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Organochlorine and Trace Element Contaminant Investigation of the Rio Grande, New Mexico

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U.S. DEPARTMENT OF THE INTERIOR

ORQANOCRLORINB AND TRACE ELEMENT CONTAMINANT INVESTIGATION OF THE RIO GRANDE, NEW MEXICO

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EXECUTIVE SUMMARY

Contaminant studies were conducted in the Rio Grande, New Mexico, from 1985-1987. The results indicate that overall, lotic habitats in the Rio Grande do not appear to be extensively contaminated by trace elements, heavy metals, or organochlorine compounds. However, this may be a function of sampling because the samples were not collected during the same year, and fish species change dramatically from the Upper Rio Grande to the Lower Rio Grande. There are, however, several sites within the study area, specifically the Red River, that have high concentrations of heavy metals, e.g., cadmium, lead, and copper in sediments. Fish in the study area are accumulating such elements as selenium, cadmium, arsenic, and zinc to higher concentrations than fish nationwide, but this does not necessarily indicate that these fish are experiencing biological effects from these elements. Fish in the Lower Rio Grande are accumulating DDE to concentrations that may potentially be harmful to fish and their predators. Any future monitoring studies should include the continuation of inorganic/organochlorine compound analysis of sediments, invertebrates, fish and birds throughout the river; however, more emphasis should be placed on sampling tributaries and reservoirs. This is essential because of recent discoveries of concentrations of mercury in edible portion fish samples from reservoirs throughout the state, including Elephant Butte, Caballo, and Cochiti. As a result, the New Mexico Environment Department has published fish consumption guidelines for these and other reservoirs.

INTRODUCTION:

Samples of sediment and terrestrial and aquatic biota were collected in the Rio Grande, New Mexico, from 1985 to 1987. This report is a compilation of the Red River-Rio Grande Contaminant Study, the Middle Rio Grande Contaminant Study, and the Lower Rio Grande Contaminant Study. The monitoring studies were developed to determine the impacts of mineral development, agriculture, and urbanization in the drainage to fish and wildlife habitats and to determine if biota were biomagnifying potentially harmful levels of organic/inorganic compounds. For the purposes of this report, only the analytical results of sediment and fish will be discussed in detail because they were the only two matrices collected in all three reaches of the river. Analytical data of inorganic compounds of the discussed samples and other forms of biota (e.g., invertebrates, birds, and mammals) are provided as dry weight concentrations in the appendices. If the reader wishes to convert these data to wet weight, use the following formula.

X = Wet Weight
5.6 ug/g = Dry Weight
70% = Moisture Content

$$(5.6)(1-(70\%/100)) = 1.68 \text{ ug/g Wet Weight}$$

As with the inorganic results, analytical results of organochlorine compounds are also provided in the appendices. These results are provided as wet weight. To convert to dry weight, use the following formula.

X = Dry Weight
1.68 ug/g = Wet Weight
70% = Moisture Content

$$X = \frac{1.68}{1-(70\%/100)}$$

Dry Weight = 5.6 ug/g

The area studied encompasses the Rio Grande from the New Mexico-Colorado border to the New Mexico-Texas-Republic of Mexico border (Fig. 1). The river was divided into three study reaches: the Upper Rio Grande, Colorado border to Cochiti Reservoir (Fig. 2), Middle Rio Grande, Cochiti Pueblo to Elephant Butte Reservoir (Fig. 3), and Lower Rio Grande, Hatch, New Mexico, to El Paso, Texas (Fig. 4).

The Upper Rio Grande (Upper study reach) includes that portion of the Rio Grande designated as a Wild and Scenic River. This area is used extensively by fish eating birds, i.e., mergansers, herons, and eagles. In addition, peregrine and prairie falcons commonly use this area. The major recreational activity is commercial and private rafting, canoeing, and kayaking, fishing, and off-road ATV/4-wheel driving. Copper and zinc have been detected in acutely toxic concentrations and cadmium, lead, mercury, and iron have been detected at chronically toxic concentrations in water from this reach of the Rio Grande (New Mexico Water Quality Control Commission [NMWQCC] 1990).

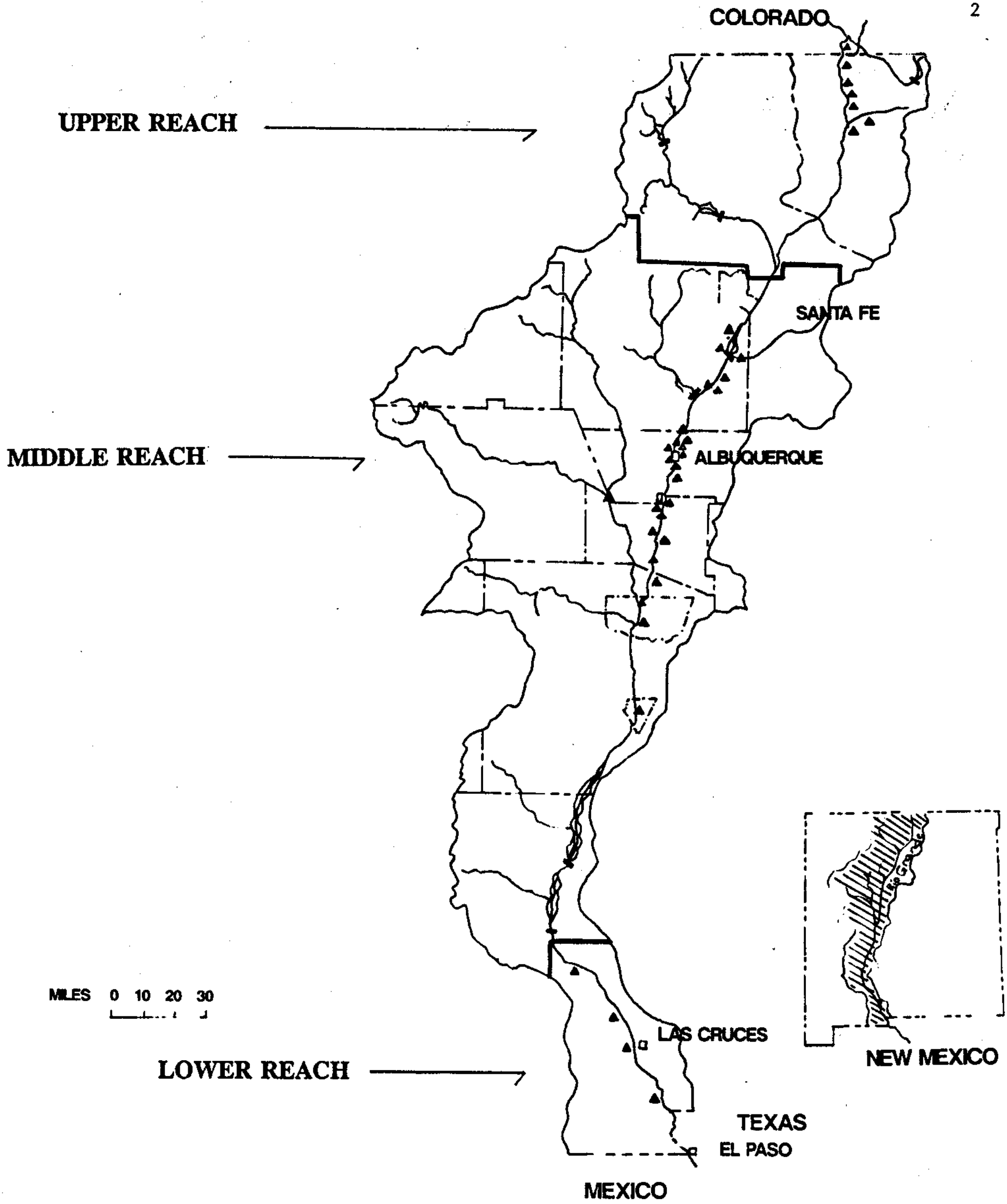

Figure 1: Rio Grande River, New Mexico

1. Border Gauge
2. Costilla Creek
3. Cow Patty
4. Lee Trail
5. Sheep Canyon
6. Upstream Red River Hatchery
7. Upstream Red River Hatchery Div.
8. Red River Pass
9. Downstream Red River Hatchery
10. Red River/Rio Grande Confluence
11. NM HWY 3 Bridge
12. Downstream Red River
13. El Aujae Campground

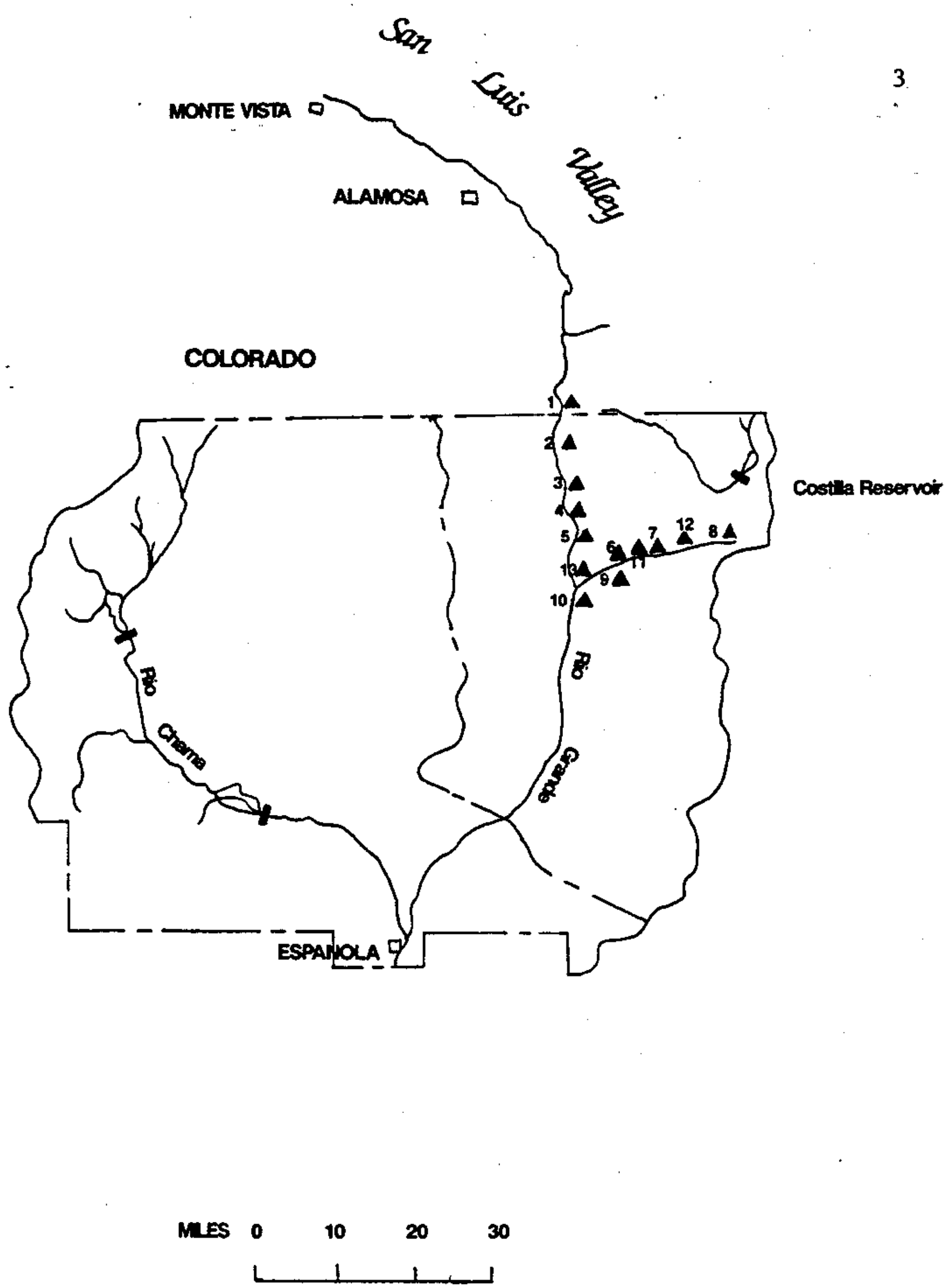

Figure 2: Upper Rio Grande Site Locations

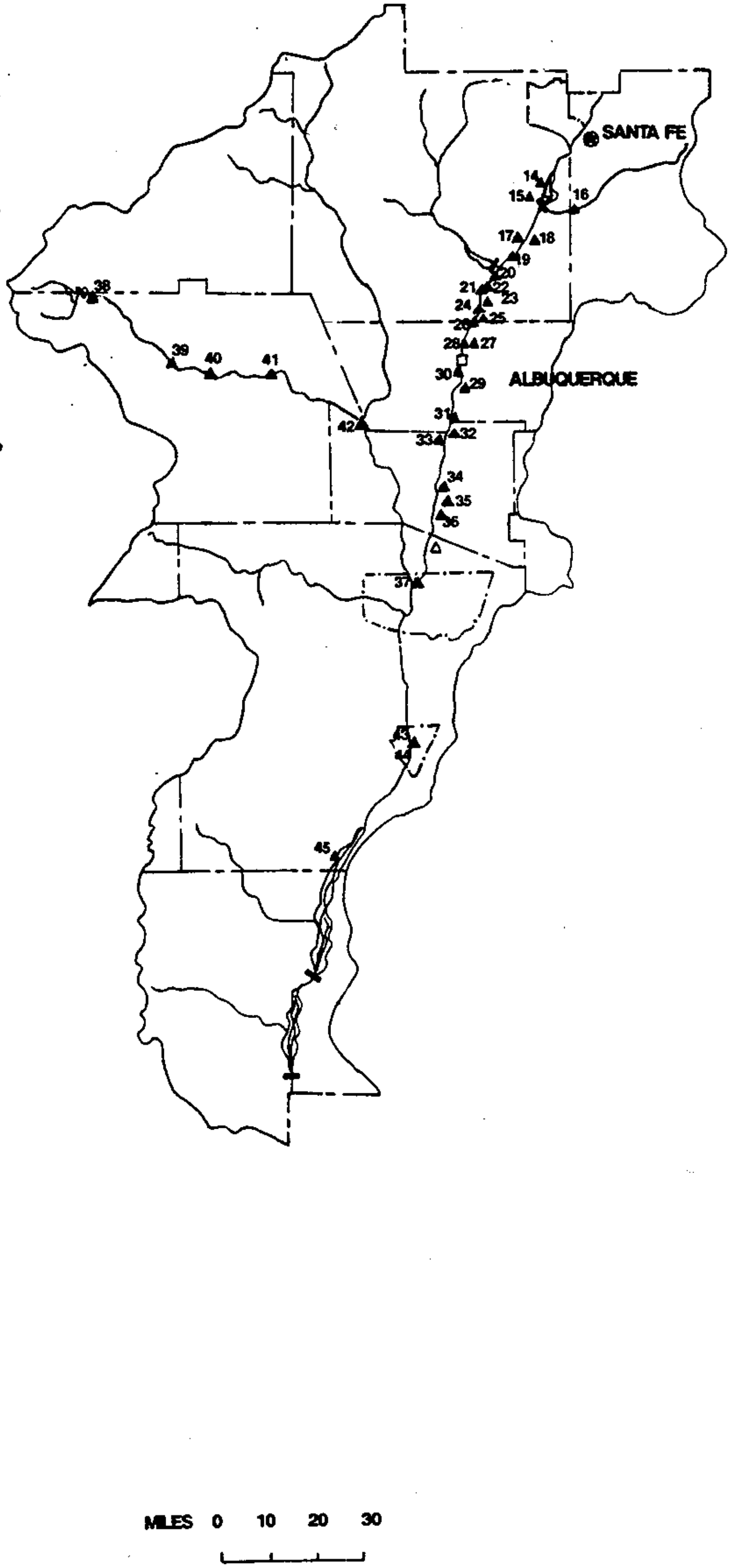

Figure 3: Middle Rio Grande Site Locations

46. Hatch

47. Radium Springs

48. West Las Cruces

49. Stahman Farms

50. Chamberino

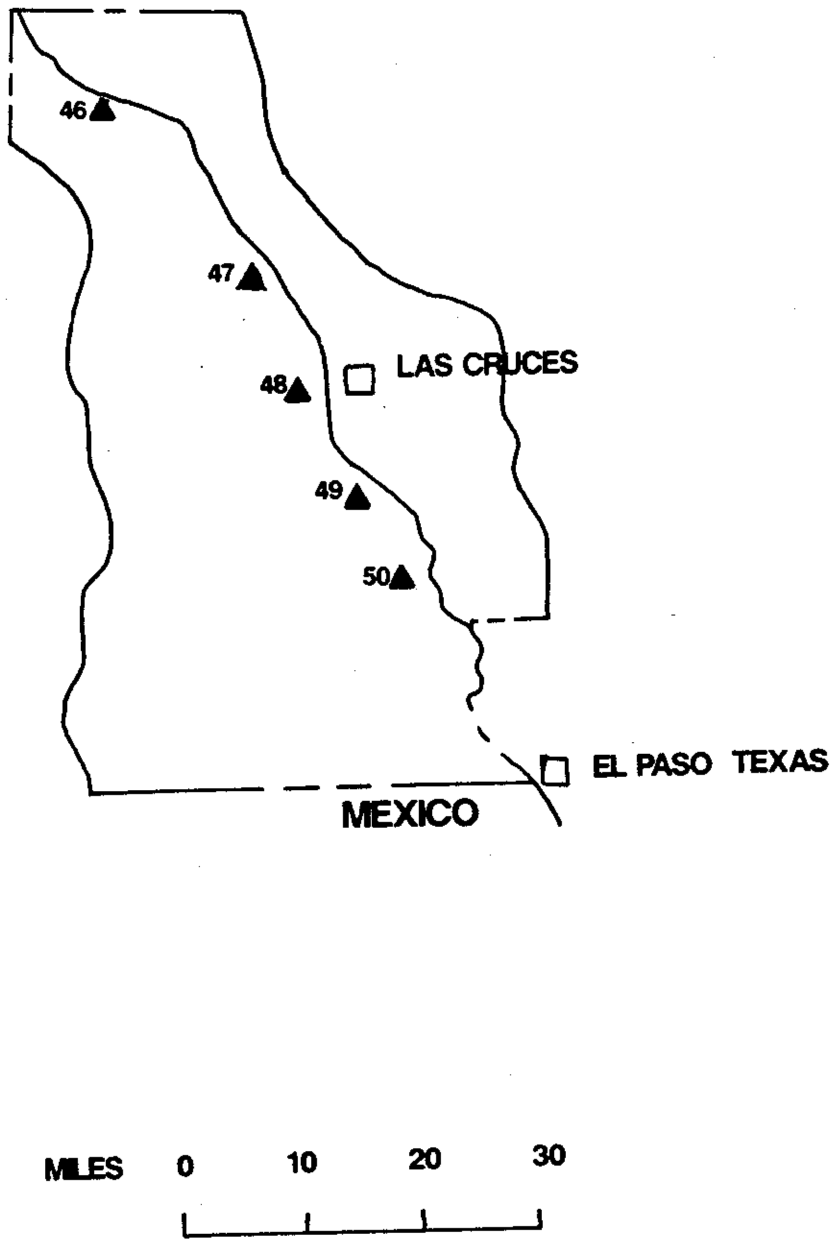

Figure 4: Lower Rio Grande Site Locations

The Red River joins the Rio Grande in the Wild and Scenic portion of the study reach. The Red River has been severely impacted by past and current mining. The river is managed by the New Mexico Department of Game and Fish as a coldwater fishery; and a fish hatchery operated by the New Mexico Department of Game and Fish is located on the Red River downstream from the molybdenum mines. Depending upon location in the Red River, copper, aluminum, cadmium, lead, silver, and zinc have been detected at acutely toxic concentrations in water (NMWQCC 1990). In addition, chromium and nickel have been detected at chronically toxic concentrations (NMWQCC 1990).

In the Middle Rio Grande (Middle study reach) contaminants may enter the river from several sources. These include irrigation return flows, industrial discharges, wastewater treatment facilities, and urban runoff. In the South Valley of Albuquerque, the microchip and petroleum industries are suspected of contributing organic and inorganic contaminants, polychlorinated biphenyls (PCBs), petroleum hydrocarbons, and heavy metals, to the groundwater. Copper and zinc have been found at acutely chronic concentrations, and cadmium, lead, zinc, mercury, iron, aluminum, and chlordane have been detected at chronically toxic concentrations in water from this reach of the river (NMWQCC 1990).

The Middle study reach supports a warmwater fishery and, to some extent, a coldwater fishery. In addition, the Category 1 candidate Rio Grande silvery minnow (Hybognathus amarus) is found within this reach. The Middle study reach also winters an estimated 60,000 snow geese, 30,000 ducks, 12,000 sandhill cranes, and countless shore and songbirds.

Especially important are the wintering populations of the Federally endangered bald eagle (Haliaeetus leucocephalus), peregrine falcon (Falco peregrinus anatum), and experimental population of the whooping crane (Grus americana) at Bosque del Apache National Wildlife Refuge.

In the Hatch-Mesilla Valley (Lower study reach), the major agricultural crops are chili peppers and cotton. Depending upon flows, the Percha Diversion Dam may divert all water in the river for irrigation purposes. Contaminants such as trace elements and agricultural chemicals may leach from the soils and enter the Rio Grande from irrigation return flows. Pesticides used to control boll weevils in cotton are of major concern. In the past, DDT and toxaphene were extensively employed for weevil control. In this reach, iron, silver, mercury, and lead have been detected in water at chronically toxic concentrations (NMWQCC 1990).

MATERIALS AND METHODS:

Whole sediment samples from riverine locations were collected in depositional areas with a stainless steel spoon. The sediment was placed in a stainless steel bowl and coarse materials such as leaves, twigs, and pebbles were removed. Sediment was then mixed thoroughly and placed in an acid-rinsed borosilicate jar on ice until frozen. Sediment samples from ponds, lakes, and wetlands were collected with a stainless steel Eckman dredge.

Fish samples were collected by electrofishing or seine. Under most circumstances, fish of the same species and size were composited in groups of at least three individuals. Whole fish to be analyzed for inorganic compounds were placed in plastic bags on ice until frozen. Fish samples to be analyzed for organochlorine compounds were handled in a similar manner, except they were wrapped in aluminum foil.

Invertebrates were collected primarily by seining and picking through aquatic vegetation, then composited. Whole-body invertebrate samples were placed in plastic bags and stored on ice until placed in a freezer.

Migratory birds were collected by shotgun with steel shot. Liver samples to be analyzed for inorganic compounds were placed in plastic bags. Carcasses (sans skin, feathers, feet, and viscera) to be analyzed for organochlorine compounds were individually wrapped in aluminum foil and stored on ice until placed in a freezer.

Exception for arsenic, mercury, and selenium, inorganic constituents were analyzed by Inductively Coupled Plasma Emission Spectroscopy (ICP). Mercury was analyzed by Cold Vapor Atomic Absorption (CVAA), and arsenic and selenium were analyzed by Hydride Generation Atomic Absorption (HGA). Organochlorine compounds were analyzed by Gas Chromatography (GC).

INORGANIC RESULTS:

Twenty-three elements were analyzed, but only the results of nine will be presented in detail. The purpose for this approach is to discuss those elements which were considered to be the appropriate indicators of the health of the environment, or were of concern because of their demonstrated toxicities to fish and wildlife. The results of the inorganic analysis for sediments are qualitatively compared to Shacklette and Boerngen (1984) and Ingersoll and Nelson (1990). When applicable, the results of the organic/inorganic analyses of fish are qualitatively compared to the National Contaminant Biomonitoring Program (NCBP) for years 1981-1984 (Schmitt and Brumbaugh 1990, Schmitt et al. 1990). The reader should be cautious in comparing the results of chemical analysis between river reaches presented in this report because the samples were not collected the same year and because fish species change dramatically between reaches. The reader should also exercise caution in comparing results of chemical analysis of fish in this report to the NCBP because of species differences. This report also provides some background chemical and toxicological information on the subject elements and compounds that may be useful to the reader.

ALUMINUM: Aluminum is one of the most abundant metals in the earth's crust and is ubiquitous in air, water, and soil (Goyer 1986). In humans, aluminum is known to affect the absorption of nutrients in the gastrointestinal tract and to cause cardiopulmonary disease and, of increasing concern, a form of dementia resembling Alzheimer's Disease (Goyer 1986). Unfortunately, very little is known regarding the toxicity of aluminum to fish and wildlife.

Aluminum appears to be most toxic to aquatic species during episodes of reduced pH, i.e., acid precipitation and snowmelt events (Kane and Rabeni 1987, McKee et al. 1989, Cleveland et al. 1986). During acid pulse events, aluminum compounds present in water, sediment, or soil are mobilized and precipitation-dissolution of the compounds occurs, resulting in increased concentrations and bioavailability of free Al+3 in water. The decrease in pH and the resulting increase of Al+3 have been noted to cause skeletal abnormalities and reduced growth and activity in fish from soft water systems (Kane and Rabeni 1987). Additionally, low pH causes mortality by failures in the ion regulation and/or respiratory systems (Kane and Rabeni 1987, Baker and Schofield 1982).

Acid deposition is not the only factor responsible for the mobilization of aluminum in aquatic ecosystems. Aluminum, in the form of aluminum sulphate is present in mine tailings and spoil. Runoff from snowmelt and precipitation reacts with the water to produce sulfuric acid and to free aluminum ions (Ramade 1987). There is no published information available revealing at what body burden concentration aluminum becomes toxic to an organism.

PREDATOR PROTECTION LIMIT: There is no known published predator protection level for aluminum.

SEDIMENT GRADIENT MONITORING: (Dry Weight) There was a slight increase in mean aluminum concentrations in sediment between the Upper and Middle study reaches (Table 1). The maximum concentration of aluminum in sediment from the Upper study reach (19,100 ug/g) was from the Red River/Rio Grande confluences (Site 12). The maximum concentration in the Middle study reach (30,600 ug/g) was from the Santa Fe Marsh (Site 14). According to Shacklette and Boergen (1984), baseline concentrations of aluminum in western soils are 1.5 to 23 percent of the mineral content of western soils (15,000 to 230,000 ug/g dry weight). Based on this information, it appears that aluminum concentrations in sediments throughout the Rio Grande are not elevated.

Table 1. Aluminum concentrations in whole sediment from the Upper, Middle, and Lower study reaches (ug/g dry weight).

	MIN	MEAN	MAX
UPPER	3.8	4,029	19,100
MIDDLE	2.3	5,393	30,600
LOWER	1,960	3,834	5,770

FISH GRADIENT MONITORING: (Wet Weight) Aluminum was not analyzed in fish collected for the NCBP; therefore, the analytical results of aluminum in fish from this report will be qualitatively compared between the Upper, Middle, and Lower study reaches. Mean concentrations of aluminum were lower in fish from the Upper study reach compared to the Middle and Lower study reaches (Table 2). The maximum concentration of aluminum in fish (364.3 ug/g) was from a Rio Grande silvery minnow sample collected from the Alameda Drain (Site 25).

Table 2. Aluminum concentrations in whole-body fish samples from the Upper, Middle, and Lower study reaches (ug/g wet weight).

	MIN	MEAN	MAX
UPPER	0.45	31.1	148.0
MIDDLE	0.38	51.7	364.3
LOWER	12.0	48.0	203.0

ARSENIC: Arsenic is ubiquitous in the environment and is associated with sulfide deposits of iron, nickel, cobalt, lead, and pyritic shales (Woolson 1975, Dudas 1984). Arsenic is primarily transported in the environment by water. Airborne arsenic is usually generated from industrial sources, i.e., mining, smelting, and combustion of fossil fuels (Goyer 1986). Arsenic has a complex chemistry and forms many compounds; it may be found in trivalent or pentavalent forms, or as a trivalent anion under low Eh conditions. In water, arsenic is usually in the form of inorganic compounds such as arsenic trioxide, sodium arsenite, or arsenic trichloride. However, the oxidation state of arsenic in water is dependent upon pH and Eh (redox potential). Arsenic may also be found in organic forms resulting from the reduction of arsenate, arsenite, and methylation of arsenic (methylarsine, methanearsonic acid, dimethylarsonic acid) by microorganisms present in marine and freshwater sediments and soils (Goyer 1986, Riedel et al. 1987).

The transport of arsenic in the environment is largely controlled by the adsorption and desorption processes in soils and sediments. The clay fraction of the sediment and the presence of ferrous and aluminum oxides that coat the clay particles are important constituents in the arsenic adsorption process along with pH, alkalinity, and organic matter (Menzer and Nelson 1986, U.S. Environmental Protection Agency, EPA, 1980a). Arsenic concentrations are usually much lower in water than in sediment. Seydel (1972) found that in Lake Michigan the concentration of arsenic in water ranged from 0.5 to 2.3 ug/l, sediment concentrations ranged from 7.2 to 28.8 mg/kg.

Bioaccumulation of arsenic species along the food chain is not common. However, in some forms of seaweeds, freshwater algae, and crustaceans, significant amounts of arsenic may be accumulated. This phenomenon is especially common in crabs, lobsters, and, to some extent, algae and Daphnia magna (Menzer and Nelson 1986). Background concentrations of arsenic in flora and fauna (terrestrial and aquatic) are usually <1 mg/kg (Menzer and Nelson 1986). However, marine organisms (sea catfish, oysters, crabs) may have concentrations of 2 to 5 mg/kg and up to 100 mg/kg (Eisler 1988a, Lunde 1977, Gamble et al. 1989).

Toxicities of arsenic compounds are positively correlated with their solubilities in water and body fluids. Arsines, inorganic arsenites, and organic trivalent compounds (arsenoxides) are the most toxic; the insoluble elemental form of arsenic is least toxic (Woolson 1975, National Research Council of Canada 1978, Pershagen and Vahter 1979, Eisler 1988a).

PREDATOR PROTECTION LEVEL: (Wet Weight) Walsh et al. (1977) considered arsenic concentrations above 0.5 ug/g (whole-body) to be potentially harmful to predatory species of fish and wildlife.

NCBP 1984: (Wet Weight) The whole-body geometric mean concentration of arsenic in fish was 0.14 ug/g. The 85th percentile whole-body concentration in fish was 0.38 ug/g (Schmitt and Brumbaugh 1990).

SEDIMENT GRADIENT MONITORING: (Dry Weight) Mean arsenic concentrations in sediments were highest in the Middle and Upper study reaches (Table 3). The maximum concentration (5.40 ug/g) was from a sediment sample collected from Pond 11C, Bosque del Apache National Wildlife Refuge (Site 44). According to Shacklette and Boerngen (1984), the baseline concentration of arsenic in western soils ranges from 1.2 to 22 ug/g dry weight. Sediments with arsenic concentrations with less than 3.0 ug/g dry weight are typical of "non-polluted" sites (Ingersoll and Nelson 1990). Based on these data, it appears that sediments in the Rio Grande do not approach concentrations considered indicative of widespread or severe contamination.

Table 3. Arsenic concentrations in whole sediment from the Upper, Middle, and Lower study reaches (ug/g dry weight).

	MIN	MEAN	MAX
UPPER	1.80	2.79	4.50
MIDDLE	1.30	3.16	5.40
LOWER	0.76	1.25	2.09

FISH GRADIENT MONITORING: (Wet Weight) Fish from the Middle study reach had arsenic concentrations considerably higher than either the Upper or Lower study reach (Table 4). The maximum concentration (5.00 ug/g) was from a carp (*Cyprinus carpio*) sample collected from Alameda (Site 25). Of the 43 whole-body fish samples collected from the Middle study reach, 20 had arsenic concentrations above the NCBP 85th percentile concentration. Based on this information, it appears that fish in the Middle study reach are accumulating arsenic to higher levels than fish in other portions of the reach and nationwide.

Table 4. Arsenic concentrations in whole-body fish from the Upper, Middle, and Lower study reaches (ug/g wet weight).

	MEAN	85th	MAX
UPPER	0.13	0.30	0.75
MIDDLE	0.56	1.39	5.00
LOWER	0.04	0.07	0.10

CADMIUM: Cadmium deposits are found as sulfides with zinc, copper, and lead deposits. Cadmium is a by-product of the smelting processes for these metals, and this action is a major source of local cadmium contamination of soil and water. Natural soil cadmium concentrations are less than 1 ug/g and average 0.04 ug/g (Menzer and Nelson 1986). Natural concentrations of cadmium in freshwater are usually less than 1 ug/kg (Fleischer et al. 1974). Higher concentrations of cadmium in surface waters or soils are usually indicative of contamination from metallurgical industries, plating operations, cadmium pigments, batteries, plastics manufacturing, sewage effluent, phosphate fertilizers, mining, or naturally occurring deposits (Menzer and Nelson 1986). Meats, fish, and fruits usually contain 1 to 50 ug/kg, grains contain 10 to 50 ug/kg, and shellfish such as mussels, scallops, and oysters typically contain from 100 to 1000 ug/kg (Frazier 1979).

In the aquatic environment, the bioavailability of cadmium is dependent upon many factors. Materials such as humic and fulvic acids are probably the major components responsible for the transport of cadmium in natural waters. These acids have the ability to control the concentration, solubility, and toxicity of cadmium through the adsorption-desorption process. However, changes in pH and Eh in water and sediment will also cause cadmium to become more or less mobile. Under saline water conditions, cadmium readily complexes with chlorine to form highly soluble chlorocadmium. The presence of the chloride ion can increase the solubility of cadmium 110 times. The discharge of wastewater into marine environments, or into bodies of water that are saline, may cause increased amounts of cadmium to become dissolved in the water column and increase its bioavailability (Snoeyink and Jenkins 1980, Eisler 1985a).

Cadmium is one of the most readily absorbed and accumulated heavy metals in plants. Cadmium contamination in vegetation is a serious concern that has impeded the use and disposal of domestic sewage sludge on agricultural lands (Menzer and Nelson 1986). Cadmium contamination of rice fields from mine tailings in Japan has been responsible for outbreaks of Itai-Itai (ouch-ouch) disease in humans. The victims consumed cadmium-enriched rice. The cadmium inhibited calcium metabolism resulting in skeletal deformities and accompanying bone pain and renal disease (Nomiyama 1980, Goyer 1986).

PREDATOR PROTECTION LEVEL: (Wet Weight) Walsh et al. (1977) considered whole-body concentrations above 0.5 ug/g in biota to be potentially harmful to predatory species of fish and wildlife.

NCBP 1984: (Wet Weight) The geometric mean whole-body concentration of cadmium in fish was 0.03 ug/g. The 85th percentile concentration was 0.05 ug/g (Schmitt and Brumbaugh 1990).

SEDIMENT GRADIENT MONITORING: (Dry Weight) There was a decrease in mean cadmium concentrations in sediment from the Upper to the Lower study reach (Table 5). The maximum concentration detected was from Red River Pass (Site 6). Shacklette and Boerngen (1984) did not establish baseline concentrations of cadmium in western soils. However, the authors did report that the observed range was 0.020 to 0.18 ug/g. Sediments with cadmium concentrations greater than 6.0 ug/g are considered to be "heavily polluted" (Ingersoll and Nelson 1990). Although several sediment samples were collected that contained extraordinary cadmium concentrations, it does not appear that cadmium contamination of sediments in the Rio Grande is widespread.

Table 5. Cadmium concentrations in whole-sediment from the Upper, Middle, and Lower study reaches (ug/g dry weight).

	MIN	MEAN	MAX
UPPER	0.15	2.72	9.85
MIDDLE	0.10	1.81	8.91
LOWER	0.10	0.14	0.30

FISH GRADIENT MONITORING: (Wet Weight) A decrease in mean cadmium concentrations in fish was noted from the Upper to the Lower study reach (Table 6). The maximum concentration detected in fish was 0.28 ug/g in a brown trout (*Salmo trutta*) sample from Upstream Red River Hatchery Diversion (Site 9). When compared to the NCBP, fish from the Upper study reach contain elevated concentrations of the element.

Table 6. Cadmium concentrations in whole-body fish samples from the Upper, Middle, and Lower study reaches (ug/g wet weight).

	MEAN	85th	MAX
UPPER	0.08	0.16	0.28
MIDDLE	0.03	0.05	0.15
LOWER	0.02	0.03	0.05

CHROMIUM: Information regarding the environmental chemistry of chromium is sparse; even less is known regarding the amount of chromium in the environment and its effect upon organisms. Chromium in nature is usually found in the more stable +3 (trivalent) and +6 (hexavalent) oxidation states. Trivalent chromium is found naturally in most biological material. On the other hand, hexavalent chromium is usually formed as a result of industrial emissions (Eisler 1986). The major sources of chromium in the environment are the result of electroplating industries, phosphate fertilizers, urban runoff, oil recovery fluid wastes, textile manufacturing, tanning, and paint manufacturing (Eisler 1986, Ramade 1987, Goyer 1986).

The toxicity of chromium is dependent upon its oxidation state, pH, hardness, salinity, alkalinity, and temperature with hexavalent chromium being the most toxic. Additionally, chromium toxicity is species-and age class-dependent. The bioavailability of chromium is also dependent upon pH, Eh, adsorption/desorption processes, and the amount of humic material. Under toxic aquatic conditions, hexavalent chromium is the most common element, and it forms several highly soluble complexes such as chromate, hydrochromate, and dichromate (Eisler 1986). Chromium +6 is also known to be mutagenic, carcinogenic, and teratogenic to many life forms (Goyer 1986).

PREDATOR PROTECTION LIMIT: (Wet Weight) The only known published predator protection limit for chromium is 0.20 mg/kg (Eisler 1986).

NCBP 1981-84: Chromium was not analyzed in fish for the NCBP.

SEDIMENT GRADIENT MONITORING: (Dry Weight) There was a dramatic decrease in mean chromium concentrations in sediments from the Upper to the Lower study reach (Table 7). The maximum concentration detected was 41.90 ug/g from Red River Pass (Site 6). According to Shacklette and Boerngen (1984), the baseline concentration of chromium in western soils is 8.5 to 200 ug/g. Sediments with chromium concentrations of greater than 75 ug/g are considered to be "heavily polluted" (Ingersoll and Nelson 1990). Based on this information, it does not appear that sediments in the Rio Grande contain elevated concentrations of chromium.

Table 7. Chromium concentrations in whole-sediment from the Upper, Middle, and Lower study reaches (ug/g dry weight).

	MIN	MEAN	MAX
UPPER	7.80	23.73	41.90
MIDDLE	3.00	15.22	34.00
LOWER	2.00	5.82	12.01

FISH GRADIENT MONITORING: (Wet Weight) The highest mean concentrations of chromium in fish were found in samples from the Upper study reach (Table 8). The maximum concentration (2.30 ug/g) detected was in a long-nosed dace (*Rhinichthys cataractae*) sample from Border Gauge (Site 1). The majority of the chromium concentrations in the fish samples in the Rio Grande were below the Recommended Predator Protection Level. Although some samples did exceed this criterion, it does not appear that widespread chromium contamination was present.

Table 8. Chromium concentrations in whole-body fish from the Upper, Middle, and Lower study reaches (ug/g wet weight).

	MIN	MEAN	MAX
UPPER	ND	0.33	2.30
MIDDLE	0.05	0.14	0.26
LOWER	0.10	0.23	0.68

COPPER: Copper is widespread in the environment and is an essential nutrient and a major component of several enzymes such as tyrosinase, cytochrome oxidase, and amine oxidase. In aquatic environments, its toxicity and mobility are controlled by pH, alkalinity, and the amount of clay and organic matter present. Soluble copper readily complexes with humic materials, carbonate, cyanide, and amino acid complexes present in natural and treated waters. Organic detrital material tends to bind copper and transfers it from the soluble to particulate form. Therefore, under most aquatic conditions, little of the copper present in water is in the highly toxic Cu +2 (cupric) form. Under soft water conditions, copper (Cu +2) is considered most toxic to fish and other aquatic organisms. Given the fact that copper readily complexes with other toxic substances such as cyanide, there is great potential for synergistic or additive effects resulting in drastically increased toxicity for aquatic life (Snoeyink and Jenkins 1980, Goyer 1986, EPA 1980b).

Copper contamination of aquatic environments is usually associated with urban runoff, industrial discharges, landfills, and wastewater treatment plants. Mining is also a large contributor of copper contamination, as can be seen throughout the State of New Mexico. Copper is considered a priority pollutant by the EPA. Copper also reacts additively or synergistically with other toxic heavy metals such as cadmium, mercury, and zinc. Fish and other aquatic organisms accumulate copper from ingesting contaminated food and directly from sediment-bound or suspended copper (EPA 1980b, Schnieder 1971, Herbert and Van Dyke 1964, Irwin 1988). However, copper does not appear to bioconcentrate at high levels in the edible portions of freshwater aquatic organisms. Additionally, closely related species have extremely variable tolerances to copper (EPA 1980b).

PREDATOR PROTECTION LIMIT: (Wet Weight) There is no known published predator protection limit for copper.

NCBP 1981-84: (Wet Weight) The geometric mean whole-body concentration of copper in fish was 0.65 ug/g. The 85th percentile concentration was 1.00 ug/g (Schmitt and Brumbaugh 1990).

SEDIMENT GRADIENT MONITORING: (Dry Weight) Mean copper concentrations in sediments dropped dramatically from the Upper to the Lower study reach (Table 9). The maximum concentration (96.50 ug/g) was from New Mexico Highway 3 bridge (Site 8). According to Shacklette and Boerngen (1984), baseline concentrations of copper in western soils is 4.9 to 90 ug/g. Sediments with copper concentrations greater than 60 ug/g are considered to be "elevated" (Ingersoll and Nelson 1990). With the exception of Site 8, it appears that sediments in the Rio Grande are not contaminated by copper.

Table 9. Copper concentrations in whole-sediment samples from the Upper, Middle, and Lower study reaches (ug/g dry weight).

	MIN	MEAN	MAX
UPPER	6.70	33.78	96.50
MIDDLE	4.50	13.45	37.20
LOWER	3.21	5.62	8.90

FISH GRADIENT MONITORING: (Wet Weight) Mean concentrations of copper in fish were highest in fish from the Lower and Upper study reaches (Table 10). The maximum concentration (6.14 ug/g) was found in carp from Hatch (Site 50). However, when compared to the NCBP, copper contamination in fish was considerably elevated throughout the study area. These data indicate that fish in the Rio Grande are accumulating copper to higher levels than fish nationwide.

Table 10. Copper concentrations in whole-body fish from the Upper, Middle, and Lower study reaches (ug/g wet weight).

	MEAN	85th	MAX
UPPER	1.78	2.87	4.72
MIDDLE	1.52	2.13	3.40
LOWER	2.26	4.06	6.14

LEAD: Lead is the most ubiquitous toxic metal in the environment and is detected in practically all phases of the biological and nonbiological system. Therefore, the issue of concern for lead is at what point is it toxic to living organisms (Goyer 1986)? The major sources of lead are auto exhausts, industrial emissions, inorganic and alkyl lead additives present in gasoline, and mining and smelting. Fallout from auto emissions is considered to be the primary source of lead contamination. Lead eventually makes its way into the aquatic environment from urban runoff or from fallout of insoluble precipitates; it then becomes incorporated in the sediments (Menzer and Nelson 1986). According to the National Academy of Sciences (1972), typical freshwater concentrations of lead are from 1 to 10 ug/l. Concentrations in soils are usually around 10 to 15 ug/g, but can range from 2 to 200 ug/g.

In aquatic systems, lead may adsorb to such ligands as carbono- and hydroxo-complexes at medium to high pH. Like most other metals, lead will also adsorb to clays or complex with organic molecules. These processes can result in the deposition of suspended lead into the sediments or transport lead to other areas within the aquatic system (Snoeyink and Jenkins 1980). Lead is more soluble and mobile, thus more bioavailable and toxic, under softwater and low pH conditions (EPA 1980c, Eisler 1988b).

Lead is readily bioconcentrated, though not biomagnified, by terrestrial and aquatic lower and higher plant species, invertebrates, reptiles and amphibians, fish, rodents, and birds. However, lead tends to concentrate in scales, bone, skin, and hair rather than in muscle tissue (Schmitt and Finger 1987). High lead levels in organisms are usually an indication of a nearby source of lead (roadways, wastewater treatment plants, smelters, and mines). Organic lead (alkyllead compounds) are thought to be more toxic than inorganic lead compounds (Eisler 1988b).

PREDATOR PROTECTION LIMIT: (Wet Weight) The only known predator protection limit for lead is 0.30 ug/g (Eisler 1988).

NCBP 1981-84: (Wet Weight) The geometric mean whole-body concentration of lead in fish was 0.11 ug/g. The 85th percentile concentration was 0.73 ug/g.

SEDIMENT GRADIENT MONITORING: (Dry Weight) Mean concentrations of lead in sediment decreased from the Upper to the Lower study reach (Table 11). The maximum concentration (183.0 ug/g) was from the Upstream Red River hatchery (Site 9). According to Shacklette and Boerngen (1984), baseline concentrations of lead in western soils are 5.2 to 55 ug/g. Sediments with concentrations of lead greater than 60 ug/g are considered to be "heavily polluted" (Ingersoll and Nelson 1990). With the exception of the sediment sample from Site 9, it appears that the sediments in the Rio Grande do not contain elevated levels of lead.

Table 11. Lead concentrations in whole-sediment from the Upper, Middle, and Lower study reaches (ug/g dry weight).

	MIN	MEAN	MAX
UPPER	2.50	23.38	183.00
MIDDLE	2.00	7.93	41.00
LOWER	3.00	5.60	10.00

FISH GRADIENT MONITORING: (Wet Weight) The detection limits of lead in fish were too insensitive to determine the trends in the reaches and for comparison to the NCBP.

MERCURY: Mercury's major source is in naturally occurring deposits. However, mining, smelting, industrial discharges, petroleum industry, combustion of fossil fuels, fungicides, and the paper pulp industry have become important sources of organic and inorganic mercury compounds (Goyer 1986). Mercury may be found in nature in elemental form as inorganic or organic compounds. According to Eisler (1987), most authorities agree on these major points: mercury or any of its compounds have no demonstrated biological function and the mere presence of mercury in biological tissue is potentially hazardous; mercury can be bioconcentrated and biomagnified through food chains; mercury is carcinogenic, mutagenic, and teratogenic; and relatively nontoxic forms of mercury may be transformed by biological or chemical reactions to form highly toxic mercury compounds, i.e., methylmercury.

Methylmercury is considered to be the most abiological form of mercury because it is very stable, highly lipophilic, and readily passes through tissue membranes such as placental membranes (Birge et al. 1979, Beijer and Jernelov 1979, Elhassani 1983, Clarkson and Marsh 1982). Schmitt and Finger (1987) stated that mercury is one of the few heavy metals that tends to concentrate in the axial muscles (edible portions) of fish.

The most important variable influencing the toxicology of mercury is chemical speciation (Boudou and Ribyre 1983). In the aquatic environment under natural conditions, mercury can take the form of Hg(OH)2, Hg+2, HgCl+, or form organic complexes such as CH3Hg+ and (CH3)2Hg (Beijer and Jernelov 1979). The mercury methylation process in the aquatic environment is dependent upon mercury loading, microbial activity, nutrient content, pH, and Eh (National Academy of Sciences 1978 in Eisler 1987).

Probably the best example of mercury contamination and poisoning occurred in the 1950's in Minimata Bay, Japan. Metallic and organomercuric compounds were discharged from industry into the bay and the Agano River. The mercury eventually bioaccumulated into edible fish species to levels as high as 11 mg/kg (Goyer 1986). Fishermen and their families were most affected by the mercury poisoning sickness which eventually was named Minimata Disease. The victims suffered from sensory impairment and altered physical and mental development (Eisler 1987). Doi et al. (1984) reported that spontaneously poisoned cats, dogs, wild birds, and pigs began to behave erratically and died soon after consuming fish from the bay.

PREDATOR PROTECTION LIMIT: (Wet Weight) The most recent mercury level recommended for the protection of predatory species of fish and wildlife is 0.1 ug/g (Eisler 1987).

NCBP 1984: (Wet Weight) The geometric mean whole-body concentration of mercury in fish was 0.1 ug/g. The 85th percentile concentration was 0.17 ug/g (Schmitt and Brumbaugh 1990).

SEDIMENT GRADIENT MONITORING: (Dry Weight) Sediment samples throughout the Rio Grande typically had mercury concentrations less than or equal to 0.02 ug/g (Table 12). The maximum concentration (0.14 ug/g) was from the Rio Grande at San Felipe Pueblo (Site 18). According to Shacklette and Boerngen (1984), the baseline concentration of mercury in western soils is 0.0085 to 0.25 ug/g. Sediment concentrations of mercury above 1.0 ug/g are considered to be "heavily polluted" (Ingersoll and Nelson 1989). Based on this information, it appears that sediments in the Rio Grande are not contaminated with mercury.

Table 12. Mercury concentrations in whole-sediment samples from the Upper, Middle, and Lower study reaches (ug/g dry weight).

	MIN	MEAN	MAX
UPPER	0.01	0.03	0.10
MIDDLE	0.01	0.04	0.14
LOWER	0.02	0.02	0.03

FISH GRADIENT MONITORING: (Wet Weight) There appears to have been little change in mean mercury concentrations in fish between reaches (Table 13). The maximum concentration (0.2017 ug/g) detected was from a composite of eight brown trout (Salmo trutta) from Border Gauge (Site 1). Although there are several samples of fish that contained elevated concentrations of mercury when compared to the NCBP, these data indicate that mercury contamination of fish is not widespread in the Rio Grande.

Table 13. Mercury concentrations in whole-body fish from the Upper, Middle, and Lower study reaches (ug/g wet weight).

	MEAN	85th	MAX
UPPER	0.06	0.12	0.20
MIDDLE	0.08	0.13	0.20
LOWER	0.06	0.09	0.11

SELENIUM: Selenium is chemically very similar to sulfur and, in fact, many of its compounds are analogous to organic and inorganic sulfur compounds (Handbook of Chemistry and Physics. 69th Ed.). Selenium occurs naturally in the environment at trace amounts rarely exceeding 2 ug/kg in soil. An exception is soils formed by the weathering of sedimentary rocks. Selenium is also found in association with sulphide ores of heavy metals such as silver, copper, and mercury (Girling 1984). Anthropogenic sources of selenium are the electronics industry, drainage of alkaline agricultural land, smelting, and wastewater involved in the recovery and combustion of fossil fuels (Lemly and Smith 1987).

In the aquatic environment, selenium exhibits varying degrees of solubility, mobility, and toxicity. Elemental selenium is relatively nonreactive in water, insoluble, and nontoxic. However, selenate, the most oxidized form of selenium, is highly soluble and mobile, is most common in highly oxygenated and alkaline waters, and is highly toxic (Deverel et al. 1987, Deverel and Millard 1986). The amount of organic matter, pH, Eh, clay content of soils and sediment, suspended solids, and microbial activity all play a role in the mobilization of selenium (Lemly and Smith 1987, Sharma and Singh 1984). Selenium also tends to bioconcentrate in the axial muscles of fish (Eisler 1985b).

PREDATOR PROTECTION LEVEL: (Dry Weight) Lemly and Smith (1987) stated that whole-body concentrations of selenium greater than 3.0 ug/g in waterfowl food items and greater than 5.0 ug/g in fish food items may cause reproductive impairment or death in either group due to food chain bioconcentration. They also stated that whole-body concentrations greater than 12.0 ug/g in fish may cause reproductive failure in fish.

NCBP 1984: (Wet Weight) The geometric mean whole-body concentration of selenium in fish was 0.42 ug/g. The 85th percentile concentration was 0.73 ug/g (Schmitt and Brumbaugh 1990).

SEDIMENT GRADIENT MONITORING: (Dry Weight) Mean selenium concentrations decreased from the Upper to the Lower study reach (Table 14). The maximum concentration (1.20 ug/g) was from Rio San Jose below Horace Springs (Site 38). Shacklette and Boerngen (1984) stated that baseline concentrations of selenium in western soils are 0.039 to 1.4 ug/g. Based on this information, it does not appear that sediments in the Rio Grande are contaminated with selenium.

Table 14. Selenium concentrations in whole-sediment samples from the Upper, Middle, and Lower study reaches (ug/g dry weight).

	MIN	MEAN	MAX
UPPER	0.01	0.41	1.15
MIDDLE	0.05	0.33	1.20
LOWER	0.10	0.10	0.11

FISH GRADIENT MONITORING: (Wet Weight) Mean selenium concentrations in whole-body fish appeared to decrease from the Upper to the Lower study reach (Table 15). The maximum concentration (1.29 ug/g) was in red shiner (*Cyprinella lutrensis*) from Rio San Jose (Site 36). When compared to the NCBP, it appears that fish from the Upper study reach have slightly elevated concentrations of selenium.

Table 15. Selenium concentrations in whole-body fish from the Upper, Middle, and Lower study reaches (ug/g wet weight).

	MEAN	85th	MAX
UPPER	0.55	0.84	1.27
MIDDLE	0.36	0.58	1.29
LOWER	0.21	0.30	0.39

ZINC: Zinc is ubiquitous in the environment and is present in most food items (seafoods, meats, whole grains, dairy products, nuts, and legumes), air, and water. Zinc is a nutritionally essential metal and deficiencies may result in severe health consequences (Goyer 1986). According to the EPA (1980d), the environmental chemistry of zinc is similar to that of cadmium and in aqueous solution, zinc always has a valence +2. In acidic and neutral aquatic conditions, inorganic/organic zinc compounds are soluble, highly mobile, and readily transported by surface waters. In aquatic environments, zinc is portioned in the sediments by adsorbing to organic materials, clays, minerals, hydrous iron, and manganese oxides. The adsorption, transport, and fate of zinc in aquatic environments is regulated by pH, Eh, salinity, and availability of organic materials and other ligands.

Zinc is usually associated with urban runoff, sewage sludge, industrial discharges, soil erosion, and leachates from municipal landfills (EPA 1980d, Lu et al. 1982). Mining and smelting are additional sources of zinc contamination within New Mexico. High concentrations of zinc in aquatic environments have especially detrimental effects upon macroinvertebrates (Gore and Bryant 1986). The toxicity of zinc is dependent upon whether it is suspended or dissolved in the water column. Zinc can occur as the free zinc ion or as dissolved complexes and compounds with varying degrees of stability and toxicity. The toxicity of zinc is affected by chemical factors such as pH, hardness, and calcium. In fresh water, zinc appears to be less toxic as hardness increases. Bioconcentration of zinc is extremely species specific, e.g., the bioconcentration factor of zinc was 43 in the soft-shell clam and 500 for a mussel species (EPA 1980d).

PREDATOR PROTECTION LIMIT: There is no known published predator protection limit for zinc.

NCBP 1984: (Wet Weight) The geometric mean concentration of zinc in whole-body fish samples was 21.7 ug/g. The 85th percentile concentration was 34.2 ug/g (Schmitt and Brumbaugh 1990).

SEDIMENT GRADIENT MONITORING: (Dry Weight) Mean zinc concentrations in whole-sediment decreased markedly from the Upper to the Lower study reach (Table 16). The maximum concentration (494 ug/g) of zinc in sediments was from New Mexico Highway 3 bridge (Site 8). According to Shacklette and Boerngen (1984), the baseline concentration of zinc in western soils is 17-180 ug/g. Sediment concentrations of zinc above 200 ug/g are considered to be "heavily polluted" (Ingersoll and Nelson 1990). With the exception of Site 8, it appears that sediments in the Rio Grande are not contaminated with zinc.

Table 16. Zinc concentrations in whole-sediment from the Upper, Middle, and Lower study reaches (ug/g dry weight).

	MIN	MEAN	MAX
UPPER	51.90	159.61	494.00
MIDDLE	20.80	53.94	184.00
LOWER	15.00	25.00	31.00

FISH GRADIENT MONITORING: (Wet Weight) Concentrations of zinc in fish from throughout the Rio Grande are elevated above the NCBP for both mean and 85th percentile concentrations. The maximum concentration (83.21 ug/g) was found in carp from Sandia Pueblo/Angostura Diversion (Site 20). Based on this information, it appears that fish in the Rio Grande are bioconcentrating zinc to levels above fish nationwide.

Table 17. Zinc concentrations in whole-body fish from the Upper, Middle, and Lower study reaches (ug/g wet weight).

	MEAN	85th	MAX
UPPER	33.09	47.53	69.23
MIDDLE	33.42	52.69	83.21
LOWER	32.55	50.91	59.80

ORGANOCHLORINE RESULTS:

A total of 23 organochlorine compounds (Upper study reach) and 29 (Middle and Lower study reaches) which included organochlorine pesticides, their metabolites, and total PCBs were analyzed in sediment and biota. For the purposes of this report, only the results of sediment and fish will be discussed in detail. In addition, only p,-p'-DDE will be discussed because it was the only compound that was consistently detected throughout the Rio Grande. Of 1,313 and 2,707 organochlorine compound analyses of sediment and fish respectively, 99 percent of the analyses had nondetectable concentrations of organochlorine compounds in sediment and 87 percent had nondetectable concentrations in fish. The results of all other analyses are included in the Appendices A, B, and C.

P,P'-DDE: Para, para'-DDE (p, p'-DDE) is one of the several breakdown products of the highly persistent and lipophilic organochlorine pesticide DDT. The accumulation of this compound in fatty tissues is a detoxification mechanism to remove the chemical from sites of action in the central nervous system. This mechanism is the reason that relatively high concentrations of p, p'-DDE can accumulate in adipose tissue when ingested at low doses over a long period of time. In the environment, DDT and other organochlorine compounds readily biomagnify between trophic levels; and ultimately, top predatory species such as birds of prey accumulate the greatest concentrations in fatty tissues (Murphy 1986).

DDE has been documented to have serious effects upon birds, especially birds of prey. The cause of serious population declines was probably due to severe eggshell thinning. The probable cause of the thinning was the DDE-induced imbalance of estrogen production and metabolism (Murphy 1986). DDE has been attributed to cause the near extinction of the peregrine falcon. DDE concentrations in fish eggs have also been demonstrated to drastically increase mortality (Ramade 1987).

<u>PREDATOR PROTECTION LEVEL</u>: (Wet Weight) The predator protection level for DDE (total DDT) is 1.0 ug/g (NAS 1973).

<u>NCBP 1984</u>: (Wet Weight) The geometric mean concentration of p,p'-DDE was 0.19 ug/g (Schmitt et al. 1990).

SEDIMENT GRADIENT MONITORING: (Dry Weight) p,p'-DDE was detected only in sediment samples from the Lower study reach (Table 18). The maximum concentration (0.05 ug/g) was from Hatch, New Mexico (Site 46). The Apparent Effects Threshold (AET) (benthic species) for this compound in Puget Sound is as low as 0.009 ug/g (Barrick et al. 1988). Because this AET was developed for marine species, the applicability of this guideline is probably not valid and is provided only as an item of interest for the reader.

Table 18. p,p'-DDE concentrations in sediments from the Upper, Middle, and Lower study reaches (ug/g dry weight).

	MIN	MEAN	MAX
UPPER	ND	ND	ND
MIDDLE	ND	ND	ND
LOWER	ND	0.024	0.05

FISH GRADIENT MONITORING: (Wet Weight) Mean concentrations of p,p'-DDE increased dramatically from the Middle to the Lower study reaches (Table 19). The maximum concentration (6.30 ug/g) was in a carp sample from Stahman Farms (Site 53). Based on these data, it is apparent that fish in the Lower study reach are accumulating p,p'-DDE to concentrations above the national norm.

Table 19. p,p'-DDE concentrations in whole-body fish from the Upper, Middle and Lower study reaches (ug/g wet weight).

	MIN	MEAN	MAX.
UPPER	0.01	0.07	0.24
MIDDLE	ND	0.03	0.15
LOWER	ND	1.17	6.30

SUMMARY AND CONCLUSION:

With the exception of some elevated concentrations of trace elements and heavy metals in a few sediment samples, there does not appear to be any widespread contamination of sediments in the Rio Grande. However, it is apparent from inorganic chemical analysis of sediment from the Red River that past and present mining operations and other anthropogenic activities may be impacting the Red River. In order to more accurately define the cause(s) and effect(s) of trace element/heavy metal contamination upon the aquatic resources of the Red River, additional research should be conducted.

Concentrations of arsenic, cadmium, copper, selenium, and zinc in fish indicate that fish are accumulating these elements to higher concentrations than the NCBP (Schmitt and Brumbaugh 1990). Because of the poor performance of the lead analysis in whole-body fish samples, no determination can be made regarding potential lead effects to fish and wildlife resources in the Rio Grande. The Lower study reach was found to have elevated concentrations of p,p'-DDE in sediments and fish.

In future contaminant monitoring studies of the Rio Grande basin, we recommend that the following detailed sediment analyses of whole sediment and less than 2.0 mm fractions following U.S. Geological Survey protocols be conducted: monitoring of inorganic/organochlorine compounds in fish be continued; more emphasis be placed on sampling reservoirs and tributaries; analyses of trace elements and organochlorine compounds in migratory birds and invertebrates in all three reaches be undertaken; and polycyclic aromatic hydrocarbons be included in future analyses of sediment and biota.

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APPENDIX A.— Concentrations of organochlorine compounds in fish samples from the Upper Rio Grande Basin, 1987.

[Concentrations are in micrograms per gram wet weight. Lower Level of Detections are 0.01 ppm for tissue and sediment, and 0.05 for Toxaphene and PCB's. No detections for these compounds: HCB, a-BHC, r-BHC, b-BHC, s-BHC, Oxychlordane, r-Chlordane, t-Nonachlor, Toxaphene, o, p'DDE, a-Chlordane, Dieldrin, Endrin, cis-Nonachlor, o,p'-DDT, Mirex, Dacthal; **, Composite Amount unknown].

Species	Sample Location	Composite Amount	Moisture %	Lipid %	HEPT. EPOX.	PCB's (total)	p, p'-DDE	o, p'-DDD	p, p'-DDT
White Sucker	Upper Reach	**	73.8	6.88	ND	ND	0.07	0.01	0.01
White Sucker	Upper Reach	**	75.6	7.28	ND	ND	0.08	ND	ND
White Sucker	Upper Reach	**	76.4	4.12	ND	ND	0.06	ND	ND
White Sucker	Upper Reach	**	76.4	4.50	ND	ND	0.08	ND	ND
White Sucker	Upper Reach	**	76.0	7.65	ND	ND	0.11	ND	ND
White Sucker	Upper Reach	**	76.4	3.01	0.01	ND	0.04	ND	ND
Brown Trout	Upper Reach	**	74.6	3.96	ND	ND	0.01	ND	ND
Brown Trout	Upper Reach	**	71.4	8.55	ND	0.3	0.19	ND	ND
Brown Trout	Upper Reach	**	71.4	8.37	ND	ND	0.24	ND	ND
Brown Trout	Upper Reach	**	71.4	7.16	ND	ND	0.17	ND	ND
Brown Trout	Upper Reach	**	67.6	9.00	ND	0.16	0.21	ND	ND
Brown Trout	Upper Reach	**	69.6	9.43	ND	ND	0.18	ND	ND
Brown Trout	Upper Reach	**	73.8	6.25	ND	ND	0.14	ND	ND
Rainbow Trout	Upper Reach	**	77.6	2.70	ND	ND	0.02	ND	ND
Rainbow Trout	Upper Reach	**	75.8	5.18	ND	ND	0.06	ND	ND
Carp	Upper Reach	**	64.2	15.60	ND	ND	0.11	ND	ND
Carp	Upper Reach	**	67.8	13.20	ND	ND	0.06	ND	ND
Carp	Upper Reach	**	66.6	13.80	ND	ND	0.10	ND	ND
Carp	Upper Reach	**	67.4	11.70	ND	ND	0.07	ND	ND
Longnose Dace	Upper Reach	**	74.4	6.10	ND	ND	0.07	0.02	ND
Longnose Dace	Upper Reach	**	70.6	9.59	ND	ND	0.07	ND	ND
Longnose Dace	Upper Reach	**	73.0	7.16	ND	ND	0.08	ND	ND
Longnose Dace	Upper Reach	**	72.8	6.95	ND	ND	0.12	ND	ND
Longnose Dace	Upper Reach	**	74.0	6.32	ND	ND	0.12	ND	ND
Longnose Dace	Upper Reach	**	72.6	6.06	ND	ND	0.15	ND	ND
Northern Pike	Upper Reach	**	77.6	2.38	ND	ND	0.09	ND	ND
Rio Grande Chub	Upper Reach	**	73.2	7.02	ND	ND	0.05	ND	ND
Crayfish	Upper Reach	**	77.0	1.95	ND	ND	0.01	ND	ND
Crayfish	Upper Reach	**	68.0	50.90	ND	ND	0.10	ND	ND
Sediment	Upper Reach	**	63.4	—	ND	ND	ND	ND	ND
Sediment	Upper Reach	**	75.0	—	ND	ND	ND	ND	ND
Sediment	Upper Reach	**	55.0	—	ND	ND	ND	ND	ND
Sediment	Upper Reach	**	18.8	—	ND	ND	ND	ND	ND
Sediment	Upper Reach	**	36.2	—	ND	ND	ND	ND	ND
Sediment	Upper Reach	**	22.8	—	ND	ND	ND	ND	ND
Sediment	Upper Reach	**	26.2	—	ND	ND	ND	ND	ND

APPENDIX B.— Concentrations of organochlorine compounds in biota and sediment from the Middle Rio Grande Basin, 1987.

[Concentrations are in micrograms per gram, wet weight. Lower Level of Detections are 0.05 ppm for Toxaphene and PCB's, and 0.01 for other organochlorine compounds. No detections for these compounds: HCB, a-BHC, r-BHC, b-BHC, s-BHC, r-Chlordane, toxaphene, Mirex, Dacthal, o,p'-DDE, a-Chlordane, Endrin, cis-Nonachlor, o,p'-DDT. Numbered Unit sites are Bosque del Apache NWR sample sites; ND, not detected; **, site unknown].

Species	Sample Location	Composite Amount	Moisture %	Lipid %	OXY-CHLORDANE	HEPT. EPOX.	t-NONA CHLOR	PCB's (total)	p, p'-DDE	o, p'-DDD	p, p'-DDT	DIELDRIN
Coot	Unit 15 B	3	72.0	2.27	ND	ND	ND	ND	0.01	ND	ND	ND
Coot	Unit 11 C	4	68.4	7.84	ND	ND	ND	ND	0.01	ND	ND	ND
Coot	Unit 25 A	7	69.0	7.81	ND	ND	ND	ND	0.02	ND	ND	ND
Coot	Unit 18 BE	2	64.0	10.90	ND	ND	ND	ND	0.12	ND	ND	ND
Coot	Elephant Butte	10	71.0	4.71	ND	ND	ND	ND	0.04	ND	ND	ND
Coot	Rio San Jose/Acoma	10	70.2	5.76	ND	ND	ND	ND	0.02	ND	ND	ND
Coot	La Joya	1	69.4	9.08	0.03	ND	ND	0.32	0.06	ND	ND	0.01
Coot	Madrone	10	70.0	9.40	ND	ND	ND	ND	0.04	ND	ND	ND
Coot	Isleta Marsh	9	67.8	11.30	ND	ND	ND	ND	0.02	ND	ND	ND
Coot	Santa Fe Marsh	5	66.6	8.14	ND	ND	ND	ND	0.09	ND	ND	ND
Western Kingbird	Elephant Butte	10	70.0	4.48	ND	ND	ND	ND	0.14	ND	ND	ND
Western Kingbird	Rio San Jose/Acoma	10	66.6	4.96	ND	ND	ND	ND	0.26	ND	ND	ND
Western Kingbird	Rio Puerco-San Jose	10	69.6	4.60	ND	ND	ND	ND	0.08	ND	ND	ND
Western Kingbird	La Joya	9	69.0	5.09	ND	ND	ND	ND	1.7	ND	ND	ND
Western Kingbird	Belen-Madrone	10	65.0	7.92	0.07	0.02	0.06	ND	0.24	ND	ND	0.02
Western Kingbird	Alb-Isleta Pueblo	10	66.6	7.12	0.01	0.01	0.01	ND	0.17	ND	ND	ND
Western Kingbird	Cochiti Pueblo	10	69.2	3.19	ND	ND	ND	ND	0.66	ND	ND	ND
Ruddy Duck	La Joya	2	58.4	14.50	ND	ND	ND	ND	3.5	0.02	0.05	ND
Flycatcher	Belen-Madrone	1	63.5	4.68	0.02	ND	0.01	ND	0.06	ND	ND	ND
Carp	Riverside Drain	10	75.8	1.86	ND	ND	ND	ND	0.01	ND	ND	ND
Carp	Unit 18 BE	10	72.4	6.23	ND	ND	ND	ND	ND	ND	ND	ND
Carp	Unit 25 A	10	78.4	1.20	ND	ND	ND	ND	ND	ND	ND	ND
Carp	Elephant Butte	6	73.2	4.79	ND	ND	ND	0.07	0.02	ND	ND	ND
Carp	La Joya	10	78.0	1.32	ND	ND	ND	0.1	0.01	0.02	ND	ND
Carp	Madrone Pond	10	78.6	0.66	ND	ND	ND	ND	ND	ND	ND	ND
Carp	Abq. Riverside Drain	10	72.0	0.60	ND	ND	0.03	0.2	0.04	0.02	ND	ND
Carp	Cochiti Reservoir	8	76.0	4.38	ND	ND	ND	ND	0.02	ND	ND	ND
Carp	Morgan Lake	10	75.0	1.45	ND	ND	ND	ND	ND	ND	ND	ND
Rio Grande Sucker	Rio San Jose/Acoma	3	61.0	7.92	ND	ND	ND	ND	0.01	ND	ND	0.01
Rio Grande Sucker	Abq. Riverside Drain	12	73.8	6.36	0.01	ND	0.04	0.41	0.15	0.04	ND	ND
Rio Grande Sucker	Cochiti Reservoir	9	74.0	4.84	ND	ND	ND	ND	0.04	0.01	ND	ND
Threadfin Shad	Elephant Butte	10	76.4	2.79	ND	ND	ND	ND	0.01	ND	ND	ND
Threadfin Shad	Madrone Pond	10	71.0	8.76	ND	ND	ND	ND	0.06	0.01	ND	ND
Channel Catfish	La Joya	10	74.4	5.54	ND	ND	ND	0.48	0.06	0.03	ND	ND
Channel Catfish	Cochiti Reservoir	10	67.8	14.50	ND	ND	0.02	ND	0.1	0.03	0.02	ND
Yellow Bullhead	Unit 25 A	10	77.4	2.25	ND	ND	ND	ND	ND	ND	ND	ND

APPENDIX B.— Concentrations of organochlorine compounds in biota and sediment from the Middle Rio Grande Basin, 1987, concluded.

Species	Sample Location	Composite Amount	Moisture %	Lipid %	OXY-CHLORDANE	HEPT. EPOX.	t-NONA CHLOR	PCB's (total)	p, p'-DDE	o, p'-DDD	p, p'-DDT	DIELDRIN
Cyprinidae	Unit 18 BE	1	76.0	2.73	ND	ND	ND	ND	ND	ND	ND	ND
Black Crappie	Cochiti Reservoir	12	71.4	8.37	ND	ND	0.01	ND	0.07	0.02	0.02	ND
Green Sunfish	Unit 25 A	10	75.2	0.57	ND	ND	ND	ND	ND	ND	ND	ND
Red Shiner	Rio San Jose	2	73.6	7.14	ND	ND	ND	ND	0.02	ND	ND	ND
Bluegill	Morgan Lake	10	75.6	1.19	ND	ND	ND	ND	ND	ND	ND	ND
Crayfish	Rio San Jose	4	71.0	2.12	ND	ND	ND	ND	ND	ND	ND	ND
Sedge	Unit 11 C	1	87.8	0.15	ND	ND	ND	ND	ND	ND	ND	ND
Bullrush	Unit 11 C	1	55.8	0.62	ND	ND	ND	ND	ND	ND	ND	ND
Pondweed	Unit 18 BE	2	91.4	0.08	ND	ND	ND	ND	ND	ND	ND	ND
Coontail	**	2	90.4	0.08	ND	ND	ND	ND	ND	ND	ND	ND
Sediment	Elemendorf Drain	3	20.4	—	ND	ND	ND	ND	ND	ND	ND	ND
Sediment	Riverside Drain	3	20.4	—	ND	ND	ND	ND	ND	ND	ND	ND
Sediment	Unit 18 BE	3	56.8	—	ND	ND	ND	ND	ND	ND	ND	ND
Sediment	Unit 11 C	3	90.0	—	ND	ND	ND	ND	ND	ND	ND	ND
Sediment	Unit 25 A	3	59.4	—	ND	ND	ND	ND	ND	ND	ND	ND
Sediment	Elephant Butte	3	78.0	—	ND	ND	ND	ND	ND	ND	ND	ND
Sediment	Acoma At MaCartys	3	44.6	—	ND	ND	ND	ND	ND	ND	ND	ND
Sediment	Rio San Jose	3	59.8	—	ND	ND	ND	ND	ND	ND	ND	ND
Sediment	Rio Puerco-San Jose	3	18.0	—	ND	ND	ND	ND	ND	ND	ND	ND
Sediment	La Joya	3	67.0	—	ND	ND	ND	ND	ND	ND	ND	ND
Sediment	Madrone Ponds	3	86.0	—	ND	ND	ND	ND	ND	ND	ND	ND
Sediment	Abq. Riverside Drain	3	27.8	—	ND	ND	ND	ND	ND	ND	ND	ND
Sediment	Santa Fe Marsh	3	78.0	—	ND	ND	ND	ND	ND	ND	ND	ND
Sediment	Cochiti Reservoir	3	64.8	—	ND	ND	ND	ND	ND	ND	ND	ND

APPENDIX C.— Concentrations of organochlorine compounds in biota and sediment samples from the Lower Rio Grande Basin, 1985.

[Concentrations are in micrograms per gram wet weight. Species: Wstn Kingbird, Western kingbird; BL Bull, black bullhead; CH Catfish, channel catfish. No detections for these compounds: HCB, a-BHC, r-BHC, s-BHC, r-Chlordane, Toxaphene, Dieldrin, a-Chlordane, Endrin, cis-Nonachlor, o, p'-DDT, Mirex. ND, not detected; %, percent; *, no value reported].

Species	Sample Location	Composite Amount	Moisture %	Lipid %	b-BHC	OXY-CHLORDANE	HEPT. EPOX.	t-NONA CHLOR	PCB's (total)	o, p'-DDE	p, p'-DDE	o, p'-DDD	p, p'-DDD	p, p'-DDT	DACTHAL
Wstn Kingbird	Hatch	7	69.7	5.68	0.03	0.03	0.01	0.03	ND	ND	5.1	ND	0.01	0.01	ND
Wstn Kingbird	Radium Springs	7	71.8	4.12	ND	0.01	ND	0.01	ND	ND	1.4	ND	ND	ND	ND
Wstn Kingbird	West Las Cruces	7	72.7	4.15	0.06	0.01	ND	0.01	ND	ND	2.4	ND	ND	ND	ND
Wstn Kingbird	Stahman Farms	7	70.3	4.02	ND	ND	ND	ND	ND	ND	3.8	ND	ND	ND	ND
Wstn Kingbird	Chamberino	7	67.6	6.63	ND	ND	ND	ND	ND	ND	2.1	ND	ND	ND	ND
Wstn Kingbird	Los Lunas Control	10	70	3.85	ND	0.01	ND	ND	ND	ND	0.13	ND	ND	ND	ND
Mouse	Hatch	20	70.1	3.7	ND	ND	ND	ND	ND	ND	0.13	ND	ND	ND	ND
Mouse	Radium Springs	7	70.9	3.78	ND	ND	ND	ND	ND	ND	0.03	ND	ND	ND	ND
Mouse	West Las Cruces	7	71.2	3.51	ND	ND	ND	ND	ND	ND	0.02	ND	ND	ND	ND
Mouse	Stahman Farms	12	70.6	3.21	ND	ND	ND	ND	ND	ND	0.06	ND	ND	ND	ND
Mouse	Chamberino	7	70.6	2.34	ND	ND	ND	ND	ND	ND	0.08	ND	ND	ND	ND
Mouse	Los Lunas Control	10	70.3	3.04	ND	ND	ND	ND	ND	ND	0.01	ND	ND	ND	ND
Lizard	Hatch	8	69.7	5.38	ND	ND	0.01	ND	ND	ND	0.07	ND	ND	ND	ND
Lizard	Radium Springs	8	70.3	4.53	ND	ND	ND	ND	ND	ND	0.02	ND	ND	ND	ND
Lizard	West Las Cruces	8	67.3	5.98	ND	ND	ND	ND	ND	ND	0.14	ND	ND	ND	ND
Lizard	Stahman Farms	7	69.5	4.58	ND	ND	ND	ND	ND	ND	0.03	ND	ND	ND	ND
Lizard	Chamberino	7	68.5	5.88	ND	ND	ND	ND	ND	ND	0.03	ND	ND	ND	ND
Lizard	Los Lunas Control	7	66	3.66	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BL Bull/CH Catfish	Hatch	10	74.6	6.15	ND	ND	0.02	0.02	ND	ND	0.69	ND	0.06	0.01	ND
CH Catfish	Radium Springs	6	75.2	2.74	ND	ND	ND	0.01	ND	ND	0.26	ND	0.02	ND	ND
CH Catfish	West Las Cruces	5	74.2	5.4	ND	ND	0.03	ND	ND	0.02	1.2	ND	0.09	0.01	0.14
BL Bull/CH Catfish	Stahman Farms	7	74	6.02	ND	ND	ND	ND	ND	0.02	1.2	ND	0.1	0.05	ND
CH Catfish	Chamberino	6	72.4	5.97	ND	ND	ND	ND	ND	ND	3	0.04	0.27	0.04	0.14
CH Catfish	Los Lunas Control	5	72.8	6.71	ND	ND	ND	0.01	0.13	ND	0.04	ND	ND	ND	ND
Carp	Hatch	6	73.8	5.52	ND	ND	ND	0.02	ND	ND	0.38	ND	0.05	0.01	0.01
Carp	Radium Springs	7	72.2	4.14	ND	ND	ND	ND	ND	0.02	1.5	ND	0.1	0.04	ND
Carp	West Las Cruces	8	74.4	5.36	ND	ND	ND	ND	ND	0.02	1.3	ND	0.09	0.01	0.07
Carp	Stahman Farms	4	68	11	ND	ND	ND	ND	ND	ND	6.3	0.09	0.47	0.05	0.01
Carp	Chamberino	6	71.2	6.81	ND	ND	ND	ND	ND	ND	0.45	ND	0.05	ND	ND
Carp	Los Lunas Control	14	72	6.86	ND	ND	ND	0.02	1.1	ND	0.1	ND	0.02	ND	ND
Sediment	Hatch	3	36.6	—	ND	ND	ND	ND	ND	ND	0.03	ND	0.02	ND	ND
Sediment	Radium Springs	3	24.2	—	ND	ND	ND	ND	ND	ND	ND	ND	0.01	ND	ND
Sediment	West Las Cruces	3	26.4	—	ND	ND	ND	ND	ND	ND	0.01	ND	0.01	ND	ND
Sediment	Stahman Farms	3	24.8	—	ND	ND	ND	ND	ND	ND	0.02	ND	0.01	ND	ND
Sediment	Chamberino	3	32.6	—	ND	ND	ND	ND	ND	ND	0.03	ND	ND	ND	ND
Sediment	Los Lunas Control	3	*	—	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

APPENDIX D.— Concentrations of inorganic compounds in biota and sediment from the Upper Rio Grande Basin, 1987.

[Concentrations are in micrograms per gram dry weight. Red River/Rio Grande Con., Red River/Rio Grande Confluence; **, Site Unknown; <, less than detection level; %, percent]

Species	Sample Location	Composite Amount	Moisture %	Al	As	Se	Ag	Hg	B	Ba	Be	Cd	Cr
White Sucker	Red River/Rio Grande Con.	12	73.9	513.0	0.30	0.84	<2.00	0.12	<2.0	15.00	<0.1	<0.2	2.0
White Sucker	Sheep Canyon	5	75.3	290.0	0.34	1.20	<2.00	0.25	<2.0	9.00	<0.1	<0.3	2.0
White Sucker	Lee Trail	4	76.5	342.0	0.20	2.00	<2.00	0.30	<2.0	10.00	<0.1	<0.3	<1.0
White Sucker	Cow Patty	3	77.4	150.0	<0.10	1.60	<2.00	0.43	<2.0	9.80	<0.1	<0.3	2.0
White Sucker	Costilla Creek	2	74.6	150.0	<0.10	1.50	<2.00	0.40	<2.0	4.60	<0.1	<0.2	2.0
White Sucker	Border Gauge	1	77.1	300.0	0.20	2.20	<2.00	0.22	<2.0	13.20	<0.1	<0.2	3.8
Brown Trout	Red River/Rio Grande Con.	12	74.8	170.0	0.20	1.80	<2.00	0.03	<2.0	3.00	<0.1	0.6	1.0
Brown Trout	Sheep Canyon	6	73.1	34.0	<0.10	2.20	<2.00	0.41	<2.0	1.10	<0.1	<0.2	1.0
Brown Trout	Lee Trail	5	72.0	9.6	<0.10	2.00	<2.00	0.71	<2.0	0.53	<0.1	<0.3	1.0
Brown Trout	Cow Patty	8	72.6	37.0	0.20	2.40	<2.00	0.68	<2.0	1.00	<0.1	<0.2	1.0
Brown Trout	Costilla Creek	3	70.9	< 3.00	<0.10	2.40	<2.00	0.49	<2.0	0.57	<0.1	<0.3	<1.0
Brown Trout	Costilla Creek	1	69.4	15.0	0.20	1.60	<2.00	0.37	<2.0	1.10	<0.1	<0.3	2.0
Brown Trout	Border Gauge	8	73.8	17.0	0.20	2.70	<2.00	0.77	<2.0	0.59	<0.1	<0.3	<1.0
Longnose Dace	Red River/Rio Grande Con.	76	73.8	110.0	0.20	2.90	<2.00	0.12	<2.0	11.90	<0.1	0.6	1.0
Longnose Dace	Sheep Canyon	84	71.3	46.0	0.10	3.40	<2.00	0.23	<2.0	6.30	<0.1	<0.2	<1.0
Longnose Dace	Lee Trail	19	71.9	140.0	0.20	3.80	<2.00	0.26	<2.0	8.40	<0.1	<0.2	2.0
Longnose Dace	Cow Patty	106	73.3	110.0	<0.10	3.70	<2.00	0.40	<2.0	9.90	<0.1	<0.2	2.0
Longnose Dace	Costilla Creek	81	74.1	83.0	<0.10	3.80	<2.00	0.36	<2.0	10.20	<0.1	<0.2	3.0
Longnose Dace	Border Gauge	144	72.9	546.0	0.10	3.70	<2.00	0.29	<2.0	14.50	<0.1	<0.2	8.5
Rainbow Trout	Red River/Rio Grande Con.	3	78.0	660.0	0.72	1.50	<2.00	0.07	<2.0	9.50	<0.1	<0.2	2.0
Rainbow Trout	Sheep Canyon	2	74.3	200.0	0.20	1.40	<2.00	0.12	<2.0	5.70	<0.1	<0.3	1.0
Rio Grande Chub	Red River/Rio Grande Con.	16	73.7	130.0	0.33	2.40	<2.00	0.07	<2.0	6.20	<0.1	<0.3	3.0
Carp	Lee Trail	5	65.9	56.0	0.20	0.50	<2.00	0.23	<2.0	4.20	<0.1	<0.3	<1.0
Carp	Cow Patty	5	70.1	74.0	0.10	0.60	<2.00	0.27	<2.0	2.70	<0.1	<0.2	2.0
Carp	Costilla Creek	5	67.5	35.0	<0.10	0.61	<2.00	0.27	<2.0	3.20	<0.1	<0.3	<1.0
Carp	Red River/Rio Grande Con.	5	68.6	30.0	<0.10	0.64	<2.00	0.37	<2.0	3.30	<0.1	<0.2	<1.0
Notrhern Pike	Costilla Creek	6	78.8	32.0	<0.10	1.90	<2.00	0.37	<2.0	2.60	<0.1	<0.2	<1.0
Crayfish	Costilla Creek	2	73.7	496.0	1.20	0.60	<2.00	0.07	2.0	100.00	<0.1	<0.3	2.0
Crayfish	Border Gauge	2	68.3	1940.0	1.60	0.80	<2.00	0.04	4.0	111.00	<0.1	<0.3	6.6
Sediment	**		76.3	19100.0	4.50	0.40	<2.00	0.02	<2.0	225.00	<0.1	1.5	18.0
Sediment	Sheep Canyon	3	23.9	5410.0	1.90	<0.02	<2.00	<0.02	<2.0	64.30	<0.1	<0.3	10.0
Sediment	Lee Trail	3	21.0	5610.0	2.20	<0.02	<2.00	<0.02	<2.0	57.80	<0.1	<0.3	17.0
Sediment	Cow Patty	3	21.0	7250.0	2.00	<0.02	<2.00	<0.01	<2.0	77.90	<0.1	<0.3	12.0
Sediment	**		36.4	9530.0	1.50	<0.02	<2.00	<0.02	3.0	174.00	<0.1	<0.2	8.9
Sediment	Costilla Creek	3	22.4	6380.0	2.00	<0.02	<2.00	<0.02	<2.0	76.70	<0.1	<0.3	7.8
Sediment	Border Gauge	3	21.0	4570.0	1.80	<0.02	<2.00	<0.01	<2.0	71.60	<0.1	<0.3	25.0

APPENDIX D.— Concentrations of inorganic compounds in biota and sediment from the Upper Rio Grande Basin, 1987, concluded.

Species	Sample Location	Composite Amount	Cu	Fe	Mg	Mn	Mo	Ni	Pb	Sr	Tl	V	Zn
White Sucker	Red River/Rio Grande Con.	12	5.4	9	1360	103.0	<1.0	2.0	<4.0	67.8	<5.0	2.3	66.0
White Sucker	Sheep Canyon	5	4.7	1380	1180	58.0	<1.0	2.0	<4.0	36.5	<5.0	4.0	56.7
White Sucker	Lee Trail	4	4.1	2350	1520	88.6	<1.0	<2.0	<4.0	74.5	<4.0	7.3	72.8
White Sucker	Cow Patty	3	7.9	792	1450	70.9	<1.0	<1.0	<4.0	89.2	<5.0	2.8	68.5
White Sucker	Costilla Creek	2	2.6	845	1030	36.7	<1.0	<1.0	<4.0	34.3	<5.0	2.6	51.6
White Sucker	Border Gauge	1	3.5	1090	1590	87.5	<1.0	<1.0	<4.0	89.3	<5.0	3.3	75.3
Brown Trout	Red River/Rio Grande Con.	12	6.4	230	1220	80.2	<1.0	2.0	<4.0	32.8	<5.0	0.7	173.0
Brown Trout	Sheep Canyon	6	7.6	113	951	10.0	<1.0	<1.0	<4.0	19.5	<5.0	0.4	110.0
Brown Trout	Lee Trail	5	7.0	66	965	3.9	<1.0	2.0	<4.0	22.3	<5.0	0.5	98.4
Brown Trout	Cow Patty	8	11.0	93	988	6.2	<1.0	<1.0	<4.0	30.3	<5.0	0.3	119.0
Brown Trout	Costilla Creek	3	3.3	53	1050	5.4	<1.0	<1.0	<4.0	27.7	<5.0	0.3	106.0
Brown Trout	Costilla Creek	1	3.3	86	1070	7.0	<1.0	<1.0	<4.0	44.9	<5.0	0.3	108.0
Brown Trout	Border Gauge	8	18.0	78	1040	3.5	<1.0	<2.0	<4.0	21.7	<4.0	<0.3	131.0
Longnose Dace	Red River/Rio Grande Con.	76	6.0	187	1330	40.8	<1.0	<1.0	<4.0	105.0	<5.0	0.5	132.0
Longnose Dace	Sheep Canyon	84	3.0	156	1150	19.0	<1.0	1.0	<4.0	79.2	<5.0	0.5	102.0
Longnose Dace	Lee Trail	19	6.2	433	1260	33.2	<1.0	2.0	<4.0	84.2	<5.0	1.3	122.0
Longnose Dace	Cow Patty	106	4.3	310	1270	30.9	<1.0	2.0	<4.0	99.4	<5.0	1.0	129.0
Longnose Dace	Costilla Creek	81	4.5	349	1330	30.3	<1.0	1.0	<4.0	109.0	<5.0	1.1	134.0
Longnose Dace	Border Gauge	144	6.0	1590	1380	63.4	<1.0	5.5	<4.0	92.6	<5.0	4.0	124.0
Rainbow Trout	Red River/Rio Grande Con.	3	6.7	719	1380	146.0	<1.0	3.0	<4.0	32.9	<5.0	1.5	142.0
Rainbow Trout	Sheep Canyon	2	3.4	499	1230	53.6	<1.0	<1.0	<5.0	36.9	<5.0	1.3	96.1
Rio Grande Chub	Red River/Rio Grande Con.	16	4.2	179	1230	25.7	<1.0	2.0	<4.0	47.3	<5.0	0.6	112.0
Carp	Lee Trail	5	2.6	141	885	20.0	<1.0	<1.0	<5.0	62.2	<5.0	1.0	203.0
Carp	Cow Patty	5	2.5	99.3	895	10.0	<1.0	<1.0	<4.0	55.8	<5.0	0.5	196.0
Carp	Costilla Creek	5	3.3	135	781	12.0	<1.0	<1.0	<4.0	40.4	<5.0	0.4	213.0
Carp	Red River/Rio Grande Con.	5	2.9	128	901	11.0	<1.0	<1.0	<4.0	59.6	<5.0	0.8	178.0
Notrhern Pike	Costilla Creek	6	1.5	75	1280	18.0	<1.0	<1.0	<4.0	42.8	<5.0	0.5	115.0
Crayfish	Costilla Creek	2	128.0	620	1620	152.0	<1.0	1.0	<4.0	722.0	<5.0	1.7	59.1
Crayfish	Border Gauge	2	98.7	3990	1750	283.0	<1.0	5.4	<4.0	543.0	<5.0	9.6	58.9
Sediment	**		53.0	28100	5330	884.0	15	29.0	41.0	84.5	<6.0	45.7	353.0
Sediment	Sheep Canyon	3	6.7	21900	2180	428.0	<2.0	6.8	8.0	32.9	<6.0	52.1	51.9
Sediment	Lee Trail	3	9.8	32500	2360	510.0	<3.0	11.0	10.0	33.2	<7.0	85.8	66.5
Sediment	Cow Patty	3	8.7	23300	2590	348.0	<3.0	9.4	9.0	34.8	<6.0	58.1	55.0
Sediment	**		6.9	12500	2780	331.0	<2.0	7.5	7.0	66.2	<6.0	29.0	28.0
Sediment	Costilla Creek	3	8.2	21100	2190	549.0	<2.0	7.0	8.0	41.5	<6.0	49.8	54.6
Sediment	Border Gauge	3	10.0	36500	2760	109.0	<3.0	18.0	9.0	29.5	<7.0	106.0	71.6

APPENDIX E.— Concentrations of inorganic compounds in fish from the Middle Rio Grande Basin, 1987.

[Concentrations are in micrograms per gram dry weight. BDANWR, Bosque del Apache National Wildlife Refuge; Div., Diversion; Species: CH Catfish, channel catfish; RB Trout, rainbow trout; ND, non detected; *, concentration not reported; %, percent; <, less than detection].

Species	Sample Location	Composite Amount	Moisture %	Al	As	Cr	Cd	Cu	Fe	Hg	Pb	Se	Zn	B	Be
White Sucker	Cochiti Pueblo	11	58.4	57.0	ND	ND	ND	4.43	199.0	0.22	1.06	0.519	66.3	ND	ND
White Sucker	Sandia Pueblo/Angostora Div.	10	73.2	54.5	ND	ND	ND	7	198	0.3	ND	1	67.8	ND	ND
White Sucker	San Felipe Pueblo	10	66.7	24.8	ND	ND	ND	6.41	136.0	0.22	ND	0.734	52.4	ND	ND
White Sucker	Rio Grande at Isleta Pueblo	10	56.5	182.0	ND	ND	ND	4.66	299.0	0.3	ND	1.42	55.4	ND	ND
White Sucker	Isleta	10	56.5	182	ND	ND	ND	4.37	299	0.3	ND	1.42	55.4	ND	ND
White Sucker	Alameda	26	71.7	76.8	ND	ND	ND	3.49	177	0.38	1.79	1.09	70	ND	ND
Carp Sucker	San Felipe Pueblo	9	67.8	366.0	1.68	ND	ND	6.45	638.0	0.11	1.18	0.683	65.4	ND	ND
Carp Sucker	Bernalillo	3	70.4	135.0	0.992	ND	ND	3.05	317.0	0.29	ND	1.08	69.9	ND	ND
Carp Sucker	Alameda	7	70.4	142	0.689	ND	ND	4.3	396	0.37	2.48	1.57	59.7	ND	ND
Carp Sucker	Rio Grande at Isleta Pueblo	9	56.5	114.0	0.49	ND	ND	4.18	187.0	0.25	ND	1.4	60.2	ND	ND
Carp Sucker	Sandia Pueblo	10	61.6	359	0.705	ND	ND	3.06	606	0.3	2.23	0.968	79.8	ND	ND
Carp Sucker	Isleta Pueblo	9	56.5	114	0.49	ND	ND	3.19	187	0.25	ND	1.4	60.2	ND	ND
Carp Sucker	Cochiti Pueblo	10	64.1	259.0	1.43	ND	ND	5.19	516.0	0.18	1.18	1.04	58.7	ND	ND
Sucker	Rio San Jose at Acomita	3	69.9	658.0	0.52	0.86	0.05	4.37	391.0	0.065	0.8	2.8	103	<2.00	0.010
Sucker	Albuquerque Riverside Drain	12	73.4	109.0	0.34	0.2	0.04	4.32	196.0	0.31	<0.50	0.98	52.8	<2.00	<0.01
White Crappie	Bernalillo	3	70.6	21.5	ND	ND	ND	1.37	78.4	0.41	ND	0.72	104	ND	ND
White Crappie	Alameda	5	76.3	44.5	0.433	ND	ND	3.03	146	0.45	ND	0.946	95.1	ND	ND
Carp	San Felipe Pueblo	10	73.0	89.1	0.514	ND	ND	6.8	150.0	0.36	ND	1.08	240	ND	ND
Carp	Albuquerque Riverside Drain	10	72.5	126.0	0.57	0.4	0.09	8.07	198.0	0.18	0.7	1.2	220	<2.00	<0.01
Carp	La Joya	10	77.4	171.0	0.6	0.2	0.05	3.77	254.0	0.16	0.5	0.95	193	<2.00	<0.01
Carp	Alameda	6	73.9	130	ND	ND	ND	6.98	234	0.3	1.14	1.26	286	ND	ND
Carp	Los Lunas	14	72.4	113.0	0.362	0.362	0.1086	6.88	208.3	0.2427	<0.36	1.12	211.9	*	0.040
Carp	Isleta	10	72.7	216	ND	ND	ND	4.81	230	0.25	1.16	1.76	191	ND	ND
Carp	BDANWR, Riverside Drain	10	75.1	289.0	1	0.61	0.089	5.93	395.0	0.13	0.5	1.2	241	<2.00	<0.01
Carp	Sandia Pueblo	10	70.7	91.4	ND	ND	ND	4.96	180	0.48	ND	0.932	284	ND	ND
Carp	Rio Grande at Isleta Pueblo	10	72.7	216.0	ND	ND	ND	7.44	230.0	0.25	1.16	1.76	191	ND	ND
Carp	Madrone Ponds	10	78.1	55.5	0.23	0.41	0.05	6.58	169.0	0.1	<0.50	0.49	225	<2.00	<0.01
Carp	Bernalillo	10	71.4	80.4	ND	ND	ND	3.53	119.0	0.4	1.57	1.88	224	ND	ND
Carp	Cochiti Pueblo	5	59.0	34.8	ND	ND	ND	5.37	178.0	0.09	ND	0.838	66.8	ND	ND
Carp	BDANWR,18BE	10	71.5	211.0	0.47	0.47	0.05	2.75	153.0	0.14	<0.50	0.48	148	<2.00	<0.01
Yellow Bullhead	Alameda	2	78.3	135	ND	ND	ND	3.3	195	0.43	ND	1.84	80.9	ND	ND
CH Catfish	Los Lunas	5	73.6	72.0	<0.19	0.378	<0.08	12.8	119.7	0.3106	<0.38	0.378	65.15	*	0.037
CH catfish	Sandia Pueblo	3	69.4	ND	ND	ND	ND	1.73	80.2	0.51	ND	1.31	54.4	ND	ND
CH Catfish	La Joya	10	74.5	218.0	1.1	0.44	0.04	2	290.0	0.22	0.6	1	61.2	<2.00	<0.01
RB trout	San Felipe Pueblo	1	75.9	9.1	ND	ND	ND	5.41	106.0	0.09	ND	1.59	101	ND	ND
RB trout	San Felipe Pueblo	5	69.8	40.5	ND	ND	0.49	7.78	151.0	0.03	ND	1.67	130	ND	ND
RB trout	Cochiti Pueblo	1	74.9	ND	ND	ND	ND	4.76	158.0	0.29	ND	1.62	95.1	ND	ND
Silvery Minnow	Alameda	12	73.6	1380	2.36	ND	ND	4.32	1850	0.36	2.4	1.08	152	ND	ND
Fathead Chub	Sandia Pueblo/Angostora Div.	15	72.9	33.8	ND	ND	ND	3.37	111	0.26	ND	2.83	115	ND	ND
Threadfin Shad	Madrone Ponds	10	71.0	435.0	0.58	0.65	0.03	2	567.0	0.04	0.7	0.46	33.7	<2.00	<0.01
Red Shiner	Rio San Jose	2	72.5	234.0	0.25	0.57	0.06	5.3	173.0	0.12	<0.40	4.7	187	<2.00	<0.01
Minnows	BDANWR,18BE		75.9	124.0	0.58	0.2	0.06	2.68	152.0	0.23	<0.50	0.81	120	3	<0.01

APPENDIX E.— Concentrations of inorganic compounds in fish from the Middle Rio Grande Basin, 1987, concluded.

Species	Sample Location	Composite Amount	Mn	Ni	Mo	Tl	Mg	Sb	Ba	Ag	Sr	Sn	V
White Sucker	Cochiti Pueblo	11	35.7	1.02	ND	ND	1080.0	ND	9.4	ND	84.9	59.8	ND
White Sucker	Sandia Pueblo/Angostora Div.	10	35	1.24	ND	ND	1220	ND	13.2	ND	90.6	ND	ND
White Sucker	San Felipe Pueblo	10	36.5	ND	ND	ND	965.0	ND	8.2	ND	73.8	ND	ND
White Sucker	Rio Grande at Isleta Pueblo	10	18.8	ND	ND	ND	1430.0	ND	21.1	ND	112	ND	ND
White Sucker	Isleta	10	18.8	ND	ND	ND	1430	ND	21.1	ND	112	ND	ND
White Sucker	Alameda	26	29.8	ND	ND	ND	1545	ND	13.2	ND	139	ND	ND
Carp Sucker	San Felipe Pueblo	9	48.1	1.26	ND	ND	1380.0	ND	20.7	ND	132	ND	1.55
Carp Sucker	Bernalillo	3	35	ND	ND	ND	1120.0	ND	15	ND	98	ND	ND
Carp Sucker	Alameda	7	18.1	1.73	ND	ND	1283	ND	16.3	ND	139	ND	ND
Carp Sucker	Rio Grande at Isleta Pueblo	9	23.9	2.09	ND	ND	1320.0	ND	12.3	ND	128	ND	ND
Carp Sucker	Sandia Pueblo	10	54	ND	ND	ND	1680	ND	22.9	ND	178	ND	ND
Carp Sucker	Isleta Pueblo	9	23.9	2.09	ND	ND	1320	ND	12.3	ND	128	ND	ND
Carp Sucker	Cochiti Pueblo	10	26.3	ND	ND	ND	1140.0	ND	14.8	ND	117	ND	1.16
Sucker	Rio San Jose at Acomita	3	8.79	0.93	<1.00	<0.40	1440.0	*	6	<2.00	133	*	0.98
Sucker	Albuquerque Riverside Drain	12	65.4	0.2	<1.00	<0.50	1330.0	*	10.3	<2.00	75.2	*	0.6
White Crappie	Bernalillo	3	14.2	ND	ND	ND	1640	ND	11	ND	212	ND	ND
White Crappie	Alameda	5	12.1	ND	ND	ND	1580	0.844	9	ND	187	ND	ND
Carp	San Felipe Pueblo	10	22.5	ND	ND	ND	1210.0	ND	11.2	ND	70	ND	ND
Carp	Albuquerque Riverside Drain	10	27.9	0.3	<1.00	<0.50	1190.0	*	12.2	<2.00	94.8	*	0.6
Carp	La Joya	10	73.8	0.3	<1.00	<0.50	1520.0	*	16.6	<2.00	232	*	0.6
Carp	Alameda	6	12.3	ND	ND	ND	990	ND	12.1	ND	60.4	ND	ND
Carp	Los Lunas	14	60.50	0.362	0.724	<2.54	1558.0	*	*	*	*	*	*
Carp	Isleta	10	7.47	1.28	ND	ND	1190	0.557	9.6	ND	62.4	ND	ND
Carp	BDANWR, Riverside Drain	10	47	3.7	<1.00	<0.50	1370.0	*	13.3	<2.00	159	*	0.7
Carp	Sandia Pueblo	10	21.6	ND	ND	ND	1270	ND	12.4	ND	124	ND	ND
Carp	Rio Grande at Isleta Pueblo	10	7.47	1.28	ND	ND	1190.0	0.557	9.6	ND	62.4	ND	ND
Carp	Madrone Ponds	10	32.3	0.1	<1.00	<0.50	1540.0	*	25.2	<2.00	169	*	<0.30
Carp	Bernalillo	10	11.7	ND	ND	ND	1390.0	ND	11.2	ND	121	ND	ND
Carp	Cochiti Pueblo	5	25.3	ND	ND	ND	1210.0	ND	12.3	ND	104	ND	ND
Carp	BDANWR, 18BE	10	12	0.48	<1.00	<0.50	1110.0	*	9.4	<2.00	19	*	0.3
Yellow Bullhead	Alameda	2	8.96	ND	ND	ND	1300	ND	6.2	ND	108	ND	ND
CH Catfish	Los Lunas	5	66.66	0.378	1.136	<2.31	1287.9	*	*	*	*	*	*
CH catfish	Sandia Pueblo	3	7.48	ND	ND	ND	727	ND	ND	ND	70.9	ND	ND
CH Catfish	La Joya	10	201	0.49	<1.00	<0.50	1190.0	*	10.3	<2.00	100	*	0.96
RB trout	San Felipe Pueblo	1	13.1	ND	ND	ND	1170.0	ND	6.21	ND	83.1	ND	ND
RB trout	San Felipe Pueblo	5	10.9	ND	ND	ND	997.0	ND	4.7	ND	67.7	ND	ND
RB trout	Cochiti Pueblo	1	7.79	ND	ND	ND	1090.0	ND	2.3	ND	48.3	81.2	ND
Silvery Minnow	Alameda	12	47.8	8.46	ND	ND	2040	ND	65.5	ND	173	ND	ND
Fathead Chub	Sandia Pueblo/Angostora Div.	15	10.6	ND	ND	ND	1170	ND	13.2	ND	104	ND	ND
Threadfin Shad	Madrone Ponds	10	62.5	0.51	<1.00	<0.50	1240.0	*	22.5	<2.00	63.3	*	1.2
Red Shiner	Rio San Jose	2	8.4	0.84	<1.00	<0.40	1180.0	*	4.2	<2.00	92.3	*	0.4
Minnows	BDANWR, 18BE		27.1	1.6	<1.00	<0.50	1340.0	*	12.5	<2.00	166	*	0.5

APPENDIX F.— Concentrations of inorganic compounds in biota and sediment samples from the Lower Rio Grande Basin, 1985.

[Concentrations are in micrograms per gram dry weight. Species: Wstn Kingbird, Western kingbird; BL Bullhead, black bullhead; CH catfish, channel catfish; %, percent; <, less than detection level].

Species	Sample Location	Composite Amount	Moisture %	Al	As	Cd	Cr	Cu	Fe	Pb	Hg	Se	Be
Wstn Kingbird	Hatch	7	63.1	2	0.05	0.22	< 0.09	4.9	514	5.5	0.089	1	0.014
Wstn Kingbird	Radium Springs	7	64.7	1.3	0.06	0.33	< 0.1	6.7	588	6.2	0.13	1.6	0.015
Wstn Kingbird	West Las Cruces	7	65.8	0.5	0.07	0.1	< 0.1	6.8	849	3.8	0.083	1.4	0.015
Wstn Kingbird	Stahman Farms	7	66.7	1.8	0.05	0.21	< 0.1	5.6	921	2.2	0.06	0.91	0.014
Wstn Kingbird	Chamberino	7	64.4	1	0.6	0.24	< 0.1	5.5	759	2.4	0.074	1.1	0.016
Wstn Kingbird	Los Lunas Control	10	65.4	5.6	<0.05	0.2	< 0.08	5.84	447	0.4	0.073	1	0.011
Mouse	Hatch	20	66.4	2.6	0.05	0.04	< 0.08	6.11	156	0.3	< 0.02	0.77	0.011
Mouse	Radium Springs	7	67.9	2.3	0.1	0.33	< 0.08	4.7	170	< 0.2	< 0.02	1.5	0.0097
Mouse	West Las Cruces	7	67.5	2	<0.05	0.05	< 0.09	5.6	147	0.2	< 0.02	1.3	0.012
Mouse	Stahman Farms	12	68.0	1.6	<0.05	0.03	< 0.08	5	152	0.2	< 0.02	0.79	0.01
Mouse	Chamberino	7	67.5	1.1	0.08	0.06	< 0.08	5.4	158	0.4	< 0.02	0.62	0.011
Mouse	Los Lunas Control	10	67.3	2.6	0.09	0.097	< 0.09	5.9	168	0.61	0.03	1.4	0.012
Lizard	Hatch	8	71.1	141	0.1	0.09	0.3	3.1	376	11	< 0.02	0.59	0.01
Lizard	Radium Springs	8	63.6	210	0.29	0.3	0.4	5.9	362	1	< 0.02	1.2	0.01
Lizard	Stahman Farms	7	68.5	206	0.1	0.2	0.3	5.6	405	4.6	0.11	0.78	0.01
Lizard	Chamberino	7	65.8	41	<0.08	0.35	< 0.2	4.1	191	1	< 0.02	0.96	< 0.007
Lizard	Los Lunas Control	7	65.2	361	< 0.2	0.3	0.4	5.3	495	3	< 0.02	0.77	< 0.01
BL Bull/CH Catfish	Hatch	10	75.5	22	<0.05	0.03	0.24	4.66	165	< 1	0.11	0.17	0.0093
CH Catfish	Radium Springs	6	76.1	81.5	<0.05	0.03	0.19	2.4	57.1	< 0.1	0.11	0.31	0.011
CH Catfish	West Las Cruces	5	75.7	52.5	<0.05	< 0.02	0.22	0.62	57.9	< 0.1	0.04	0.15	0.011
BL Bull/CH Catfish	Stahman Farms	7	73.1	14	<0.05	< 0.02	0.1	0.59	40.7	1.3	0.04	0.17	0.0092
CH Catfish	Chamberino	6	74.1	17	0.05	< 0.02	0.1	1.1	29.9	< 0.1	0.04	0.1	0.01
CH Catfish	Los Lunas Control	5	73.6	19	<0.05	< 0.02	0.1	3.4	31.6	< 0.1	0.082	0.1	0.0098
Carp	Hatch	6	74.3	38.9	<0.05	< 0.02	0.4	6.14	54.4	< 0.1	0.04	0.1	0.01
Carp	Radium Springs	7	73.4	203	<0.05	0.05	0.68	2.9	196	< 0.1	0.11	0.39	0.019
Carp	West Las Cruces	8	74.2	18	<0.05	0.03	0.1	1.2	42.8	< 0.1	0.03	0.18	0.0095
Carp	Stahman Farms	4	69.3	12	0.08	< 0.03	0.2	1.2	43.4	< 0.2	0.03	0.2	0.011
Carp	Chamberino	6	72.4	17	0.1	< 0.02	0.1	1.8	45.2	< 0.1	0.03	0.3	0.01
Carp	Los Lunas Control	14	72.4	31.2	0.1	0.03	0.1	1.9	57.5	< 0.1	0.067	0.31	0.011
Sediment	Hatch	3	39.3	5770	2.1	< 0.2	6.8	8.9	8410	10	< 0.05	<0.2	0.44
Sediment	Radium Springs	3	24.3	4720	1.2	< 0.2	5.2	5.9	6540	6	< 0.05	<0.2	0.36
Sediment	West Las Cruces	3	22.0	1960	0.75	< 0.2	2	3.2	3980	< 6	< 0.05	<0.2	0.16
Sediment	Stahman Farms	3	26.7	3070	0.91	< 0.2	12	4.7	5410	6	< 0.05	<0.2	0.26
Sediment	Chamberino	3	33.3	3650	1.3	0.3	3.1	5.4	5970	< 6	< 0.05	<0.2	0.29
Sediment	Los Lunas Control	3	45.7	4540	3.2	< 0.2	4.8	6.7	7760	8	< 0.05	0.3	0.36

APPENDIX F.— Concentrations of inorganic compounds in biota and sediment samples from the Lower Rio Grande Basin, 1985, concluded.

Species	Sample Location	Composite Amount	Mn	Mo	Ni	Tl	Zn
Wstn Kingbird	Hatch	7	2.24	1.8	0.2	< 0.9	23.7
Wstn Kingbird	Radium Springs	7	2.6	2.7	0.31	< 1	27.1
Wstn Kingbird	West Las Cruces	7	2.41	2.6	< 0.1	< 1	27.8
Wstn Kingbird	Stahman Farms	7	2.12	2.6	0.1	< 1	26.9
Wstn Kingbird	Chamberino	7	2.13	1.9	0.2	< 1	24
Wstn Kingbird	Los Lunas Control	10	2.07	2.1	0.2	< 0.8	27.4
Mouse	Hatch	20	2.33	2	0.2	< 0.8	25.6
Mouse	Radium Springs	7	1.95	1.3	0.2	< 0.8	24.1
Mouse	West Las Cruces	7	2.28	1.6	0.35	< 0.9	25.4
Mouse	Stahman Farms	12	1.62	1.9	0.2	< 0.8	23.8
Mouse	Chamberino	7	1.95	2.3	0.34	< 0.8	23.1
Mouse	Los Lunas Control	10	2.46	2.3	0.2	< 0.9	24.1
Lizard	Hatch	8	4.73	0.4	1	< 7	26.6
Lizard	Radium Springs	8	5.62	< 0.3	0.9	< 10	31.8
Lizard	Stahman Farms	7	6.09	< 0.2	0.58	< 7	29.1
Lizard	Chamberino	7	2.63	< 0.2	0.6	< 9	26.7
Lizard	Los Lunas Control	7	6.83	< 0.4	1	< 20	35.8
BL Bull/CH Catfish	Hatch	10	9.45	0.31	0.22	< 0.6	17.8
CH Catfish	Radium Springs	6	7.64	< 0.1	0.18	< 0.6	20.9
CH Catfish	West Las Cruces	5	11.7	< 0.1	0.2	< 0.6	19.5
BL Bull/CH Catfish	Stahman Farms	7	10.5	0.37	0.1	< 0.6	16.8
CH Catfish	Chamberino	6	8.06	0.1	0.09	< 0.6	16.7
CH Catfish	Los Lunas Control	5	17.6	0.3	0.1	< 0.6	17.2
Carp	Hatch	6	17.3	< 0.1	0.19	< 0.6	55.2
Carp	Radium Springs	7	15	0.34	0.36	< 0.6	17.3
Carp	West Las Cruces	8	4.95	0.3	0.09	< 0.6	49.6
Carp	Stahman Farms	4	7.53	0.2	0.2	< 0.8	51.9
Carp	Chamberino	6	14.5	0.48	0.1	< 0.7	59.8
Carp	Los Lunas Control	14	16.7	0.2	0.1	< 0.7	58.5
Sediment	Hatch	3	1040	< 0.5	7.5	< 10	31
Sediment	Radium Springs	3	203	2.4	5.6	< 10	20
Sediment	West Las Cruces	3	1560	1	2	< 10	15
Sediment	Stahman Farms	3	284	2	4.4	< 10	31
Sediment	Chamberino	3	1300	2.6	5.3	< 10	28
Sediment	Los Lunas Control	3	2900	< 0.5	5.5	< 10	26