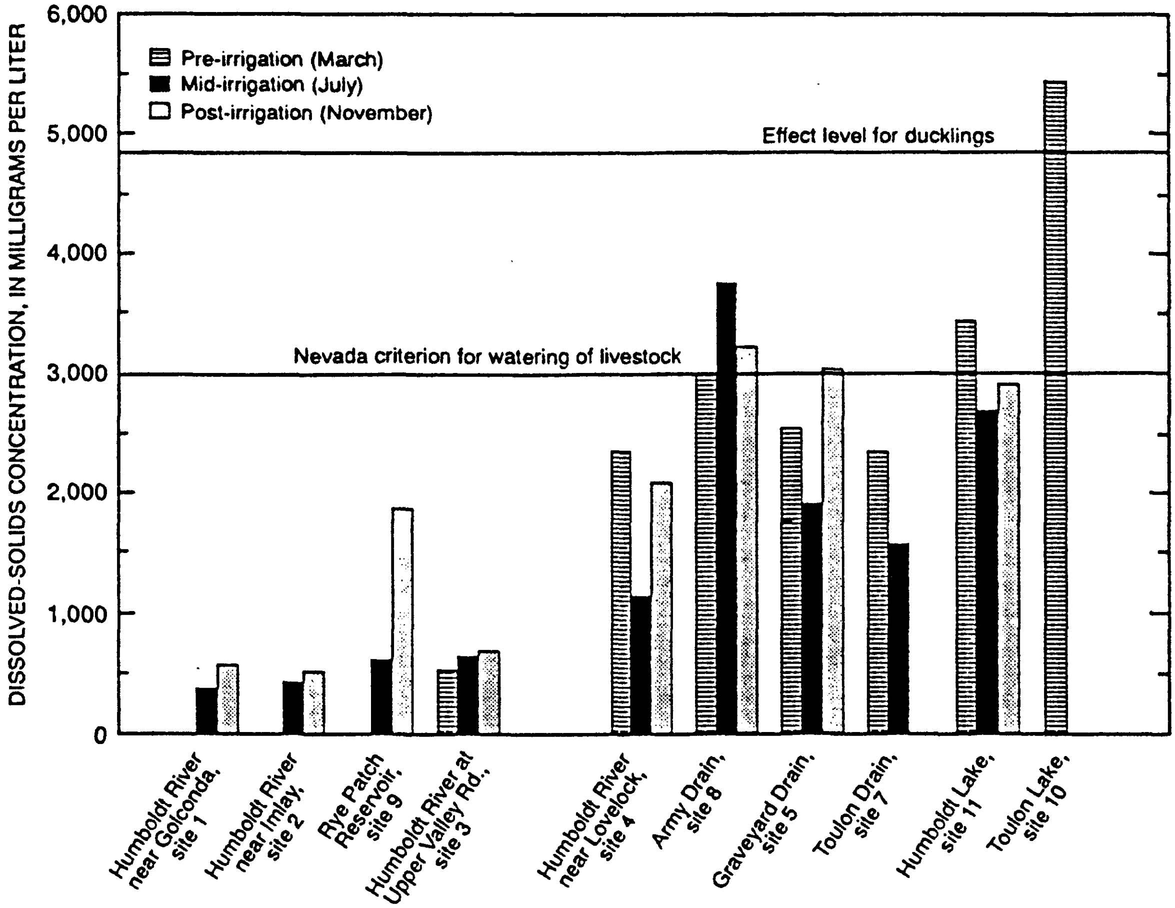

Figure 11. Concentrations of dissolved solids in surface-water samples from reference sites and from sites receiving irrigation drain water, 1990. (Effect level for ducklings from Mitcham and Wobeson (1988b)).

8,580 mg/L during the pre-irrigation season in March 1988, and a median concentration of 3,530 mg/L. The highest quality water in the drains, based on dissolved-solids concentration, was in Toulon Drain (site 7), which had a median dissolved-solids concentration of 1,640 mg/L. Although Toulon Drain receives saline inflow from Graveyard Drain (median dissolved solids of 2,530 mg/L), it also receives water that is low in dissolved solids from the treated sewage effluent in Lovelock Drain. The median dissolved-solids concentration in the Humboldt River near Lovelock (site 4) was 2,050 mg/L.

At the shallow ground-water site in Upper Valley (site 12), dissolved-solids concentrations for two samples were 814 and 902 mg/L. The median dissolved-solids concentration in the wetlands (sites 10 and 11) was 3,140 mg/L. The maximum concentration measured, 5,420 mg/L, was in Toulon Lake in March 1990, shortly before the lake became dry.

The data indicate a large increase in dissolved solids in the downstream direction. The increase between the Humboldt River near Golconda and the Humboldt River at Upper Valley Road is principally due to evaporation and to dissolution of minerals in the lake bottom sediment during storage in Rye Patch Reservoir. The increase between the Humboldt River at Upper Valley Road and the water in the drains entering the wetlands is principally a result of application and subsequent drainage of irrigation water from beneath fields in the study area.

Water with specific-conductance values equal to or exceeding 7,500 μS/cm can adversely affect ducklings unless a freshwater source is also available to them (Mitcham and Wobesen, 1988*b*, p. 45, 49). The relation between specific conductance and dissolved-solids concentration depends on the chemical composition of the water (Hem, 1985, p. 66). A least-squares-regression equation (equation 1) was computed using data collected

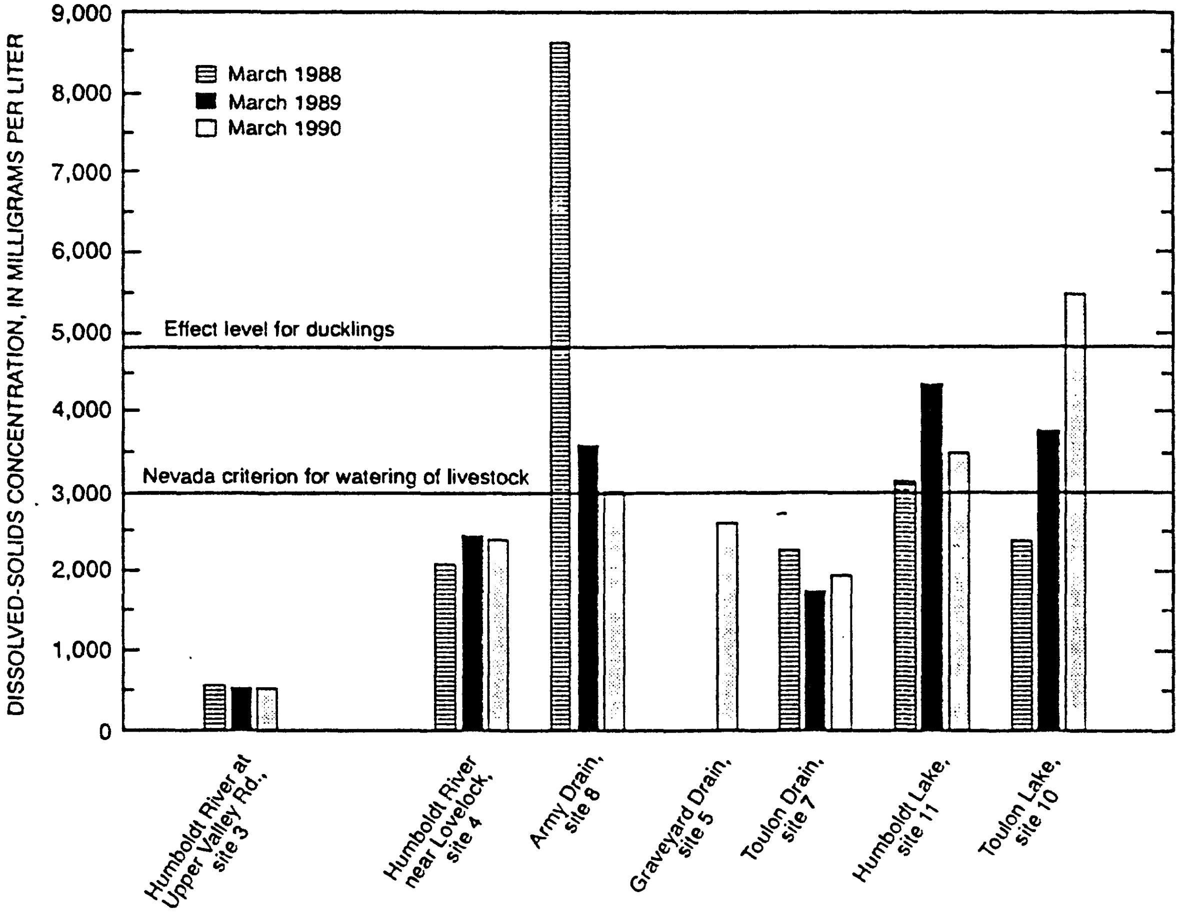

Figure 12. Concentrations of dissolved solids in surface-water samples from reference sites and from sites receiving irrigation drain water, March 1988, March 1989, and March 1990. (Effect level for ducklings from Mitcham and Wobeson (1988b))

during this investigation (coefficient of determination, r^2 = 0.99; number of data pairs, n = 43):

Dissolved solids, in milligrams per liter
= 0.603 (specific conductance, in microsiemens per centimeter) - 23 (1)

Within the study area, the effect level of a specific conductance of 7,500 µS/cm corresponds to about 4,500 mg/L of dissolved solids. During 1987-90, concentrations exceeding this level were measured twice in Army Drain (site 8 in fig. 10) and once in Toulon Lake (site 10).

Dissolved Sodium

The chemical composition of water in the Humboldt River changes in a downstream direction along with the previously described increase in dissolved-solids concentration. At the reference sites, the measured concentration of sodium is typically less than 150 mg/L (fig. 14) and the predominant constituents in the water are sodium, calcium, and bicarbonate. The predominant constituents in samples of drain water and lake water are sodium and chloride. These constituents are commonly found in high concentrations in drain water in areas of low rainfall and irrigated agriculture.

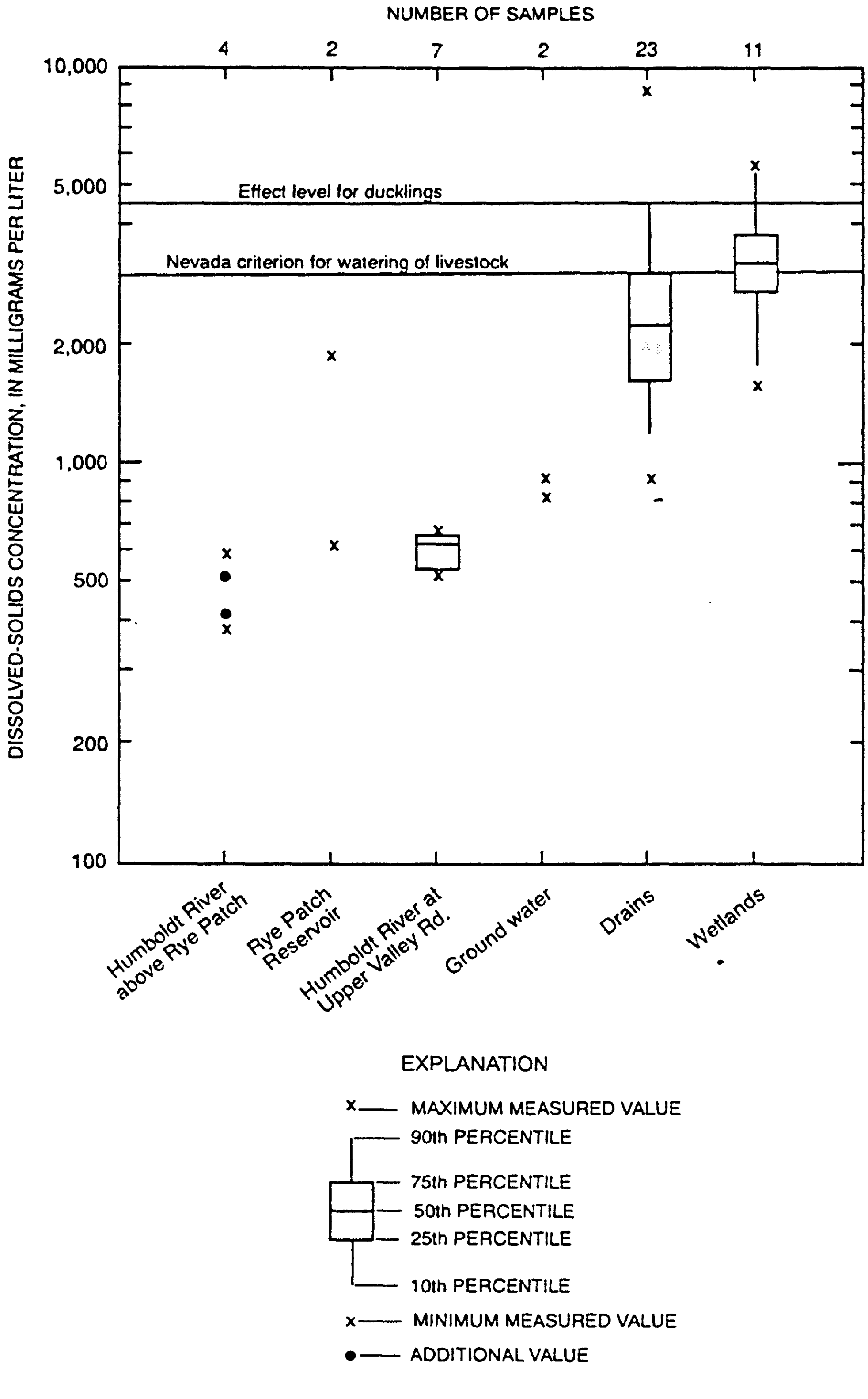

Figure 13. Concentrations of dissolved solids in surface-water samples from reference sites and from sites receiving irrigation drain water, 1987-90.

In the two samples collected at the shallow ground-water site (subsurface flow), sodium concentrations were 210 and 220 mg/L. The median sodium concentration in the drain water was 680 mg/L; in the lakes it was 1,000 mg/L (fig. 14).

The effect level for sodium is 1,500 mg/L; sodium concentrations exceeding this concentration result in decreased feather growth in mallard ducklings (Mitcham and Wobeser, 1988*a*, p. 30). The 1,500-mg/L effect level was exceeded in two samples collected during this study: at site 8 in Army Drain in March 1988 and at site 10 in Toulon Lake in March 1990.

Trace Elements

Concentrations of dissolved aluminum, barium, cadmium, chromium, copper, lead, nickel, silver, and zinc in all samples were either less than the Nevada water-quality standard for the protection of aquatic life, (table 4) or less than the analytical reporting level. Results of analyses of these trace elements are in table 15 in the Supplemental Data section.

Toxicity to algae occurs at antimony concentrations as low as 610 µg/L (U.S. Environmental Protection Agency, 1986); however, none of the samples in this study exceeded this effect level. Lithium was identified at concentrations greater than the analytical reporting limit; however, no standards or effect levels have been identified. The National Academy of Sciences (1974) recommended a standard of 100 µg/L for vanadium in water for livestock and poultry. No samples in this study exceeded this recommended standard.

Arsenic

The median arsenic concentration from the Humboldt River upstream from Rye Patch Reservoir (sites 1 and 2 in fig. 1) was 16 µg/L (fig. 15). The arsenic concentration increases in Rye Patch Reservoir, probably because of evaporative concentration and dissolution from Lake Lahontan sediment. The median arsenic concentration in water entering Lovelock agricultural area at site 3 (fig. 10) was 29 µg/L. At stream and drain sites containing irrigation drainage, the median arsenic concentration was 64 µg/L. The median concentration in the lakes was 90 µg/L.

The pre-1991 Nevada single-value standard for the protection of aquatic life (40 µg/L) was exceeded in more than 90 percent of the samples from the drains and lakes. The arsenite species of arsenic (As(III)) is more toxic than the arsenate species (As(V)) (Fowler, 1977); therefore in 1991, Nevada law was changed, and the new standard for arsenic depends on its oxidation state. The determination of the oxidation state of arsenic was not part of this investigation, and all comparisons between measured concentrations and standards use the pre-1991 standard.

Wind-dispersed tailings from the former arsenic mill near Toulon may be the source of much of the arsenic in Toulon Drain and Toulon Lake. The prevailing winds carry the tailings to the northeast where they would be deposited along Toulon Drain. In this study, water from Toulon Drain (site 7) had the highest measured concentration of arsenic (760 µg/L) and the greatest observed instantaneous load, 4.3 g/min. The median arsenic concentration in Toulon Lake (site 10) was 185 µg/L.

Tailings from the arsenic mill are not the only source of arsenic to the wetlands. Application of irrigation water mobilizes naturally occurring arsenic in Lake Lahontan sediment. Measured concentrations of dissolved arsenic in Rye Patch Reservoir were 32 and 59 µg/L; in ground-water samples from a well about 14 miles northwest of the arsenic mill, they were 42 and 44 µg/L. The median concentration of arsenic in Humboldt River near Lovelock (site 4) was 57 µg/L and in Humboldt Lake (site 11) was 78 µg/L.

Amphibians are nearly absent in the wetlands but normally would be expected there. The median concentration of arsenic in water in the wetlands (90 µg/L) is more than twice the effect level, 40 µg/L, for amphibians (Birge, 1978). Arsenic probably contributed to their disappearance from the wetlands.

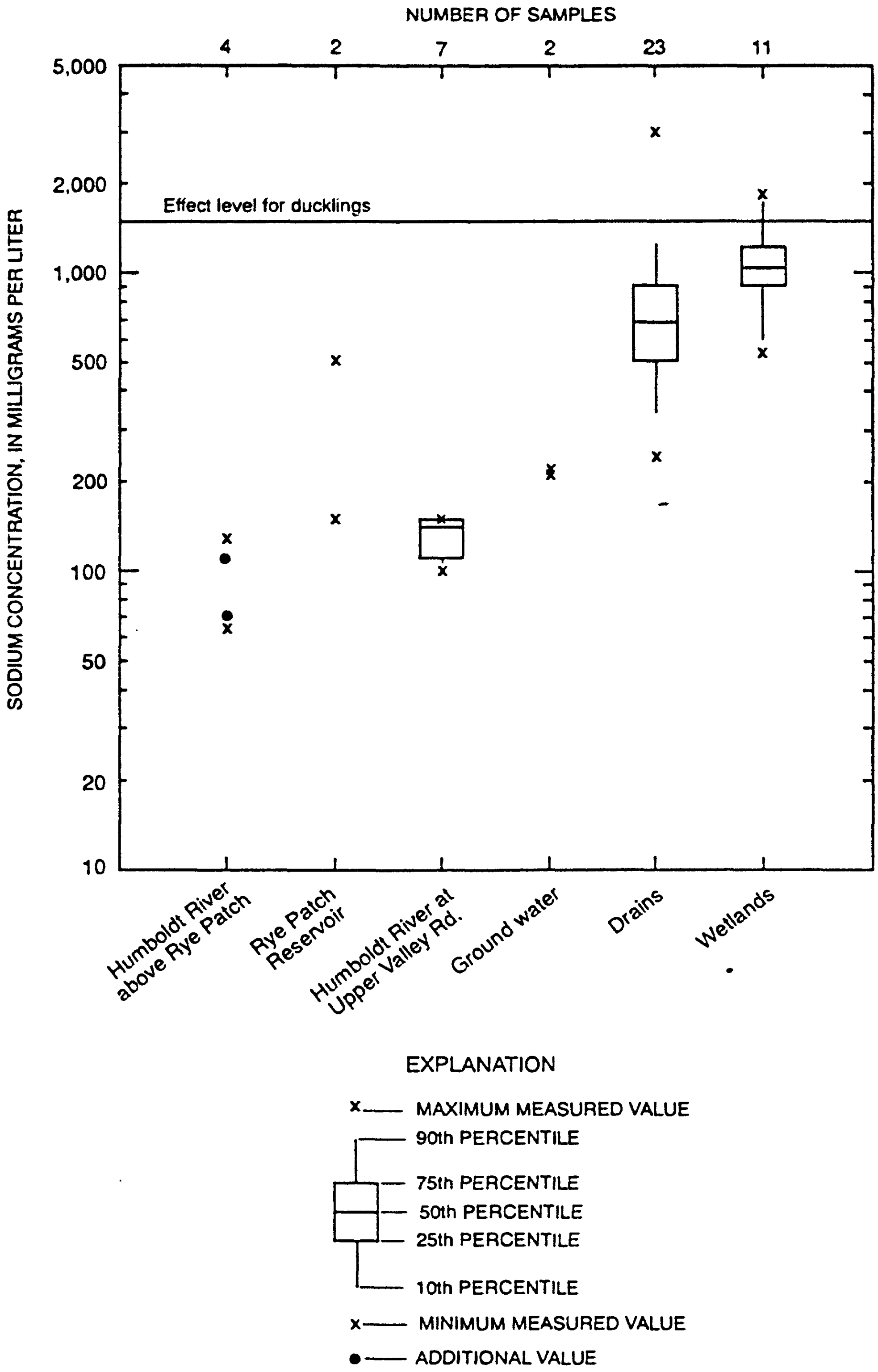

Figure 14. Concentrations of dissolved sodium in water samples from reference sites and sites receiving irrigation drain water, 1987-90.

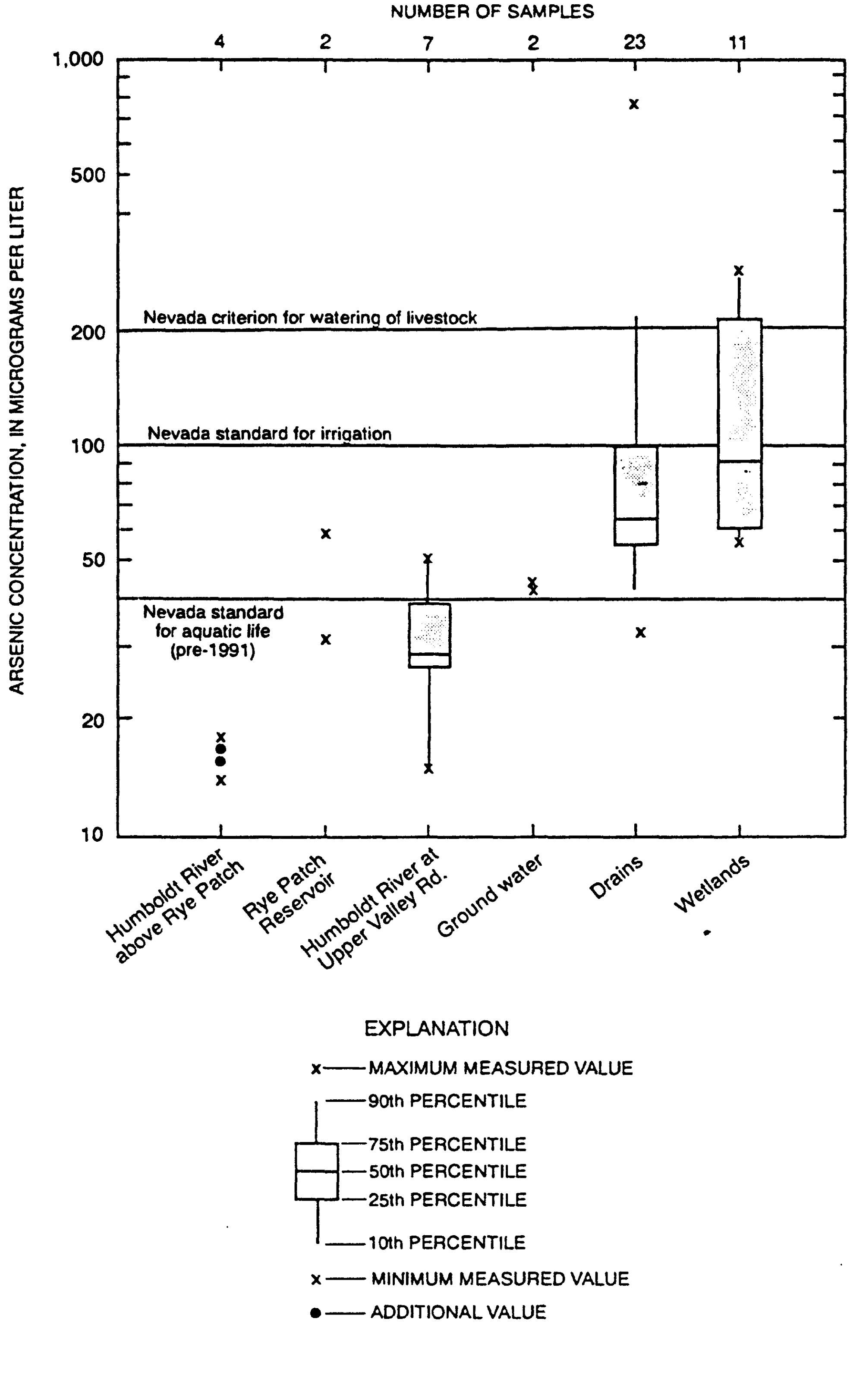

Figure 15. Concentrations of dissolved arsenic in water samples from reference sites and sites receiving irrigation drain water, 1987-90.

Boron

The median boron concentration in samples from sites upstream of Rye Patch Reservoir (sites 1 and 2, fig. 1) was 480 µg/L (fig. 16). The median boron concentration in water entering Lovelock Valley was only slightly greater at 550 µg/L. For the protection of sensitive crops during long-term irrigation, the Nevada standard for boron is 750 µg/L; concentrations in all samples of the source water were less than this standard. In shallow ground-water, the boron concentration was slightly above the standard; measured values were 940 and 980 µg/L.

In contrast, the median boron concentration at sites that contain irrigation drainage was very much greater: 3,500 µg/L in the drains and 3,900 µg/L in the lakes. At sites receiving irrigation drainage, boron concentrations were 2-18 times greater than the Nevada standard for the protection of aquatic life (550 µg/L). The maximum dissolved-boron concentration, 10,000 µg/L, was measured in a sample from Army Drain.

According to Birge and Black (1977, p. 27), depending on water hardness and the particular compound, boron concentrations of 1 to 100 µg/L could reduce the reproductive potential of very sensitive species such as trout, and concentrations exceeding 200 µg/L would likely impair survival of developmental stages for other fish species. The effect levels for boron or fish (Birge and Black, 1977) were exceeded in all water samples, at both the upstream reference sites and downstream drain-water site, during this reconnaissance investigation.

Mercury

The median concentration of dissolved mercury was less than 0.1 µg/L in water samples from the reference sites, as well as the downstream sites. Although the median mercury concentration for the downstream sites was less than 0.1 µg/L, some samples from all downstream sites except Graveyard Drain had concentrations at or above the analytical reporting limit. Based on the current 96-hour average Nevada mercury standard, any detectable mercury would exceed the standard for the protection of aquatic life. The highest concentration of dissolved mercury was in a water sample from Army Drain (0.5 µg/L). Mercury concentrations exceeding the standard also were measured at an upstream reference site (Humboldt River at Upper Valley Road; site 3). No mercury was detected in the two ground-water samples.

Molybdenum

The median concentration of dissolved molybdenum in samples upstream of Rye Patch Reservoir (sites 1 and 2, fig. 1) was 3 µg/L and was only slightly higher in water entering Lovelock Valley (10 µg/L; site 4, fig. 10). Slightly less than one-half the samples from the drains exceeded the Nevada standard for molybdenum for the protection of aquatic life (19 µg/L), and more than 75 percent of samples from the wetlands exceeded this standard.

Selenium

Lemly and Smith (1987, p. 9) identified selenium concentrations in water of 2-5 µg/L as causing reproductive failure or mortality in fish and waterfowl due to food-chain bioconcentration. The U.S. Environmental Protection Agency (1987, p. 34) suggests that most fresh-water organisms will be protected if the 96-hour average concentration of selenium does not exceed 5 µg/L more than once every 3 years, or a 1-hour average concentration does not exceed 20 µg/L more than once every 3 years. The Nevada standards for selenium for the protection of aquatic life are 20 µg/L for the 1-hour average concentration and 5 µg/L for the 96-hour average concentration (table 4).

Concentrations of dissolved selenium were low--5 µg/L or less--at all surface-water sites sampled. One sample from Graveyard Drain had a concentration equal to the State 96-hour average selenium standard (5 µg/L). Although low compared with other areas in the Western United States that receive irrigation drainage, selenium concentrations in the drain water in the study area sometimes meet or exceed levels identified as having adverse effects on wildlife due to bioaccumulation.

Because of the large number of samples with concentrations less than the reporting level, the median selenium concentration in the drain sites was estimated, using adjusted log-normal maximum likelihood methods (Helsel and Cohn, 1988).

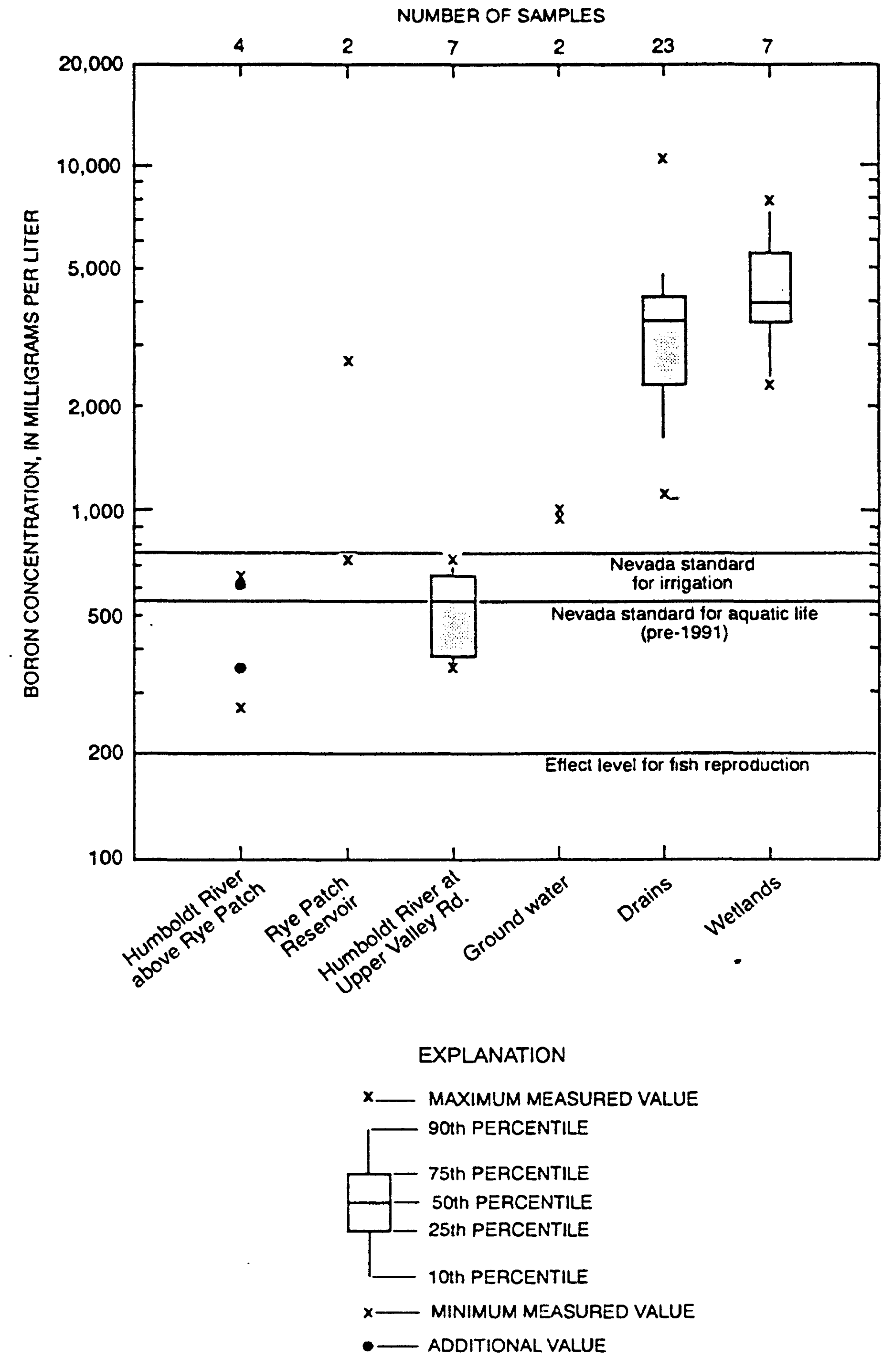

Figure 16. Concentrations of dissolved boron in water samples from reference sites and sites receiving irrigation drain water, 1987-90.

The estimated median concentration was 0.95 μg/L. The highest concentrations were in samples from Graveyard Drain, which consistently contained measurable amounts of selenium. Concentrations of 2 μg/L or more were measured at all sites receiving irrigation drain water except the Humboldt River near Lovelock (site 3 in fig. 10). Measured selenium concentrations in the lakes were low (range of less than 1 μg/L to 2 μg/L) and were similar to selenium concentrations at the reference sites (range of less than 1 μg/L to 1 μg/L). The concentration of selenium in two water samples from shallow ground water in Upper Valley were below the analytical reporting limit of 1 μg/L.

Radioactive Substances

High concentrations of radioactive elements are harmful to human health and Maximum Contaminant Levels (MCL's) in drinking water have been proposed for some radioactive substances. Effect and concern levels for radioactive substances for fish and wildlife have not been identified. The proposed MCL for total uranium in drinking water is 20 μg/L (U.S. Environmental Protection Agency, 1991). The median dissolved uranium concentration at the sites upstream from Lovelock Valley was 6.9 μg/L (fig. 17). Two samples from shallow ground water had uranium concentrations of 4.9 and 9.3 μg/L. The median uranium concentration in the drains was 13.5 μg/L and in the lakes, 34 μg/L. The greatest measured uranium concentration, 140 μg/L, was in Toulon Lake, and generally the highest values were from the lakes. Uranium concentrations in the lakes and drain water may be increasing because of oxidation of organic matter in sediment, which is releasing bound uranium to the water.

During 1987, radiochemical analyses were done on water from several of the sampling sites. The maximum measured gross dissolved alpha activity of the sites that receive irrigation drainage was 54 μg/L, or approximately 37 pCi/L as natural uranium, at Army Drain (site 8 in fig. 10). After correction for uranium and radium-226 concentrations, the gross alpha activity did not exceed the proposed MCL of 15 pCi/L. The maximum measured gross dissolved beta activity was 170 pCi/L as cesium-137 in Toulon Lake (site 10). Measured dissolved radium-226 activities ranged from 0.03 to 0.12 pCi/L--much less than the proposed MCL of 20 pCi/L in drinking water (U.S. Environmental Protection Agency, 1991).

Nitrogen and Phosphorus

The concentration of nitrate, nitrite, ammonia, and phosphorus in water is important because unionized ammonia is acutely toxic to fish and nitrogen and phosphorus compounds can accelerate eutrophication of surface water. High pH and temperature--conditions often found in the drains and lakes during the summer--will cause a high percentage of the total ammonia to be in the toxic un-ionized form.

Of the inorganic nitrogen species, ammonia (sum of both the ionized and un-ionized ammonia) was found in the greatest concentrations. At the sampling sites in the drains, the measured dissolved ammonia concentrations ranged from less than 0.01 to 1.3 mg/L, with a median concentration of 0.03 mg/L.

The Nevada criteria for un-ionized ammonia for the propagation of aquatic life depends on water temperature; for cold-water sites, the criterion is 0.02 mg/L and for warm-water sites, a site-specific determination is required. The drains in Lovelock Valley would be considered warm water and, to the authors' knowledge, site-specific determinations have not been made.

The calculated concentrations of dissolved unionized ammonia in the drains ranged from less than 0.01 to 0.26 mg/L (table 14 in Supplemental Data section). The concentration of un-ionized ammonia in 2 of 17 samples from the drains was greater than the criterion for cold-water aquatic life and the maximum concentration was 13 times greater than the criterion. High dissolved-solids concentrations reduce the fraction of ammonia that is un-ionized; however, both samples exceeded the criterion even after correction for the dissolved-solids concentration (using the tables of Skarheim; 1973).

More than 90 percent of the samples had nitrate concentrations less than the reporting limit of 0.1 mg/L; only four samples exceeded 0.1 mg/L. The maximum measured dissolved-nitrate concentration was 0.7 mg/L, and three of the four samples exceeding 0.1 mg/L were collected in

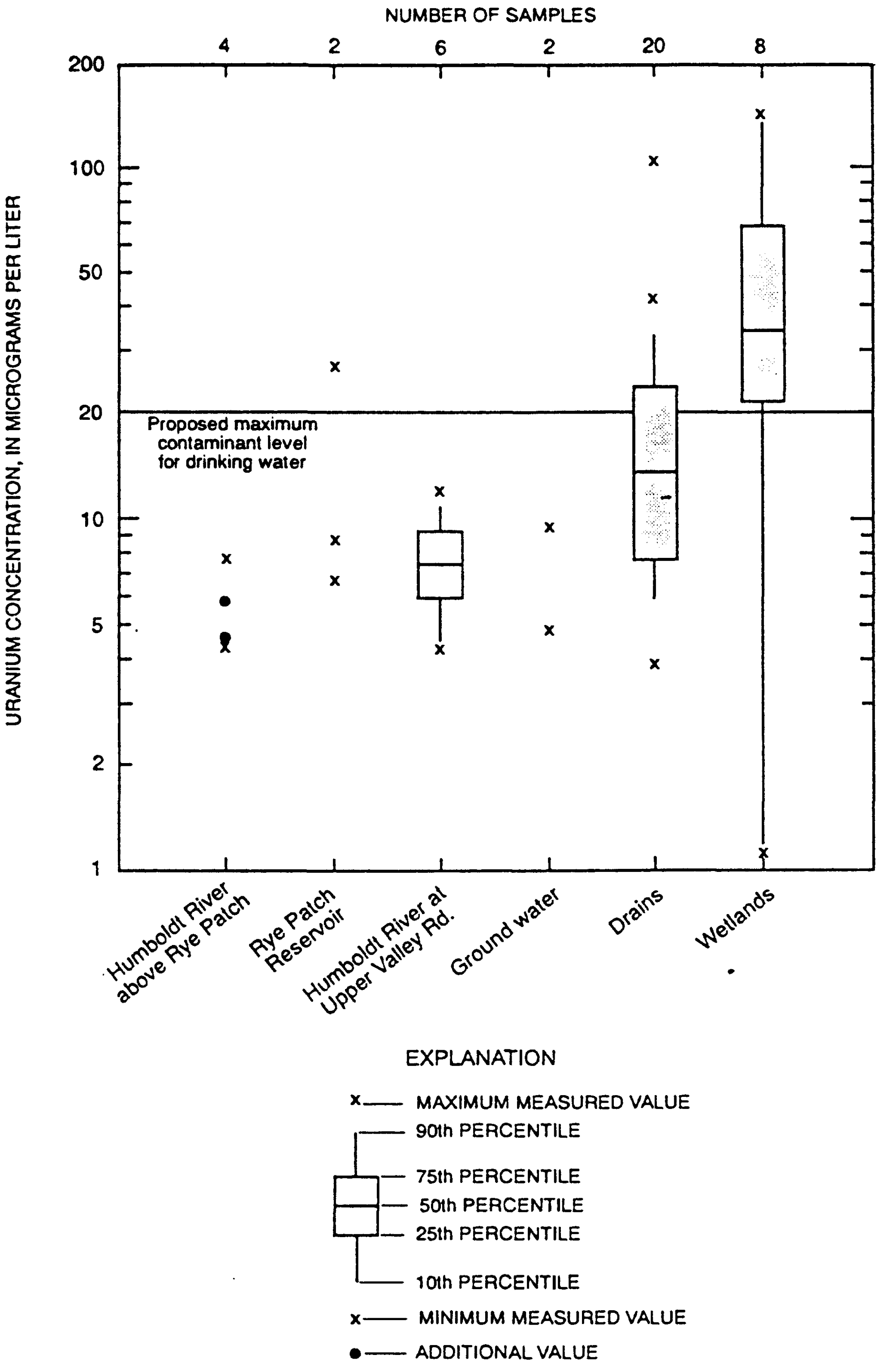

Figure 17. Concentrations of dissolved uranium in water samples from reference sites and sites receiving irrigation drain water, 1987-90.

Toulon Drain (site 7 in fig. 10). Seventeen of twenty ortho-phosphorus concentrations were 0.1 mg/L or less; the highest measured concentration, 1.0 mg/L, was measured in a sample from Toulon Drain.

The highest concentrations of nutrients were always found at Toulon Drain (site 7). Toulon Drain receives treated sewage effluent from the city of Lovelock via Lovelock Drain (fig. 5). Both un-ionized ammonia samples that exceeded the criterion were from Toulon Drain. All of the ortho-phosphorus values that exceeded 0.1 mg/L were from Toulon Drain or Toulon Lake.

Carbamate Pesticides

Carbamate pesticides, principally carbofuran, are used in Lovelock Valley agricultural area to control weevils and aphids. Carbamate pesticides readily degrade in water, and none were detected in four samples collected at sites 4, 7, 8, and 11 during the 1990 irrigation season.

Herbicides

Herbicides, principally 2,4-D, are used in Lovelock Valley agricultural area for control of broadleaf weeds. During the irrigation season in 1990, four samples were collected from Toulon and Army Drains and Humboldt and Toulon Lakes. The samples from Toulon Drain and Humboldt Lake, however, were ruined during sample extraction in the laboratory. The only herbicide detected was 2,4-D (0.5 µg/L in Army Drain; site 8 in fig. 10).

Bottom-Sediment Samples

Trace Elements

Bottom-sediment samples were collected at four sites in the Humboldt River, three sites in drains, and three sites in lakes. Analyses were made from two size fractions: <2 mm [material smaller than very fine gravel (Guy, 1969, p. 7)] and <62 µm (material smaller than coarse silt). Three sites on the Humboldt River (sites 1, 2, and 3) and the Rye Patch Reservoir site (site 9) were reference sites unaffected by irrigation drainage. Most bottom-sediment samples from the drains were mixtures of anaerobic mud and sand.

The concentrations of trace elements in bottom sediment from areas receiving irrigation drainage (table 17 in Supplemental Data section) were compared with those from the reference sites. Furthermore, the concentrations were compared with "geochemical baseline" values for B-horizon soils in the Western United States (R.C. Severson, U.S. Geological Survey, written commun., 1987, using data from Shacklette and Boerngen, 1984).[1] The samples collected for the Humboldt WMA study are not geochemically related to samples of B-horizon soils, but the geochemical data of Shacklette and Boerngen (1984) are the only guidelines available at this time and are used here for qualitative comparison only.

Severson and others (1991) describe partioning of elements between the two size fractions in samples from other irrigation drainage investigations in the Western United States. They found only minimal differences between the coarse and fine fractions for selenium and mercury; lithium is enriched in the fine fraction. Severson and others (1991) report arsenic is either partitioned in the coarse fraction or evenly partitioned between the coarse and fine fractions. At the Humboldt WMA, arsenic, lithium, molybdenum, mercury, and selenium concentrations are consistently enriched in the fine fraction. All concentrations reported in the following discussion are from the <62-µm fraction.

Concentrations of arsenic in bottom-sediment samples increased in a downstream direction. At reference sites, the arsenic concentration ranged from about 4 to 14 mg/kg; in the drains it ranged from 9.4 to 17 mg/kg. The highest concentrations

[1] The baseline value for each trace element in the sampled western soils consists of upper and lower concentrations that bound the central 95 percent of the data set. Thus, 2.5 percent of the data-set concentrations are greater than the upper baseline value, and 2.5 percent are less than the lower value. In the Humboldt WMA bottom sediment discussed herein, only the concentrations that exceed the upper baseline value are of concern.

were found in Toulon Lake (22 mg/kg) and Humboldt Lake (21 mg/kg). None of the samples exceeded the maximum baseline value for soils of 22 mg/kg arsenic. Nevertheless, the fact that an arsenic mill operated on the edge of Toulon Lake and that the one sample collected from Toulon Lake equaled the maximum baseline value suggests that samples from other parts of the lake nearer the arsenic mill may exceed the maximum baseline value.

Boron concentrations in bottom sediment generally increased in a downstream direction. The median boron concentration in sites receiving irrigation drainage was 10 mg/kg (range 1-90 mg/kg). At three of the reference sites, material was insufficient for analysis, and the only measured concentration was 2 mg/kg in sediment from Rye Patch Reservoir. None of the samples exceeded the maximum baseline value for soils (91 mg/kg).

Lithium concentrations in bottom sediment generally increased in a downstream direction. The median lithium concentration in sites receiving irrigation drainage was 62 mg/kg (range 46-95 mg/kg) and the median in the reference sites was 43 mg/kg (range 40-54 mg/kg). Samples from all of the sites receiving irrigation drainage, except Humboldt Lake, exceeded the maximum baseline value (55 mg/kg). The maximum value (95 mg/kg) was from Toulon Lake.

The highest concentrations of mercury in bottom sediment are from the reference sites. The median concentration of mercury at reference sites was 0.09 mg/kg (range 0.08-0.12 mg/kg). At sites receiving irrigation drainage, the median concentration was 0.04 mg/kg (range 0.02 to 0.08 mg/kg). None of the samples exceeded the maximum baseline value for mercury in soils (0.25 mg/kg).

Molybdenum concentrations in bottom sediment from the reference sites and drains were low, ranging from <2 to 3 mg/kg. Molybdenum concentrations in the wetlands were higher, 10 mg/kg in Toulon Lake and 5 mg/kg in Humboldt Lake. Both of these samples exceeded the maximum baseline value in soils (4.0 mg/kg).

Selenium concentrations in bottom-sediment samples increased in a downstream direction; the lowest concentrations were in samples from the reference sites (0.2 to 0.4 mg/kg), intermediate concentrations were in samples from the drains (0.5 to 0.9 mg/kg), and the highest concentrations were in samples from Toulon and Humboldt Lakes (1.2 to 1.4 mg/kg). All bottom-sediment samples had selenium concentrations less than or equal to the maximum baseline value for soils (1.4 mg/kg). None of the selenium concentrations in sediment exceeded 4 mg/kg dry weight, which is a level of concern to fish and wildlife (Lemly and Smith, 1987, p. 9).

Uranium concentrations in bottom sediment were highest in the wetlands (7.90 mg/kg in Toulon Lake and 9.17 mg/kg in Humboldt lake) and in Toulon Drain (6.22 mg/kg). All these concentrations exceed the maximum baseline value for soils (5.3 mg/kg).

Samples from one reference site contained much larger concentrations of two trace metals than samples from any other sites. The bottom sediment from the Humboldt River near Golconda contained 440 mg/kg of lead and 73 mg/kg of tin. The source of the metals is unknown.

Organochlorine Compounds

Bottom-sediment samples from Toulon and Humboldt Lakes were analyzed for organochlorine insecticide residues during March 1988 and November 1990. Metabolites of DDT (DDE and DDD) were at or near the analytical reporting limit (0.1 µg/kg) in Humboldt Lake in 1990, but were not detected in 1988. DDE concentration was 0.1 µg/kg in Toulon Lake during 1988 and 1990.

Organic carbon was not measured during 1990 so only the pesticide concentration in samples measured during 1988 can be compared with Sediment Quality Criteria (SQC). The normalized DDE concentration at Toulon Lake in 1988 was 0.01 µg/gC (microgram per gram of carbon). Criteria for DDE and DDD have not been established; however, for comparison, the mean SQC for DDT is 0.83 µg/gC (U.S. Environmental Protection Agency, 1988).

No detectable amounts of polychlorinated biphenyls (PCB), polychlorinated naphthalenes (PCN), aldrin, chlordane, DDD, DDT, dieldrin, endosulfan, endrin, heptachlor, heptachlor epoxide, lindane, methoxychlor, mirex, perthane, or toxaphene were found in bottom-sediment samples (table 18 in Supplemental Data section). The low concentrations of organochlorine insecticide residues in bottom sediment indicate that these synthetic compounds are not an immediate threat to fish and wildlife in the area.

Biological Samples

Seven trace elements have been identified in plant and animal tissue from the study area in concentrations that exceed concern or effect levels (listed in table 5); they are arsenic, boron, chromium, copper, mercury, selenium, and zinc. However, direct adverse effects of these trace elements were not demonstrated. Other trace elements also may be potentially toxic, but data to determine effects of these concentrations are not available. Data on trace-element concentrations in biological samples are presented in table 20 in Supplemental Data section.

The discussion in the following section is arranged according to trace elements and organochlorine pesticides. The trace elements are listed alphabetically and, for each element, the biota are discussed in order of ascending trophic level. Unless otherwise noted, all concentrations are expressed in units of dry weight.

Arsenic

Plants

As primary producers, aquatic plants in the study area are important food for higher trophic-level organisms. As little as 30 µg/g arsenic as sodium arsenate in the diet is known to retard growth of female mallard ducklings (Patuxent Wildlife Research Center, 1987, p. 9-13). Arsenic concentrations in plant tissue ranged from 0.2 to 110 µg/g. Concentrations greater than the 30-µg/g effect level were found in composite samples of filamentous algae at three sites and in samples of sago pondweed at four sites. The highest arsenic concentration, 110 µg/g, was found in filamentous algae collected from Rennie Road drain 3. The median arsenic concentration in filamentous algae was 27 µg/g; samples with the highest concentration were collected from sites in Rennie Road drain.

Insects

Aquatic insects are important dietary items to many migratory birds, including ducklings. All arsenic concentrations in insect tissue were less than the dietary effect level. The highest arsenic concentration, 26 µg/g, was found in brine-fly samples collected from Rennie Road drain 2.

Fish

Gilderhus (1966, p. 295) reported that a residue level of about 4.7 µg/g, dry weight, of arsenic in whole juvenile bluegills (*Lepomis macrochirus*) was associated with poor growth and survival. There were no species of fish with arsenic concentrations approaching this biological effect level during this study. However, 11 of 42 fish analyzed contained arsenic levels that exceeded the concern level of 0.8 µg/g, dry weight (Lowe and others, 1985, p. 370). Five of the eleven fish that exceeded the concern level were from reference sites. The median arsenic concentrations in whole fish tissue from carp collected from Humboldt Lake, Army Drain, and the Humboldt River near Lovelock was 1.08 µg/g, which exceeds the concern level. The concern level was also exceeded in carp collected from the Humboldt River near Golconda (site 1) and in a channel catfish (*Ictalurus punctatus*) collected from the Humboldt River near Imlay (site 2). The greatest arsenic concentrations were consistently found in bottom fish (carp, channel catfish, and Tahoe suckers [*Castostomus tahoensis*]).

Birds

Geode (1985, p. 303) has defined a concern level for arsenic residue in bird liver as between 7.2 and 36 µg/g, dry weight. The maximum arsenic concentration observed in bird liver was 0.65 µg/g, much less than the concern level.

Boron

Plants

Boron has been demonstrated to adversely affect growth of mallard ducklings at 100 µg/g in their diet (Patuxent Wildlife Research Center, 1987, p. 9-13). Boron concentrations in plant tissue from reference sites were low (28-35 µg/g) and did not exceed the dietary effect level. Boron concentrations in 16 of 35 plant tissue samples from sites receiving irrigation drainage exceeded the dietary effect level.

Pondweed is an important forage plant for waterfowl in Humboldt WMA, and management practices are based upon production of this plant. Eight of 10 pondweed samples had concentrations greater than the dietary effect level. The highest boron concentration observed in plant material was 620 µg/g in a sample of pondweed from Humboldt Lake and the next highest, 561 µg/g, was also in a pondweed sample from Toulon Lake.

Insects

Data for evaluating direct effects of boron residue levels on aquatic insects are unavailable. The dietary effect level (100 µg/g; Patuxent Wildlife Research Center, 1987, p. 9-13) was exceeded in 1 of 10 samples, a sample of brine fly larvae from Rennie Road drain 2 (130 µg/g). Determining whether boron concentrations in insect tissue increased in a downstream direction was impossible because limited amounts of tissue from the reference site resulted in a high reporting limit.

Fish

Because of the paucity of toxicological information concerning boron in fish, a discussion is not attempted in this report. Most of the boron concentrations in fish were less than or near the analytical reporting limit.

Birds

Fifty-six bird tissue samples were analyzed for boron. Smith and Anders (1989) report that 17 µg/g of boron in mallard duck livers is associated with impaired reproduction and duckling growth. This effect level was exceeded in five of five tissue samples from juvenile black-necked stilts, and four of five juvenile coot samples collected in 1986 from Humboldt Lake. The maximum concentration was 190 µg/g in a juvenile stilt sample.

The median boron concentration in five juvenile coot and five juvenile stilt samples collected in 1986 from Humboldt Lake was 46 µg/g. In 1987-88, the median concentration in 12 juvenile coot and 5 juvenile stilt samples was 4 µg/g. The reason for the large difference in boron concentration between 1986 and 1987-88 is not known. Differences in laboratory analytical procedures, possible sample contamination, or both were ruled out as a cause.

Smith and Anders (1989) report that 13 µg/g boron in duck eggs was associated with reduced hatch weight and that 49 µg/g boron in eggs was associated with reduced hatch rate and juvenile survival. Thirty-seven eggs were analyzed for boron in 1988; the median boron concentration in the eggs was 6.9 µg/g. Two eggs containing 14 µg/g boron exceeded the effect level.

Chromium

Plants

Haseltine and others (1985, p. 2) determined that dietary chromium concentrations at or above 36 µg/g adversely affect growth and survival of black ducks (*Anas rubripes*). None of the 37 plant tissue samples exceeded this dietary effect level.

Insects

Suitable data for evaluating the significance of chromium in invertebrate tissue are not available. The dietary effect level is 36 µg/g (Haseltine and others, 1985, p. 2). Chromium in 10 insect tissue samples ranged from less than the analytical reporting limit (1 µg/g) to 20 µg/g. The highest concentration was in a sample of dipteran larvae from Humboldt Lake.

Fish

The concern level for chromium in fish tissue is a concentration in excess of 4.0 µg/g (Eisler, 1986, p. 44). This level was exceeded in all the fish samples collected from Humboldt Lake. The highest chromium concentration, 7.6 µg/g, was found in a Sacramento perch. Tissue samples collected from the reference site and from the Humboldt River near Lovelock had chromium concentrations at or near the concern level.

Birds

Eisler (1986, p. 44) has defined a concern level for chromium in wildlife tissue to be a concentration in excess of 4.0 µg/g. The concern level was not exceeded in any bird tissue sample.

Copper

Fish

The concern level for copper in fish is 3.7 µg/g, dry weight (Lowe and others, 1985, p. 370). This level was exceeded in 10 of 42 fish tissue samples. The two highest concentrations, 9.9 and 7.3 µg/g, were in samples from the reference site at Humboldt River near Imlay (site 2 in fig. 1). Four of six carp samples from areas receiving irrigation drainage exceeded the concern level.

Mercury

Plants

Heinz (1979, p. 395) observed adverse reproductive effects among mallard ducks maintained on a diet containing as little as 0.50 µg/g methylmercury (or 0.47 µg/g total mercury). Only one sample exceeded this dietary effect level and that was an unidentified plant at a reference site on the Humboldt River near Imlay, near the site of a mercury mill that operated during 1913-14.

Insects

Suitable data for evaluating the significance of mercury residue in invertebrate tissue are not available. The dietary effect level is 0.47 µg/g mercury (Heinz, 1979, p. 395). No insect samples exceeded the effect level.

Fish

The concern level for mercury residue in whole fish that may affect fish reproduction is 0.65 µg/g, dry weight (Lowe and others, 1985, p. 370). Carp from Humboldt Lake contained concentrations that ranged from 0.46 to 0.72 µg/g. Game fish have become scarce in the Humboldt WMA, thus only one game fish was taken from Humboldt Lake. The fish, a Sacramento perch (*Archoplites interruptus*), had a whole-body residue of 0.66 µg/g mercury. Seven bluegill sunfish (*Lepomis macrochirus*) from the Humboldt River near Lovelock had a median whole-body mercury residue level of 0.85 µg/g (range 0.62 to 1.4 µg/g). Cooper and others (1985, p. 57) have reported that carnivorous game fish may be expected to contain higher concentrations of mercury than herbivorous non-game fish.

The dietary effect level for mercury in fish (as a dietary item for birds) is 0.47 µg/g (Heinz, 1979, p. 395). Of 16 single fish or composite fish samples analyzed from Lovelock Valley, 12 exceeded this value. Levels from all channel catfish samples from the reference sites equaled or exceeded the dietary effect level. The median concentration was 0.55 µg/g. The highest concentration, 1.3 µg/g, was in a channel catfish sample from the Humboldt River near Imlay (site 2). The lowest mercury concentrations (median 0.11 µg/g) were in white crappie samples also collected at the Humboldt River near Imlay.

Birds

The mean liver residue level of mercury in female mallard ducks associated with reduced reproductive success is 4.3 µg/g (Heinz, 1979, p. 396). This effect level was exceeded in only 1 of 53 bird liver tissue samples that were analyzed; a juvenile black-necked stilt sample from Humboldt Lake. The concentration of mercury in eggs associated with reduced hatch rate and juvenile survival is 3.1 µg/g (Heinz, 1979). This effect level was not exceeded in any of 37 eggs that were analyzed.

Selenium

Plants

The dietary effect level was used to describe the importance of selenium in plants. Lemly and Smith (1987, p. 9) have, on the basis of reproductive effects, identified a dietary effect level of 5 µg/g for selenium in fish food. This level was not exceeded in any of the 37 plant tissue samples analyzed.

Insects

Invertebrates are commonly consumed by fish and migratory birds. Accordingly, the dietary effect level for fish (5 µg/g) was used as a guideline for interpretation of the insect data. The median selenium concentration in insects from the study area was 4.1 µg/g. The dietary effect level for fish was met or exceeded in two insect samples collected from Toulon and Humboldt Lakes.

Fish

Data used to evaluate selenium residue in whole fish are: (1) concern level of 4.0 µg/g, dry weight (Lemly and Smith, 1987, p. 9); (2) effect level of 10.0 µg/g, dry weight (Lillebo and others, 1988, p. 48); and (3) dietary effect level for fish of 5.0 µg/g, dry weight (Lemly and Smith, 1987, p. 9).

Selenium concentrations in whole carp and composite fish samples collected throughout the study area are shown in figure 18. The median selenium concentration in fish from areas affected by irrigation drainage (2.8 µg/g) was statistically higher (Mann-Whitney nonparametric *t*-test, $P < 0.01$) than in fish from reference sites (2.2 µg/g). The highest concentration of selenium (4.9 µg/g) was in a sample from the Humboldt River near Imlay, a reference site (fig. 1). This value exceeded the concern level for fish. Fish from the reference site contained a range of selenium concentrations (0.09 to 4.9 µg/g) similar to that collected from sites affected by irrigation drainage (1.9 to 3.9 µg/g).

Birds

The level for direct effects upon birds, 9.0 µg/g dry weight, was used to evaluate the possible adverse effects of selenium. This effect level is based upon residue levels in female mallard duck livers associated with decreased productivity and duckling survival (Heinz and others, 1987). Concentrations of selenium in coot, stilt, and duck tissue are shown in figure 19. The figure, which includes data from the Stillwater WMA for comparison, shows that selenium concentrations in stilts, coots, and ducks are higher in Humboldt WMA than in Stillwater WMA.

The selenium concentration in bird livers exceeded the effect level in 44 of 53 samples collected from Humboldt and Toulon Lakes. The median selenium concentration in juvenile stilt livers was 29 µg/g and the highest concentration was 48 µg/g. In juvenile coot livers, the median selenium concentration was 9.9 µg/g and the maximum was 15 µg/g. In 17 samples of duck liver, the median selenium concentration was 13 µg/g and the maximum was 23 µg/g.

Three samples of muscle tissue from ducks, collected in October 1989, had selenium concentrations ranging from 2.7 to 7.5 µg/g, dry weight. The 7.5-µg/g dry-weight concentration is very near the Nevada Public Health advisory criterion: 2 µg/g, wet weight (equivalent to 7.2 µg/g, dry weight). The species collected for muscle tissue analysis--shovelers, and green-winged teal--do not normally breed in the Humboldt WMA and were probably recent arrivals (Norman A. Saake, Nevada Department of Wildlife, oral commun., March 1992).

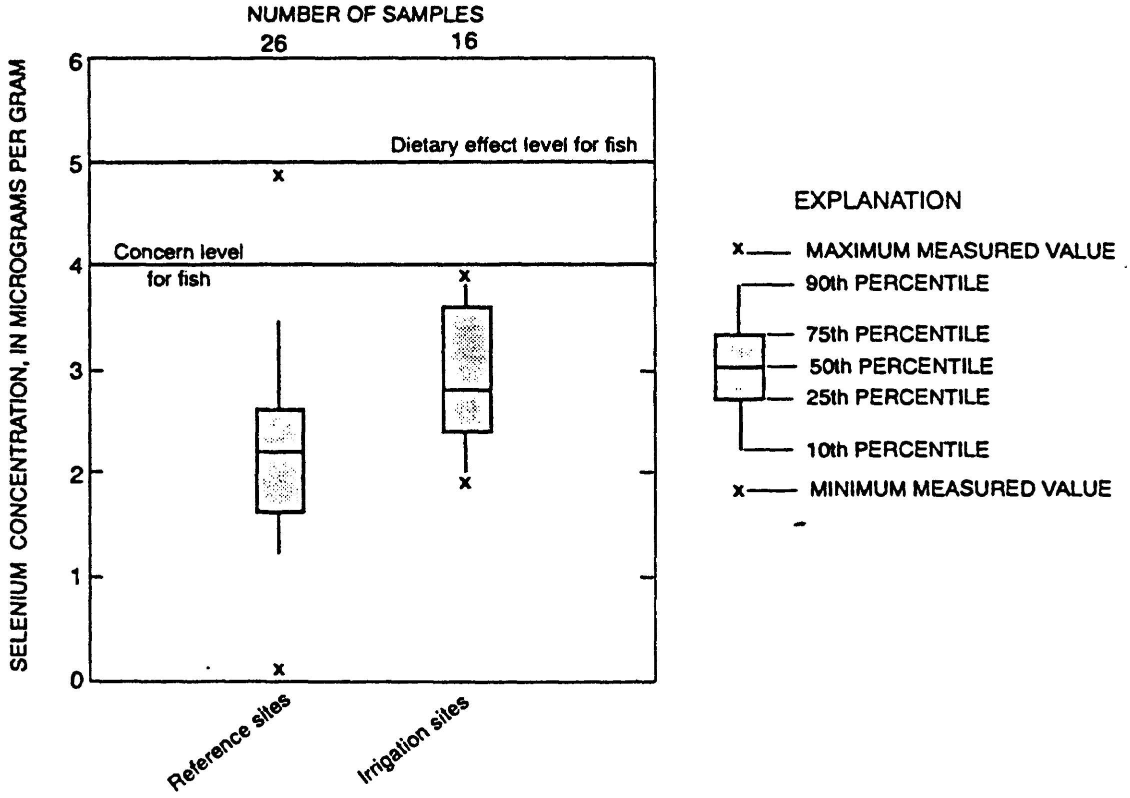

Figure 18. Concentrations of selenium in fish tissue from reference sites and sites receiving irrigation drain water, 1986, 1987, and 1990.

Coot and duck embryos were inspected for deformities in 1988 and none were found. The median selenium concentration in 27 coot eggs and 10 duck eggs collected during May-June 1988 from Toulon Lake was 3.0 µg/g and the maximum was 4.48 µg/g. These levels are much lower than those in coot eggs from Ouray National Wildlife Refuge that were associated with embryo deformities and death (Stephens and others, 1988).

Zinc

Fish

The 85th-percentile concentration of zinc residue in whole-body fish found in the National Contaminant Biomonitoring Program was 155 µg/g (Lowe and others, 1985, p. 370). This concentration was exceeded in three carp samples; two were from a reference site (Humboldt River near Golconda) and one from Army Drain.

Organochlorine Compounds

A total of 15 fish samples were analyzed for an array of organochlorine compounds that had been used in the study area. None of these compounds were detected in fish from areas that receive irrigation drainage. A channel catfish from the Humboldt River near Imlay contained small concentrations of *p*',*p*'-DDE (0.03 µg/g), *p*',*p*'-DDT (0.01 µg/g), and *trans*-Nonachlor (0.01 µg/g). A walleye from the same site contained 0.02 µg/g DDE. This site is considered a reference site and the sources of the pesticides are not known.

Biotoxicity Tests

Water samples from 34 sites in irrigation drains, the Humboldt River, and Toulon Lake were screened for toxicity using Microtox procedures and specific-conductance measurements. Nine of the 34 sites in Lovelock Valley where toxicity was

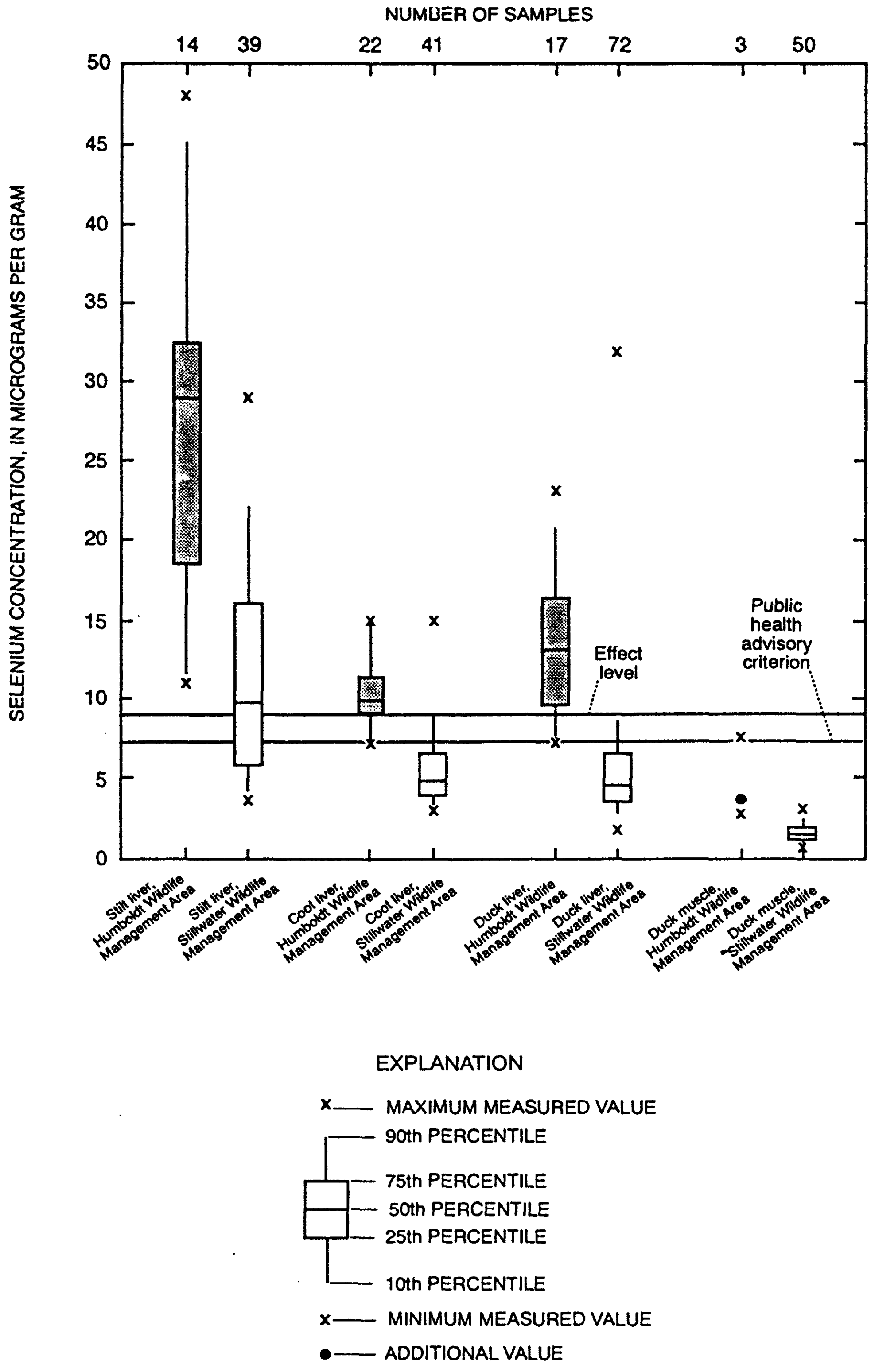

Figure 19. Concentrations of selenium in bird tissue from Humboldt Wildlife Management Area (shaded) and Stillwater Wildlife Management Area, 1986-89.

suspected and two reference sites upstream of the study area were chosen for subsequent biotoxicity tests. Field water-quality measurements made at selected sites during the site screening are shown in table 7. Measured specific-conductance values ranged from 410 μS/cm at the Humboldt River near Golconda (site 1 in fig. 1) to 22,400 μS/cm in Rennie Road drain 2 (site 15). Multiple measurements were made at Army Drain 2 (site 17 in fig. 10) and Toulon Drain at the inflow (site 19). Specific conductance of the water at Army Drain changed greatly over short periods. Army Drain receives water pumped in from drainage ditches, and quality of drain-water samples depends on the time of sample collection in relation to pumping and operational spills.

At reference sites, the bacterium used in the Microtox procedure showed no adverse response to the water. The EC_{50} readings were greater than 80 percent at 5-, 15-, and 30-minute intervals, indicating no toxicity.

Reference Sites

No mortality occurred during biotoxicity tests of water collected from the reference sites (Humboldt River near Golconda and the Humboldt River near Imlay, sites 1 and 2; table 8). Two of these tests were extended beyond the planned 48 hours; the daphnids appeared normal after 10 days and were reproducing in all tests as would be expected in healthy organisms. In these extended tests, the daphnids produced a brood on day 8; microscopic examination of some adults at the end of the tests revealed production of eggs for a second brood. Specific conductances of water at the reference sites were low compared with those of samples from other locations (table 7). Concentrations of potential inorganic contaminants in test water and in sediment samples collected from the reference sites also were relatively low compared with those from other locations (tables 22 and 23 in Supplemental Data section).

Drains

Based on the findings of the initial reconnaissance, biotoxicity tests were conducted on water samples collected from two sites on Army Drain, three sites on Rennie Road drain, one site on Toulon drain and one site on Graveyard Drain. Tests were also conducted on sediment from Rennie Road drain 2 and Toulon Drain.

Specific-conductance measurements made at sites selected for biotoxicity tests show that water quality in the drains can change rapidly over a short period of time (table 7). The rapid changes in water quality suggest that the toxicity of water in a drain also might change rapidly. Specific conductance was high at Rennie Road drain 2 (site 15, 22,400 μS/cm) and Army Drain 2 (site 17, 14, 400 μS/cm), but was lower in Graveyard Drain (site 13, 3,320 μS/cm) and Toulon Drain at inflow (site 19, 3,510 μS/cm) (table 7).

Aquatic biotoxicity tests for Army Drain 2 and Army Drain at inflow (sites 17 and 18) and Graveyard Drain 2 (site 13) were conducted using water collected from the Golconda site (site 1) as the dilution water. Water from Army Drain 2, Army Drain at inflow, and Graveyard Drain 2 showed no evidence of acute toxicity to daphnid neonates exposed to drain water for 2 days (table 7). The same was true of fathead-minnow larvae after 4 days of exposure to drain water collected from Army Drain at the inflow and Graveyard Drain 2. Full-strength samples and 50-percent dilutions of water from Army Drain 2 caused 5 percent to 10 percent mortality in fathead-minnow larvae, and the full-strength water caused 75 percent mortality to mysid shrimp after 2 days. In control tests on water from Army and Graveyard Drains, no mortality was recorded for any species. Tests using sediment were not conducted for Army Drain and Graveyard Drain sites because no adverse response to water was observed in tests with daphnids and fathead-minnow larvae.

Chemical analysis of test water for toxic contaminants indicated relatively low concentrations of potentially toxic trace elements in Army Drain at the inflow in comparison to water from the Toulon Drain at the inflow, and the Rennie Road drain sites (table 22 in Supplemental Data section). Specific conductance in Toulon Drain near the inlet to Toulon Lake increased greatly as the lake rapidly dried up (table 6). At this site, specific conductance decreased between June 11 and June 15--possibly the result of inflow of fresh water during this period. The time of sample collection may greatly influence the results of the biotoxicity tests.

No tests were conducted using water from one of the Toulon Drain sites (site 7) because of the drought. In tests using sediment from that site, however, complete chironomid mortality occurred after 2 days of exposure to undiluted sediment. After 10 days of exposure, chironomid mortality was complete in undiluted and 50-percent-dilution tests, and in 25-percent-dilution tests, mortality was 70 percent. No mortality occurred in the 12.5-percent-dilution or control tests.

Complete mortality of daphnids, fathead-minnow larvae, and mysid shrimp occurred in all tests using undiluted drain water from Toulon Drain at the inflow to Toulon Lake (site 19). In 50-percent-dilution tests of drain water, complete mortality of daphnids and mysid shrimp and 60-percent mortality of fathead-minnow larvae occurred. After 4 days of exposure 70-80 percent mortality of mysid shrimp occurred in the 25-percent and 12.5-percent dilutions of drain water. There was 10-percent mortality in the control test with mysid shrimp but this was considered acceptable and within limits of the study design. After 10 days of exposure to undiluted and 50-percent dilutions of sediment from the site, there was complete mortality of chironomids and 60-percent mortality in the 25-percent dilution. No mortality occurred in the 12.5-percent-dilution test or the control.

The water in Rennie Road drain was tea colored, odiferous, and had a thin film of powdery material floating on the surface. Furthermore, a large population of brine flies (*Ephydra sp.*) flourished on the surface of the water. The largest specific conductance of any of the water samples was measured in Rennie Road drain 2, and the concentrations of potentially toxic inorganic trace elements measured were also large there as well (table 22). In the Rennie Road drain, the mean concentration of arsenic in sediment samples was 21.5 mg/kg and boron was 43 mg/kg (table 23 in Supplemental Data section).

Complete mortality of daphnids, fathead-minnow larvae, mysid shrimp, and chironomids occurred by the end of all tests using undiluted drain water and sediment from the Rennie Road drains (table 8). The rate at which the organisms died indicated the relative toxicity of the drain water to the organisms that could inhabit it. Complete mortality of daphnids and fathead-minnow larvae occurred in full-strength drain water from the Rennie Road drain sites within 12 hours of exposure; and in Rennie Road drain 2, complete mortality occurred within 4 hours of exposure to full-strength drain water and sediment. No mortality was observed in control tests, except in mysid shrimp where 10-percent mortality occurred in the Rennie Road drain 1 test. This 10-percent mortality in the control test was considered acceptable and within limits of the study design.

In biotoxicity tests using sediment from Rennie Road drain 2, 20-percent to 80-percent mortality of chironomid larvae occurred in most tests within 2 days of exposure--except in the 12.5-percent-dilution tests where no mortality had occurred after 2 days (table 8). After 4 days of exposure, complete mortality occurred in all treatments, except in 12.5-percent-dilution treatment where 80 percent of the organisms had died. Complete mortality of the chironomids occurred in all dilutions of the sediment after 10 days. In Toulon Drain sediment and the Rennie Road drain sediment and water, a dose-response pattern was evident in some treatments. Although salinity was undoubtedly stressful to test organisms, cumulative mortalities in treatments with mysids, a salt-tolerant marine organism, were similar to mortalities in treatments with other test organisms. This result suggests that mortalities in test organisms did not occur as a result of exposure to salinity alone. Finger and others (1993) concluded that a combination of toxic trace elements may be the cause of mortality in biotoxicity tests of similar water from Stillwater WMA.

Lakes

Water samples were collected as grab samples from the center of Toulon Lake across from the old arsenic mill. Specific conductance was 20,300 μS/cm in the center of Toulon Lake and both water and sediment were toxic to all species tested (table 8). In tests with daphnids, fathead-minnow larvae, and mysid shrimp, mortality occurred rapidly: 100-percent mortality occurred within 2 days of exposure to undiluted water from Toulon Lake. Exposure of organisms to 50-percent water from Toulon Lake resulted in mortality of at least 60-90 percent after 4 days of exposure. In some of the control treatments cumulative mortalities of

Table 7. Field water-quality measurements and 15-minute Microtox readings for biotoxicity test sites, 1990 (data from U.S. Fish and Wildlife Service.)

[Abbreviations and symbols: °C, degrees Celsius; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 °C; EC_{50}, see section on "Biotoxicity Tests," p. 26; --, no data; <, less than; > greater than.]

Site No. (figs. 1 and 10)	Location	Date	Specific conductance (µS/cm)	pH (standard units)	Water temperature (°C)	Oxygen, dissolved (mg/L)	EC_{50} (percent)
			Reference Sites				
1	Humboldt River near Golconda	6-26-90	410	--	21.0	--	>80
2	Humboldt River near Imlay	6-26-90	456	8.7	27.0	7.3	>80
			Irrigation Drainage Sites				
17	Army Drain 2	5-03-90	14,400	9.1	21.5	--	<25
		5-09-90	19,200	8.0	20.5	--	<25
		5-25-90	8,800	8.6	25.0	7.6	<25
		5-30-90	14,100	8.8	22.5	7.2	<25
		6-15-90	3,890	8.7	21.0	--	<25
		6-27-90	2,640	8.7	20.0	--	<25
18	Army Drain at inflow into Humboldt Lake	6-15-90	2,810	8.4	28.0	7.4	<25
13	Graveyard Drain	5-03-90	3,320	--	21.5	--	<25
		5-09-90	3,800	--	22.0	--	<25
14	Rennie Road drain 1	5-25-90	11,400	7.9	25.0	7.0	<25
15	Rennie Road drain 2	5-25-90	22,400	8.2	24.0	6.8	<25
16	Rennie Road drain 3	5-25-90	7,600	8.3	22.0	--	<25
19	Toulon Drain at inflow into Toulon Lake	5-03-90	3,510	8.2	24.5	4.7	<25
		5-09-90	8,320	8.4	30.0	5.8	<25
		6-11-90	16,500	8.6	28.0	5.2	<25
		6-15-90	12,600	8.8	29.0	--	<25
20	Toulon Lake (center)	5-25-90	20,300	--	--	--	--

Table 8. Cumulative mortality of daphnids, fathead-minnow larvae, mysid shrimp, and chironomids after exposure to water and sediment collected from reference sites and sites receiving irrigation drain water, 1990 (data from U.S. Fish and Wildlife Service.)

Site No. (figs. 1 and 10)	Location	Medium	Test organism	Days	Percent dead for different concentrations of drain water or sediment[a]: 100-percent sample	50-percent sample	25-percent sample	12.5-percent sample	Control
			Reference Sites						
1	Humboldt River near Golconda	Water	Daphnids	2	0	0	0	0	0
				10	0	0	0	0	0
			Fathead-minnow larvae	4	0	0	0	0	0
			Mysid shrimp	2	0	0	0	0	0
				4	0	0	0	0	0
2	Humboldt River near Imlay	Water	Daphnids	2	0	0	0	0	0
				10	0	0	0	0	0
			Fathead-minnow larvae	4	0	0	0	0	0
			Mysid shrimp	2	0	0	0	0	0
				4	0	0	0	0	0
			Irrigation Drainage Sites						
17	Army Drain 2	Water	Daphnids	2	0	0	0	0	0
			Fathead-minnow larvae	4	10	5	0	0	0
			Mysid shrimp	2	75	5	0	0	0
18	Army Drain at inflow into Humboldt Lake	Water	Daphnids	2	0	0	0	0	0
			Fathead-minnow larvae	4	0	0	0	0	0
13	Graveyard Drain 2	Water	Daphnids	2	0	0	0	0	0
			Fathead-minnow larvae	4	0	0	0	0	0
7	Toulon Drain	Sediment	Chironomids	2	100	40	0	0	0
				10	100	100	70	0	0
19	Toulon Drain at inflow into Toulon Lake	Water	Daphnids	2	100	100	0	0	0
			Fathead-minnow larvae	4	100	60	0	0	0
			Mysid shrimp	2	100	100	80	40	10
				4	100	100	80	70	10
		Sediment	Chironomids	2	20	0	0	0	0
				10	100	100	60	10	0
14	Rennie Road drain 1	Water	Daphnids	2	100	0	0	0	0
			Fathead-minnow larvae	4	100	20	0	0	0
			Mysid shrimp	2	40	30	30	0	0
				4	100	90	80	70	10
15	Rennie Road drain 2	Water	Daphnids	2	100	40	0	0	0
			Fathead-minnow larvae	4	100	40	0	0	0
			Mysid shrimp	4	100	80	60	40	0
		Sediment	Chironomids	2	80	60	20	0	0
				4	100	100	100	80	0
				10	100	100	100	100	0
16	Rennie Road drain 3	Water	Daphnids	2	100	10	0	0	0
			Fathead-minnow larvae	4	100	0	0	0	0

TABLE 8. Cumulative mortality of daphnids, fathead-minnow larvae, mysid shrimp, and chironomids after exposure to water and sediment collected from reference sites and sites receiving irrigation drain water, 1990 (data from U.S. Fish and Wildlife Service.)--Continued

Site No. (figs. 1 and 10)	Location	Medium	Test organism	Days	Percent dead for different concentrations of drain water or sediment[a] 100-percent sample	50-percent sample	25-percent sample	12.5-percent sample	Control
20	Toulon Lake at center	Water	Daphnids	2	100	100	0	0	0
			Fathead-minnow larvae	2	100	40	20	0	10
				4	100	60	30	10	0
			Mysid shrimp	2	100	90	30	40	10
				4	100	90	40	50	10
		Sediment	Chironomids	2	60	20	0	0	0
				10	100	100	60	0	0
				2	100	100	80	0	0
				10	100	100	100	60	0

[a] Control samples and dilution media were water from reference site and "clean" sand from Monterey, Calif. Oxygen levels in all treatments exceeded 40-percent saturation.

10 percent of mysid shrimp and 10 percent of fathead-minnow larvae were observed on day 2, but this loss was considered acceptable and within limits of the study design.

Complete mortality occurred in chironomid larvae after 10 days of exposure to undiluted and 50-percent dilutions of sediment from Toulon Lake. In one test with sediment from the center of Toulon Lake, greater than 80-percent mortality occurred after 2 days of exposure to 100-percent, 50-percent, and 25-percent dilutions of the sediment. Complete mortality did not take place in the 25-percent-dilution treatment until day 8 of the test. In one test, 60-percent mortality of chironomids occurred after 10 days of exposure to 12.5-percent dilution of sediment; in the other test, there was no mortality.

Benthic Biosurveys

In aquatic ecosystems, sensitive species can be eliminated from an area by stress, such as change in habitat or the addition of contaminants, and will not return until the stress is removed. Thus, changes in biotic composition are regarded as the primary evidence of environmental impact (Pratt, 1990). Therefore, biodiversity studies were conducted using benthic biosurveys. In May 1990, benthic insects were collected from the Humboldt River near Golconda (site 1), the Humboldt River near Imlay (site 2), the Humboldt River near Lovelock (site 3), the Rennie Road drains (sites 14, 15, 16), and Toulon Drain (site 19) and Army Drain (site 18) near the inflows to Toulon and Humboldt Lakes. A list of the insects collected at the sites is presented in table 9.

The benthic biosurvey results indicate that insect diversity and abundance were diminished in the drains (sites 4, 15, 18, and 19) as compared with the reference sites 1 and 2. These changes can be the result of changes in water chemistry or the result of changes in habitat--in particular water temperature and substrate differences.

At reference sites 1 and 2, 245 insects were collected, which included species in seven families. Ephemeropteran, plecopteran, and tricopteran insect species were abundant and constituted about 41 percent of the species collected (table 9). No pollution-tolerant taxa, such as Chironomidae and Oligochaetae, were collected as part of the benthic biosurvey; however, in June 1990, chironomids were found at the Humboldt

Table 9. Taxonomic list and number of benthic invertebrates collected from reference sites and sites receiving irrigation drain water, 1990

Site number (figs. 1 and 10)	Taxa	Number of invertebrates
	Reference Sites	
1 and 2	Diptera	
	Tabanidae (horseflies, emerging adults)	1
	Ephemeroptera	
	Ephemeridea (mayflies, mainly nymphs)	101
	Hemiptera	
	Corixidae (water boatmen, mainly emerging adults)	52
	Notonectidae (backswimmers, mainly emerging adults)	48
	Odonata	
	Gomphidea (dragonflies, mainly naids)	32
	Plecoptera	
	Peltoerlidae (stoneflies, emerging adults)	1
	Trichoptera	
	Lepidostomatidae (caddisflies, mainly larvae)	10
		Total 245
	Irrigation Drainage Sites	
4	Hemiptera	
	Corixidae (water boatmen, mainly emerging adults)	17
	Notonectidae (backswimmers, mainly emerging adults)	12
	Tricoptera	
	Lepidostomatidae (caddisflies, mainly emerging adults)	4
		Total 33
15	Diptera	
	Ephydridae (brine flies, larvae and emerging adults)	500+
		Total 500+
18 and 19	Diptera	
	Chironomidae (midges, larvae)	3
	Hemiptera	
	Corixidae (water boatmen)	11
	Notonectidae (backswimmers)	7
		Total 21

River near Golconda site and were collected for tissue analysis. Other insects collected from the sites were in the Orders Odonata, Hemiptera, and Diptera in different developmental stages, particularly the nymph stage.

The Humboldt River near Lovelock (site 4) showed less taxa richness in comparison to the reference sites. There were 33 insects collected in 3 families. Most of the insects (88 percent) were from the Order Hemiptera, mostly corixids and notonectids. In contrast to the reference sites, no ephemeropteran and plecopteran species and only one tricopteran species were collected. Tricopterans are a pollution-sensitive taxon and may indicate relatively good water quality in comparison to other downstream sites where no ephemopteran, plecopteran, or tricopteran species were found.

Taxa richness was very low at Rennie Road drain 2 (site 15). Only one species, *Ephydra*, was found. *Ephydra* is a salt-tolerant species which is an indicator of poor water quality. More than 500 individuals, mainly larvae and emerging adults, were collected.

Taxa richness in Toulon and Army Drains (sites 18 and 19) was greater than in Rennie Road drain. Although two species of Hemiptera (water boatman and backswimmers) and one species of Diptera (midge flies) were found, the occurrence of only three resident families is indicative of biological stress at these sites. The absence of dragonflies, mayflies, and other adult flying insects from the sites may indicate that the survey results were highly impacted by the drought conditions; these insects are normally very common in the Humboldt Sink (Norman A. Saake, Nevada Department of Wildlife, written commun., 1991).

Results of the benthic biosurvey indicate lower biodiversity in the benthic community in the lower Humboldt River and irrigation drains in Lovelock Valley. In comparison to the reference sites, there is a decrease in the abundance and diversity of pollution-sensitive taxa (Ephemeroptera, Plecoptera, and Tricoptera) in the Humboldt River near Lovelock and these taxa are completely absent from the Army Drain, Toulon Drain, and Rennie Road drain 2. Also noted were low taxa richness relative to the reference sites and an increase in the percent contribution by the dominant family. More data would be needed to determine how much of the change in biotic composition is due to the effects of irrigation drain water on water quality as opposed to natural changes in water quality and habitat.

BIOLOGICAL EFFECTS OF CONTAMINANTS

At Kesterson National Wildlife Refuge (NWR) in California, grossly deformed birds and a few hundred dead coots were found in the ponds between 1984-85. Adult coots were emaciated and were shown to have abnormal feather loss and atrophied breast muscles (Ohlendorf and others, 1988). No similar effects were found at Humboldt WMA. At Kesterson NWR, deformed birds and adverse reproductive effects on migratory birds were documented to be caused by selenium alone (Ohlendorf and others, 1986, p. 53).

At Humboldt WMA, selenium concentrations in water are lower than at Kesterson NWR. There are multiple contaminants at Humboldt WMA, and the effects on wildlife may be subtle. In a natural setting, subtle effects are difficult to document.

Examples of subtle effects caused by chronic contamination include induced starvation, increased susceptibility to predators, and increased susceptibility to disease and parisitism. Heinz and others (1988, p. 561) recorded reductions in food consumption, as well as weight, of mallard ducklings fed selenium. They reported that the selenium concentration in liver was not diagnostic of death, but suggested that "...selenium-induced starvation may have been related to duckling mortality."

Concentration of Selenium and Exposure Pathways

Selenium is biomagnified through the food chain in Humboldt WMA. Lemly and Smith (1987, p. 4) described biomagnification of selenium from water through a food chain. Selenium concentrations were generally low in most filtered water samples from Lovelock Valley. However, in areas receiving irrigation drain water, the median selenium concentration was 0.87 µg/g in sago pondweed and 4.1 µg/g in insect tissue.

Pondweed and insects are important food items of waterfowl in Humboldt WMA. Biomagnification occurs to the extent that the selenium concentrations in livers of many juvenile birds analyzed during this study greatly exceeds that found in their food items.

Selenium concentrations in birds from Humboldt WMA were lower than in birds from Kesterson NWR, Calif.; Ouray NWR, Utah; and the Kendrick Reclamation Project Area, Wyo. (table 10). They were, however, similar to those in birds from the Salton Sea Area, Calif., and about twice those in birds collected from the nearby Stillwater WMA, Nev. Comparison among these sites is made difficult by the fact that selenium concentration in bird tissue may change over a breeding season, and there may be between-year differences in selenium concentrations (Schroeder and others, 1988). Age of the birds may be important because bird diets can change as they mature; the coots sampled at Kesterson NWR were adults, whereas the coots sampled at Humboldt were juveniles.

Skorupa and others (1990) devised what they called the 10/30 guideline for assessing biological risk associated with selenium concentrations in breeding waterfowl. Mean selenium concentrations below 10 μg/g in a population of birds are not associated with biological risk; mean concentrations greater than 30 μg/g are associated with teratogenesis. Concentrations in the range of 10-30 μg/g require individual studies of reproductive performance to assess risk. These guidelines cannot be directly applied to Humboldt WMA, because primarily juvenile birds rather than breeding birds were collected. The mean selenium concentration in the juvenile stilts was 27 μg/g; in juvenile coots, it was 10 μg/g; and in ducks it was 13 μg/g. These data suggest stilts are at greater biological risk than coots or ducks. No deformed embryos were observed in Humboldt WMA, perhaps because only coot and duck eggs were collected and examined.

The primary source of selenium in wetland organisms is still unknown but probably originates from the soils in and near irrigated areas in Lovelock Valley. Insufficient data exist to describe the pathways by which selenium enters the wetlands and ultimately bird tissue. More data would be required to characterize the distribution and concentrations of selenium in shallow ground water and bottom sediment in Lovelock Valley.

Possible reasons for not finding selenium in water samples are as follows:

1. Bound selenium may be the principal way selenium moves from the irrigation drains to the lake. Selenium in ground water entering the open drains may be readily absorbed by living organisms, such as algae, or bound to sediment and detritus. This uptake may explain why selenium concentrations in water from the reference sites were similar to those from the lakes. It may also explain why the selenium in bottom sediment was three to four times greater in the wetlands than in the reference sites. Selenium was analyzed in filtered water samples, thus selenium bound to particulate matter greater than 0.45 μm in diameter would not have been measured.
2. Evidence from the nearby Carson Desert indicates that selenium may be unevenly distributed in the shallow alluvial aquifer beneath irrigated areas and adjacent land (U.S. Bureau of Reclamation, 1987). Soluble selenium may be entering wetlands directly as ground-water inflow.
3. Selenium now found in the wetlands may not have originated in irrigated lands and been transported by drain water. Rather, selenium may always have existed in wetlands and soils of created wetlands.
4. Lovelock Valley was settled in 1862, and many of the agricultural fields have been irrigated for years. The selenium now being detected in various plant and animal tissues may have been transported in surface and ground water to the wetlands long ago.

Explanations 3 and 4 are believed to be the least likely because they imply that selenium now in the wetlands has been there a long time. Selenium does cycle and has several volatile forms; if it were deposited years ago, most of it probably would be gone now. Even selenium trapped in sediment may volatilize and escape, particularly since the lakes have completely dried up several times within the last 150 years.

Table 10. Concentrations of selenium in livers of aquatic birds from six areas of the Western United States

[Abbreviations and symbols: µg/g, microgram per gram; N, number of samples, rather than number of birds--many samples are composites of more than one bird; NWR, National Wildlife Refuge; WMA, Wildlife Management Area; --, no data available.]

	Location					
Species	Humboldt WMA[a]	Stillwater WMA[b]	Kesterson NWR[c]	Ouray NWR[d]	Kendrick Reclamation Project Area[e]	Salton Sea Area[f]
Coot						
N	22	41	23	4	--	3
Geometric mean (µg/g, dry weight)	10.0	5.1	81.5	32	--	16.8
Range (µg/g, dry weight)	7.0-15	2.9-15	19-160	25-43	--	14-21
Year	1986-88	1986-88	1984	1986	--	1986-87
Stilt						
N	14	39	9	--	--	3
Geometric mean (µg/g, dry weight)	25.4	9.8	46.4	--	--	21.7
Range (µg/g, dry weight)	11-48	3.6-29	19-80	--	--	19-27
Year	1986-88	1986-88	1984	--	--	1986-87
Duck						
N	17	72	--	--	7	8
Geometric mean (µg/g, dry weight)	12.9	4.65	--	--	20.6	16.5
Range (µg/g, dry weight)	7.2-23	1.8-32	--	--	13-56	7.0-27
Year	1986-88	1986-88	--	--	1986	1986-87

[a] This investigation.
[b] Hoffman and others, 1990; and Rowe and others, 1991.
[c] Ohlendorf and others, 1987.
[d] Stephens and others, 1988.
[e] Peterson and others, 1988
[f] Setmire and others, 1990.

The data suggest that the primary pathway of selenium from agricultural areas to migratory birds involves sediment and insects rather than water and plants. This conclusion is supported by the following facts:

1. The selenium concentration in water in Humboldt and Toulon Lakes is similar to that in the reference sites, whereas the selenium concentration in sediment is three to four times greater in the lakes than in the reference sites.
2. The median concentration of selenium in insects from Humboldt and Toulon Lakes was 4.6 µg/g, whereas the median concentration in plant tissue from the lakes was 0.68 µg/g.
3. The mean selenium concentration in juvenile stilt livers was almost three times greater than in juvenile coot livers, and the difference is significant (Mann-Whitney nonparametric *t*-test, $P < 0.001$). Stilts feed on aquatic insects and coots feed primarily on plants but supplement their diet with insects (Ohlendorf and others, 1986).

Concentration of Dissolved Solids

Management of water in wetland areas is determined in part by the dissolved-solids concentrations and the ability of important forage plants in the wetlands to tolerate these concentrations. Increasing salinity may kill vegetation directly by osmotic effects, by the effects of specific ions such as sodium, or by increasing their susceptibility to disease. Minton-Anderson (1976) demonstrated that increase in salinity caused the decline of cattails at a waterfowl management area in northern Utah, in part by facilitating the rapid growth of *Chaetophoma confluens*--a fungus which rots the rhizome of the cattails.

Dissolved-solids concentrations are believed to be a major cause of the loss of emergent vegetation in Stillwater WMA (U.S. Department of Interior, 1988, Appendix E, p. 76) and may be the cause of similar losses of emergent vegetation at Humboldt WMA. Stewart and Kantrud (1972, p. D19) described the responses of dominant emergent vegetation to changes in specific conductance of the water. The loss of emergent vegetation results in the loss of nesting habitat for migratory birds, escape cover for juvenile fish, and habitat for some invertebrate species which provide a forage base for fish and birds.

Some of the biological effects observed at Humboldt WMA, such as the decrease of sago pondweed and the increase of salt-tolerant weed plants like muskgrass, are principally the result of increased salinity. The increased salinity results from reduced water deliveries to the wetlands caused by the current drought, as well as upstream consumption of water for irrigation.

Avian Botulism

The primary waterfowl and shorebird disease identified in the wetlands area is avian botulism, which is caused by the anaerobic bacterium *Clostridium botulinum*, type C. In 1972, an outbreak of the disease killed about 9,000 birds in the Humboldt Sink (Vega, 1987, table 4) and another outbreak in the early 1980's killed several thousand more birds (Norman A. Saake, Nevada Department of Wildlife, oral commun., 1991). Because wetland habitats are only about 20 percent of their predevelopment size, and waterfowl populations are more concentrated now than in the past, and this factor increases the severity of outbreaks. Historically, wetlands were estimated at about 58,000 acres and in 1981 averaged about 12,850 acres (Hallock and others, 1981).

Botulism outbreaks are associated with insect dieoffs which provide a substrate for the growth of the bacteria. Insect mortality can be expected when evaporative water loss increases water temperature, decreases dissolved-oxygen concentration, and increases salinity and the concentration of toxic trace elements and pesticides to intolerable levels. Waterfowl and shorebirds are poisoned when they ingest maggots and decaying aquatic insects in which the botulism bacteria are growing (Locke and Friend, 1987, p. 83-94).

The botulism bacteria generally are present in wetlands, but only grow under anaerobic conditions. Inundated organic sediment is invariably anoxic, and one of the more common practices to prevent avian botulism is to periodically allow wetlands to dry and aerate the sediment.

Human Health

Edible tissue in three adult ducks taken during the 1989 hunting season was sampled to identify potentially toxic levels of contaminants because hunting is popular in the Humboldt WMA wetland habitats that receive irrigation drain water. Because of the drought and the absence of wetlands during the 1990 hunting season, no more samples were collected. Of the species collected in the Humboldt WMA, only ducks and coots are eaten by humans, and coots are not commonly hunted by people in the study area. No edible tissue in fish was sampled, because there is no sport fishery in the wetland habitats that receive irrigation drain water.

Mercury in Birds

The criterion for mercury in edible bird tissue established for public-health advisories in Nevada and California is 1 μg/g, wet weight (approximately 3.6 μg/g dry weight). Edible muscle tissue samples from three adult ducks from Humboldt WMA were analyzed, and none exceeded the mercury criterion. No samples of duck liver exceeded the criterion either; however, one sample of coot liver did exceed the criterion, but coots are not game birds.

Selenium in Birds

The level for selenium in edible bird tissue established for public-health advisories in Nevada and California is 2.0 μg/g, wet weight (approximately 7.2 μg/g, dry weight). The selenium in one of three duck muscle samples collected from Humboldt WMA during the hunting season in 1989 was 7.5 μg/g, dry weight, which exceeds the level. It is not known how long the ducks had fed in the area before being taken, but the species collected do not normally breed in Humboldt WMA and may be recent arrivals.

Selenium concentrations in duck and coot livers typically exceed the public-health advisory level. However, consumption of liver is considered a "worst-case human exposure" because duck livers are not commonly eaten (Klasing and Pilch, 1988, p. 9).

SUMMARY AND CONCLUSIONS

A reconnaissance investigation was begun in March 1990 to determine whether the quality of irrigation drainage in and near the Humboldt Wildlife Management Area has caused or has potential to cause harmful effects on human health, fish, and wildlife or to adversely affect other beneficial uses of water. This reconnaissance study focused on human health and on fish and wildlife.

Relatively dilute water from the Humboldt River is used to irrigate about 31,000 acres of pasture and cropland, principally alfalfa, in Lovelock Valley, which is the service area for the U.S. Bureau of Reclamation Humboldt Project. The Lovelock Valley is arid and has alkaline soil. The Humboldt WMA covers 36,235 acres, including an average of 12,850 acres of wetlands at the terminus of the Humboldt River in the Humboldt Sink. The wetlands in the Humboldt Sink receive irrigation drain water containing measured concentrations of dissolved solids ranging from 907 to 8,580 mg/L.

Samples of water, bottom sediment, and biota were collected from sites upstream and downstream from the Lovelock agricultural area. The samples were analyzed for potentially toxic trace elements, major ions, nitrogen, phosphorus, carbamate pesticides, herbicides, and radioactive substances in water, as well as organochlorine pesticide residues in bottom sediment and biota. Water samples were collected three times from March to November 1990; bottom-sediment were collected once during November 1990; and biological samples were collected from May through July in 1990. Data collected from the Humboldt WMA between October 1987 and March 1989 as part of the Stillwater WMA investigations were combined with data collected during this study.

The data were collected while the study area was undergoing an extended drought. Below-average amounts of runoff from the upper Humboldt River Basin during 1987-90 resulted in an almost complete disappearance of standing water in the Humboldt Sink and the near emptying of Rye Patch Reservoir during the summer of 1990.

A summary of potential contaminants and an indication of whether the concentrations of these contaminants at Humboldt Wildlife Management Area exceed Nevada water-quality standards for the protection of aquatic life, exceed geochemical baselines, or exceed concern levels are given in table 11. The results of this reconnaissance indicate that (1) arsenic, boron, mercury, and selenium concentrations are of primary concern to human health or to fish and wildlife in and near Humboldt Wildlife Management Area; and (2) un-ionized ammonia, sodium, and dissolved-solids concentrations may approach this level of concern.

The findings of this reconnaissance study indicate that contamination exists in wetland areas that receive irrigation drain water. Some of the contamination is due to historic mining activities, the hydrogeologic setting, and the current (1990) drought. Contamination also is caused by irrigation drainage and reduced water deliveries to the wetland habitats due to upstream use of water for irrigation. Dramatic effects, such as grossly deformed birds and nearly complete reproductive failure, were not observed at Humboldt WMA as were observed at Kesterson National Wildlife Refuge in California. This does not mean, however, that irrigation drain water has no effect at Humboldt WMA. The effects of irrigation drain

Table 11. Summary of inorganic and organic constituents in water, bottom sediment, and biota of potential concern to human health, fish, and wildlife in Humboldt Wildlife Management Area

[--, basis for evaluation not available]

Constituent	Present at elevated[a] levels		
	In filtered surface water	In bottom sediment	In biota[b]
Arsenic	yes	yes	yes
Barium	no	no	unknown[c]
Boron	yes	no	yes
Cadmium	no	--	unknown[c]
Chromium	no	no	yes
Copper	no	no	yes
Lead	no	no	no
Lithium	no	yes	--
Mercury	yes	no	yes
Molybdenum	yes	yes	unknown[c]
Nickel	no	no	unknown[c]
Selenium	yes	no	yes
Silver	no	no	--
Uranium	yes	yes	--
Vanadium	no	no	--
Zinc	no	no	yes
Radium-226	no	--	--
Gross alpha radioactivity	no	--	--
Carbamate insecticides	no	--	--
Organochlorine compounds	--	no	no
Sodium	yes	no	--
Dissolved solids	yes	--	--
Un-ionized ammonia	yes	--	--

[a] Concentration exceeds Nevada State standard or criterion in water sample; exceeds geochemical baseline values in bottom-sediment sample; or exceeds concern or effect level in biota.

[b] Includes one or more of four categories: birds, fish, insects, and plants.

[c] "Unknown" indicates that one or more values are substantially greater than the background concentration, but doubt exists that the constituent concentrations are at a concern level.

water on the wildlife in Humboldt WMA may be subtle and include increased susceptibility to predators, disease, and parasites. Although not caused by irrigation drainage, one obvious effect during this study was the loss of wetlands while remaining water was consumed for agricultural purposes.

Important findings of this study include the following:

1. In general, the concentrations of solutes in drain water were lowest during the irrigation season.
2. Dissolved-solids concentrations are much higher at the drain sites and lakes compared with the reference sites.
3. Water storage in Rye Patch Reservoir produces increased dissolved-solids and arsenic concentrations compared with the upstream sites as a result of evaporation and of dissolution of minerals in the lake bottom sediment.
4. Dissolved solids and sodium were found in sufficiently high concentrations in Toulon Lake to cause an adverse effect on duckling survival.
5. More than 90 percent of the water samples from sites receiving irrigation drain water contained arsenic in concentrations that exceed the pre-1990, 40-µg/L Nevada standard for the protection of aquatic life. Arsenic concentrations as high as 760 µg/L and loads as great as 4.3 g/min were measured in drains. The source of some of the arsenic in Toulon Drain and Toulon Lake probably is tailings from old mills rather than irrigation drain water. It is likely that the high arsenic concentrations contributed to the absence of amphibians in the wetlands.
6. Dissolved-boron concentrations exceeding 2,000 µg/L generally were measured in drains and lakes receiving irrigation drain water. At sites receiving irrigation drainage, boron concentrations were 2-18 times higher than the Nevada water-quality standard for the protection of aquatic life.
7. Selenium concentrations in the fine part (<62 µm) of bottom sediment from the drains, lakes, and Humboldt River were generally higher than in the coarse part (<2 mm). Selenium concentrations in bottom sediment increased in a downstream direction and were highest in Toulon and Humboldt Lakes. The highest selenium concentration was 1.4 mg/kg in a sample from Toulon Lake.
8. Selenium concentrations were low in water sampled during this study; the maximum concentration measured was 5 µg/L. Selenium in one sample was equal to the Nevada 96-hour water-quality standard for the protection of aquatic life. The highest selenium concentrations were in Graveyard Drain (site 5).
9. Although selenium concentrations in drain water were low in comparison with other areas in the Western United States that receive irrigation drain water, they met or exceeded levels causing food-chain bioconcentration. Biomagnification of selenium is occurring in the study area to the extent that concentrations of selenium in livers of juvenile migratory birds greatly exceed selenium concentrations in their food sources. The median selenium concentration in livers of juvenile black-necked stilts (29 µg/g dry weight) is about three times higher than the effect level (9 µg/g).
10. The public-health-advisory criterion for selenium in edible tissue (approximately 7.2 µg/g dry weight) was exceeded in one of three adult duck muscle samples; however, the residence time of these ducks in the WMA is unknown. Additional samples were unavailable because the study area was nearly dry in October as a result of the extended drought.

11. The potential is great for toxic concentrations of un-ionized ammonia to form in the Humboldt WMA when pH and temperature of the water are high. The maximum observed concentration of un-ionized ammonia was nearly 13 times greater than the criterion for the propagation of cold-water aquatic life. The primary source of nitrogen in the area is discharge from the Lovelock sewage treatment plant rather than irrigation drain water.
12. Bottom sediment contained low concentrations of DDT metabolites. Organochlorine residues were found only in fish from one of the reference sites.
13. Uranium concentrations in the water from Humboldt and Toulon Lakes greatly exceeded the proposed Maximum Contaminant Levels for drinking water. Uranium concentrations in bottom sediment from Toulon Drain (site 7), Toulon Lake (site 10), and Humboldt Lake (site 11) exceeded baseline values.
14. Insect diversity and abundance were diminished in flowing irrigation drain water compared with reference sites above Lovelock Valley. Changes in biotic composition can result from natural changes in water quality and habitat, as well as irrigation-induced changes in water quality.
15. Water and sediment from five irrigation drains and one lake were acutely toxic to fish and invertebrates as determined by biotoxicity tests. Thus, some water and sediment may not support food chains essential to some migratory birds.

Habitat degradation in Humboldt Wildlife Management Area has resulted from reduced water deliveries to the wetlands caused by upstream consumption of water for irrigation and the extended drought of recent years. Although selenium concentrations in water in the wetlands may not exceed Nevada water-quality standards, the high concentrations of selenium in juvenile birds indicate that it is biomagnified in waterfowl. This investigation did not identify the exposure pathway with certainty.

The findings of this investigation indicate that water in the Humboldt Sink may not be suitable for some of its designated beneficial uses and that irrigation drainage is at least partly to blame. Evidence supporting the conclusion that irrigation drain water is an important source of contamination includes the following:

1. Water from the Rennie Road drains was acutely toxic to all of the organisms used in the biotoxicity tests conducted during this study.
2. Sediment from drains and the wetlands was acutely toxic to organisms used in the biotoxicity tests.
3. Types and concentrations of many potentially toxic constituents exceeded published effect levels in waterfowl (selenium, in particular).
4. Selenium and other toxic constituents were present at higher concentrations in water and bottom sediment from irrigation drains and wetland habitats than in the reference sites.

- PAGE TO FOLLOWS -

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TABLE 12. Field measurements of physical properties and chemical constituents for surface-water samples from the study area and upstream sites, 1987-90

[Specific conductance, pH, and dissolved oxygen were measured in the field. Those marked 'L' were measured in the laboratory. Other abbreviations and symbols: E, estimated; Q (marked after the date) indicates duplicate and triplicate samples collected for quality assurance purpose and these were not used in statistical analyses; ft^3/s, cubic foot per second; mg/L, milligram per liter; µg/L, microgram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degree Celsius; --, not determined; <, less than;]

Site No. (figs. 1 and 10)	Station name	Date sampled	Time	Discharge, instantaneous (ft^3/s)	Specific conductance (µS/cm)	pH (standard units)	Air temperature (°C)	Water temperature (°C)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)
	Reference Sites									
1	Humboldt River near Golconda	07-10-90	0900	75 E	610	8.2	28.0	21.3	7.3	96
		11-27-90	0830	2.0 E	926	8.5	-8.0	2.0	12.2	103
2	Humboldt River near Imlay	02-05-90	1015	55	790	--	--	0.5	--	--
		03-20-90	1440	254	540	--	--	11.5	--	--
		05-07-90	1645	257	674	--	--	16.5	--	--
		07-10-90	1245	106	653	8.5	31.0	25.9	6.5	92
		09-11-90	1455	7.6	854	--	--	26.5	--	--
		11-14-90	1410	11	823	--	--	6.0	--	--
		11-27-90	1200	14	888	8.7	0.0	1.0	12.1	98
9	Rye Patch Reservoir near Rye Patch	07-19-90	0830	--	1,070	8.4 L	23.0	22.1	6.9	92
		11-26-90	1500	--	3,240	8.6	5.0	4.6	9.4	86
3	Humboldt River at Upper Valley Road near Lovelock	10-07-87	1500	158 E	1,010	8.5	27.0	18.0	8.7	107
		03-18-88	0900	--	916 L	8.3 L	--	--	--	--
		08-24-88	0730	247 E	1,060	8.1	19.0	18.7	8.0	100
		03-28-89	0750	0.50	895	8.6	5.5	7.0	9.7	93
		03-27-90	0730	.33	863	8.7	--	7.4	8.6	83
		07-10-90	1545	147 E	1,110	8.5	36.0	24.2	7.2	99
		11-20-90	1400	.50 E	1,120	8.7	--	8.3	11.1	110
	Irrigation Drainage Sites									
4	Humboldt River near Lovelock	10-07-87	0730	2.9	2,720	8.4	9.0	14.0	7.9	89
		03-17-88	1530	--	3,620 L	8.1 L	--	--	--	--
		08-24-88	0930	14	1,520	8.4	27.5	23.0	7.9	107
		03-28-89	1400	3.2	4,270	8.8	--	16.0	9.8	116
		03-27-90	1230	.40	3,950	8.8	--	15.1	10.7	125
		07-18-90	1540	6.8	2,030	8.9 L	36.0	29.3	10.1	153
		07-18-90 Q	1540	6.8	2,030	8.8 L	36.0	29.3	10.1	153
		11-19-90	1400	8.5	3,690	8.6	13.0	7.9	11.8	118

TABLE 12. Field measurements of physical properties and chemical constituents for surface-water samples from the study area and upstream sites, 1987-90--Continued

Site No. (figs. 1 and 10)	Station name	Date sampled	Time	Discharge, instantaneous (ft^3/s)	Specific conductance (µS/cm)	pH (standard units)	Air temperature (°C)	Water temperature (°C)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)
	Irrigation Drainage Sites--Continued									
7	Toulon Drain at Derby Field near Toulon	10-06-87	1300	11	2,420	8.5	26.0	18.0	13	159
		03-17-88	0830	--	3,630 L	7.9 L	--	--	--	--
		08-23-88	1730	5.7	1,950	8.4	34.0	26.0	10.6	153
		03-27-89	1500	1.2	2,840	9.1	12.5	17.0	20	242
		03-26-90	1030	1.6	3,010	8.6	--	14.0	15	170
		07-09-90	1230	.20	2,540	9.6	36.0	27.3	14.9	217
5	Graveyard Drain at Lovelock Drain near Lovelock	03-27-90	1030	0.33	4,110	8.5	--	11.2	10.5	113
		07-11-90	0800	.03	3,180	8.7	24.0	18.8	2.5	31
		11-20-90	0715	.01 E	5,300	7.9	4.0	4.9	6.8	61
		11-20-90 Q	0715	.01 E	5,300	7.9	4.0	4.9	6.8	61
6	Lovelock Drain above Graveyard Drain near Lovelock	03-27-90	1030	--	2,740	8.1	--	12.0	--	--
		07-11-90	0805	--	2,410	8.1	--	18.5	--	--
		11-20-90	0730	1.0 E	2,380	7.8	--	4.5	--	--
8	Army Drain at Iron Bridge near Toulon	10-06-87	1500	19	7,900	8.3	28.0	18.5	11.3	142
		03-16-88	1530	--	13,700 L	7.9 L	--	--	--	--
		08-24-88	1230	19	4,370	8.2	33.0	24.0	5.7	79
		03-28-89	0800	1.7	5,900	8.4	15.0	10.0	6.0	63
		03-26-90	1415	4.4	5,010	8.5	--	15.5	12.9	152
		07-18-90	1215	3.3	6,550	7.9 L	35.0	30.1	10.8	167
		07-18-90 Q	1215	3.3	6,550	7.9 L	35.0	30.1	10.8	167
		07-18-90 Q	1215	3.3	6,550	7.9 L	35.0	30.1	10.8	167
		11-19-90	1110	.71	5,420	8.5	10.0	5.2	13.1	122
		11-19-90 Q	1110	.71	5,420	8.5	10.0	5.2	13.1	122
10	Toulon Lake	10-17-87	1200	--	2,600	8.8	23.5	18.0	8.2	101
		03-17-88	1330	--	3,820 L	8.2 L	--	--	--	--
		03-28-89	1230	--	5,930	9.4	--	15.5	9.6	113
		03-26-90	1630	--	8,370	9.0	--	18.2	8.5	107
11	Upper Humboldt Lake near center	10-07-87	1030	--	5,960	8.2	23.5	15.0	6.1	71
		03-17-88	1030	--	5,320 L	8.1 L	--	--	--	--
		08-24-88	1130	--	5,490	8.6	32.5	29.5	12.3	189
		03-28-89	1045	--	7,140	8.8	15.0	18.0	8.6	107
		03-26-90	1500	--	5,840	8.6	--	22.1	10.5	142
		07-09-90	1500	--	4,700	8.2	37.0	36.5	7.4	129
		11-26-90	1200	--	5,440	8.6	3.0	9.0	--	--

TABLE 13. Water hardness and concentrations of major dissolved chemical constituents in surface-water samples from the study area and upstream sites, 1987-90

[Alkalinity, bicarbonate, and carbonate were measured in the field, except for those marked 'L'. Those marked 'L', as well as determination of all other constituents, were conducted at the U.S. Geological Survey National Water Quality Laboratory in Arvada, Colo. Other abbreviations and symbols: Q (marked after the date) indicates duplicate and triplicate samples collected for quality assurance and these were not used in statistical analyses; mg/L, milligram per liter; °C, degrees celsius; --, not determined]

Site No. (figs. 1 and 10)	Date	Hardness (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Bicarbonate, (mg/L as HCO_3)	Carbonate (mg/L as CO_3)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, dissolved, residue at 180°C (mg/L)
							Reference Sites							
1	07-10-90	170	50	12	65	7.5	226	267	4	48	37	--	--	384
	11-27-90	220	59	17	130	9.2	326	387	5	89	67	0.8	--	588
2	07-10-90	190	53	14	72	8.9	238	270	10	59	43	--	--	425
	11-27-90	210	51	20	110	8.2	233	284	0	100	82	.6	--	520
9	07-19-90	190	43	19	150	16	219 L	267 L	0 L	100	160	--	--	620
	11-26-90	430	91	49	500	34	319	365	12	170	790	.9	--	1,860
3	10-07-87	190	44	20	140	16	249	259	22	96	130	.8	41	624
	03-18-88	220	57	18	110	10	194 L	237 L	0 L	97	110	.5	39	552
	08-24-88	180	39	21	140	13	230	281	0	100	130	--	--	641
	03-29-89	210	51	20	120	11	176 L	215 L	0 L	93	130	--	--	544
	03-27-90	190	49	17	99	12	176	206	4	85	110	--	--	520
	07-10-90	190	44	20	150	16	235	266	10	110	160	--	--	652
	11-20-90	200	48	20	150	13	180	209	5	96	190	.6	--	666
							Irrigation Drainage Sites							
4	10-07-87	240	36	36	530	25	324	395	0	290	430	1.2	27	1,590
	03-17-88	250	61	23	670	35	310 L	378 L	0 L	210	710	1.7	44	2,050
	08-24-88	190	44	20	240	27	287	315	17	120	230	--	--	907
	03-28-89	230	50	26	830	43	371	400	26	210	1,000	--	--	2,420
	03-27-90	200	39	24	800	41	368	365	41	200	1,100	--	--	2,360
	07-18-90	120	18	19	350	30	284 L	346 L	0 L	150	410	--	--	1,140
	07-18-90 Q	120	18	19	350	30	273 L	333 L	0 L	140	360	--	--	1,130
	11-19-90	250	59	26	630	37	312	377	2	180	880	1.8	--	2,090

TABLE 13. Water hardness and concentrations of major dissolved chemical constituents in surface-water samples from the study area and upstream sites, 1987-90--Continued

Site No. (figs. 1 and 10)	Date	Hardness (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Bicarbonate, (mg/L as HCO_3)	Carbonate (mg/L as CO_3)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, dissolved, residue at 180°C (mg/L)
7	10-06-87	310	75	30	420	24	486	534	29	280	360	1.3	44	1,500
	03-17-88	430	100	43	680	23	498 L	607 L	0 L	430	450	1.4	41	2,210
	08-23-88	280	69	25	320	25	424	454	31	190	280	--	--	1,210
	03-27-89	320	82	29	510	23	438	408	62	250	560	--	--	1,710
	03-26-90	400	100	36	500	25	432	482	22	290	590	--	--	1,870
	07-09-90	260	58	27	420	22	356	207	112	260	490	--	--	1,570
5	03-27-90	370	73	45	750	40	489	582	7	450	860	--	--	2,530
	07-11-90	250	39	36	540	24	303	339	15	370	600	--	--	1,910
	11-20-90	580	110	73	870	40	323	394	0	540	1,100	1.0	--	3,040
	11-20-90 Q	570	110	72	850	36	323	394	0	550	1,200	1.4	--	3,010
8	10-06-87	900	210	91	1,300	49	462	564	0	700	2,100	1.5	37	5,040
	03-16-88	1,200	250	130	2,900	63	454 L	554 L	0 L	1,200	3,600	1.7	28	8,580
	08-24-88	490	120	47	800	24	564	688	0	360	970	--	--	2,560
	03-28-89	570	130	59	1,100	34	550	622	24	450	1,500	--	--	3,530
	03-26-90	470	110	47	900	40	410	455	22	450	1,200	--	--	2,990
	07-18-90	610	140	64	1,200	44	450 L	549 L	0 L	450	1,800	--	--	3,740
	07-18-90 Q	570	130	60	1,000	45	336 L	410 L	0 L	440	1,800	--	--	3,780
	07-18-90 Q	580	130	63	1,100	46	339 L	413 L	0 L	440	1,800	--	--	3,650
	11-19-90	330	70	38	1,000	41	351	428	0	250	1,500	2.1	--	3,120
	11-19-90 Q	330	70	37	980	39	351	428	0	250	1,500	2.1	--	3,230
10	10-07-87	210	45	23	540	27	444	488	26	170	560	1.2	42	1,560
	03-17-88	380	78	44	760	26	507 L	618 L	0 L	440	550	1.4	26	2,310
	03-28-89	260	36	41	1,200	50	492	381	108	690	1,300	--	--	3,690
	03-26-90	300	26	57	1,800	73	755	715	101	900	2,100	--	--	5,420
11	10-07-87	540	100	71	1,200	42	346	422	0	560	1,500	1.4	29	3,540
	03-17-88	450	75	64	980	28	230 L	280 L	0 L	460	1,100	1.3	11	3,070
	08-24-88	390	57	61	1,000	44	344	381	19	560	1,200	--	--	3,140
	03-28-89	530	83	78	1,300	47	356	381	26	630	1,900	--	--	4,300
	03-26-90	360	53	56	1,100	50	315	345	19	540	1,500	--	--	3,430
	07-09-90	460	100	51	890	36	305	372	0	340	1,200	--	--	2,680
	11-26-90	310	63	36	1,000	41	298	353	5	270	1,500	1.5	--	2,900

TABLE 14. Concentrations of nutrient constituents in surface-water samples from the study area and upstream sites, 1987-90

[All analyses conducted by the U.S. Geological Survey National Water-Quality Laboratory in Arvada, Colo. Abbreviations and symbols: Q (marked after the date) indicates duplicate samples collected for quality assurance and these were not used in statistical analysis; mg/L, milligram per liter; --, not determined; <, less than]

Site No. (figs. 1 and 10)	Date	Nitrogen species, dissolved (mg/L as N)					Orthophosphorus, dissolved (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Carbon, organic, dissolved (mg/L)
		Nitrate	Nitrite	Ammonia[a]	Ammonia, un-ionized[b]	Organic			
					Reference Sites				
1	07-10-90	<0.10	<0.01	<0.01	<0.01	--	--	--	--
	11-27-90	<.10	<.01	.07	<.01	--	0.06	--	--
2	07-10-90	<.10	<.01	<.01	<.01	--	--	--	--
	11-27-90	<.10	<.01	.06	<.01	--	<.01	--	--
9	07-19-90	<.10	<.01	<.01	--	--	--	--	--
	11-26-90	<.10	<.01	.07	<.01	--	.04	--	--
3	10-07-87	<.10	<.01	.02	<.01	--	.02	0.04	--
	03-18-88	--	--	.02	--	--	--	--	2.6
	08-24-88	<.10	--	<.01	<.01	--	--	--	4.6
	03-29-89	<.10	--	<.01	<.01	--	--	--	3.1
	03-27-90	<.10	--	<.01	<.01	0.30	.02	.04	--
	07-10-90	<.10	<.01	<.01	<.01	--	--	--	--
	11-20-90	<.10	<.01	.03	<.01	--	.01	--	--
					Irrigation Drainage Sites				
4	10-07-87	<.10	<.01	.01	<.01	--	.04	.03	--
	03-17-88	--	--	.01	--	--	--	--	3.8
	08-24-88	<.10	--	.03	<.01	--	--	--	4.2
	03-28-89	<.10	--	<.01	<.01	--	--	--	4.9
	03-27-90	<.10	--	<.01	<.01	.50	.03	.05	--
	07-18-90	<.10	<.01	<.01	--	--	--	--	--
	07-18-90 Q	<.10	<.01	<.01	--	--	--	--	--
	11-19-90	<.10	<.01	.06	<.01	--	.02	--	--
7	10-06-87	.33	.03	.03	<.01	--	.26	.24	--
	03-17-88	--	--	1.2	--	--	--	--	4.0
	08-23-88	<.10	--	<.01	<.01	--	--	--	5.9
	03-27-89	.41	--	.90	.26	--	--	--	6.8
	03-26-90	.70	--	1.3	.12	.50	1.0	1.0	--
	07-09-90	<.10	<.01	.03	.02	--	--	--	--

TABLE 14. Concentrations of nutrient constituents in surface-water samples from the study area and upstream sites, 1987-90--Continued

Site No. (figs. 1 and 10)	Date	Nitrogen species, dissolved (mg/L as N)					Orthophosphorus, dissolved (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Carbon, organic, dissolved (mg/L)
		Nitrate	Nitrite	Ammonia[a]	Ammonia, un-ionized[b]	Organic			
5	03-27-90	<0.10	--	0.05	<0.01	0.75	0.09	0.10	--
	07-11-90	<.10	<0.01	.05	<.01	--	--	--	--
	11-20-90	<.10	<.01	.18	<.01	--	.03	--	--
	11-20-90 Q	<.10	<.01	.16	<.01	--	.03	--	--
8	10-06-87	--	--	--	--	--	--	.06	--
	03-16-88	--	--	.10	--	--	--	--	12
	08-24-88	.29	--	.20	.02	--	--	--	7.0
	03-28-89	<.10	--	.05	<.01	--	--	--	8.9
	03-26-90	<.10	--	.05	<.01	.55	.04	.05	--
	07-18-90	<.10	.02	.07	--	--	--	--	--
	07-18-90 Q	<.10	.03	.05	--	--	--	--	--
	07-18-90 Q	<.10	.03	.06	--	--	--	--	--
	11-19-90	<.10	.01	.07	<.01	--	.03	--	--
	11-19-90 Q	<.10	.01	.07	<.01	--	.03	--	--
10	10-07-87	<.10	<.01	.02	<.01	--	.02	.05	--
	03-17-88	--	--	.03	--	--	--	--	--
	03-28-89	<.10	--	.03	.01	--	--	--	--
	03-26-90	<.10	--	.02	<.01	2.4	.44	.45	--
11	10-07-87	<.10	<.01	.04	<.01	--	<.01	.01	--
	03-17-88	--	--	.03	--	--	--	--	--
	08-24-88	<.10	--	.02	<.01	--	--	--	--
	03-28-89	<.10	--	.01	<.01	--	--	--	--
	03-26-90	<.10	--	<.01	<.01	.80	<.01	.02	--
	07-09-90	<.10	.03	.16	.03	--	--	--	--
	11-26-90	<.10	<.01	.07	<.01	--	.02	--	--

[a] Ammonia here is the sum of both the ionized and un-ionized ammonia.
[b] Un-ionized ammonia calculated using equations of Thurston and others (1974) that assume zero salinity.

TABLE 15. Concentrations of trace-element constituents in surface-water samples from the study area and upstream sites, 1987-90

[All analyses conducted by the U.S. Geological Survey National Water-Quality Laboratory in Arvada, Colo. Abbreviations and symbols: Q (marked after the date) indicates duplicate samples collected for quality assurance and these were not used in statistical analysis; μg/L, microgram per liter; --, not determined; <, less than.]

Site No. (figs. 1 and 10)	Date	Alu-minum, dissolved (μg/L as Al)	Antimony, dissolved (μg/L as Sb)	Arsenic, dissolved (μg/L as As)	Barium, dissolved (μg/L as Ba)	Boron, dissolved (μg/L as B)	Cad-mium, dis-solved (μg/L as Cd)	Chromium, dissolved (μg/L as Cr)	Copper, dis-solved (μg/L as Cu)	Iron, dis-solved (μg/L as Fe)	Lead, dis-solved (μg/L as Pb)	Lithium, dis-solved (μg/L as Li)	Manga-nese, dis-solved (μg/L as Mn)
						Reference Sites							
1	07-10-90	--	--	14	--	270	1	2	2	--	<1	--	--
	11-27-90	--	--	18	--	610	<1	<1	1	--	<1	--	--
2	07-10-90	--	--	17	--	350	<1	2	2	--	<1	--	--
	11-27-90	--	--	16	--	650	<1	<1	1	--	<1	--	--
9	07-19-90	--	--	32	--	720	1	1	4	--	<1	--	--
	11-26-90	--	--	59	--	2,700	<1	<1	2	--	<1	--	--
3	10-07-87	<10	7	39	59	550	<1	<10	<10	--	<5	140	2
	03-18-88	<10	1	33	--	350	1	<1	<1	<10	<5	90	20
	08-24-88	--	--	51	--	620	--	<1	--	--	--	170	--
	03-29-89	--	--	29	--	400	--	<1	--	--	--	110	--
	03-27-90	--	--	15	--	380	2	<5	<10	--	<10	--	--
	07-10-90	--	--	27	--	730	<1	1	3	--	<1	--	--
	11-20-90	--	--	28	--	660	<1	<1	3	--	<1	--	--
						Irrigation Drainage Sites							
4	10-07-87	10	<1	85	100	2,200	<1	<40	<10	--	<5	390	<10
	03-17-88	<10	3	52	--	3,500	1	<1	<1	<10	<5	740	40
	08-24-88	--	--	57	--	1,100	--	<1	--	--	--	270	--
	03-28-89	--	--	40	--	4,500	--	<1	--	--	--	730	--
	03-27-90	--	--	65	--	4,200	<1	1	2	--	<1	--	--
	07-18-90	--	--	52	--	2,000	1	1	4	--	<1	--	--
	07-18-90 Q	--	--	45	--	2,000	<1	<1	3	--	<1	--	--
	11-19-90	--	--	59	--	3,600	<1	<1	1	--	<1	--	--

TABLE 15. Concentrations of trace-element constituents in surface-water samples from the study area and upstream sites, 1987-90--Continued

Site No. (figs. 1 and 10)	Date	Alu-minum, dissolved (µg/L as Al)	Antimony, dissolved (µg/L as Sb)	Arsenic, dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Boron, dissolved (µg/L as B)	Cad-mium, dis-solved (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)	Copper, dis-solved (µg/L as Cu)	Iron, dis-solved (µg/L as Fe)	Lead, dis-solved (µg/L as Pb)	Lithium, dis-solved (µg/L as Li)	Manga-nese, dis-solved (µg/L as Mn)
7	10-06-87	<10	11	230	100	1,900	<1	<10	<10	--	<5	340	<10
	03-17-88	<10	12	110	--	3,200	1	<1	<1	10	<5	400	110
	08-23-88	--	--	33	--	1,400	--	<1	--	--	--	270	--
	03-27-89	--	--	55	--	2,600	--	<1	--	--	--	300	--
	03-26-90	--	--	64	--	2,700	<1	2	2	--	<1	--	--
	07-09-90	--	--	760	--	2,300	<1	1	4	--	<1	--	--
5	03-27-90	--	--	120	--	4,200	<1	1	2	--	<1	--	--
	07-11-90	--	--	55	--	2,900	<1	1	4	--	<1	--	--
	11-20-90	--	--	48	--	4,000	<1	<1	1	--	<1	--	--
	11-20-90 Q	--	--	48	--	3,900	<1	<1	1	--	<1	--	--
8	10-06-87	<10	10	100	100	5,000	<1	<10	<10	--	<5	760	160
	03-16-88	<10	28	200	--	10,000	1	<1	<1	30	<5	920	440
	08-24-88	--	--	83	--	3,000	--	<1	--	--	--	520	--
	03-28-89	--	--	73	--	3,700	--	<1	--	--	--	540	--
	03-26-90	--	--	69	--	3,600	<1	2	1	--	<1	--	--
	07-08-90	--	--	64	--	3,600	<1	2	2	--	<1	--	--
	07-18-90 Q	--	--	59	--	3,500	<1	1	2	--	<1	--	--
	07-18-90 Q	--	--	50	--	3,500	<1	1	2	--	<2	--	--
	11-19-90	--	--	60	--	4,100	<1	<1	2	--	<1	--	--
	11-19-90 Q	--	--	77	--	4,000	<1	<1	1	--	<1	--	--
10	10-07-87	<10	13	60	100	2,300	<1	2	<10	--	<5	350	<10
	03-17-88	<10	16	150	--	3,400	1	<1	<1	10	<5	420	<10
	03-28-89	--	--	220	--	5,700	--	<1	--	--	--	490	--
	03-26-90	--	--	280	--	7,700	<1	<1	2	--	5	--	--
11	10-07-87	<10	7	210	100	3,900	<1	<10	<10	--	<5	660	<10
	03-17-88	<10	2	56	--	3,500	1	<1	<1	10	<5	560	<10
	08-24-88	--	--	90	--	4,300	--	<1	--	--	--	700	--
	03-28-89	--	--	98	--	5,400	--	<1	--	--	--	710	--
	03-26-90	--	--	78	--	4,500	<1	1	2	--	<1	--	--
	07-09-90	--	--	59	--	2,700	<1	2	1	--	<1	--	--
	11-26-90	--	--	76	--	3,800	<1	<1	2	--	<1	--	--

TABLE 15. Concentrations of trace-element constituents in surface-water samples from the study area and upstream sites, 1987-90--Continued

Site (figs. 1 and 10)	Date	Mercury, dissolved (μg/L as Hg)	Molybdenum, dissolved (μg/L as Mo)	Nickel, dissolved (μg/L as Ni)	Selenium, dissolved (μg/L as Se)	Silver, dissolved (μg/L as Ag)	Vanadium, dissolved (μg/L as V)	Zinc, dissolved (μg/L as Zn)
				Reference Sites				
1	07-10-90	<0.1	5	--	<1	--	9	<3
	11-27-90	<.1	<1	--	<1	--	4	<3
2	07-10-90	<.1	6	--	<1	--	11	3
	11-27-90	<.1	<1	--	<1	--	5	<3
9	07-19-90	<.1	13	--	1	--	21	6
	11-26-90	<.1	21	--	<1	--	25	<10
3	10-07-87	<.1	11	3	1	<1	15	16
	03-18-88	<.1	7	--	1	--	8	<10
	08-24-88	<.1	11	--	1	--	16	<3
	03-29-89	<.1	9	--	1	--	6	7
	03-27-90	.2	<10	--	1	--	<6	13
	07-10-90	<.1	12	--	1	--	17	6
	11-20-90	<.1	2	--	<1	--	10	5
				Irrigation Drainage Sites				
4	10-07-87	<.1	17	<1	1	<1	22	<10
	03-17-88	<.1	12	--	1	--	21	<10
	08-24-88	<.1	10	--	<1	--	18	15
	03-28-89	<.1	13	--	<1	--	15	<10
	03-27-90	.1	13	--	<1	--	23	<10
	07-18-90	<.1	13	--	<1	--	24	<3
	07-18-90 Q	<.1	14	--	<1	--	24	21
	11-19-90	<.1	9	--	<1	--	28	<10
7	10-06-87	.1	23	1	<1	<1	27	<10
	03-17-88	<.1	32	--	2	--	34	10
	08-23-88	<.1	10	--	<1	--	19	<3
	03-27-89	<.1	21	--	1	--	30	<10
	03-26-90	<.1	10	--	2	--	24	10
	07-09-90	<.1	12	--	<1	--	23	<10

TABLE 15. Concentrations of trace-element constituents in surface-water samples from the study area and upstream sites, 1987-90--Continued

Site (figs. 1 and 10)	Date	Mercury, dissolved (µg/L as Hg)	Molybdenum, dissolved (µg/L as Mo)	Nickel, dissolved (µg/L as Ni)	Selenium, dissolved (µg/L as Se)	Silver, dissolved (µg/L as Ag)	Vanadium, dissolved (µg/L as V)	Zinc, dissolved (µg/L as Zn)
5	03-27-90	<0.1	48	--	2	--	32	20
	07-11-90	<.1	15	--	2	--	23	<10
	11-20-90	<.1	17	--	4	--	24	<10
	11-20-90 Q	<.1	20	--	5	--	25	<10
8	10-06-87	<.2	58	1	2	<1	62	20
	03-16-88	<.1	100	--	<1	--	69	10
	08-24-88	<.1	20	--	2	--	45	<10
	03-28-89	.5	22	--	<1	--	38	10
	03-26-90	<.1	24	--	1	--	40	20
	07-18-90	.1	25	--	<1	--	38	20
	07-18-90 Q	.2	25	--	<1	--	37	20
	07-18-90 Q	.1	24	--	<1	--	16	10
	11-19-90	<.1	13	--	<1	--	24	10
	11-19-90 Q	<.1	15	--	<1	--	22	<10
10	10-07-87	.1	12	<1	<1	<1	21	<10
	03-17-88	<.1	35	--	1	--	41	10
	03-28-89	<.1	140	--	2	--	91	10
	03-26-90	<.1	76	--	2	--	59	<10
11	10-07-87	.2	31	1	2	<1	43	10
	03-17-88	<.1	27	--	<1	--	33	20
	08-24-88	<.1	38	--	<1	--	41	10
	03-28-89	<.1	44	--	<1	--	45	10
	03-26-90	<.1	26	--	<1	--	48	<10
	07-09-90	.2	24	--	1	--	37	<10
	11-26-90	<.1	19	--	<1	--	19	<10

TABLE 16. Concentrations of dissolved radiochemical constituents in surface-water samples from the study area and upstream sites, 1987-90

[Abbreviations and symbols: Q (marked after date) indicates duplicate samples collected for quality assurance and these were not used in statistical analysis; µg/L, microgram per liter; pCi/L, picocurie per liter; Cs-137, cesium-137; Sr-90/Y-90, strontium-90/yttrium-90; --, not determined; <, less than]

Site No. (figs. 1 and 10)	Date	Radium-226, dissolved, radon method (pCi/L)	Uranium, natural, dissolved (µg/L as U)	Gross alpha, dissolved (µg/L as U, natural)	Gross beta, dissolved (pCi/L as Cs-137)	Gross beta, dissolved (pCi/L as Sr-90/Y-90)
			Reference Sites			
1	07-10-90	--	4.6	--	--	--
	11-27-90	--	5.8	--	--	--
2	07-10-90	--	4.4	--	--	--
	11-27-90	--	7.8	--	--	--
9	07-19-90	--	6.7	--	--	--
	11-26-90	--	8.8	--	--	--
3	10-07-87	0.03	7.6	11	15	11
	08-24-88	--	8.3	--	--	--
	03-29-89	--	12	--	--	--
	03-27-89	--	4.3	--	--	--
	07-10-90	--	7.2	--	--	--
	11-20-90	--	6.6	--	--	--
			Irrigation Drainage Sites			
4	10-07-87	.05	6.5	10	43	28
	08-24-88	--	8.4	--	--	--
	03-28-89	--	7.5	--	--	--
	03-27-90	--	3.9	--	--	--
	07-18-90	--	5.9	--	--	--
	07-18-90 Q	--	5.6	--	--	--
	11-19-90	--	6.3	--	--	--
7	10-06-87	.06	24	29	48	32
	08-23-88	--	13	--	--	--
	03-27-89	--	18	--	--	--
	03-26-90	--	13	--	--	--
	07-09-90	--	8.4	--	--	--
5	03-27-90	--	27	--	--	--
	07-11-90	--	14	--	--	--
	11-20-90	--	27	--	--	--
8	10-06-87	.12	42	54	66	50
	08-24-88	--	22	--	--	--
	03-28-89	--	34	--	--	--
	03-26-90	--	21	--	--	--
	07-18-90	--	20	--	--	--
	07-18-90 Q	--	19	--	--	--
	07-18-90 Q	--	21	--	--	--
	11-19-90	--	11	--	--	--
	11-19-90 Q	--	12	--	--	--
10	10-07-87	.03	20	14	170	110
	03-28-89	--	140	--	--	--
	03-26-90	--	75	--	--	--
11	10-07-87	.07	38	46	64	43
	08-24-88	--	30	--	--	--
	03-28-89	--	44	--	--	--
	03-26-90	--	26	--	--	--
	11-26-90	--	1.1	--	--	--

TABLE 17. Concentrations of trace-element constituents and carbon in bottom-sediment samples from the study area and upstream sites, 1990

[Abbreviations and symbols: Q (marked after date) indicates duplicate samples collected for quality assurance; ins, insufficient material; mg/kg, milligram per kilogram; --, not determined; <, less than]

Site No. (figs. 1 and 10)	Date	Fraction	Carbon, inorganic, percent	Carbon, organic, percent	Carbon, total, percent	Arsenic, total (mg/kg as As)	Barium, total (mg/kg as Ba)	Beryllium, total (mg/kg as Be)	Bismuth, total (mg/kg as Bi)
					Reference Sites				
1	11-27-90	<2mm	0.31	0.26	0.57	6.3	1,100	2	<10
	11-27-90	<62μm	2.58	1.54	4.12	11	1,000	2	<10
2	11-27-90	<2mm	.16	.10	.26	4.0	1,100	2	<10
	11-27-90	<62μm	1.84	.70	2.54	5.4	950	2	<10
9	11-26-90	<2mm	.35	.12	.47	9.9	820	2	<10
	11-26-90	<62μm	.87	.21	1.08	13	760	2	<10
3	11-20-90	<2mm	.28	.08	.36	5.8	900	2	<10
	11-20-90	<62μm	1.12	.38	1.5	14	860	2	<10
					Irrigation Drainage Sites				
4	11-19-90	<2mm	0.65	0.40	1.05	6.4	990	2	<10
	11-19-90 Q	<2mm	.64	.33	.97	6.2	1,000	2	<10
	11-19-90	<62μm	2.89	1.58	4.47	12	770	2	<10
	11-19-90 Q	<62μm	2.93	1.59	4.52	13	760	2	<10
7	11-19-90	<2mm	1.34	.58	1.92	8.6	950	2	<10
	11-19-90	<62μm	2.44	1.36	3.8	11	740	2	<10
5	11-20-90	<2mm	1.3	1.19	2.49	8.4	910	2	<10
	11-20-90	<62μm	1.22	1.1	2.32	9.4	860	2	<10
8	11-19-90	<2mm	3.74	1.35	5.09	15	580	1	<10
	11-19-90	<62μm	3.0	1.58	4.58	17	610	2	<10
10	11-19-90	<2mm	4.12	1.36	5.48	18	600	1	<10
	11-19-90	<62μm	4.25	1.67	5.92	22	530	1	<10
11	11-26-90	<2mm	7.35	1.11	8.46	20	400	<1	<10
	11-26-90	<62μm	7.5	1.71	9.21	21	410	<1	<10

TABLE 17. Concentrations of trace-element constituents and carbon in bottom-sediment samples from the study area and upstream sites, 1990--Continued

Site No. (figs. 1 and 10)	Date	Fraction	Boron, total (mg/kg as B)	Cadmium, total (mg/kg as Cd)	Cerium, total (mg/kg as Ce)	Chromium, total (mg/kg as Cr)	Cobalt, total (mg/kg as Co)	Copper, total (mg/kg as Cu)	Europium, total (mg/kg as Eu)	Gallium, total (mg/kg as Ga)
					Reference Sites					
1	11-27-90	<2mm	1	<2	63	31	6	10	<2	12
	11-27-90	<62μm	ins	<2	72	43	11	19	<2	15
2	11-27-90	<2mm	0.7	<2	47	24	4	6	<2	12
	11-27-90	<62μm	ins	<2	60	48	9	16	<2	16
9	11-26-90	<2mm	2	<2	54	32	9	18	<2	18
	11-26-90	<62μm	2	<2	64	55	14	29	<2	18
3	11-20-90	<2mm	1	<2	53	24	6	6	<2	16
	11-20-90	<62μm	ins	<2	83	60	13	18	<2	16
					Irrigation Drainage Sites					
4	11-19-90	<2mm	4	<2	46	26	6	8	<2	13
	11-19-90 Q	<2mm	4	<2	51	26	6	10	<2	14
	11-19-90	<62μm	1	<2	45	44	10	21	<2	14
	11-19-90 Q	<62μm	9	<2	42	43	11	24	<2	14
7	11-19-90	<2mm	8	<2	45	26	7	13	<2	14
	11-19-90	<62μm	10	<2	49	41	10	21	<2	14
5	11-20-90	<2mm	20	<2	51	36	9	35	<2	16
	11-20-90	<62μm	10	<2	55	48	11	39	<2	17
8	11-19-90	<2mm	10	<2	38	32	10	30	<2	14
	11-19-90	<62μm	10	<2	43	39	11	29	<2	16
10	11-19-90	<2mm	99	<2	25	16	6	13	<2	9
	11-19-90	<62μm	90	<2	27	19	6	15	<2	10
11	11-26-90	<2mm	21	<2	18	17	6	16	<2	8
	11-26-90	<62μm	10	<2	18	19	6	17	<2	8

TABLE 17. Concentrations of trace-element constituents and carbon in bottom-sediment samples from the study area and upstream sites, 1990--Continued

Site No. (figs. 1 and 10)	Date	Fraction	Gold, total (mg/kg as Au)	Holmium, total (mg/kg as Ho)	Lanthanum, total (mg/kg as La)	Lead, total (mg/kg as Pb)	Lithium, total (mg/kg as Li)	Manganese, total (mg/kg as Mn)	Mercury, total (mg/kg as Hg)	Molybdenum, total (mg/kg as Mo)
					Reference Sites					
1	11-27-90	<2mm	<8	<4	39	140	23	680	0.02	<2
	11-27-90	<62µm	<8	<4	41	440	43	3,000	.08	2
2	11-27-90	<2mm	<8	<4	32	16	20	210	<.02	<2
	11-27-90	<62µm	<8	<4	35	17	40	730	.10	<2
9	11-26-90	<2mm	<8	<4	30	26	34	420	.02	<2
	11-26-90	<62µm	<8	<4	36	15	54	600	.08	<2
3	11-20-90	<2mm	<8	<4	31	16	21	340	.06	<2
	11-20-90	<62µm	<8	<4	48	46	43	860	.12	3
					Irrigation Drainage Sites					
4	11-19-90	<2mm	<8	<4	30	14	29	320	.02	<2
	11-19-90 Q	<2mm	<8	<4	31	16	30	310	.02	<2
	11-19-90	<62µm	<8	<4	26	20	70	810	.04	<2
	11-19-90 Q	<62µm	<8	<4	26	23	70	800	.10	<2
7	11-19-90	<2mm	<8	<4	27	14	35	550	.04	<2
	11-19-90	<62µm	<8	<4	29	15	59	840	.08	2
5	11-20-90	<2mm	<8	<4	30	12	51	750	<.02	<2
	11-20-90	<62µm	<8	<4	33	17	62	890	.04	3
8	11-19-90	<2mm	<8	<4	21	25	55	1,600	.04	<2
	11-19-90	<62µm	<8	<4	24	20	62	1,800	.04	<2
10	11-19-90	<2mm	<8	<4	15	8	89	510	.02	9
	11-19-90	<62µm	<8	<4	15	9	95	550	.02	10
11	11-26-90	<2mm	<8	<4	11	7	45	1,100	.02	4
	11-26-90	<62µm	<8	<4	11	6	46	1,100	.08	5

TABLE 17. Concentrations of trace-element constituents and carbon in bottom-sediment samples from the study area and upstream sites, 1990--Continued

Site No. (figs. 1 and 10)	Date	Fraction	Neodymium, total (mg/kg as Nd)	Nickel, total (mg/kg as Ni)	Niobium, total (mg/kg as Nb)	Scandium, total (mg/kg as Sc)	Selenium, total (mg/kg as Se)	Silver, total (mg/kg as Ag)	Strontium, total (mg/kg as Sr)	Tantalum, total (mg/kg as Ta)
					Reference Sites					
1	11-27-90	<2mm	30	12	<4	4	<0.1	<2	240	<40
	11-27-90	<62µm	36	27	<4	8	.4	<2	470	<40
2	11-27-90	<2mm	23	8	<4	4	.2	<2	260	<40
	11-27-90	<62µm	30	21	<4	8	.3	<2	470	<40
9	11-26-90	<2mm	27	13	7	9	.3	<2	450	<40
	11-26-90	<62µm	35	22	11	13	.4	<2	420	<40
3	11-20-90	<2mm	26	8	5	6	<.1	<2	430	<40
	11-20-90	<62µm	39	20	5	10	.2	<2	450	<40
					Irrigation Drainage Sites					
4	11-19-90	<2mm	22	10	<4	5	.1	<2	410	<40
	11-19-90 Q	<62µm	23	10	4	5	<.1	<2	420	<40
	11-19-90	<2mm	25	21	<4	9	.5	<2	720	<40
	11-19-90 Q	<62µm	23	21	<4	9	.5	<2	720	<40
7	11-19-90	<2mm	22	10	5	5	.4	<2	500	<40
	11-19-90	<62µm	27	17	7	9	.9	<2	620	<40
5	11-20-90	<2mm	26	15	7	8	.6	<2	490	<40
	11-20-90	<62µm	28	19	10	10	.7	<2	480	<40
8	11-19-90	<2mm	23	18	4	7	.6	<2	670	<40
	11-19-90	<62µm	22	19	6	9	.6	<2	620	<40
10	11-19-90	<2mm	16	10	<4	5	1.0	<2	1,100	<40
	11-19-90	<62µm	17	11	<4	5	1.2	<2	1,100	<40
11	11-26-90	<2mm	18	11	<4	4	1.1	<2	1,200	<40
	11-26-90	<62µm	17	12	<4	4	1.4	<2	1,200	<40

TABLE 17. Concentrations of trace-element constituents and carbon in bottom-sediment samples from the study area and upstream sites, 1990--Continued

Site No. (figs. 1 and 10)	Date	Fraction	Thorium, total (mg/kg as Th)	Tin, total (mg/kg as Sn)	Uranium, total (mg/kg as U)	Vanadium, total (mg/kg as V)	Ytterbium, total (mg/kg as Yb)	Yttrium, total (mg/kg as Y)	Zinc, total (mg/kg as Zn)
					Reference Sites				
1	11-27-90	<2mm	10	20	2.98	63	2	18	39
	11-27-90	<62μm	14	73	5.10	75	2	21	84
2	11-27-90	<2mm	7.8	<5	2.43	50	1	14	31
	11-27-90	<62μm	11	<5	4.99	68	2	18	73
9	11-26-90	<2mm	11	<5	3.50	77	2	20	60
	11-26-90	<62μm	14	<5	4.95	110	2	23	90
3	11-20-90	<2mm	8.7	<5	3.22	61	2	17	37
	11-20-90	<62μm	17	<5	--	120	3	24	82
					Irrigation Drainage Sites				
4	11-19-90	<2mm	7.3	<5	2.87	55	2	16	44
	11-19-90 Q	<2mm	7.2	<5	2.71	56	1	15	44
	11-19-90	<2mm	10	<5	3.67	84	2	15	94
	11-19-90 Q	<62μm	7.0	<5	3.63	84	2	16	94
7	11-19-90	<2mm	6.5	<5	3.79	56	1	15	48
	11-19-90	<62μm	10	<5	6.22	82	1	16	80
5	11-20-90	<2mm	9.1	<5	4.10	73	2	18	80
	11-20-90	<62μm	9.0	<5	5.01	89	2	19	99
8	11-19-90	<2mm	6.0	<5	3.94	76	2	14	77
	11-19-90	<62μm	8.0	<5	4.90	86	2	15	88
10	11-19-90	<2mm	7.1	<5	5.98	44	<1	9	45
	11-19-90	<62μm	<4.0	<5	7.90	49	1	9	50
11	11-26-90	<2mm	<5.1	<5	8.09	52	1	6	43
	11-26-90	<62μm	<4.0	<5	9.17	55	<1	6	46

TABLE 18. Concentrations of organochlorine compounds and carbon in bottom-sediment samples from the study area, 1988-90

[Abbreviations and symbols: PCB, polychlorinated biphenyls; PCN, polychlorinated naphthalenes; g/kg, gram per kilogram; µg/kg, microgram per kilogram; --, not determined; <, less than]

Site No. (fig. 10)	Date	Carbon, inorganic (g/kg)	Carbon, inorganic plus organic (g/kg)	PCB, total (µg/kg)	PCN, total (µg/kg)	Aldrin, total (µg/kg)	Chlordane, total (µg/kg)	DDD, total (µg/kg)	DDE, total (µg/kg)	DDT, total (µg/kg)	Dieldrin, total (µg/kg)
10	03-17-88	50	59	<1.0	<1.0	<0.10	<1.0	<0.10	0.10	<0.10	<0.10
	11-19-90	--	--	<1.0	<1.0	<.10	<1.0	<.10	.10	<.10	<.10
11	03-17-88	90	100	<1.0	<1.0	<.10	<1.0	<.10	<.10	<.10	<.10
	11-26-90	--	--	<1.0	<1.0	<.10	<1.0	.10	.20	<.10	<.10

Site No. (fig. 10)	Date	Endosulfan, total (µg/kg)	Endrin, total (µg/kg)	Heptachlor, total (µg/kg)	Heptachlor epoxide, total (µg/kg)	Lindane, total (µg/kg)	Methoxychlor, total (µg/kg)	Mirex, total (µg/kg)	Perthane (µg/kg)	Toxaphene, total (µg/kg)
10	03-17-88	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<1.0	<10
	11-19-90	<.10	<.10	<.10	<.10	<.10	<10	<.10	<1.0	<10
11	03-17-88	<.10	<.10	<.10	<.10	<.10	<.10	<.10	<1.0	<10
	11-26-90	<.10	<.10	<.10	<.10	<.10	<10	<.10	<1.0	<10

TABLE 19. Data on physical properties and chemical constituents for ground-water samples from the study area, 1990

[Abbreviations and symbols: mg/L, milligram per liter; µg/L, microgram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; --, not determined; <, less than]

Site No. (fig. 10)	Local site designation[a]	Altitude of land surface (feet)	Total depth of well[b] (feet)	Date sampled	Time	Water level (feet below land surface)	Specific conductance (µS/cm)	pH (standard units)	Water temperature (°C)	Oxygen, dissolved (mg/L)	Hardness (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)
12	N27 E31 12DDDA1	4,000	42	07-11-90	1215	7.2	1,470	7.4	15.5	0.3	240	69	17	220
				11-20-90	1200	12.5	1,320	7.6	17.0	1.0	230	65	16	210

Potassium, dissolved (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Bicarbonate, (mg/L as HCO_3)	Carbonate, (mg/L as CO_3)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Flouride, dissolved (mg/L as F)	Silica, dissolved, (mg/L as SiO_2)	Solids, dissolved, residue at 180 °C (mg/L)	Solids, dissolved, sum of constituents (mg/L)	Nitrogen species, dissolved (mg/L as N): Nitrate	Nitrite	Ammonia	Ammonia, un-ionized	Orthophosphorus, dissolved (mg/L as P)
12	418	510	0	130	140	--	65	902	904	<0.10	<0.01	0.01	<0.01	--
11	361	440	0	120	140	1.6	74	814	854	<.10	<.01	.06	<.01	.06

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, dissolved (µg/L as U)
42	980	<1	1	1	<1	<0.1	10	<1	65	10	4.9
44	940	<1	<1	3	1	<.1	8	<1	46	7	9.3

[a] A local site designation is used in Nevada to identify a site by the official rectangular subdivision of the public lands referenced to the Mount Diablo base line and meridian. The first unit is the township, preceded by an N or S to indicate location north or south of the base line. The second unit is the range preceded by an E to indicate location east of the meridian. The third unit consists of the section number and letters designating the quarter section, quarter-quarter section, and so on (A, B, C, and D indicate the northeast, northwest, southwest, and southeast quarters, respectively) followed by a number indicating the sequence in which the site was recorded.

[b] Total depth of well: Source of information is drillers' log (on file at Nevada Division of Water Resources, Carson City)

TABLE 20. Concentrations of trace-element constituents and percent moisture in biological samples from the study area and upstream sites, 1986-90 (data from U.S. Fish and Wildlife Service)

[All values in microgram per gram, dry weight. Except as noted, bird tissue is liver. Abbreviations and symbols: J, juvenile; M, muscle; --, not analyzed; <, less than]

Category	Species	Location	Date	Percent moisture	Aluminum	Arsenic	Barium	Berylium	Boron	Cadmium	Chromium
PLANT	Algae	Army Drain 2	06-02-87	70.1	--	12	155	<0.34	91	<1.3	17
PLANT	Algae	Army Drain 2	05-25-90	95.0	2,110	5.4	56	<.10	150	0.30	2
PLANT	Algae	Rennie Road drain 1	05-25-90	89.5	1,810	61	70	<.10	170	.40	2
PLANT	Algae	Rennie Road drain 3	06-09-87	70.0	--	31	88	.39	128	<.19	6.6
PLANT	Algae	Rennie Road drain 3	05-25-90	89.6	8,230	110	157	.32	130	.30	5.5
PLANT	Algae	Carpenter Road Drain	08-12-87	61.8	--	15	238	.84	46	.60	13
PLANT	Algae	Seventeen Ditch	06-09-87	78.6	--	42	121	.23	223	<.23	5.5
PLANT	Algae	Westfall Road Drain	06-07-87	85.1	479	28	83	<.34	175	.60	2
PLANT	Algae	Toulon Lake	06-02-87	82.6	--	26	99	<1.3	121	<.29	2
PLANT	Algae	Humboldt Lake N	06-15-90	69.0	7,340	16	156	.30	100	<.20	4.9
PLANT	Alkali Bullrush	Rennie Road drain 3	09-07-87	84.7	993	9.3	15	<.33	15	<.33	7.2
PLANT	Alkali Bullrush	Carpenter Road Drain	09-07-87	83.7	632	5.1	11	<.31	7.5	<.31	15
PLANT	Alkali Bullrush	Westfall Road Drain	09-07-87	85.8	845	8.2	14	<.35	12	<.35	2.4
PLANT	Alkali Bullrush	Toulon Lake	02-07-87	90.6	--	3.6	25	<.53	16	<.53	3.7
PLANT	Alkali Bullrush	Humboldt Lake	09-19-86	90.5	--	14	30	<1	25	<2	22
PLANT	Alkali Bullrush	Humboldt Lake	09-19-86	9.0	--	.20	4.4	<.55	14	<1.1	1.4
PLANT	Alkali Bullrush	Humboldt Lake	09-19-86	88.8	--	14	31	<.85	46	<1.7	27
PLANT	Alkali Bullrush	Humboldt Lake	09-19-86	12.0	--	.28	5.7	<.57	14	<1.1	1.4
PLANT	Alkali Bullrush	Humboldt Lake	09-19-86	87.6	--	27	22	<.79	49	<1.6	16
PLANT	Alkali Bullrush	Humboldt Lake	09-19-86	7.6	--	.22	4.1	<.52	13	<1	1.3
PLANT	Cattail Root	Rennie Road drain 3	07-07-87	90.4	--	10	39	<.49	4.9	<.49	1
PLANT	Cattail Root	Carpenter Road Drain	07-07-87	89.8	--	11	71	<.52	27	<.52	5.9
PLANT	Cattail Root	S Meridian Road	07-07-89	92.2	--	1.5	39	<.64	6.4	<.64	1.7
PLANT	Cattail Root	Westfall Road Drain	09-07-87	94.0	--	4.5	56	<.83	158	1.2	5.5
PLANT	Cattail Root	Toulon Lake	07-07-87	93.7	--	4.8	22	<.79	7.9	<.79	1.6
PLANT	Musk Grass	Humboldt R Imlay	06-26-90	86.0	4,740	24	205	.60	55	<.20	3.4
PLANT	Sago Pondweed	Army Drain 2	02-07-87	87.5	--	82	129	<.40	431	3.8	14
PLANT	Sago Pondweed	Rennie Road Drain 2	06-20-90	89.9	939	57	39	<.10	87	.30	2
PLANT	Sago Pondweed	Carpenter Road Drain	09-07-87	86.3	--	18	29	<.36	3.7	<.36	0.70
PLANT	Sago Pondweed	S Meridian Road	02-07-87	83.6	--	8.4	163	.73	216	<.30	25
PLANT	Sago Pondweed	Seventeen Ditch	09-07-87	86.9	--	32	1.5	<.38	283	<.38	8.5
PLANT	Sago Pondweed	Toulon Lake	02-07-87	90.3	--	14	82	<.52	561	<.52	5.3
PLANT	Sago Pondweed	Toulon Lake	07-02-87	90.3	--	82	82	<.52	431	<.52	14
PLANT	Sago Pondweed	Toulon Lake	06-11-90	87.8	3,280	14	119	<.10	180	<.20	3.2
PLANT	Sago Pondweed	Toulon Lake	05-25-90	89.3	1,340	24	45	<.10	432	<.20	1

TABLE 20. Concentrations of trace-element constituents and percent moisture in biological samples from the study area and upstream sites, 1986-90 (data from U.S. Fish and Wildlife Service)--Continued

Category	Species	Location	Date	Percent moisture	Aluminum	Arsenic	Barium	Berylium	Boron	Cadmium	Chromium
PLANT	Sago Pondweed	Humboldt Lake	06-15-90	85.8	734	14	40	<0.10	620	<0.20	1
PLANT	Submerged plant	Humboldt R Imlay	06-26-90	96.2	7,080	2.8	164	.20	35	1.2	6.8
INSECT	Brine Fly	Rennie Road drain 2	05-25-90	92.3	2,110	26	35	.30	130	<.50	3
INSECT	Chironomid	Humboldt R Golconda	06-26-90	98.5	15,000	<70	310	<30	<600	60	<300
INSECT	Chironomid	Humboldt Lake C	06-15-90	84.0	5,420	14	117	.30	44	.40	4
INSECT	Chironomid	Humboldt Lake N	06-15-90	81.8	6,330	4.7	74	.50	29	<.40	5
INSECT	Diptera	Toulon Lake	06-23-87	85.4	--	7.8	146	.20	30	.30	5.4
INSECT	Diptera	Humboldt Lake	08-05-86	89.2	--	7.6	48	<.93	<46	<.93	20
INSECT	Hemiptera	Toulon Lake	06-23-87	86.1	180	0.40	6.5	<.10	9.5	.60	<1
INSECT	Hemiptera	Humboldt Lake	08-05-86	81.5	260	.87	8.6	<.54	<27	<.54	<1.6
INSECT	Water Boatman	Rennie Road drain 2	05-25-90	89.9	398	6.3	6.9	<.10	75	.30	<1
INSECT	Water Boatman	Humboldt Lake C	06-15-90	86.4	498	3.0	16	.10	29	1.9	<1
FISH	Bluegill Sunfish	Humboldt R Golconda	07-27-90	72.5	12	.40	4.8	<.10	2	<.20	4
FISH	Bluegill Sunfish	Humboldt R Lovelock	07-27-90	75.2	13	.40	5.1	<.10	2	<.20	3
FISH	Bluegill Sunfish	Humboldt R Lovelock	07-27-90	73.8	26	.59	4.9	<.10	2	<.20	2
FISH	Bluegill Sunfish	Humboldt R Lovelock	07-27-90	74.5	37	.30	5.2	<.10	3	<.20	3
FISH	Bluegill Sunfish	Humboldt R Lovelock	07-20-90	76.1	14	.30	4.5	<.10	7.1	<.20	1
FISH	Bluegill Sunfish	Humboldt R Lovelock	07-27-90	73.5	8	.20	5	<.10	5	<.20	<1
FISH	Bluegill Sunfish	Humboldt R Lovelock	07-27-90	75.8	50	.30	5	<.10	7.6	<.20	2
FISH	Bluegill Sunfish	Humboldt R Lovelock	07-27-90	74.2	29	.40	6.3	<.10	3	<.20	3.5
FISH	Bluegill Sunfish	Humboldt R Lovelock	07-27-90	75.0	25	.20	6.6	<.10	4	<.20	4.3
FISH	Carp	Humboldt R Golconda	07-19-90	76.1	1,090	1.0	24	<.10	2	<.20	3.7
FISH	Carp	Humboldt R Golconda	07-19-90	75.3	31	.64	5.6	<.10	2	<.20	3.2
FISH	Carp	Humboldt R Lovelock	07-27-90	78.5	29	1.3	5.9	<.10	6.2	<.20	<1
FISH	Carp	Humboldt R Lovelock	07-19-90	77.6	13	1.6	7.3	<.10	5	<.20	2
FISH	Carp	Army Drain	07-09-87	80.1	24	.31	6.4	<.10	2	<.20	1
FISH	Carp	Humboldt Lake	10-29-86	81.7	--	.81	4.3	<.54	<27	<1.1	6.8
FISH	Carp	Humboldt Lake	10-29-86	78.0	--	.96	5.5	<.45	<23	<.91	6.3
FISH	Carp	Humboldt Lake	10-29-86	81.1	--	1.2	4.1	<.51	<26	<1	6.4
FISH	Channel Catfish	Humboldt R Golconda	07-19-90	79.5	55	<.20	11	<.10	3	.80	<1
FISH	Channel Catfish	Humboldt R Golconda	07-19-90	79.6	308	.20	16	<.10	<2	.50	<1
FISH	Channel Catfish	Humboldt R Golconda	07-19-90	76.6	88	<.20	11	<.10	<2	.30	<1
FISH	Channel Catfish	Humboldt R Golconda	07-19-90	77.1	99	.20	13	<.09	2	<.20	3
FISH	Channel Catfish	Humboldt R Golconda	07-19-90	76.9	170	<.20	7.7	<.10	3	.90	2
FISH	Channel Catfish	Humboldt R Imlay	07-20-90	79.8	1,080	.61	18	<.10	2	.30	2
FISH	Channel Catfish	Humboldt R Imlay	07-20-90	83.2	2,560	1.2	40	<.10	4	.30	3
FISH	Redside Shiner	Humboldt R Golconda	07-19-90	59.7	23	.10	3	<.10	2	<.20	1
FISH	Redside Shiner	Humboldt R Golconda	07-09-90	59.9	27	.20	4.7	<.10	2	<.30	1
FISH	Redside Shiner	Humboldt R Golconda	07-09-90	61.9	13	.10	2.4	<.10	2	<.20	1
FISH	Sacramento Perch	Humboldt Lake	10-29-86	74.7	--	.54	3.8	<.38	<19	<.76	7.6

TABLE 20. Concentrations of trace-element constituents and percent moisture in biological samples from the study area and upstream sites, 1986-90 (data from U.S. Fish and Wildlife Service)--Continued

Category	Species	Location	Date	Percent moisture	Aluminum	Arsenic	Barium	Berylium	Boron	Cadmium	Chromium
FISH	Tahoe Sucker	Humboldt R Golconda	07-19-90	70.0	240	0.96	9.9	<0.09	2	<0.20	4.3
FISH	Tahoe Sucker	Humboldt R Golconda	07-09-90	67.4	52	.63	5.9	<.10	2	<.20	1
FISH	Tahoe Sucker	Humboldt R Golconda	07-09-90	70.5	1,840	.82	34	.10	2	<.20	3.8
FISH	Tahoe Sucker	Humboldt R Golconda	07-09-90	66.2	180	.71	9.5	<.09	2	<.20	1
FISH	Tahoe Sucker	Humboldt R Golconda	07-09-90	68.9	723	.86	16	<.10	2	<.20	2
FISH	Tahoe Sucker	Humboldt R Lovelock	07-27-90	72.2	17	1.4	15	<.10	8.6	<.20	6.9
FISH	White Crappie	Humboldt R Imlay	07-20-90	75.8	77	.64	9.7	<.10	2	<.20	1
FISH	White Crappie	Humboldt R Imlay	07-20-90	75.3	81	.70	10	<.10	2	<.20	1
FISH	White Crappie	Humboldt R Imlay	07-20-90	76.8	71	.73	9.7	<.20	2	<.20	1
FISH	White Crappie	Humboldt R Imlay	07-20-90	77.2	91	.66	10	<.20	2	<.20	1
FISH	White Crappie	Humboldt R Imlay	07-09-90	71.9	67	.30	7.8	<.10	2	<.20	1
FISH	Walleye	Humboldt R Imlay	07-29-90	78.2	74	.50	4.2	<.10	<2	<.20	<1
FISH	White Bass	Humboldt R Imlay	07-20-90	75.0	32	.40	117	.30	<2	.40	<1
FISH	White Bass	Humboldt R Imlay	07-20-90	82.3	75	.30	4.2	<.10	<2	.50	<1
BIRD	J American Coot	Toulon Lake	07-02-87	74.3	<3	<.20	0.10	<.10	2	<.20	<1
BIRD	J American Coot	Toulon Lake	07-02-87	77.5	<3	<.20	<.10	<.10	3	<.20	<1
BIRD	J American Coot	Toulon Lake	07-02-87	76.9	<3	<.20	<.10	<.10	<2	<.20	<1
BIRD	J American Coot	Toulon Lake	07-02-87	76.8	3	<.20	<.10	<.10	4	<.20	<1
BIRD	J American Coot	Toulon Lake	07-02-87	80.2	<3	<.20	<.10	<.10	3	<.20	<1
BIRD	J American Coot	Humboldt Lake	08-09-88	68.1	4	.30	<.10	<.10	5	.80	<2
BIRD	J American Coot	Humboldt Lake	08-09-88	68.6	<3	.52	<.10	<.10	8	.70	<2
BIRD	J American Coot	Humboldt Lake	08-09-88	69.0	3	.20	<.10	<.10	5	<.40	<2
BIRD	J American Coot	Humboldt Lake	08-09-88	70.9	<3	.20	<.10	<.10	5	<.40	<2
BIRD	J American Coot	Humboldt Lake	08-09-88	69.6	4	.41	.10	<.10	4	1	<2
BIRD	J American Coot	Humboldt Lake	08-09-88	70.3	<3	.20	.10	<.10	3	<.40	<2
BIRD	J American Coot	Humboldt Lake	08-09-88	66.8	3	.20	<.10	<.10	4	1	<2
BIRD	J American Coot	Humboldt Lake	08-09-88	68.8	<3	.38	.10	<.10	6	.50	<2
BIRD	J American Coot	Humboldt Lake	08-09-88	69.6	4	.50	<.10	<.10	3	.90	<2
BIRD	J American Coot	Humboldt Lake	08-09-88	71.2	4	.30	<.10	<.10	<2	1	<2
BIRD	J American Coot	Humboldt Lake	08-09-88	69.0	4	.38	<.10	<.10	5	.70	<2
BIRD	J American Coot	Humboldt Lake	08-09-88	69.4	<3	.36	<.10	<.10	5	<.40	<2
BIRD	J American Coot	Humboldt Lake	08-04-86	76.9	8	.36	<.42	<.42	11	<.42	<1.3
BIRD	J American Coot	Humboldt Lake	08-04-86	75.7	9	.39	<.40	<.40	39	<.40	<1.2
BIRD	J American Coot	Humboldt Lake	08-04-86	72.8	13	.40	<.36	<.36	73	<.36	<1.1
BIRD	J American Coot	Humboldt Lake	08-04-86	76.6	12	.65	<.43	<.43	47	<.43	<1.3
BIRD	J American Coot	Humboldt Lake	08-04-86	74.9	12	.36	<.39	<.39	51	<.39	<1.2
BIRD	J Black-necked Stilt	Toulon Lake	08-12-87	69.4	<3	<.20	.43	<.10	<2	<.20	<1
BIRD	J Black-necked Stilt	Toulon Lake	08-12-87	70.7	<3	<.20	.20	<.10	<2	<.20	<1
BIRD	J Black-necked Stilt	Toulon Lake	08-12-87	71.6	<3	<.20	.10	<.10	<2	<.20	<1
BIRD	J Black-necked Stilt	Toulon Lake	08-12-87	71.4	<3	<.20	.20	<.10	<2	.20	<1

TABLE 20. Concentrations of trace-element constituents and percent moisture in biological samples from the study area and upstream sites, 1986-90 (data from U.S. Fish and Wildlife Service)--Continued

Category	Species	Location	Date	Percent moisture	Aluminum	Arsenic	Barium	Berylium	Boron	Cadmium	Chromium
BIRD	J Black-necked Stilt	Humboldt Lake	08-04-86	72.4	6.9	<0.17	<0.36	<0.36	24	<0.36	<1.1
BIRD	J Black-necked Stilt	Humboldt Lake	08-04-86	74.2	7.2	<.18	<.38	<.38	25	2.7	1.4
BIRD	J Black-necked Stilt	Humboldt Lake	08-04-86	72.2	25	<.17	<.40	<.40	190	<.40	1.9
BIRD	J Black-necked Stilt	Humboldt Lake	08-04-86	72.4	21	<.18	<.42	<.42	110	<.42	1.4
BIRD	J Black-necked Stilt	Humboldt Lake	08-04-86	71.9	10	<.17	<.53	<.53	45	<.53	2.6
BIRD	J Black-necked Stilt	Humboldt Lake	07-30-87	74.9	<3	<.20	.20	<.10	2	.40	<1
BIRD	J Black-necked Stilt	Humboldt Lake	07-30-87	73.3	<3	<.20	.10	<.10	<2	<.20	<1
BIRD	J Black-necked Stilt	Humboldt Lake	07-30-87	76.2	5	<.20	.20	<.10	<2	3.3	<1
BIRD	J Black-necked Stilt	Humboldt Lake	08-12-87	71.1	<3	<.20	.10	.10	<2	.20	<1
BIRD	J Black-necked Stilt	Humboldt Lake	08-12-87	71.2	<3	<.20	.20	<.10	<2	1.8	<1
BIRD	Cinnamon Teal	Army Drain	07-19-88	74.1	<6.3	<.30	.23	<.03	5.1	.41	<.50
BIRD	Cinnamon Teal	Army Drain	07-19-88	73.9	<6.3	.46	.22	<.03	1.8	<.40	<.50
BIRD	Cinnamon Teal	Army Drain	07-19-88	72.5	<6.3	<.30	.26	<.03	2	<.40	.63
BIRD	Cinnamon Teal	Humboldt Lake	07-23-88	76.9	<6.3	<.30	<.18	<.03	3.6	.53	<.50
BIRD	Cinnamon Teal	Humboldt Lake	07-23-88	74.9	<6.3	<.30	.46	.24	3.2	.92	.91
BIRD	Cinnamon Teal	Humboldt Lake	07-23-88	75.2	<6.3	<.30	<.18	<.03	3.4	<.40	.54
BIRD	Gadwall	Humboldt Lake	08-09-88	74.2	<3	.20	.30	<.10	4	<.50	<2
BIRD	Green-winged Teal M	Toulon Lake	10-14-89	81.1	<3	.20	--	--	2	--	1
BIRD	Mallard	Humboldt Lake	07-23-88	72.0	<6.3	.38	<.18	<.03	3.4	<.40	.62
BIRD	Mallard	Humboldt Lake	07-23-88	72.9	<6.3	.40	<.18	<.03	2.7	<.40	.60
BIRD	Mallard	Humboldt Lake	07-23-88	71.9	<6.3	.47	<.18	.03	3.9	<.40	.63
BIRD	Mallard	Humboldt Lake	07-23-88	74.1	6.7	<.30	<.18	<.03	3.1	<.40	<.50
BIRD	Mallard	Humboldt Lake	08-09-88	73.9	5	.36	.30	<.10	9	<.40	<2
BIRD	Mallard	Humboldt Lake	08-09-88	73.0	<3	.10	<.10	<.10	10	<.40	<2
BIRD	Mallard	Humboldt Lake	08-09-88	74.7	<3	.20	.30	<.10	9	<.40	<2
BIRD	Northern Shoveler M	Toulon Lake	10-14-89	72.7	7	.20	--	--	2	--	1
BIRD	Northern Shoveler M	Toulon Lake	10-14-89	73.6	<3	.30	--	--	2	--	1
BIRD	Redhead	Humboldt Lake	07-23-88	75.6	<6.3	.56	.30	<.03	5.2	<.40	.55
BIRD	Redhead	Humboldt Lake	07-23-88	76.0	7.2	.73	.51	.07	6.1	.58	.85
BIRD	Redhead	Humboldt Lake	08-09-88	72.4	4	.10	<1	<1	3	<.50	<2
EGG	Cinnamon Teal	Toulon Lake	06-28-88	65.8	<6.3	<.30	10	.05	2.8	<.40	<.50
EGG	Cinnamon Teal	Toulon Lake	06-01-88	67.9	<6.3	<.30	8.3	.06	5.2	<.40	<.50
EGG	American Coot	Toulon Lake	05-17-88	72.2	<6.3	.50	12	.14	9	<.40	<.50
EGG	American Coot	Toulon Lake	05-17-88	74.5	<6.3	.55	1.6	.08	4.5	.40	<.50
EGG	American Coot	Toulon Lake	05-17-88	75.4	<6.3	.42	3.9	.07	6.4	<.40	<.50
EGG	American Coot	Toulon Lake	05-17-88	73.1	<6.3	.49	3.6	<.03	6.9	<.40	<.50
EGG	American Coot	Toulon Lake	05-17-88	74.0	<6.3	.46	4.9	.21	6.7	1.2	.86
EGG	American Coot	Toulon Lake	06-08-88	73.4	<6.3	.76	3.7	.15	7.1	.93	<.50
EGG	American Coot	Toulon Lake	06-08-88	74.0	<6.3	<.30	11	.17	9.5	.91	<.50
EGG	American Coot	Toulon Lake	06-08-88	77.2	<6.3	<.30	6	.19	14	.81	.54

TABLE 20. Concentrations of trace-element constituents and percent moisture in biological samples from the study area and upstream sites, 1986-90 (data from U.S. Fish and Wildlife Service)--Continued

Category	Species	Location	Date	Percent moisture	Aluminum	Arsenic	Barium	Berylium	Boron	Cadmium	Chromium
EGG	American Coot	Toulon Lake	05-25-88	72.2	<6.3	<0.30	1.3	0.13	5.1	1.0	<0.50
EGG	American Coot	Toulon Lake	05-17-88	73.5	<6.3	<.30	7.4	.11	8.7	.55	<.50
EGG	American Coot	Toulon Lake	05-17-88	73.5	<6.3	<.30	3.4	<.03	7.8	.69	.89
EGG	American Coot	Toulon Lake	05-17-88	72.7	<6.3	.64	3.1	<.03	7.2	<.40	<.50
EGG	American Coot	Toulon Lake	05-25-88	66.5	<6.3	.49	3.2	<.03	4.4	<.40	<.50
EGG	American Coot	Toulon Lake	05-25-88	63.6	<6.3	.51	9.1	<.03	9.8	<.40	<.50
EGG	American Coot	Toulon Lake	05-25-88	63.7	<6.3	.63	3.9	<.03	14	<.40	<.50
EGG	American Coot	Toulon Lake	05-17-88	65.4	<6.3	.46	4	.12	9.1	.44	<.50
EGG	American Coot	Toulon Lake	05-17-88	63.3	<6.3	.50	2.9	.32	5.2	<.40	<.50
EGG	American Coot	Toulon Lake	05-17-88	59.8	<6.3	<.30	1	<.03	5.4	<.40	.91
EGG	American Coot	Toulon Lake	05-17-88	65.5	<6.3	<.30	4.2	.03	7.7	<.40	.58
EGG	American Coot	Toulon Lake	05-17-88	62.4	<6.3	.47	5.4	<.03	8.6	<.40	<.50
EGG	American Coot	Toulon Lake	05-17-88	54.0	<6.3	.43	8.9	<.03	8.5	<.40	<.50
EGG	American Coot	Toulon Lake	05-25-88	55.8	<6.3	<.30	6	<.03	4.5	<.40	.62
EGG	American Coot	Toulon Lake	05-26-88	59.7	<6.3	<.30	6.2	.04	5.5	<.40	.59
EGG	American Coot	Toulon Lake	05-25-88	77.8	<6.3	.51	3.8	<.03	10	<.40	<.50
EGG	American Coot	Toulon Lake	05-25-88	75.3	<6.3	<.30	7.3	<.03	8.6	<.40	<.50
EGG	American Coot	Toulon Lake	05-26-88	75.6	<6.3	<.30	6.3	<.03	6.8	<.40	<.50
EGG	American Coot	Toulon Lake	06-01-88	74.9	<6.3	.43	2.2	<.03	5.7	<.40	<.50
EGG	Gadwall	Toulon Lake	06-08-88	65.9	<6.3	<.30	9.3	.04	3.9	<.40	<.50
EGG	Mallard	Toulon Lake	05-25-88	65.7	<6.3	<.30	4.7	.04	10	<.40	<.50
EGG	Redhead	Toulon Lake	05-25-88	51.5	<6.3	<.30	9.3	.11	3.1	<.40	<.50
EGG	Redhead	Toulon Lake	05-25-88	65.1	<6.3	<.30	19	.19	7.2	.56	<.50
EGG	Redhead	Toulon Lake	06-08-88	68.2	<6.3	<.30	9	<.03	4.7	<.40	<.50
EGG	Redhead	Toulon Lake	06-01-88	66.9	<6.3	<.30	13	.04	6.3	<.40	.53
EGG	Redhead	Toulon Lake	06-01-88	68.3	<6.3	<.30	11	.24	9.6	.73	.56
EGG	Redhead	Toulon Lake	06-08-88	66.2	<6.3	<.30	12	.14	4.8	<.40	<.50

TABLE 20. Concentrations of trace-element constituents and percent moisture in biological samples from the study area and upstream sites, 1986-90 (data from U.S. Fish and Wildlife Service)--Continued

Category	Species	Location	Date	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum
PLANT	Algae	Army Drain 2	06-02-87	20	--	40	--	--	0.04	<13
PLANT	Algae	Army Drain 2	05-25-90	11	1,800	4	8,390	204	.04	3.3
PLANT	Algae	Rennie Road drain 1	05-25-90	6.2	1,550	4	5,220	1,070	.03	3
PLANT	Algae	Rennie Road drain 3	06-09-87	14	--	22	--	220	.04	<1.9
PLANT	Algae	Rennie Road drain 3	05-25-90	9.1	6,360	6	7,900	330	.03	3
PLANT	Algae	Carpenter Road Drain	08-12-87	14	--	9	--	--	.05	<2
PLANT	Algae	Seventeen Ditch	06-09-87	24	--	15	--	--	.06	3.6
PLANT	Algae	Westfall Road Drain	06-07-87	5.1	407	6.7	--	866	.09	<3.4
PLANT	Algae	Toulon Lake	06-02-87	7.4	--	9.2	--	142	.07	<2.9
PLANT	Algae	Humboldt Lake	06-15-90	8.8	5,220	8	8,290	786	.03	<1
PLANT	Alkali Bullrush	Rennie Road drain 3	09-07-87	11	--	6.5	--	352	.16	<3.3
PLANT	Alkali Bullrush	Carpenter Road Drain	09-07-87	3.9	816	6.1	779	217	.15	<3.1
PLANT	Alkali Bullrush	Westfall Road Drain	09-07-87	6.9	739	7	986	274	.18	<3.5
PLANT	Alkali Bullrush	Toulon Lake	02-07-87	8.7	--	11	--	86	.27	<5.3
PLANT	Alkali Bullrush	Humboldt Lake	09-19-86	8.4	--	.10	--	--	.22	<2
PLANT	Alkali Bullrush	Humboldt Lake	09-19-86	2.5	--	.55	--	--	.11	<1.1
PLANT	Alkali Bullrush	Humboldt Lake	09-19-86	3.9	--	.85	--	--	.17	2.7
PLANT	Alkali Bullrush	Humboldt Lake	09-19-86	3.3	--	.55	--	--	.12	<1.1
PLANT	Alkali Bullrush	Humboldt Lake	09-19-86	3.8	--	.80	--	--	.20	2.9
PLANT	Alkali Bullrush	Humboldt Lake	09-19-86	3.6	--	.50	--	--	.10	<1
PLANT	Cattail Root	Rennie Road drain 3	07-07-87	42	--	9.8	--	--	.25	<4.9
PLANT	Cattail Root	Carpenter Road Drain	07-07-87	17	--	10	--	--	.26	<5.2
PLANT	Cattail Root	S Meridian Road	07-07-89	13	--	13	237	265	.32	<6.4
PLANT	Cattail Root	Westfall Road Drain	09-07-87	9.7	--	17	--	--	.42	<8.3
PLANT	Cattail Root	Toulon Lake	07-07-87	28	870	16	--	70	.40	<7.9
PLANT	Musk Grass	Humboldt R Imlay	06-26-90	6.9	3,420	5	5,960	481	.03	2
PLANT	Sago Pondweed	Army Drain 2	02-07-87	21	--	13	--	--	.20	7.3
PLANT	Sago Pondweed	Rennie Road drain 2	06-20-90	5.4	1,020	4	6,750	708	.03	17
PLANT	Sago Pondweed	Carpenter Road Drain	09-07-87	31	20	7.3	--	869	.18	<3.6
PLANT	Sago Pondweed	S Meridian Road	02-07-87	71	--	33	--	--	.15	<3.1
PLANT	Sago Pondweed	Seventeen Ditch	09-07-87	24	--	16	--	--	.19	<3.8
PLANT	Sago Pondweed	Toulon Lake	02-07-87	17	--	10	--	103	.26	<5.1
PLANT	Sago Pondweed	Toulon Lake	07-02-87	18	--	<10	--	103	<.26	<5.1
PLANT	Sago Pondweed	Toulon Lake	06-11-90	7.3	2,280	4	6,890	162	.04	<1
PLANT	Sago Pondweed	Toulon Lake	05-25-90	5.7	1,080	4	7,840	74	.03	3.3

TABLE 20. Concentrations of trace-element constituents and percent moisture in biological samples from the study area and upstream sites, 1986-90 (data from U.S. Fish and Wildlife Service)--Continued

Category	Species	Location	Date	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum
PLANT	Sago pondweed	Humboldt Lake	06-15-90	5.5	729	4	7,140	54	0.03	3.1
PLANT	Submerged plant	Humboldt R Imlay	06-26-90	21	4,920	7	3,840	1,210	.55	2
INSECT	Brine Fly	Rennie Road drain 2	05-25-90	12	2,210	<9	3,910	443	.28	43
INSECT	Chironomid	Humboldt R Golconda	06-26-90	200	13,000	<1,000	8,400	1,000	<1.0	<300
INSECT	Chironomid	Humboldt Lake	06-15-90	20	4,630	6	6,650	245	.10	<1
INSECT	Chironomid	Humboldt Lake	06-15-90	16	5,230	<8	3,940	331	.15	<2
INSECT	Diptera	Toulon Lake	06-23-87	18	--	<4	--	276	.08	<1
INSECT	Diptera	Humboldt Lake	08-05-86	26	--	<1.9	--	270	<.44	<0.93
INSECT	Hemiptera	Toulon Lake	06-23-87	23	270	<4	--	18	.10	2
INSECT	Hemiptera	Humboldt Lake	08-05-86	26	310	<1.1	--	43	.33	1.7
INSECT	Water Boatman	Rennie Road drain 2	05-25-90	10	443	<4	2,520	74	.16	6.6
INSECT	Water Boatman	Humboldt Lake C	06-15-90	33	555	<4	2,020	39	.10	1
FISH	Bluegill Sunfish	Humboldt R Golconda	07-27-90	2.0	58	4	1,350	19	.69	<1
FISH	Bluegill Sunfish	Humboldt R Lovelock	07-27-90	1.9	54	4	1,470	16	.85	<1
FISH	Bluegill sunfish	Humboldt R Lovelock	07-27-90	1.7	50	4	1,470	18	1	<1
FISH	Bluegill Sunfish	Humboldt R Lovelock	07-27-90	1.6	64	4	1,440	17	.77	<1
FISH	Bluegill Sunfish	Humboldt R Lovelock	07-20-90	2.5	50	<4	1,360	18	.79	<1
FISH	Bluegill Sunfish	Humboldt R Lovelock	07-27-90	1.8	51	<4	1,170	13	.91	<1
FISH	Bluegill Sunfish	Humboldt R Lovelock	07-27-90	2.1	80	<4	1,400	16	1.4	<1
FISH	Bluegill Sunfish	Humboldt R Lovelock	07-27-90	1.4	58	4	1,320	16	.64	<1
FISH	Bluegill Sunfish	Humboldt R Lovelock	07-27-90	1.5	65	4	1,390	12	.62	<1
FISH	Carp	Humboldt R Golconda	07-19-90	6.8	754	4	1,610	37	.48	<1
FISH	Carp	Humboldt R Golconda	07-19-90	5.1	88	4	1,280	5.3	.46	<1
FISH	Carp	Humboldt R Lovelock	07-27-90	5.8	104	<4	1,290	6	.53	<1
FISH	Carp	Humboldt R Lovelock	07-19-90	4.3	90	<4	1,240	4.5	.36	<1
FISH	Carp	Army Drain	07-09-87	4.0	170	<4	--	10	.43	<.76
FISH	Carp	Humboldt Lake	10-29-86	2.6	--	<1.1	--	--	.46	50
FISH	Carp	Humboldt Lake	10-29-86	1.8	--	1.9	--	--	.72	<1
FISH	Carp	Humboldt Lake	10-29-86	3.8	--	<1	--	--	.54	<1
FISH	Channel Catfish	Humboldt R Golconda	07-19-90	2.3	69	<6	1,290	24	.53	<1
FISH	Channel Catfish	Humboldt R Golconda	07-19-90	3.2	276	<4	1,510	46	.47	<1
FISH	Channel Catfish	Humboldt R Golconda	07-19-90	3.5	78	<4	1,290	23	.52	<1
FISH	Channel Catfish	Humboldt R Golconda	07-19-90	2.8	131	4	1,310	42	.56	1
FISH	Channel Catfish	Humboldt R Golconda	07-19-90	2.6	146	<8	957	18	.55	<1
FISH	Channel Catfish	Humboldt R Imlay	07-20-90	3.2	905	<4	1,590	27	1.3	<1
FISH	Channel Catfish	Humboldt R Imlay	07-20-90	7.3	2,030	<4	2,020	55	.79	<1
FISH	Redside Shiner	Humboldt R Golconda	07-19-90	1.4	49	4	856	4.4	.45	<1
FISH	Redside Shiner	Humboldt R Golconda	07-09-90	1.2	51	4	831	2.9	.57	<1
FISH	Redside Shiner	Humboldt R Golconda	07-09-90	1.4	38	4	866	4.2	.78	1
FISH	Scaramento Perch	Humboldt Lake	10-29-86	0.92	--	<0.76	--	--	.66	<.93

TABLE 20. Concentrations of trace-element constituents and percent moisture in biological samples from the study area and upstream sites, 1986-90 (data from U.S. Fish and Wildlife Service)--Continued

Category	Species	Location	Date	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum
FISH	Tahoe Sucker	Humboldt R Golconda	07-19-90	2.2	173	4	1,340	19	0.36	<0.90
FISH	Tahoe Sucker	Humboldt R Golconda	07-09-90	1.8	64	4	1,050	13	.59	<1
FISH	Tahoe Sucker	Humboldt R Golconda	07-09-90	4.5	1,220	4	1,810	63	.46	<1
FISH	Tahoe Sucker	Humboldt R Golconda	07-09-90	1.2	140	4	1,160	17	.35	<.90
FISH	Tahoe Sucker	Humboldt R Golconda	07-09-90	2.4	514	4	1,440	34	.48	<1
FISH	Tahoe Sucker	Humboldt R Lovelock	07-27-90	1.9	60	4	1,260	27	.45	<1
FISH	White Crappie	Humboldt R Imlay	07-20-90	0.82	69	4	1,640	17	.09	<1
FISH	White Crappie	Humboldt R Imlay	07-20-90	.96	74	4	1,610	23	.10	<1
FISH	White Crappie	Humboldt R Imlay	07-20-90	.92	67	4	1,600	20	.11	<1
FISH	White Crappie	Humboldt R Imlay	07-20-90	.83	80	4	1,580	21	.10	<1
FISH	White Crappie	Humboldt R Imlay	07-09-90	1.7	65	4	1,480	14	.44	<1
FISH	Walleye	Humboldt R Imlay	07-29-90	1.5	84	<4	1,420	5.1	.16	<1
FISH	White Bass	Humboldt R Imlay	07-20-90	4.6	65	<4	1,780	4.9	.27	<1
FISH	White Bass	Humboldt R Imlay	07-20-90	9.9	199	<4	1,540	2.9	.95	<1
BIRD	J American Coot	Toulon Lake	07-02-87	81	427	<4	784	8.2	.44	2
BIRD	J American Coot	Toulon Lake	07-02-87	60	909	<4	738	10	.20	2
BIRD	J American Coot	Toulon Lake	07-02-87	135	914	<4	776	10	.55	3
BIRD	J American Coot	Toulon Lake	07-02-87	71	464	<4	776	12	.49	3
BIRD	J American Coot	Toulon Lake	07-02-87	135	577	<4	775	9.6	.44	3.5
BIRD	J American Coot	Humboldt Lake	08-09-88	13	3,460	<4	585	13	1.5	4
BIRD	J American Coot	Humboldt Lake	08-09-88	26	5,370	<4	595	8.1	.44	4.7
BIRD	J American Coot	Humboldt Lake	08-09-88	28	4,340	<4	685	13	.42	4
BIRD	J American Coot	Humboldt Lake	08-09-88	27	3,470	<4	716	12	3.2	4.3
BIRD	J American Coot	Humboldt Lake	08-09-88	35	5,480	<4	678	9.7	.42	6
BIRD	J American Coot	Humboldt Lake	08-09-88	33	4,370	<4	628	7.7	.27	4.3
BIRD	J American Coot	Humboldt Lake	08-09-88	32	2,330	<4	586[1]	9.9	.27	3
BIRD	J American Coot	Humboldt Lake	08-09-88	18	4,460	<4	557	9.9	.31	4.6
BIRD	J American Coot	Humboldt Lake	08-09-88	13	5,320	<4	625	11	.42	4
BIRD	J American Coot	Humboldt Lake	08-09-88	26	4,770	<4	706	15	.41	4
BIRD	J American Coot	Humboldt Lake	08-09-88	17	6,490	<4	700	12	.62	5.6
BIRD	J American Coot	Humboldt Lake	08-09-88	15	3,840	<4	564	8.4	.21	3
BIRD	J American Coot	Humboldt Lake	08-04-86	63	--	<0.84	840	9.8	.41	5.5
BIRD	J American Coot	Humboldt Lake	08-04-86	29	470	<.79	870	9.3	.75	3.4
BIRD	J American Coot	Humboldt Lake	08-04-86	80	250	<.72	800	24	.35	4.4
BIRD	J American Coot	Humboldt Lake	08-04-86	77	440	<.85	820	14	.68	3.9
BIRD	J American Coot	Humboldt Lake	08-04-86	110	380	<.78	--	18	.53	4.5
BIRD	J Black-necked Stilt	Toulon Lake	08-12-87	16	918	<4	732	12	2.7	2
BIRD	J Black-necked Stilt	Toulon Lake	08-12-87	22	961	<4	728	15	2.8	2
BIRD	J Black-necked Stilt	Toulon Lake	08-12-87	20	--	<4	723	14	3.1	3
BIRD	J Black-necked Stilt	Toulon Lake	08-12-87	20	--	<4	700	13	2.2	2

TABLE 20. Concentrations of trace-element constituents and percent moisture in biological samples from the study area and upstream sites, 1986-90 (data from U.S. Fish and Wildlife Service)--Continued

Category	Species	Location	Date	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum
BIRD	J Black-necked Stilt	Humboldt Lake	08-04-86	18	--	<0.72	940	15	4.4	2.5
BIRD	J Black-necked Stilt	Humboldt Lake	08-04-86	18	--	<.76	910	16	0.51	2.1
BIRD	J Black-necked Stilt	Humboldt Lake	08-04-86	17	890	<.81	890	17	.44	2.1
BIRD	J Black-necked Stilt	Humboldt Lake	08-04-86	18	--	<.84	920	16	.61	2.3
BIRD	J Black-necked Stilt	Humboldt Lake	08-04-86	19	730	<1.1	860	12	.38	1.7
BIRD	J Black-necked Stilt	Humboldt Lake	07-30-87	22	--	<4	822	14	2.5	2
BIRD	J Black-necked Stilt	Humboldt Lake	07-30-87	24	798	<4	790	14	2.4	2
BIRD	J Black-necked Stilt	Humboldt Lake	07-30-87	16	--	<4	714	11	1.9	2
BIRD	J Black-necked Stilt	Humboldt Lake	08-12-87	23	771	<4	686	12	2.1	2
BIRD	J Black-necked Stilt	Humboldt Lake	08-12-87	33	941	<4	744	13	2.4	3
BIRD	Cinnamon Teal	Army Drain	07-19-88	42	681	<9	994	15	1.6	<7
BIRD	Cinnamon Teal	Army Drain	07-19-88	80	310	<9	1,040	15	.61	<7
BIRD	Cinnamon Teal	Army Drain	07-19-88	69	786	<9	929	15	1.1	<7
BIRD	Cinnamon Teal	Humboldt Lake	07-23-88	115	431	11	809	16	1.2	<7
BIRD	Cinnamon Teal	Humboldt Lake	07-23-88	216	369	<9	802	16	.79	<7
BIRD	Cinnamon Teal	Humboldt Lake	07-23-88	167	1,140	<9	616	11	.43	<7
BIRD	Gadwall	Humboldt Lake	08-09-88	117	735	<4	822	11	.84	4.2
BIRD	Green-winged Teal M	Toulon Lake	10-14-89	20	226	4	999	1.3	.10	--
BIRD	Mallard	Humboldt Lake	07-23-88	93	542	<9	723	10	.34	<7
BIRD	Mallard	Humboldt Lake	07-23-88	175	513	<9	750	9.4	.49	<7
BIRD	Mallard	Humboldt Lake	07-23-88	189	594	<9	651	11	.35	9
BIRD	Mallard	Humboldt Lake	07-23-88	117	627	<9	634	9.6	.27	<7
BIRD	Mallard	Humboldt Lake	08-09-88	16	1,090	<4	925	10	.70	3.8
BIRD	Mallard	Humboldt Lake	08-09-88	46	685	<4	744	11	.71	2
BIRD	Mallard	Humboldt Lake	08-09-88	12	1,860	<4	808	9.5	.59	3
BIRD	Northern Shoveler M	Toulon Lake	10-14-89	29	199	4	1,080	1.4	.74	--
BIRD	Northern Shoveler M	Toulon Lake	10-14-89	25	209	4	1,010	1.5	.87	--
BIRD	Redhead	Humboldt Lake	07-23-88	724	1,390	<9	798	14	.83	<7
BIRD	Redhead	Humboldt Lake	07-23-88	833	1,270	<9	714	15	.84	<7
BIRD	Redhead	Humboldt Lake	08-09-88	65	522	<4	655	12	.58	2
EGG	Cinnamon Teal	Toulon Lake	06-28-88	4.0	119	<9	485	2	.39	<7
EGG	Cinnamon Teal	Toulon Lake	06-01-88	4.9	119	<9	402	1.4	.52	<7
EGG	American Coot	Toulon Lake	05-17-88	6.4	109	<9	481	1.1	.13	<7
EGG	American Coot	Toulon Lake	05-17-88	5.5	84	<9	604	1.3	.14	<7
EGG	American Coot	Toulon Lake	05-17-88	3.6	87	<9	681	1.4	.10	<7
EGG	American Coot	Toulon Lake	05-17-88	4.5	116	<9	519	1.4	.23	<7
EGG	American Coot	Toulon Lake	05-17-88	5.2	118	<9	607	1.7	.15	<7
EGG	American Coot	Toulon Lake	06-08-88	4.6	114	<9	518	0.70	.11	<7
EGG	American Coot	Toulon Lake	06-08-88	4.0	153	<9	483	1.1	.18	<7
EGG	American Coot	Toulon Lake	06-08-88	5.6	121	<9	569	1.5	.13	<7

TABLE 20. Concentrations of trace-element constituents and percent moisture in biological samples from the study area and upstream sites, 1986-90 (data from U.S. Fish and Wildlife Service)--Continued

Category	Species	Location	Date	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum
EGG	American Coot	Toulon Lake	05-25-88	4.3	96	<9	598	1.1	0.16	<7
EGG	American Coot	Toulon Lake	05-17-88	3.8	108	<9	603	1.1	.08	<7
EGG	American Coot	Toulon Lake	05-17-88	5.8	80	10	659	1.6	.10	<7
EGG	American Coot	Toulon Lake	05-17-88	4.9	98	<9	728	0.80	.14	<7
EGG	American Coot	Toulon Lake	05-25-88	3.9	127	<9	703	1.2	.17	<7
EGG	American Coot	Toulon Lake	05-25-88	4.2	102	<9	598	1	.14	<7
EGG	American Coot	Toulon Lake	05-25-88	6.6	103	<9	684	.60	.09	<7
EGG	American Coot	Toulon Lake	05-17-88	5.7	130	13	627	1.6	.20	7.3
EGG	American Coot	Toulon Lake	05-17-88	3.4	90	<9	479	<.40	.20	<7
EGG	American Coot	Toulon Lake	05-17-88	4.0	77	<9	502	2.2	.15	<7
EGG	American Coot	Toulon Lake	05-17-88	3.4	74	<9	480	<.40	.12	<7
EGG	American Coot	Toulon Lake	05-17-88	4.0	80	<9	495	.50	.11	<7
EGG	American Coot	Toulon Lake	05-17-88	3.3	100	<9	424	.70	1.4	<7
EGG	American Coot	Toulon Lake	05-25-88	3.7	89	<9	300	.70	.48	<7
EGG	American Coot	Toulon Lake	05-26-88	4.5	89	<9	496	1.8	.29	<7
EGG	American Coot	Toulon Lake	05-25-88	5.0	105	<9	455	.80	.10	<7
EGG	American Coot	Toulon Lake	05-25-88	4.7	112	<9	566	.50	.10	<7
EGG	American Coot	Toulon Lake	05-26-88	5.1	118	<9	493	1.5	.22	<7
EGG	American Coot	Toulon Lake	06-01-88	3.2	77	<9	526	1.1	.13	<7
EGG	Gadwall	Toulon Lake	06-08-88	4.5	139	<9	491	1.2	.22	<7
EGG	Mallard	Toulon Lake	05-25-88	5.1	78	<9	299	.60	.51	7.5
EGG	Redhead	Toulon Lake	05-25-88	6.8	124	<9	789	1.4	.60	<7
EGG	Redhead	Toulon Lake	05-25-88	4.8	157	14	395	1.5	.08	<7
EGG	Redhead	Toulon Lake	06-08-88	4.4	152	<9	482	.70	.08	<7
EGG	Redhead	Toulon Lake	06-01-88	5.3	181	<9	392	3.1	1.7	<7
EGG	Redhead	Toulon Lake	06-01-88	6.5	106	<9	547	1.1	.07	<7
EGG	Redhead	Toulon Lake	06-08-88	4.6	132	<9	381	.90	.27	<7

TABLE 20. Concentrations of trace-element constituents and percent moisture in biological samples from the study area and upstream sites, 1986-90 (data from U.S. Fish and Wildlife Service)--Continued

Category	Species	Location	Date	Nickel	Selenium	Strontium	Tin	Vanadium	Zinc
PLANT	Algae	Army Drain 2	06-02-87	<11	0.50	184	--	33	58
PLANT	Algae	Army Drain 2	05-25-90	6.0	1.6	221	--	14	36
PLANT	Algae	Rennie Road drain 1	05-25-90	4.2	1.8	828	--	11	23
PLANT	Algae	Rennie Road drain 3	06-09-87	6.9	.35	753	--	18	26
PLANT	Algae	Rennie Road drain 3	05-25-90	5.3	.81	719	--	32	52
PLANT	Algae	Carpenter Road Drain	08-12-87	9.7	1.0	511	--	37	46
PLANT	Algae	Seventeen Drain	06-09-87	13	.94	461	--	37	31
PLANT	Algae	Westfall Road Drain	06-07-87	3.3	.84	509	--	18	8.6
PLANT	Algae	Toulon Lake	06-02-87	2.4	.68	466	--	6.9	11
PLANT	Algae	Humboldt Lake	06-15-90	5.4	1.4	695	--	23	26
PLANT	Alkali Bullrush	Rennie Road drain 3	09-07-87	3.7	.09	19	--	<3.3	21
PLANT	Alkali Bullrush	Carpenter Road Drain	09-07-87	4.9	.24	11	--	4.1	17
PLANT	Alkali Bullrush	Westfall Road Drain	09-07-87	2.8	.15	18	--	<3.5	16
PLANT	Alkali Bullrush	Toulon Lake	02-07-87	4.8	.17	62	--	<5.3	20
PLANT	Alkali Bullrush	Humboldt Lake	09-19-86	--	.95	--	--	<1.0	10
PLANT	Alkali Bullrush	Humboldt Lake	09-19-86	--	.23	--	--	<.55	13
PLANT	Alkali Bullrush	Humboldt Lake	09-19-86	--	.89	--	--	<.85	<8.5
PLANT	Alkali Bullrush	Humboldt Lake	09-19-86	--	.22	--	--	<.57	6.0
PLANT	Alkali Bullrush	Humboldt Lake	09-19-86	--	.71	--	--	<.79	<7.9
PLANT	Alkali Bullrush	Humboldt Lake	09-19-86	--	.22	--	--	.52	14
PLANT	Cattail Root	Rennie Road drain 3	07-07-87	11	.26	78	--	9.1	53
PLANT	Cattail Root	Carpenter Road Drain	07-07-87	16	.30	75[1]	--	13	29
PLANT	Cattail Root	S Meridian Road	07-07-89	6.8	.09	51	--	<6.4	25
PLANT	Cattail Root	Westfall Road Drain	09-07-87	<6.7	.53	103	--	13	31
PLANT	Cattail Root	Toulon Lake	07-07-87	<6.4	.22	91	--	<7.9	22
PLANT	Musk Grass	Humboldt R Inlay	06-26-90	4.4	1.2	624	--	18	20
PLANT	Sago Pondweed	Army Drain 2	02-07-87	14	.96	192	--	32	53
PLANT	Sago Pondweed	Rennie Road drain 2	06-20-90	4.3	1.6	787	--	17	16
PLANT	Sago Pondweed	Carpenter Road Drain	09-07-87	12	.82	58	--	6.8	39
PLANT	Sago Pondweed	S Meridian Road	02-07-87	59	.54	170	--	29	74
PLANT	Sago Pondweed	Seventeen Ditch	09-07-87	20	1.1	212	--	30	36
PLANT	Sago Pondweed	Toulon Lake	02-07-87	5.3	.87	428	--	8.5	53
PLANT	Sago Pondweed	Toulon Lake	07-02-87	5.3	.87	428	--	8.5	--
PLANT	Sago Pondweed	Toulon Lake	06-11-90	<1	.94	409	--	8.7	38
PLANT	Sago Pondweed	Toulon Lake	06-25-90	<1	.48	154	--	3.2	25

TABLE 20. Concentrations of trace-element constituents and percent moisture in biological samples from the study area and upstream sites, 1986-90 (data from U.S. Fish and Wildlife Service)--Continued

Category	Species	Location	Date	Nickel	Selenium	Strontium	Tin	Vanadium	Zinc
PLANT	Sago Pondweed	Humboldt Lake	06-15-90	2.0	0.54	259	--	5.2	15
PLANT	Submerged plant	Humboldt R Imlay	06-26-90	6.1	1.0	122	--	16	53
INSECT	Brine Fly	Rennie Road drain 2	05-25-90	7.0	2.9	406	--	46	51
INSECT	Chironomid	Humboldt R Golconda	06-26-90	<300	<10	280	--	<90	850
INSECT	Chironomid	Humboldt Lake	06-15-90	4.4	5.0	580	--	15	58
INSECT	Chironomid	Humboldt Lake	06-15-90	6.9	2.6	263	--	19	73
INSECT	Diptera	Toulon Lake	06-23-87	4.6	5.1	330	--	14	71
INSECT	Diptera	Humboldt Lake	08-05-86	8.3	2.5	200	--	16	--
INSECT	Hemiptera	Toulon Lake	06-23-87	<1	4.1	20	--	0.60	175
INSECT	Hemiptera	Humboldt Lake	08-05-86	<1.6	5.1	22	--	1.1	170
INSECT	Water Boatman	Rennie Road drain 2	05-25-90	<1	1.8	97	--	5.7	92
INSECT	Water Boatman	Humboldt Lake	06-15-90	<1	4.6	104	--	2.2	163
FISH	Bluegill Sunfish	Humboldt R Golconda	07-27-90	2	3.3	173	--	<.30	82
FISH	Bluegill Sunfish	Humboldt R Lovelock	07-27-90	<1	3.7	194	--	<.30	85
FISH	Bluegill Sunfish	Humboldt R Lovelock	07-27-90	<1	3.0	191	--	<.30	84
FISH	Bluegill Sunfish	Humboldt R Lovelock	07-27-90	<1	3.2	189	--	<.30	73
FISH	Bluegill Sunfish	Humboldt R Lovelock	07-20-90	<2	2.9	190	--	<.40	74
FISH	Bluegill Sunfish	Humboldt R Lovelock	07-27-90	<2	2.7	168	--	<.40	70
FISH	Bluegill Sunfish	Humboldt R Lovelock	07-27-90	<2	3.7	200	--	<.40	83
FISH	Bluegill Sunfish	Humboldt R Lovelock	07-27-90	2	2.7	186	--	<.30	71
FISH	Bluegill Sunfish	Humboldt R Lovelock	07-27-90	2	2.6	191	--	<.30	67
FISH	Carp	Humboldt R Golconda	07-19-90	2	2.1	90	--	2.1	174
FISH	Carp	Humboldt R Golconda	07-19-90	2	1.6	64	--	.40	167
FISH	Carp	Humboldt R Lovelock	07-27-90	<2	2.7	155	--	.40	--
FISH	Carp	Humboldt R Lovelock	07-19-90	<2	2.2	166	--	<.40	146
FISH	Carp	Army Drain	07-09-87	<1	3.8	281	--	.90	187
FISH	Carp	Humboldt Lake	10-29-86	--	3.9	--	--	1.7	110
FISH	Carp	Humboldt Lake	10-29-86	--	1.9	--	--	2.1	120
FISH	Carp	Humboldt Lake	10-29-86	--	2.4	--	--	2.4	100
FISH	Channel Catfish	Humboldt R Golconda	07-19-90	5	3.0	62	--	10	75
FISH	Channel Catfish	Humboldt R Golconda	07-19-90	<2	2.7	90	--	.90	98
FISH	Channel Catfish	Humboldt R Golconda	07-19-90	<2	2.0	76	--	<.40	89
FISH	Channel Catfish	Humboldt R Golconda	07-19-90	1	4.1	78	--	.40	90
FISH	Channel Catfish	Humboldt R Golconda	07-19-90	11	.09	16	--	23	49
FISH	Channel Catfish	Humboldt R Imlay	07-20-90	<2	2.0	69	--	2.7	77
FISH	Channel Catfish	Humboldt R Imlay	07-20-90	2	2.3	51	--	6.1	127
FISH	Redside Shiner	Humboldt R Golconda	07-19-90	<1	1.7	34	--	<.30	71
FISH	Redside Shiner	Humboldt R Golconda	07-09-90	1	2.3	31	--	1.9	74
FISH	Redside Shiner	Humboldt R Golconda	07-09-90	<1	2.0	29	--	<.30	83
FISH	Sacramento Perch	Humboldt Lake	10-29-86	--	3.1	--	--	1.1	35

TABLE 20. Concentrations of trace-element constituents and percent moisture in biological samples from the study area and upstream sites, 1986-90 (data from U.S. Fish and Wildlife Service)--Continued

Category	Species	Location	Date	Nickel	Selenium	Strontium	Tin	Vanadium	Zinc
FISH	Tahoe Sucker	Humboldt R Golconda	07-19-90	2	1.2	59	--	0.50	74
FISH	Tahoe Sucker	Humboldt R Golconda	07-09-90	<1	1.4	34	--	<.30	46
FISH	Tahoe Sucker	Humboldt R Golconda	07-09-90	2	1.5	60	--	3.7	82
FISH	Tahoe Sucker	Humboldt R Golconda	07-09-90	<1	1.1	50	--	.50	84
FISH	Tahoe Sucker	Humboldt R Golconda	07-09-90	1	1.3	45	--	1.5	79
FISH	Tahoe Sucker	Humboldt R Lovelock	07-27-90	3	2.1	116	--	.30	77
FISH	White Crappie	Humboldt R Imlay	07-20-90	<1	2.3	195	--	<.30	67
FISH	White Crappie	Humboldt R Imlay	07-20-90	<1	2.5	173	--	<.30	69
FISH	White Crappie	Humboldt R Imlay	07-20-90	<1	2.6	184	--	<.30	72
FISH	White Crappie	Humboldt R Imlay	07-20-90	<1	2.6	173	--	<.30	69
FISH	White Crappie	Humboldt R Imlay	07-09-90	1	1.7	107	--	<.30	58
FISH	Walleye	Humboldt R Imlay	07-29-90	<2	2.3	66	--	<.40	61
FISH	White Bass	Humboldt R Imlay	07-20-90	4.4	3.3	177	--	<.40	88
FISH	White Bass	Humboldt R Imlay	07-20-90	<2	4.9	69	--	2.9	76
BIRD	J American Coot	Toulon Lake	07-02-87	<1	7.0	0.64	--	<.30	231
BIRD	J American Coot	Toulon Lake	07-02-87	<1	9.6	.76	--	<.30	159
BIRD	J American Coot	Toulon Lake	07-02-87	<1	10	.78	--	<.30	156
BIRD	J American Coot	Toulon Lake	07-02-87	<1	10	.79	--	<.30	229
BIRD	J American Coot	Toulon Lake	07-02-87	<1	9.1	1.2	--	<.30	234
BIRD	J American Coot	Humboldt Lake	08-09-88	<3	8.7	.30	--	<.50	93
BIRD	J American Coot	Humboldt Lake	08-09-88	<3	9.1	.68	--	2.1	96
BIRD	J American Coot	Humboldt Lake	08-09-88	<3	11	.48	--	1.0	121
BIRD	J American Coot	Humboldt Lake	08-09-88	<3	13	.38	--	<.50	137
BIRD	J American Coot	Humboldt Lake	08-09-88	<3	11	.68	--	2.1	118
BIRD	J American Coot	Humboldt Lake	08-09-88	<3	11	.38	--	<.50	111
BIRD	J American Coot	Humboldt Lake	08-09-88	<3	8.5	.47	--	1.0	111
BIRD	J American Coot	Humboldt Lake	08-09-88	<3	8.8	.70	--	<.50	98
BIRD	J American Coot	Humboldt Lake	08-09-88	<3	9.8	.64	--	2.4	88
BIRD	J American Coot	Humboldt Lake	08-09-88	<3	12	.65	--	1.0	132
BIRD	J American Coot	Humboldt Lake	08-09-88	<3	7.8	.45	--	<.50	144
BIRD	J American Coot	Humboldt Lake	08-09-88	<3	10	.33	--	1.6	81
BIRD	J American Coot	Humboldt Lake	08-04-86	<1.3	15	<.42	--	<.42	220
BIRD	J American Coot	Humboldt Lake	08-04-86	<1.2	9.3	<.40	--	<.40	170
BIRD	J American Coot	Humboldt Lake	08-04-86	<1.1	11	<.36	--	.87	240
BIRD	J American Coot	Humboldt Lake	08-04-86	<1.3	12	<.43	--	<.43	220
BIRD	J American Coot	Humboldt Lake	08-04-86	<1.2	9.0	2.7	--	.66	200
BIRD	J Black-necked Stilt	Toulon Lake	08-12-87	<1	12	1.2	--	<.30	88
BIRD	J Black-necked Stilt	Toulon Lake	08-12-87	<1	19	.96	--	<.30	88
BIRD	J Black-necked Stilt	Toulon Lake	08-12-87	<1	18	1.2	--	<.30	87
BIRD	J Black-necked Stilt	Toulon Lake	08-12-87	<1	26	.67	--	<.30	88

TABLE 20. Concentrations of trace-element constituents and percent moisture in biological samples from the study area and upstream sites, 1986-90 (data from U.S. Fish and Wildlife Service)--Continued

Cate-gory	Species	Location	Date	Nickel	Selenium	Strontium	Tin	Vanadium	Zinc
BIRD	J Black-necked Stilt	Humboldt Lake	08-04-86	<1.1	34	<0.36	--	<0.36	110
BIRD	J Black-necked Stilt	Humboldt Lake	08-04-86	<1.1	31	<.38	--	<.38	98
BIRD	J Black-necked Stilt	Humboldt Lake	08-04-86	<1.2	29	<.40	--	<.40	81
BIRD	J Black-necked Stilt	Humboldt Lake	08-04-86	<1.3	42	<.42	--	<.42	120
BIRD	J Black-necked Stilt	Humboldt Lake	08-04-86	<1.6	29	<.53	--	<.53	82
BIRD	J Black-necked Stilt	Humboldt Lake	07-30-87	<1	11	1.2	--	<.30	100
BIRD	J Black-necked Stilt	Humboldt Lake	07-30-87	<1	31	.94	--	<.30	97
BIRD	J Black-necked Stilt	Humboldt Lake	07-30-87	<1	48	.30	--	<.30	86
BIRD	J Black-necked Stilt	Humboldt Lake	08-12-87	<1	32	.32	--	<.30	88
BIRD	J Black-necked Stilt	Humboldt Lake	08-12-87	<1	23	.39	--	<.30	94
BIRD	Cinnamon Teal	Army Drain	07-19-88	<4.5	16	1.1	<21	<.57	153
BIRD	Cinnamon Teal	Army Drain	07-19-88	<4.5	13	1.1	<21	<.57	128
BIRD	Cinnamon Teal	Army Drain	07-19-88	<4.5	16	1.5	<21	<.57	174
BIRD	Cinnamon Teal	Humboldt Lake	07-23-88	<4.5	17	1.5	<21	<.57	184
BIRD	Cinnamon Teal	Humboldt Lake	07-23-88	<4.5	18	2.3	<21	<.57	154
BIRD	Cinnamon Teal	Humboldt Lake	07-23-88	<4.5	12	1.4	<21	<.57	155
BIRD	Gadwall	Humboldt Lake	08-09-88	<3	16	1.7	--	<.50	164
BIRD	Green-winged Teal M	Toulon Lake	10-14-89	<1	3.6	.20	--	<.30	32
BIRD	Mallard	Humboldt Lake	07-23-88	<4.5	7.2	1.8	<21	<.57	171
BIRD	Mallard	Humboldt Lake	07-23-88	<4.5	7.4	1.5	<21	<.57	205
BIRD	Mallard	Humboldt Lake	07-23-88	<4.5	9.8	1.1	<21	<.57	198
BIRD	Mallard	Humboldt Lake	07-23-88	<4.5	8.8	1.8	<21	<.57	188
BIRD	Mallard	Humboldt Lake	08-09-88	<3	23	2.2	--	<.50	164
BIRD	Mallard	Humboldt Lake	08-09-88	<3	13	1.0	--	<.50	167
BIRD	Mallard	Humboldt Lake	08-09-88	<3	20	2.1	--	<.50	135
BIRD	Northern Shoveler M	Toulon Lake	10-14-89	<1	2.7	.58	--	<.30	37
BIRD	Northern Shoveler M	Toulon Lake	10-14-89	<1	7.5	.20	--	<.30	41
BIRD	Redhead	Humboldt Lake	07-23-88	<4.5	12	2.3	<21	<.57	266
BIRD	Redhead	Humboldt Lake	07-23-88	<4.5	13	2.2	<21	<.57	232
BIRD	Redhead	Humboldt Lake	08-09-88	<3	9.1	.64	--	<.50	225
EGG	Cinnamon Teal	Toulon Lake	06-28-88	<4.5	2.8	27	<21	<.57	79
EGG	Cinnamon Teal	Toulon Lake	06-01-88	<4.5	3.7	22	<21	<.57	78
EGG	American Coot	Toulon Lake	05-17-88	<4.5	3.3	43	<21	<.57	72
EGG	American Coot	Toulon Lake	05-17-88	<4.5	2.1	25	<21	<.57	58
EGG	American Coot	Toulon Lake	05-17-88	<4.5	2.9	27	<21	<.57	65
EGG	American Coot	Toulon Lake	05-17-88	<4.5	2.1	26	<21	<.57	59
EGG	American Coot	Toulon Lake	05-17-88	7.4	2.8	29	<21	<.57	64
EGG	American Coot	Toulon Lake	06-08-88	<4.5	2.4	41	<21	<.57	65
EGG	American Coot	Toulon Lake	06-08-88	<4.5	2.2	45	39	<.57	80
EGG	American Coot	Toulon Lake	06-08-88	<4.5	4.0	36	<21	<.57	74

TABLE 20. Concentrations of trace-element constituents and percent moisture in biological samples from the study area and upstream sites, 1986-90 (data from U.S. Fish and Wildlife Service)--Continued

Category	Species	Location	Date	Nickel	Selenium	Strontium	Tin	Vanadium	Zinc
EGG	American Coot	Toulon Lake	05-25-88	<4.5	2.1	32	<21	<0.57	57
EGG	American Coot	Toulon Lake	05-17-88	<4.5	3.8	33	<21	<.57	67
EGG	American Coot	Toulon Lake	05-17-88	<4.5	3.4	33	52	<.57	60
EGG	American Coot	Toulon Lake	05-17-88	<4.5	2.4	47	<21	<.57	61
EGG	American Coot	Toulon Lake	05-25-88	<4.5	2.6	42	26	<.57	66
EGG	American Coot	Toulon Lake	05-25-88	<4.5	2.9	39	<21	.90	67
EGG	American Coot	Toulon Lake	05-25-88	<4.5	4.5	34	35	.59	57
EGG	American Coot	Toulon Lake	05-17-88	5.5	2.3	23	<21	.91	68
EGG	American Coot	Toulon Lake	05-17-88	<4.5	1.8	22	<21	<.57	57
EGG	American Coot	Toulon Lake	05-17-88	<4.5	2.4	9.8	<21	.59	69
EGG	American Coot	Toulon Lake	05-17-88	<4.5	2.8	23	<21	<.57	64
EGG	American Coot	Toulon Lake	05-17-88	<4.5	3.3	14	<21	<.57	56
EGG	American Coot	Toulon Lake	05-17-88	<4.5	2.6	23	<21	.58	68
EGG	American Coot	Toulon Lake	05-25-88	<4.5	2.0	23	<21	<.57	74
EGG	American Coot	Toulon Lake	05-26-88	<4.5	4.1	13	<21	.64	62
EGG	American Coot	Toulon Lake	05-25-88	<4.5	3.1	17	<21	<.57	52
EGG	American Coot	Toulon Lake	05-25-88	<4.5	3.1	29	31	<.57	62
EGG	American Coot	Toulon Lake	05-26-88	<4.5	3.9	15	25	<.57	58
EGG	American Coot	Toulon Lake	06-01-88	<4.5	3.3	18	<21	<.57	54
EGG	Gadwall	Toulon Lake	06-08-88	<4.5	3.1	24	<21	<.57	88
EGG	Mallard	Toulon Lake	05-25-88	<4.5	3.0	16	<21	<.57	56
EGG	Redhead	Toulon Lake	05-25-88	<4.5	3.0	86	<21	<.57	66
EGG	Redhead	Toulon Lake	05-26-88	<4.5	3.1	25	<21	<.57	86
EGG	Redhead	Toulon Lake	06-08-88	<4.5	3.7	21	<21	<.57	78
EGG	Redhead	Toulon Lake	06-01-88	<4.5	3.0	27	<21	<.57	89
EGG	Redhead	Toulon Lake	06-01-88	7.9	3.0	24	<21	.84	64
EGG	Redhead	Toulon Lake	06-08-88	<4.5	3.6	27	<21	<.57	75

TABLE 21. Concentrations of organochlorine compounds and percent moisture and percent lipid in fish samples from the study area and upstream sites, 1990 (data from U.S. Fish and Wildlife Service)

[All values in micrograms per gram, wet weight. Abbreviations and symbols: Q (following the date) indicates duplicate sample collected for quality assurance; PCB, polychlorinated biphenyls; BHC, benzene hexachloride (the gamma isomer of BHC is commonly known as Lindane); <, less than]

Species	Location	Date	Percent moisture	Percent lipid	PCB, total (μg/g)	alpha BHC (μg/g)	beta BHC (μg/g)	gamma BHC (μg/g)	delta BHC (μg/g)	alpha Chlor-dane (μg/g)	gamma Chlor-dane (μg/g)
Channel Catfish	Humboldt R Golconda	07-19-90	75.0	2.04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Channel Catfish	Humboldt R Golconda	07-19-90	76.5	2.42	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Channel Catfish	Humboldt R Golconda	07-19-90	76.5	6.56	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Channel Catfish	Humboldt R Golconda	07-19-90	74.5	7.38	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Channel Catfish	Humboldt R Golconda	07-19-90 Q	73.5	8.08	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Channel Catfish	Humboldt R Imlay	07-20-90	77.5	2.6	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Walleye	Humboldt R Imlay	07-20-90	80.0	1.76	<.01	<.01	<.01	<.01	<.01	<.01	<.01
White Bass	Humboldt R Imlay	07-29-90	76.5	1.14	<.01	<.01	<.01	<.01	<.01	<.01	<.01
White Bass	Humboldt R Imlay	07-20-90	74.5	2.5	<.01	<.01	<.01	<.01	<.01	<.01	<.01
White Bass	Humboldt R Imlay	07-20-90	76.0	.86	<.01	<.01	<.01	<.01	<.01	<.01	<.01
White Bass	Humboldt R Lovelock	07-20-90	72.0	4.47	<.01	<.01	<.01	<.01	<.01	<.01	<.01
White Bass	Humboldt R Lovelock	07-27-90	75.0	4.94	<.01	<.01	<.01	<.01	<.01	<.01	<.01
White Bass	Humboldt R Lovelock	07-27-90	75.0	2.96	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Carp	Humboldt R Lovelock	07-27-90	76.5	3.86	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Carp	Humboldt R Lovelock	07-19-90	76.5	5.0	<.01	<.01	<.01	<.01	<.01	<.01	<.01

TABLE 21. Concentrations of organochlorine compounds and percent moisture and percent lipid in fish samples from the study area and upstream sites, 1990--Continued

Species	Location	Date	o,p'-DDD (µg/g)	p,p'-DDD (µg/g)	o,p'-DDE (µg/g)	p,p'-DDE (µg/g)	o,p'-DDT (µg/g)	p,p'-DDT (µg/g)	Dieldrin, total (µg/g)	Endo-sulfan 1 (µg/g)	Endo-sulfan 2 (µg/g)
Channel Catfish	Humboldt R Golconda	07-19-90	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Channel Catfish	Humboldt R Golconda	07-19-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Channel Catfish	Humboldt R Golconda	07-19-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Channel Catfish	Humboldt R Golconda	07-19-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Channel Catfish	Humboldt R Golconda	07-19-90 Q	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Channel Catfish	Humboldt R Imlay	07-20-90	<.01	<.01	<.01	.03	<.01	.01	<.01	<.01	<.01
Walleye	Humboldt R Imlay	07-20-90	<.01	<.01	<.01	.02	<.01	<.01	<.01	<.01	<.01
White Bass	Humboldt R Imlay	07-29-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
White Bass	Humboldt R Imlay	07-20-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
White Bass	Humboldt R Imlay	07-20-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
White Bass	Humboldt R Lovelock	07-20-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
White Bass	Humboldt R Lovelock	07-27-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
White Bass	Humboldt R Lovelock	07-27-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Carp	Humboldt R Lovelock	07-27-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Carp	Humboldt R Lovelock	07-19-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01

TABLE 21. Concentrations of organochlorine insecticide residues and percent moisture and percent lipid in fish samples from the study area and upstream sites, 1990--Continued

Species	Location	Date	Endrin, total (µg/g)	Heptachlor epoxide, total (µg/g)	Hexa-chloro-benzene, total (µg/g)	Mirex (µg/g)	*cis*-Nona-chlor (µg/g)	*trans*-Nonachlor (µg/g)	Oxy-chlordane (µg/g)	Toxa-phene, total (µg/g)
Channel Catfish	Humboldt R Golconda	07-19-90	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.10
Channel Catfish	Humboldt R Golconda	07-19-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.10
Channel Catfish	Humboldt R Golconda	07-19-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.10
Channel Catfish	Humboldt R Golconda	07-19-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.10
Channel Catfish	Humboldt R Golconda	07-19-90 Q	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.10
Channel Catfish	Humboldt R Imlay	07-20-90	<.01	<.01	<.01	<.01	<.01	.01	<.01	<.10
Walleye	Humboldt R Imlay	07-20-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.10
White Bass	Humboldt R Imlay	07-29-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.10
White Bass	Humboldt R Imlay	07-20-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.10
White Bass	Humboldt R Imlay	07-20-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.10
White Bass	Humboldt R Lovelock	07-20-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.10
White Bass	Humboldt R Lovelock	07-27-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.10
White Bass	Humboldt R Lovelock	07-27-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.10
Carp	Humboldt R Lovelock	07-27-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.10
Carp	Humboldt R Lovelock	07-19-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.10

TABLE 22. Concentrations of trace elements and magnesium in water used for biotoxicity tests (data from U.S. Fish and Wildlife Service)

[Abbreviations and symbol: mg/L, milligram per liter; µg/L, microgram per liter; nd, not detected; <, less than]

Location	Date	Aluminum (µg/L)	Arsenic (µg/L)	Boron (µg/L)	Chromium (µg/L)	Copper (µg/L)	Iron (µg/L)	Lead (µg/L)	Magnesium (mg/L)
Humboldt R Golconda	07-31-90	4,350	20	300	<10	10	3,600	<40	15
Humboldt R Golconda	07-31-90	860	10	200	<10	nd	740	<40	12
Humboldt R Golconda	07-31-90	3,400	20	300	<10	10	3,000	<40	14
Humboldt R Imlay	07-31-90	1,500	20	400	<10	10	1,290	<40	16
Army Drain 2	05-09-90	1,400	910	21,900	<50	30	1,200	<200	111
Army Drain 2	07-31-90	5,100	110	3,900	<50	70	4,700	<200	81
Army Drain at inflow	07-10-90	14,400	80	2,600	10	20	12,300	<40	57
Rennie Road drain 1	07-17-90	<200	380	12,400	<50	30	280	<200	136
Rennie Road drain 2	05-25-90	1,600	10	200	<10	nd	1,270	<40	13
Rennie Road drain 2	07-17-90	<200	190	6,900	<50	20	50	<200	344
Rennie Road drain 3	07-24-90	<200	110	9,000	<50	20	<50	<200	265
Toulon Drain at inflow	07-10-90	1,400	490	16,600	<50	30	1,300	<200	186

Location	Date	Manganese (µg/L)	Mercury (µg/L)	Selenium (µg/L)	Strontium (µg/L)	Vanadium (µg/L)	Zinc (µg/L)
Humboldt R Golconda	07-31-90	120	<0.30	0.60	368	20	28
Humboldt R Golconda	07-31-90	30	<.30	.50	320	10	20
Humboldt R Golconda	07-31-90	100	<.30	.60	355	20	43
Humboldt R Imlay	07-31-90	40	<.30	.60	372	20	20
Army Drain 2	05-09-90	50	.40	10	1,330	30	20
Army Drain 2	07-31-90	730	<.30	1	1,620	40	64
Army Drain at inflow	07-10-90	790	<.30	5	1,490	70	48
Rennie Road drain 1	07-17-90	140	<.30	2	3,050	40	62
Rennie Road drain 2	05-25-90	40	<.30	.60	344	130	16
Rennie Road drain 2	07-17-90	330	<.30	1	7,490	20	10
Rennie Road drain 3	07-24-90	<10	<.30	.70	5,790	<20	30
Toulon Drain at inflow	07-10-90	50	.40	10	1,460	20	30

TABLE 23.--Concentrations of inorganic elements and percent moisture in sediment used for biotoxicity tests (data from U.S. Fish and Wildlife Service)

[All values in microgram per gram, dry weight]

Location	Date	Percent moisture	Aluminum	Arsenic	Boron	Chromium	Copper	Iron	Lead	Magnesium
Humboldt R Imlay	06-26-90	46	28,600	13	28	21	32	28,000	24	13,800
Rennie Road drain 1	05-25-90	44	23,000	17	47	15	31	21,700	19	9,590
Rennie Road drain 2	05-25-90	46	20,000	38	46	12	38	17,100	10	8,750
Rennie Road drain 3	05-25-90	47	28,700	9.6	36	20	22	27,200	21	11,100
Toulon Drain at inflow	05-25-90	44	13,000	16	60	5.1	9.8	9,390	10	14,400
Toulon Drain at inflow	06-11-90	44	11,000	16	56	5.8	10	9,020	9	12,700

Location	Date	Manganese	Mercury	Selenium	Strontium	Vanadium	Zinc
Humboldt R Imlay	06-26-90	728	0.06	0.30	261	37	95
Rennie Road drain 1	05-25-90	405	.63	.63	304	54	79
Rennie Road drain 2	05-25-90	480	.05	.80	386	58	62
Rennie Road drain 3	05-25-90	452	.04	.20	275	57	95
Toulon Drain at inflow	05-25-90	410	.02	.72	823	20	35
Toulon Drain at inflow	06-11-90	423	.01	.61	842	21	32

TABLE 24. Concentrations of organochlorine compounds and percent moisture in sediment used for biotoxicity tests (data from U.S. Fish and Wildlife Service)

[Abbreviations and symbol: µg/g, microgram per gram, BHC, benzene hexachloride (the gamma isomer of BHC is commonly known as Lindane); PCB, polychlorinated biphenyls; <, less than]

Location	Date	Percent moisture	PCB, total (µg/g)	alpha BHC (µg/g)	beta BHC (µg/g)	gamma BHC (µg/g)	delta BHC (µg/g)	alpha Chlordane (µg/g)	gamma Chlordane (µg/g)
Humboldt R Imlay	06-26-90	44	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Rennie Road drain 1	05-25-90	48	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Rennie Road drain 2	05-25-90	53	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Rennie Road drain 3	05-25-90	45	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Toulon drain at Inflow	06-11-90	43	<.01	<.01	<.01	<.01	<.01	<.01	<.01

Location	Date	*o,p'*-DDD (µg/g)	*p,p'*-DDD (µg/g)	*o,p'*-DDE (µg/g)	*p,p'*-DDE (µg/g)	*o,p'*-DDT (µg/g)	*p,p'*-DDT (µg/g)	Dieldrin, total (µg/g)	Endosulfan 1 (µg/g)	Endosulfan 2 (µg/g)
Humboldt R Imlay	06-26-90	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Rennie Road drain 1	05-25-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Rennie Road drain 2	05-25-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Rennie Road drain 3	05-25-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Toulon Drain at inflow	06-11-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01

Location	Date	Endrin, total (µg/g)	Heptachlor epoxide, total (µg/g)	Hexachlor benzene, total (µg/g)	Mirex (µg/g)	*cis*-Nona-chlor (µg/g)	*trans*-Nonachlor (µg/g)	Oxy-chlordane (µg/g)	Toxaphene, total (µg/g)
Humboldt R Imlay	06-26-90	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.10
Rennie Road drain 1	05-25-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.10
Rennie Road drain 2	05-25-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.10
Rennie Road drain 3	05-25-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.10
Toulon Drain at inflow	06-11-90	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.10