RECONNAISSANCE INVESTIGATION OF WATER QUALITY, BOTTOM SEDIMENT, AND BIOTA ASSOCIATED WITH IRRIGATION DRAINAGE IN THE LOWER COLORADO RIVER VALLEY, ARIZONA, CALIFORNIA, AND NEVADA, 1986-87

By D.B. Radtke, U.S. Geological Survey, W.G. Kepner, U.S. Fish and Wildlife Service, and R.J. Effertz, U.S. Bureau of Reclamation

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CONVERSION FACTORS

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

Multiply inch-pound unit	By	To obtain metric unit
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
acre	0.4047	hectare (ha)
acre-foot (acre-ft)	0.001233	cubic hectometer (hm)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
ton (short)	0.9072	megagram (Mg)
degree Fahrenheit (°F)	°C = 5/9 (°F-32)	degree Celsius (°C)

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

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By

D.B. Radtke[1], W.G. Kepner[2], and R.J. Effertz[3]

ABSTRACT

During the last several years, there has been increasing concern about the quality of irrigation drainage and its potential effects on humans, fish, and wildlife. The lower Colorado River valley area was selected for an irrigation drainage reconnaissance study because sufficient information existed to indicate that potential contamination problems may exist.

The Lower Colorado River Valley Irrigation Drainage Project area includes the Colorado River and its environs from Davis Dam to just above Imperial Dam. The area includes Havasu, Cibola, and Imperial National Wildlife Refuges; Colorado River, Chemehuevi, and Fort Mohave Indian Reservations; and Havasu, Palo Verde, and Cibola Irrigation Districts. Water, bottom sediment, and biota were sampled at selected locations within the study area and analyzed for selected inorganic and synthetic organic constituents that are likely to be present at toxic concentrations. Although selenium was the primary element of concern, analyses were done for other trace elements and selected organochlorine pesticides.

Specific water-quality problems (salinity) have been prevalent in the lower Colorado River valley for many years. With exception of selenium and DDE, this study found sampling locations to be relatively free of large concentrations of toxic constituents that could be a threat to humans, fish, and wildlife. Excluding one cadmium value of 69 micrograms per liter, dissolved trace-metal, trace-metalloid, and organochlorine-pesticide data from the lower Colorado River disclosed no elevated concentrations exceeding State of Arizona maximum allowable limits for protected uses of surface water.

Dissolved-selenium concentrations in water at all mainstream Colorado River sites exceeded the 75-percent national baseline. Dissolved-selenium concentrations in water were smaller at sites that were directly influenced by irrigation drainage. Dissolved barium, molybdenum, vanadium, and zinc concentrations at sites directly influenced by agricultural drainage, however, were at least twice the concentrations at sites not directly influenced by irrigation drainage.

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[1] U.S. Geological Survey.

[2] U.S. Fish and Wildlife Service.

[3] U.S. Bureau of Reclamation.

Selenium concentrations in bottom sediment (less than 63-micron diameter) at all mainstream Colorado River sites equaled (approximate) or exceeded the 95-percent baseline when compared to soil samples of the western United States. Selenium concentrations ranged from two to five times the 95-percent baseline for western soils. Largest selenium concentrations were found in backwater areas of the mainstream Colorado River. These areas, lacustrine in character, are composed mainly of fine-grained bottom sediment with a greater percentage of organic material. Selenium concentrations were smaller at sites that are directly influenced by irrigation drainage. Thorium and uranium concentrations in bottom sediment also surpassed the 95-percent baseline at several sites, and the largest concentrations were found at the site, Colorado River below Davis Dam. These large concentrations probably are an artifact of extensive uranium mining, mine spills, and mine discharges in the upper Colorado River basin. Persistent organochlorine pesticides (DDT, DDD, and DDE) and other organic residues were detected in bottom sediment in the study area. Concentrations of DDE were found at all sites and ranged from 0.1 to 7.5 micrograms per kilogram, wet weight.

Selenium was the only inorganic constituent to exceed any existing standard, criterion, or guideline for protection of fish and wildlife resources. Reported mean selenium concentrations in whole-body carp composites for all sites ranged from 0.62 to 4.0 with a mean of 1.49 micrograms per gram, wet weight, and are approaching concentrations that could result in reproductive impairment and lack of recruitment in fish, especially bass, sunfish, and crappie. Sixteen percent of fish composite samples equaled or exceeded the guideline of 2.0 micrograms per gram, wet weight, for reproductive impairment. Mean selenium and zinc concentrations in carp-tissue samples at all sites exceeded the 85-percent national baselines for fish. Organochlorine-pesticide residues do not appear to present environmental problems to fish in the lower Colorado River. Concentrations of DDE in double-crested cormorants, however, exceeded the criterion of 1.0 microgram per gram established by the National Academy of Sciences and National Academy of Engineering for DDT and its metabolites for protection of wildlife.

Dissolved-selenium concentrations in water from the lower Colorado River appear to be derived from sources above Davis Dam. Selenium concentrations in all media were lower in agricultural-drain samples than in nearby mainstream Colorado River samples taken above irrigation projects. At this time, therefore, agricultural practices in the lower Colorado River valley do not appear to exacerbate selenium concentrations.

The fact that agricultural practices in the lower Colorado River valley do not appear to exacerbate selenium concentrations, however, does not mean that aquatic organisms and their predators are not in jeopardy. Selenium appears to be a constituent of concern in the lower Colorado River aquatic system. Continued selenium loading to the lower Colorado River environment could severely affect important components of the ecosystem. A continued monitoring effort would be required to detect perturbations in the watershed that could increase selenium concentrations in the food chain, which could result in an impoverished natural resource.

INTRODUCTION

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

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

The DOI developed a management strategy and the Task Group prepared a comprehensive plan for reviewing irrigation-drainage concerns. Initially, the Task Group identified 19 locations in 13 states that warranted reconnaissance-level field investigations. These locations relate to three specific areas of Interior Department responsibilities: (1) Irrigation or drainage facilities constructed or managed by DOI, (2) national wildlife refuges managed by DOI, and (3) other migratory bird or endangered-species management areas that receive water from DOI-funded projects. Of the 19 locations, 9 were selected for the start of reconnaissance studies in 1986. The locations are:

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

Each reconnaissance investigation was conducted by interbureau field teams composed of scientists representing different disciplines from the U.S. Geological Survey, U.S. Fish and Wildlife Service, and U.S. Bureau of Reclamation.

Purpose and Scope

The purpose of this reconnaissance study was to determine if irrigation drainage from DOI-sponsored irrigation projects in the lower Colorado River valley has caused or has potential to cause significant harmful effects on humans, fish, and wildlife, or may reduce suitability of water for beneficial uses. This report presents findings of the lower Colorado River valley reconnaissance investigation.

Reconnaissance field samples of water, bottom sediment, and plant and animal tissues were collected and analyzed for selected inorganic and organic constituents in order to determine if elevated concentrations exist. Selenium, thallium, toxaphene, and DDT and its degradation products were of particular concern because these constituents have been either detected or found at elevated concentrations in the study area during previous studies.

Acknowledgments

The authors wish to acknowledge the many people who gave assistance during the study. We wish to acknowledge the aid and cooperation of A.W. "Will" Nidecker, III, Wesley V. Martin, and James R. Good, Refuge Managers of Imperial, Cibola, and Havasu National Wildlife Refuges, respectively, and their staffs.

Our thanks go to the staffs of the U.S. Geological Survey National Water Quality Laboratory and the U.S. Fish and Wildlife Service Patuxent Analytical Control Facility for their extra effort and patience in dealing with the special analytical needs of the irrigation-drainage studies. Special thanks go to Steve A. Wilson and Ronald C. Severson of the U.S. Geological Survey Branch of Exploration Geochemistry for their valuable assistance and cooperation.

The authors also acknowledge the field personnel who, during the process of data collection, had to endure long working hours, strenuous and tedious working conditions, and severe (very hot) weather conditions. Thanks go to William P. Roberts, U.S. Geological Survey; Diane M. Laush, John G. Wegrzyn, Gregory Lamme, and Frank M. Baucom, U.S. Fish and Wildlife Service; Wayne Pinkerton, U.S. Bureau of Reclamation; and Steven A. Daniels, Northwest Bureau of the Arizona Republic. Special thanks go to Scott Yess of the U.S. Fish and Wildlife Service Parker Fisheries Assistance Office for his valuable assistance and cooperation which made the entire field operations a complete success.

Thanks go to all personnel who under severe time constraints have assisted in the preparation of this report. Special thanks go to Diane Laush, U.S. Fish and Wildlife Service, and Jean Roberts, Arizona Department of Environmental Quality, for their undaunted help in data compilation and for their helpful suggestions regarding the report.

DESCRIPTION OF THE STUDY AREA

Location

The study area (fig. 1) includes the Colorado River and its environs from Davis Dam to just above Imperial Dam. The area includes parts of Yuma, La Paz, and Mohave Counties, Arizona; Clark County, Nevada; and Imperial, Riverside, and San Bernardino Counties, California.

History

The annual flow of the lower Colorado River is vital to the economic well-being of millions of people in Arizona, California, Nevada, and northern Mexico. The natural and hydrologic environment of the river has been altered greatly by man since about 1870 in attempts to utilize more fully the flow of the river. Need for flood control, water storage, hydroelectric power, and development of agriculture in the flood plain has resulted in impoundments, channeling, dredging, and bank reinforcement along much of the lower Colorado River. Demands for water include not only municipal, irrigation, and electrical-power-generation demands but also recreational and wildlife habitat uses.

The U.S. Department of Interior has five important functions as land and water steward in the lower Colorado River valley:

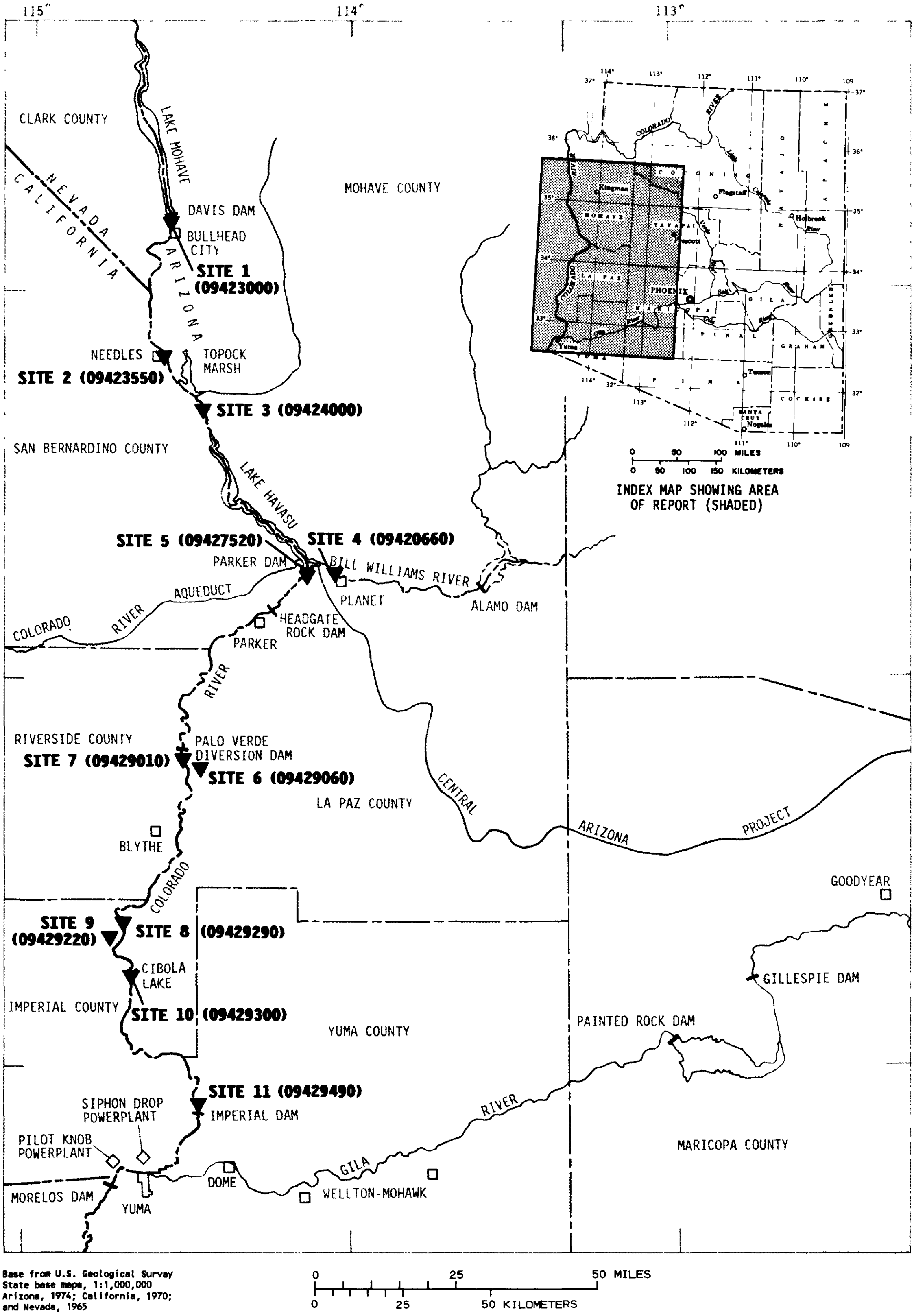
1. Bureau of Reclamation manages Colorado River diversions to private irrigation districts that irrigate hundreds of thousands of acres of intensively farmed agricultural areas in Arizona and California.

2. Bureau of Indian Affairs manages agricultural areas irrigated by Colorado River diversions to all Indian lands along the Colorado River including the Colorado River and Fort Mohave Indian Reservations.

3. Bureau of Land Management leases irrigated agricultural land above the respective National Wildlife Refuges along the Colorado River.

4. Fish and Wildlife Service manages the Havasu, Cibola, and Imperial National Wildlife Refuges for migratory and endangered-wildlife habitat, warm-water fish habitat, and public-use recreation.

5. Geological Survey assesses quality and quantity of the Nation's water resources.



Base from U.S. Geological Survey
State base maps, 1:1,000,000
Arizona, 1974; California, 1970;
and Nevada, 1965

Figure 1.--Location of study area and data-collection sites.

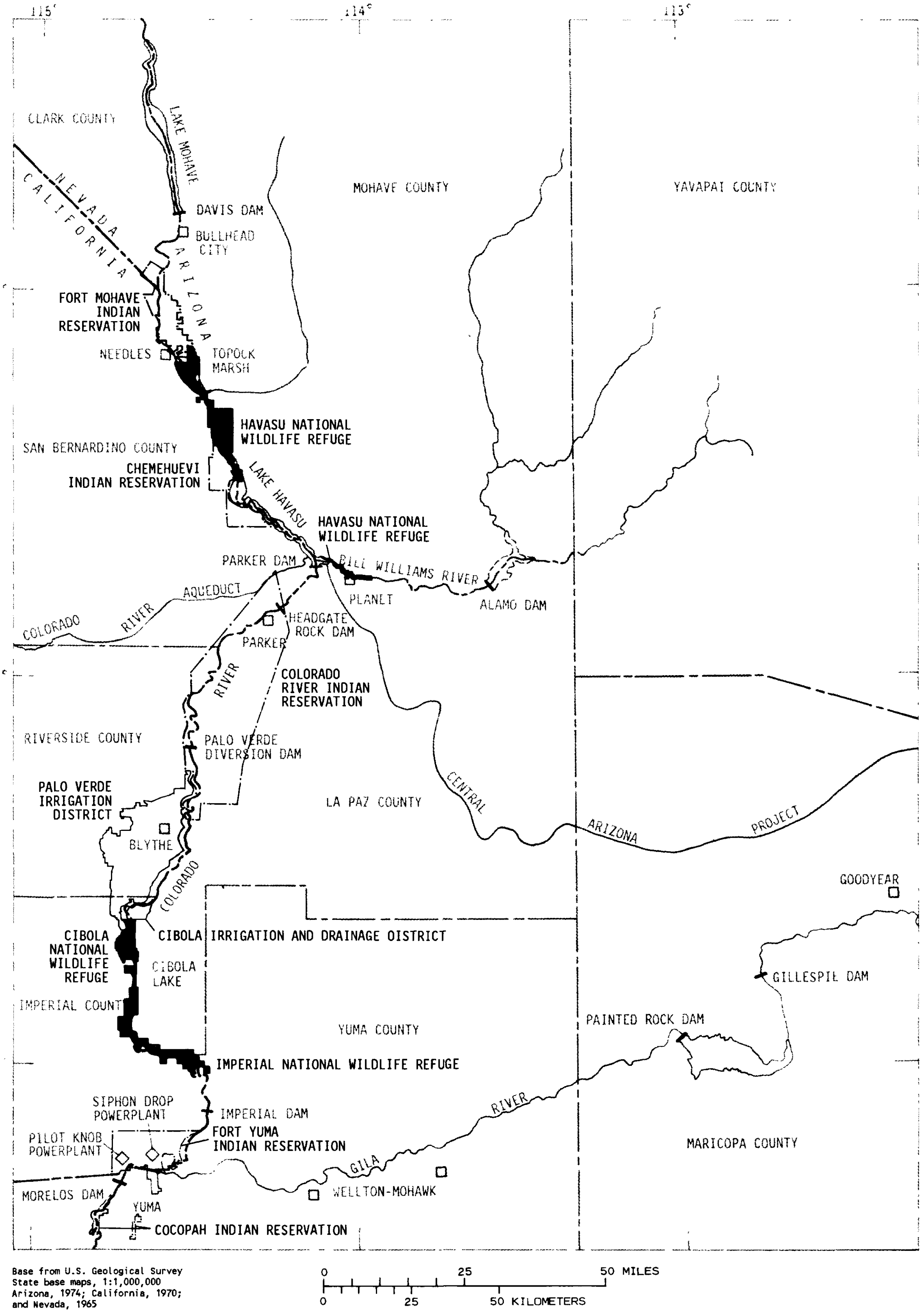
National Wildlife Refuges

Havasu, Cibola, and Imperial National Wildlife Refuges (NWR) were established to mitigate loss of fish and wildlife habitat involved in the U.S. Bureau of Reclamation's water salvage and channelization projects along the Colorado River. All three refuges are near intensively farmed agricultural areas (fig. 2).

Havasu NWR was established by Executive Order 8647 on January 22, 1941, to provide migration and wintering habitat for waterfowl. The refuge is on the Colorado and Bill Williams Rivers between Needles, California, and Parker Dam, Arizona, and includes 45,854 acres in Mohave and La Paz Counties, Arizona, and San Bernardino County, California. The refuge is divided into three distinct units—Topock Marsh, Topock Gorge, and Bill Williams Delta. Topock Marsh unit includes the 4,000-acre Topock Marsh, which is fed by a 4-mile-long inlet canal. The Colorado River bisects the Topock Gorge unit, which is 18 miles long, and the river is bordered on each side by marshes isolated by emergent zones of cattails and bulrush. Bill Williams unit is bisected by the Bill Williams River for 10 miles, with 1 mile of open lake where the river flows into Lake Havasu. Many species of shorebirds, waterfowl, and wading birds spend the winter or migrate through the refuge. Bald eagle (*Haliaeetus leucocephalus*), peregrine falcon (*Falco peregrinus*), and Yuma clapper rail (*Rallus longirostris yumanensis*) are endangered species known to use the refuge. Refuge habitats consist of the following approximate acreages—desert uplands, 31,000 acres; open water, 7,950 acres; wetlands, 6,000 acres; and croplands, 480 acres. Bottomland vegetation includes saltcedar (*Tamarix chinensis*), quailbrush (*Atriplex lentiformis*), arrowweed (*Tessaria sericea*), willow (*Salix goodingii*), cottonwood (*Populus fremontii*), and mesquite (*Prosopis spp.*).

Cibola NWR was established in 1964 by Public Land Order 3224 to provide wintering habitat for waterfowl and other migratory birds. The refuge is about 20 miles south of Blythe, California; approximately two-thirds of the refuge is in La Paz County, Arizona, and one-third is in Imperial County, California. It includes 16,627 acres, is 12 miles long, and adjoins the Imperial NWR on the south. The main part of the refuge is alluvial river bottom with dense growths of saltcedar, mesquite, and arrowweed. The Colorado River flows through this area in a dredged channel and parts of the original channel. The refuge contains 2,000 acres of farmland and 785 acres of desert foothills and ridges. Present wetlands include the 600-acre Cibola Lake, about 10 miles of Colorado River backwaters, seasonally flooded croplands, and the recently improved Hart Mine Marsh. More than 200 species of birds are found on the refuge and include many species of songbirds, herons, shorebirds, and waterfowl. Bald eagle, brown pelican (*Pelecanus occidentalis*), peregrine falcon, and Yuma clapper rail are endangered species known to use the refuge.

Imperial NWR was established in 1941 by Executive Order 8685 to provide migration and wintering habitat for a variety of birds. The 25,765-acre refuge, located 40 miles northeast of Yuma, Arizona, straddles 30 miles of the Colorado River with 17,167 acres in Yuma and La Paz Counties, Arizona, and 7,958 acres in Imperial County, California. Habitat



Base from U.S. Geological Survey State base maps, 1:1,000,000 Arizona, 1974; California, 1970; and Nevada, 1965

Figure 2.--Location of national wildlife refuges, Indian reservations, and selected private irrigation districts.

types include upland desert, 15,310 acres; brushlands and wetlands, 7,423 acres; and riverine habitat, 2,010 acres. Large numbers of ducks, geese, and water birds use the marshes extensively during the winter migration period. Bald eagle, brown pelican, peregrine falcon, and Yuma clapper rail are endangered species known to use the refuge.

Irrigated Agriculture

Although the lower Colorado River valley is one of the most arid parts of the United States, agriculture made possible by irrigation with Colorado River water is the mainstay of the local economy. Productivity of land is enhanced by an almost continuous growing season with occasional frost occurring during most winters.

The Colorado River provides irrigation water to about 218,000 acres in the lower Colorado River valley between Davis and Imperial Dams. All crops are irrigated because the mean annual precipitation of about 4 inches is insufficient for growing crops. Many agricultural fields are double or triple cropped annually. Furrow, sprinkler, and flood irrigation are the principal methods of water application to crops in the study area. Principal crops in the Palo Verde Irrigation District include alfalfa, cotton, feed grains, truck crops (vegetables), citrus, and melons. Principal crops on the Colorado River Indian Reservation include cotton, alfalfa, grains (mostly wheat with some rye and barley), vegetables, melons, and bermuda grass seed.

Pesticide-use data for the lower Colorado River basin indicate a significant increase in use of readily degradable organophosphate and carbamate pesticides in addition to continued use of persistent organochlorine compounds (U.S. Environmental Protection Agency, 1973). Compared to most other crops, alfalfa and cotton generally have the least and most pesticides applied per acre, respectively. Herbicides and fungicides are applied more heavily on grain crops. Truck crops (vegetables) generally have less herbicides applied per acre (Anderson and Ohmart, 1982, p. 231).

Climate

The study area has an arid, warm climate, which is characterized by mild winters and hot summers. Average annual precipitation on the flood plains is from less that 4 to about 5 inches, and average annual evaporation is about 90 inches. Precipitation occurs in two periods, summer and winter. In summer, moist air from the Gulf of Mexico and high temperatures result in local, high-intensity thunderstorms. Winter storms originate in the Pacific Ocean and cause more gentle rains with little or no runoff. Precipitation at Blythe, California, ranged from 0.48 to 8.74 inches between 1917 and 1984, and mean annual precipitation was 3.88 inches (Owen-Joyce and Kimsey, 1987, p. 14). Precipitation at Parker, Arizona, ranged from 0.36 to 12.60 in. between 1938 and 1984, and mean annual precipitation was 4.52 inches (S.J. Owen-Joyce, hydrologist, U.S. Geological Survey, written commun., 1987). In the Needles, California, area, mean annual precipitation on the flood plain and piedmont slopes is about 5 to 6 inches (Metzger and Loeltz, 1973).

Geology

The study area is in the Sonoran Desert section of the Basin and Range physiographic province (Fenneman, 1931). The section is characterized by barren, rugged mountains separated by broad, desert alluvial basins in which lie the present flood plains of the Colorado River and its principal southern tributary, the Gila River. Landforms in the area are grouped as mountains and hills, piedmont slopes and dissected uplands, river flood plains, and sand dunes. Mountains and hills are chiefly rugged exposures of igneous (plutonic and volcanic) rocks, metamorphic rocks of Paleozoic and Mesozoic ages, and deformed indurated sedimentary and volcanic rocks of Tertiary age. The lower end of the study area includes less rugged exposures of semiconsolidated nonmarine and marine sedimentary rocks. The study area contains formations of marine sediment and volcanic rocks of Cretaceous age that could potentially contribute trace metals and metalloids to the hydrologic system. Rock units exposed as piedmont slopes and dissected uplands include virtually undeformed alluvial and windblown deposits of Tertiary and Quaternary age. Younger alluvium (predominantly clean medium to coarse sand) of the Colorado River underlies the river flood plain. Geology of the area is described in detail by McDonald and Loeltz (1976), Metzger and others, (1973), Metzger and Loeltz (1973), and Olmsted and others (1973).

Soils

The study area generally has deep, alkaline, fine and moderately fine textured soils except on flood plains, which have medium- to coarse-textured soils. Locally on flood plains, soil profiles have high water tables that require drainage.

HYDROLOGIC SETTING

The hydrologic system in the study area includes the regulated Colorado River and its tributaries, shallow alluvial aquifers that underlie the respective flood plains, river water diverted or pumped into systems of canals for application to fields on flood plains, and ground water discharged to networks of drainage ditches or to the Colorado River. The hydrologic system is complex and is described in detail by Owen-Joyce (1984), Owen-Joyce and Kimsey (1987), Leake (1984), Metzger and others (1973), and Metzger and Loeltz (1973).

Water Supply

Water in the Colorado River is an important resource to millions of people in Arizona, California, Nevada, and northern Mexico.

Distribution of Colorado River water is subject to provisions of an international treaty, interstate compacts, congressional acts, and court decrees. The river is a source of water for small cities within its basin, large cities outside its basin, and irrigation of large agricultural areas within and outside its basin (fig. 3).

Wet and dry cycles have played a significant role in bringing about development of the Colorado River reservoir complex. In the past, annual streamflow of the river has ranged from less than 6 million to more than 20 million acre-feet per year. The reservoir complex has allowed sufficient storage of water to maintain streamflow in the river to meet downstream needs during dry periods. Any discussion of water supply involves many elements of the water-control and distribution systems.

Davis Dam, 67 miles downstream from Hoover Dam, began storing water in 1950. Storage capacity of Lake Mohave behind Davis Dam is 1,810,000 acre-feet. The dam is used for power generation, regulation of release flows from Hoover Dam, and regulation of flows released for delivery at the international boundary as required by treaty with Mexico. Bullhead City, Arizona, is located below Davis Dam and has a contract for 8,200 acre-feet per year. City of Needles, California, has a perfected right to 950 acre-feet per year but used an estimated 2,800 acre-feet in 1984.

Lake Havasu extends behind Parker Dam for about 45 miles and serves as a forebay from which the Metropolitan Water District of Southern California and the Central Arizona Project pump water into aqueducts. Parker Dam is 88 miles downstream from Davis Dam, just below the confluence of Bill Williams and Colorado Rivers, and 147 miles upstream from Imperial Dam. Storage began in 1938, and capacity available for regulation of streamflow is 180,000 acre-feet. Water pumped from Lake Havasu into the Colorado River aqueduct, built and operated by Metropolitan Water District of southern California, is one of several supplies for southern California coastal basins. Pumping began in 1939, and Metropolitan Water District used about 1,234,000 acre-feet in 1984. Colorado River Basin Project Act authorizes the Central Arizona Project to furnish irrigation and municipal water supplies through direct diversion or exchange of water to water-deficient areas of Arizona and western New Mexico.

A maximum diversion capacity of about 2.2 million acre-feet per year of Colorado River water will be possible when the Central Arizona Project is fully completed. Central Arizona Project must withstand shortages of as much as its full allocation should the Secretary of Interior determine that mainstream water is insufficient to satisfy an annual consumptive use of 7.5 million acre-feet, as allocated under the Supreme Court decree (1964) to the States of Arizona, California, and Nevada.

Headgate Rock Dam, Palo Verde Diversion Dam, and Imperial Dam serve as diversion structures with almost no storage. Headgate Rock Dam, 14 miles downstream from Parker Dam, has controlled diversions to Parker Valley for the Colorado Indian Reservation since 1942. Diversion to Palo Verde Valley is made at Palo Verde Diversion Dam, 59 miles downstream from Parker Dam. Imperial Dam, 147 miles downstream from Parker Dam, is the major diversion structure for irrigation projects in Imperial and Coachella

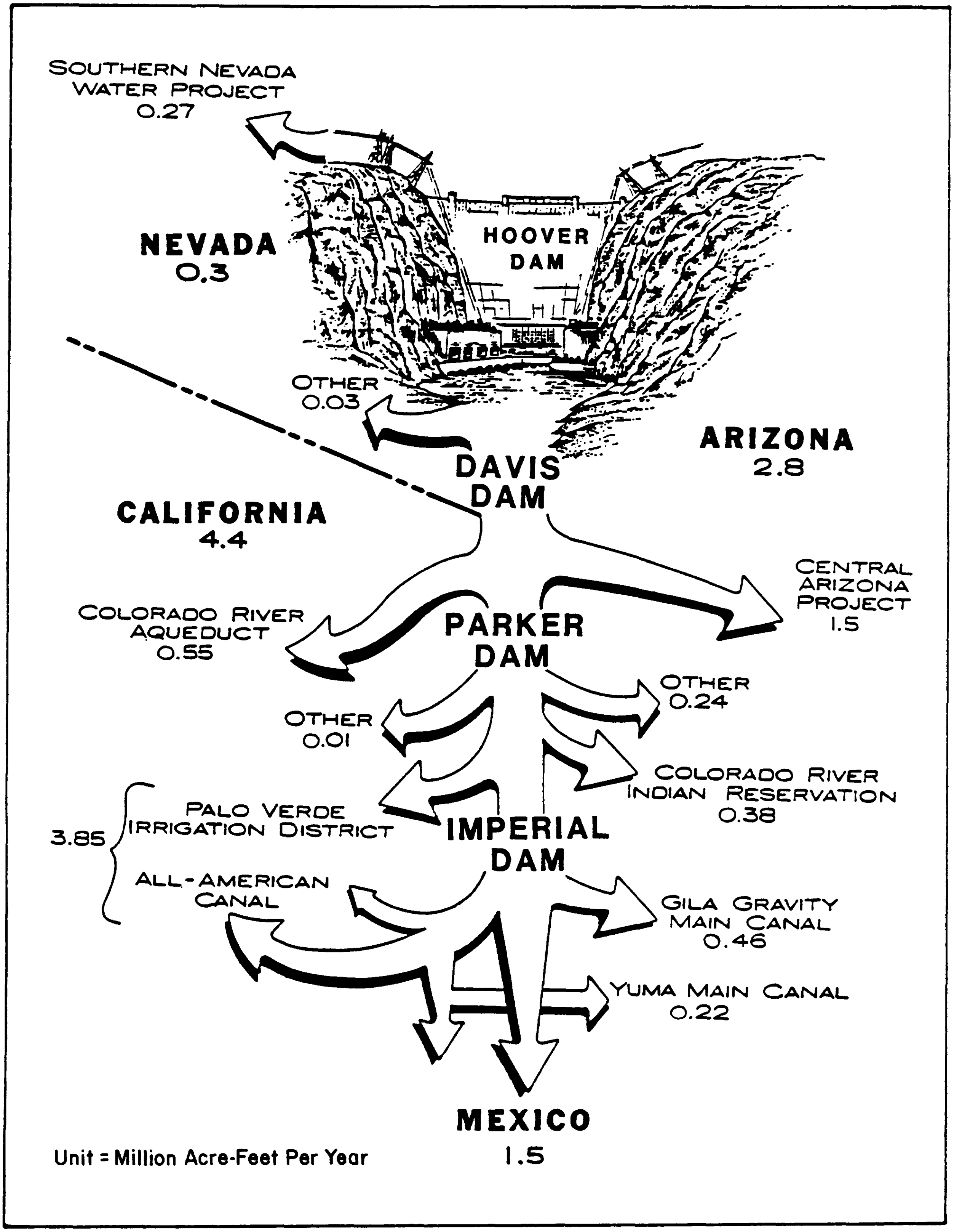


Figure 3.--Lower Colorado River water entitlements. From U.S. Bureau of Reclamation (1986).

Valleys and the Wellton-Mohawk and Yuma areas. Also, much of the water released for delivery to Mexico is diverted here and returned to the river through Siphon-Drop and Pilot Knob powerplants.

Runoff

Streamflow in the Colorado River varies daily, seasonally, yearly, and from place to place along the river. Releases of water for irrigation and power generation, diversions, evapotranspiration, spillage from canals, and return flows to the river all contribute to daily fluctuations in streamflow. Changes in streamflow in the Colorado River correlate with changes in river stage. Changes in river stage also produce fluctuations in ground-water levels beneath the flood plain and in the amount of ground water in storage (S.J. Owen-Joyce, written commun., 1987; Owen-Joyce, 1984, p. 15; Owen-Joyce and Kimsey, 1987, p. 6-9; Leake, 1984, p. 6).

Surface-water return flow includes water that spills from canals, laterals, and wasteways in addition to ground water that returns to the river in open-channel drainage ditches. Flow in drainage ditches originates as return flow from applied irrigation water, seepage from the river, and tributary ground-water and surface-water inflows.

Agricultural Diversions and Return Flows

Fort Mohave Indian Reservation, located below Davis Dam, is allocated 122,648 acre-feet of water by Supreme Court (1964) decree to irrigate 14,916, 2,119, and 1,939 acres in Arizona, California, and Nevada, respectively. A contract between the DOI and Mohave Irrigation and Drainage District allows for an annual diversion of 41,000 acre-feet. A 1984 decree accounting showed that Mohave Irrigation and Drainage District diverted 23,500 acre-feet of mainstream water.

Colorado River Indian Reservation diverts approximately 600,000 acre-feet of water from Headgate Rock Dam. Various wells along the river pump water to irrigate about 82,000 acres, and about 260,000 acre-feet of water is returned to the Colorado River.

Lake Havasu Irrigation District, by contract, is allowed an annual diversion of 14,500 acre-feet. In 1984, the district diverted only 9,100 acre-feet from the Colorado River. It is anticipated that the district will use its full entitlement by the year 1990.

Palo Verde Irrigation District (PVID) is a privately developed irrigation district in Riverside and Imperial Counties, California. Palo Verde Diversion Dam was constructed by the U.S. Bureau of Reclamation under special authorization by Congress in August 31, 1954 (68 Stat. 1045). PVID serves about 93,000 acres of alluvial valley near Blythe, California. PVID diverts about 900,000 acre-feet with a maximum diversion rate of 1,800 cubic feet per second and returns 500,000 acre-feet to the Colorado River. Water for irrigation is diverted from the Colorado River at the Palo Verde

Diversion Dam and is conveyed through 253 miles of canals and laterals. Irrigation-return flows are collected in a 149-mile-long drainage system and returned to the Colorado River.

Cibola NWR has an established water right, reserved by Secretarial notice on December 9, 1982, for 16,973 acre-feet of consumptive use per year. The refuge diverted 5,400 acre-feet in 1984, and it is projected that all appropriated water rights will be fully developed by 1990.

Ground Water

Ground water occurs under water-table conditions in the alluvial aquifers. River reaches are in hydraulic connection with the alluvial aquifers that underlie the river and adjacent flood plains (S.J. Owen-Joyce, written commun., 1987; Owen-Joyce, 1984, p. 15; Owen-Joyce and Kimsey, 1987, p. 10; Leake, 1984, p. 6; Metzger and others, 1973, p. 13). When releases from reservoirs satisfy downstream water requirements, most reaches of the river adjacent to irrigated areas gain water from the aquifer. When the annual average river stage rises, some of the gaining reaches of the river become losing reaches (Owen-Joyce and Kimsey, 1987, p. 6-9).

Agricultural development has caused changes in the ground-water flow patterns in the flood-plain alluvial aquifers. Irrigation and its associated network of drainage ditches has a significant effect on the saturated thickness of the aquifers and on the direction of ground-water movement through the aquifers. In general, water from upstream diversions recharges the alluvial aquifers as canal seepage and excess irrigation. Water returns to the river as ground-water seepage and as surface-water flow in drainage ditches (Loeltz and Leake, 1983, p. 13). Drainage ditches lower the water table beneath cropland and maintain it at sufficient depths to reduce waterlogging and damage to crops.

PREVIOUS STUDIES

A number of hydrologic and environmental investigations that provide supplemental information to the current study have been done in the study area. Summaries of investigations from which information has been used are presented in the following sections.

Existing Water-Quality, Soils, and Sediment Data

U.S. Geological Survey has operated stream-gaging stations, measured suspended sediment, and monitored water quality at selected locations in the study area for many years. Data are published annually in "Water Resoures Data for Arizona" (U.S. Geological Survey, 1973-87). Some important locations where data have been collected are:

09421500	Colorado River below Hoover Dam, Arizona-Nevada.
09426600	Bill Williams River at Mineral Wash near Planet, Arizona.
09427520	Colorado River below Parker Dam, Arizona-California.
09429490	Colorado River above Imperial Dam, Arizona-California.
09518000	Gila River above diversions, at Gillespie Dam, Arizona.
09520700	Gila River near mouth, near Yuma, Arizona.
09522000	Colorado River at northern international boundary above Morelos Dam, near Andrade, California.

Although "Quality of Water, Colorado River Basin, Progress Reports" (U.S. Department of Interior, 1966-87) are prepared and updated every 2 years to summarize the status of water quality in the Colorado River basin, the reports deal only with total dissolved-solids loading. Historically, the Colorado River carries about 9 million tons of salt past Hoover Dam in 10 million acre-feet of water per year. Salinity (dissolved solids) is primarily from geologic sources, saline springs, and agricultural sources. Natural sources add almost half the total salt load, and irrigation return flows add more than one-third; a minor part of the salt load is from municipal and industrial sources. Development in the basin, which reduces flow of the river and its ability to dilute the salt, is projected to cause salinity to increase significantly. In 1985, the average dissolved-solids concentration in the Colorado River at Imperial Dam was 607 milligrams per liter (mg/L). More than a million tons of salt per year will need to be removed by year 2010 to maintain average salinity below the criterion of 879 mg/L at Imperial Dam (U.S. Department of the Interior, 1966-87).

Irelan (1971) states that the virgin salinity regimen of the Colorado River is unknown but probably was similar to the regimen observed during earlier years of sampling. Before closure of Hoover Dam, water composition and dissolved-solids concentrations varied substantially daily, seasonally, and annually and also spatially (dissolved solids generally increasing) with distance downstream. Observed dissolved-solids concentrations, which ranged between 200 and 1,800 mg/L, consisted mainly of calcium bicarbonate at lower concentration levels and mixed sulfate and chloride salts at higher concentration levels.

Although selenium has recently become the constituent of primary concern, few data exist on selenium concentrations in water for the area. Since 1975, the maximum concentration of selenium at five stations along the lower Colorado River valley was 8 micrograms per liter (μg/L), and the median selenium concentration was 3 μg/L (table 1). Selenium concentrations at U.S. Geological Survey National Stream Quality Accounting Network

Stations on the Gila River at Gillespie Dam and near the river mouth at Yuma indicate median selenium concentrations of 5 and 7 μg/L, respectively. Maximum selenium concentrations (Gila River at Gillespie Dam, 14 μg/L, and Gila River near mouth near Yuma, 16 μg/L) exceed U.S. Environmental Protection Agency (EPA) criterion for drinking water of 10 μg/L. The maximum selenium concentration at Gila River occurred at the mouth during low flows, which presumably were irrigation-return flows from the Wellton-Mohawk area. Minimum selenium concentrations were detected during high flows that represented releases from Painted Rock Dam.

An EPA report summarizes findings from an extensive study to assess pesticide contamination of the lower Colorado River (U.S. Environmental Protection Agency, 1973). Of 140 water samples collected, none contained organochlorine, organophosphate, or carbamate pesticide residues at significant levels. EPA concluded that a pesticide problem did not exist in the lower Colorado River during the study period.

Kister (1973) presented data on areal and vertical distribution of dissolved-solids and fluoride concentrations in ground water for the lower Colorado River region. Maps were prepared using data from previously published reports; data collected by other Federal, State, and local agencies; and data from the U.S. Geological Survey files. Kister (1973) stated that along the southernmost reach of the Colorado River, water in the upper alluvial aquifer unit was slightly more saline than water in the underlying gravel unit. Water in the gravel unit generally was more saline than the flow of the Colorado River. Irelan (Metzger and others, 1973, p. 96) concluded from a study of chemical analyses of water from wells in the Parker-Blythe-Cibola area that most of the water came from the Colorado River and was altered mainly by four processes—concentration by evapotranspiration, precipitation of insoluble calcium and magnesium carbonates, ion exchange, and reduction of sulfate. Recent studies, however, indicate that these reactions are possibly not accurate in describing the evolution of ground-water chemistry. Alterations in water chemistry are due primarily to weathering reactions and dissolution of halite and gypsum (F.N. Robertson, hydrologist, U.S. Geological Survey, written commun., 1987).

Few data exist on concentrations of trace metals in ground water in the study area. Data from 11 wells along the lower Colorado River indicate a mean selenium concentration of 0.3 μg/L; data from 4 wells in the Yuma area show larger amounts of iron, manganese, zinc, and lead (F.N. Robertson, oral commun., 1986).

U.S. Geological Survey has analyzed 25 soil and bottom-sediment samples from the study area for selenium. The maximum selenium concentration of 1,530 micrograms per kilogram (μg/kg) was greater than concentrations that would be expected 95 percent of the time (less than 1,400 μg/kg) as determined for soils west of the 97th meridian within the conterminous United States by Shacklette and Boerngen (1984, p. 6). The median selenium concentration (180 μg/kg) was less than that for the conterminous United States (300 μg/kg). Measurable concentrations of 3.5 to 47 μg/kg DDE were found in bottom material from the Gila River at Gillespie Dam, U.S. Geological Survey (1973-87). EPA found large concentrations of thallium and lead (21 and 32,000 μg/kg, respectively) in bottom sediment from the Colorado River at Parker downstream from the Bill

Williams River (U.S. Environmental Protection Agency, 1977, p. 61). Aquatic studies by U.S. Bureau of Land Management have identified acute and chronic stresses on biological communities relative to heavy metal toxicity downstream from abandoned and existing copper mines in the Bill Williams watershed (Kepner, 1979; 1980).

Existing Fish and Wildlife Data

Fish and wildlife contaminant-residue data are available from scattered samples collected on a regular basis by various agencies. The most thorough evaluation of wildlife contamination in the lower Colorado River basin is a recently completed contaminant study of the entire lower Gila River drainage done by the U.S. Fish and Wildlife Service (Kepner, 1986). This comprehensive study for June through September 1985 was to determine the extent of organochlorine-pesticide, trace metal, and metalloid contamination in bottom sediment and selected resident fish and wildlife species. All samples were collected in triplicate composites at each of 10 sites. A total of 208 composite samples were scanned for 23 organochlorine-pesticide compounds and 13 trace metals and metalloids. Data (1) indicate clear geographic trends in organochlorine-pesticide contamination for the lower Gila River, (2) document continued risk of pesticide exposure to fish and wildlife resources, and (3) infer possible sources of contamination.

Sixteen of twenty-three organochlorine pesticides analyzed were detected in tissue and bottom-sediment samples collected from the Gila River (Kepner, 1986). Except for Gambel's quail (*Callipepla gambellii*), concentrations of p,p'-DDE in biota exceeded 1.0 micrograms per gram (μg/g), wet weight. Results indicate elevated p,p'-DDE and toxaphene residues. DDE was particularly elevated in red-winged blackbird (*Agelaius phoeniceus*), carp (*Cyprinus carpio*), and spiny softshell turtle (*Trionyx spiniferus*) samples. Organochlorine-pesticide residues were consistently elevated, particularly for those river reaches and irrigation conveyances between the Salt-Gila confluence and Painted Rock Borrow Pit.

Flood-control and irrigation-diversion dams, such as Painted Rock and Gillespie Dams, appear to be acting as contaminant sinks for organochlorine pesticides. Data in this report indicate that fish and wildlife are being exposed to a major source of DDE and toxaphene, which could present a threat of reduced viability and recruitment to wildlife resources of the lower Gila River drainage.

Recent information from the U.S. Fish and Wildlife Service National Contaminant Biomonitoring Program for two sites adjacent to Havasu and Imperial NWR's indicate detectable concentrations of DDD, DDE, and PCB's in fish (Schmitt and others, 1985). This program also has isolated DDD, DDE, and toxaphene contamination in fish and birds in the lower Gila River valley. U.S. Fish and Wildlife Service found concentrations of DDE (9.6 to 29 μg/g, wet weight) in seven of eight duck-muscle samples from the Gila River that exceed the established tolerance of 5.0 μg/g, wet weight, for human consumption of domestic animals (Clark and Krynitsky, 1983). DDE residues in starlings collected upstream from Gillespie Dam adjacent to the Gila River near Goodyear, Arizona, were the greatest concentrations (8.4 µg/g, wet weight) from all sites collected nationwide in 1982 (Bunck and others, 1987)

Anderson and Ohmart (1982) examined patterns of insecticide and herbicide use in selected agricultural areas in the lower Colorado River valley and studied the effects on avian populations in the study areas. Evidence indicated that pesticides caused a decrease in avian populations. Crops that typically are treated more heavily with pesticides were used less frequently by birds, and those agricultural areas with more of such crops had smaller avian densities.

U.S. Fish and Wildlife Service has sampled fish from several locations along the lower Colorado River (table 2). Selenium concentrations in most of these samples exceeded concentrations found in 85 percent of fish sampled in the United States as determined by Lowe and others (1985). In addition to selenium, detectable levels of other inorganic and organic contaminants have been detected in fish samples collected from the Colorado River (Lowe and others, 1985; May and McKinney, 1981; Schmitt and others, 1985; Walsh and others, 1977; Henderson and others, 1969; 1971; 1972).

No "reported" fish and wildlife die-offs, avian reproductive failures, or avian embryonic deformities in the study area can be attributed directly to selenium. Occasional fish die-offs related to recent agricultural pesticide applications, however, have been documented.

SAMPLE COLLECTION AND ANALYSIS

Objectives

This study focused on irrigation and drainage facilities constructed or managed by the DOI, national wildlife refuges managed by DOI, and other migratory bird or endangered species management areas that receive water from DOI-funded projects. An effort was made to distribute sampling sites upstream and downstream from irrigation districts, national wildlife refuges, and population centers along the lower Colorado River between Davis and Imperial Dams. Samples of water, bottom sediment, and plant and animal tissue were collected once at 11 sites.

Resident and abundant species with widespread distribution were selected as indicator organisms to eliminate variation and cross contamination that presumably would be introduced by migration. Species were American coot (*Fulica americana*), common gallinule (*Gallinula chloropus*), and Yuma clapper rail eggs; double-crested cormorant (*Phalacrocorax auritus*); carp (*Cyprinus carpio*); and spiny naiad (*Najas *marina*). Resident species tend to stay in one place; therefore, tissue concentrations are representative of what has accumulated in the food chain near the sampling site. Analysis of resident species, therefore, enhances data interpretation and provides an optimum amount of information at minimum cost. Whole-body specimens were used for reconnaissance purposes to indicate consumptive concentrations in the food chain. Whole-body specimens are also considered better than selected viscera as indicators of elevated concentrations of organochlorine pesticides. Therefore, whole-body specimens were used to optimize comparisons with data collected by the U.S. Fish and Wildlife Service in the lower Gila River valley where organochlorine pesticides were the principal contaminant found in tissue samples (Kepner, 1986). Qualitative reconnaissance observations were made on health and population dynamics of plant and animal communities within the respective wildlife refuges.

Sample collection was not planned for the lower Gila River valley because of recently completed contaminant studies (bottom-sediment and tissue samples) by the U.S. Fish and Wildlife Service (Kepner, 1986). Results of the study by Kepner (1986) are discussed in this report in the section "Existing Fish and Wildlife Survey Data".

Sampling Sites

Samples of water, bottom sediment, and plant and animal tissue were collected and field observations were made in the vicinity of each of 11 sites along the lower Colorado River from Davis Dam to Imperial Dam (fig. 1; table 3). Water samples were collected and concurrent water-quality field observations were made at U.S. Geological Survey or U.S. Bureau of Reclamation stream-gaging stations (table 3). Bottom sediment and biological specimens were collected near each of the sites at locations where contaminants were most likely to accumulate and where biological productivity was the greatest (for example, backwater areas, oxbow lakes, and lake bottoms). No bottom sediment was obtained from site 7 because of insufficient material. Because of sampling difficulties, no biological specimens were collected from the Colorado River Indian Reservation lower drain near Parker, Arizona (table 3). Specimens were collected just below the confluence of the lower drain and the Colorado River. Cormorant specimens were collected at each of the national wildlife refuges.

A good control site did not appear to exist within a reasonable distance from or within the lower Colorado River basin owing in part to widespread agricultural practices. Colorado River below Davis Dam (site 1) therefore was selected as the upstream ambient and (or) background site.

Samples of water, bottom sediment, and plant and animal tissue were analyzed for organochlorine pesticides and other trace constituents (table 4). Tissue samples also were analyzed for percent lipid and moisture content. All tissue samples were collected and analyzed as whole-body triplicate composites, and results are expressed as micrograms per gram, wet weight. The pesticides selected were those reasonably expected to be present at elevated levels within the study area.

Sampling Methods

All samples were collected using approved collection techniques. Water and bottom-sediment samples were collected and field processed in accordance with the National Handbook of Recommended Methods for Water Data Acquistion (U.S. Department of the Interior, 1984), Wershaw and others (1987), and Kister and Garrett (1983). Water samples were composites of depth-integrated subsamples collected at several discharge-weighted increments across the vertical section of flow. Samples were obtained with a US DH-76 TM using recommended depth-integrating techniques described by Guy and Norman (1970).

Bottom-sediment samples were collected using the epoxy-coated aluminum US BMH-60 sampler with stainless-steel bucket designed by the Federal Interagency Sedimentation Project. Each bottom-sediment sample was a homogenized composite of at least six subsamples, all collected near the designated site, to form one sample per site. Organic analyses were performed on unsieved samples. Laboratory-sample preparation procedures for trace-metal and trace-metalloid analysis were as follows: (1) Sample was dried at room temperature, (2) material was crushed to pass through a 10-mesh screen, (3) material was sieved using a 230-mesh stainless-steel screen (63 micrometers), and (4) the fine material that passed through the 230-mesh screen was analyzed.

Standard equipment or techniques were used for collecting biological specimens for contaminant analysis (U.S. Fish and Wildlife Service, 1985b). Avian samples were collected by steel shot. Fish specimens were collected using electroshocking equipment and gill nets. Egg and plant specimens were obtained by "grab" sampling. Indicator organisms of similar species, age or size, and from comparable habitats were collected at all sites. All samples were collected as triplicate whole-body composites and quick-frozen in the field. Only trap-mortality specimens of Yuma clapper rails from a concurrent study were used for liver analysis.

Analytical Support

After field processing, water samples were shipped chilled to the U.S. Geological Survey National Water Quality Laboratory in Arvada, Colorado, for analysis. Analyses were performed using analytical procedures described by Fishman and Friedman (1985) and Wershaw and others (1987). Laboratory quality-assurance procedures are described by Friedman and Erdmann (1982). Bottom-sediment samples were analyzed at the U.S. Geological Survey, Geologic Division, Branch of Exploration Geochemistry Laboratory, in Denver, Colorado, using procedures described by Severson and Wilson (1987).

All biological specimens were analyzed at the U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, Patuxent Analytical Control Facility (PACF), in Laurel, Maryland. All analyses were performed following analytical procedures prescribed by U.S. Fish and Wildlife Service (1985a).

Additionally, samples were collected and analyzed as part of the EPA, Region IX Priority Pollutant Program. This program includes contaminant scans for organochlorine pesticides, trace metals and metalloids, and volatile and semi-volatile organics in water, sediment, and tissue matrices (table 5). All EPA Priority Pollutant analyses were completed at the Environmental Monitoring Systems Laboratory in Las Vegas, Nevada.

DISCUSSION OF RESULTS

Water

Analytical results for all water samples and field measurements are listed in table 6. Table 7 is a summary of water data, and table 8 lists selected water-quality criteria for the State of Arizona (McClennan, 1984, 1986) and EPA (U.S. Environmental Protection Agency, 1986a, b, c). Data are compared to State of Arizona criteria where possible. Emphasis is placed on values or concentrations that exceed criteria; little or no discussion is given to those values or concentrations considered to be at acceptable water-quality criteria levels.

The National Stream Quality Accounting Network (NASQAN) and the National Water Quality Surveillance System (NWQSS) have provided information on the Nation's water quality since 1973. A summary of data relevant to the DOI Irrigation Drainage Program collected at 388 sampling stations in these national monitoring programs is given in table 9, which is extracted from Smith and others (1987). If water-quality property determinations or constituent concentrations are greater than the 75-percent baseline in table 9, it is reasonable to say that such values are elevated in relation to national-baseline values (M.A. Sylvester, hydrologist, U.S. Geological Survey, written commun., 1987). Even if values are elevated in relation to national-baseline values, this does not mean necessarily that such values have resulted or will result in adverse biological effects.

Elevated Constituent Concentrations in Water

Only one constituent in a water sample exceeded State of Arizona Maximum Allowable Limits (MALs). A cadmium concentration of 69 μg/L at Colorado River near Topock (site 3) exceeded the State MAL of 10 μg/L (dissolved) for "Aquatic and Wildlife" protected use. No organochlorine-pesticide concentrations above detection limits were found in the water column. Organophosphorus pesticides, however, were found in the water column in the Palo Verde Outfall drain (site 9). These organic compounds were found by a dedicated laboratory analyst routinely (but unrequested) scanning water samples for the presence or absence of organophosphate pesticides. Concentrations of diazinon, methyl parathion, ethyl parathion, and chlorpyrifos were 0.01, 0.05, 0.11, and 0.15 μg/L, respectively.

A 1987 update to "Quality Criteria for Water" by the EPA (1986a) states that, possibly where locally an important species is very sensitive, freshwater aquatic organisms and their uses should not be affected unacceptably if the 4-day average concentration of ethyl parathion does not exceed 0.013 μg/L more than once every 3 years on the average and if the 1-hour average concentration does not exceed 0.065 μg/L more than once every 3 years on the average. For chlorpyrifos, EPA (1986a) states that, possibly where locally an important species is very sensitive, freshwater aquatic organisms and their uses should not be affected unacceptably if the 4-day average concentration does not exceed 0.041 μg/L more than once every 3 years on the average and if the 1-hour average concentration does not exceed 0.083 μg/L more than once every 3 years on the average. No criteria for protection of freshwater and marine aquatic life exist for diazinon and methyl parathion.

Concentrations of synthetic organic semi-volatile priority-pollutant compounds were detected also at sites 9, 11, and in Lake Mohave (table 5). Phthalate esters and phenols were the principal compounds detected for the EPA Priority Pollutant Program. These concentrations, however, are not considered a threat to aquatic life or human health.

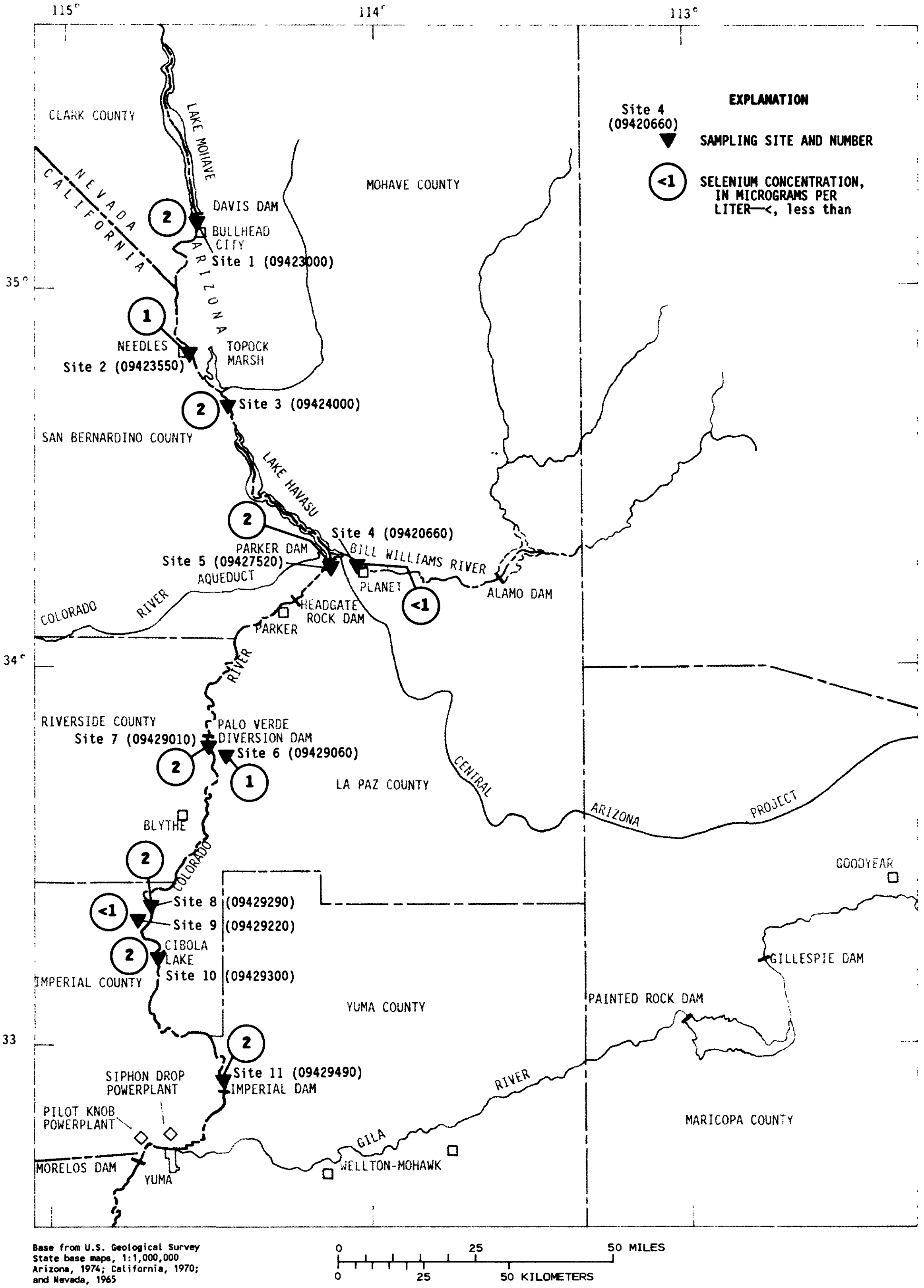
Although dissolved-selenium concentrations were small (less than 1 to 2 μg/L) throughout the study area, concentrations of 2 μg/L at all mainstream Colorado River sites (1, 3, 5, 7, 8, 10, and 11) exceeded the 75-percent national baseline (table 9). Dissolved-arsenic concentraions of 4 and 8 μg/L at sites 2 and 4, respectively, also exceeded the 75-percent national baseline. The importance of selenium in aquatic systems can be underestimated if judged solely on dissolved-selenium concentrations in water. Aquatic organisms through food chains can effectively concentrate selenium compounds from small environmental concentrations.

Spatial Variation of Constituent Concentrations in Water

Dissolved-selenium concentrations were lower at sites 2, 4, 6, and 9, which were directly influenced by agricultural drainage, than at other sites (fig. 4). Because dissolved-selenium concentrations in the mainstream Colorado River did not increase with increasing distance downstream and were lower in tributaries and drains, dissolved selenium in the lower Colorado River from Davis Dam to Imperial Dam appears to be derived from sources above Davis Dam. Thus, agricultural practices in the mainstream lower Colorado River valley do not at this time exacerbate selenium concentrations in water. Dissolved barium, molybdenum, vanadium, and zinc concentrations at sites directly influenced by agricultural drainage, however, were at least twice the concentrations at sites not directly influenced by irrigation drainage (fig. 5, table 6).

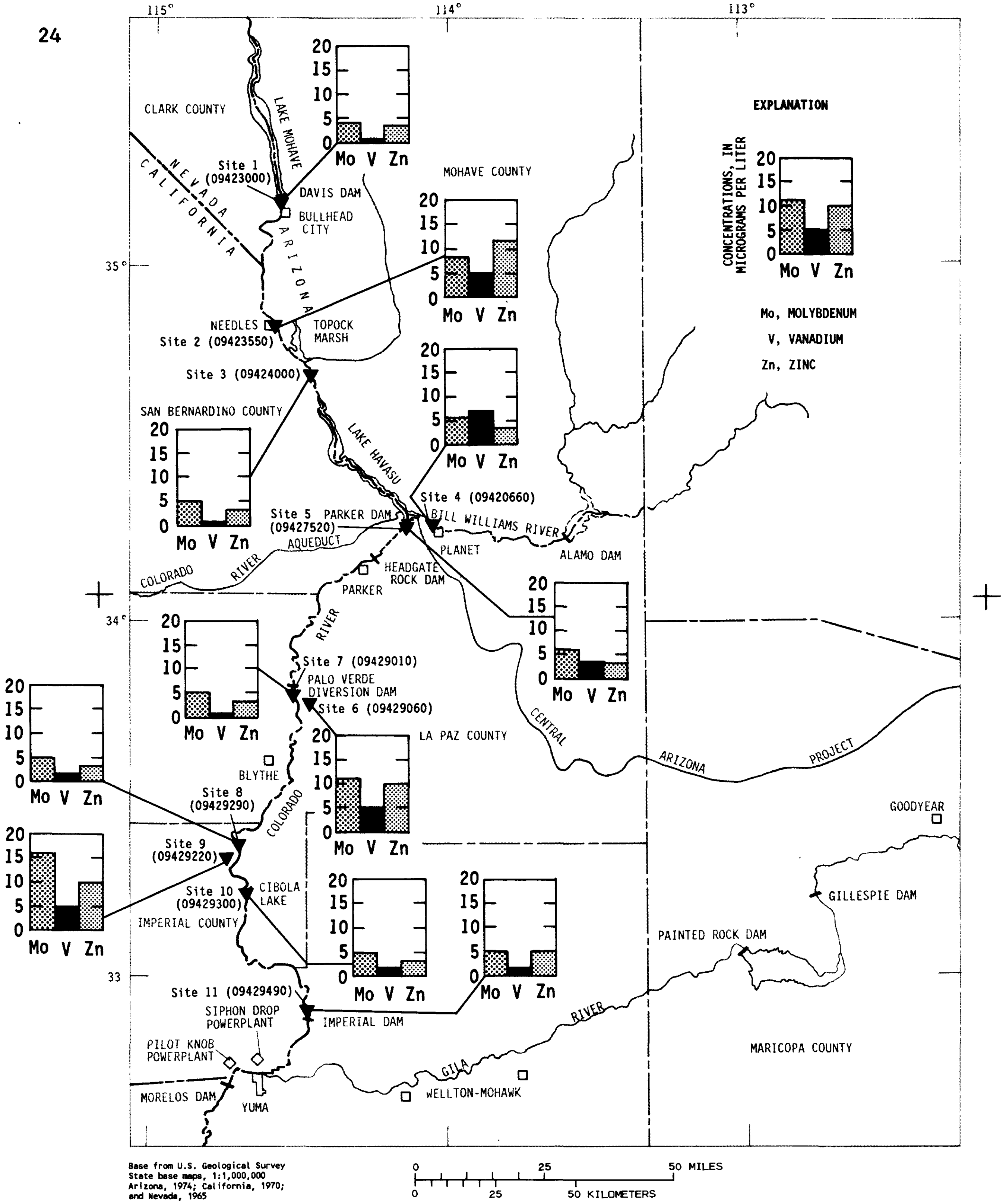
Bottom Sediment

Analytical results for bottom-sediment samples are listed in tables 10 and 11. Table 12 is a statistical summary of bottom-sediment data. Because of the absence of trace-element criteria for bottom sediment, analytical results from the study are compared to geochemical



Base from U.S. Geological Survey
State base maps, 1:1,000,000
Arizona, 1974; California, 1970;
and Nevada, 1965

Figure 4.--Spatial distribution of dissolved selenium concentrations in water from the lower Colorado River, 1986.



Base from U.S. Geological Survey State base maps, 1:1,000,000 Arizona, 1974; California, 1970; and Nevada, 1965

Figure 5.--Spatial distribution of dissolved molybdenum, vanadium, and zinc concentrations in water from the lower Colorado River, 1986.

baseline information from soils of the western United States as compiled by the U.S. Geological Survey (Shacklette and Boerngen, 1984). Table 13 has been modified from Shacklette and Boerngen to include only constituents analyzed for in bottom sediment. Supplementary information relative to metals, metalloids, and synthetic organic compounds in bottom sediment from the Gila River, a major tributary to the lower Colorado, also was made available (Kepner, 1986).

Geochemical background concentrations are intended to represent natural concentrations, which exclude man's influence. This idealized situation is rarely, if ever, attained. Geochemical baselines represent the concentration measured at some point in time and may or may not be a true background. If environmental changes in an area are suspected to have occurred, as in the irrigation- and drainage-project areas, then a background must be established by collecting data from outside the suspect area. These alternative areas should contain materials similar in nature to those of the suspect area.

Soil-sample data in table 13 consist of samples from all natural soils west of the 97th meridian within the conterminous United States. Samples were collected from the B horizon or below 20 centimeters where the B horizon was undefined. Single samples were collected at approximately 80-kilometer intervals.

Baseline concentrations were selected to represent an expected 95-percent range and were based on the geometric mean and geometric deviation (Tidball and Ebens, 1976). From a suite of randomly selected soils, 95 percent are expected to occur within plus or minus two standard deviations. Values falling within this range of a frequency distribution are defined as common, and those values falling outside the range are defined as uncommon.

Baselines are valid for comparing analyses of the same kind of sample from within the area in which the baseline was developed. It should be applied with caution to different sample media or to samples collected outside the baseline area. Irrigation and drainage projects collected samples of bottom sediment and analyzed the less than 63-micrometer fraction. The validity of baselines for use in comparing such material from these areas is questionable. However, it can be rationalized that such comparisons are marginally acceptable because bottom sediment derived from soils, climate, and geology of areas adjacent to those for which baselines were developed are reasonably similar.

Elevated Constituent Concentrations in Bottom Sediment

Selenium concentrations in bottom sediment (less than 63 micrometers) equaled (approximately) or exceeded the upper limit of the 95-percent baseline for western soils at all mainstream Colorado River sites (1, 3, 5, 8, 10, and 11) sampled (tables 10, 12, and 13). At these sites, selenium concentrations ranged from one to five times the upper limit of the 95-percent baseline for western soils. Although dissolved-selenium concentrations in the water column at all mainstream sites were relatively small (exceeded the national baseline in water but were only slightly above detection limits), concentrations in bottom sediment at mainstream sites appear to be large (greater than the upper limit of the 95-percent baseline for western soils). Mainstream Colorado River sediment of less than 63 micrometers in diameter appears to be acting as a sink for selenium. Largest selenium concentrations were found in backwater areas of the mainstream Colorado River. These areas, more lacustrine in character, are composed mainly of fine-grained bottom sediment with a larger percentage of organic material. U.S. Fish and Wildlife Service studies have shown that selenium has a high affinity for fine-grained, highly organic pond sediment and that the association of selenium with sediment can reduce selenium concentrations in overlying waters (John Besser, research biologist, U.S. Fish and Wildlife Service, written commun., 1987). The accumulation of selenium in sediment could result in a reservoir of selenium that may be remobilized by biological activity or changes in physical and chemical conditions. U.S. Fish and Wildlife Service studies have shown that although selenium inputs generally occur as selenite or selenate, selenium undergoes complex biogeochemical cycling processes that can produce organic selenium compounds (John Besser, written commun., 1987). These studies have demonstrated that selenomethionine, an organic form of selenium, had the highest affinity for sediment, was most rapidly lost from the system through volatilization, and was more biologically available than the inorganic forms of selenium. Thorium and uranium concentrations also surpassed the 95-percent baseline for western soils at sites 1 and 4 and sites 1 and 11, respectively (tables 10 and 13). Manganese concentrations equaled or exceeded the 95-percent baseline at sites 6 and 9, which are directly influenced by irrigation drainage.

Persistent organochlorine pesticides and other organic compounds were detected in relatively small concentrations in bottom sediment (less than 63 micrometers) in the study area (table 11). DDT was detected in bottom sediment at Palo Verde Drain (site 9) at 0.8 μg/kg, wet weight, and at Colorado River below Cibola (site 10) at 0.6 μg/kg, wet weight, despite the State of Arizona 1969 DDT ban. Presence of DDT probably is not a result of recent or illegal application but an indication of the persistence of this compound in the environment. DDE was found at all sites and ranged from 0.1 to 7.5 μg/kg, wet weight (table 12). DDD was detected at sites 1, 4, 9, 8, 10, and 11 and ranged from <0.1 to 2.4 μg/kg, wet weight (table 11). PCBs and chlordane were detected in bottom sediment at Colorado River below Davis Dam (site 1) at concentrations of 4.0 and 1.0 μg/kg, wet weight, respectively. Although these organochlorine-pesticide residue concentrations are relatively small, their presence is of concern because of persistence in the environment and the ability of these organic compounds to bioaccumulate through the food chain. Elevated concentrations of organic semi-volatile and volatile priority-pollutant compounds were also detected at sites 2, 9, and 11, with site 9 (Palo Verde drain) having the largest concentration (18,400 μg/kg) of phthalate esters (table 5).

Spatial Variation of Constituent Concentrations in Bottom Sediment

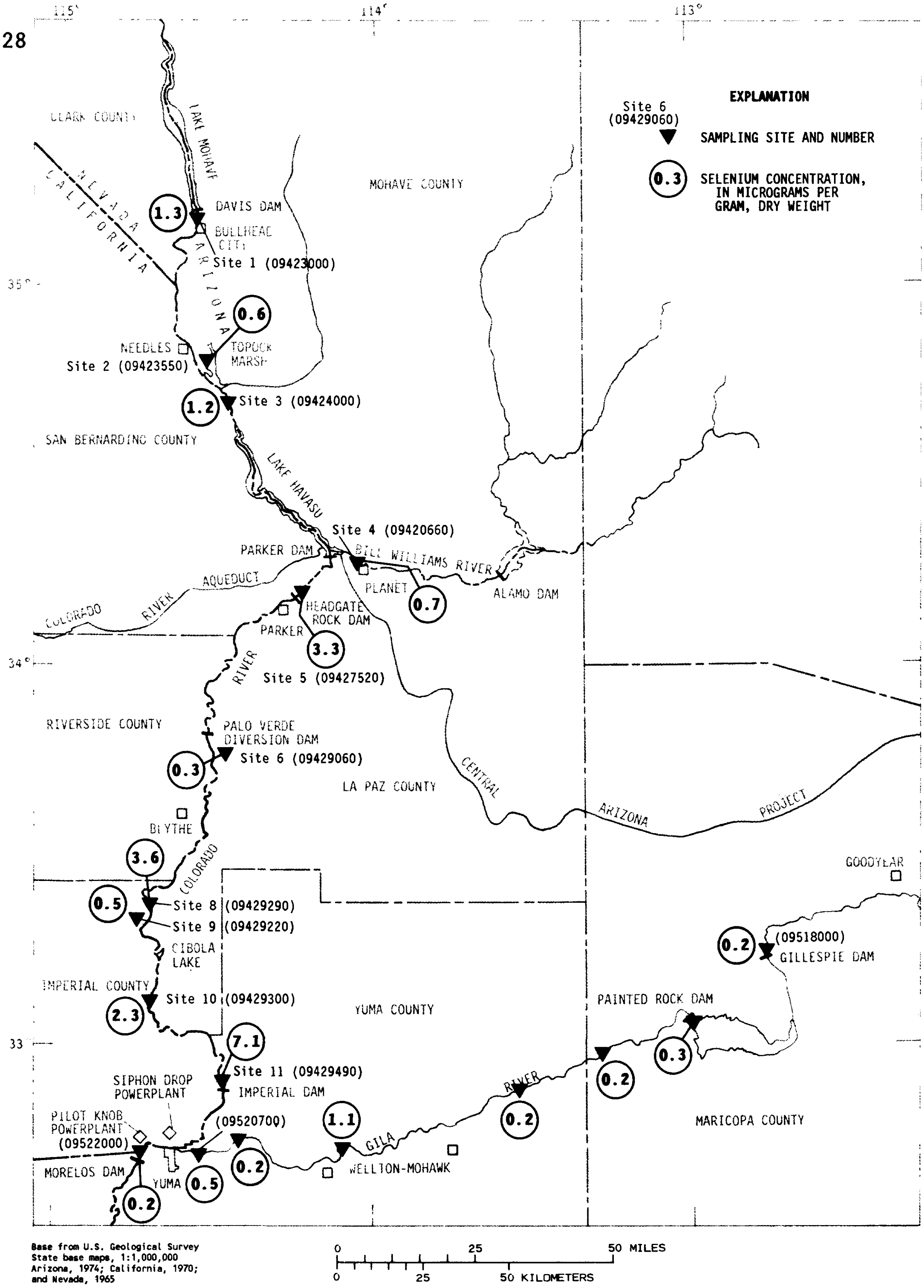
Selenium concentrations in bottom sediment of less than 63 micrometers were lower and did not exceed the upper limit of the 95-percent baseline for western soils at sites 2, 4, 6, and 9, which are directly under the influence of irrigation drainage, than at other sites (fig. 6). At the mainstream Colorado River stations, selenium and boron concentrations tended to increase with increasing distance downstream (table 10 and fig. 6). Bottom sediment from the Bill Williams River (site 4) consistently had the largest concentrations of arsenic, chromium, copper, mercury, nickel, lead, vanadium, and zinc (table 10). These large concentrations probably are a result of mining and irrigation activities in that basin. Greatest concentrations of thorium and uranium were found at Colorado River below Davis Dam (site 1) and probably are an artifact of extensive uranium mining, mine spills, and mine discharges in the upper Colorado River basin (Webb and others, 1987).

If detailed studies were to be conducted in the lower Colorado River valley, they should consider the temporal, spatial, and discharge related distribution and fate of trace-element concentrations sorbed on suspended sediment; spatial distribution of trace-element concentrations in agricultural soils and fodder; and the spatial distribution of trace elements in bottom sediment from the large reservoirs. Any further studies should also consider determining the spatial distribution and trace-element concentration of total organic material in bottom sediment and soils in the lower Colorado River valley including the Yuma valley.

Biota

Chemical, physical, and biological interactions are dynamic and variable among aquatic habitats. Chemical interactions involved in a consumer organism's diet are complex and include synergistic, antagonistic, or other interactions between metals and metalloids. Effects of these interactions can be extremely variable at different trophic levels of organisms; between species; on the age, sex, and reproductive condition of individuals; and from site to site. Consequently, in natural systems no definitive or universal guidelines have been established for specific concentrations of metals or metalloids in fish and other wildlife that can be used as indicative of various levels of toxicity. Also, because of the complexity and variability in natural systems, finding significant chemical levels and toxic effects in biota from one area does not necessarily mean that the same effects will occur in biota from another area that contains similar chemical concentrations. Information from controlled diet studies or from other areas can be used only as a guideline or indication as to whether or not potentially harmful concentrations appear to exist in biota from another area. The investigation conducted in the lower Colorado River valley was a reconnaissance study. The study was limited in scope and designed to obtain insight into whether or not certain chemicals exist in various media at concentrations that may present a potential contaminant concern.

The U.S. Fish and Wildlife Service has participated in the National Contaminant Biomonitoring Program (NCBP), formerly called the National Pesticide Monitoring Program, since 1967 by periodically analyzing residues of selected organochlorine contaminants and toxic trace elements in samples of fish and wildlife collected from a nationwide network of stations. Sampling results for selected trace elements are shown in table 14.



Base from U.S. Geological Survey
State base maps, 1:1,000,000
Arizona, 1974; California, 1970;
and Nevada, 1965

Figure 6.--Spatial distribution of total selenium concentrations in bottom sediment from the lower Colorado River and Gila River valleys, 1985 and 1986.

Comparisons with data from this study need to be qualified by the fact that values in table 14 are not specific for the lower Colorado River valley but are derived from a national sampling program. Also, values in table 14 are for an aggregate of fish species that might not be the same as those sampled in this study. Nevertheless, such values are national baselines and might be useful for comparison with values from this study.

If appropriate comparisons are possible and concentrations of trace elements and pesticides from this study are less than or equal to 85-percent baseline values in table 14, it is reasonable to say that such concentrations are not elevated in relation to national-baseline values. If concentrations are greater than 85-percent baseline values in table 14, it is reasonable to say that such concentrations are elevated in relation to national-baseline values. Even if concentrations are elevated in relation to national-baseline values, this does not mean necessarily that such concentrations have resulted or will result in adverse biological effects.

A complete tabulation of analytical results[4] for selected trace metals, metalloids, and organic compounds on a wet-weight basis are shown in tables 15 and 16 and summarized in table 17. Results discussed are limited primarily to selenium because of its toxicity to fish and wildlife and because most other constituents occurred at small concentrations. Also, historical data generated by the National Contaminant Biomonitoring Program identified greater potential for selenium to occur at elevated concentrations in the study area than any other metal, metalloid, or organic compound (table 18).

Carp were collected in triplicate five-specimen composites at all sampling stations. Spiny naiad were collected also in triplicate composites at all sites except site 9. Collection of double-crested cormorants was restricted to each of the three national wildlife refuges; cormorants were collected as triplicate five-specimen composites. Sites 6 and 9 were located in or near major agricultural drains. Supplementary information relative to inorganic and organic concentrations in carp tissue from the Gila River, a major tributary to the lower Colorado, also was made available (Kepner, 1986).

Elevated Inorganic Constituent Concentrations in Biota

With the exception of selenium, no inorganic constituents exceeded any existing standards, criteria, or guidelines for the protection of fish and wildlife resources. Arithmetic mean selenium concentrations for cormorant, carp, and spiny naiad for all stations sampled were 1.56, 1.49, and 0.09 μg/g, wet weight, respectively (table 17). Selenium concentrations in carp exceeded the 85-percent national-baseline value of 0.71 μg/g, wet weight, by a factor greater than two for fish collected under the

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[4] All analytical results are arithmetic mean values for each whole-body composite unless stated otherwise.

National Contaminant Biomonitoring Program during 1980-81 (Lowe and others, 1985). Zinc concentrations in all but one carp tissue sample exceeded the 1980-81 85-percent baseline for zinc of 40.1 μg/g, wet weight (Lowe and others, 1985).

Fish reproduction appears to be the most sensitive indicator of selenium toxicity. Selenium residues of 2 μg/g, wet weight, or greater may result in conditions that cause reproductive impairment and lack of recruitment in fishes (Baumann and May, 1984). Consequently, elevations in residual selenium could severely impact or possibly eliminate a fishery while little or no effect is observed simultaneously for other biota. Centrarchids, which include bass, sunfish, and crappie, appear to be the most sensitive fish family relative to selenium body burdens and reproductive failure.

During this study, arithmetic mean selenium concentrations in whole-body carp composites were as large as 4.0 μg/g, wet weight. Five of 31 fish composite samples (16 percent) were equal to or exceeded the guideline of 2.0 μg/g, wet weight, for reproductive impairment (table 15). Elevated concentrations were detected at site 11 (Imperial Oasis), site 8 (Palo Verde Oxbow Lake), and site 2 (Topock Marsh). These sites are backwater or oxbow lakes that receive inflow from the main river. These aquatic systems, more lacustrine in character, are predominated by fine bottom sediment with a larger percentage of organic material. According to Lemly (1986), such systems are the most sensitive to selenium accumulation. Selenium is most effectively trapped in these shallow, standing, or slow-moving waters with slow turn-over rates. Greatest selenium residues in fish were recorded from Palo Verde Oxbow Lake, which is used as a county recreational park (fig. 7). Population censusing conducted at this lake during the past 4 years has documented a general decline in centrarchid fish, particularly bluegill sunfish (Ron Powell, fisheries biologist, California Department of Fish and Game, oral commun., 1987).

California State Water Resources Control Board has recommended a no-effect level of 1.1 μg/g, wet weight, of selenium in fish tissue for the protection of aquatic life (Lillebo and others, 1987). The adverse-effect level in fish tissue was considered 2.87 μg/g, wet weight, and above. Similarly, the maximum allowable selenium-residue level of 1.0 μg/g, wet weight, for edible fish tissue was recommended for protection of human health. Fish captured from all sites except sites 6 and 9 exceeded the 1.1 μg/g residue-tolerance level, and fish captured at Palo Verde Oxbow Lake and Imperial Oasis exceeded the 2.87 μg/g, wet-weight, adverse-effect level recommended by Lillebo and others (1987).

Mean selenium wet-weight concentrations for birds and fish were almost equivalent, presumably reflecting the diet of cormorants and Yuma clapper rails and their equal ability to bioaccumulate metals and metalloids from the environment. Selenium concentration in the liver of a single adult Yuma clapper rail was 26.0 μg/g, dry weight, and exceeded the 12-16 μg/g range reported for areas without selenium contamination (Blus and others, 1977; King and others, 1983). This clapper rail liver concentration was comparable to the mean concentration of 28.6 μg/g, dry weight, determined for ducks at Kesterson National Wildlife Refuge, an area

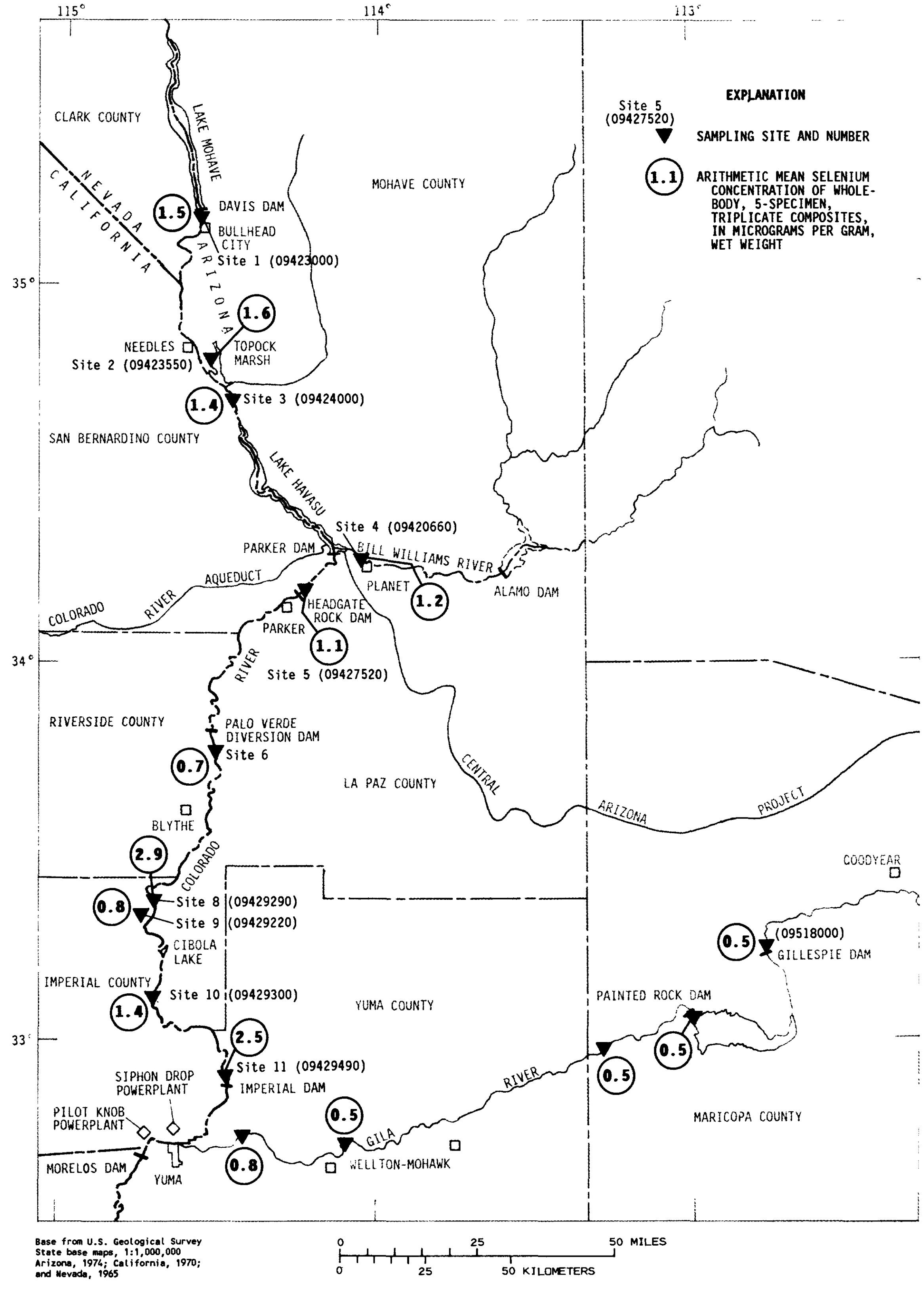

Figure 7.--Spatial distribution of mean selenium concentrations in carp tissue from the lower Colorado River and Gila River valleys, 1985 and 1986.

of known selenium contamination (Ohlendorf and others, 1986). Any future studies in the lower Colorado River valley should consider not only whole-body specimens but selected viscera from adult male waterfowl as indicators of elevated trace-metal and metalloid concentrations. Even though there are currently no criteria established for trace metals and metalloids in selected viscera, certain target organs like liver tissue appear to be good indicators of trace-metal and metalloid accumulation and exposure in selected waterfowl (Gregory Smith, research biologist, U.S. Fish and Wildlife Service, oral commun., 1988). Several waterfowl species should be chosen over a diverse range of functional feeding groups (piscivores, herbivores, omnivores, and carnivores) in the food chain.

Elevated Organic Constituent Concentrations in Biota

Cormorant body burdens for DDE were higher than those reported for carp (table 16). DDE wet-weight residue concentrations in cormorants (4.478 μg/g) were more than forty times greater than those found in carp (0.107 μg/g). Cormorant DDE concentrations were similar for each of the three national wildlife refuges (table 15). All cormorant DDE concentrations exceeded the criterion of 1.0 μg/g, wet weight, established by the National Academy of Science and National Academy of Engineering (1973, p. 198) for DDT and its metabolites for protection of aquatic wildlife, including predators. The criterion reads, "In order to protect most species of aquatic wildlife, the total DDT concentration on a wet-weight basis should be less than 1 μg/g in any aquatic plant or animal." This criterion was established to protect and assure survival of sensitive fish-eating and raptorial birds that occupy the apex of long food chains. Endangered species such as bald eagles and peregrine falcons are known to use the area. Not only has egg-shell thinning from DDE been well documented for bald eagles and peregrine falcons, but White and others (1987, p. 41) report egg-shell thinning from DDE contamination as being implicated in declining double-crested cormorant populations at the Channel Islands, California. No carp samples exceeded this level. Analyses of carp indicate that (1) residue concentrations appear to be consistent with those previously reported for the Colorado River and (2) contamination by organochlorine pesticides appears to be insignificant and nonproblematic. This conclusion is in complete contrast to values reported for fish and other biota in the lower Gila River (Kepner, 1986). The lower Gila River is severely contaminated with DDE, toxaphene, and other organochlorine pesticide residues. Reported DDE and toxaphene concentrations in carp from the lower Gila River were as large as 23.0 and 8.4 μg/g, wet weight, respectively (Kepner, 1986).

Organochlorine pesticides do not appear to present environmental problems to fish in the lower Colorado River study area, and this finding appears to be consistent with previous reports (U.S. Environmental Protection Agency, 1973). Although agricultural practices have changed owing to cancellations and restrictions of organochlorine pesticides, total irrigable acreage and pesticide usage have actually increased. Use of agricultural chemicals remains high, and use of nonpersistent, acutely toxic organophosphate and carbamate pesticides has replaced traditional agricultural dependency on organochlorines pesticides. Although organophosphates and carbamate pesticides are not known for their propensity to bioaccumulate, they pose localized threats to biota owing to their acute toxicity. Recent pesticide spills have resulted in major kills of more than 200,000 fish along the Colorado River (S.A. Daniels, Arizona Republic, written commun., 1987).

Organophosphate pesticides were detected in water samples from the Palo Verde Main drain during this study (see section entitled "Elevated Constituent Concentrations in Water"). Problems of indiscriminant use, spray drift, and improper disposal of organophosphate and carbamate pesticides present major threats of acute toxicity to resident biota, particularly aquatic species (Scott Yess, fisheries biologist, U.S. Fish and Wildlife Service, written commun., 1988).

Spatial Variation of Inorganic Constituent Concentrations in Biota

Metal and metalloid concentrations in fish, bird, and aquatic-plant tissues were variable (table 15). Certain elements, such as aluminum and iron, exhibited wide ranges in their detection, and both intersample and intrasample composites were highly variable. Presumably, this variability reflects their ubiquitous distribution and abundance in the environment rather than a result of agricultural or land-use practices. Other elements, such as arsenic, beryllium, cadmium, and mercury, were more consistent in their concentrations and exhibited less variance between identical species composites or sites and were either present in small concentrations, absent, or demonstrated little ability for bioaccumulation in tissue. Greatest metal and metalloid concentrations were detected at sites 2, 6, and 11. At site 6, biological samples were collected directly below the influence of agricultural wastewaters from the Colorado River Indian Reservation Lower drain. Sites 2 and 11 are backwater lakes that receive inflow from the main river. No clear upstream-to-downstream trends were detected for constituents analyzed; however, certain site-specific disparities were observed.

Concentrations of lead, cadmium, mercury, arsenic, copper, and zinc in carp were similar to those previously determined for the lower Colorado River valley for the National Contaminant Biomonitoring Program (table 18). The arithmetic mean selenium value during this study for carp of 1.49 μg/g, wet weight, was less than the mean concentration, 2.94 μg/g, wet weight, compiled for previous years (1972-80) for the lower Colorado River (Kepner, 1985). Reduced body burdens may reflect the influence of dilution owing to a 3-year wet hydrologic period versus an actual reduction of selenium in the environment. Mean selenium and zinc concentrations in carp tissue from all sites, however, did exceed the 85-percent national baseline (Lowe and others, 1985).

Other than the preponderance of inorganic constituents at sites 2, 6, and 11, geographical trends appeared to be lacking. The most significant exception to this observation appears to be the small selenium concentrations in fish tissue from sites associated with irrigation drains (fig. 7), such as site 9 (Palo Verde drain), site 6 (directly below the Colorado River Indian Reservation Lower Main drain), and Gila River at Dome

(W.G. Kepner, environmental specialist, U.S. Fish and Wildlife Service, written commun., 1987,).

Selenium concentration for carp at all stations ranged from 0.62 to 4.0 µg/g, wet weight, and the arithmetic mean concentration was 1.49 µg/g. Selenium concentrations at mainstream stations were larger by a factor greater than two (mean 1.67, range 1.1 - 4.0 µg/g) when compared to irrigation drain (including Gila River) stations (mean 0.77, range 0.61 - 1.20 µg/g). This differs markedly with observations reported for the tile drain systems in the San Joaquin Valley of California (Saiki, 1986). However, these data are consistent with selenium data summarized for the National Contaminant Biomonitoring Program in Arizona, which demonstrated that only Colorado mainstream stations were elevated in selenium residues in fish as opposed to selenium concentrations in fish from tributary drainages (Kepner, 1985).

Selenium appears to be the constituent of concern in the lower Colorado River aquatic ecosystem. The source of selenium presumably reflects influence of the upper basin where selenium is most likely mobilized by natural weathering of seleniferous shales, combustion of coal at electric generating stations, extraction of uranium and coal ore, and perhaps irrigation-based agriculture. All appear to contribute to the downstream loading and transport of selenium to the lower basin and hence its availability for biological uptake.

The significance of selenium availability in aquatic systems is governed by the ability of aquatic organisms to biologically accumulate and concentrate the element to toxic levels from dilute sources. This is particularly evident for warmwater fish, which appear to be the most sensitive indicators of selenium toxicity. Fish populations are either directly affected, particularly from dietary intake, or indirectly from reproductive impairment independent of adult mortality. Indeed, following the gradual increase of selenium in the water, sediment, and biota in warmwater aquatic ecosystems, the first toxic symptom appears to be reproductive impairment in fish, particularly centrarchids. Consequently, fish populations can be seriously impacted with little or no similar effect observed in other biota.

The end point for selenium toxicity in fish varies with species but appears to be very well defined. The chronic no-effect level for waterborne selenium (total) for warmwater fish is 2 to 5 µg/L (Lemly, 1986). The lowest chronic effect level is 5 to 8 µg/L (Lemly, 1986). Although selenium concentrations in water were equal to or less than 2 µg/L during this study (table 6, fig. 4), historical concentrations of selenium have been as great as 8 µg/L (table 1).

The lower Colorado River appears to be near the threshold for selenium toxicity in warmwater fish. Some areas have already sustained observable declines in certain components of the fishery (Ron Powell, fisheries biologist, California Department of Fish and Game, oral commun., 1987). Fish appear to be a very sensitive group of aquatic organisms to environmental selenium owing to their propensity to accumulate selenium, even when exposed to waterborne concentrations in the low microgram per liter range (Lemly, 1986). Thus, any further perturbations in the watershed that could increase the input level of selenium to the aquatic system, and subsequently the food chain, could result in an impoverished sport fishery. An increase in waterborne selenium concentration of 3 to 4 μg/L could move the system to a finite theshold and leave little margin of safety for certain fish species in the lower Colorado River.

Any future studies should consider long-term monitoring of the population dynamics of selected fish (centrarchids) to determine temporal and spatial variations in the lower Colorado River valley aquatic system. Additional studies should also consider using not only whole-body specimens but selected viscera (spleen, heart, or liver tissues) from centrarchid species as indicators of elevated trace-metal and metalloid concentrations. Even though there are currently no criteria, guidelines, or baselines established for selected viscera, target organs appear to be good indicators of trace-metal and metalloid accumulation and exposure in certain fish (Lemly, 1986).

Spatial Variation of Organic Constituent Concentrations in Biota

Only 3 of 13 organochlorine compounds were detected in tissue samples during this study (p,p'-DDE, PCB 1254, and PCB 1260). The mean DDE concentration in carp was 0.107 μg/g, wet weight. DDE concentrations in carp were approximately half the reported geometric mean concentration for fish sampled nationwide (Schmitt and others, 1985). PCB residues were not detected in carp tissue (table 16). No upstream-to-downstream trends were observed; however, DDE concentrations were greatest in fish captured at site 9, Palo Verde Main drain (arithmetic mean 0.24 μg/g, wet weight). DDE concentrations were similar to concentrations previously determined in carp from sites in the lower Colorado River by the National Contaminant Biomonitoring Program (table 18).

No apparent trends in concentration appear to exist for organochlorine compounds in birds collected at each of the national wildlife refuges. As previously mentioned, mean DDE concentrations for cormorant composites were approximately equal among refuges. DDE concentrations in cormorants, however, were greater than any DDE concentrations detected in carp tissue. PCB concentrations were detected only in cormorants. PCB 1254 concentrations in cormorants were greatest at Cibola NWR but were not detected at Havasu NWR. PCB 1260 concentrations were detected only at Havasu NWR. All PCB 1254 and 1260 concentrations were less than 1.0 μg/g, wet weight (table 16).

SUMMARY

Specific water-quality problems (salinity) have been prevalent in the lower Colorado River valley for many years. With exception of selenium, this study found sampling locations to be relatively free of large concentrations of selected toxic inorganic and synthetic organic constituents that could be a threat to humans, fish, and wildlife.

With the exception of cadmium, the dissolved-trace-metal, metalloid, radionuclide, and organochlorine data from the lower Colorado River indicates no elevated levels that exceed State of Arizona maximum allowable limits for protected uses of surface water. One sample collected at Colorado River near Topock, Arizona, contained a cadmium concentration of 69 µg/L. The most stringent State of Arizona protected use maximum allowable limit for cadmium is 10 µg/L.

Dissolved-selenium concentrations in water in the lower Colorado River appear to be derived from sources above Davis Dam. Not only did dissolved-selenium concentrations in water not increase with increasing distance downstream, but dissolved-selenium concentrations in water were smaller at sites that were directly influenced by irrigation drainage. Dissolved-selenium concentrations at all mainstream Colorado River sites exceeded the 75-percent national baseline. Agricultural practices in the lower Colorado River valley, therefore, do not at this time exacerbate dissolved-selenium concentrations in water. Dissolved barium, molybdenum, vanadium, and zinc concentrations at sites directly influenced by agricultural drainage, however, were at least twice the concentrations at sites not directly influenced by irrigation drainage.

Selenium concentrations in bottom sediment (less than 63 micrometers in diameter) equaled (approximately) or exceeded the 95-percent baseline for western soils at all mainstream sites. Selenium concentrations ranged from about one to five times the 95-percent baseline for western soils. It appears that sediment particles less than 63 micrometers in the mainstream Colorado River are acting as a sink for selenium. Thorium and uranium concentrations in bottom sediment also exceed the 95-percent baseline for western soils at several sites, and the greatest concentrations were found at Colorado River at Davis Dam. These large concentrations probably are an artifact of extensive uranium mining, mine spills, and mine discharges in the upper Colorado River basin. Persistent organochlorine pesticides (DDT, DDD, and DDE) and other synthetic organic compounds were detected in bottom sediment in the study area. DDE was found at all sites and ranged from 0.1 to 7.5 µg/kg, wet weight.

Selenium concentrations in bottom sediment were smaller at sites that are directly influenced by irrigation drainage. Bottom sediment from the Bill Williams River at Mineral Wash near Planet, Arizona, generally had the largest concentrations of trace-metal and trace-metalloid constituents. These large concentrations probably are a result of mining and irrigation activities within the basin.

With exception of selenium, no inorganic constituents exceeded any existing standards, criteria, or guidelines for the protection of fish and wildlife resources. Mean selenium and zinc concentrations in fish at all sites exceeded the respective 85-percent national baselines. During this study, mean selenium concentrations in whole-body carp composites were as large as 4.0 µg/g, wet weight. Fish collected at all sites (except sites directly under agricultural-drainage influence) exceeded the "no-effect" level of 1.1 µg/g, wet weight, recommended by the California State Water Resources Board for selenium in fish tissue for protection of wildlife. Fish captured at Palo Verde Oxbow Lake and Imperial Oasis also exceeded the "adverse-effect" level of 2.87 µg/g, wet weight, recommended by the California State Water Resources Board. Sixteen percent of the composite fish samples also equaled or exceeded the guideline of 2.0 µg/g, wet weight, at which selenium concentrations could begin to cause reproductive impairment and lack of recruitment in certain fish.

Organochlorine-pesticide residues do not appear to present environmental problems to fish in the lower Colorado River. DDE concentrations in cormorants, however, exceeded the 1.0 µg/g, wet weight, criterion established by the National Academy of Science and National Academy of Engineering for DDT and its metabolites for the protection of wildlife. In contrast, fish and wildlife in the lower Gila River valley are being exposed to a major source of DDE and toxaphene. These compounds present a threat of reduced viability and recruitment to wildlife resources of the lower Gila River, a tributary to the lower Colorado River.

Metal- and metalloid-element concentrations in fish, bird, and aquatic-plant tissue were spatially variable. No clear upstream-to-downstream trends were detected. The most significant exception to this observation appears to be selenium concentrations, which were lower at stations directly under the influence of agricultural drainage.

Selenium appears to be a constituent of concern in the lower Colorado River aquatic system. Its source apparently reflects influences in the upper Colorado River basin where selenium could be mobilized by natural weathering of seleniferous soils or rocks, combustion of seleniferous coal at electric generating stations, extraction of various seleniferous ore deposits, and perhaps irrigation-based agriculture. All these sources could be contributors to the downstream loading and transport of selenium to the lower Colorado River basin and, hence, its distribution and availability for bioaccumulation in the ecosystem.

The fact that agricultural practices in the lower Colorado River valley do not appear to exacerbate selenium concentrations, however, does not mean that aquatic organisms and their predators are not in jeopardy. Reported selenium concentrations in whole-body carp composites for all sites ranged from 0.62 to 4.0 with a mean of 1.49 µg/g, wet weight, and are approaching and possibly exceeding concentrations that could result in reproductive impairment and lack of recruitment in fish, especially bass, sunfish, and crappie. Increased or current selenium loading to the lower Colorado River environment could severely affect the fishery while little or no apparent effect might be observed in other media. A continuing and long-term monitoring effort would be required to detect any perturbations in the watershed that could increase selenium concentrations in the food chain, which could result in a depauperate natural resource.

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DATA TABLES

Table 1.--Selenium concentrations in surface waters at U.S. Geological Survey stations within the lower Colorado River and Gila River valleys since 1975

[Concentrations in micrograms per liter; N, number of samples analyzed; >, greater than; selenium concentrations dissolved unless noted otherwise]

Station number	Location	N	Median	Maximum
09421500	Colorado River below Hoover Dam, Arizona-Nevada	42	4	6
09426600	Bill Williams River at Mineral Wash near Planet, Arizona	58	>1	1
09427520	Colorado River below Parker Dam, California-Arizona	9 62	3 3	8 8 totals
09429490	Colorado River above Imperial Dam, California-Arizona	42	3	5
09518000	Gila River above diversions at Gillespie Dam, Arizona	39	5	14
09520700	Gila River near mouth near Yuma, Arizona	34	7	16
09522000	Colorado River at Northern International Boundary above Morelos Dam near Andrade, California	49	3	8

Table 2.--Selenium concentrations in fish collected from the lower Colorado River valley, Arizona and California, 1972-80

[Concentrations in micrograms per gram, wet weight; data from U.S. Fish and Wildlife Service, National Contaminant Biomonitoring Program]

Sampling site	Date	Fish species	Selenium concentrations
Colorado River at Lake Havasu, Arizona-California	1972	Largemouth bass	1.40
	1972	Yellow bullhead	3.20
	1972	Carp	3.60
	1973	Largemouth bass	1.40
	1973	Black crappie	2.10
	1973	Carp	3.00
	1978	Largemouth bass	1.43
	1978	Channel catfish	2.32
	1978	Channel catfish	3.64
	1980	Carp	2.07
	1980	Carp	1.29
	1980	Largemouth bass	0.98
Colorado River at Imperial Reservoir, Arizona-California	1972	Largemouth bass	3.60
	1972	Carp	3.00
	1972	Bluegill	2.60
	1973	Largemouth bass	2.10
	1973	Carp	3.20
	1978	Largemouth bass	2.83
	1978	Channel catfish	1.99
	1978	Channel catfish	2.24
	1980	Carp	1.79
	1980	Carp	1.51
	1980	Largemouth bass	2.13
Colorado River at Yuma, Arizona	1978	Largemouth bass	1.54
	1978	Channel catfish	1.76
	1980	Striped mullet	1.37
	1980	Largemouth bass	1.00
	1980	Striped mullet	1.00
	1980	Striped mullet	2.04
Colorado River at Poston Drain, Arizona	1980	Largemouth bass	1.30
	1980	Largemouth bass	1.03
	1980	Carp	1.70
Colorado River at Topock Marsh, Arizona	1980	Carp	2.90
	1980	Largemouth bass	3.30
Colorado River at Walter's Camp (Palo Verde Outfall Drain), California	1980	Carp	1.60
	1980	Largemouth bass	0.68
	1980	Channel catfish	0.49
Colorado River at Yuma Drain, Arizona	1980	Largemouth bass	0.86
	1980	Largemouth bass	0.79
	1980	Tilapia	0.70
	1980	Carp	0.46

Table 3.--Sampling sites for collection of water, bottom sediment, and biota from the lower Colorado River valley, 1986-87

[W, water; S, bottom sediment; P, spiny naiad; F, carp; B, cormorant; E, coot, gallinule, and rail eggs; each carp, cormorant, and egg tissue sample was a composite of five whole-body specimens; each spiny naiad tissue sample was a composite of three specimens; ( ), location of bottom sediment and biota samples]

Site number	USGS station number	Station location	Media					
			W	S	P	F	B	E
1	09423000	Colorado River below Davis Dam, Nevada-Arizona	1	1	3	3		
2	09423550	Topock Marsh Inlet near Needles, California (Topock Marsh)	4	3	4	4	3	
3	09424000	Colorado River near Topock, Arizona	1	1	3	3		5
4	09426600	Bill Williams River at Mineral Wash near Planet, Arizona (Bill Williams River at mouth)	1	1	3	3		
5	09427520	Colorado River below Parker Dam, California-Arizona (Headgate Rock Dam)	1	1	3	3		
6	09429060	Colorado River Indian Reservation - Lower Drain near Parker, Arizona (confluence of Lower Drain and Colorado River)	1	1	3	3		
7	09429010	Colorado River at Palo Verde Dam, California-Arizona	1					
8	09429290	Colorado River above Palo Verde Outfall Drain, California-Arizona (Oxbow Lake)	1	1	3	3		
9	09429220	Palo Verde Outfall Drain near Palo Verde, California	1	1		3		3
10	09429300	Colorado River below Cibola Valley, Arizona (Draper Lake)	1	1	3	3	3	
11	09429490	Colorado River above Imperial Dam, California-Arizona (Imperial Oasis)	1	1	3	3	3	
		Total number of samples	14	12	28	31	9	8

Table 4.--Chemical and physical determinations of water, bottom sediment, and biota collected from the lower Colorado River valley, 1986-87

[mg/L, milligrams per liter; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °Celsius; cfs, cubic feet per second; µg/L, micrograms per liter; µg/kg, micrograms per kilogram; µg/g, microgram per gram; pCi/L, picocuries per liter]

Water

Field determinations

- Alkalinity (mg/L)
- Discharge (cfs)
- Dissolved oxygen (mg/L)
- pH (units)
- Specific conductance (µS/cm)
- Temperature (°C)

Metals and metalloids (µg/L, dissolved)

- Arsenic (As)
- Barium (Ba)
- Boron (B)
- Cadmium (Cd)
- Chromium (Cr)
- Copper (Cu)
- Lead (Pb)
- Mercury (Hg)
- Molybdenum (Mo)
- Nickel (Ni)
- Radium (Ra-226)
- Selenium (Se)
- Silver (Ag)
- Thallium (Tl)
- Uranium (U)
- Vanadium (V)
- Zinc (Zn)

Radionuclide activities (pCi/L)

- Gross alpha radioactivity (dissolved as U)
- Gross alpha radioactivity (suspended as U)
- Gross beta radioactivity (dissolved as Cs 137)
- Gross beta radioactivity (suspended as Cs 137)
- Gross beta radioactivity (dissolved as Sr 90)
- Gross beta radioactivity (suspended as Sr 90)

Organics (µg/L, total recoverable)

- Aldrin
- Chlordane
- DDD
- DDE
- DDT
- Dieldrin
- Endosulfan
- Endrin
- Heptachlor
- Heptachlor epoxide
- Lindane
- Methoxychlor
- Mirex
- PCN
- Perthane
- Toxaphene

Bottom sediment

Metals and metalloids (µg/g, dry weight, total)

- Arsenic (As)
- Barium (Ba)
- Boron (B)
- Cadmium (Cd)
- Chromium (Cr)
- Copper (Cu)
- Lead (Pb)
- Mercury (Hg)
- Manganese (Mn)
- Molybdenum (Mo)
- Nickel (Ni)
- Selenium (Se)
- Silver (Ag)
- Thorium (Th)
- Uranium (U)
- Vanadium (V)
- Zinc (Zn)

Organic (µg/kg, wet weight, total recoverable)

- Aldrin
- Chlordane
- DDD
- DDE
- DDT
- Dieldrin
- Endosulfan
- Endrin
- Heptachlor
- Heptachlor epoxide
- Lindane
- Methoxychlor
- Mirex
- PCB
- PCN
- Perthane
- Toxaphene

Biological materials

Metals and metalloids (µg/g, wet weight, total)

- Aluminum (Al)
- Arsenic (As)
- Barium (Ba)
- Beryllium (Be)
- Boron (B)
- Cadmium (Cd)
- Chromium (Cr)
- Copper (Cu)
- Iron (Fe)
- Lead (Pb)
- Magnesium (Mg)
- Manganese (Mn)
- Mercury (Hg)
- Molybdenum (Mo)
- Nickel (Ni)
- Selenium (Se)
- Strontium (Sr)
- Tin (Sn)
- Vanadium (V)
- Zinc (Zn)

Organic (µg/g, wet weight, total recoverable)

- cis-Chlordane
- cis-Nonachlor
- Dieldrin
- Endrin
- Heptachlor expoxide
- Oxychlordane
- PCB 1254
- PCB 1260
- p,p'-DDD
- p,p'-DDE
- p,p'-DDT
- trans-Chlordane
- trans-Nonachlor

Table 5.--Analytical results of selected organic compounds, metals, and metalloids collected in the lower Colorado River valley for the 1986 U.S. Environmental Protection Agency, Priority Pollutant Program

[See table 3 for site identifications; M, Lake Mohave; dashes indicate concentrations less than analytical detection limit; analytical results of biota are arithmetic mean values for a whole-body composite]

Constituent	Water, in micrograms per liter				Sediment, in micrograms per gram, dry weight				Carp, in milligrams per kilogram, wet weight				Spiny Naiad, in milligrams per kilogram, wet weight			
	Site 11	Site 9	Site 2	Site M	Site 11	Site 9	Site 2	Site M	Site 11	Site 9	Site 2	Site M	Site 11	Site 9	Site 2	Site M
Semi-volatile organic compounds																
Di-n-butyl phthalate	[1]0.5	[1]0.6	------	[1]0.5	[1]174.0	---------	[1]24.0	-----	----	-------	------	-----	------	-------	------	----
Benzyl butyl phthalate	[1]0.6	-----	------	-----	[1]116.0	---------	---------	-----	----	-------	------	-----	------	-------	------	----
Di-n-octyl phthalate	[1]0.8	[1]1.5	------	-----	[1]58.0	---------	---------	-----	----	-------	------	-----	------	[2]0.3	------	----
1,3-Isobenzofurandione	[1]46.0	-----	------	-----	-------	---------	---------	-----	----	-------	------	-----	[1]0.4	-------	------	----
4 Nitrophenylester butanic acid	[1]81.0	-----	------	-----	-------	---------	---------	-----	----	-------	------	-----	------	-------	------	----
Phenol	------	-----	------	12.5	-------	---------	---------	-----	----	-------	------	-----	------	-------	------	----
Benzoic acid	------	-----	------	62.5	-------	---------	---------	-----	----	-------	[1]0.5	-----	[1]0.2	-------	------	----
2-Methylphenol	------	-----	------	12.5	-------	---------	---------	-----	----	-------	------	-----	------	-------	------	----
4-Methylphenol	------	-----	------	12.5	-------	---------	---------	-----	----	-------	------	-----	------	-------	------	----
2,4,5-Trichlorophenol	------	-----	------	62.5	-------	---------	---------	-----	----	-------	------	-----	------	-------	------	----
Bis(2-Ethylhexyl)phthalate	------	-----	------	-----	-------	18,400.0	---------	-----	----	-------	------	-----	------	-------	------	----
Diethyl phthalate	------	-----	------	-----	-------	[1]970.0	---------	-----	----	-------	------	-----	------	-------	------	----
Dihydro-2(3H)-furanone	------	-----	------	-----	-------	---------	[1]1,200.0	-----	----	-------	------	-----	------	-------	------	----
1-1-1-Trichloro-2-methyl-2-propanol	------	-----	------	-----	-------	---------	[1]850.0	-----	----	-------	------	-----	------	-------	------	----
4-Methyl-5-thiazole-ethanol	------	-----	------	-----	-------	---------	---------	-----	----	[1]0.23	------	-----	------	-------	------	----
3-Pyridinecarboxamide	------	-----	------	-----	-------	---------	---------	-----	----	[1]14.0	------	[1]4.6	------	-------	------	----
1,2,3-Propanetriol	------	-----	------	-----	-------	---------	---------	-----	----	-------	[1]2.2	-----	------	-------	------	----
Dioctyl-ester hexanedioic acid	------	-----	------	-----	-------	---------	---------	-----	----	-------	------	-----	[1]6.1	-------	------	----

Table 5.--Analytical results of selected organic compounds, metals, and metalloids collected in the lower Colorado River valley for the 1986 U.S. Environmental Protection Agency, Priority Pollutant Program--Continued

Constituent	Water, in micrograms per liter				Sediment, in micrograms per gram, dry weight				Carp, in milligrams per kilogram, wet weight				Spiny Naiad, in milligrams per kilogram, wet weight			
	Site 11	Site 9	Site 2	Site M	Site 11	Site 9	Site 2	Site M	Site 11	Site 9	Site 2	Site M	Site 11	Site 9	Site 2	Site M
Volatile organic compounds																
Methylene chloride	------	^{1}2.1	^{1}4.0	6.0	>500.0	132.0	81.0	-----	----	148.0	156.0	-----	83.0	^{2}75.0	75.0	----
Chloroform	------	^{1}1.7	------	-----	^{1}2.0	---------	---------	^{1}1.0	----	-------	------	^{1}2.0	------	-------	------	----
Acetone	------	-----	^{1}1.0	-----	28.0	1,000.0	---------	-----	----	-------	92.0	-----	------	-------	15.0	----
2-Butanone	------	-----	------	-----	19.0	---------	^{1}4.0	-----	----	-------	45.0	-----	18.0	^{2}6.0	^{1}3.0	----
Bromodichloromethane	------	-----	------	-----	^{1}1.0	---------	---------	-----	----	-------	------	-----	------	-------	------	----
Trichloroethane	------	-----	------	-----	^{1}2.0	---------	---------	-----	----	-------	------	-----	------	-------	------	----
Dibromochloromethane	------	-----	------	-----	^{1}1.0	---------	---------	-----	----	-------	------	-----	------	-------	------	----
Bromoform	------	-----	------	-----	^{1}2.0	---------	---------	-----	----	-------	------	-----	------	-------	------	----
1,1,2,2,-Tetrachloroethane	------	-----	------	-----	^{1}1.0	---------	---------	-----	----	-------	------	-----	------	-------	------	----
Toluene	------	-----	------	-----	^{1}1.0	^{1}1.0	^{1}1.0	^{1}1.0	----	-------	------	-----	35.0	^{2}14.0	62.0	----
Benzene	------	-----	------	-----	-------	^{1}1.0	---------	-----	----	23.0	^{1}4.0	52.0	^{1}1.0	^{1,2}1.0	------	----
Chloromethane	------	-----	------	-----	-------	---------	---------	^{1}2.9	----	^{1}2.0	^{1}1.0	^{1}1.0	------	-------	^{1}1.0	----
Vinyl acetate	------	-----	------	-----	-------	---------	^{1}1.0	^{1}2.0	----	------	------	-----	------	-------	^{1}8.0	----
Carbon disulfide	------	-----	------	-----	-------	---------	---------	-----	----	^{1}2.0	^{1}1.0	-----	------	-------	------	----
4-Methyl-2-pentanone	------	-----	------	-----	-------	---------	---------	-----	----	^{1}3.0	------	-----	------	-------	------	----
Thiobismethane	------	-----	------	-----	-------	---------	---------	-----	----	^{1}431.0	------	-----	------	-------	------	----
2-Heptanone	------	-----	------	-----	-------	---------	---------	-----	----	^{1}87.0	------	-----	------	-------	------	----
Ethylbenzene	------	-----	------	-----	-------	---------	---------	-----	----	-------	^{1}1.0	-----	^{1}1.0	-------	------	----
Total xylenes	------	-----	------	-----	-------	---------	---------	-----	----	-------	^{1}4.0	20.0	------	^{1,2}1.0	^{1}1.0	----
2-Hexanone	------	-----	------	-----	-------	---------	---------	-----	----	-------	------	37.0	------	-------	------	----
1,1-Dichloroethane	------	-----	------	-----	-------	---------	---------	-----	----	-------	------	-----	^{1}1.0	-------	------	----

Table 5.--Analytical results of selected organic compounds, metals, and metalloids collected in the lower Colorado River valley for the 1986 U.S. Environmental Protection Agency, Priority Pollutant Program--Continued

Constituent	Water, in micrograms per liter				Sediment, in micrograms per gram, dry weight				Carp, in milligrams per kilogram, wet weight				Spiny Naiad, in milligrams per kilogram, wet weight			
	Site 11	Site 9	Site 2	Site M	Site 11	Site 9	Site 2	Site M	Site 11	Site 9	Site 2	Site M	Site 11	Site 9	Site 2	Site M
Methanethiol	------	-----	------	-----	-------	---------	---------	-----	----	-------	------	-----	^{1}575.0	-------	------	----
Dimethyl disulfide	------	-----	------	-----	-------	---------	---------	-----	----	-------	------	-----	^{1}222.0	-------	------	----
Methyl butanoate	------	-----	------	-----	-------	---------	---------	-----	----	-------	------	-----	^{1}187.0	-------	------	----
Pesticide/PCB Scan																
Endosulfan 1	------	-----	------	-----	-------	---------	---------	-----	----	0.006	------	-----	------	-------	------	----
P,p-DDE	------	-----	------	-----	-------	---------	---------	-----	----	0.17	------	0.20	------	-------	------	----
P,p-DDD	------	-----	------	-----	-------	---------	---------	-----	----	0.022	------	0.03	------	-------	------	----
Trace metals and metalloids																
Arsenic	^{1}2.1	-----	^{1}2.90	-----	^{1}7.5	^{1}1.86	6.59	^{1}8.1	----	--------	------	-----	------	^{1,2}0.90	------	----
Copper	^{1}6.5	^{1}11.5	^{1}12.6	^{1}5.7	^{1}20.0	^{1}3.05	^{1}7.26	^{1}10.0	----	--------	^{1}3.60	^{1}2.6	------	-------	^{1}3.90	----
Selenium	^{1}1.60	^{1}1.5	------	-----	6.20	--------	0.32	^{1}1.2	----	^{1}0.85	^{1}1.5	^{1}0.81	------	-------	------	----
Zinc	23.0	34.0	^{1}15.0	^{1}3.1	77.4	30.6	23.5	46.0	----	^{1}77.0	62.0	41.0	^{1}7.7	^{2}10.8	^{1}6.55	----
Cadmium	-----	^{1}3.4	^{1}3.60	^{1}2.5	^{1}7.1	^{1}2.53	^{1}1.12	^{1}5.3	----	--------	------	-----	------	-------	------	----
Lead	-----	^{1}2.4		6.6	18.5	6.41	7.65	23.0	----	--------	------	4.0	------	^{1,2}2.40	------	----
Nickel	-----	^{1}13.0	^{1}30.0	^{1}18.0	46.2	^{1}12.7	125.0	^{1}15.0	----	--------	------	-----	------	-------	------	----
Chromium	-----	-----	^{1}5.8	-----	16.2	^{1}5.07	3.87	-----	----	--------	^{1}3.10	-----	------	^{1,2}3.05	^{1}3.40	----
Antimony	-----	-----	-----	-----	-----	----------	--------	^{1}5.7	----	--------	------	-----	------	-------	------	----
Mercury	-----	-----	-----	-----	-----	----------	0.10	-----	----	--------	0.10	-----	------	-------	------	----

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[1] Estimated value. Results less than specified detection limit but greater than 0.

[2] Myriophyllum.

Table 6--Field determinations and analytical results of selected trace constituents in water from the lower Colorado River valley, 1986

[See table 3 for site locations; <, less than analytical detection limit; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °Celsius; ft^3/s, cubic feet per second; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter; dashes indicate no data]

SITE NUMBER	DATE	TIME	TEMPERATURE WATER (°C)	STREAMFLOW, INSTANTANEOUS (ft^3/s)	SPECIFIC CONDUCTANCE (µS/cm)	OXYGEN, DISSOLVED (mg/L)	PH (STANDARD UNITS)	ALKALINITY TOTAL FIELD mg/L AS $CaCO_3$	ARSENIC DISSOLVED (µg/L AS As)	BARIUM, DISSOLVED (µg/L AS Ba)	BORON, DISSOLVED (µg/L AS B)
1	8-13-86	1200	19.5	24600	840	8.4	8.00	111	2	100	100
2	8-27-86	1730	35.0	-------	1450	7.3	8.25	139	4	160	240
	8-27-86	1645	35.0	-------	1450	7.3	8.25	139	4	160	240
	8-27-86	1620	35.0	-------	1450	7.3	8.25	139	<1	10	<10
	8-27-86	1600	35.0	-------	1450	7.3	8.25	139	4	160	240
3	8-27-86	1030	20.0	24000	840	8.1	7.90	124	2	100	100
4	8-12-86	1630	35.0	106	660	5.8	8.00	147	8	68	280
5	8-12-86	1200	24.5	24700	840	8.3	8.00	111	2	100	100
7	8-28-86	0900	26.0	19500	870	8.3	8.00	127	2	100	110
6	8-28-86	1000	26.5	254	2500	6.4	8.00	240	2	100	340
9	8-25-86	1200	27.0	574	2600	6.3	7.80	244	2	<100	540
8	8-26-86	0900	26.0	18	880	7.9	7.95	127	2	100	110
10	8-26-86	1000	25.5	19	910	7.7	8.00	130	2	100	120
11	8-19-86	1330	28.0	21400	920	7.4	7.80	120	2	100	120

SITE NUMBER	DATE	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)	THALLIUM, DISSOLVED (µg/L AS Tl)	MOLYBDENUM, DISSOLVED (µg/L AS Mo)	NICKEL, DISSOLVED (µg/L AS Ni)	SILVER, DISSOLVED (µg/L AS Ag)
1	8-13-86	<1	<10	<10	<5	0.1	------	4	4	<1
2	8-27-86	<1	<10	<10	<5	<0.1	<1	8	1	<1
	8-27-86	<1	<10	<10	<5	<0.1	<1	8	1	<1
	8-27-86	<1	<10	<10	<5	<0.1	<1	2	<1	<1
	8-27-86	2	<10	<10	<5	<0.1	<1	12	1	<1
3	8-27-86	69	<10	<10	<5	<0.1	<1	5	4	<1
4	8-12-86	<1	<10	<10	<5	0.1	------	6	2	<1
5	8-12-86	<1	<10	<10	<5	0.1	------	6	2	<1
7	8-28-86	<1	<10	<10	<5	<0.1	<1	5	2	<1
6	8-28-86	<1	<10	10	<5	<0.1	<1	11	3	<1
9	8-25-86	<1	<10	10	<5	<0.1	<1	16	3	<1
8	8-26-86	<1	<10	<10	<5	<0.1	<1	5	1	<1
10	8-26-86	<1	<10	<10	<5	<0.1	<1	5	<1	<1
11	8-19-86	<1	<10	<10	<5	0.1	<1	5	1	<1

Table 6.--Field determinations and analytical results of selected trace constituents in water from the lower Colorado River valley, 1986--Continued

SITE NUMBER	DATE	VANADIUM, DISSOLVED (µg/L AS V)	ZINC, DISSOLVED (µg/L AS Zn)	SELENIUM, DISSOLVED (µg/L AS Se)	URANIUM NATURAL DISSOLVED (µg/L AS U)	GROSS BETA, DISSOLVED (pCi/L AS Cs-137)	GROSS BETA, SUSP. TOTAL (pCi/L AS Cs-137)	Ra-226, DISSOLVED, PLANCHET COUNT (pCi/L)	GROSS ALPHA, DISSOLVED (µg/L AS U-Nat)	GROSS ALPHA, SUSP. TOTAL (µg/L AS U-Nat)
1	8-13-86	1	3	2	-------	-------	-------	-------	------	------
2	8-27-86	6	<3	1	5.9	14	2.5	0.2	10	0.6
	8-27-86	5	12	1	7.6	12	2.6	0.3	<8.9	<0.8
	8-27-86	<1	<3	<1	<0.4	<0.5	<0.6	0.1	<0.4	<0.8
	8-27-86	5	11	1	5.5	13	2.4	0.2	7.5	0.8
3	8-27-86	1	<3	2	4.3	4.6	2.0	0.2	<5.5	<0.7
4	8-12-86	7	3	<1	3.6	8.9	2.8	0.2	4.5	0.6
5	8-12-86	3	<3	2	4.8	5.5	2.0	0.1	5.4	<0.4
7	8-28-86	1	<3	2	4.5	5.7	1.7	0.2	7.3	<0.6
6	8-28-86	5	10	1	-------	-------	-------	-------	------	------
9	8-25-86	5	10	<1	3.8	9.7	1.6	0.1	<13	<0.9
8	8-26-86	2	<3	2	5.2	5.9	1.8	0.2	<5.9	0.7
10	8-26-86	2	<3	2	4.5	5.1	2.1	0.2	5.2	<0.7
11	8-19-86	2	5	2	4.8	5.9	1.9	0.1	8.2	0.6

SITE NUMBER	DATE	GROSS BETA, DISSOLVED (pCi/L AS Sr/Yt-90)	ALDRIN, DISSOLVED (µg/L)	LINDANE DISSOLVED (µg/L)	CHLORDANE, DISSOLVED (µg/L)	DDD, DISSOLVED (µg/L)	DDE, DISSOLVED (µg/L)	DDT, DISSOLVED (µg/L)	DIELDRIN DISSOLVED (µg/L)	ENDRIN, DISSOLVED (µg/L)
1	8-13-86	------	<0.01	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01
2	8-27-86	9.4	<0.01	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01
	8-27-86	8.6	<0.01	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01
	8-27-86	<0.5	<0.01	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01
	8-27-86	8.7	<0.01	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01
3	8-27-86	3.5	<0.01	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01
4	8-12-86	6.9	<0.01	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01
5	8-12-86	4.1	<0.01	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01
7	8-28-86	4.2	<0.01	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01
6	8-28-86	------	<0.01	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01
9	8-25-86	6.1	<0.01	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01
8	8-26-86	4.5	<0.01	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01
10	8-26-86	3.8	<0.01	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01
11	8-19-86	4.4	<0.01	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01

Table 6.--Field determinations and analytical results of selected trace constituents in water from the lower Colorado River valley, 1986--Continued

SITE NUMBER	DATE	TOX- APHENE, DIS- SOLVED (μg/L)	HEPTA- CHLOR, DIS- SOLVED (μg/L)	HEPTA- CHLOR EPOXIDE DIS- SOLVED (μgL)	PCB, DIS- SOLVED (μg/L)	MIREX, DIS- SOLVED (μg/L)	PER- THANE DIS- SOLVED (μg/L)	METH- OXY- CHLOR DIS- SOLVED (μg/L)	ENDO- SULFAN- DIS- SOLVED (μg/L)	PCN DIS- SOLVED (μg/L)
1	8-13-86	<1.0	<0.01	<0.01	<0.1	<0.01	<0.10	<0.01	<0.01	<0.10
2	8-27-86	<1.0	<0.01	<0.01	<0.1	<0.01	<0.10	<0.01	<0.01	<0.10
	8-27-86	<1.0	<0.01	<0.01	<0.1	<0.01	<0.10	<0.01	<0.01	<0.10
	8-27-86	<1.0	<0.01	<0.01	<0.1	<0.01	<0.10	<0.01	<0.01	<0.10
	8-27-86	<1.0	<0.01	<0.01	<0.1	<0.01	<0.10	<0.01	<0.01	<0.10
3	8-27-86	<1.0	<0.01	<0.01	<0.1	<0.01	<0.10	<0.01	<0.01	<0.10
4	8-12-86	<1.0	<0.01	<0.01	<0.1	<0.01	<0.10	<0.01	<0.01	<0.10
5	8-12-86	<1.0	<0.01	<0.01	<0.1	<0.01	<0.10	<0.01	<0.01	<0.10
7	8-28-86	<1.0	<0.01	<0.01	<0.1	<0.01	<0.10	<0.01	<0.01	<0.10
6	8-28-86	<1.0	<0.01	<0.01	<0.1	<0.01	<0.10	<0.01	<0.01	<0.10
9	8-25-86	<1.0	<0.01	<0.01	<0.1	<0.01	<0.10	<0.01	<0.01	<0.10
8	8-26-86	<1.0	<0.01	<0.01	<0.1	<0.01	<0.10	<0.01	<0.01	<0.10
10	8-26-86	<1.0	<0.01	<0.01	<0.1	<0.01	<0.10	<0.01	<0.01	<0.10
11	8-19-86	<1.0	<0.01	<0.01	<0.1	<0.01	<0.10	<0.01	<0.01	<0.10

Table 7.--Statistical summaries of chemical and physical determinations for water samples collected from the lower Colorado River valley, 1986-87

[Concentrations in micrograms per liter unless noted otherwise; <, less than analytical detection limit; mg/L, milligrams per liter; ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 °Celsius; pCi/L, picocuries per liter]

Constituent	Number of samples	Minimum	Maximum	Median
Alkalinity, (mg/L)	11	111	244	127
Discharge, (ft^3/s)	10	18	24,700	19,500
Dissolved oxygen, (mg/L)	11	5.8	8.4	7.4
pH, (units)	11	7.8	8.25	8.0
Specific conductance, (µS/cm)	11	660	2,600	870
Temperature (°Celsius)	11	19.5	35.0	26.5
Arsenic, dissolved	11	2	8	2
Barium, dissolved	11	68	160	100
Boron, dissolved	11	100	540	120
Cadmium, dissolved	11	<1	69	<1
Chromium, dissolved	11	<1	<1	<1
Copper, dissolved	11	<10	10	<10
Lead, dissolved	11	<5	<5	<5
Mercury, dissolved	11	<0.1	0.1	<0.1
Molybdenum, dissolved	11	4	16	5
Nickel, dissolved	11	<1	4	2
Radium-226, dissolved	9	0.1	0.2	0.2
Selenium, dissolved	11	<1	2	2
Silver, dissolved	11	<1	<1	<1
Thallium, dissolved	8	<1	<1	<1
Uranium, dissolved	9	<0.4	5.9	4.5
Vanadium, dissolved	11	1	7	2
Zinc, dissolved	11	<3	12	<3
Gross alpha, dissolved as U	9	4.5	10	7.3
Gross alpha, suspended as U	9	<0.4	0.9	0.7
Gross beta, dissolved as Cs 137 (pCi/L)	9	4.6	12	5.9
Gross beta, dissolved as Sr 90 (pCi/L)	9	3.5	8.6	4.4
Gross beta, suspended as Cs 137 (pCi/L)	9	1.6	2.8	2.0
Gross beta, suspended as Sr 90 (pCi/L)	9	1.5	2.7	2.0

Table 7.--Statistical summaries of chemical and physical determinations for water samples collected from the lower Colorado River valley, 1986-87--Continued

Constituent	Number of samples	Minimum	Maximum	Median
Aldrin, total recoverable	11	<0.01	<0.01	<0.01
Chlordane, total recoverable	11	<0.1	<0.1	<0.1
DDD, total recoverable	11	<0.01	<0.01	<0.01
DDE	11	<0.01	<0.01	<0.01
DDT, total recoverable	11	<0.01	<0.01	<0.01
Dieldrin, total recoverable	11	<0.01	<0.01	<0.01
Endosulfan, total recoverable	11	<0.01	<0.01	<0.01
Endrin, total recoverable	11	<0.01	<0.01	<0.01
Heptachlor, total recoverable	11	<0.01	<0.01	<0.01
Heptachlor epoxide, total recoverable	11	<0.01	<0.01	<0.01
Lindane, total recoverable	11	<0.01	<0.01	<0.01
Methoxychlor, total recoverable	11	<0.01	<0.01	<0.01
Mirex, total recoverable	11	<0.01	<0.01	<0.01
PCB, total recoverable	11	<0.1	<0.1	<0.1
PCN, total recoverable	11	<0.10	<0.10	<0.10
Perthane, total recoverable	11	<0.10	<0.10	<0.10
Toxaphene, total recoverable	11	<1.0	<1.0	<1.0

Table 8.--Maximum contaminant levels for selected constituents in water in Arizona

[Maximum contaminant levels, in milligrams per liter, total recoverable concentration unless noted. Dashes, no established maximum contaminant levels; D, dissolved concentration or activity; I, insoluble activity]

Constituent	U.S. Environmental Protection Agency[1]	State of Arizona					
		Drinking water[2]		Surface water[3,4]			All water[4]
		Community water system	Noncommunity water system	Domestic water source	Aquatic and wildlife	Agricultural and livestock	
Arsenic........	0.05	0.05	0.10	0.05D	0.05D	0.20	--------
Barium.........	1	1.	2.	1.00D	-------------	-----------	--------
Boron..........	----------	---------	---------	------------	-------------	-----------	--------
Cadmium........	0.010	0.01	0.02	0.01	0.01D	0.05	--------
Chloride.......	[5]250	(6)	(6)	------------	-------------	-----------	--------
Chromium, total........	0.05	0.05	0.5	0.05D	0.05D	1.00	--------
Copper.........	1	(6)	(6)	1.00D	0.05D	0.50	--------
Dissolved solids.......	[5]500	(6)	(6)	(6)	(6)	(6)	--------
Fluoride[7]......	4.0	1.4-2.4	6.0	------------	------------	------------	--------
Gross alpha (picocuries per liter)...	[8]15	[8]15	[8]15	------------	------------	------------	--------
Gross alpha plus gross beta (picocuries per liter).......	----------	---------	---------	[9]30	[9]30	[9]30	[9]30
Gross beta (picocuries per liter)...	50	---------	---------	------------	------------	------------	--------
Iron...........	[5]0.3	(6)	(6)	------------	------------	------------	--------
Lead...........	0.05	0.05	0.1	0.05D	0.05D	0.10	--------
Lead-210 (picocuries per liter)...	----------	---------	---------	100D 200,000I	100D 200,000I	100D 200,000I	100D 200,000I
Manganese......	[5]0.05	(6)	(6)	------------	------------	------------	--------
Mercury........	0.002	0.002	0.004	0.0020	0.0002	0.0100	--------
pH (units).....	[5]6.5-8.5	(6)	(6)	------------	6.5-9.0	6.5-9.0	--------
Polonium-210 (picocuries per liter)...	----------	---------	---------	700D 30,000I	700D 30,000I	700D 30,000I	700D 30,000I
Radium-226 (picocuries per liter)...	(10)	(10)	(10)	30D 30,000I 30,000I	30D 30,000I 30,000I	30D 30,000I 30,000I	30D 30,000I 30,000I
Radium-228 (picocuries per liter)...	----------	---------	---------	30D 30,000I	30D 30,000I	30D 30,000I	30D 30,000I

Table 8.--Maximum contaminant levels for selected constituents in water in Arizona--Continued

Constituent	U.S. Environmental Protection Agency[1]	State of Arizona					
		Drinking water[2]		Surface water[3],[4]			All water[4]
		Community water system	Noncommunity water system	Domestic water source	Aquatic and wildlife	Agricultural and livestock	
Radium-226 plus radium-228 (picocuries per liter).......	5	5	5	5	5	5	--------
Selenium.......	0.01	0.01	0.02	0.010D	0.050	0.050	--------
Silver.........	0.05	0.05	0.10	0.050D	0.050D	------------	--------
Sulfate........	[5]250	(6)	(6)	------------	------------	------------	--------
Thorium-230 (picocuries per liter)...	----------	---------	---------	2,000D 30,000I	2,000D 30,000I	2,000D 30,000I	2,000D 30,000D
Uranium, total.	[12]0.035	[12]0.035	[12]0.035	45	45	45	45
Zinc...........	[5]5	(6)	(6)	5.000D	0.500D	25.00	--------

[1] U.S. Environmental Protection Agency, 1986a, Maximum contaminant levels (subpart B of part 141, National Interim Primary Drinking Water Regulations: U.S. Code of Federal Regulations, Title 40, Parts 100 to 149, revised as of July 1, 1986, p. 524-528. Unless noted, all values in this column are primary drinking water maximum contaminant levels and apply to water in public water systems.

[2] McClennan, J.J., 1984, Official compilation of administrative rules and regulations: Phoenix, Arizona, State of Arizona report, Supplement 84-3, p. 68-84. Unless noted, all values in these columns are primary drinking water maximum contaminant levels and apply to water in public water systems.

[3] McClennan, J.J., 1986, Official compilation of administrative rules and regulations: Phoenix, Arizona, State of Arizona report, Advance Supplement 86-4, p. 1-49. Unless noted, all values in this column are maximum allowable limits and apply to surface water in the lower Colorado River valley.

[4] State of Arizona Atomic Energy Commission, 1977, Rules and regulations, title 12: Phoenix, Arizona, State of Arizona report, Supplement 77-3, p. 1-113. These standards (maximum permissible levels) apply to all waters released from external sources in unrestricted areas.

[5] U.S. Environmental Protection Agency, 1986b, Secondary maximum contaminant levels (Section 143.3 of part 143, National Secondary Drinking Water Regulations): U.S. Code of Federal Regulations, Title 40, Parts 100 to 149, revised as of July 1, 1986, p. 587-590. These regulations are not Federally enforceable but are intended as guidelines for the States and apply to water in public water systems.

[6] To be monitored. No maximum contaminant level.

[7] Fluoride maximum contaminant levels are a function of mean annual maximum daily air temperature.

[8] Includes radium-226 but excludes radon and uranium.

[9] If either the identity or the concentration of any radionuclide in the mixture is not known, see footnote 4.

[10] If radium-226 exceeds 3 picocuries per liter, radium-228 must be measured.

[11] Recommended levels (Lappenbusch, W.L., and Cothern, C.R., 1985, Regulatory development of the interim and revised regulations for radioactivity in drinking water--past and present issues and problems: Health Physics, v. 48, p. 535-551).

[12] Glyn G. Caldwell, M.D., Arizona Department of Health Services, written commun., 1985. These values apply to chemical toxicity.

Table 9.--Baseline values of trace metals and metalloids, alkalinity, dissolved oxygen, and pH in water

[Trace-metal and metalloid concentrations in micrograms per liter; alkalinity and dissolved-oxygen concentrations in milligrams per liter; pH in units; <, less than analytical detection limit; table modified from Smith and others (1987)]

Water-quality property or constituent	Number of stations	Station-mean concentration of percent baseline		
		25	50	75
pH	290	7.3	7.8	8.1
Dissolved oxygen	369	8.7	9.8	10.5
Alkalinity as $CaCO_3$	289	42.0	104.3	161.8
Arsenic	293	<1	1	3
Cadmium	285	<2	<2	<2
Chromium	161	9	10	10
Lead	292	3	4	6
Iron	293	36	63	157
Manganese	286	11	24	51
Mercury	199	0.2	0.2	0.3
Selenium	211	<1	<1	1
Zinc	288	12	15	21

Table 10.--Analytical results of selected trace metals and metalloids in bottom sediment from the lower Colorado River valley, 1986

[Ag, silver; As, arsenic; Ba, barium; B, boron; Cd, cadmium; Cr, chromium; Cu, copper; Hg, mercury; Mn, manganese; Mo, molybdenum; Ni, nickel; Pb, lead; Se, selenium; Th, thorium; U, uranium; V, vanadium; Zn, zinc; concentrations in micrograms per gram, dry weight, total, less than 63-micrometer fraction; <, less than analytical detection limit; see table 3 for site locations]

Site number	Date	Constituent																
		Ag	As	Ba	B	Cd	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Se	Th	V	U	Zn
1	8-13-86	<1	8.1	840	--	<2	56	18	0.03	580	<2	20	22	1.3	26.8	73	8.07	66
2	8-27-86	<1	6.6	530	.7	<2	41	18	.02	460	<2	18	24	.6	11.3	56	3.27	63
	8-27-86	<1	6.1	530	.6	<2	41	18	.02	470	<2	17	22	.6	11.9	56	3.21	63
	8-27-86	<1	7.6	530	.6	<2	43	19	.02	470	<2	17	20	<.1	11.5	56	3.27	65
3	8-12-86	<1	7.9	680	.9	<2	57	48	.05	480	<2	28	36	1.2	15.0	158	3.79	110
4	8-28-86	<1	12.0	740	1.0	<2	94	110	.07	1,200	<2	59	42	.7	23.0	186	4.45	150
5	8-12-86	<1	4.5	520	1.0	<2	35	29	.03	350	<2	17	19	3.3	9.0	36	3.96	52
6	8-28-86	<1	6.2	660	1.0	<2	43	16	.02	2,800	<2	16	17	.3	12.0	55	4.35	57
9	6-25-86	<1	5.4	640	2.1	<2	39	15	.02	1,500	<2	16	15	.5	8.0	54	3.78	53
8	7-02-86	<1	8.5	520	1.2	<2	31	20	.03	480	<2	16	20	3.6	4.0	47	4.85	62
10	6-26-86	<1	9.2	550	1.5	<2	40	25	.04	620	<2	20	23	2.3	7.0	59	3.65	74
11	6-24-86	<1	8.3	480	1.4	<2	34	21	.04	460	<2	16	16	7.1	5.0	43	5.59	49

Table 11.--Analytical results of selected organic compounds in bottom sediment from the lower Colorado River valley, 1986

[Concentrations in micrograms per kilogram, wet weight, total recoverable; <, less than analytical detection limit; see table 3 for site locations]

Site number	Date	Time	Perthane	Endosulfan	Aldrin	Chlordane	DDD	DDE	DDT	Dieldrin
1	8-13-86	1400	<1.00	<0.1	<0.1	1.0	0.1	0.1	0.1	<0.1
2	8-27-86	1730	<1.00	<0.1	<0.1	<1.0	<0.1	0.1	<0.1	<0.1
	8-27-86	1645	<1.00	<0.1	<0.1	<1.0	<0.1	0.1	<0.1	<0.1
	8-27-86	1600	<1.00	<0.1	<0.1	<1.0	<0.1	0.1	<0.1	<0.1
4	8-12-86	1630	<1.00	<0.1	<0.1	<1.0	1.2	5.2	<0.1	<0.1
6	8-28-86	1000	<1.00	<0.1	<0.1	<1.0	<0.1	3.9	<0.1	<0.1
9	6-25-86	1700	<1.00	<0.1	<0.1	<1.0	2.4	7.5	0.8	<0.1
8	7-02-86	1500	<1.00	<0.1	<0.1	<1.0	0.2	1.7	<0.1	<0.1
10	6-26-86	1200	<1.00	<0.1	<0.1	1.0	0.7	2.8	0.6	<0.1
11	6-24-86	1800	<1.00	<0.1	<0.1	<1.0	0.3	4.1	<0.1	<0.1

Site number	Date	Endrin	Heptachlor	Heptachlor epoxide	Lindane	Toxaphene	PCB	PCN	Methoxychlor	Mirex
1	8-13-86	<0.1	<0.1	<0.1	<0.1	<10	4	<1.0	<0.1	<0.1
2	8-27-86	<0.1	<0.1	<0.1	<0.1	<10	<1	<1.0	<0.1	<0.1
	8-27-86	<0.1	<0.1	<0.1	<0.1	<10	<1	<1.0	<0.1	<0.1
	8-27-86	<0.1	<0.1	<0.1	<0.1	<10	<1	<1.0	<0.1	<0.1
4	8-12-86	<0.1	<0.1	<0.1	<0.1	<10	<1	<1.0	<0.1	<0.1
6	8-28-86	<0.1	<0.1	<0.1	<0.1	<10	<1	<1.0	<0.1	<0.1
9	6-25-86	<0.1	<0.1	<0.1	<0.1	<10	<1	<1.0	<0.1	<0.1
8	7-02-86	<0.1	<0.1	<0.1	<0.1	<10	<1	<1.0	<0.1	<0.1
10	6-26-86	<0.1	<0.1	<0.1	<0.1	<10	<1	<1.0	<0.1	<0.1
11	6-24-86	<0.1	<0.1	<0.1	<0.1	<10	<1	<1.0	<0.1	<0.1

Table 12.--Statistical summaries of chemical determinations of sediment samples collected from the lower Colorado River valley, 1986

[Concentrations of metal and metalloid elements in micrograms per gram, dry weight, less than 63-micrometer fraction; concentration of organic compounds in micrograms per kilogram, wet weight; <, less than analytical detection limit]

Constituent	Number of samples	Minimum	Maximum	Median
Arsenic	10	4.5	12.0	7.9
Barium	10	480	840	550
Boron	9	0.6	2.1	1.0
Cadmium	10	<2	<2	<2
Chromium	10	31	94	40
Copper	10	15	110	20
Lead	10	15	42	20
Manganese	10	350	2,800	480
Mercury	10	0.02	0.07	0.03
Molybdenum	10	<2	<2	<2
Nickel	10	16	59	17
Selenium	10	0.3	7.1	1.2
Silver	10	<1	<1	<1
Thorium	10	4.0	26.8	9.0
Uranium	10	3.27	8.07	3.96
Vanadium	10	36	186	55
Zinc	10	49	150	62
Aldrin	8	<0.1	<0.1	<0.1
Chlordane	8	<1.0	<1.0	<1.0
DDD	8	<0.1	2.4	0.7
DDE	8	0.1	7.5	3.9
DDT	8	<0.1	0.8	0.1
Dieldrin	8	<0.1	<0.1	<0.1
Endosulfan	8	<0.1	<0.1	<0.1
Endrin	8	<0.1	<0.1	<0.1
Heptachlor	8	<0.1	<0.1	<0.1
Heptachlor epoxide	8	<0.1	<0.1	<0.1
Lindane	8	<0.1	<0.1	<0.1
Methoxychlor	8	<0.1	<0.1	<0.1
Mirex	8	<0.1	<0.1	<0.1
PCB	8	<1	4	<1
PCN	8	<1.0	<1.0	<1.0
Perthane	8	<1.0	<1.0	<1.0
Toxaphene	8	<10	<10	<10

Table 13.--Geochemical baselines for soils from the western United States

[Concentrations in microgram per gram, dry weight; detection ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed; <, less than; baseline, expected 95-percent range; ---, not determined. Modified from Shacklette and Boerngen (1984)]

Constituent	Detection ratio	Geometric mean	Geometric deviation	Baseline	Observed range
Arsenic	728:730	5.5	1.98	1.2-22	<0.1-97
Barium	778:778	580	1.72	200-1,700	70-5,000
Boron	506:778	23	1.99	5.8-91	<20-300
Cadmium	-------	-------	----	------------	-----------
Chromium	778:778	41	2.19	8.5-200	3-2,000
Copper	778:778	21	2.07	4.9-90	2-30
Lead	712:778	17	1.80	5.2-55	<10-700
Manganese	777:777	380	1.98	97-1,500	30-5,000
Mercury	729:733	0.046	2.33	0.0085-0.25	<0.01-4.6
Molybdenum	57:774	0.85	2.17	0.18-4.0	<3-7
Nickel	747:778	15	2.10	3.4-66	<5-700
Selenium	590:733	0.23	2.43	0.039-1.4	<0.1-4.3
Silver	-------	-------	----	-----------	-----------
Thorium	195:195	9.1	1.49	4.1-20.0	2.4-31.0
Uranium	224:224	2.5	1.45	1.2-5.3	0.68-7.9
Vanadium	778:778	70	1.95	18-270	70-500
Zinc	766:766	55	1.79	17-180	10-2,100

Table 14.--Baseline concentrations of selected trace metals and metalloids in fish tissue

[Concentrations in micrograms per gram, wet weight. Modified from Lowe and others (1985)]

Constituent	Collection period	Geometric mean	Minimum	85-percent baseline	Maximum
Lead	1978-79	0.19	0.10	0.32	6.73
	1980-81	0.17	0.10	0.25	1.94
Mercury	1978-79	0.11	0.01	0.18	1.10
	1980-81	0.11	0.01	0.18	0.77
Cadmium	1978-79	0.04	0.01	0.09	0.41
	1980-81	0.03	0.01	0.06	0.35
Arsenic	1978-79	0.16	0.04	0.23	2.08
	1980-81	0.14	0.05	0.22	1.69
Selenium	1978-79	0.46	0.09	0.70	3.65
	1980-81	0.47	0.09	0.71	2.47
Copper	1978-79	0.86	0.29	1.14	38.75
	1980-81	0.68	0.25	0.90	24.10
Zinc	1978-79	25.63	7.69	46.26	168.10
	1980-81	23.82	8.82	40.09	109.21

Table 15.--Analytical results of selected trace metals and metalloids in biota from the lower Colorado River valley, 1986

[Except for Yuma clapper rail samples, all analytical results are arithmetic mean values for each whole-body composite. No., number of specimens in composite; Wt, weight in grams; Lg, length in millimeters; Mstr, moisture content in percent; Al, aluminum; As, arsenic; B, boron; Ba, barium; Be, beryllium; Cd, cadmium; Cr, chromium; Cu, copper; Fe, iron; Mg, magnesium; Mn, manganese; Hg, mercury; Mo, molybdenum; Ni, nickel; Pb, lead; Se, selenium; Sr, strontium; Sn, tin; V, vanadium; Zn, zinc; C, carp; SN, spiny naiad; DCC, double-crested cormorant; CRL, Yuma clapper rail, liver; CR, Yuma clapper rail, whole body; concentrations in micrograms per gram, wet weight; <, less than analytical detection limit; see table 3 for site locations]

Site number	Date	Media	No.	Wt	Lg	Mstr	Al	As	B	Ba	Be	Cd	Cr	Cu	Fe	Mg
1	08-19-86	C	5	1281.8	442.8	79.08	16.0	0.048	5.0	1.30	<0.10	<0.10	<0.100	0.54	40.0	320.0
			5	973.0	413.0	80.65	21.0	<0.050	<5.0	1.40	<0.10	<0.10	<0.100	0.84	67.0	270.0
			5	731.4	379.8	77.02	12.0	<0.050	<5.0	1.40	<0.10	<0.10	<0.100	0.64	42.0	410.0
		SN	3	50.0	-----	96.50	6.0	<0.050	<5.0	1.30	<0.10	<0.10	6.000	0.64	27.0	190.0
			3	68.0	-----	95.55	6.4	<0.050	5.2	1.70	<0.10	<0.10	3.100	0.13	19.0	230.0
			3	64.0	-----	95.25	6.7	<0.050	<5.0	1.90	<0.10	<0.10	1.900	0.30	15.0	240.0
2	08-20-86	C	5	936.8	441.2	80.27	27.0	0.070	<5.0	1.90	<0.10	<0.10	<0.100	0.49	69.0	470.0
			5	842.0	428.0	81.03	18.0	<0.050	<5.0	1.50	<0.10	<0.10	<0.100	0.42	59.0	420.0
			5	710.4	411.0	84.64	27.0	<0.050	14.0	1.10	<0.10	<0.10	<0.100	0.39	55.0	330.0
			5	1386.2	481.8	85.42	24.0	<0.050	33.0	0.98	<0.10	<0.10	0.140	0.38	34.0	200.0
		DCC	5	2246.6	-----	68.31	8.8	<0.050	<5.0	0.23	<0.10	0.12	0.130	1.50	87.0	270.0
			5	1922.2	-----	68.86	1.3	<0.050	<5.0	0.38	<0.10	<0.10	<0.100	1.50	85.0	260.0
			5	1796.6	-----	66.92	3.5	<0.050	<5.0	0.27	<0.10	<0.10	<0.100	1.30	110.0	370.0
		SN	3	144.0	-----	90.64	1600.0	0.830	<5.0	17.00	<0.10	<0.10	4.100	0.60	860.0	1200.0
			3	122.0	-----	89.41	2500.0	0.770	<5.0	23.00	<0.10	<0.10	6.600	0.81	1300.0	1500.0
			3	104.0	-----	94.41	370.0	0.440	4.8	3.10	<0.10	<0.10	2.300	1.20	190.0	420.0
			3	126.0	-----	94.72	190.0	0.270	<5.0	3.50	<0.10	<0.10	1.600	0.25	94.0	370.0
3	08-13-86	C	5	1343.4	460.8	75.96	25.0	0.055	7.0	1.50	<0.10	<0.10	0.150	0.74	54.0	390.0
			5	1103.8	449.2	76.24	32.0	<0.050	9.8	1.60	<0.10	<0.10	0.190	1.00	66.0	300.0
			5	951.0	416.2	76.66	31.0	0.057	10.0	1.20	<0.10	<0.10	0.190	0.84	51.0	310.0
		SN	3	73.0	-----	96.02	8.0	<0.050	<5.0	1.30	<0.10	<0.10	1.100	0.26	12.0	190.0
			3	95.0	-----	95.84	6.6	<0.050	<5.0	1.00	<0.10	<0.10	0.300	0.21	17.0	190.0
			3	72.0	-----	95.62	32.0	0.057	<5.0	1.60	<0.10	<0.10	2.700	0.23	49.0	210.0
4	08-12-86	C	5	1410.4	477.0	73.30	32.0	0.140	15.0	1.30	<0.10	<0.10	<0.100	0.90	64.0	340.0
			5	1246.0	460.6	76.59	23.0	0.100	9.1	1.40	<0.10	<0.10	<0.100	0.64	70.0	390.0
			5	1111.4	448.2	79.16	7.0	<0.050	12.0	1.30	<0.10	<0.10	<0.100	0.83	54.0	300.0
		SN	3	133.0	-----	96.83	150.0	0.120	<5.0	3.00	<0.10	<0.10	1.000	0.24	160.0	89.0
			3	92.0	-----	96.36	230.0	0.130	<5.0	3.30	<0.10	<0.10	2.900	0.31	210.0	150.0
			3	98.0	-----	96.66	140.0	0.130	<5.0	2.90	<0.10	<0.10	2.900	0.28	130.0	100.0
5	07-31-86	C	5	2048.2	533.8	75.09	79.0	0.170	5.4	3.00	<0.10	<0.10	0.240	0.81	110.0	360.0
			5	1710.2	509.0	75.67	80.0	0.150	6.0	2.30	<0.10	<0.10	0.340	1.00	98.0	360.0
			5	1362.0	469.4	73.81	67.0	0.140	<5.0	2.40	<0.10	<0.10	0.240	0.83	89.0	450.0
		SN	3	50.0	-----	92.80	62.0	0.090	<5.0	2.60	<0.10	<0.10	1.800	0.72	58.0	460.0
			3	62.0	-----	94.03	69.0	0.096	<5.0	2.90	<0.10	<0.10	4.800	0.38	130.0	370.0
			3	56.0	-----	94.92	100.0	0.090	<5.0	3.10	<0.10	<0.10	16.000	0.49	170.0	350.0
6	07-30-86	C	5	579.2	346.8	73.39	87.0	0.110	<5.0	1.60	<0.10	<0.10	0.680	0.49	85.0	620.0
			5	556.2	346.4	76.06	120.0	0.092	<5.0	2.70	<0.10	<0.10	0.750	0.69	110.0	500.0
			5	494.4	333.2	75.34	87.0	0.100	<5.0	2.20	<0.10	<0.10	0.520	0.54	100.0	600.0
		SN	3	63.0	-----	92.15	900.0	0.550	<5.0	9.40	<0.10	<0.10	7.800	0.49	750.0	730.0
			3	81.0	-----	93.00	850.0	0.440	<5.0	8.70	<0.10	<0.10	6.200	0.45	720.0	660.0
			3	79.0	-----	87.47	2000.0	0.690	<5.0	23.00	<0.10	<0.10	31.000	1.30	1500.0	1300.0

Table 15.--Analytical results of selected trace metals and metalloids in biota from the lower Colorado River valley, 1986--Continued

Site number	Date	Media	No.	Wt	Lg	Mstr	Al	As	B	Ba	Be	Cd	Cr	Cu	Fe	Mg
8	06-11-86	C	5	915.6	423.0	74.85	32.0	0.057	<5.0	1.60	<0.10	<0.10	0.140	0.60	4 .0	580.0
			5	663.6	375.4	79.37	1000.0	<0.050	13.0	0.90	<0.10	<0.10	0.180	0.92	2 .0	370.0
			5	495.0	337.4	79.88	15.0	<0.050	<5.0	1.40	<0.10	<0.10	0.120	0.58	2 .0	440.0
		SN	3	95.0	-----	96.61	140.0	0.080	<5.0	3.40	<0.10	<0.10	1.600	0.26	11 .0	340.0
			3	84.0	-----	95.60	110.0	0.097	<5.0	3.80	<0.10	<0.10	1.300	0.33	7 .0	290.0
			3	110.0	-----	96.15	190.0	0.085	<5.0	3.50	<0.10	<0.10	1.500	0.35	13 .0	310.0
9	06-11-86	C	5	400.6	321.0	77.31	77.0	0.061	5.7	1.50	<0.10	<0.10	0.300	0.49	95.0	510.0
			5	325.8	301.2	76.95	53.0	<0.050	<5.0	1.60	<0.10	<0.10	0.290	0.64	80.0	590.0
			5	303.8	288.6	76.89	62.0	0.110	15.0	1.50	<0.10	<0.10	1.900	0.54	82.0	490.0
		DCC	5	2364.6	-----	65.32	1.8	<0.050	<5.0	0.23	<0.10	<0.10	0.098	1.40	84.0	310.0
			5	2121.6	-----	67.31	<1.0	<0.050	<5.0	0.19	<0.10	<0.10	<0.100	1.30	81.0	370.0
			5	1931.6	-----	66.73	1.1	<0.050	<5.0	0.27	<0.10	<0.10	<0.100	1.40	74.0	350.0
10	06-05-86	C	5	1169.8	456.4	78.50	51.0	0.110	5.3	1.90	<0.10	<0.10	0.120	0.73	47.0	450.0
			5	888.4	404.8	75.00	70.0	0.100	<5.0	2.10	<0.10	<0.10	0.160	0.74	70.0	480.0
			5	568.0	347.8	78.06	83.0	0.014	<5.0	2.40	<0.10	<0.10	<0.100	1.50	87.0	550.0
		SN	3	71.0	-----	94.11	310.0	0.450	<5.0	5.50	<0.10	<0.10	2.900	0.45	240.0	250.0
			3	80.0	-----	95.80	540.0	0.170	<5.0	3.40	<0.10	<0.10	3.300	0.33	400.0	400.0
			3	89.0	-----	94.81	660.0	0.180	<5.0	4.40	<0.10	<0.10	6.000	0.40	560.0	480.0
11	06-04-86	C	5	678.6	378.6	76.95	64.0	0.045	<5.0	1.80	<0.10	<0.10	0.530	0.59	7 .0	430.0
			5	532.0	338.0	76.03	110.0	0.061	<5.0	2.40	<0.10	<0.10	1.500	0.73	11 .0	530.0
			5	468.4	329.6	77.99	50.0	0.075	6.4	2.30	<0.10	<0.10	0.580	0.69	6 .0	500.0
		DCC	5	2144.0	-----	68.18	1.6	0.050	<5.0	0.19	<0.10	<0.10	0.280	1.50	7 .0	380.0
			5	1991.4	-----	69.36	1.4	0.087	<5.0	0.23	<0.10	<0.10	<0.100	2.70	7 .0	310.0
			5	1646.6	-----	68.23	1.8	<0.050	<5.0	0.20	<0.10	0.13	<0.100	1.40	9 .0	410.0
		SN	3	51.0	-----	92.96	840.0	0.270	4.9	6.10	<0.10	<0.10	3.500	0.43	61 .0	550.0
			3	48.0	-----	94.65	570.0	0.230	11.0	5.50	<0.10	<0.10	1.800	0.32	42 .0	380.0
			3	65.0	-----	93.58	830.0	0.330	8.7	7.40	0.14	<0.10	1.000	3.80	57 .0	490.0
	04-14-85	CRL	1	8.0	-----	71.93	1.4	<0.050	<5.0	0.14	0.14	0.14	0.740	4.90	570.0	180.0
	07-11-86	CR	1	119.1	-----	67.43	5.8	<0.050	<5.0	0.19	<0.10	<0.10	0.190	2.90	56.0	270.0
	07-28-86	CR	1	91.8	-----	71.88	7.0	<0.050	<5.0	<0.10	<0.10	<0.10	0.250	2.80	81.0	260.0

Table 15.--Analytical results of selected trace metals and metalloids in biota from the lower Colorado River valley, 1986--Continued

Site number	Date	Media	Mn	Hg	Mo	Ni	Pb	Se	Sr	Sn	V	Zn
1	08-19-86	C	1.4	0.052	<0.10	<0.100	<0.20	1.500	50.0	<1.0	<0.10	41.0
			1.0	0.054	<0.10	<0.100	<0.20	1.600	42.0	1.2	<0.10	67.0
			1.4	0.050	<0.10	<0.100	<0.20	1.400	33.0	1.6	<0.10	85.0
		SN	1.8	<0.050	<0.10	2.300	<0.20	<0.050	8.5	<1.0	<0.10	1.7
			1.6	<0.050	<0.10	1.400	<0.20	0.150	11.0	<1.0	<0.10	1.1
			1.8	<0.050	<0.10	1.200	<0.20	<0.050	11.0	<1.0	<0.10	2.5
2	08-20-86	C	1.6	<0.050	<0.10	0.950	<0.20	2.000	81.0	1.0	<0.10	59.0
			1.4	<0.050	<0.10	<0.100	<0.20	1.700	82.0	<1.0	<0.10	59.0
			1.3	<0.050	<0.10	<0.100	<0.20	1.200	69.0	<1.0	<0.10	57.0
			<1.0	<0.050	<0.10	<0.100	<0.20	1.300	30.0	<1.0	<0.10	41.0
		DCC	<1.0	2.000	<0.10	<0.100	0.25	1.900	23.0	<1.0	<0.10	22.0
			<1.0	1.100	<0.10	<0.100	<0.20	1.300	16.0	1.4	<0.10	24.0
			<1.0	0.850	<0.10	<0.100	0.68	1.300	21.0	1.4	<0.10	27.0
		SN	29.0	<0.050	0.13	1.800	0.66	0.094	58.0	21.0	1.40	3.5
			45.0	<0.050	0.16	2.300	1.10	<0.050	76.0	30.0	1.90	4.7
			6.2	<0.050	0.15	1.000	<0.20	<0.050	27.0	2.7	0.18	8.1
			7.3	<0.050	<0.10	0.740	<0.20	<0.050	21.0	2.0	0.25	1.1
3	08-13-86	C	1.8	0.051	<0.10	<0.100	0.20	1.200	48.0	<1.0	<0.10	77.0
			2.1	0.046	<0.10	0.260	<0.20	1.300	28.0	1.3	<0.10	67.0
			2.0	0.056	0.16	<0.100	<0.20	1.600	29.0	1.0	<0.10	68.0
		SN	3.6	<0.050	<0.10	0.660	<0.20	0.078	6.4	<1.0	<0.10	4.0
			3.5	<0.050	<0.10	0.210	<0.20	<0.050	7.0	<1.0	<0.10	1.0
			4.2	<0.050	<0.10	1.300	<0.20	<0.050	7.8	1.2	<0.10	1.0
4	08-12-86	C	3.8	0.075	<0.10	0.130	<0.20	1.200	40.0	1.1	<0.10	53.0
			3.3	0.082	<0.10	0.130	<0.20	1.200	48.0	1.2	<0.10	63.0
			3.0	0.073	<0.10	<0.100	0.26	1.100	67.0	1.1	0.14	39.0
		SN	39.0	<0.050	<0.10	0.530	<0.20	0.069	6.9	3.4	0.22	2.6
			51.0	<0.050	<0.10	1.800	<0.20	0.073	7.5	4.4	0.29	2.7
			35.0	<0.050	<0.10	1.700	<0.20	0.059	6.9	3.1	1.90	2.5
5	07-13-86	C	1.8	0.065	<0.10	0.160	<0.20	1.100	24.0	1.1	0.18	75.0
			3.1	0.090	<0.10	0.190	<0.20	1.100	29.0	1.9	0.21	63.0
			2.4	0.045	<0.10	0.150	<0.20	1.100	55.0	1.4	<0.10	86.0
		SN	7.9	<0.050	<0.10	1.200	<0.20	0.160	17.0	1.1	<0.10	1.1
			9.1	<0.050	1.70	5.000	0.25	0.130	16.0	2.5	0.16	2.7
			9.4	<0.050	0.21	7.200	<0.20	0.110	16.0	3.3	0.29	2.5
6	07-30-86	C	19.0	<0.050	<0.10	0.250	<0.20	0.650	72.0	1.2	<0.10	60.0
			19.0	<0.050	<0.10	0.350	0.33	0.860	44.0	1.9	0.25	59.0
			23.0	<0.050	<0.10	0.460	<0.20	0.620	68.0	1.5	<0.10	61.0
		SN	94.0	<0.050	0.13	2.700	0.43	0.120	24.0	20.0	1.00	3.3
			69.0	<0.050	0.15	2.600	0.30	0.049	17.0	21.0	1.10	3.4
			110.0	0.083	0.33	13.000	0.86	0.066	31.0	43.0	2.00	3.1

Table 15.--Analytical results of selected trace metals and metalloids in biota from the lower Colorado River valley, 1986--Continued

Site number	Date	Media	Mn	Hg	Mo	Ni	Pb	Se	Sr	Sn	V	Zn
8	06-11-86	C	1.9	0.038	<0.10	<0.100	<0.20	4.000	62.0	<1.0	0.19	63.0
			1.2	<0.050	0.73	<0.100	<0.20	3.000	35.0	<1.0	<0.10	60.0
			1.3	<0.050	<0.10	0.100	<0.20	1.600	48.0	<1.0	<0.10	65.0
		SN	5.8	<0.050	<0.10	0.760	<0.20	0.130	17.0	2.2	0.26	2.2
			7.5	<0.050	0.14	0.690	<0.20	0.063	18.0	1.9	0.23	1.9
			7.2	<0.050	0.16	0.690	<0.20	0.110	16.0	2.5	0.23	2.1
9	06-11-86	C	11.0	0.056	<0.10	0.160	<0.20	0.810	55.0	1.6	0.14	56.0
			11.0	0.065	0.14	0.170	<0.20	0.830	61.0	1.2	<0.10	87.0
			16.0	0.047	<0.10	0.580	<0.20	0.710	56.0	1.4	0.16	68.0
		DCC	<1.0	0.420	<0.10	<0.100	0.27	2.200	11.0	1.5	<0.10	26.0
			<1.0	0.490	<0.10	<0.100	0.21	1.500	21.0	1.4	<0.10	27.0
			<1.0	0.520	0.16	<0.100	2.70	1.200	21.0	1.3	<0.10	25.0
10	06-05-86	C	3.4	<0.050	<0.10	0.120	<0.20	1.400	45.0	<1.0	0.20	45.0
			3.0	<0.050	<0.10	0.110	<0.20	1.300	50.0	1.2	0.16	56.0
			4.6	0.047	0.24	0.130	<0.20	1.400	51.0	1.4	0.24	59.0
		SN	23.0	<0.050	0.19	1.300	<0.20	0.056	8.4	6.5	0.84	4.1
			14.0	<0.050	<0.10	1.100	<0.20	<0.050	10.0	11.0	0.48	3.6
			18.0	<0.050	0.16	2.200	<0.20	<0.050	13.0	15.0	0.74	3.8
11	06-04-86	C	2.2	<0.050	<0.10	0.210	<0.20	3.400	45.0	1.2	0.15	54.0
			3.6	<0.050	0.12	1.700	<0.20	1.600	55.0	1.8	0.14	60.0
			3.0	<0.050	<0.10	0.230	<0.20	2.400	44.0	1.2	0.12	69.0
		DCC	<1.0	0.380	0.11	<0.100	<0.20	1.300	20.0	1.4	<0.10	25.0
			<1.0	0.580	<0.10	<0.100	3.50	1.800	13.0	1.5	<0.10	23.0
			<1.0	0.410	<0.10	<0.100	0.96	1.500	22.0	1.4	<0.10	27.0
		SN	15.0	<0.050	0.12	1.600	0.23	0.180	20.0	15.0	1.10	1.9
			12.0	<0.050	0.14	0.850	0.32	0.150	13.0	11.0	0.95	1.1
			15.0	<0.050	0.49	0.620	3.00	0.210	17.0	15.0	1.40	1.4
	04-14-85	CRL	1.8	0.720	0.14	0.250	0.27	7.200	0.1	87.0	0.14	21.0
	07-11-86	CR	<1.0	0.370	<0.10	0.096	<0.20	1.100	12.0	9.1	<0.10	21.0
	07-28-86	CR	<1.0	0.350	<0.10	0.190	<0.20	1.500	18.0	14.0	<0.10	26.0

Table 16.--Analytical results of selected organic compounds in biota from the lower Colorado River valley, 1986

[Analytical results are arithmetic mean values for each whole-body composite. Concentrations in micrograms per gram, wet weight, whole-body composite; DCC; double-crested cormorant; C, carp, SN, spiny naiad; <, less than analytical detection limit; dashes indicate no data; see table 3 for site locations]

Site number	Date	Species	Number of specimens	Weight, in grams	Length, in millimeters	p,p'-DDE	PCB1254	PCB1260	Lipid content
1	08-19-86	SN	3	64.0	-----	<0.01	<0.1	<0.1	0.08
1	08-19-86	SN	3	68.0	-----	<0.01	<0.1	<0.1	0.05
1	08-19-86	SN	3	50.0	-----	<0.01	<0.1	<0.1	0.04
1	08-19-86	C	5	731.4	379.8	0.0520	<0.1	<0.1	2.72
1	08-19-86	C	5	973.0	413.0	0.0820	<0.1	<0.1	2.25
1	08-19-86	C	5	1,281.8	442.8	<0.01	<0.1	<0.1	2.13
2	08-20-86	SN	3	126.0	-----	<0.01	<0.1	<0.1	0.06
2	08-20-86	SN	3	104.0	-----	<0.01	<0.1	<0.1	0.03
2	08-20-86	SN	3	122.0	-----	<0.01	<0.1	<0.1	0.02
2	08-20-86	SN	3	144.0	-----	<0.01	<0.1	<0.1	0.04
2	08-20-86	C	5	1,386.2	481.8	<0.01	<0.1	<0.1	1.22
2	08-20-86	C	5	710.4	411.0	<0.01	<0.1	<0.1	1.11
2	08-20-86	C	5	842.0	428.0	<0.01	<0.1	<0.1	0.35
2	08-20-86	C	5	936.8	441.2	<0.01	<0.1	<0.1	0.70
2	08-20-86	DDC	5	1,796.6	-----	2.100	<0.1	1.000	4.81
2	08-20-86	DDC	5	1,922.2	-----	6.6000	<0.1	0.560	5.29
2	08-20-86	DDC	5	2,246.6	-----	4.000	<0.1	0.770	4.82
3	08-13-86	SN	3	72.0	-----	<0.01	<0.1	<0.1	0.02
3	08-13-86	SN	3	95.0	-----	<0.01	<0.1	<0.1	0.02
3	08-13-86	SN	3	73.0	-----	<0.01	<0.1	<0.1	0.07
3	08-13-86	C	5	951.0	416.2	<0.01	<0.1	<0.1	3.16
3	08-13-86	C	5	1,103.8	449.2	0.0820	<0.1	<0.1	4.24
3	08-13-86	C	5	1,343.4	460.8	0.0390	<0.1	<0.1	3.11
4	08-12-86	SN	3	98.0	-----	<0.01	<0.1	<0.1	0.06
4	08-12-86	SN	3	92.0	-----	<0.01	<0.1	<0.1	0.06
4	08-12-86	SN	3	133.0	-----	<0.01	<0.1	<0.1	0.03
4	08-12-86	C	5	1,111.4	448.2	0.0840	<0.1	<0.1	4.34
4	08-12-86	C	5	1,246.0	460.6	0.1500	<0.1	<0.1	7.26
4	08-12-86	C	5	1,410.4	477.0	0.1200	<0.1	<0.1	8.83
5	07-31-86	SN	3	56.0	-----	<0.01	<0.1	<0.1	0.19
5	07-31-86	SN	3	62.0	-----	<0.01	<0.1	<0.1	0.14
5	07-31-86	SN	3	50.0	-----	<0.01	<0.1	<0.1	0.18
5	07-31-86	C	5	1,362.0	469.4	0.0900	<0.1	<0.1	8.45
5	07-31-86	C	5	1,710.2	509.0	0.1000	<0.1	<0.1	9.26
5	07-31-86	C	5	2,048.2	533.8	0.1400	<0.1	<0.1	7.95
6	07-30-86	SN	3	79.0	-----	<0.01	<0.1	<0.1	0.01
6	07-30-86	SN	3	81.0	-----	<0.01	<0.1	<0.1	0.12
6	07-30-86	SN	3	63.0	-----	<0.01	<0.1	<0.1	0.07
6	07-30-86	C	5	494.4	333.2	0.1400	<0.1	<0.1	2.58
6	07-30-86	C	5	556.2	346.4	0.1200	<0.1	<0.1	2.45
6	07-30-86	C	5	579.2	346.8	0.0650	<0.1	<0.1	3.23
8	06-11-86	SN	3	110.0	-----	0.0420	<0.1	<0.1	0.07
8	06-11-86	SN	3	84.0	-----	0.0420	<0.1	<0.1	0.06

Table 16.--Analytical results of selected organic constituents in biota from the lower Colorado River valley--Continued

Site number	Date	Species	Number of specimens	Weight, in grams	Length, in millimeters	p,p'-DDE	PCB1254	PCB1260	Lipid content
8	06-11-86	C	5	495.0	337.4	0.0380	<0.1	<0.1	1.65
8	06-11-86	C	5	663.6	375.4	0.0730	<0.1	<0.1	2.04
8	06-11-86	C	5	915.6	423.0	0.0910	<0.1	<0.1	3.25
9	06-11-86	C	5	303.8	288.6	0.1300	<0.1	<0.1	1.62
9	06-11-86	C	5	325.8	301.2	0.3800	<0.1	<0.1	1.92
9	06-11-86	C	5	400.6	321.0	0.2100	<0.1	<0.1	0.74
8	06-11-86	DCC	5	1,931.6	-----	3.9000	0.17	<0.1	5.58
8	06-11-86	DCC	5	2,121.6	-----	3.9000	0.410	<0.1	6.59
8	06-11-86	DCC	5	2,364.6	-----	4.3000	0.500	<0.1	10.26
10	06-05-86	SN	3	89.0	-----	<0.01	<0.1	<0.1	0.10
10	06-05-86	SN	3	80.0	-----	<0.01	<0.1	<0.1	0.05
10	06-05-86	SN	3	71.0	-----	0.0320	<0.1	<0.1	0.00
10	06-05-86	C	5	568.0	347.8	0.0770	<0.1	<0.1	1.99
10	06-05-86	C	5	888.4	404.8	0.1100	<0.1	<0.1	4.14
10	06-05-86	C	5	1,169.8	456.4	0.1400	<0.1	<0.1	3.03
11	06-04-86	SN	3	65.0	-----	<0.01	<0.1	<0.1	0.01
11	06-04-86	SN	3	48.0	-----	0.0300	<0.1	<0.1	0.05
11	06-04-86	SN	3	51.0	-----	0.0270	<0.1	<0.1	0.05
11	06-04-86	C	5	468.4	329.6	0.0510	<0.1	<0.1	2.67
11	06-04-86	C	5	532.0	338.0	0.0540	<0.1	<0.1	4.33
11	06-04-86	C	5	678.6	378.6	0.0460	<0.1	<0.1	3.46
11	06-04-86	DCC	5	1,646.6	-----	3.8000	<0.1	<0.1	4.60
11	06-04-86	DCC	5	1,991.4	-----	5.1000	0.180	<0.1	5.47
11	06-04-86	DCC	5	2,144.0	-----	6.6000	<0.1	<0.1	7.06

Table 17.--Statistical summaries of chemical determinations of biota samples from the lower Colorado River valley, 1986

[Analytical results are arithmetic mean values for each whole-body composite sample. Concentrations in micrograms per gram, wet weight; weight in grams; length in millimeters; moisture content in percent; <, less than analytical detection limit]

Measurement/ Constituent	Number of samples	Minimum	Maximum	Arithmetic mean
		Carp		
Weight	31	303.8	2,048.2	909.3
Length	31	288.6	533.8	404.8
Moisture content	31	73.30	85.42	77.52
Aluminum	31	7.0	1,000.0	80.1
Arsenic	31	<0.050	.170	.079
Barium	31	<0.10	3.00	1.72
Beryllium	31	<0.10	.100	.098
Boron	31	4.8	33.0	7.9
Cadmium	31	<0.10	.10	.10
Chromium	31	<0.100	1.900	.330
Copper	31	.38	1.50	.70
Iron	31	26.0	110.0	68.5
Lead	31	<0.20	3.50	.99
Magnesium	31	200.0	620.0	427.7
Manganese	31	1.0	23.0	5.0
Mercury	31	<0.050	.090	.051
Molybdenum	31	<0.10	.73	.13
Nickel	31	<0.100	1.700	.246
Selenium	31	.62	4.00	1.49
Strontium	31	24.0	82.0	49.9
Tin	31	<1.0	1.9	1.2
Vanadium	31	<0.10	.25	.13
Zinc	31	39.0	87.0	62.0
p,p'-DDE	31	.01	.38	.09
PCB 1254	31	<0.10	.10	.10
PCB 1260	31	<0.10	.10	.10
Lipid content	31	.35	9.26	3.43

Table 17.--Statistical summaries of chemical determinations of biota samples from the lower Colorado River valley, 1986.--Continued

Measurement/ Constituent	Number of samples	Minimum	Maximum	Arithmetic mean
		Spiny Naiad		
Weight	27	48.0	144.0	82.3
Moisture content	27	87.47	96.83	94.38
Aluminum	27	6.0	2,500.0	483.2
Arsenic	27	<0.050	.830	.236
Barium	27	1.00	23.00	5.70
Beryllium	27	<0.10	.14	.10
Boron	27	4.7	11.0	5.2
Cadmium	27	<0.10	.10	.10
Chromium	27	.30	31.00	4.62
Copper	27	.13	3.80	.55
Iron	27	12.0	1,500.0	345.8
Lead	27	<0.20	3.00	.40
Magnesium	27	89.0	1,500.0	445.1
Manganese	27	1.6	110.0	23.7
Mercury	27	<0.050	.083	.046
Molybdenum	27	<0.10	1.70	.20
Nickel	27	.21	13.00	2.13
Selenium	27	<0.050	.210	.090
Strontium	27	6.4	76.0	17.8
Tin	27	<1.0	43.0	8.9
Vanadium	27	<0.10	2.00	.64
Zinc	27	<1.0	4.7	2.5
p,p'-DDE	26	.01	.04	.02
PCB 1254	26	<0.10	.10	.10
PCB 1260	26	<0.10	.10	.10
Lipid content	26	<0.00	.19	.06

Table 17.--Statistical summaries of chemical determinations of biota samples from the lower Colorado River valley, 1986.--Continued

Measurement/ Constituent	Number of samples	Minimum	Maximum	Arithmetic mean
Double-Crested Cormorant				
Weight	9	1,646.6	2.364.6	2,018.4
Moisture content	9	65.32	69.36	67.69
Aluminum	9	<1.0	8.8	2.5
Arsenic	9	<0.050	.087	.050
Barium	9	.19	.38	.24
Beryllium	9	<0.10	.10	.10
Boron	9	4.7	4.9	4.8
Cadmium	9	<0.10	.13	.10
Chromium	9	<0.100	.280	.121
Copper	9	1.30	2.70	1.56
Iron	9	74.0	110.0	85.2
Lead	9	<0.20	3.50	1.00
Magnesium	9	260.0	410.0	336.7
Manganese	9	<1.0	1.0	1.0
Mercury	9	.38	2.00	.75
Molybdenum	9	<0.10	.16	.10
Nickel	9	<0.100	.099	.097
Selenium	9	1.20	2.20	1.56
Tin	9	1.30	1.50	1.42
Strontium	9	11.0	23.0	18.7
Vanadium	9	<0.10	.10	.10
Zinc	9	22.0	27.0	25.1
p,p'-DDE	9	2.10	6.60	4.48
PCB 1254	9	<0.10	.50	.19
PCB 1260	9	<0.10	1.00	.32
Lipid content	9	4.60	10.26	6.05

Table 18.--Concentrations of selected trace metals, metalloids, and organic compounds in whole-body carp composite samples from the lower Colorado River collected for the National Contaminant Biomonitoring Program, 1978-80, and the U.S. Department of Interior Irrigation Drainage Study, 1986-87

[Concentrations in micrograms per grams, wet weight; National Contaminant Biomonitoring Program data from Lowe and others (1985) and Schmitt and others (1985); NCBP, National Contaminant Biomonitoring Program; DOI, U.S. Department of Interior]

Constituent	Year	Site				
		NCBP 115 (Pilot Knob)	DOI 11	NCBP 36 (Imperial Dam)	DOI 4	NCBP 91 (Lake Havasu)
Lead	1978	0.1		0.1		0.35,0.64
	1980			0.1		0.21,0.26
	1984			0.1,0.1		0.10,0.20
	1986		<0.2,<0.2,<0.2		<0.2,<0.2,0.26	
Cadmium	1978	0.01		0.01,0.02		0.02
	1980			0.01		0.02
	1984			0,0		0,0
	1986		<0.1,<0.1,<0.1		<0.10,<0.10,<0.10	
Mercury	1978	0.01		0.01,0.02		0.03
	1980			0.01		0.03,0.06
	1984			0,0		0,0
	1986		<0.05,<0.05,<0.05		0.073,0.075,0.082	
Arsenic	1978	0.18		0.09,0.12		0.06,0.13
	1980			0.05,0.08		0.11,0.13
	1984			0,0		0.1,0.1
	1986		0.07,0.06,0.04		<0.05,0.10,0.14	
Selenium	1978	1.75		1.96,2.21		2.31,3.65
	1980			1.49,1.79		1.27,2.05
	1984			1.2,1.2		1.0,0.7
	1986		3.4,2.4,1.6		1.2,1.2,1.1	
Copper	1978	0.9		1.2		1.3,1.5
	1980			0.6,0.7		1.2,1.5
	1984			0.5,0.3		0.5,0.5
	1986		0.73,0.69,0.59		0.90,0.83,0.64	
Zinc	1978	47.9		63.6,101.6		85.2,110.4
	1980			42.4,47.4		77.8,71.3
	1984			30.4,26.9		35.0,26.7
	1986		69.0,60.0,54.0		63.0,53.0,39.0	
p,p'-DDE	1980			0.06,0.04		0.10,0.09
	1984			0.10,0.06		0.19,0.17
	1986		0.05,0.05,0.05		0.15,0.12,0.08	