U.S. Fish and Wildlife Service

Region 2

Environmental Contaminants Program

PRE-RECONNAISSANCE INVESTIGATION OF WATER QUALITY, BOTTOM SEDIMENT, AND BIOTA ASSOCIATED WITH IRRIGATION DRAINAGE IN YUMA VALLEY, ARIZONA

by

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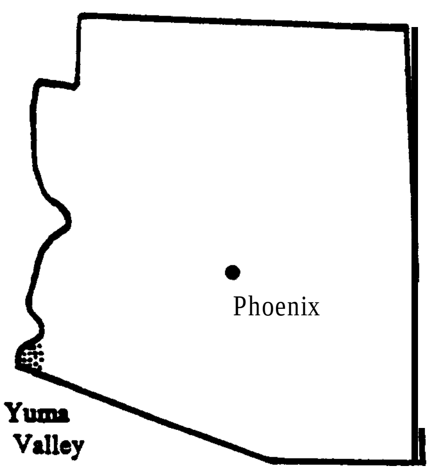

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ABSTRACT

Water, sediment, and aquatic plants were collected in 1989 from five irrigation drainage locations within the Yuma Valley, Arizona. Fish were collected from three irrigation drainage locations. Sediment and fish samples were analyzed for organochlorine compounds, including dicofol and total PCBs. All abiotic and biotic samples were analyzed for trace elements.

Irrigation drainage waters in the Yuma Valley may have the potential to cause significant harmful effects on fish and wildlife resources. Toxaphene, DDE, dieldrin, and chlordane concentrations remained stable from 1976 to 1989 at levels below those known to affect fish and wildlife; however, several trace elements including aluminum, arsenic, barium, beryllium, boron, chromium, copper, iron, manganese, vanadium, and zinc appear to be increasing in plant tissues and/or sediments. Selenium was present in Yuma Valley irrigation drainage waters at concentrations that can be bioconcentrated in the food chain. Selenium concentrations in aquatic vegetation exceeded the Department of the Interior (DOI) environmental criterion for algae. Arsenic, copper, and selenium were present at potentially hazardous levels in fish (>NCBP 85 percentile) and arsenic and copper appear to be temporally accumulating. The maximum concentrations of mercury in striped mullet was above the level reported to affect fish-eating birds. Therefore, we recommend that the Yuma Valley irrigation drainage area be elevated to a full reconnaissance-level study by the DO1 Irrigation Drainage Task Group.

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INTRODUCTION

The objective of the pre-reconnaissance study was to determine if irrigation drainage waters from Department of the Interior (DOI) irrigation delivery systems have the clear potential to cause significant harmful effects on fish and wildlife resources. This effort focused on irrigation and drainage facilities constructed or managed by DO1 and on migratory bird or endangered species habitats that receive water from DOI-funded projects.

An additional objective of this study was to determine if there is sufficient justification to elevate this study to a full reconnaissance-level investigation by the DO1 Irrigation Drainage Task Group. The DO1 Task Group's evaluation criteria is presented in Appendix A.

DESCRIPTION OF THE STUDY AREA

The study area (Figure 1) includes four irrigation projects, i.e. Yuma Valley, Gila, Quechan, and Cocopah (64,474 irrigable hectares) in Southwest Arizona. The Yuma Valley includes 18,709 irrigated hectares adjacent to the Colorado River downstream of the Imperial Dam. The Gila Project is located on the Gila River above its confluence with the Colorado River. It is divided into two divisions, the Wellton-Mohawk Division (26,325 hectares) and the Yuma Mesa Division (16,200 hectares). The Quechan Project (2,835 hectares) and the Cocopah Project (405 hectares) are located adjacent to the Colorado River north and south of Yuma, respectively.

The entire study area is chemically influenced by frequent applications of agricultural chemicals primarily for field and vegetable crops and citrus. Principal crops harvested within the combined irrigation projects include upland cotton, alfalfa, wheat, vegetables (western lettuce, cauliflower, and broccoli) and citrus (lemon, orange, grapefruit, and tangerine). Although use of agricultural insecticides remains high, agricultural practices now utilize nonpersistent, acutely toxic organophosphate and carbamate pesticides in place of the former traditional chlorinated hydrocarbon pesticides.

Agricultural development, primarily the irrigation system, has caused changes in surface water distribution, ground water flow patterns, and the saturated thickness of the aquifer. Agricultural practices and the soils within the Yuma Valley, which are generally deep, alkaline, fine to moderately fine in texture and possess a high water table, require a ground water drainage system. Ground water is collected in subsurface drains and delivered either back into the irrigation system or into the Gila and Colorado Rivers.

The Colorado and Gila Rivers provide important wetland habitat for migratory birds, especially waterfowl and shorebirds. The area is particularly valuable for both small and nongame resources. Two federal wildlife facilities (Imperial and Cibola National Wildlife Refuges) and one state wildlife management area (Mittry Lake) are located north of the study area. All three wildlife areas provide significant public warmwater sportfishery resources and are also managed to provide important wintering areas for migratory waterfowl. Important harvestable species include mourning dove (*Zenaida macroura),* white-winged dove (Z. asiatica), Gambel's quail (*Callipepla gaznbelii),* and various waterfowl. Species of special importance and interest include four federally endangered avian species: Yuma clapper rail (*Rallus longirostris yumanensis),* bald eagle *(Haliaeetus leucocephalus),* peregrine falcon (*Falco peregrinus),* and brown pelican *(Pelecanus occidentalis).*

HISTORICAL ACCOUNTS OF WATER QUALITY AND ENVIRONMENTAL CONTAMINANT DATA

A number of hydrologic and environmental investigations have been conducted within the lower Colorado and Gila River watersheds. Included among these are water quality surveillance conducted at selected stream-gaging stations (U.S. Geological Survey 1960-1992), Investigation of Pesticide Pollution in the Lower Colorado River Basin (U.S. Environmental Protection Agency 1973), National Contaminant Biomonitoring Program (U.S. Fish and Wildlife Service 1976-1984), Organochlorine Contaminant Investigation of the Lower Gila River (Kepner 1987), Reconnaissance Investigation of Water Quality, Bottom Sediment and Biota Associated with Irrigation Drainage in the Lower Colorado River Valley (Radtke et al. 1988), and Ecology of the Lower Colorado River from Davis Dam to the Mexico-United States International Boundary (Ohmart et al. 1988).

Previous monitoring has identified elevated selenium levels in fish from the lower Colorado River (Schmitt and Brumbaugh 1990). Recent information derived from DO1 Irrigation Drainage Studies has further clarified that observation (Radtke et al. 1988). A variety of sample matrices, i.e. water, sediment, double-crested cormorant *(Phalacrocorax auritus),* spiny naiad *(Najas marina),* and carp *(Cyprinus carpio), were* sampled for trace elements, organochlorine pesticides, and radionuclides throughout a 378-km reach of the lower Colorado River from Davis Dam to Imperial Dam in 1986. Of all parameters examined, selenium was the only contaminant present in elevated concentrations (Radtke et al. 1988). This was particularly evident for fish collected near Imperial Dam. Selenium values in carp were detected as high as 3.4 $\mu g/g$, wet weight. Several stations had mean whole body fish selenium values greater than 2.0 $\mu g/g$, wet weight; concentrations >2.0 $\mu g/g$ may cause reproductive impairment and lack of recruitment in fishes (Baumann and May 1984).

Mean selenium levels determined for liver tissues (25.3 $\mu g/g$, dry weight) from Yuma clapper rails collected on the lower Colorado River at Mittry Lake and Crystal Beach during 1986-87 (Kepner et al. in prep.) were similar to liver selenium concentrations in mallards (20.2 and 24.3 $\mu g/g$, dry weight) and teal (23.9 and 20.0 $\mu g/g$) reported at Kesterson National Wildlife Refuge in California, an area where massive avian reproductive failure resulted from selenium toxicity associated with agricultural irrigation (Ohlendorf et al. 1989).

Whole body fish (predator and bottom feeder) from the Colorado River below Yuma have been monitored for contaminant residues under the National Contaminant Biomonitoring Program (NCBP) since 1976. Detections have consistently included three polychlorinated biphenyls (PCBs), 15 organochlorine insecticides, and seven trace elements. Since 1976, the national geometric mean concentrations of PCBs, other organochlorines, and selenium, arsenic, cadmium, and lead have declined (Schmitt et al. 1990, Schmitt and Brumbaugh 1990). However, among the 25 environmental contaminants previously detected in fish tissues near Yuma, eight were elevated above national baseline values during one or more years for freshwater fish. They include four organochlorine pesticides (toxaphene, DDE, DDD, and DDT; Table 1) and four trace elements (selenium, arsenic, lead, and copper; Table 2).

METHODS AND MATERIALS

Water, sediment, and aquatic plants were sampled from the Wellton-Mohawk Channel, Drainage Pump Outlet Channel (DPOC), Quechan Indian Main Drain (QIMD), Colorado River at Pilot Knob (Pilot Knob), and Yuma Main Drain at San Luis (YMD) locations within the Yuma Valley in July and August 1989 (Table 3, Figure 1). Fish samples were collected from three localities, Wellton-Mohawk, Pilot Knob, and YMD (Table 3). Water was filtered into 1,000 ml jars. Three sediment samples of similar texture and particle-size were collected and composited into a single sample at each site. Plants were collected and composited **into** a single sample at each site. Fish were collected and arranged in five-specimen whole body composites of near equal length and weight for each species. All sediment, plant, and fish samples were weighed and measured following collection and frozen. Water, sediment, plant, and fish samples were later submitted for organochlorine and trace element through Patuxent Analytical Control Facility (PACF) to their designated contract laboratories. Organochlorine analyses were conducted by the Mississippi State Chemical Laboratory, Mississippi State, Mississippi. Trace element analyses were conducted by Environmental Trace Substances Research Center, Columbia, Missouri. The PACF was responsible for assessing quality assurance and control (QA/QC) procedures for both contract labs and QA/QC met PACF standards.

Sediment and fish samples were analyzed for organochlorine pesticides, including dicofol and total PCBs (Table 3). Organochlorine pesticides and PCBs were analyzed by electron capture gas chromatography. The lower limit of detection was 0.01 $\mu g/g$ (wet weight) for all organochlorine pesticides and 0.05 $\mu g/g$ (wet weight) for toxaphene and total PCBs. Percent moisture content was determined for all tissue samples. Organochlorine results are reported in $\mu g/g$ wet weight.

All water, sediment, plant, and fish samples were also analyzed for trace elements (Table 3). Arsenic and selenium were analyzed by atomic absorption hydride and mercury was analyzed by cold vapor reduction. All other elements were analyzed by inductively coupled plasma atomic emission spectroscopy. The lower limit of detection for arsenic was 0.0003 $\mu g/ml$ in water, 0.1 $\mu g/g$ (dry weight) in sediment and plants, and 0.2 $\mu g/g$ (dry weight) in fish. Minimum limits of detection for selenium in water was 0.0004 $\mu g/ml$ and in sediment, plants, and fish the lower limit of detection was 0.2 $\mu g/g$ (dry weight). The lower limits of detection for mercury in water was 0.0003 $\mu g/ml$. Mercury was quantified in sediment at 0.01 $\mu g/g$, dry weight, and in plants and fish at 0.005 $\mu g/g$ (dry weight). Results reported for plant, sediment, and fish are in $\mu g/g$, dry weight (Tables 7,8). For fish, results are reported on a dry weight (Table 7) and wet weight (Table 9) basis to facilitate comparison of our data with results of other studies.

Water and sediment samples from Wellton-Mohawk, DPOC, and YMD were split; one-half of the samples were analyzed for organochlorines and/or trace elements and the remaining one-half was used in bioassay tests by the Cooperative Fish and Wildlife Research Unit at the University of Minnesota, St. Paul (Table 3). Sediment was utilized for chironomid bioassay and water for cladocera *(Daphnia magna)* and juvenile fathead minnow *(Pimephales promelas)* acute bioassay tests.

Water, sediment, and fish tissues were simultaneously sampled at the YMD site (Table 3) as part of the U.S. Environmental Protection Agency (EPA), Region IX Priority Pollutant Analysis Program. The Priority Pollutant Program provided an additional assessment of inorganics, pesticides, semi-volatile and volatile organic compounds (Table 4) in water, sediment, and fish tissue matrices. Water was filtered and preserved with 5 ml of 1:1 nitric acid:deionized water for dissolved trace element analysis. In addition, unfiltered water was preserved with 0.5 ml of 1:1 hydrochloric acid:deionized water for volatile organic analysis. Analysis were conducted by the EPA Environmental Monitoring Systems Laboratory, Las Vegas, Nevada.

RESULTS AND DISCUSSION

ORGANOCHLORINES

Sediment

None of the sediment samples collected in this study contained detectible levels of organochlorine compounds including dicofol. Our findings, when compared to those of other authors, suggest that organochlorine concentrations in sediments are declining. Radtke et al. (1988) reported levels of DDD (0.3 μg/kg) and DDE (4.1 μg/kg) in sediments collected from Imperial Dam in 1986. Kepner (1987) reported levels of DDE in sediments collected from the YMD in 1985 (0.03 μg/g) and Gila/Colorado River (0.01 μg/g).

Concentrations of four organic semi-volatile compounds were detected in sediment from the YMD site, but they were reported as estimated values (Table 5; Lawson and Machado 1991). Methylene chloride was the only volatile organic detected. These concentrations, however, are not considered a threat to aquatic life.

Fish

Eight of the 23 organochlorine pesticides were detected in whole body fish tissue. Only toxaphene, DDE, DDD, DDT, dieldrin, and chlordane were recovered in more than one-half of the fish samples (Table 6). The highest toxaphene value was 0.38 μg/g wet weight for channel catfish *(Ictalurus punctatus)* from the YMD site. Toxaphene concentrations in catfish samples did not exceed the estimated 1984 NCBP 90th percentile of 0.5 μg/g (Schmitt et al. 1990). Toxaphene values were at or below those (0.4-0.6 μg/g) considered hazardous to fish health (National Academy of Sciences, National Academy of Engineering 1973).

Levels of DDE in fish ranged from 0.24 μg/g in striped mullet *(Mugil cephalus)* from Pilot Knob to 1.5 μg/g in channel catfish from the YMD site. DDE concentrations in catfish from Wellton-Mohawk (0.44 μg/g) and YMD sites exceeded the estimated 1984 NCBP 90th percentile of 0.4 μg/g. Concentrations of DDE in channel catfish tissue from the YMD site also exceeded the National Academy of Sciences and National Academy of Engineering (1973) 1.0 μg/g DDT and metabolites criterion established for protection of wildlife.

The maximum concentration of DDD (0.11 μg/g) was recovered in channel catfish from the YMD site. Concentrations of DDD did not exceed the estimated 1984 NCBP 90th percentile of 0.25 μg/g. DDT values were similar for both catfish (0.04 μg/g) and striped mullet (0.03 μg/g). These concentrations did not exceed the estimated NCBP 90th percentile of 0.1 μg/g. Dieldrin ranged from none detected in channel catfish from Wellton-Mohawk to 0.03 μg/g in channel catfish from the YMD site and levels were below the estimated NCBP (0.12 µg/g) 90th percentile. Total chlordane (0.01 - 0.09 µg/g) was below the estimated NCBP 90th percentile of 0.24 µg/g. Dicofol was not detected in fish tissue samples.

Benzoic acid was the only semi-volatile organic compound detected in whole body tilapia *(Tilapia aurea)* tissue samples taken during the EPA Priority Pollutant Program (Table 5; Lawson and Machado 1991). Of the 34 volatile organics analyzed, four were detected (Table 5; Lawson and Machado 1991).

INORGANIC ELEMENTS

Water

Eight of 14 inorganic elements were detected in the water samples (Table 7). Four of the eight elements exceeded the 75-percent national baseline for arsenic 0.003 µg/ml, manganese 0.051 µg/ml, selenium 0.001 µg/ml, and zinc 0.021 µg/ml. Concentrations greater than the 75-percent baseline are considered elevated in relation to national-baseline values (Radtke et al. 1988). Arsenic concentrations of 0.114 and 0.015 µg/ml at the Wellton-Mohawk and DPOC sites, respectively, exceeded the 75-percent national baseline by 5 to 38 times. The arsenic concentration at Wellton-Mohawk exceeded the level (two to six times) that can cause adverse effects in aquatic organisms (0.019-0.048 µg/ml; Eisler 1988). The ensuing effect may inhibit the growth of aquatic vegetation such as the predominant spiny naiad in the Yuma Valley. Manganese concentrations of 0.08, 0.83, and 0.13 µg/ml at the Wellton-Mohawk, DPOC, and QIMD sites exceeded the 75-percent national baseline by 1.5 to 16 times.

Selenium from the DPOC (0.002 µg/ml) site exceeded the 75-percent national baseline. The selenium concentrations were below the lowest concentration (0.026 µg/ml) observed by Schuler (1987) in water from selenium contaminated Kesterson Reservoir, California. Biomagnification of selenium usually ranges from 2-6 times between the producers (algae and plants) and lower consumers (insects and forage fish). For example, selenium can biomagnify up to 500 times from water to plankton and then biomagnify up to 4 times from plankton to fish. Overall the total bioconcentration factor for fish would be 2,000 (Lemly and Smith 1987). Field and laboratory data suggest that selenium at concentrations greater than 2-5 µg/l in water can be bioconcentrated in food chains and cause toxicity and reproductive failure in fish (Lemly and Smith 1987). Selenium concentrations in water from the DPOC and YMD sites were elevated enough to result in bioconcentration of selenium in the food chain. Selenium levels in water, however, generally did not exceed the 2-5 µg/g level associated with toxicity and reproductive failure in fish (Lemly and Smith 1987).

Zinc concentrations from Wellton-Mohawk, DPOC, and QIMD (0.003 µg/ml) sites exceeded (1.4 times) the 75-percent national baseline.

Sediment

Seventeen of the 21 trace elements were detected in sediment samples for all sites (Table 8). Summaries for inorganic elements detected by Radtke et al. (1988) are also presented in Table 8 for comparison to our data. Arsenic concentrations (3.3-20 μg/g) in our samples were much higher than the International Joint Commission (IJC) (1988) suggested background level (1.1 mg/kg, dry weight) for sediment. Arsenic in the YMD sample (4.9 μg/g) was approximately 1.4 times greater than the average level (3.5 μg/g) for sediments collected at the same site in 1985 (unpublished data). Similarly, the arsenic concentration of 4.3 μg/g at the Pilot Knob site was 1.5 times greater than the level (2.8 μg/g) observed in 1985 from the Morelos Dam site located approximately 2.5 miles downstream from the Pilot Knob site (unpublished data).

Copper in the DPOC sample (28 μg/g) was higher than the IJC (1988) suggested background level (21.1 μg/g) for sediment. However, copper from the DPOC site was below the average level (35.1 μg/g) for sediments collected in 1985 at the Gila/Colorado River site located approximately 1 mile downstream from the DPOC site (unpublished data). Copper from the Pilot Knob site (14 μg/g) was below the average level (21.6 μg/g) in sediments during 1985 from the Morelos Dam site (unpublished data). Sediment from the YMD had a copper concentration of 19 μg/g, which was slightly higher than the average level of 15.6 μg/g from the same site in 1985 (unpublished data).

Although, concentrations of zinc from all sites (31.5 - 70.7 μg/g) were below the IJC (1988) sediment background level of 120 μg/g, zinc concentrations appear to have increased since 1985. Sediments from the YMD had a zinc concentration (57.3 μg/g) 1.4 times greater than the average level (42 μg/g) from the same site in 1985 (unpublished data). Zinc concentrations from DPOC (70.7 μg/g) and Pilot Knob (46.6 μg/g) sites were approximately 1.4 and 1.7 times greater than the average concentrations at the respective Gila/Colorado River (48.9 μg/g) and Morales Dam (27.7 μg/g) sites in 1985 (unpublished data).

Concentrations of mercury from all sites (0.02 to 0.03 μg/g) were either at or below the IJC (1988) suggested (0.03 μg/g) sediment background level. Mercury in sediments (0.03 μg/g) from YMD was approximately 9 times less than the level (0.29 μg/g) from the same site in 1985 (unpublished data). These mercury concentrations are within the range (0.02-0.06 μg/g) that should pose no threat to benthic organisms and fish (Eisler 1987).

Concentrations of lead from all sites (7 - 16 μg/g) were below the IJC (1988) suggested sediment background level of 27.5 μg/g. Lead recovered in sediments from DPOC, Pilot Knob, and YMD sites was approximately 1.3 to 1.8 times greater than the average levels in 1985 at the respective Gila/Colorado River (10 μg/g), Morelos Dam (8 μg/g), and YMD (10 μg/g) sites (unpublished data).

Chromium concentrations at 15 to 18 μg/g in sediments from all sites were below the IJC (1988) suggested background level of 37.1 μg/g for sediment. Chromium recovered in sediments from the Pilot Knob and YMD sites (Table 8) was greater than the average concentrations from the respective Morelos Dam (8.4 μg/g) and YMD sites (9.6 μg/g) in 1985 (unpublished data). However, chromium from the DPOC site (Table 8) was much lower than the average level (23.7 μg/g) in 1985 at the Gila/Colorado River site (unpublished data). Generally, most chromium present in soil and sediment is unavailable to living organisms (Eisler 1986).

Selenium recovered in sediments from Pilot Knob and the YMD (Table 8) exceeded the average concentrations of 0.06 and 0.3 μg/g from Morelos Dam and YMD sites, respectively, in 1985 (unpublished data). However, selenium from the DPOC site (Table 8) did not exceed the average level from the Gila/Colorado River (7.03 μg/g) site in 1985 (unpublished data). Selenium concentrations in the study area were at the lower end of the range detected in sediments from Kesterson Reservoir (0.3-22 μg/g; Schuler 1987). Concentrations of selenium in sediments from the Yuma Valley study area have decreased greatly from the 1986 level (7.1 μg/g; Radtke et al. 1988). Selenium concentrations in the study area were below the level of concern (≥4 μg/g dry weight) in sediments for fish and wildlife (Lemly and Smith 1987).

Aluminum, boron, iron, and vanadium concentrations in sediments collected in 1989 from the DPOC, Pilot Knob, and YMD sites exceeded the average 1985 levels from the respective Gila/Colorado River (8,960; <0.5; 17,900; 37.7 μg/g), Morelos Dam (4,463; 3; 7,593; 13.7 μg/g), and YMD (7,737; 4.3; 11,967; 13 μg/g) sites (unpublished data). Suggested IJC sediment background levels have not been established for aluminum, boron, iron, and vanadium.

Current barium, magnesium, and nickel levels (Table 8) in sediments from Pilot Knob and the YMD exceeded the average 1985 levels from the respective Morelos Dam (149; 5,617; 6.3 μg/g) and YMD (176; 8,627; 11.6 μg/g) sites (unpublished data). However, concentrations from the DPOC site did not exceed the average levels of 158; 7,180; and 19.3 μg/g for each element respectively, at the Gila/Colorado River site in 1985 (unpublished data). No IJC suggested sediment background levels have been established for barium, magnesium, and nickel.

Beryllium recovered in sediments at 0.8 μg/g from the YMD site exceeded the average level (0.55 μg/g) from the same site in 1985 (unpublished data). However, beryllium concentrations at 0.5 and 0.3 μg/g from the Pilot Knob and DPOC sites, respectively, did not exceed the average concentrations of 0.71 and 0.44 μg/g at the Morelos Dam and Gila/Colorado River sites, respectively in 1985 (unpublished data). An established IJC suggested sediment background level has not been determined for beryllium.

Manganese concentrations at Wellton-Mohawk, DPOC, and YMD (Table 8) exceeded the 95-percent baseline (1,500 μg/g) for western soils (Shacklette and Boerngen 1984). Manganese from the DPOC, Pilot Knob, and YMD sites (Table 8) were below the average concentrations of 2,100, 735, and 1,983 µg/g at the Gila/Colorado River, Morelos Dam, and YMD sites, respectively, in 1985 (unpublished data). An established IJC suggested sediment background level has not been determined for manganese.

Strontium at 205 µg/g from the YMD site was below the average level (236 µg/g) for sediments collected at the same site in 1985 (unpublished data). In addition, strontium at 96.4 µg/g from the DPOC site was below the average level (162 µg/g) for sediments collected downstream at the Gila/Colorado River site in 1985 (unpublished data). However, the strontium level at 161 µg/g from Pilot Knob exceeded the average level (69.7 µg/g) by 2.3 times for sediments collected downstream at Morelos Dam in 1985 (unpublished data). An established IJC suggested sediment background level has not been determined for strontium.

Eight of 13 inorganics were detected in sediment samples taken from the YMD site during the EPA Priority Pollutant Program (Table 5; Lawson and Machado 1991). Arsenic concentrations reported for the EPA Priority Pollutant Program (EPA STORET data 1989) from the YMD site in 1982 (3.8 µg/g dry weight) and 1985 (5.3 µg/g) were similar to the level in 1989 (Table 5). Copper concentrations in sediment have increased approximately two fold from 10.4 µg/g in 1982 to 17.7 µg/g in 1989. Lead and zinc (Table 5) concentrations in sediments have increased nearly 2.5 times since 1982 (6.2 and 30.1 µg/g, respectively). Beryllium, mercury, and nickel were first reported in sediment samples in 1989. Two of the eight elements detected, arsenic and mercury exceeded the IJC (1988) suggested sediment background levels. Trend analysis of arsenic, copper, lead, and zinc in Priority Pollutant Program data confirms our findings that these trace elements are increasing in sediments.

Plant Tissue

Thirteen of 14 inorganic elements were detected in spiny naiad plant tissue at each site (Tables 7,9). Summaries for inorganic elements detected by Radtke et al. (1988) are also presented in Table 9. Arsenic in spiny naiad samples from Wellton-Mohawk (51.4 µg/g) and DPOC (14.7 µg/g) were higher than levels observed in widgeongrass (*Ruppia maritima*) at Kesterson Reservoir (0.72-1.9 µg/g, dry weight; Hothem and Ohlendorf 1989). The concentration of arsenic from Wellton-Mohawk exceeded levels (0.59-18 µg/g, dry weight) in submerged aquatic plants reported by Schuler (1987) at Kesterson Reservoir. In addition, arsenic from Wellton-Mohawk and DPOC sites were higher than levels reported at the Volta Wildlife Area (1.3-8.2 µg/g; Schuler 1987). However, arsenic concentrations (Table 9) in the study area did not exceed the dietary level (120 µg/g, wet weight) that would cause adverse effects in aquatic organisms (Eisler 1988).

Selenium from Wellton-Mohawk, DPOC, QIMD, and Pilot Knob samples (Table 7) were at much higher concentrations than background levels (0.4 µg/g; Eisler 1985). Concentrations of selenium were lower than average levels at

Kesterson Reservoir (38.2 µg/g; Hothem and Ohlendorf 1989). As a dietary source for waterfowl, spiny naiad selenium levels did not exceed the concentration (≥3 µg/g, dry weight) that could cause reproductive failure or mortality in waterfowl due *to* food-chain bioconcentration (Lemly and Smith 1987).

The cadmium concentration of 1.5 µg/g at the DPOC site exceeded the concentration (none detected - 0.85 µg/g) at Kesterson Reservoir in submerged aquatic plants (Schuler 1987). Copper concentration from Wellton-Mohawk (11.4 µg/g) was slightly higher than the level reported at Kesterson Reservoir (3-11 µg/g; Schuler 1987). Chromium concentrations of 11.0 µg/g at the DPOC and Pilot Knob sites exceeded the concentrations (O-10 µg/g) at Kesterson Reservoir (Schuler 1987). All mercury concentrations (Table 7) in the Yuma Valley study area *were* well below the concentrations at Kesterson Reservoir (O-3.4 µg/g; Schuler 1987).

Fish

Twelve of 14 inorganic elements were detected in whole body channel catfish and striped mullet samples at three sites (Tables 7,9). Summaries for inorganic elements reported by Radtke et al. (1988) are also presented in Table 9. The NCBP 85th percentile concentration for each of seven trace elements in freshwater fish from 1976-81 to 1984 are provided in Table 10. The 85th percentile is a subjective figure considered as a level significantly higher than background concentrations. Only four individual samples contained trace elements above the NCBP 85th percentile (Schmitt and Brumbaugh 1990). Arsenic in the striped mullet sample (1.85 µg/g) from Pilot Knob was almost 7 times higher than the NCBP 85th percentile of 0.27 µg/g . Similar arsenic values (1.13 and 1.44 µg/g wet weight) for striped mullet tissue were observed at the NCBP Colorado River at Yuma site in 1984 (Schmitt and Brumbaugh 1990). The Yuma Valley regional area has a history of elevated arsenic levels (Schmitt and Brumbaugh 1990). This may have resulted from the use of arsenical agricultural chemicals in the intensively farmed region of the Lower Colorado River watershed.

Copper in one channel catfish sample from Wellton-Mohawk (6.75 µg/g) and striped mullet sample from Pilot Knob (3.08 µg/g) were elevated above the NCBP 85th percentile of 1.0 µg/g (Schmitt and Brumbaugh 1990).

Selenium concentrations in channel catfish (Table 9) were similar for all three samples and below the NCBP 85th percentile of 0.73 µg/g (Schmitt and Brumbaugh 1990). However, selenium in striped mullet (1.46 µg/g) exceeded the NCBP 85th percentile by two times. Similar selenium values (1.61 and 1.39 µg/g) for striped mullet tissue were reported at the NCBP Colorado River at Yuma station in 1984 (Table 2; Schmitt and Brumbaugh 1990). Concentrations of selenium, however, in striped mullet were below the 6.9-7.2 µg/g level associated with selenium-induced reproductive failure in bluegills *(Lepomis macrochirus)* from a selenium contaminated reservoir (Gillespie and Baumann 1986).

Although the maximum mercury concentration (Table 9) did not exceed the NCBP 85 percentile (0.17 µg/g), mercury may still present a hazard to some wildlife species. The minimum concentration of mercury which may cause effects on fish-eating avian predators is 0.1 µg/g (Eisler 1987). The striped mullet sample from Pilot Knob (0.111 µg/g) exceeded that level. Therefore, brown pelicans, bald eagles, and other fish-eating birds may be ingesting potentially harmful levels of mercury while feeding on fish from the Colorado River near Pilot Knob.

Nine of the 13 inorganics were detected in whole body tilapia taken during the EPA Priority Pollutant Program (Table 5; Lawson and Machado 1991). Arsenic was elevated nearly two fold above the 1984 NCBP 85th percentile of 0.27 µg/g (Schmitt and Brumbaugh 1990). Copper and lead were at least three fold above the NCBP baseline limits of 1.0 and 0.22 µg/g, respectively. Mercury was slightly elevated above the NCBP 85th percentile of 0.17 µg/g. Zinc concentration was below the NCBP baseline limit of 34.2 µg/g.

BIOASSAY ANALYSIS

Water Samoles

There was no significant reduction in mobility or increased mortality observed in *D. magna* exposed to water from the Wellton-Mohawk, DPOC, or YMD sites for 48-hours (Henry et al. 1991). No significant mortality of fathead minnow was noted in **48-hour** bioassay tests using water from Wellton-Mohawk, DPOC, **YMD** sites (Henry et al. 1991).

Sediment Samoles

Evidence of contaminants was suggested by a relatively high **24-hour** median effective concentration (24-h EC,,,) value of 4.73 in the chironomid test using DPOC sediments (Henry et al. 1991). The EC,, is the concentration of material in water to which test organisms are exposed that is estimated to be effective in producing some sublethal response to 50 percent of the test organisms. Tests using sediments from the remaining two sites, **Wellton-**Mohawk and YMD, resulted in low 24-h **EC_{50}** values indicating sub-acute levels of toxicants in the sediments. Overall, sediment at the DPOC site may be more toxic than the water to the test organisms (Henry et al. 1991).

TRENDS IN RESIDUES

Levels of DDE, toxaphene, dieldrin, and total chlordane in fish tissue from the Yuma Valley are consistent with the concentrations reported in NCBP (Schmitt et al. 1990). There has been no apparent increase or decrease in concentrations of these compounds in fish since 1976. Concentrations of DDD and DDT, however, have decreased.

Arsenic, boron, copper, manganese, and zinc found in sediment appear to be increasing compared with levels in sediment collected in 1986 (Radtke et al. 1988). These increases were primarily associated with agricultural return flows within the Yuma Valley study area (i.e. Wellton-Mohawk, DPOC, and YMD drainages). In addition, aluminum, arsenic, barium, beryllium, chromium, iron, magnesium, nickel, vanadium, and zinc appear to be increasing compared with levels in sediment collected throughout the Yuma Valley in 1985 (unpublished data).

Selenium concentrations in sediment from the YMD have increased slightly from 1985 to 1989. However, selenium has decreased in sediments collected from all Yuma Valley study sites compared to sediments collected in 1986 at the Imperial Dam (Radtke et al. 1988).

There appears to have been an increase of aluminum, arsenic, iron, manganese, and zinc concentrations in spiny naiad from 1986 to 1989 when our data are compared to those of Radtke et al. (1988). These increases were primarily observed in the agricultural return flows from Wellton-Mohawk and DPOC drainages. Selenium concentrations in spiny naiad exceeded the background levels for aquatic vegetation (Eisler 1985).

Arsenic, copper, and selenium concentrations in fish tissue continue to be elevated above NCBP baseline concentrations and arsenic and copper appear to have increased over time (Table 2).

SUMMARY AND RECOMMENDATIONS

Selenium was present in Yuma Valley irrigation drainage waters at concentrations that can be bioconcentrated in food chains. Selenium concentrations in aquatic vegetation at two sites in the Yuma Valley exceeded the DO1 environmental criterion (1 μg/g, dry weight: Appendix A) for algae. In addition, selenium exceeded background concentrations in aquatic vegetation; thus indicating a bioconcentration pattern of selenium from water to aquatic vegetation.

There has been an increase of selenium in sediments particularly at the southern area of the Yuma Valley. Selenium in sediments has also been recovered within the range reported at Kesterson Reservoir. Selenium, however, in sediments did not exceed the DO1 criterion (1.5 μg/g, dry weight; Appendix A).

Selenium concentration in striped mullet tissue continue to be elevated above the NCBP baseline. Selenium, however, did not exceed the DO1 criterion (2.5 μg/g, dry weight; Appendix A) for fish tissue.

The maximum concentration of mercury in striped mullet was above the level reported to affect fish-eating birds.

Overall, results indicate that irrigation drainage waters in the Yuma Valley may have the potential to cause significant harmful effects on fish and wildlife resources. Selenium appears to be bioconcentrating in the food chain in the Yuma Valley; from water (0.001-0.002 μg/ml), to sediments (0.2-0.8 μg/g dry weight), to aquatic vegetation (0.64-1.3 μg/g dry weight), and to fish (1.1-3.4 μg/g dry weight). Elevated levels of organic and inorganic contaminants identified in the project area merit further investigation to assess environmental contaminant impacts relative to the operation and drainage of agricultural irrigation projects. Therefore, we recommend that the Yuma Valley irrigation drainage area be elevated to a full reconnaissance-level study by the DO1 Irrigation Drainage Task Group.

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APPENDIX A

The DO1 Task Group evaluation approach will compile and analyze information from appropriate federal and state agencies on land and water management practices, geohydrology, soils, climate, water quality, and fish and wildlife within areas receiving irrigation drainage waters. Based on the analysis of available information, such areas were divided into four classes:

Class A: Areas where existing information indicates reason for concern and the need for further analysis of associated impacts.

Class B: Areas where there is some information to justify concern, but the information is inadequate to justify classification into Class A.

Class C: Areas where existing information does not justify concern.

Class D: Areas where there is some information does not justify concern, but the information is inadequate to determine the potential for impact by selenium.

Information used to classify these areas included: 1) observed health condition of aquatic and terrestrial plants and animals, 2) existing environmental criteria for selenium, and 3) recorded concentrations of selenium in various environmental media. Existing environmental criteria for selenium concentrations was designated as "high" at levels or greater than 1,500 parts per billion (ppb) (1.5 $\mu g/g$, dry weight) for soils and 2,500 ppb (2.5 $\mu g/g$; dry weight) for fish. Selenium concentrations in algae and eggs were considered "high" if they exceeded 1,000 ppb (1 $\mu g/g$; dry weight). An area was considered to be in Class A if selenium concentrations met the criteria as stated above for the appropriate media. The Yuma Valley area was classified as Class A, based on high selenium concentrations in soils and sediments, and fish tissue (Department of the Interior 1985).

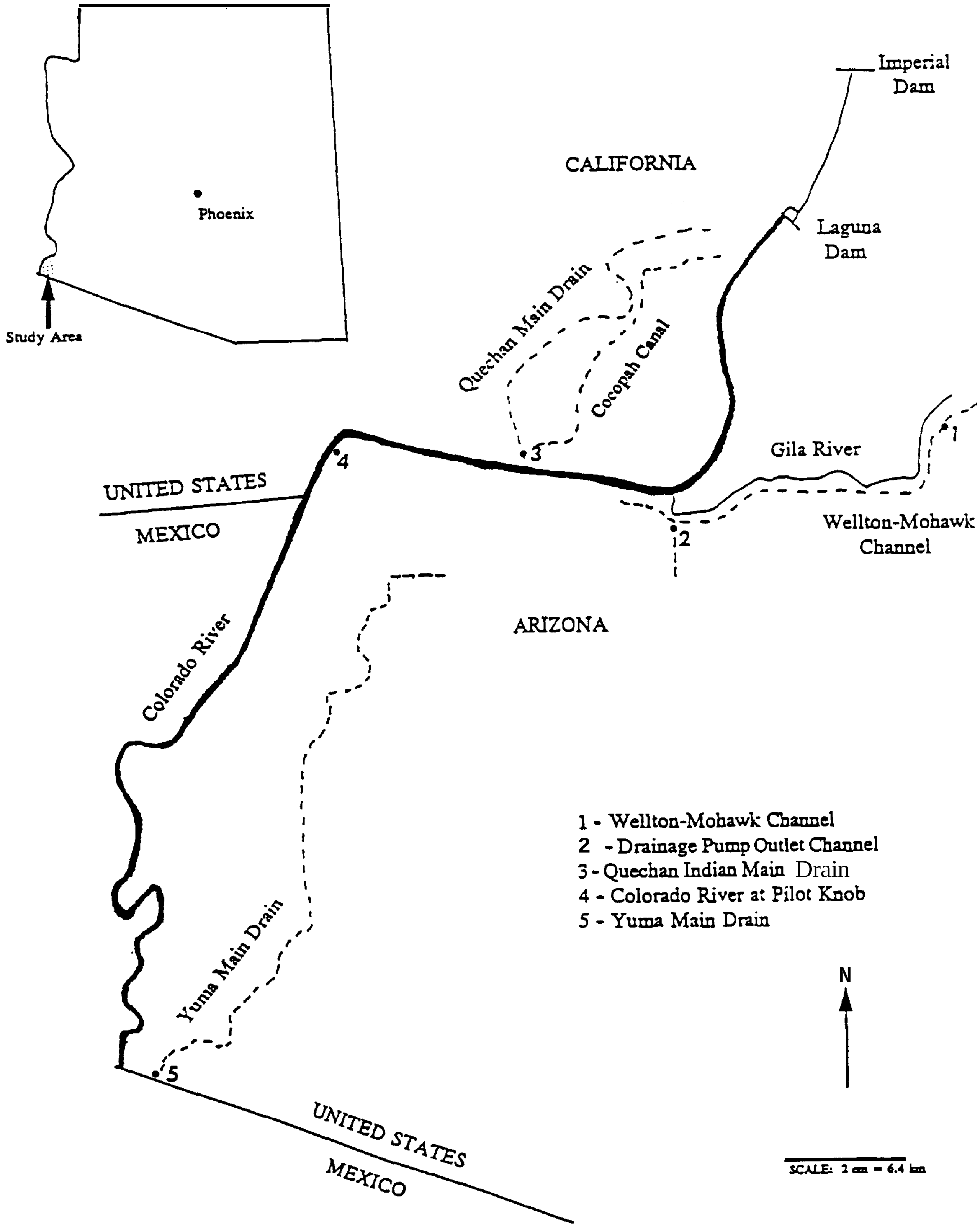

Figure 1. Yuma valley study area and data collection sites, Arizona, 1989.

Table 1. A comparison of organochlorine mean concentrations ($\mu g/g$ wet weight) in fish collected from the Colorado River at Yuma in 1984 with the national baseline mean concentrations (Schmitt et al. 1990).

	Oraanochlorine Pesticides			
	Toxaphene	DDE	DDD	DDT
Baseline levels	0.14	0.19	0.06	0.03
Species				
Largemouth bass	0.70	1.87	0.20	0.17
Striped mullet	0.40	1.56	0.19	0.20
Striped mullet	0.40	0.56	0.07	0.09

Table 2. Concentrations (µg/g wet weight) of trace elements in fishes collected from the Colorado River at Yuma, Arizona from 1976-81 to 1984[1].

Element		As	Cd	Cu	Pb	Hg	Se	Zn
NCBP 85 Percent[2]		0.27	0.05	1.0	0.22	0.17	0.73	34.2
Year	Species							
1976	Carp	0.25	0.05	NA[3]	0.23	0.02		NA
1978	Carp	0.18	0.01	0.90	0.10	0.01	1.75	47.90
1976	LMB[4]	0.25	0.05	NA	0.20	0.03		NA
1978	LMB	0.08	0.02	0.40	0.10	0.04	1.54	22.50
1980	LMB	0.29	0.01	0.40	0.10	0.14	0.99	13.41
1984	LMB	0.49	0.00	0.63	0.09	0.09	1.10	14.07
1978	SM[5]	1.16	0.01	2.30	0.16	0.01	1.37	13.70
1980	SM	1.17	0.01	2.52	0.10	0.01	1.00	12.72
1980	SM	0.84	0.01	2.53	0.17	0.01	2.02	14.96
1984	SM	1.13	0.01	3.00	0.34	0.01	1.61	13.32
1984	SM	1.44	0.02	3.15	0.36	0.01	1.39	13.68

[1] Data from May and McKinney 1981, Lowe et al. 1985, Schmitt and Brumbaugh 1990

[2] National Contaminant Biomonitoring Program 85th percentile for 1984 (Schmitt and Brumbaugh 1990)

[3] NA - None analyzed

[4] LMB - Largemouth bass

[5] SM - Striped mullet

Table 3. Station locations, analyses and media tested. W = water, F = fish tissue, P = plant tissue, and S = sediment.

Location	Trace[1] Elements	OC[2]	EPA[3] PPA	Bioassay[4]
Wellton-Mohawk	W,S,P,F	S,F		W,S
DPOC[5]	W,S,P			W,S
Quechan IMD	W,S,P			
Colorado River at Pilot Knob	W,S,P,F	S,F		
Yuma Main Drain	W,S,P,F	S,F	W,S,F	W,S

[1]Trace elements - include 14 elements (Al, As, Be, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Se, Tl, Zn)
[2]OC - Organochlorine pesticide scan (includes 20 pesticides and total PCBs)
[3]EPA PPA - Environmental Protection Agency Priority Pollutant Analysis
[4]Bioassay - Bioassay analysis for water and sediment
[5]DPOC - Drainage Pump Outlet Channel

Table 4. Environmental Protection Agency's list of priority pollutants, 1991.

Trace Elements

Antimony
Arsenic
Beryllium
Cadmium
Chromium
Copper
Lead
Mercury
Nickel
Selenium
Silver
Thallium
Zinc

Other

Cyanide
Asbestos

Pesticides

Aldrin
Chlordane
Dieldrin
4, 4'DDT
4, 4'DDE
4, 4'DDD
Alpha Endosulfan
Beta Endosulfan
Endosulfan Sulfate
Endrin
Endrin Aldehyde
Heptachlor
Heptachlor Epoxide
Alpha BHC
Beta BHC
Gamma BHC (Lindane)
Delta BHC
Toxaphene
PCB 1016
PCB 1221
PCB 1232
PCB 1242
PCB 1248
PCB 1254
PCB 1260

Semivolatile Organics - Base/Neutral Extractibles

Acenaphthene
Benzidine
1,2,4-Trichlorobenzene
Hexachlorobenzene
Hexachloroethane
Bis(2-Chloroethyl)Ether
2-Chloronaphthalene
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
3,3-Dichlorobenzidine
2,4-Dinitrotoluene
2,6-Dinitrotoluene
1,2-Diphenylhydrazine
Fluoranthene
4-Chlorophenyl Phenyl Ether
4-Bromophenyl Phenyl Ether
Bis(2-Chloroisopropyl)Ether
Bis(2-Chloroethoxy)Methane
Hexachlorobutadiene
Hexachlorocyclopentadiene
Isophorone
Naphthalene
Nitrobenzene
N-Nitrosodimethylamine
N-Nitrosodi-N-Propylamine
N-Nitrosodiphenylamine
Bis(2-Ethylhexyl)Phthalate
N-Butyl Benzyl Phthalate
Di-N-Butyl Phthalate
Di-N-Octyl Phthalate
Diethyl Phthalate
Dimethyl Phthalate
1,2-Benzanthracene
3,4-Benzo-Pyrene
3,4-Benzofluoranthene
11,12-Benzofluoranthene
Chrysene
Acenaphthylene
Anathracene
1,12-Benzoperylene
Fluorene
Phenanthrene
1,2,5,6-Dibenzanthracene
Indeno(1,2,3-CD)Pyrene
Pyrene
TCDD

Semivolatile Organic8 - Acid Extractibles

2,4,6-Trichlorophenol
P-Chloro-M-Cresol
2-Chlorophenol
2,4-Dichlorophenol
2,4-Dimethylphenol
2-Nitrophenol
4-Nitrophenol
2,4-Dinitrophenol
4,6-Dinitro-0-Cresol
Pentachlorophenol
Phenol

Volatile Oraanics

Acrolein
Acrylonitrile
Benzene
Carbon Tetrachloride
Chlorobenzene
1,2-Dichloroethane
1,1,1-Trichloroethane
l,l-Dichloroethane
1,1,2-Trichloroethane
1,1,2,2-Tetrachloroethane
Chloroethane
2-Chloroethyl-Vinyl Ether
Chloroform
l,l-Dichloroethylene
1,2-Trans-Dichloroethylene
1,2-Dichloropropane
1,3-Dichloropropene
Ethylbenzene
Methylene Chloride
Methyl Chloride
Methyl Bromide
Bromoform
Bromodichloromethane
Dibromochloromethane
Tetrachloroethylene
Toluene
Trichloroethylene
Vinyl Chloride

Table 5. Inorganic, semi-volatile, and volatile concentrations in water, sediment, and fish tissue' from the Yuma Main Drain site, Environmental Protection Agency Priority Pollutant Program, Yuma Valley study, Arizona 1989 (Lawson and Machado 1991).

Parameter	Water	Sediment	Fish Tissue
	Matrix		
	µg/l	µg/g DW[2]	µg/g WW[3]
Inoraanics			
Antimony	ND4	ND	0.94 B[5] N[6]
Arsenic	2.7 B	4.8	0.46 B
Beryllium	ND	0.5 B	0.45 B
Chromium	4.4 B	13.8	9.0 *[7]
Copper	ND	17.1	2.9
Lead	ND	16.3	0.74 B
Mercury	0.53	0.21	0.2
Nickel	ND	12.5 B	ND
Selenium	2.6 N	ND	0.72 B N
Zinc	13.9 B	77.1 *	15.0
		µg/kg	µg/kg
Semi-Volatile8			
Bis(2-Ethylhexyl)Phthalate	2 J[8]	200 J	ND
Naphthalene	ND	800-9000 J	ND
Benzoic Acid	ND	ND	610 J
2-Methylnaphthalene	ND	2600 J	ND
Pentachlorophenol	ND	510 J	ND
Volatile8			
Ethylbenzene	ND	ND	5
Methylene Chloride	ND	28	6
Toluene	ND	ND	2
Total Xylene	ND	ND	1

[1]Fish tissue - *Tilapia aurea*
[2]DW - Dry weight
[3]WW - Wet weight
[4]ND - None Detected
[5]B - The reported value was obtained from a reading that was less than the Contract Required Detection Limit but greater than or equal to the Instrument Detection Limit
[6]N - Spiked sample recovery not within control limits
[7]* - Duplicate analysis not within control limits
[8]J - Estimated level, the compound is present above zero, but the compound is below the confidence level of the instrument

Table 6. Organochlorine concentrations in fish whole body tissue (µg/g wet weight) from Yuma Valley study area in Arizona, 1989'.

		Oraanochlorine				
Site & Species	Toxaphene	p,p' DDE	p,p' DDD	PIP' DDT	Dieldrin	Chlordane
NCBP 90 Percent'	0.5	0.4	0.25	0.1	0.12	0.24
Wellton-Mohawk						
Channel catfish	0.29	0.44	0.02	ND[3]	ND	0.01
Channel catfish	0.34	0.32	0.02	0.04	ND	0.01
Pilot Knob						
Striped mullet	ND	0.24	0.04	0.03	0.01	0.01
Yuma Main Drain						
Channel catfish	0.38	1.50	0.11	0.04	0.03	0.09

'Additional organochlorinee detected in fewer than 1/2 the fish samples - o,p'-DDE (0.03 µg/g) and o,p'-DDD (0.02 µg/g)
*National Contaminant Biomonitoring Program 90th percentile, estimated, µg/g wet weight (Schmitt et al. 1990)
[3]ND - None detected

Table 7. Trace element concentrations in water ($\mu g/ml$), plant and fish tissue ($\mu g/g$, dry weight) from Yuma Valley area in Arizona, 1989.

	Element[1]												
Matrix & Site	Al	As	Be	cd	Cr	cu	Fe	Hg	Mn	Ni	Pb	Se	Zn
<u>Water</u>													
Wellton-Mohawk	0.027	0.114	ND[2]	0.0005	ND	ND	0.03	ND	0.08	ND	ND	ND	0.03
DPOC[3]	0.004	0.015	ND	0.001	ND	0.0005	0.05	ND	0.83	ND	ND	0.002	0.03
QIMD[4]	ND	0.002	ND	ND	ND	ND	0.03	ND	0.13	ND	ND	ND	0.01
Pilot Knob	ND	0.002	ND	ND	ND	ND	0.03	ND	0.02	ND	ND	0.001	0.02
YMD[5]	0.016	0.022	ND	0.0014	ND	ND	0.01	ND	0.04	ND	ND	ND	0.03
<u>Spiny Naiad</u>													
Wellton-Mohawk	4410	51.4	0.22	0.55	7.6	11.4	8420	0.030	>9060	7.5	4	0.84	15.6
DPOC	8490	14.7	0.41	1.50	11.0	26.4	9920	0.032	6070	12.0	7	1.20	30.6
QIMD	16800	4.7	0.72	0.41	9.1	17.2	16700	0.034	7000	13.0	14	0.90	47.1
Pilot Knob	9350	4.7	0.43	0.52	11.0	15.8	8900	0.033	679	13.0	11	1.30	43.0
YMD	14000	4.0	0.60	0.39	9.6	15.4	11400	0.054	2260	12.0	13	0.64	48.7
<u>Channel Catfish</u>													
Wellton-Mohawk	10.7	0.5	ND	0.01	0.03	0.51	33.7	0.087	4.3	ND	ND	1.4	14.9
Wellton-Mohawk	13.4	0.4	ND	0.01	0.06	6.75	38.7	0.071	5.3	ND	ND	1.1	17.2
YMD	27.0	0.3	ND	ND	0.05	0.29	31.8	0.091	3.0	0.05	0.2	1.5	21.3
<u>Striped Mullet</u>													
Pilot Knob	7.3	4.3	ND	ND	ND	3.08	30.3	0.026	1.8	ND	ND	3.4	10.8

[1]Thallium was not detected in any samples
[2]NA - Data not available; ND - No residue detected
[3]DPOC - Drainage Pump Outlet Channel
[4]QIMD - Quechan Indian Main Drain
[5]YMD - Yuma Main Drain

Table 8. Trace element concentrations in sediment ($\mu g/g$, dry weight) from the Yuma Valley area in Arizona, 1989.

	Element'																
Site	Al	As	B	Ba	Be	Cr	cu	Fe	Hg	Mg	Mn	Ni	Pb	Se	Sr	V	Zn
IJC[2]	NA[3]	1.1	NA	NA	NA	37.1	21.1	NA	0.03	NA	NA	NA	27.5	NA	NA	NA	120
WM[4]	7520	20	7.3	149	0.2	16	12	12500	0.02	5950	8870	11	7	0.8	685	33	58.9
DPOC[5]	9700	4.1	3.0	132	0.3	17	28	21600	0.02	4050	1830	13	13	ND[3]	96	58	70.7
QIMD[6]	11300	3.3	3.0	175	0.4	15	10	13600	0.02	7640	1480	10	9	0.2	109	17	31.5
PK[7]	13500	4.3	4.0	255	0.5	18	14	14700	0.03	8990	622	13	15	0.4	161	22	46.6
YMD'	21200	4.9	8.6	213	0.8	17	19	18100	0.03	10400	1550	14	16	0.4	205	26	57.3
Radt[9]	NA	8.3	1.4	480	NA	34	21	NA	0.04	N A	460	16	16	7.1	NA	43	49.0

'Cadmium, molybdenum, silver, and thallium were not detected in any samples
[2]IJC - International Joint Commission suggested sediment background level, mg/kg, dry weight
[3]NA - Not analyzed, ND - None detected
[4]WM - Wellton-Mohawk
[5]DPOC - Drainage Pump Cutlet Channel
[6]QIMD - Quechan Indian Main Drain
[7]PK - Pilot Knob
'YMD - Yuma Main Drain
[9]Data from Radtke et al. 1988, $\mu g/g$, dry weight

Table 9. Trace **element concentrations plant and fish tissue** (µg/g, **wet weight) from Yuma Valley area in** Arizona, 1989.

Matrix & Site	Al	As	Be	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Se	Zn
					Element[1]								
NCBP 85 Percent[2]	NA[3]	0.27	NA	0.05	NA	1.00	NA	0.17	NA	NA	0.2	0.73	34.2
Spiny Naiad													
Wellton-Mohawk	781	9.1	0.04	0.10	1.3	2.02	1490.3	0.005	>1604.0	1.3	0.6	0.15	2.76
DPOC	696	1.2	0.03	0.12	0.9	2.16	813.4	0.003	497.7	1.0	0.6	0.10	2.51
QIMD	1562	0.4	0.07	0.04	0.8	1.60	1832.1	0.003	651.0	1.2	1.3	0.08	4.38
Pilot Knob	636	0.3	0.03	0.03	0.7	1.07	605.2	0.002	46.2	0.9	0.7	0.09	2.92
YMD	1512	0.4	0.06	0.04	1.0	1.66	1231.2	0.006	287.3	1.3	1.4	0.07	5.26
Radtke et al.[7]	747	0.3	0.14	ND	2.1	1.5	53.3	ND	14.0	1.0	1.2	0.18	1.5
Channel Catfish													
Wellton-Mohawk	10.7	0.13	ND	0.01	0.03	0.51	33.7	0.022	4.3	ND	ND	0.36	14.9
Wellton-Mohawk	13.4	0.12	ND	0.01	0.06	6.75	38.7	0.021	5.3	ND	ND	0.32	17.2
YMD	27.0	0.07	ND	ND	0.05	0.29	31.8	0.022	3.0	0.05	0.2	0.36	21.3
Striped Mullet													
Pilot Knob	7.3	1.85	ND	ND	ND	3.08	30.3	0.111	1.8	ND	ND	1.46	10.8
Radtke et al.[8]	74.7	0.06	<0.1	<0.1	0.87	0.67	8.0	<0.05	2.9	0.71	ND	2.56	61.0

[1]Thallium was not detected in any samples
[2]National Contaminant Biomonitoring Program 85th percentile, fishes, µg/g, wet weight (Schmitt and Brumbaugh 1990)
[3]NA - Data not available; ND - No residue detected
[4]DPOC - Drainage Pump Cutlet Channel
[5]QIMD - Quechan Indian Main Drain
[6]YMD - Yuma Main Drain
[7]Data from Radtke et al. 1988, Imperial Dam site data, an average of composites (n=3)
[8]Data from Radtke et al. 1988, Imperial Dam site data, an average of composites of carp (n=5)

Table 10. The 85th percentile[1] concentrations (μg/g wet weight) of seven elements in whole fish, 1976-81 to 1984 (Schmitt and Brumbaugh 1990).

	Collection Period			
	1976-77	1978-79	1980-81	1984
Element				
Arsenic	0.38	0.23	0.22	0.27
Cadmium	0.11	0.09	0.06	0.05
Copper	NA[2]	1.10	0.90	1.00
Lead	0.44	0.32	0.25	0.22
Mercury	0.19	0.18	0.17	0.17
Selenium	0.82	0.70	0.71	0.73
Zinc	NA	46.30	40.10	34.20

[1]National Contaminant Biomonitoring Program 85th percentile for the distribution of geometric station means
[2]NA - none analyzed