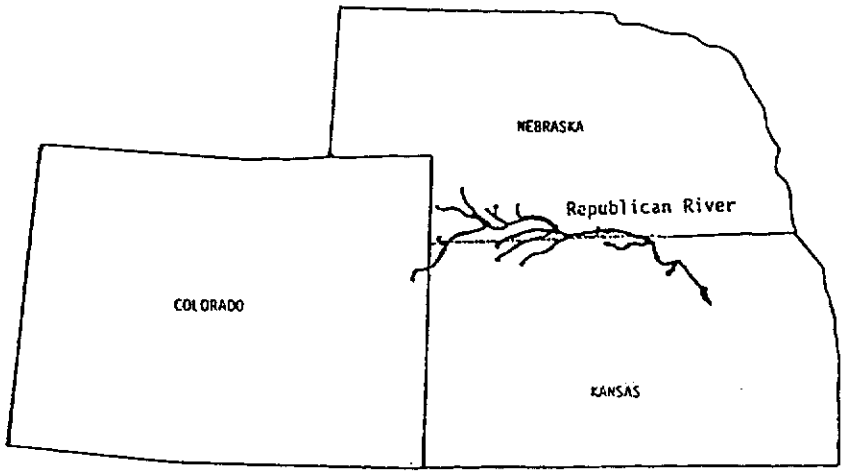
Contaminant Report Number: R6/512M/93

U.S. FISH & WILDLIFE SERVICE
REGION 6

CONTAMINANTS PROGRAM

BACKGROUND CONTAMINANTS EVALUATION OF THE REPUBLICAN RIVER DRAINAGE COLORADO, KANSAS, AND NEBRASKA



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U.S. FISH AND WILDLIFE SERVICE
Fish and Wildlife Enhancement
315 Houston Street
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SUMMARY

- This study was conducted to determine background levels of metals and organochlorine compounds in aquatic habitats in the Republican River basin, a large watershed in eastern Colorado, eastern Wyoming, southern Nebraska, and northwestern and northcentral Kansas. Reservoirs and their tributaries in the basin are concentration areas for bald eagles, migratory waterfowl, and occasionally for whooping cranes and other federally-listed threatened and endangered wildlife. The sampling was done to assess risk to federal trustee resources that use aquatic habitats in the basin.

- We sampled sediments at 29 locations and fish at 30 locations on the Republican River and tributaries in eastern Colorado, southern Nebraska, and northern Kansas in 1989 and 1990 to assess concentrations of metals and long-lived organochlorine compounds in the basin.

- Arsenic concentrations in sediments from the upper end of Lovewell Reservoir and from White Rock Creek below the reservoir were very high. Further investigation of the source(s) of the arsenic and its distribution may be warranted.

- Copper concentrations in White Rock Creek and upper Lovewell Reservoir sediments are suspect, and copper concentrations in the upper end of Norton Reservoir are high.

- Zinc concentrations in many of the sediment composites we collected were well above the mean concentrations found in U.S., western U.S., and northern Great Plains soils.

- Barium concentrations in fish were higher than those in fish from other collection locations in Kansas. The concentration found in the dace and chub composite from the St. Francis Wildlife Area was especially high. However, because information about the effects of barium on fish or wildlife is very limited, we can not estimate the effects, if any, of the concentrations in fish samples we collected.

- Fish composites at ten sampling locations contained high levels of chromium. However, assessment of these concentrations is difficult because there are no obvious sources of contamination associated with the collection locations.

- Copper concentrations in 11 fish composites exceeded the 1978-1979 NCBP 85th percentile concentration. The concentrations at Medicine Creek Reservoir in Nebraska and at White Rock Creek in Kansas were exceptionally high. However, some locations with high copper concentrations in fish did not have high sediment concentrations, nor did high sediment concentrations mean high concentrations in fish.

- Manganese concentrations in some fish composites collected for this study were considerably higher than those found in fish from other Kansas sampling locations, but they were not as high as some concentrations found in Missouri River fish. The high concentrations found in fish from Bonny Reservoir in Colorado, from the St. Francis Wildlife Area and from Norton Reservoir in Kansas, and from east of Haigler, at Max, from Rock Creek Reservoir, Swanson Reservoir, Medicine Creek, at Perry, from the Bartley Diversion Canal, and at the Cambridge Diversion Dam in Nebraska all suggest a review of the sources of the manganese may be necessary. None of these locations at which a suitable sediment concentration was collected had an elevated manganese concentration.

- The molybdenum concentration found in a river carpsucker composite from the Republican River at Perry, Nebraska was relatively high. Although molybdenum concentrations are usually well controlled, further examination of the site is recommended.

- In general, chlorinated hydrocarbon concentrations in sediments and fish from the sampling locations were low. At Junction City, Kansas (the last sampling site on the Republican River in Kansas), the concentration of chlordane compounds was more than twice the recommended level. However, that was the only location at which chlordane compounds were high in sediments or fish.

- Some fish samples indicated that toxaphene, mirex, and DDT may have been used recently in the basin. However, residues of the chemicals in samples we collected should not warrant serious concern on the part of resource managers.

- Overall, contaminant concentrations in the basin in sediments and fish were low. The Republican River basin need not be the focus of follow-up studies. We recommend regular monitoring of the basin at five to 10 year intervals.

ABBREVIATIONS AND CONVERSION FACTORS

Abbreviations

micrograms per gram	µg/g
not detected (i.e. below analytical detection limits) ...	ND
not analyzed (i.e. no test for this element or compound)	NA
not sampled at this location	NS

Conversions

micrograms per gram = parts per million (ppm)

ACKNOWLEDGMENTS

Steve Price of the Kansas Department of Wildlife and Parks collected fish from Norton Reservoir in 1989. Kyle Austin of the Kansas Department of Wildlife and Parks collected fish from Lovewell Reservoir in 1990. Gene Hansmann and Tom Jackson of the Fish and Wildlife Service in Denver coordinated project funding and sample submission, and Gene helped with reviews of this report. Bill Gill, Dewey Caster, and Ronel Finley of the Manhattan, Kansas office of the Fish and Wildlife Service also assisted in project efforts. Brent Esmoil, Rick Krueger, and Pedro Ramirez provided helpful comments on the draft of this report.

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INTRODUCTION

The Republican River Basin is a very large watershed in west-central Kansas, eastern Colorado, Wyoming and southern Nebraska. The area is intensively farmed, and in the basin there are nine U.S. Bureau of Reclamation reservoirs and canal systems for providing irrigation water. The reservoirs and their tributaries in the basin are concentration areas for bald eagles, migratory waterfowl, and occasionally for whooping cranes (*Grus americana*) and other threatened and endangered wildlife. In addition, the Kansas Department of Wildlife and Parks has spent Grant-In-Aid funds at the reservoirs in Kansas for fish and wildlife habitat management.

This study was conducted to determine background levels of metals and organochlorine compounds in aquatic habitats in the Republican River basin, and to determine if these habitats or fisheries may have been negatively impacted by Department of the Interior irrigation projects or by other activities. The sampling was intended as a preliminary assessment of risk to fish and wildlife that use aquatic habitats in the basin.

STUDY AREA AND METHODS

We collected sediments and/or fish from 33 locations in fall 1989 and/or fall 1990 (Table 1, Figure 1). Samples were collected from most planned locations along the Republican River drainage in Colorado, Nebraska, and Kansas in the fall of 1989. However, some locations in Kansas could not be sampled because the river froze in December. Because of concerns about selenium and toxaphene in the vicinity of the Bostwick Irrigation Project after the 1989 sampling, our sampling in 1990 began at the Nebraska border and included several locations sampled in 1989. We completed sampling in October 1990.

Separate sediment samples were collected in chemically-cleaned jars for inorganics and organics analyses. In most locations, the bottom in the Republican River is comprised of sand. Because sediments comprised mostly of silt and clay are preferred for analyses, we did not collect sediments in all locations.

Large fish were weighed, measured, and individually wrapped in aluminum foil. Small fish were composited and weighed as a sample and wrapped in aluminum foil. All samples were kept frozen until they were prepared for analysis.

Table 1. Republican River Basin fish[a] and sediment samples, 1989 and 1990.

	Location	Collection Date	Fish Sample(s)	Sample Mass (g)	Sediment Sample(s)
1	north of Bethune	10/Oct/1989	6 white suckers	750	same location
2	Bonny Reservoir	11/Oct/1989	6 gizzard shad	3950	no suitable sediment
3	St. Francis Wildlife Area	12/Oct/1989	longnose dace, creek chubs	550	no suitable sediment
4	Haigler	13/Oct/1989	sand shiners, plains killifish	650	no organochlorine sample
5	Rock Creek Reservoir	13/Oct/1989	4 gizzard shad	1550	same location
6	Max	14/Oct/1989	sand shiners, sand shiners, plains killifish	550	no suitable sediment
7	Swanson Reservoir	17/Nov/1989	2 river carpsucker 1 northern pike	3150 6800	creek just above the reservoir
8	Enders Reservoir	16/Nov/1989	6 gizzard shad	3250	creek just above the reservoir
9	Stinking Water Creek	15/Oct/1989	3 creek chub	180	same location
10	Frenchman Creek	15/Oct/1989	7 creek chub	245	same location
11	Hugh Butler Reservoir	19/Nov/1989	2 northern pike 3 common carp	7200 5100	creek just above the reservoir
12	Red Willow Creek	16/Oct/1989	9 creek chub	245	same location
13	Harry Strunk Reservoir	18/Nov/1989	4 white bass	1250	creek just above the reservoir
14	Medicine Creek	15/Nov/1989	3 river carpsucker	525	same location

Table 1 (continued). Republican River Basin fish and sediment samples, 1989 and 1990.

	Location	Collection Date	Fish Sample(s)	Sample Mass (g)	Sediment Sample(s)
15	Perry	16/Oct/1989	4 river carpsucker	1750	no suitable sediment
16	Bartley Diversion Canal	17/Oct/1989	7 river carpsucker	3850	same location
			5 common carp	4400	
17	Cambridge Diversion Dam	17/Oct/1989	6 common carp	11450	same location
			6 river carpsucker	2350	
18	Harlan County Reservoir	20/Nov/1989	1 northern pike	3350	1 km above reservoir on river (a)[a]
			3 common carp	6100	north shore at upper end of reservoir (b)
			4 common carp	9150	north shore just above dam (c)
			3 river carpsucker	4500	
			2 freshwater drum	2950	
19	Guide Rock	6/Dec/1989	sand shiners	550	same location
20	Superior	4/Dec/1989	5 common carp	10400	same location (a)
		27/Oct/1990	5 common carp	6500	same location (b)
			6 river carpsucker	2450	
21	Thompson Creek	5/Nov/1989	9 creek chubs	650	same location
22	Beaver Creek	15/Oct/1989	none	-	Rawlins/Decatur county line
23	Sappa Creek	15/Oct/1989	none	-	Just west of Lyle, Kansas
24	Norton Reservoir	26/Oct/1989	5 common carp	4700	creek just above the reservoir
			7 gizzard shad	1300	
25	Prairie Dog Creek	15/Oct/1989	none	-	at Kansas/Nebraska state line

Table 1 (continued). Republican River Basin fish and sediment samples, 1989 and 1990.

	Location	Collection Date	Fish Sample(s)	Sample Mass (g)	Sediment Sample(s)
26	White Rock Creek	7/Dec/1989	4 goldeye	1550	4 km below Lovewell Reservoir (a)
			1 common carp	1100	same location
		27/Oct/1990	5 common carp (I)[b]	8800	1 km above Republican River (b)
			5 common carp (O)[c]	8500	same location
27	Lovewell Reservoir	6/Dec/1989	2 freshwater drum	2650	White Rock Creek 1 km above the reservoir (a)
			5 walleye	9650	upper end of the reservoir (b)
			5 common carp	9400	north shore at upper end (c)
			5 gizzard shad (I)	5250	
			5 gizzard shad (O)	5200	
		2/Nov/1990	3 walleye (I)	2175	White Rock Creek 1 km above the reservoir (d)
			3 walleye (O)	2040	upper end of the reservoir (e)
			4 common carp (I)	5735	north shore at upper end (f)
			5 common carp (O)	6375	
28	Scandia	7/Dec/1989	5 common carp	6950	same location (a)
			5 river carpsuckers	4700	
		27/Oct/1990	2 common carp	3050	same location (b)
29	Elm Creek	28/Oct/1990	none		
30	Clyde	28/Oct/1990	3 common carp	5300	same location
			4 river carpsucker	5600	
31	Clay Center	29/Oct/1990	4 common carp	4600	same location
			4 common carp	4500	

Table 1 (concluded). Republican River Basin fish and sediment samples, 1989 and 1990.

	Location	Collection Date	Fish Sample(s)	Sample Mass (g)	Sediment Sample(s)
32	Milford Reservoir	30/Oct/1990	10 white bass	5050	river just above the reservoir
			9 goldeye	550	
			9 gizzard shad	650	
			1 smallmouth buffalo	1700	
			1 river carpsucker	1550	
			1 walleye	850	
33	Junction City	30/Oct/1990	4 river carpsucker	3250	same location
			1 common carp	1700	

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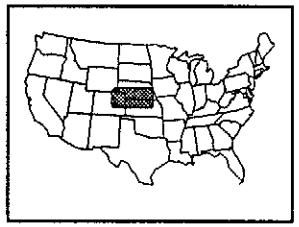
[a] Scientific names: white sucker is Catostomus commersoni, gizzard shad is Dorosoma cepedianum, longnose dace is Rhinichthys cataractae, creek chub is Semotilus atromaculatus, sand shiner is Notropis stramineus, plains killifish is Fundulus kansae, river carpsucker is Carpiodes carpio, northern pike is Esox lucius, common carp is Cyprinus carpio, white bass is Morone chrysops, freshwater drum is Aplodinota grunniens.

[b] for inorganics analyses

[c] for organics analyses

[d] later tables refer to these particular sampling locations or samples from one of the sampling years.



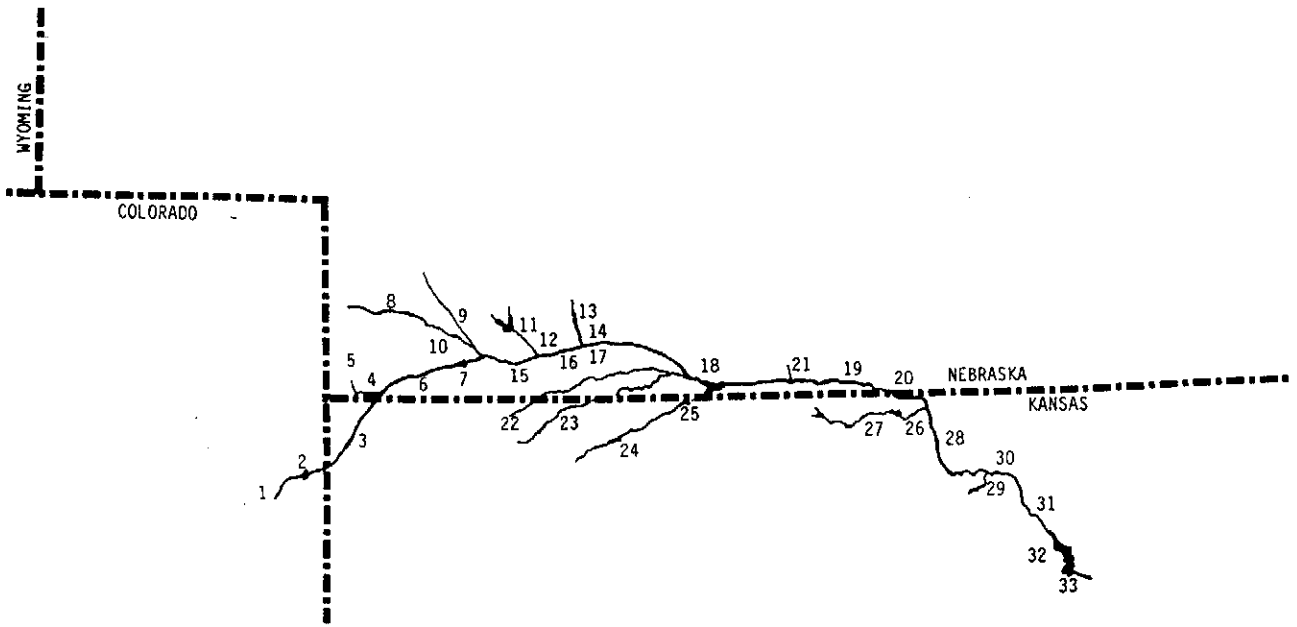


Figure 1. Sampling locations in the Republican River Basin, 1989 and 1990. Numbers on the map correspond to sampling locations in Table 1.

Metals analyses were conducted by the Patuxent Analytical Control Facility (PACF) of the U.S. Fish and Wildlife Service (Service) and by the Environmental Trace Substances Research Center (ETSRC) in Rolla, Missouri. Total arsenic, mercury, and selenium were analyzed using atomic absorption spectroscopy. Induction coupled plasma emission spectroscopy (ICP) without preconcentration was used to test for aluminum, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, magnesium, manganese, molybdenum, nickel, silver, strontium, thallium, vanadium, and zinc. Sediment samples were prepared for analysis using strong acid digestion, which gives a measure of the potential bioavailability of metals analyzed. ETSRC reported dry weight concentrations for metals in most catalogs, so for comparison to wet weight concentrations reported in the literature, we calculated wet weight concentrations by multiplying the dry weight concentrations by [1 - (% moisture/100)]. Detection limits for metals are shown in Table 2.

Organochlorine analyses were conducted by PACF or by the Mississippi State Chemical Laboratory (MSCL) at Mississippi State University. Concentrations of chlorinated hydrocarbon compounds were determined using electron capture gas chromatography. In both sediment and fish, the detection limit for chlorinated hydrocarbons was 0.01 μg/g wet weight, except for toxaphene and total PCBs, for which the detection limit was 0.05 μg/g wet weight.

No anomalies were reported in the samples. Each sample collected was large enough for the laboratory to determine the concentration of each element or compound at the limit of the analytical equipment. Laboratory quality control is reviewed by PACF. Precision and accuracy of the laboratory analyses are confirmed with procedural blanks, duplicate analyses, test recoveries of spiked materials, and reference material analyses. Round-robin tests among Service and contract analytical labs also are part of the quality control.

A new Service sample submission system was started during the period in which samples for this study were submitted. Because of a misunderstanding on the part of the senior author about requesting sample analyses, some of the fish composites were analyzed for arsenic, mercury, and selenium by ICP scans. Detection limits for these metals in those samples were much higher than those in the other samples.

Table 2. Normal detection limits for metals in Republican River sediment and fish samples, 1989 and 1990. Detection limits vary according to sample size.

Element	Detection Limit (µg/g dry weight)			
	Sediment		Fish	
	AAS	ICP	AAS	ICP
Aluminum	NA	3-6	NA	3
Arsenic	0.1-0.2	20	0.2-0.4	4-5
Barium	NA	0.1-0.2	NA	0.1
Beryllium	NA	0.1-0.2	NA	0.05-0.1
Boron	NA	2-4	NA	2-4
Cadmium	NA	0.3-0.5	NA	0.4
Chromium	NA	1-2	NA	1
Copper	NA	0.2-0.4	NA	0.2-0.3
Iron	NA	1-2[a]	NA	1
Lead	NA	6-10	NA	4
Magnesium	NA	7-20	NA	2-4
Manganese	NA	0.2-0.4	NA	0.2
Mercury	0.03-0.4	NA	0.01	NA
Molybdenum	NA	1-2	NA	1
Nickel	NA	1-4	NA	1-2
Selenium	0.1-0.4	30-60	0.1-0.2	5-6
Silver	NA	3-4	NA	2
Strontium	NA	0.1-0.2	NA	0.1
Tellurium	NA	9-10	NA	4-6
Vanadium	NA	0.4-1	NA	0.3
Zinc	NA	0.3-0.6	NA	0.2

[a] A few unexplained detection limits of 30-60 µg/g.

RESULTS AND DISCUSSION

METALS

Metals in Sediments

Results of the arsenic, mercury, and selenium analyses of sediments are shown in Table 3. Except for arsenic concentrations at Lovewell Reservoir and White Rock Creek in Kansas, arsenic and mercury concentrations were comparable to those for western U.S. soils and sediments (Table 4) in all locations. Arsenic concentrations along White Rock Creek and perhaps in Lovewell Reservoir should be investigated further.

Virtually all selenium concentrations in sediment samples we collected were very low. However, concentrations of 4.0 μg/g or greater are cause for concern (Lemly and Smith 1987), so the concentrations found at the upper end of Lovewell Reservoir in 1989 (samples analyzed by PACF) were high enough to warrant concern. However, selenium was not detected in 1990 samples from the same locations analyzed by ETSRC.

Concentrations of other metals in sediments are shown in Table 5. Neither thallium nor silver was detected in any sediment sample. Concentrations of aluminum, barium, boron, chromium, iron, magnesium, and molybdenum were within the ranges of normal U.S. and north-central U.S. soil concentrations.

Beryllium has low solubility in water, and a low tendency to bioaccumulate (Phillips and Russo 1978). Therefore, although sediment beryllium concentrations at several locations were greater than the means in soils from the U.S. and the western U.S., and a few were larger than the mean concentrations in northern Great Plains soils, the concentrations do not indicate a problem. This assessment is confirmed by the failure to detect beryllium in any fish composite.

Copper is a minor nutrient for plants and animals. Copper availability depends on water hardness in many settings (Hodson 1988). Copper concentrations in sediments from Norton Reservoir and Lovewell Reservoir were well above the means for western U.S., and northern Great Plains soils. However, concentrations reported by ETSRC in 1990 samples from White Rock Creek just above Lovewell Reservoir and at the entrance of the creek to the reservoir were much greater than the concentrations found in samples from the same locations by PACF in 1989 samples. The concentrations in White Rock Creek and upper Lovewell Reservoir

Table 3. Arsenic, mercury, and selenium concentrations in Republican River Basin sediments, 1989 and 1990.

Location	State	Element Concentration (µg/g dry weight)					
		Arsenic		Mercury		Selenium	
		Dry	Wet	Dry	Wet	Dry	Wet
north of Bethune	Colorado	2.6	1.5	0.07	0.04	1.9	1.1
east of Haigler	Nebraska	1.0	0.81	ND	ND	ND	ND
Rock Creek Reservoir	Nebraska	3.2	1.9	ND	ND	0.57	0.96
Swanson Reservoir	Nebraska	1.1	0.84	ND	ND	ND	ND
Enders Reservoir	Nebraska	1.3	0.93	ND	ND	0.30	0.20
Stinking Water Creek	Nebraska	2.1	1.5	0.07	0.05	ND	ND
Frenchman Creek near Hamlet	Nebraska	1.7	1.2	ND	ND	0.10	0.10
Red Willow Reservoir	Nebraska	4.4	3.1	0.04	0.03	0.40	0.30
Red Willow Creek	Nebraska	2.7	2.1	ND	ND	ND	ND
Medicine Creek Reservoir	Nebraska	2.2	1.5	ND	ND	ND	ND
Medicine Creek at Cambridge	Nebraska	1.4	1.1	0.04	0.03	0.10	0.10
Bartley Diversion Canal	Nebraska	1.0	0.82	ND	ND	0.10	0.10
Cambridge Diversion Dam	Nebraska	0.81	0.63	0.02	0.02	ND	ND
Harlan County Reservoir (a)	Nebraska	2.9	1.5	ND	ND	0.40	0.22
Harlan County Reservoir (b)	Nebraska	2.6	1.7	ND	ND	0.19	0.12
Harlan County Reservoir (c)	Nebraska	4.0	2.5	ND	ND	0.17	0.10
at Superior (a)	Nebraska	0.28	0.17	ND	ND	ND	ND
at Superior (b)	Nebraska	1.9	1.3	ND	ND	0.30	0.20
Thompson Creek	Nebraska	0.92	0.71	ND	ND	0.52	0.40
Beaver Creek	Kansas	3.7	2.9	0.05	0.04	0.39	0.30
Sappa Creek	Kansas	3.2	2.6	0.09	0.07	0.56	0.50
Norton Reservoir	Kansas	7.6	3.7	0.10	0.05	0.89	0.40
Prairie Dog Creek	Nebraska	3.6	2.8	0.05	0.03	ND	ND
White Rock Creek (a)	Kansas	6.1	3.7	ND	ND	0.98	0.60
White Rock Creek (b)	Kansas	10	5.7	0.02	0.04	1.1	0.60
Lovewell Reservoir (a)	Kansas	6.1	3.0	ND	ND	10	5.3
Lovewell Reservoir (b)	Kansas	5.7	3.0	ND	ND	9.3	4.8
Lovewell Reservoir (c)	Kansas	2.2	1.5	ND	ND	0.28	0.20
Lovewell Reservoir (d)	Kansas	15	7.2	0.05	0.10	ND	ND
Lovewell Reservoir (e)	Kansas	18	9.0	0.04	0.08	ND	ND
Lovewell Reservoir (f)	Kansas	3.5	2.4	ND	ND	ND	ND
at Scandia (a)	Kansas	2.2	1.4	ND	ND	ND	ND
at Scandia (b)	Kansas	3.7	2.2	ND	ND	ND	ND
Elm Creek	Kansas	2.3	1.6	ND	ND	ND	ND
at Clyde	Kansas	2.2	1.5	ND	ND	0.30	0.20
at Clay Center	Kansas	1.8	1.4	ND	ND	0.10	0.10
Milford Reservoir	Kansas	6.6	4.1	0.05	0.03	0.53	0.30
at Junction City	Kansas	3.8	2.5	ND	ND	0.30	0.20

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* Concentration from ICP scan, which has a higher detection limit than atomic absorption spectroscopy.

sediments are suspect, and copper concentrations in the upper end of Norton Reservoir are high.

Lead concentrations in sediments from the upper end of Lovewell Reservoir in 1990 were much higher than the means from U.S. soil studies. However, concentrations found by ETSRC in the 1990 samples were much greater than those found by PACF in 1989 samples from the same locations.

The same is true for manganese concentrations. The only locations at which manganese concentrations were notably higher than the U.S. norms were found at the upper end of Lovewell Reservoir in 1990. The reported 1989 concentrations from those locations were considerably lower.

Nickel concentrations in sediments were high at the same four locations at which copper concentrations were high. Nickel has been considered less problematic than many other heavy metals, and was considered by Phillips and Russo (1978) to have a low bioaccumulative tendency.

Strontium concentrations in sediments were high only north of Bethune, Colorado and at the upper end of Lovewell Reservoir in 1990. Concentrations in sediments at those locations did not correspond to high concentrations in fish. We do not know if the high sediment concentrations have any effects on biota.

In the samples analyzed for tin, the concentration at the one location where tin was found (the upper end of Harlan County Reservoir in Nebraska) was very high compared to means for U.S. and western U.S. soils. We have no explanation for the high concentration, and are suspicious of the reported value.

Vanadium concentrations in sediments were high only in the 1990 samples from the upper end of Lovewell Reservoir. Those concentrations were slightly higher than the mean concentrations for U.S. and western U.S. soils, and we do not suspect any problems related to the sediment concentrations found.

Zinc is a relatively mobile metal in natural settings, but zinc concentrations in many locations have been greatly increased by human activities (*e.g.* Beyer *et al.* 1985, Johnson *et al.* 1978, Niethammer *et al.* 1985, Roch *et al.* 1985, Sileo and Beyer 1985). Zinc availability and toxicity are affected by pH and by water hardness (Phillips and Russo 1978). Zinc concentrations in many of the sediment composites we collected were well above the mean concentrations found in U.S., western U.S., and northern Great Plains soils.

Table 4. Soil or sediment element concentrations from the U.S. Except as noted, concentrations are in $\mu g/g$.

Element	Location			
	Conterminous U.S. soils[a,d]	Western U.S. soils[a,d]	Northern Great Plains soils	North-Central U.S. sediments
Aluminum	4.7%	5.8%	5.6%	NA
Antimony	0.48	0.47	NA	NA
Arsenic	5.2	5.5	7.1	4.4[f], 2.4[g]
Barium	440	580	1100	NA
Beryllium	0.63	0.68	1.6	NA
Boron	26	23	41	NA
Cadmium	NA	NA	NA	0.52[f], 0.26[g]
Chromium	37	41	45	NA
Copper	17	21	19	NA
Iron	1.8%	2.1%	2.1%	NA
Lead	16	17	16	13[f], 6.6[g]
Magnesium	0.44%	0.74%	0.66%	NA
Manganese	330	380	460	NA
Mercury	0.058	0.046	0.023	0.03[f], 0.03[g]
Molybdenum	0.59	0.85	3.8	NA
Nickel	13	15	18	NA
Selenium	0.26	0.23	0.45	0.89[f], 0.52[g]
Strontium	120	200	NA	NA
Tin	0.89	0.90	NA	NA
Vanadium	58	70	54	NA
Zinc	48	55	63	NA

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[a] Shacklette and Boerngen 1984
[b] Severson and Tidball 1979
[c] Martin and Hartman 1984
[d] geometric means
[e] unspecified means
[f] mean for pothole wetlands
[g] mean for riverine wetlands

Table 5. Metal concentrations from ICP scans in Republican River Basin sediments, 1989 and 1990. NS = Not Sampled, ND = Not Detected.

Location	State	Element Concentration (µg/g)					
		Aluminum		Barium		Beryllium	
		Dry	Wet	Dry	Wet	Dry	Wet
north of Bethune	Colorado	10000	5280	406	236	0.59	0.34
east of Haigler	Nebraska	3060	2470	98	79	0.20	0.20
Rock Creek Reservoir	Nebraska	5450	3240	187	111	0.30	0.20
Swanson Reservoir	Nebraska	2340	1810	207	160	0.10	0.10
Enders Reservoir	Nebraska	3470	2540	105	77	0.30	0.20
Stinking Water Creek	Nebraska	12100	8760	181	131	0.55	0.40
Frenchman Creek near Hamlet	Nebraska	7440	5390	167	121	0.48	0.35
Red Willow Reservoir	Nebraska	23300	16400	299	210	1.20	0.87
Red Willow Creek	Nebraska	14700	10800	281	206	0.85	0.62
Medicine Creek Reservoir	Nebraska	14000	9410	219	147	0.82	0.55
Medicine Creek at Cambridge	Nebraska	4370	3410	113	89	0.30	0.20
Bartley Diversion Canal	Nebraska	2980	2360	133	105	0.30	0.20
Cambridge Diversion Dam	Nebraska	4700	3650	76	59	0.20	0.20
Harlan County Reservoir (a)	Nebraska	8400	4400	300	160	0.92	0.48
Harlan County Reservoir (b)	Nebraska	4100	2700	110	72	ND	ND
Harlan County Reservoir (c)	Nebraska	5700	3700	100	65	ND	ND
at Superior (a)	Nebraska	1500	950	42	26	ND	ND
at Superior (b)	Nebraska	5370	3620	108	73	0.20	0.10
Thompson Creek	Nebraska	19500	15100	325	252	1.20	0.92
Beaver Creek	Kansas	17500	13800	282	223	1.00	0.80
Sappa Creek	Kansas	16000	12900	288	232	0.88	0.71
Norton Reservoir	Kansas	45100	21800	535	259	2.30	1.10
Prairie Dog Creek	Nebraska	36400	27900	301	230	1.60	1.20
White Rock Creek (a)	Kansas	24400	14900	308	188	1.30	0.78
White Rock Creek (b)	Kansas	26900	14700	344	188	1.60	0.88
Lovewell Reservoir (a)	Kansas	11000	5500	140	69	ND	ND
Lovewell Reservoir (b)	Kansas	9200	4800	100	52	ND	ND
Lovewell Reservoir (c)	Kansas	2900	2000	43	30	ND	ND
Lovewell Reservoir (d)	Kansas	60800	29900	508	250	3.00	1.50
Lovewell Reservoir (e)	Kansas	65700	32300	518	255	3.30	1.60
Lovewell Reservoir (f)	Kansas	11700	8040	134	92	0.61	0.42
at Scandia (a)	Kansas	1600	1100	39	26	ND	ND
at Scandia (b)	Kansas	9230	5500	300	179	0.50	0.30
Elm Creek	Kansas	2450	1710	78	55	0.10	0.07
at Clyde	Kansas	10400	7030	225	152	0.50	0.34
at Clay Center	Kansas	2620	2060	186	146	0.30	0.20
Milford Reservoir	Kansas	34000	21300	315	197	1.50	0.93
at Junction City	Kansas	12100	7880	195	127	0.80	0.52

Table 5 (continued). Metal concentrations from ICP scans in Republican River Basin sediments, 1989 and 1990. NS = Not Sampled, ND = Not Detected.

Location	State	Element Concentration (µg/g)							
		Boron		Cadmium		Chromium		Copper	
		Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
north of Bethune	Co	ND	ND	ND	ND	9.3	5.4	7.6	4.4
east of Haigler	Ne	4.0	3.0	ND	ND	2.0	2.0	2.2	1.8
Rock Creek Reservoir	Ne	ND	ND	ND	ND	9.9	5.9	6.4	3.8
Swanson Reservoir	Ne	ND	ND	ND	ND	3.0	2.0	1.8	1.4
Enders Reservoir	Ne	ND	ND	ND	ND	4.2	3.1	1.9	1.4
Stinking Water Creek	Ne	4.0	3.0	ND	ND	11	8.2	6.3	4.6
Frenchman Creek near Hamlet	Ne	ND	ND	ND	ND	8.1	5.9	4.8	3.5
Red Willow Reservoir	Ne	4.0	3.0	ND	ND	23	16	16	11.0
Red Willow Creek	Ne	4.0	3.0	ND	ND	15	11	9.7	7.1
Medicine Creek Reservoir	Ne	ND	ND	ND	ND	15	10	8.8	5.9
Medicine Creek at Cambridge	Ne	ND	ND	ND	ND	5.3	4.1	2.4	1.9
Bartley Diversion Canal	Ne	ND	ND	ND	ND	3.0	2.0	2.4	1.9
Cambridge Diversion Dam	Ne	2.0	2.0	ND	ND	4.1	3.2	2.2	1.7
Harlan County Reservoir	Ne	ND	ND	ND	ND	7.6	4.0	12	6.3
Harlan County Reservoir	Ne	ND	ND	ND	ND	4.1	2.7	7.1	4.7
Harlan County Reservoir	Ne	ND	ND	ND	ND	5.7	3.7	8.7	5.6
at Superior (a)	Ne	ND	ND	ND	ND	1.4	0.9	2.5	1.6
at Superior (b)	Ne	ND	ND	ND	ND	4.0	2.7	2.5	1.7
Thompson Creek	Ne	4.0	3.0	0.5	0.4	19	15	15	12.0
Beaver Creek	Ks	3.0	2.0	ND	ND	18	14	13	10.0
Sappa Creek	Ks	4.0	3.0	0.4	0.3	15	12	11	9.1
Norton Reservoir	Ks	8.0	4.0	0.8	0.4	37	18	31	15.0
Prairie Dog Creek	Ne	9.9	7.6	0.5	0.4	26	20	20.6	15.8
White Rock Creek (a)	Ks	5.0	3.0	0.7	0.4	21	13	18	11.0
White Rock Creek (b)	Ks	9.0	5.0	0.7	0.4	22	12	24	13.0
Lovewell Reservoir (a)	Ks	ND	ND	ND	ND	10	5.0	17	8.3
Lovewell Reservoir (b)	Ks	ND	ND	ND	ND	8.7	4.5	14	7.3
Lovewell Reservoir (c)	Ks	ND	ND	ND	ND	3.1	2.2	4.5	3.2
Lovewell Reservoir (d)	Ks	10	5.0	1.7	0.8	45	22	42.5	20.9
Lovewell Reservoir (e)	Ks	13	6.3	1.9	0.9	47	23	45.9	22.6
Lovewell Reservoir (f)	Ks	ND	ND	ND	ND	13	8.7	8.2	5.6
at Scandia (a)	Ks	ND	ND	ND	ND	1.8	1.2	3.5	2.3
at Scandia (b)	Ks	3.0	2.0	ND	ND	8.1	4.8	6.4	3.8
Elm Creek	Ks	ND	ND	ND	ND	2.0	1.0	1.1	0.8
at Clyde	Ks	4.0	3.0	ND	ND	6.1	4.1	5.3	3.6
at Clay Center	Ks	ND	ND	ND	ND	3.0	2.0	1.5	1.2
Milford Reservoir	Ks	6.0	4.0	ND	ND	27	17	19	12.0
at Junction City	Ks	ND	ND	ND	ND	13	8.5	10	6.6

Table 5 (continued). Metal concentrations from ICP scans in Republican River Basin sediments, 1989 and 1990. NS = Not Sampled, ND = Not Detected.

Location	State	Element Concentration (µg/g)							
		Iron		Lead		Magnesium		Manganese	
		Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
north of Bethune	Co	9950	5780	ND	ND	3670	2130	167	97
east of Haigler	Ne	2890	2330	ND	ND	890	720	112	91
Rock Creek Reservoir	Ne	5520	3280	ND	ND	1850	1100	63	38
Swanson Reservoir	Ne	2330	1800	ND	ND	800	620	127	98
Enders Reservoir	Ne	3640	2660	ND	ND	1370	1000	84	61
Stinking Water Creek	Ne	10900	7920	ND	ND	4090	2970	174	126
Frenchman Creek near Hamlet	Ne	7150	5180	ND	ND	2910	2110	132	96
Red Willow Reservoir	Ne	19300	13600	10	10	7330	5150	448	315
Red Willow Creek	Ne	13700	10000	10	7.0	4870	3570	270	198
Medicine Creek Reservoir	Ne	13000	8720	ND	ND	5030	3380	220	148
Medicine Creek at Cambridge	Ne	5240	4090	ND	ND	1410	1100	109	85
Bartley Diversion Canal	Ne	3250	2570	ND	ND	100	860	85	68
Cambridge Diversion Dam	Ne	3950	3070	ND	ND	1360	1060	75	59
Harlan County Reservoir	Ne	11000	5500	9.3	4.9	4800	2500	380	200
Harlan County Reservoir	Ne	6000	3900	9.5	6.2	2600	1700	170	110
Harlan County Reservoir	Ne	8900	5700	8.0	5.2	3500	2300	160	100
at Superior (a)	Ne	2900	1800	ND	ND	690	430	290	180
at Superior (b)	Ne	4560	3080	12	8.0	1150	776	344	232
Thompson Creek	Ne	18100	14000	10	10	6530	5060	382	296
Beaver Creek	Ks	15600	12300	10	8.0	6030	4760	284	224
Sappa Creek	Ks	13900	11200	10	9.0	4390	3530	303	244
Norton Reservoir	Ks	35100	17000	20	10	11200	5440	779	377
Prairie Dog Creek	Ne	26700	20400	17	13	7610	5830	339	259
White Rock Creek (a)	Ks	21600	13200	20	10	4740	2890	462	282
White Rock Creek (b)	Ks	23600	12900	20	10	5600	3060	449	245
Lovewell Reservoir (a)	Ks	14000	6700	12	5.9	4100	2000	360	180
Lovewell Reservoir (b)	Ks	11000	5600	11	5.5	3000	1600	400	210
Lovewell Reservoir (c)	Ks	4800	3400	3.6	2.5	1300	930	110	77
Lovewell Reservoir (d)	Ks	48000	23600	35	17	11800	5820	1020	500
Lovewell Reservoir (e)	Ks	51400	25300	39	19	12600	6220	1120	553
Lovewell Reservoir (f)	Ks	12200	8350	7.0	5.0	2730	1870	190	130
at Scandia (a)	Ks	2500	1700	2.5	1.7	680	450	280	190
at Scandia (b)	Ks	8980	5350	10	7.0	2250	1340	599	357
Elm Creek	Ks	2880	2010	5.0	3.0	489	341	523	365
at Clyde	Ks	8130	5480	ND	ND	1930	1300	220	148
at Clay Center	Ks	3350	2630	ND	ND	560	440	453	356
Milford Reservoir	Ks	25200	15800	20	10	6220	3890	591	370
at Junction City	Ks	11900	7790	ND	ND	2960	1930	161	105

Table 5 (continued). Metal concentrations from ICP scans in Republican River Basin sediments, 1989 and 1990. NS = Not Sampled, ND = Not Detected.

Location	State	Element Concentration (µg/g)							
		Molybdenum		Nickel		Strontium		Tin	
		Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
north of Bethune	Co	ND	ND	9.0	5.2	318	185	NA	NA
east of Haigler	Ne	ND	ND	ND	ND	24.9	20.1	NA	NA
Rock Creek Reservoir	Ne	ND	ND	5.0	3.0	56.4	33.5	NA	NA
Swanson Reservoir	Ne	ND	ND	ND	ND	42.1	32.6	NA	NA
Enders Reservoir	Ne	ND	ND	3.0	2.0	42	30.7	NA	NA
Stinking Water Creek	Ne	ND	ND	8.0	5.5	63.4	46	NA	NA
Frenchman Creek near Hamlet	Ne	ND	ND	4.0	3.0	59	42.7	NA	NA
Red Willow Reservoir	Ne	ND	ND	17	12	112	78.8	NA	NA
Red Willow Creek	Ne	ND	ND	11	8.1	76.3	55.9	NA	NA
Medicine Creek Reservoir	Ne	ND	ND	10	7.0	74.1	49.8	NA	NA
Medicine Creek at Cambridge	Ne	ND	ND	3.0	2.0	27.2	21.2	NA	NA
Bartley Diversion Canal	Ne	ND	ND	4.0	3.0	33.2	26.3	NA	NA
Cambridge Diversion Dam	Ne	ND	ND	2.0	2.0	29.6	23	NS	NS
Harlan County Reservoir	Ne	ND	ND	13	6.8	76	40	68	35
Harlan County Reservoir	Ne	ND	ND	7.3	4.8	60	39	ND	ND
Harlan County Reservoir	Ne	3.4	2.2	12	7.7	41	27	ND	ND
at Superior (a)	Ne	0.8	0.5	3.2	2.0	23	15	ND	ND
at Superior (b)	Ne	ND	ND	3.0	2.0	31.4	21.2	NA	NA
Thompson Creek	Ne	ND	ND	17	13	99.2	76.9	NA	NA
Beaver Creek	Ks	ND	ND	14	11	81.8	64.6	NA	NA
Sappa Creek	Ks	ND	ND	14	11	62.9	50.6	NA	NA
Norton Reservoir	Ks	ND	ND	31	15	136	65.8	NA	NA
Prairie Dog Creek	Ne	ND	ND	20	15	67.1	51.4	NA	NA
White Rock Creek (a)	Ks	ND	ND	21	13	121	73.9	NA	NA
White Rock Creek (b)	Ks	ND	ND	29	16	130	70.9	NA	NA
Lovewell Reservoir (a)	Ks	2.5	1.2	19	9.3	130	65	ND	ND
Lovewell Reservoir (b)	Ks	1.2	0.6	15	7.9	100	54	ND	ND
Lovewell Reservoir (c)	Ks	ND	ND	5.8	4.0	40	28	ND	ND
Lovewell Reservoir (d)	Ks	ND	ND	51	25	280	138	NA	NA
Lovewell Reservoir (e)	Ks	ND	ND	51	25	325	160	NA	NA
Lovewell Reservoir (f)	Ks	ND	ND	11	7.5	62.1	42.5	NA	NA
at Scandia (a)	Ks	ND	ND	3.9	2.6	23	15	ND	ND
at Scandia (b)	Ks	ND	ND	7.5	4.5	120	71.5	NA	NA
Elm Creek	Ks	ND	ND	1.0	0.7	12.7	8.9	NA	NA
at Clyde	Ks	ND	ND	7.0	5.0	52.5	35.4	NA	NA
at Clay Center	Ks	ND	ND	3.0	2.0	24.3	19.1	NA	NA
Milford Reservoir	Ks	ND	ND	21	13	109	68.4	NA	NA
at Junction City	Ks	ND	ND	13	8.2	45	29.4	NA	NA

Table 5 (concluded). Metal concentrations from ICP scans in Republican River Basin sediments, 1989 and 1990. NS = Not Sampled, ND = Not Detected.

Location	State	Element Concentration (µg/g)			
		Vanadium		Zinc	
		Dry	Wet	Dry	Wet
north of Bethune	Co	31	18	35	20.1
east of Haigler	Ne	8.7	7.0	8.9	7.2
Rock Creek Reservoir	Ne	29	17	25	15
Swanson Reservoir	Ne	5.3	4.1	7.1	5.5
Enders Reservoir	Ne	10	7.4	9.8	7.2
Stinking Water Creek	Ne	23	17	32	23
Frenchman Creek near Hamlet	Ne	15	11	23	17
Red Willow Reservoir	Ne	33	23	63	44
Red Willow Creek	Ne	27	20	44	32
Medicine Creek Reservoir	Ne	22	15	42	29
Medicine Creek at Cambridge	Ne	13	9.8	14	11
Bartley Diversion Canal	Ne	6.3	5.0	11	8.6
Cambridge Diversion Dam	Ne	9.4	7.3	13	10
Harlan County Reservoir	Ne	17	8.7	39	20
Harlan County Reservoir	Ne	12	7.7	21	14
Harlan County Reservoir	Ne	14	8.9	28	18
at Superior (a)	Ne	4.1	2.5	9.1	5.7
at Superior (b)	Ne	10	6.7	14	9.4
Thompson Creek	Ne	31	24	58	45
Beaver Creek	Ks	27	21	49	39
Sappa Creek	Ks	26	21	48	39
Norton Reservoir	Ks	54	26	126	61
Prairie Dog Creek	Ne	44	34	90	69
White Rock Creek (a)	Ks	44	27	79	48
White Rock Creek (b)	Ks	55	30	84	46
Lovewell Reservoir (a)	Ks	29	14	50	24
Lovewell Reservoir (b)	Ks	23	12	40	21
Lovewell Reservoir (c)	Ks	11	8.0	13	9.2
Lovewell Reservoir (d)	Ks	81	40	167	82
Lovewell Reservoir (e)	Ks	95	47	182	89
Lovewell Reservoir (f)	Ks	28	19	37	25
at Scandia (a)	Ks	4.5	3.0	8.6	5.8
at Scandia (b)	Ks	18	11	32	19
Elm Creek	Ks	6.1	4.3	6.5	4.5
at Clyde	Ks	19	13	22	15
at Clay Center	Ks	6.6	5.2	7.6	6.0
Milford Reservoir	Ks	45	28	78	49
at Junction City	Ks	20	13	39	26

Metals in Fish

Table 6 shows arsenic, mercury, and selenium concentrations in fish. Background arsenic concentrations in freshwater biota normally are less than 1 μg/g fresh weight, partly because arsenic usually is rapidly excreted after exposure (Eisler 1988). All fish composites collected for this study contained less than 1 μg/g arsenic wet weight. The mean and 85th percentile concentrations for arsenic in fish from the National Contaminant Biomonitoring Program (NCBP) in 1984 were 0.14 and 0.27 μg/g wet weight (Schmitt and Brumbaugh 1990). Although concentrations in some fish composites, particularly those from the upstream areas of the river (Bonny Reservoir in Colorado; St. Francis Wildlife Area in Kansas, at Haigler, Nebraska and Rock Creek Reservoir in Nebraska) and from three scattered locations downstream were above the 85th percentile NCBP concentrations, the concentrations found do not warrant concern.

Mercury is a nonessential metal with extreme potential toxicity. It is a persistent teratogen, mutagen, and carcinogen. Mercury was used in the past in agriculture, but industrial processes are now the most probable sources of mercury contamination. Mercury can be bioconcentrated and biomagnified (Beyer 1986, Biddinger and Gloss 1984, Eisler 1987, Jernelov and Lann 1971, Phillips *et al.* 1980). Both processes are increased by methylation (Hodson 1988). Methylmercury has a high potential for bioaccumulation and toxicity to fish and wildlife (Phillips and Russo 1978). No mercury concentration in Republican River study fish composites was greater than the 1984 NCBP mean of 0.10 μg/g wet weight (Schmitt and Brumbaugh 1990).

Selenium is an essential trace nutrient for terrestrial and freshwater organisms. However, proper selenium levels in animals fall in narrow ranges, and the effects of organic and inorganic forms of selenium differ on aquatic and terrestrial plants and animals [U.S. Environmental Protection Agency (EPA) 1987]. Nationwide geometric means for selenium concentration in fish collected for the NCBP ranged from 0.48 μg/g wet weight in 1978-1979 to 0.42 μg/g in 1984 (Lowe *et al.* 1985, May and McKinney 1981, Schmitt and Brumbaugh 1990, Walsh *et al.* 1977). Comparable NCBP 85th percentile concentrations were 0.70. 0.71, and 0.73 μg/g. Nearly every fish sample analyzed by atomic absorption for this study contained a selenium concentration greater than the NCBP means. Most samples we collected also were above the NCBP 85th percentile values. However, all concentrations detected in fish were well below the 12 μg/g dry weight whole body concentration of concern of Lemly and Smith (1987).

Table 7 shows concentrations of metals in fish analyzed by ICP. Not detected in any fish sample were beryllium, lead, silver, and thallium.

Table 6. Arsenic, mercury, and selenium concentrations in Republican River Basin fish, 1989 and 1990.

Location	State	Fish Species	Percent Moisture	Element Concentration (µg/g)					
				Arsenic		Mercury		Selenium	
				Dry	Wet	Dry	Wet	Dry	Wet
north of Bethune	Co	White Sucker	75.9	0.69	0.17	0.15	0.04	6.50	1.57
Bonny Reservoir	Co	Gizzard Shad	68.4	1.20	0.38	0.10	0.03	3.30	1.04
St. Francis Wildlife Area	Ks	Dace, Chubs	79.0	2.50	0.53	0.39	0.08	5.90	1.24
east of Haigler	Ne	Shiners, Killifish	76.3	1.80	0.43	0.16	0.04	8.10	1.92
Rock Creek Reservoir	Ne	Gizzard Shad	72.2	1.70	0.47	0.05	0.01	5.80	1.61
at Max	Ne	Shiners, Killifish	75.8	1.10	0.27	0.28	0.07	8.00	1.94
Swanson Reservoir	Ne	River Carpsucker	59.2	0.20	0.08	0.06	0.02	2.10	0.86
Swanson Reservoir	Ne	Northern Pike	73.4	0.60	0.16	0.34	0.09	2.80	0.74
Enders Reservoir	Ne	Gizzard Shad	73.2	0.86	0.23	0.05	0.01	4.80	1.29
Stinking Water Creek	Ne	Creek Chub	81.1	0.20	0.04	0.26	0.05	4.70	0.89
Frenchman Creek near Hamlet	Ne	Creek Chub	80.1	0.40	0.08	0.23	0.05	5.10	1.01
Red Willow Reservoir	Ne	Northern Pike	72.7	0.66	0.18	0.57	0.16	1.70	0.46
Red Willow Reservoir	Ne	Common Carp	77.1	0.40	0.09	0.34	0.08	4.00	0.92
Red Willow Creek	Ne	Creek Chub	77.1	0.30	0.07	0.20	0.05	3.5	0.80
Medicine Creek Reservoir	Ne	White Bass	73.3	2.40	0.64	0.30	0.08	3.9	1.04
Medicine Creek at Cambridge	Ne	River Carpsucker	78.0	0.40	0.09	0.27	0.06	5.6	1.23
at Perry	Ne	River Carpsucker	71.0	ND	ND	0.11	0.03	6.6	1.91
Bartley Diversion Canal	Ne	River Carpsucker	69.6	0.68	0.21	0.18	0.05	3.5	1.06
Bartley Diversion Canal	Ne	Common Carp	73.9	ND	ND	0.22	0.06	4.7	1.23
Cambridge Diversion Dam	Ne	Common Carp	74.3	ND	ND	0.38	0.10	4.4	1.13
Cambridge Diversion Dam	Ne	River Carpsucker	73.9	0.40	0.10	0.22	0.06	4.8	1.25
Harlan County Reservoir	Ne	Northern Pike	74.6	ND	ND	ND	ND	3.0	0.76
Harlan County Reservoir	Ne	Common Carp	69.7	ND	ND	0.27	0.08	3.7	1.10
Harlan County Reservoir	Ne	Common Carp	68.2	NA	NA	NA	NA	NA	NA
Harlan County Reservoir	Ne	River Carpsucker	65.8	NA	NA	NA	NA	NA	NA
Harlan County Reservoir	Ne	Freshwater Drum	73.5	NA	NA	NA	NA	NA	NA
at Guide Rock	Ne	Sand Shiner	73.5	1.50	0.40	0.17	0.05	4.3	1.14
at Superior	Ne	Common Carp	69.9	NA	NA	NA	NA	NA	NA
at Superior	Ne	River Carpsucker	75.8	ND	ND	0.23	0.06	5.4	1.31
at Superior	Ne	Common Carp	73.9	ND	ND	0.02	0.01	5.1	1.33
Thompson Creek	Ne	Creek Chub	77.5	0.20	0.05	0.25	0.06	7.9	1.78
Norton Reservoir	Ks	Common Carp	74.0	ND	ND	0.20	0.05	2.3	0.60
Norton Reservoir	Ks	Gizzard Shad	78.4	0.60	0.13	0.07	0.02	2.5	0.54
White Rock Creek	Ks	Goldeye	77.9	ND	ND	0.41	0.09	4.8	1.06
White Rock Creek	Ks	Common Carp	76.6	ND	ND	0.36	0.08	7.0	1.64
White Rock Creek	Ks	Common Carp	75.5	ND	ND	0.33	0.08	6.6	1.62
White Rock Creek	Ks	Common Carp	73.5	ND	ND	0.29	0.08	6.3	1.67
Lovewell Reservoir	Ks	Freshwater Drum	71.1	NA	NA	NA	NA	NA	NA
Lovewell Reservoir	Ks	Walleye	68.3	NA	NA	NA	NA	NA	NA
Lovewell Reservoir	Ks	Common Carp	72.7	NA	NA	NA	NA	NA	NA
Lovewell Reservoir	Ks	Gizzard Shad	65.4	NA	NA	NA	NA	NA	NA
Lovewell Reservoir	Ks	Gizzard Shad	70.2	0.40	0.12	0.03	0.01	7.7	2.29
Lovewell Reservoir	Ks	Common Carp	73.9	0.30	0.08	0.19	0.05	6.9	1.80
Lovewell Reservoir	Ks	Common Carp	73.4	0.20	0.05	0.16	0.04	5.6	1.49
Lovewell Reservoir	Ks	Walleye	74.0	1.10	0.29	0.09	0.02	3.9	1.01
Lovewell Reservoir	Ks	Walleye	73.9	0.6	0.16	0.11	0.03	3.6	0.94
at Scandia	Ks	Common Carp	72.5	NA	NA	NA	NA	NA	NA
at Scandia	Ks	River Carpsucker	75.2	NA	NA	NA	NA	NA	NA
at Scandia	Ks	Common Carp	75.4	ND	ND	0.49	0.12	4.2	1.03

Table 6 (concluded). Arsenic, mercury, and selenium concentrations in Republican River Basin fish, 1989 and 1990.

Location	State	Fish Species	Percent Moisture	Element Concentration (µg/g)					
				Arsenic		Mercury		Selenium	
				Dry	Wet	Dry	Wet	Dry	Wet
at Clyde	Ks	Common Carp	73.5	ND	ND	0.58	0.15	3.1	0.82
at Clyde	Ks	River Carpsucker	66.2	ND	ND	0.26	0.09	4.8	1.62
at Clay Center	Ks	Common Carp	75.9	ND	ND	0.33	0.08	3.1	0.75
at Clay Center	Ks	Common Carp	75.5	ND	ND	0.52	0.13	4.2	1.03
Milford Reservoir	Ks	White Bass	70.7	0.60	0.18	0.26	0.08	3.0	0.88
Milford Reservoir	Ks	Gizzard Shad	71.8	0.30	0.08	0.08	0.02	2.7	0.76
Milford Reservoir	Ks	Smallmouth Buffalo	69.7	0.30	0.09	0.31	0.09	4.1	1.24
Milford Reservoir	Ks	River Carpsucker	61.5	0.30	0.12	0.14	0.05	1.9	0.73
at Junction City	Ks	River Carpsucker	71.4	ND	ND	0.30	0.09	3.7	1.06
at Junction City	Ks	Common Carp	76.3	ND	ND	0.31	0.07	3.9	0.92

There are limited published data for whole body concentrations of aluminum in fish (*e.g.* Brumbaugh and Kane 1985, Guthrie and Cherry 1979, Wells *et al*. 1988). Brumbaugh and Kane (1985) reported that the differences in aluminum concentrations in gut contents of fish analyzed add corresponding variability to whole body aluminum analyses and the aluminum concentrations measured. Concentrations in fish samples collected for this study were comparable to, and as highly variable as, those in fish composites collected for studies in Kansas and Nebraska (*e.g.* Allen 1991a, 1991b, 1992a, 1992b; Allen and Wilson 1991a, 1991b).

Barium concentrations in fish from Republican River drainage collection sites were higher than those in fish from the Neosho River in Kansas (Allen 1991a), Kirwin Reservoir in Kansas (Allen 1992b), the Marais des Cygnes river and surroundings (Allen 1992a), and the Missouri and Kansas rivers (Allen 1992b). The concentration found in the dace and chub composite from the St. Francis Wildlife Area was especially high. We have little information about the effects of barium on fish, so we can not estimate the effects, if any, of concentrations in the composites we collected.

Phillips and Russo (1978) considered boron to have a low potential for causing pollution problems because of its relatively low toxicity to aquatic animals. There are limited data on boron concentrations in fish. Ohlendorf *et al*,. (1986) reported whole body boron concentrations up to 3.6 µg/g dry weight in mosquitofish (*Gambusia affinis*) from an undisturbed area in California. Based on the available information about boron, we conclude that concentrations in fish collected for this study are not a cause for concern.

Cadmium is a biologically nonessential teratogen, carcinogen, and

Table 7. Metal concentrations from ICP scans in Republican River Basin fish, 1989 and 1990.

Location	State	Fish Species	Element Concentration (µg/g)							
			Aluminum		Barium		Boron		Cadmium	
			Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
north of Bethune	Co	White Sucker	120	29	10.4	2.5	ND	ND	ND	ND
Bonny Reservoir	Co	Gizzard Shad	1500	474	39	12	2.0	0.6	ND	ND
St. Francis Wildlife Area	Ks	Dace, Chubs	2480	521	172	36	3.0	0.6	ND	ND
east of Haigler	Ne	Shiners, Killifish	519	123	48	11	ND	ND	ND	ND
Rock Creek Reservoir	Ne	Gizzard Shad	711	198	36	10	ND	ND	ND	ND
at Max	Ne	Shiners, Killifish	2080	503	57	14	ND	ND	ND	ND
Swanson Reservoir	Ne	River Carpsucker	35	14	9.7	4.0	ND	ND	ND	ND
Swanson Reservoir	Ne	Northern Pike	11	2.9	3.9	1.0	ND	ND	ND	ND
Enders Reservoir	Ne	Gizzard Shad	16	4.3	14	3.8	ND	ND	ND	ND
Stinking Water Creek	Ne	Creek Chub	66	12	14	2.6	ND	ND	ND	ND
Frenchman Creek near Hamlet	Ne	Creek Chub	150	30	15	3.0	ND	ND	ND	ND
Red Willow Reservoir	Ne	Northern Pike	15	4.1	5.5	1.5	ND	ND	ND	ND
Red Willow Reservoir	Ne	Common Carp	49	11	25	5.7	ND	ND	ND	ND
Red Willow Creek	Ne	Creek Chub	44	10	26	5.9	ND	ND	ND	ND
Medicine Creek Reservoir	Ne	White Bass	23	6.1	7.1	1.9	ND	ND	ND	ND
Medicine Creek at Cambridge	Ne	River Carpsucker	260	57	60	13	ND	ND	ND	ND
at Perry	Ne	River Carpsucker	817	237	37	11	ND	ND	ND	ND
Bartley Diversion Canal	Ne	River Carpsucker	1040	316	33	10	3.0	0.9	ND	ND
Bartley Diversion Canal	Ne	Common Carp	100	26	15	4.0	ND	ND	ND	ND
Cambridge Diversion Dam	Ne	Common Carp	64	16	10	2.6	ND	ND	1.10	0.28
Cambridge Diversion Dam	Ne	River Carpsucker	1190	311	48	13	2.0	0.5	ND	ND
Harlan County Reservoir	Ne	Northern Pike	6.8	1.7	ND	ND	ND	ND	ND	ND
Harlan County Reservoir	Ne	Common Carp	140	43	ND	ND	ND	ND	0.40	0.11
Harlan County Reservoir	Ne	Common Carp	280	88	NA	NA	ND	ND	0.60	0.19
Harlan County Reservoir	Ne	River Carpsucker	140	49	NA	NA	ND	ND	ND	ND
Harlan County Reservoir	Ne	Freshwater Drum	46	12	NA	NA	ND	ND	ND	ND
at Guide Rock	Ne	Sand Shiner	230	61	34	9.1	ND	ND	ND	ND
at Superior	Ne	Common Carp	11	3.2	NA	NA	ND	ND	ND	ND
at Superior	Ne	River Carpsucker	230	56	38	9.1	ND	ND	ND	ND
at Superior	Ne	Common Carp	34	8.9	14	3.6	ND	ND	ND	ND
Thompson Creek	Ne	Creek Chub	52	12	14	3.1	ND	ND	ND	ND
Norton Reservoir	Ks	Common Carp	180	47	30	7.8	ND	ND	ND	ND
Norton Reservoir	Ks	Gizzard Shad	1100	238	39	8.5	ND	ND	ND	ND
White Rock Creek	Ks	Goldeye	31	6.9	3.9	0.9	ND	ND	ND	ND
White Rock Creek	Ks	Common Carp	13	3.0	6.7	1.6	ND	ND	ND	ND
White Rock Creek	Ks	Common Carp	91	22	14	3.4	ND	ND	ND	ND
White Rock Creek	Ks	Common Carp	75	20	14	3.7	ND	ND	ND	ND
Lovewell Reservoir	Ks	Freshwater Drum	4.5	1.3	NA	NA	ND	ND	ND	ND
Lovewell Reservoir	Ks	Walleye	4.3	1.4	NA	NA	ND	ND	ND	ND
Lovewell Reservoir	Ks	Common Carp	19	5.2	NA	NA	ND	ND	ND	ND
Lovewell Reservoir	Ks	Gizzard Shad	ND	ND	NA	NA	ND	ND	ND	ND
Lovewell Reservoir	Ks	Gizzard Shad	7.0	2.1	8.8	2.6	ND	ND	ND	ND
Lovewell Reservoir	Ks	Common Carp	170	44	16	4.1	ND	ND	ND	ND
Lovewell Reservoir	Ks	Common Carp	210	56	12	3.2	ND	ND	ND	ND
Lovewell Reservoir	Ks	Walleye	9.1	2.4	2.7	0.7	ND	ND	ND	ND
Lovewell Reservoir	Ks	Walleye	13	3.4	2.2	0.6	ND	ND	ND	ND
at Scandia	Ks	Common Carp	13	3.6	NA	NA	ND	ND	ND	ND
at Scandia	Ks	River Carpsucker	28	6.9	NA	NA	ND	ND	ND	ND
at Scandia	Ks	Common Carp	160	39	16	3.9	3.0	0.7	1.20	0.30

Table 7 (continued). Metal concentrations from ICP scans in Republican River Basin fish, 1989 and 1990.

Location	State	Fish Species	Element Concentration (µg/g)							
			Aluminum		Barium		Boron		Cadmium	
			Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
at Clyde	Ks	Common Carp	140	37	17	4.5	ND	ND	ND	ND
at Clyde	Ks	River Carpsucker	110	37	30	10	ND	ND	ND	ND
at Clay Center	Ks	Common Carp	59	14	14	3.4	ND	ND	0.70	0.17
at Clay Center	Ks	Common Carp	62	15	14	3.4	ND	ND	0.50	0.12
Milford Reservoir	Ks	White Bass	26	7.6	5.0	1.5	ND	ND	ND	ND
Milford Reservoir	Ks	Gizzard Shad	69	19	5.5	1.6	ND	ND	ND	ND
Milford Reservoir	Ks	Smallmouth Buffalo	120	36	4.5	1.4	ND	ND	ND	ND
Milford Reservoir	Ks	River Carpsucker	130	50	8.2	3.2	ND	ND	ND	ND
at Junction City	Ks	River Carpsucker	ND	ND	14	4.1	ND	ND	ND	ND
at Junction City	Ks	Common Carp	ND	ND	6.6	1.6	ND	ND	0.40	0.09

Table 7 (continued). Metal concentrations from ICP scans in Republican River Basin fish, 1989 and 1990.

Location	State	Fish Species	Element Concentration (µg/g)					
			Chromium		Copper		Iron	
			Dry	Wet	Dry	Wet	Dry	Wet
north of Bethune	Co	White Sucker	5.1	1.2	4.3	1.04	169	41
Bonny Reservoir	Co	Gizzard Shad	3.0	0.95	2.6	0.82	1280	404
St. Francis Wildlife Area	Ks	Dace, Chubs	3.0	0.63	9.3	1.95	1830	384
east of Haigler	Ne	Shiners, Killifish	2.0	0.47	3.7	0.88	477	113
Rock Creek Reservoir	Ne	Gizzard Shad	3.0	0.83	2.6	0.72	787	219
at Max	Ne	Shiners, Killifish	1.0	0.24	4.8	1.16	759	184
Swanson Reservoir	Ne	River Carpsucker	ND	ND	1.7	0.69	112	46
Swanson Reservoir	Ne	Northern Pike	14	3.7	2.5	0.66	639	170
Enders Reservoir	Ne	Gizzard Shad	ND	ND	2.4	0.64	106	28
Stinking Water Creek	Ne	Creek Chub	ND	ND	9.0	1.70	162	31
Frenchman Creek near Hamlet	Ne	Creek Chub	2.0	0.40	4.5	0.90	229	46
Red Willow Reservoir	Ne	Northern Pike	15	4.1	3.6	0.98	581	159
Red Willow Reservoir	Ne	Common Carp	6.7	1.5	4.2	0.96	397	91
Red Willow Creek	Ne	Creek Chub	ND	ND	3.8	0.87	98	22
Medicine Creek Reservoir	Ne	White Bass	ND	ND	12	3.20	65	17
Medicine Creek at Cambridge	Ne	River Carpsucker	2.0	0.44	3.4	0.75	799	176
at Perry	Ne	River Carpsucker	13	3.8	4.8	1.39	774	224
Bartley Diversion Canal	Ne	River Carpsucker	2.0	0.61	1.9	0.58	781	237
Bartley Diversion Canal	Ne	Common Carp	9.1	2.4	5.3	1.38	170	44
Cambridge Diversion Dam	Ne	Common Carp	11	2.8	6.2	1.59	564	145
Cambridge Diversion Dam	Ne	River Carpsucker	10	2.6	4.0	1.04	1090	284
Harlan County Reservoir	Ne	Northern Pike	ND	ND	ND	ND	ND	ND
Harlan County Reservoir	Ne	Common Carp	ND	ND	ND	ND	ND	ND
Harlan County Reservoir	Ne	Common Carp	1.9	0.60	ND	ND	NA	NA
Harlan County Reservoir	Ne	River Carpsucker	ND	ND	ND	ND	NA	NA
Harlan County Reservoir	Ne	Freshwater Drum	ND	ND	ND	ND	NA	NA
at Guide Rock	Ne	Sand Shiner	ND	ND	2.4	0.64	193	51
at Superior	Ne	Common Carp	ND	ND	ND	ND	NA	NA
at Superior	Ne	River Carpsucker	1.0	0.24	2.3	0.56	354	86
at Superior	Ne	Common Carp	ND	ND	3.2	0.84	159	41
Thompson Creek	Ne	Creek Chub	ND	ND	4.3	0.97	104	23
Norton Reservoir	Ks	Common Carp	8.5	2.2	4.8	1.25	247	64
Norton Reservoir	Ks	Gizzard Shad	19	4.1	5.1	1.10	1550	35
White Rock Creek	Ks	Goldeye	ND	ND	2.5	0.55	105	23
White Rock Creek	Ks	Common Carp	6.5	1.5	5.5	1.29	533	125
White Rock Creek	Ks	Common Carp	ND	ND	27	6.54	173	42
White Rock Creek	Ks	Common Carp	ND	ND	11	2.92	145	38
Lovewell Reservoir	Ks	Freshwater Drum	ND	ND	ND	ND	NA	NA
Lovewell Reservoir	Ks	Walleye	ND	ND	ND	ND	NA	NA
Lovewell Reservoir	Ks	Common Carp	ND	ND	ND	ND	NA	NA
Lovewell Reservoir	Ks	Gizzard Shad	ND	ND	ND	ND	NA	NA
Lovewell Reservoir	Ks	Gizzard Shad	ND	ND	1.7	0.51	79	24
Lovewell Reservoir	Ks	Common Carp	ND	ND	2.9	0.76	192	50
Lovewell Reservoir	Ks	Common Carp	ND	ND	2.3	0.61	191	51
Lovewell Reservoir	Ks	Walleye	ND	ND	1.3	0.34	36	10
Lovewell Reservoir	Ks	Walleye	ND	ND	1.2	0.31	43	11
at Scandia	Ks	Common Carp	ND	ND	ND	ND	NA	NA
at Scandia	Ks	River Carpsucker	ND	ND	ND	ND	NA	NA
at Scandia	Ks	Common Carp	1.0	0.25	6.0	1.48	231	57

Table 7 (continued). Metal concentrations from ICP scans in Republican River Basin fish, 1989 and 1990.

Location	State	Fish Species	Element Concentration (µg/g)					
			Chromium		Copper		Iron	
			Dry	Wet	Dry	Wet	Dry	Wet
at Clyde	Ks	Common Carp	ND	ND	3.3	0.87	176	47
at Clyde	Ks	River Carpsucker	1.0	0.34	1.5	0.51	459	155
at Clay Center	Ks	Common Carp	ND	ND	4.6	1.11	167	40
at Clay Center	Ks	Common Carp	ND	ND	5.0	1.23	158	39
Milford Reservoir	Ks	White Bass	ND	ND	7.4	2.17	54	16
Milford Reservoir	Ks	Gizzard Shad	ND	ND	1.8	0.51	113	32
Milford Reservoir	Ks	Smallmouth Buffalo	ND	ND	2.1	0.64	233	71
Milford Reservoir	Ks	River Carpsucker	ND	ND	1.3	0.50	159	61
at Junction City	Ks	River Carpsucker	ND	ND	1.8	0.51	153	44
at Junction City	Ks	Common Carp	ND	ND	4.2	1.00	140	33

Table 7 (continued). Metal concentrations from ICP scans in Republican River Basin fish, 1989 and 1990.

Location	State	Fish Species	Element Concentration (µg/g)					
			Magnesium		Manganese		Molybdenum	
			Dry	Wet	Dry	Wet	Dry	Wet
north of Bethune	Co	White Sucker	1280	308	13	3.1	ND	ND
Bonny Reservoir	Co	Gizzard Shad	1370	433	33	11	ND	ND
St. Francis Wildlife Area	Ks	Dace, Chubs	2050	431	105	22	ND	ND
east of Haigler	Ne	Shiners, Killifish	1670	396	33	7.9	ND	ND
Rock Creek Reservoir	Ne	Gizzard Shad	1240	345	18	5.0	ND	ND
at Max	Ne	Shiners, Killifish	2030	491	71	17	ND	ND
Swanson Reservoir	Ne	River Carpsucker	826	337	6.6	2.7	ND	ND
Swanson Reservoir	Ne	Northern Pike	1180	314	13	3.5	ND	ND
Enders Reservoir	Ne	Gizzard Shad	1120	300	9.2	2.5	ND	ND
Stinking Water Creek	Ne	Creek Chub	1320	249	5.1	1.0	ND	ND
Frenchman Creek near Hamlet	Ne	Creek Chub	1290	257	6.2	1.2	ND	ND
Red Willow Reservoir	Ne	Northern Pike	1190	325	13	3.5	ND	ND
Red Willow Reservoir	Ne	Common Carp	1480	339	12	2.7	ND	ND
Red Willow Creek	Ne	Creek Chub	1460	334	7.1	1.6	ND	ND
Medicine Creek Reservoir	Ne	White Bass	1230	328	4.3	1.1	ND	ND
Medicine Creek at Cambridge	Ne	River Carpsucker	1670	367	42	9.3	1.0	0.22
at Perry	Ne	River Carpsucker	1610	467	32	9.4	5.8	1.68
Bartley Diversion Canal	Ne	River Carpsucker	1660	505	39	12	2.0	0.61
Bartley Diversion Canal	Ne	Common Carp	1610	420	22	5.7	2.0	0.52
Cambridge Diversion Dam	Ne	Common Carp	1390	357	11	2.8	ND	ND
Cambridge Diversion Dam	Ne	River Carpsucker	1930	504	41	11	ND	ND
Harlan County Reservoir	Ne	Northern Pike	1100	280	5.9	1.5	ND	ND
Harlan County Reservoir	Ne	Common Carp	1300	390	10	3.1	ND	ND
Harlan County Reservoir	Ne	Common Carp	970	310	9.7	3.1	ND	ND
Harlan County Reservoir	Ne	River Carpsucker	1000	350	7.9	2.7	ND	ND
Harlan County Reservoir	Ne	Freshwater Drum	1800	460	5.1	1.4	ND	ND
at Guide Rock	Ne	Sand Shiner	1530	405	36	9.4	ND	ND
at Superior	Ne	Common Carp	910	274	5.5	1.7	ND	ND
at Superior	Ne	River Carpsucker	1590	385	50	12	ND	ND
at Superior	Ne	Common Carp	1280	334	19	5.0	ND	ND
Thompson Creek	Ne	Creek Chub	1360	306	8.3	1.9	ND	ND
Norton Reservoir	Ks	Common Carp	1510	393	19	4.9	ND	ND
Norton Reservoir	Ks	Gizzard Shad	1610	348	60	13	1.0	0.22
White Rock Creek	Ks	Goldeye	1540	340	6.0	1.3	ND	ND
White Rock Creek	Ks	Common Carp	1450	339	14	3.3	ND	ND
White Rock Creek	Ks	Common Carp	1400	343	17	4.2	ND	ND
White Rock Creek	Ks	Common Carp	1340	355	15	4.0	ND	ND
Lovewell Reservoir	Ks	Freshwater Drum	890	260	4.7	1.4	ND	ND
Lovewell Reservoir	Ks	Walleye	720	230	3.3	1.0	ND	ND
Lovewell Reservoir	Ks	Common Carp	900	250	5.4	1.5	ND	ND
Lovewell Reservoir	Ks	Gizzard Shad	310	110	4.4	1.5	ND	ND
Lovewell Reservoir	Ks	Gizzard Shad	1130	337	16	4.8	ND	ND
Lovewell Reservoir	Ks	Common Carp	1370	358	13	3.4	ND	ND
Lovewell Reservoir	Ks	Common Carp	1090	290	11	2.9	ND	ND
Lovewell Reservoir	Ks	Walleye	1160	302	4.3	1.1	ND	ND
Lovewell Reservoir	Ks	Walleye	1080	282	4.9	1.3	ND	ND
at Scandia	Ks	Common Carp	950	260	8.3	2.3	ND	ND
at Scandia	Ks	River Carpsucker	1500	380	16	3.9	ND	ND
at Scandia	Ks	Common Carp	1300	320	25	6.1	ND	ND

Table 7 (continued). Metal concentrations from ICP scans in Republican River Basin fish, 1989 and 1990.

Location	State	Fish Species	Element Concentration (µg/g)					
			Magnesium		Manganese		Molybdenum	
			Dry	Wet	Dry	Wet	Dry	Wet
at Clyde	Ks	Common Carp	1390	368	17	4.5	ND	ND
at Clyde	Ks	River Carpsucker	1340	453	17	5.7	ND	ND
at Clay Center	Ks	Common Carp	1340	323	28	6.7	ND	ND
at Clay Center	Ks	Common Carp	1400	343	20	4.9	ND	ND
Milford Reservoir	Ks	White Bass	1310	384	5.2	1.5	ND	ND
Milford Reservoir	Ks	Gizzard Shad	971	274	12	3.4	ND	ND
Milford Reservoir	Ks	Smallmouth Buffalo	1000	303	8.9	2.7	ND	ND
Milford Reservoir	Ks	River Carpsucker	818	315	10	3.9	ND	ND
at Junction City	Ks	River Carpsucker	1420	406	33	9.5	ND	ND
at Junction City	Ks	Common Carp,	996	236	8.0	1.9	ND	ND

Table 7 (continued). Metal concentrations from ICP scans in Republican River Basin fish, 1989 and 1990.

Location	State	Fish Species	Element Concentration (µg/g)					
			Nickel		Strontium		Tin	
			Dry	Wet	Dry	Wet	Dry	Wet
north of Bethune	Co	White Sucker	ND	ND	76	18	NA	NA
Bonny Reservoir	Co	Gizzard Shad	ND	ND	95	30	NA	NA
St. Francis Wildlife Area	Ks	Dace, Chubs	ND	ND	134	28	NA	NA
east of Haigler	Ne	Shiners, Killifish	ND	ND	165	39	NA	NA
Rock Creek Reservoir	Ne	Gizzard Shad	ND	ND	79	22	NA	NA
at Max	Ne	Shiners, Killifish	ND	ND	207	50	NA	NA
Swanson Reservoir	Ne	River Carpsucker	ND	ND	109	44	NA	NA
Swanson Reservoir	Ne	Northern Pike	4.0	1.1	73	19	NA	NA
Enders Reservoir	Ne	Gizzard Shad	ND	ND	101	27	NA	NA
Stinking Water Creek	Ne	Creek Chub ,	ND	ND	59	11	NA	NA
Frenchman Creek near Hamlet	Ne	Creek Chub	ND	ND	77	15	NA	NA
Red Willow Reservoir	Ne	Northern Pike	4.0	1.1	83	23	NA	NA
Red Willow Reservoir	Ne	Common Carp	3.0	0.69	198	45	NA	NA
Red Willow Creek	Ne	Creek Chub	ND	ND	161	37	NA	NA
Medicine Creek Reservoir	Ne	White Bass	ND	ND	94	25	NA	NA
Medicine Creek at Cambridge	Ne	River Carpsucker	ND	ND	186	41	NA	NA
at Perry	Ne	River Carpsucker	8.9	2.6	216	63	NA	NA
Bartley Diversion Canal	Ne	River Carpsucker	2.0	0.61	169	51	NA	NA
Bartley Diversion Canal	Ne	Common Carp	10	2.61	228	60	NA	NA
Cambridge Diversion Dam	Ne	Common Carp	3.0	0.77	142	36	NA	NA
Cambridge Diversion Dam	Ne	River Carpsucker	5.4	1.4	242	63	NA	NA
Harlan County Reservoir	Ne	Northern Pike	ND	ND	ND	ND	ND	ND
Harlan County Reservoir	Ne	Common Carp	ND	ND	NA	NA	ND	ND
Harlan County Reservoir	Ne	Common Carp	ND	ND	NA	NA	ND	ND
Harlan County Reservoir	Ne	River Carpsucker	ND	ND	NA	NA	ND	ND
Harlan County Reservoir	Ne	Freshwater Drum	ND	ND	NA	NA	ND	ND
at Guide Rock	Ne	Sand Shiner	ND	ND	136	36	NA	NA
at Superior	Ne	Common Carp	ND	ND	NA	NA	10	3.0
at Superior	Ne	River Carpsucker	ND	ND	131	32	NA	NA
at Superior	Ne	Common Carp	ND	ND	79	21	NA	NA
Thompson Creek	Ne	Creek Chub	2.0	0.45	62	14	NA	NA
Norton Reservoir	Ks	Common Carp	4.0	1.0	120	31	NA	NA
Norton Reservoir	Ks	Gizzard Shad	5.0	1.1	71	15	NA	NA
White Rock Creek	Ks	Goldeye	ND	ND	89	20	NA	NA
White Rock Creek	Ks	Common Carp	ND	ND	91	21	NA	NA
White Rock Creek	Ks	Common Carp	ND	ND	97	24	NA	NA
White Rock Creek	Ks	Common Carp	ND	ND	94	25	NA	NA
Lovewell Reservoir	Ks	Freshwater Drum	ND	ND	NA	NA	ND	ND
Lovewell Reservoir	Ks	Walleye	ND	ND	NA	NA	ND	ND
Lovewell Reservoir	Ks	Common Carp	ND	ND	NA	NA	ND	ND
Lovewell Reservoir	Ks	Gizzard Shad	ND	ND	NA	NA	ND	ND
Lovewell Reservoir	Ks	Gizzard Shad	ND	ND	44	13	NA	NA
Lovewell Reservoir	Ks	Common Carp	ND	ND	107	28	NA	NA
Lovewell Reservoir	Ks	Common Carp	ND	ND	102	27	NA	NA
Lovewell Reservoir	Ks	Walleye	1.0	0.26	39	10	NA	NA
Lovewell Reservoir	Ks	Walleye	ND	ND	34	9.0	NA	NA
at Scandia	Ks	Common Carp	ND	ND	NA	NA	ND	ND
at Scandia	Ks	River Carpsucker	ND	ND	NA	NA	21	5.2
at Scandia	Ks	Common Carp	ND	ND	76	19	NA	NA

Table 7 (continued). Metal concentrations from ICP scans in Republican River Basin fish, 1989 and 1990.

Location	State	Fish Species	Element Concentration (µg/g)					
			Nickel		Strontium		Tin	
			Dry	Wet	Dry	Wet	Dry	Wet
at Clyde	Ks	Common Carp	ND	ND	78	21	NA	NA
at Clyde	Ks	River Carpsucker	ND	ND	109	37	NA	NA
at Clay Center	Ks	Common Carp	ND	ND	112	27	NA	NA
at Clay Center	Ks	Common Carp	ND	ND	99	24	NA	NA
Milford Reservoir	Ks	White Bass	ND	ND	97	28	NA	NA
Milford Reservoir	Ks	Gizzard Shad	ND	ND	40	11	NA	NA
Milford Reservoir	Ks	Smallmouth Buffalo	1.0	0.30	45	14	NA	NA
Milford Reservoir	Ks	River Carpsucker	ND	ND	58	22	NA	NA
at Junction City	Ks	River Carpsucker	ND	ND	133	38	NA	NA
at Junction City	Ks	Common Carp,	ND	ND	49	12	NA	NA

Table 7 (continued). Metal concentrations from ICP scans in Republican River Basin fish, 1989 and 1990.

Location	State	Fish Species	Element Concentration (µg/g) Vanadium		Zinc	
			Dry	Wet	Dry	Wet
north of Bethune	Co	White Sucker	0.4	0.10	61	15
Bonny Reservoir	Co	Gizzard Shad	3.6	1.14	40	13
St. Francis Wildlife Area	Ks	Dace, Chubs	5.9	1.24	163	34
east of Haigler	Ne	Shiners, Killifish	2.3	0.55	172	41
Rock Creek Reservoir	Ne	Gizzard Shad	3.4	0.95	38	11
at Max	Ne	Shiners, Killifish	2.9	0.70	177	43
Swanson Reservoir	Ne	River Carpsucker	1.3	0.53	29	12
Swanson Reservoir	Ne	Northern Pike	0.3	0.08	98	26
Enders Reservoir	Ne	Gizzard Shad	1.2	0.32	41	11
Stinking Water Creek	Ne	Creek Chub	0.4	0.08	66	12
Frenchman Creek near Hamlet	Ne	Creek Chub	1.6	0.32	91	18
Red Willow Reservoir	Ne	Northern Pike	ND	ND	129	35
Red Willow Reservoir	Ne	Common Carp	1.3	0.30	267	61
Red Willow Creek	Ne	Creek Chub	0.4	0.09	95	22
Medicine Creek Reservoir	Ne	White Bass	ND	ND	46	12
Medicine Creek at Cambridge	Ne	River Carpsucker	1.2	0.26	69	15
at Perry	Ne	River Carpsucker	2.8	0.81	54	16
Bartley Diversion Canal	Ne	River Carpsucker	4.2	1.28	49	15
Bartley Diversion Canal	Ne	Common Carp	1.6	0.42	253	66
Cambridge Diversion Dam	Ne	Common Carp	1.4	0.36	197	51
Cambridge Diversion Dam	Ne	River Carpsucker	3.9	1.02	62	16
Harlan County Reservoir	Ne	Northern Pike	ND	ND	ND	ND
Harlan County Reservoir	Ne	Common Carp	1.1	0.32	NA	NA
Harlan County Reservoir	Ne	Common Carp	1.0	0.33	NA	NA
Harlan County Reservoir	Ne	River Carpsucker	1.6	0.55	NA	NA
Harlan County Reservoir	Ne	Freshwater Drum	0.8	0.21	NA	NA
at Guide Rock	Ne	Sand Shiner	1.1	0.29	203	54
at Superior	Ne	Common Carp	ND	ND	NA	NA
at Superior	Ne	River Carpsucker	1.0	0.24	60	15
at Superior	Ne	Common Carp	0.7	0.18	198	52
Thompson Creek	Ne	Creek Chub	0.4	0.09	99	22
Norton Reservoir	Ks	Common Carp	1.3	0.34	236	61
Norton Reservoir	Ks	Gizzard Shad	3.5	0.76	63	14
White Rock Creek	Ks	Goldeye	0.3	0.07	97	21
White Rock Creek	Ks	Common Carp	0.8	0.19	265	62
White Rock Creek	Ks	Common Carp	1.1	0.27	308	75
White Rock Creek	Ks	Common Carp	1.1	0.29	220	58
Lovewell Reservoir	Ks	Freshwater Drum	0.4	0.12	NA	NA
Lovewell Reservoir	Ks	Walleye	ND	ND	NA	NA
Lovewell Reservoir	Ks	Common Carp	ND	ND	NA	NA
Lovewell Reservoir	Ks	Gizzard Shad	ND	ND	NA	NA
Lovewell Reservoir	Ks	Gizzard Shad	0.7	0.21	40	12
Lovewell Reservoir	Ks	Common Carp	1.1	0.29	315	82
Lovewell Reservoir	Ks	Common Carp	1.0	0.26	233	62
Lovewell Reservoir	Ks	Walleye	0.5	0.13	32	8
Lovewell Reservoir	Ks	Walleye	2.2	0.57	35	9
at Scandia	Ks	Common Carp	ND	ND	NA	NA
at Scandia	Ks	River Carpsucker	1.2	0.30	NA	NA
at Scandia	Ks	Common Carp	1.0	0.24	277	68

Table 7 (concluded). Metal concentrations from ICP scans in Republican River Basin fish, 1989 and 1990.

Location	State	Fish Species	Element Concentration (µg/g)			
			Vanadium		Zinc	
			Dry	Wet	Dry	Wet
at Clyde	Ks	Common Carp	0.7	0.19	159	42
at Clyde	Ks	River Carpsucker	1.0	0.34	44	15
at Clay Center	Ks	Common Carp	1.2	0.29	169	41
at Clay Center	Ks	Common Carp	0.8	0.20	192	47
Milford Reservoir	Ks	White Bass	ND	ND	52	15
Milford Reservoir	Ks	Gizzard Shad	0.6	0.17	41	12
Milford Reservoir	Ks	Smallmouth Buffalo	1.2	0.36	36	11
Milford Reservoir	Ks	River Carpsucker	0.8	0.31	28	11
at Junction City	Ks	River Carpsucker	1.0	0.29	51	15
at Junction City	Ks	Common Carp	0.7	0.17	220	52

probable mutagen. It usually is present in water as a result of discharges from human activities (Eisler 1985a, Pratrap *et al.* 1989). Its subsequent availability to aquatic biota apparently is dependent on a variety of physical conditions (Kent and Johnson 1979, Pita and Hyne 1975, Wiener and Giesy 1979). Freshwater biota are especially sensitive to cadmium (Eisler 1985a), but it has a low tendency to bioaccumulate (Phillips and Russo 1978). Although documentation of cadmium body burdens in wildlife and fish and effects of long-term exposure are lacking, according to Eisler (1985a), 5.0 µg/g wet weight should be considered life-threatening in whole animals.

The lowest geometric mean and 85th percentile wet weight cadmium concentrations in fish collected for the NCBP were 0.03 and 0.05 µg/g in 1984 (Lowe *et al.* 1985, May and McKinney 1981, Schmitt and Brumbaugh 1990, Walsh *et al.* 1977). Common carp composites comprised virtually all of the samples with high cadmium concentrations in the 1984 NCBP sampling. The common carp composites from the Cambridge Diversion dam and from Harlan County Reservoir were the only samples with detectable cadmium. The concentrations were high compared to the 1984 NCBP values, but we do not believe that they represent a serious contamination problem in the drainage.

Relatively little is known about the effects of low levels of chromium on organisms, but at high ambient levels chromium is a mutagen, a teratogen, and a carcinogen. The chemistry of chromium in aquatic settings is not well understood, and can be modified by a variety of environmental factors. Chromium is a trace nutrient for some animals, but its requirement in fish has not been established. Chromium is not known to be biomagnified in food webs, and concentrations are usually greatest in the lowest trophic levels (Eisler 1986a). Phillips and

Russo (1978) stated that chromium has a low tendency to bioaccumulate.

Analyses of chromium in biota have produced widely varying results, and interpretation of reported chromium concentrations is difficult. Nevertheless, a whole body chromium concentration of 4.0 µg/g dry weight or more should be considered to be evidence of chromium contamination (Eisler 1986a). According to Buhler *et al.* (1977), Giesy and Wiener (1977), and Tong *et al.* (1974), fish usually contain less than 0.4 µg/g of chromium (dry weight). Fish composites at ten locations we sampled were contaminated with chromium. Most of those concentrations were well above Eisler's (1986a) 4.0 µg/g recommended concentration. However, assessment of these concentrations is difficult. For example, there is no industrial facility upstream of the Bethune, Colorado sampling site, of Swanson Reservoir, or of Red Willow Reservoir. Further investigations of the possible sources of the chromium in the locations in question should be considered.

Hill (1977) did not consider copper toxicosis a serious problem for terrestrial organisms because copper levels are well controlled by the liver and is seldom encountered in problematic concentrations. Copper concentrations in fish usually are homeostatically controlled (Cross *et al.* 1973, Giesy and Wiener 1977, Goodyear and Boyd 1972, Wiener and Giesy 1979), but there are numerous documented cases of deleterious effects of copper in aquatic and terrestrial organisms, usually due to anthropogenic activities (*e.g.* Chupp and Dalke 1964, Clausen and Wolstrup 1978, Imlay and Winger 1983, McKim and Benoit 1971, Sprague *et al.* 1965). Mean whole body wet weight copper concentrations in fish collected for the NCBP were 0.82 µg/g in 1978-1979, 0.65 µg/g in 1980-1981, and 0.65 µg/g in 1984 (Lowe *et al.* 1985, Schmitt and Brumbaugh 1990). The corresponding 85th percentile values were 1.1, 0.9, and 1.0 µg/g wet weight.

Copper concentrations in 11 fish composites we collected exceeded the 1.1 µg/g 1978-1979 NCBP 85th percentile concentration. Copper concentrations at Medicine Creek Reservoir in Nebraska and at White Rock Creek in Kansas were exceptionally high. However, high sediment concentrations did not necessarily lead to high concentrations in fish. In addition, some of the locations with high copper concentrations in fish did not have high concentrations in sediments. Therefore, although copper concentrations may be homeostatically controlled, the high concentrations in fish from some locations may be a cause for concern.

Iron is necessary for metabolic processes and especially for hemoglobin in fish, and can be expected to be found in higher concentrations than most other elements. However, iron has a high

tendency to bioaccumulate, and large doses may cause serious problems.

Radtke *et al.* (1988) and Schroeder *et al.* (1988) found relatively consistent iron concentrations between sampling locations in their western U.S. studies, whereas Peterson *et al.* (1988), Stephens *et al.* (1988), and Wells *et al.* (1988) found greater variation in their whole fish samples. These results suggest that iron concentrations may differ both between locations and between species. Therefore, we believe that iron concentrations in fish we collected were not abnormal.

Magnesium concentrations in the fish composites were comparable to the concentrations found in common carp at Flint Hills National Wildlife Refuge (Allen 1991a), Kirwin National Wildlife Refuge (Allen 1991b), and the Kansas and Missouri rivers in Kansas (Allen 1992b), and probably are normal.

Though it is a required trace element in plants and animals, we have very little information on normal concentrations of manganese in biota. Manganese levels in fish are apparently well regulated under most conditions (Cross *et al.* 1973, Giesy and Wiener 1977, Goodyear and Boyd 1972, Wiener and Giesy 1979), and manganese has a low tendency to bioaccumulate (Phillips and Russo 1978). In fish, manganese tends to accumulate in bone and scales (Schmitt and Finger 1987).

Manganese concentrations in some fish composites collected for this study were considerably higher than those found in fish from Kirwin Reservoir, Kansas (Allen 1991b), the Neosho River in Kansas (Allen 1991a), in the Spring River drainage in southeastern Kansas (Allen and Wilson 1991b), and in the Kansas and Missouri Rivers in Kansas (Allen 1992b). However, they were not as high as some concentrations found in Missouri River fish in 1988 (Allen and Wilson 1991a). The high concentrations found in fish from Bonny Reservoir in Colorado, from the St. Francis Wildlife Area and from Norton Reservoir in Kansas, and from east of Haigler, at Max, from Rock Creek Reservoir, Swanson Reservoir, Medicine Creek, at Perry, from the Bartley Diversion Canal, and at the Cambridge Diversion Dam in Nebraska all suggest that a review of the sources of the manganese is necessary. None of these locations at which a suitable sediment concentration was collected had an elevated sediment manganese concentration.

"Molybdenum is present in all plant, human, and animal tissues, and is considered an essential micronutrient for most life forms" (Eisler 1989a). Leland and Kuwabara (1985) stated that freshwater fish can regulate their molybdenum concentrations over a wide range of ambient conditions. If that is true, most concentrations found in fish we collected should not warrant concern. However, the 5.8 µg/g in the

river carpsucker composite from the Republican River at Perry, Nebraska warrants concern.

Nickel has been found in most aquatic organisms, but concentrations in whole fish from unpolluted locations should be less than 2.0 µg/g wet weight (Jenkins 1980). Nickel concentrations in many locations have been greatly altered as a result of mining and smelting operations, many industrial processes, and fossil fuel combustion. However, nickel has been considered less problematic than many other heavy metals, and was considered by Phillips and Russo (1978) to have a low bioaccumulative tendency. However, it is bioaccumulated by at least some fish species (Tjalve *et al.* 1988). We have little comparative information on background nickel concentrations in fish. Bluegills (*Lepomis macrochirus*) and common carp collected by Saiki and May (1988) in the San Joaquin River and some of its tributaries in California had a maximum mean nickel concentration of 0.495 µg/g wet weight. Nickel was detected in only a few of the fish composites we collected, but the concentrations in most of those samples exceeded Saiki and May's 0.495 µg/g value. The concentrations were not as high as some found in Missouri River fish in 1988 (Allen and Wilson 1991a). Nickel was detected in a variety of species in this study. We have no explanation for the occurrence of the nickel in the samples collected. Nor do we know of the effects of the concentrations observed.

Non-radioactive strontium has very low toxicity to aquatic animals and man, but radioactive strontium is extremely toxic (Phillips and Russo 1978). Strontium apparently can be remobilized and recycled (Beddington *et al.* 1989). Strontium was detected in almost every fish composite analyzed by ETSRC. Body burdens of strontium are not well understood, and we do not have any means to assess the strontium concentrations found in Republican River drainage fish composites.

We do not know the effects, if any, of the two sample concentrations in which tin was detected. Tin is believed to have moderate potential for bioconcentration. It is not essential for life, but is widely used in industry, and virtually all exposure of aquatic biota is likely from industrial contamination or other human activities. Inorganic tin compounds are not likely to be toxic, but organotin compounds may be toxic at very low levels (Eisler 1989b). The tin concentrations found at Superior, Nebraska and Scandia, Kansas in 1989 would indicate that further examination of the sites should be done, but tin was not found in samples collected at the sites in 1990.

Although vanadium was detected in almost every fish composite for which it was analyzed, we have no information on background levels of vanadium in fish. Because most vanadium concentrations in sediments

were within background norms, we suspect that the concentrations found in fish also are normal.

Zinc is well controlled metabolically, but the zinc concentration in 15 of the fish composites we collected exceeded the 34.2 µg/g wet weight 85th percentile concentration from the 1984 NCBP. The highest zinc concentrations in fish from the 1978-79, 1980-81, and 1984 NCBP sampling efforts were in common carp (Lowe *et al.* 1985, Schmitt and Brumbaugh 1990). Zinc concentrations in carp from our sampling were well below the maximum concentrations observed in the NCBP (168 µg/g in 1978-1979, 109.2 µg/g in 1980-1981, and 118.4 µg/g in 1984). We do not believe that zinc concentrations in samples we collected represent a problem.

CHLORINATED HYDROCARBONS

Chlorinated Hydrocarbons in Sediments

The only organochlorine residue detected in Republican River Basin sediments was p,p'-DDE, which was detected at Swanson Reservoir (0.03 µg/g wet weight), Enders Reservoir (0.01 µg/g), and on Thompson Creek 21 (0.01 µg/g). Organochlorine concentrations in sediments in the Republican River basin are low.

Chlorinated Hydrocarbons in Fish

Organochlorine concentrations in fish are shown in Table 8. Hexachlorobenzene, benzene hexachloride, and endrin were not detected in any fish composite.

Martin and Hartman (1985) found that fish from nine of 17 north-central U.S. wetlands contained higher organochlorine insecticide and PCB residues than were found in sediments. Trans-nonachlor, the only chlordane compound found in fish, was present in very low concentrations. The geometric mean chlordane compound (excluding methoxychlor) concentrations in fish collected for the NCBP from 1976 through 1984 ranged from 0.12 to 0.20 µg/g wet weight (Schmitt *et al.* 1983, 1985, 1990). The National Academy of Science and National Academy of Engineering [(NAS/NAE) 1973] recommended that to protect aquatic life, the whole body wet weight concentration of all cyclodiene compounds (chlordane compounds, heptachlor, aldrin, endrin, dieldrin, and endosulfan) together should not exceed 0.1 µg/g. The cyclodiene concentration in the river carpsucker composite from Junction City, Kansas was the only fish sample that exceeded 0.1 µg/g, but it was more

Table 8. Chlorinated hydrocarbon concentrations in Republican River Basin fish composites in 1989 and 1990. Concentrations in $\mu g/g$ wet weight.

Location	State	Fish Species	Percent Moisture	Percent Lipid	Compound	
					oxychlordane	heptachlor epoxide
north of Bethune	Co	White Sucker	76.0	4.84	ND	ND
Bonny Reservoir	Co	Gizzard Shad	71.0	13.40	ND	ND
St. Francis Wildlife Area	Ks	Dace, Chubs	78.0	1.40	ND	ND
east of Haigler	Ne	Shiners, Killifish	78.5	3.08	ND	ND
Rock Creek Reservoir	Ne	Gizzard Shad	74.0	5.08	ND	ND
at Max	Ne	Shiners, Killifish	77.0	2.94	ND	ND
Swanson Reservoir	Ne	River Carpsucker	60.0	23.50	ND	ND
Swanson Reservoir	Ne	Northern Pike	75.0	3.70	ND	ND
Enders Reservoir	Ne	Gizzard Shad	72.0	7.26	ND	ND
Stinking Water Creek	Ne	Creek Chub	74.0	1.22	ND	ND
Frenchman Creek near Hamlet	Ne	Creek Chub	80.5	1.90	ND	ND
Red Willow Reservoir	Ne	Northern Pike	73.0	6.48	ND	ND
Red Willow Reservoir	Ne	Common Carp	77.0	2.12	ND	ND
Red Willow Creek	Ne	Creek Chub	76.0	1.52	ND	ND
Medicine Creek Reservoir	Ne	White Bass	71.5	5.48	ND	ND
Medicine Creek at Cambridge	Ne	River Carpsucker	79.5	1.68	ND	ND
at Perry	Ne	River Carpsucker	71.5	5.36	ND	ND
Bartley Diversion Canal	Ne	River Carpsucker	73.5	7.02	ND	0.01
Bartley Diversion Canal	Ne	Common Carp	76.0	3.0	ND	ND
Cambridge Diversion Dam	Ne	Common Carp	76.5	3.00	ND	ND
Cambridge Diversion Dam	Ne	River Carpsucker	74.5	2.68	ND	ND
Harlan County Reservoir	Ne	Northern Pike	74.6	12.08	ND	ND
Harlan County Reservoir	Ne	Common Carp	69.7	13.95	ND	ND
Harlan County Reservoir	Ne	Common Carp	68.2	11.70	ND	ND
Harlan County Reservoir	Ne	River Carpsucker	65.8	19.36	ND	ND
Harlan County Reservoir	Ne	Freshwater Drum	73.5	13.13	ND	ND
at Guide Rock	Ne	Sand Shiner	75.0	4.04	ND	ND
at Superior	Ne	Common Carp	69.9	11.04	ND	ND
at Superior	Ne	River Carpsucker	79.0	2.52	ND	ND
at Superior	Ne	Common Carp	75.0	4.94	0.01	0.01
Thompson Creek	Ne	Creek Chub	79.0	2.32	ND	ND
Norton Reservoir	Ks	Common Carp	76.0	3.40	ND	ND
Norton Reservoir	Ks	Gizzard Shad	79.0	2.94	ND	ND
White Rock Creek	Ks	Goldeye	79.5	1.56	ND	ND
White Rock Creek	Ks	Common Carp	78.5	1.48	ND	ND
White Rock Creek	Ks	Common Carp	76.4	3.28	ND	ND
White Rock Creek	Ks	Common Carp	73.6	4.06	ND	ND
Lovewell Reservoir	Ks	Freshwater Drum	71.1	17.43	ND	ND
Lovewell Reservoir	Ks	Walleye	68.3	18.96	ND	ND
Lovewell Reservoir	Ks	Common Carp	72.7	14.91	ND	ND
Lovewell Reservoir	Ks	Gizzard Shad	65.4	21.40	ND	0.01
Lovewell Reservoir	Ks	Gizzard Shad	70.5	10.50	ND	0.01
Lovewell Reservoir	Ks	Common Carp	72.4	5.68	0.01	0.02
Lovewell Reservoir	Ks	Common Carp	73.0	3.80	ND	ND
Lovewell Reservoir	Ks	Walleye	72.0	8.28	ND	0.02
Lovewell Reservoir	Ks	Walleye	73.6	6.72	ND	ND
at Scandia	Ks	Common Carp	72.5	11.64	ND	ND
at Scandia	Ks	River Carpsucker	75.2	11.25	ND	ND
at Scandia	Ks	Common Carp	75.6	3.84	ND	ND

Table 8 (continued). Chlorinated hydrocarbon concentrations in Republican River Basin fish composites in 1989 and 1990. Concentrations in µg/g wet weight.

Location	State	Fish Species	Percent Moisture	Percent Lipid	Compound	
					oxychlordane	heptachlor epoxide
at Clyde	Ks	Common Carp	74.4	5.58	0.01	0.02
at Clyde	Ks	River Carpsucker	68.2	9.86	0.01	0.02
at Clay Center	Ks	Common Carp	75.8	4.40	0.01	0.01
at Clay Center	Ks	Common Carp	74.4	3.18	ND	ND
Milford Reservoir	Ks	White Bass	71.6	7.84	ND	ND
Milford Reservoir	Ks	Gizzard Shad	69.8	12.70	ND	0.01
Milford Reservoir	Ks	Smallmouth Buffalo	70.2	9.68	ND	0.01
Milford Reservoir	Ks	River Carpsucker	61.4	21.80	ND	0.02
at Junction City	Ks	River Carpsucker	70.8	7.18	0.01	0.01
at Junction City	Ks	Common Carp	78.0	2.96	ND	0.01

Table 8 (continued). Chlorinated hydrocarbon concentrations in Republican River Basin fish composites in 1989 and 1990. Concentrations in µg/g wet weight.

Location	State	Fish Species	Compound			
			trans-chlordane	alpha-chlordane	cis-nonachlor	trans-nonachlor
north of Bethune	Co	White Sucker	ND	ND	ND	ND
Bonny Reservoir	Co	Gizzard Shad	ND	ND	ND	ND
St. Francis Wildlife Area	Ks	Dace, Chubs	ND	ND	ND	ND
east of Haigler	Ne	Shiners, Killifish	ND	ND	ND	ND
Rock Creek Reservoir	Ne	Gizzard Shad	ND	ND	ND	ND
at Max	Ne	Shiners, Killifish	ND	ND	ND	ND
Swanson Reservoir	Ne	River Carpsucker	ND	0.02	ND	0.02
Swanson Reservoir	Ne	Northern Pike	ND	0.01	ND	0.01
Enders Reservoir	Ne	Gizzard Shad	ND	0.01	ND	0.01
Stinking Water Creek	Ne	Creek Chub	ND	ND	ND	ND
Frenchman Creek near Hamlet	Ne	Creek Chub	ND	ND	ND	ND
Red Willow Reservoir	Ne	Northern Pike	ND	0.02	0.01	0.02
Red Willow Reservoir	Ne	Common Carp	ND	ND	ND	ND
Red Willow Creek	Ne	Creek Chub	ND	ND	ND	ND
Medicine Creek Reservoir	Ne	White Bass	ND	ND	ND	ND
Medicine Creek at Cambridge	Ne	River Carpsucker	ND	ND	ND	ND
at Perry	Ne	River Carpsucker	ND	0.01	ND	0.01
Bartley Diversion Canal	Ne	River Carpsucker	0.01	0.02	0.01	0.02
Bartley Diversion Canal	Ne	Common Carp	ND	0.01	ND	0.01
Cambridge Diversion Dam	Ne	Common Carp	ND	0.01	ND	0.01
Cambridge Diversion Dam	Ne	River Carpsucker	ND	0.01	ND	0.02
Harlan County Reservoir	Ne	Northern Pike	ND	ND	ND	ND
Harlan County Reservoir	Ne	Common Carp	ND	ND	ND	ND
Harlan County Reservoir	Ne	Common Carp	0.01	ND	ND	ND
Harlan County Reservoir	Ne	River Carpsucker	0.01	0.01	0.01	0.02
Harlan County Reservoir	Ne	Freshwater Drum	ND	0.01	ND	ND
at Guide Rock	Ne	Sand Shiner	ND	ND	ND	ND
at Superior	Ne	Common Carp	ND	ND	ND	ND
at Superior	Ne	River Carpsucker	ND	ND	ND	ND
at Superior	Ne	Common Carp	0.01	0.01	ND	0.01
Thompson Creek	Ne	Creek Chub	ND	ND	ND	ND
Norton Reservoir	Ks	Common Carp	ND	ND	ND	ND
Norton Reservoir	Ks	Gizzard Shad	ND	ND	ND	ND
White Rock Creek	Ks	Goldeye	ND	ND	ND	ND
White Rock Creek	Ks	Common Carp	ND	ND	ND	ND
White Rock Creek	Ks	Common Carp	ND	ND	ND	ND
White Rock Creek	Ks	Common Carp	ND	ND	ND	ND
Lovewell Reservoir	Ks	Freshwater Drum	0.02	0.01	0.01	0.03
Lovewell Reservoir	Ks	Walleye	0.02	0.01	0.01	0.02
Lovewell Reservoir	Ks	Common Carp	0.02	ND	0.01	0.02
Lovewell Reservoir	Ks	Gizzard Shad	0.02	0.02	0.01	0.03
Lovewell Reservoir	Ks	Gizzard Shad	ND	0.01	ND	0.01
Lovewell Reservoir	Ks	Common Carp	0.01	0.01	ND	0.01
Lovewell Reservoir	Ks	Common Carp	ND	ND	ND	ND
Lovewell Reservoir	Ks	Walleye	ND	0.01	ND	0.01
Lovewell Reservoir	Ks	Walleye	ND	ND	ND	ND
at Scandia	Ks	Common Carp	0.02	0.02	0.02	0.01
at Scandia	Ks	River Carpsucker	0.01	0.02	0.02	0.02
at Scandia	Ks	Common Carp	ND	ND	ND	0.01

Table 8 (continued). Chlorinated hydrocarbon concentrations in Republican River Basin fish composites in 1989 and 1990. Concentrations in µg/g wet weight.

Location	State	Fish Species	Compound			
			trans-chlordane	alpha-chlordane	cis-nonachlor	trans-nonachlor
at Clyde	Ks	Common Carp	0.01	0.02	ND	0.02
at Clyde	Ks	River Carpsucker	0.01	0.02	ND	0.02
at Clay Center	Ks	Common Carp	0.01	0.01	ND	0.02
at Clay Center	Ks	Common Carp	ND	0.01	ND	0.01
Milford Reservoir	Ks	White Bass	ND	ND	ND	ND
Milford Reservoir	Ks	Gizzard Shad	ND	0.01	ND	0.01
Milford Reservoir	Ks	Smallmouth Buffalo	0.01	0.01	ND	0.01
Milford Reservoir	Ks	River Carpsucker	0.01	0.02	ND	0.01
at Junction City	Ks	River Carpsucker	0.05	0.06	0.04	0.08
at Junction City	Ks	Common Carp	0.02	0.02	ND	0.03

Table 8 (continued). Chlorinated hydrocarbon concentrations in Republican River Basin fish composites in 1989 and 1990. Concentrations in µg/g wet weight.

Location	State	Fish Species	Compound			
			chlordane total	dieldrin	toxaphene	mirex
north of Bethune	Co	White Sucker	ND	ND	ND	ND
Bonny Reservoir	Co	Gizzard Shad	ND	0.01	ND	ND
St. Francis Wildlife Area	Ks	Dace, Chubs	ND	ND	ND	ND
east of Haigler	Ne	Shiners, Killifish	ND	ND	ND	ND
Rock Creek Reservoir	Ne	Gizzard Shad	ND	ND	ND	ND
at Max	Ne	Shiners, Killifish	ND	ND	ND	ND
Swanson Reservoir	Ne	River Carpsucker	0.04	0.01	ND	ND
Swanson Reservoir	Ne	Northern Pike	0.02	ND	ND	ND
Enders Reservoir	Ne	Gizzard Shad	0.02	ND	ND	ND
Stinking Water Creek	Ne	Creek Chub	ND	ND	ND	ND
Frenchman Creek near Hamlet	Ne	Creek Chub	ND	ND	ND	ND
Red Willow Reservoir	Ne	Northern Pike	0.05	0.01	ND	ND
Red Willow Reservoir	Ne	Common Carp	ND	ND	ND	ND
Red Willow Creek	Ne	Creek Chub	ND	ND	ND	ND
Medicine Creek Reservoir	Ne	White Bass	ND	ND	ND	ND
Medicine Creek at Cambridge	Ne	River Carpsucker	ND	ND	ND	ND
at Perry	Ne	River Carpsucker	0.02	0.02	ND	ND
Bartley Diversion Canal	Ne	River Carpsucker	0.07	0.02	ND	0.10
Bartley Diversion Canal	Ne	Common Carp	0.02	0.01	ND	ND
Cambridge Diversion Dam	Ne	Common Carp	0.02	0.01	ND	ND
Cambridge Diversion Dam	Ne	River Carpsucker	0.03	0.01	ND	ND
Harlan County Reservoir	Ne	Northern Pike	ND	0.01	ND	NA
Harlan County Reservoir	Ne	Common Carp	ND	0.01	ND	NA
Harlan County Reservoir	Ne	Common Carp	0.01	ND	ND	NA
Harlan County Reservoir	Ne	River Carpsucker	0.05	0.02	ND	NA
Harlan County Reservoir	Ne	Freshwater Drum	0.01	ND	ND	NA
at Guide Rock	Ne	Sand Shiner	ND	ND	ND	ND
at Superior	Ne	Common Carp	ND	0.01	ND	NA
at Superior	Ne	River Carpsucker	ND	ND	ND	ND
at Superior	Ne	Common Carp	0.05	0.01	ND	ND
Thompson Creek	Ne	Creek Chub	ND	ND	ND	ND
Norton Reservoir	Ks	Common Carp	ND	ND	ND	ND
Norton Reservoir	Ks	Gizzard Shad	ND	ND	ND	ND
White Rock Creek	Ks	Goldeye	ND	0.01	ND	ND
White Rock Creek	Ks	Common Carp	ND	0.01	ND	ND
White Rock Creek	Ks	Common Carp	ND	ND	ND	ND
White Rock Creek	Ks	Common Carp	ND	0.01	ND	ND
Lovewell Reservoir	Ks	Freshwater Drum	0.07	0.02	ND	NA
Lovewell Reservoir	Ks	Walleye	0.06	0.04	ND	NA
Lovewell Reservoir	Ks	Common Carp	0.04	0.02	1.30	NA
Lovewell Reservoir	Ks	Gizzard Shad	0.09	0.06	2.10	NA
Lovewell Reservoir	Ks	Gizzard Shad	0.03	0.02	ND	ND
Lovewell Reservoir	Ks	Common Carp	0.06	ND	ND	ND
Lovewell Reservoir	Ks	Common Carp	ND	ND	ND	ND
Lovewell Reservoir	Ks	Walleye	0.04	ND	ND	ND
Lovewell Reservoir	Ks	Walleye	ND	0.01	ND	ND
at Scandia	Ks	Common Carp	0.06	0.03	1.20	NA
at Scandia	Ks	River Carpsucker	0.06	0.03	0.59	NA
at Scandia	Ks	Common Carp	0.01	0.01	ND	ND

Table 8 (continued). Chlorinated hydrocarbon concentrations in Republican River Basin fish composites in 1989 and 1990. Concentrations in µg/g wet weight.

Location	State	Fish Species	Compound			
			chlordane Total	dieldrin	toxaphene	mirex
at Clyde	Ks	Common Carp	0.08	ND	ND	ND
at Clyde	Ks	River Carpsucker	0.08	0.03	ND	ND
at Clay Center	Ks	Common Carp	0.06	0.01	ND	ND
at Clay Center	Ks	Common Carp	0.02	ND	ND	ND
Milford Reservoir	Ks	White Bass	ND	0.01	ND	ND
Milford Reservoir	Ks	Gizzard Shad	0.03	0.02	ND	ND
Milford Reservoir	Ks	Smallmouth Buffalo	0.04	0.01	ND	ND
Milford Reservoir	Ks	River Carpsucker	0.06	0.01	ND	ND
at Junction City	Ks	River Carpsucker	0.25	0.02	ND	ND
at Junction City	Ks	Common Carp	0.08	ND	ND	ND

Table 8 (continued). Chlorinated hydrocarbon concentrations in Republican River Basin fish composites in 1989 and 1990. Concentrations in µg/g wet weight.

Location	State	Fish Species	Compound				
			arochlor 1254	total PCBs	p,p'-DDT	o,p'-DDT	p,p'-DDE
north of Bethune	Co	White Sucker	NA	ND	ND	ND	ND
Bonny Reservoir	Co	Gizzard Shad	NA	ND	ND	ND	0.04
St. Francis Wildlife Area	Ks	Dace, Chubs	NA	ND	ND	ND	ND
east of Haigler	Ne	Shiners, Killifish	NA	ND	ND	ND	0.02
Rock Creek Reservoir	Ne	Gizzard Shad	NA	ND	ND	ND	0.01
at Max	Ne	Shiners, Killifish	NA	ND	ND	ND	0.01
Swanson Reservoir	Ne	River Carpsucker	NA	ND	ND	ND	0.04
Swanson Reservoir	Ne	Northern Pike	NA	ND	ND	ND	0.04
Enders Reservoir	Ne	Gizzard Shad	NA	ND	ND	ND	0.02
Stinking Water Creek	Ne	Creek Chub	NA	ND	ND	ND	0.01
Frenchman Creek near Hamlet	Ne	Creek Chub	NA	ND	ND	ND	0.01
Red Willow Reservoir	Ne	Northern Pike	NA	ND	ND	ND	0.08
Red Willow Reservoir	Ne	Common Carp	NA	ND	ND	ND	0.02
Red Willow Creek	Ne	Creek Chub	NA	ND	ND	ND	0.01
Medicine Creek Reservoir	Ne	White Bass	NA	ND	ND	ND	0.01
Medicine Creek at Cambridge	Ne	River Carpsucker	NA	ND	ND	ND	0.01
at Perry	Ne	River Carpsucker	NA	ND	ND	ND	0.04
Bartley Diversion Canal	Ne	River Carpsucker	NA	ND	0.01	ND	0.06
Bartley Diversion Canal	Ne	Common Carp	NS	ND	ND	ND	0.06
Cambridge Diversion Dam	Ne	Common Carp	NA	ND	ND	ND	0.04
Cambridge Diversion Dam	Ne	River Carpsucker	NA	ND	ND	ND	0.03
Harlan County Reservoir	Ne	Northern Pike	0.15	NA	ND	NA	0.02
Harlan County Reservoir	Ne	Common Carp	0.14	NA	ND	NA	0.04
Harlan County Reservoir	Ne	Common Carp	0.05	NA	ND	NA	0.03
Harlan County Reservoir	Ne	River Carpsucker	0.16	NA	ND	NA	0.05
Harlan County Reservoir	Ne	Freshwater Drum	ND	NA	ND	NA	0.04
at Guide Rock	Ne	Sand Shiner	NA	ND	ND	ND	0.01
at Superior	Ne	Common Carp	0.16	NA	ND	NA	0.04
at Superior	Ne	River Carpsucker	NA	ND	ND	NA	0.02
at Superior	Ne	Common Carp	NA	ND	ND	ND	0.05
Thompson Creek	Ne	Creek Chub	NA	ND	ND	ND	0.01
Norton Reservoir	Ks	Common Carp	NA	ND	ND	ND	0.03
Norton Reservoir	Ks	Gizzard Shad	NA	ND	ND	ND	0.02
White Rock Creek	Ks	Goldeye	NA	ND	ND	ND	0.01
White Rock Creek	Ks	Common Carp	NA	ND	ND	ND	0.02
White Rock Creek	Ks	Common Carp	NA	ND	ND	ND	0.01
White Rock Creek	Ks	Common Carp	NA	ND	ND	ND	0.01
Lovewell Reservoir	Ks	Freshwater Drum	0.21	NA	ND	NA	0.08
Lovewell Reservoir	Ks	Walleye	0.11	NA	ND	NA	0.08
Lovewell Reservoir	Ks	Common Carp	0.23	NA	ND	NA	0.09
Lovewell Reservoir	Ks	Gizzard Shad	0.08	NA	ND	NA	0.09
Lovewell Reservoir	Ks	Gizzard Shad	NA	ND	ND	ND	0.03
Lovewell Reservoir	Ks	Common Carp	NA	ND	ND	ND	0.04
Lovewell Reservoir	Ks	Common Carp	NA	ND	ND	ND	0.03
Lovewell Reservoir	Ks	Walleye	NA	ND	ND	ND	0.02
Lovewell Reservoir	Ks	Walleye	NA	ND	ND	ND	0.02
at Scandia	Ks	Common Carp	0.09	NA	ND	NA	0.04
at Scandia	Ks	River Carpsucker	0.06	NA	ND	NA	0.08
at Scandia	Ks	Common Carp	NA	ND	ND	ND	0.01

Table 8 (continued). Chlorinated hydrocarbon concentrations in Republican River Basin fish composites in 1989 and 1990. Concentrations in μg/g wet weight.

Location	State	Fish Species	Compound				
			arochlor 1254	total PCBs	p,p'-DDT	o,p'-DDT	p,p'-DDE
at Clyde	Ks	Common Carp	NA	ND	ND	ND	0.03
at Clyde	Ks	River Carpsucker	NA	ND	0.02	0.01	0.08
at Clay Center	Ks	Common Carp	NA	ND	ND	ND	0.04
at Clay Center	Ks	Common Carp	NA	ND	ND	ND	0.03
Milford Reservoir	Ks	White Bass	NA	ND	ND	ND	0.02
Milford Reservoir	Ks	Gizzard Shad	NA	ND	ND	ND	0.05
Milford Reservoir	Ks	Smallmouth Buffalo	NA	ND	ND	0.01	0.05
Milford Reservoir	Ks	River Carpsucker	NA	ND	ND	ND	0.03
at Junction City	Ks	River Carpsucker	NA	ND	0.03	0.01	0.08
at Junction City	Ks	Common Carp	NA	ND	ND	0.01	0.05

Table 8 (continued). Chlorinated hydrocarbon concentrations in Republican River Basin fish composites in 1989 and 1990. Concentrations in $\mu g/g$ wet weight.

Location	State	Fish Species	Compound			
			o,p'-DDE	p,p'-DDD	o,p'-DDD	DDT Compounds
north of Bethune	Co	White Sucker	ND	ND	ND	ND
Bonny Reservoir	Co	Gizzard Shad	ND	0.01	ND	0.05
St. Francis Wildlife Area	Ks	Dace, Chubs	ND	ND	ND	ND
east of Haigler	Ne	Shiners, Killifish	ND	ND	ND	0.02
Rock Creek Reservoir	Ne	Gizzard Shad	ND	ND	ND	0.01
at Max	Ne	Shiners, Killifish	ND	ND	ND	0.01
Swanson Reservoir	Ne	River Carpsucker	ND	0.02	ND	0.06
Swanson Reservoir	Ne	Northern Pike	ND	0.01	ND	0.05
Enders Reservoir	Ne	Gizzard Shad	ND	0.01	ND	0.03
Stinking Water Creek	Ne	Creek Chub	ND	ND	ND	0.01
Frenchman Creek near Hamlet	Ne	Creek Chub	ND	ND	ND	0.01
Red Willow Reservoir	Ne	Northern Pike	ND	0.02	ND	0.10
Red Willow Reservoir	Ne	Common Carp	ND	ND	ND	0.02
Red Willow Creek	Ne	Creek Chub	ND	ND	ND	0.01
Medicine Creek Reservoir	Ne	White Bass	ND	ND	ND	0.01
Medicine Creek at Cambridge	Ne	River Carpsucker	ND	ND	ND	0.01
at Perry	Ne	River Carpsucker	ND	0.01	ND	0.05
Bartley Diversion Canal	Ne	River Carpsucker	ND	0.02	ND	0.09
Bartley Diversion Canal	Ne	Common Carp	ND	0.01	ND	0.07
Cambridge Diversion Dam	Ne	Common Carp	ND	ND	ND	0.04
Cambridge Diversion Dam	Ne	River Carpsucker	ND	0.01	ND	0.04
Harlan County Reservoir	Ne	Northern Pike	NA	ND	NA	0.02
Harlan County Reservoir	Ne	Common Carp	NA	ND	NA	0.04
Harlan County Reservoir	Ne	Common Carp	NA	ND	NA	0.03
Harlan County Reservoir	Ne	River Carpsucker	NA	0.01	NA	0.06
Harlan County Reservoir	Ne	Freshwater Drum	NA	ND	NA	0.04
at Guide Rock	Ne	Sand Shiner	ND	ND	ND	0.01
at Superior	Ne	Common Carp	NA	0.03	NA	0.07
at Superior	Ne	River Carpsucker	ND	0.01	ND	0.03
at Superior	Ne	Common Carp	ND	0.03	0.01	0.09
Thompson Creek	Ne	Creek Chub	ND	ND	ND	0.01
Norton Reservoir	Ks	Common Carp	ND	ND	ND	0.03
Norton Reservoir	Ks	Gizzard Shad	ND	ND	ND	0.02
White Rock Creek	Ks	Goldeye	ND	ND	ND	0.01
White Rock Creek	Ks	Common Carp	ND	ND	ND	0.02
White Rock Creek	Ks	Common Carp	ND	ND	ND	0.01
White Rock Creek	Ks	Common Carp	ND	ND	ND	0.01
Lovewell Reservoir	Ks	Freshwater Drum	NA	0.04	NA	0.12
Lovewell Reservoir	Ks	Walleye	NA	0.04	NA	0.12
Lovewell Reservoir	Ks	Common Carp	NA	0.03	NA	0.12
Lovewell Reservoir	Ks	Gizzard Shad	NA	0.05	NA	0.14
Lovewell Reservoir	Ks	Gizzard Shad	ND	0.01	ND	0.04
Lovewell Reservoir	Ks	Common Carp	ND	ND	ND	0.04
Lovewell Reservoir	Ks	Common Carp	ND	ND	ND	0.03
Lovewell Reservoir	Ks	Walleye	ND	ND	ND	0.02
Lovewell Reservoir	Ks	Walleye	ND	ND	ND	0.02
at Scandia	Ks	Common Carp	NA	0.04	NA	0.08
at Scandia	Ks	River Carpsucker	NA	0.05	NA	0.13
at Scandia	Ks	Common Carp	ND	ND	ND	0.01

Table 8 (concluded). Chlorinated hydrocarbon concentrations in Republican River Basin fish composites in 1989 and 1990. Concentrations in µg/g wet weight.

Location	State	Fish Species	Compound			
			o,p'-DDE	p,p'-DDD	o,p'-DDD	DDT Compounds
at Clyde	Ks	Common Carp	ND	0.02	0.02	0.07
at Clyde	Ks	River Carpsucker	ND	0.04	0.02	0.17
at Clay Center	Ks	Common Carp	ND	0.01	0.02	0.07
at Clay Center	Ks	Common Carp	ND	0.01	ND	0.04
Milford Reservoir	Ks	White Bass	ND	ND	ND	0.02
Milford Reservoir	Ks	Gizzard Shad	ND	0.02	0.01	0.08
Milford Reservoir	Ks	Smallmouth Buffalo	ND	0.03	0.01	0.10
Milford Reservoir	Ks	River Carpsucker	ND	0.01	0.01	0.05
at Junction City	Ks	River Carpsucker	ND	0.04	0.02	0.18
at Junction City	Ks	Common Carp	ND	0.02	0.02	0.10

than double the NAS/NAE criterion. The decreasing concentrations of chlordane and the increasing proportions of trans-nonachlor, the most persistent component of chlordane, in fish collected for the NCBP indicated that the input of chlordane to aquatic systems in the U.S. is declining (Schmitt *et al.* 1990). Our sampling indicates that chlordane compound concentrations in most of the Republican River basin are negligible. Higher concentrations were only in the last reach of the river.

Toxaphene is a broad-spectrum insecticide for which all but a few registered uses were cancelled in 1982. It has long been recognized as very toxic to fish (*e.g.* Henderson *et al.* 1959), and has been used as a piscicide. "Tissue residues of 0.4 µg/g [wet(?) weight] were associated with reduced growth, bone development, and reproductive success in brook trout [*Salvelinus fontinalis*] and reduced growth in fathead minnows [*Pimephales promelas*]. In channel catfish [*Ictalurus punctatus*] fry, toxaphene residues of 3.4 µg/g and greater decreased growth, and residues of 0.6 µg/g adversely altered bone development" (Mehrle and Mayer 1975a, 1975b, Stickel and Hickey 1977). Johnson and Julin (1980) suggested that yolk-sac fry of fish may be the development stage most susceptible to toxaphene because of the lipid-solubility of the chemical. Eisler (1985b) concluded that toxaphene has a bioconcentration factor of 52,000 for fathead minnows and 40,000 for channel catfish fry. Therefore, toxaphene should be of special concern when found in biota, and the concentrations observed in fish from Lovewell Reservoir and from the Republican River at Scandia in 1989 would warrant further testing of biota for toxaphene. However, toxaphene was not detected in fish from those locations analyzed by MSCL in 1990. Toxaphene may have been used in 1989 above Lovewell Reservoir.

More detailed sampling would be needed to determine if toxaphene is in use in the lower portions of the Republican River and if toxaphene residues present a danger to biota.

Mirex is a long-lived chlorinated hydrocarbon pesticide and fire retardant that was banned for all uses in 1978 (Eisler 1985c, Huckins *et al.* 1982, Skaar *et al.* 1981). Although Eisler (1985c) stated that aquatic organisms are "comparatively resistant to mirex in short term toxicity tests", detrimental effects of mirex on fish have been well documented (*e.g.* Buckler *et al.* 1981, Mehrle *et al.* 1981). The mirex detected in the river carpsucker composite from the head of the Bartley diversion canal in 1989 was confirmed by mass spectrometry and was well above the detection limit for the compound. It indicates that mirex may have been recently used in the vicinity.

Polychlorinated biphenyls (PCBs) are slow to degrade, and have been found in most environments throughout the world (*e.g.* Muir *et al.* 1988, Solbakken *et al.* 1984, Weber 1983). They are strongly adsorbed on aquatic sediments (Eisler 1986b), and benthic organisms are at special risk from PCBs (Dunnivant *et al.* 1989, Fry and Fisher 1990, Stainken 1984). PCBs are bioaccumulated and biomagnified in the environment, (Crossland *et al.* 1987, Hunter *et al.* 1980, Macek *et al.* 1979, Thomann 1981). The bioconcentration factor for PCBs in freshwater invertebrates can be as high as 47,000 (Eisler 1986b). Effects of PCBs include a variety of maladies in many animals (Eisler 1986b). PCBs also may alter the effects of other contaminants (Bills *et al.* 1981, Wren *et al.* 1987). In addition, PCB impurities such as polychlorinated dibenzofurans may be extremely toxic. However, we did not have the samples analyzed for such impurities.

The whole body fresh weight concentration of PCBs should be less than 0.4 μg/g (EPA 1980). However, fresh weight whole body concentrations of 0.4 μg/g were associated with reproductive toxicity in rainbow trout (EPA 1980). Eisler (1986b) believed that the criterion should be less than 0.4 μg/g for nonmigratory benthic species.

In the north-central United States, Martin and Hartman (1985) found PCB concentrations in only a few of the whole fish samples that they analyzed. For the NCBP, mean Aroclor® 1254 (a common PCB) and total PCB concentrations were 0.47 and 0.87 μg/g in 1976-1977, and 0.47 and 0.86 μg/g in 1978-1979 (Schmitt *et al.* 1983). In 1980-1981, the values were 0.24 and 0.53 μg/g (Schmitt *et al.* 1985). By 1984, the Aroclor® 1254 and total PCB mean concentrations nationwide had declined to 0.21 and 0.39 μg/g wet weight, respectively. The maximum nationwide values in 1984 were 4.0 μg/g and 6.7 μg/g. Both Aroclor® 1254 and total PCB mean concentrations showed highly significant declines between 1976 and 1984

(Schmitt *et al.* 1990).

PCBs were not detected in most fish composites we collected. Arochlor 1254 was found in fish from Harlan County Reservoir and from Lovewell Reservoir at concentrations that are not likely to present a serious problem. The highest concentrations found were approximately equal to the mean from the 1984 NCBP collections.

DDT compounds are very persistent and have been shown to have many detrimental effects in biota (*e.g.* Berlin *et al.* 1981, Burdick *et al.* 1964, Geluso *et al.* 1976, Hickey and Anderson 1968, Kirk 1988, Lundholm 1987, Newton and Bogan 1978, Ratcliffe 1967). DDT is metabolized to DDE and DDD by most fish species, so the ratio of DDT to its metabolites indicates the time elapsed since introduction (Aguilar 1984). High proportions of o,p'- forms of DDT or its metabolites also indicate "relatively recent inputs and pollution sources other than insecticides - *e.g.*, pesticide manufacturing and formulation sites or chemical waste dumps" (Schmitt *et al.* 1985).

Inputs of DDT compounds into most aquatic systems have diminished (Schmitt *et al.* 1990). Wet weight geometric means of p,p' DDT and its metabolites from the NCBP were 6.54 μg/g in 1976-1977, 10.62 μg/g in 1978-1979, 6.50 μg/g in 1980-1981, and 9.08 μg/g in 1984 (Schmitt *et al.* 1983, 1985, 1990). The occurrence of o,p'-DDT in fish composites from several locations along the lower reaches of the Republican River in Kansas indicate that DDT is still being used in some places. Nevertheless, the total DDT compound concentrations in all fish composites we collected were well below the means from the 1984 NCBP, and DDT compounds do not present a problem for biota in the locations we sampled.

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