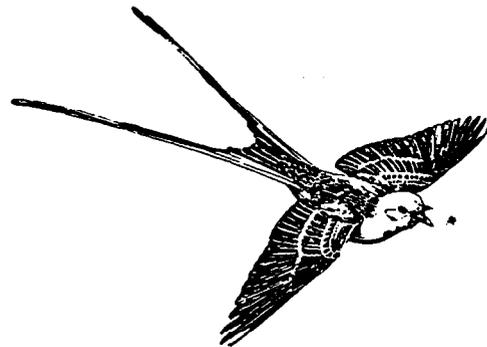
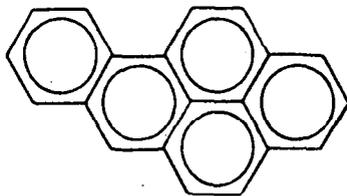
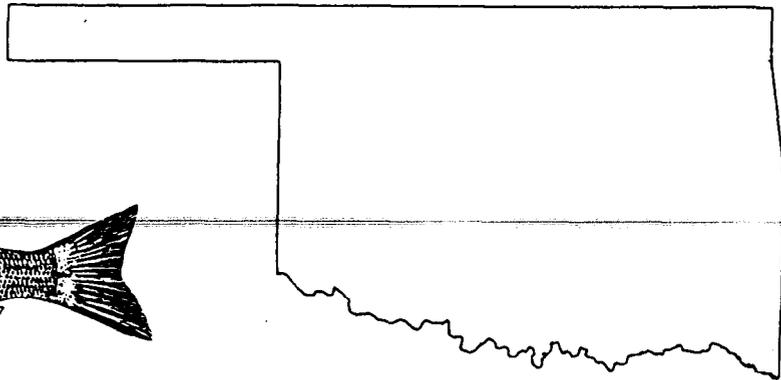
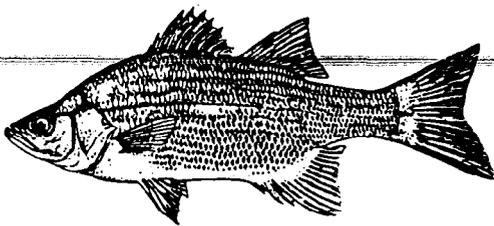


**AN ASSESSMENT OF TRACE ELEMENTS AND ORGANOCHLORINE  
PESTICIDES IN THE W. C. AUSTIN IRRIGATION PROJECT, JACKSON  
AND GREER COUNTIES, OKLAHOMA**



*U.S. FISH AND WILDLIFE SERVICE*

*DEPARTMENT OF THE INTERIOR*



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February 1995

## EXECUTIVE SUMMARY

A 1989 study by the U.S. Fish and Wildlife Service (Service) at the Bureau of Reclamation's (BR) W.C. Austin Irrigation Project (WCA Project) in southwest Oklahoma indicated potential contamination with organochlorine (OC) pesticides. Additional work was funded in 1991 to address this issue. In 1992, native small-sized fish, native and caged channel catfish, sediment, and water were collected from the WCA Project area. Channel catfish were analyzed for OCs; small fish and sediment were analyzed for OCs and elements; and water was analyzed for elements. Semipermeable membrane devices (SPMDs) were also used in the WCA Project area to assess uptake of water-borne OCs.

High concentrations of dieldrin, p,p'-DDE, and toxaphene were detected in fish. Small-sized fish burdens of dieldrin, while not apparently acutely toxic, generally exceeded suggested predator protection levels. P,p'-DDE concentrations in 6 of the 26 small-sized fish samples exceeded the 1984 national maximum residue concentration of p,p'-DDE reported by the National Contaminant Biomonitoring Program (NCBP). P,p'-DDE concentrations in 16 of these samples also exceeded the National Academy of Science's suggested total DDT predator protection standard. P,p'-DDE concentrations in all catfish samples were up to 55 times greater than the 1984 NCBP national geometric mean concentration. Toxaphene concentrations in 11 small-sized fish samples exceeded the 1984 NCBP national Toxaphene due concentration. concentrations in all catfish samples were at least 10 times greater than the 1984 NCBP national geometric mean concentration.

Hatchery-raised channel catfish were kept for about 49 days in cages in two creeks receiving drainwater runoff from the WCA Project area. Caged catfish had dieldrin and toxaphene concentrations more than twice as high as concentrations in native channel catfish. This suggested recent releases of dieldrin and toxaphene either during or immediately prior to the caged catfish study. Movement of native catfish between the two creeks and less polluted waters downstream was another potential factor. Concentrations of p,p'-DDE were higher in native catfish than in caged catfish, indicating the importance of a dietary route of DDE uptake, since caged catfish fed mainly on pelleted fish food.

Concentrations of arsenic, copper, zinc, and especially selenium in small-sized fish samples generally exceeded respective 1984 NCBP national geometric means. However, only selenium appeared to pose toxicological risks to predatory fish and wildlife within the WCA Project area. Spatial distributions of selenium concentrations in fish within the WCA Project area indicated that irrigation practices probably increased selenium loads in drainwater through weathering and leaching of soils with naturally high selenium content.

Concentrations of aluminum, strontium, and vanadium were elevated in water samples. However, spatial distribution of these concentrations suggested that additional sources, both natural and anthropogenic, contributed to the elevated concentrations of these elements in the WCA Project area.

P,p'-DDE was detected in 14 of 16 sediment samples collected around the WCA Project area. Concentrations of p,p'-DDE in these samples were up to 23 times higher than concentrations which routinely cause effects in clinical bioassays. All sediment samples containing p,p'-DDE were collected from the two creeks which receive irrigation drainwater from the WCA Project.

None of the sediment samples contained elevated levels of any element included in this study. Selenium concentrations were comparable to background concentrations.

Concentrations of several OCs, especially p,p'-DDE and toxaphene, were highest in SPMDs set in the two creeks receiving irrigation drainwater from the WCA Project. However, dry-weight OC concentrations in SPMDs could not be calculated, so meaningful comparisons could not be made with OC concentrations in fish. Additional comparative research should be conducted with SPMDs before definitive inferences on contaminant uptake by fish are made.

~~Contamination of fish within the WCA Project area, especially with dieldrin, DDT metabolites, and toxaphene, has been confirmed. Further studies should focus on potential bioaccumulation of these contaminants in Service trust resources, including piscivorous and insectivorous birds. More extensive sampling of the WCA Project area should also be done to further define the sources of contamination.~~

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## CONVERSION FACTORS

1) Analytical chemistry results are usually reported in parts per million (ppm). One part per million is equivalent to one pound of contaminant residue in 500 tons of a mixture (fish, sediment, etc.) The equivalent weight per unit volume and weight per unit weight are given below:

$$\begin{aligned}\text{ppm} &= \text{mg/L (milligrams per liter)} \\ &= \mu\text{g/g (micrograms per gram)} \\ &= \text{mg/kg (milligrams per kilogram)}\end{aligned}$$

Some results (e.g., water concentrations) are reported in parts per billion (ppb). One part per billion is equivalent to one pound of contaminant residue in 500,000 tons of a mixture. The equivalent weight per unit volume and weight per unit weight are given below:

$$\begin{aligned}\text{ppb} &= \mu\text{g/L (micrograms per liter)} \\ &= \text{ng/g (nanograms per gram)} \\ &= \mu\text{g/kg (micrograms per kilogram)}\end{aligned}$$

2) Analytical results in this report are expressed in dry weight where possible. To convert from dry weight values to wet weight values, use this formula:

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$$\text{Wet Weight} = (\text{Dry Weight} \times 100) \times (100 - \% \text{ moisture})$$

## ACKNOWLEDGEMENTS

We would like to thank the people of the following agencies for their assistance with this report: Oklahoma Ecological Services State Office (OK ESSO), Patuxent Analytical Control Facility, and the Midwest Science Center. Wayne Cain and Wesley Webb allowed us onto their land to collect samples. The Midwest Science Center provided SPMDs, technical advice, and post-sampling preparation. Ken Collins (OK ESSO) assisted with fish collections. The Oklahoma City office of the Bureau of Reclamation, Kirke King (Phoenix ESSO), and Mark Wilson (Albuquerque ESSO) reviewed a draft. Numerous others also helped make this report possible.

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## INTRODUCTION

In response to a directive to evaluate potential water quality problems in drainwater from Department of the Interior (DOI) irrigation systems, the U.S. Fish and Wildlife Service (FWS), Oklahoma Ecological Services State Office (ESSO) conducted a pre-reconnaissance contaminant survey in 1989 at the Bureau of Reclamation's W. C. Austin Irrigation Project (WCA Project) in southwest Oklahoma. This survey assessed stream sediment and aquatic biota within the project area for possible contamination by selected trace elements and pesticides. Samples of sediment, common carp, channel catfish, and crayfish collected for this survey contained elevated levels of DDT metabolites, toxaphene, and other organochlorine (OC) pesticides. This evidence highlighted the need for further studies to more accurately assess the extent and severity of OC pesticide contamination in the WCA Project. To address this need, a contaminant study was approved in 1991 with funding provided both by FWS (Ecological Services) and the Bureau of Reclamation (BR). The field work and submission of samples for chemical analyses was scheduled for FY 1992, with subsequent data analysis and compilation of a report on findings. This study consisted of several components, listed below:

- (1) The collection of native small fish species from within the WCA Project area for purposes of (a) determining and evaluating the concentrations of various OCs and elements; (b) determining whether or not the irrigation project is the source of these contaminants; (c) comparing contaminant concentrations in fish among water courses; and (d) comparing contaminant loads among species.
- (2) The analysis of native catfish and caged catfish from within the WCA Project area for the purpose of determining and evaluating concentrations of various OCs.
- (3) The collection of water samples from within the project area for purposes of (a) determining and evaluating the concentrations of various elements; (b) determining whether or not the irrigation project is the source of elemental contaminants; and (c) comparing elemental concentrations among water courses.
- (4) The collection of sediment samples from within the project area for purposes of (a) determining and evaluating the concentrations of various OCs and elements; (b) identifying any potential "hot spots"; and (c) comparing contaminant concentrations.
- (5) The deployment of semipermeable membrane devices (SPMDs) for the purposes of: (a) comparing SPMD concentrations of OCs with those in fish collected from each sampling site; and (b) comparing SPMD concentrations of OCs among sampling sites. SPMDs (furnished by the Midwest Science Center [MSC] in Columbia, Missouri) were used to provide an additional indicator of contaminant concentrations in drainwater within the WCA Project area. These

devices, developed to imitate the uptake of organic contaminants by fish, were intended to provide an alternative method for assessing uptake of water-borne contaminants in aquatic organisms. The Oklahoma ESSO incorporated these experimental devices into the WCA Project study to assess their potential.

### STUDY AREA

The WCA Project, established in 1948, covers an area of 18,751 hectares in Jackson and Greer Counties, southwestern Oklahoma (Figure 1); the boundaries of this project coincide with those of the Lugert Altus Watershed. The watershed is an intensively farmed area, with more than 98 percent of the total acreage under cultivation. Cotton and wheat are the principal crops grown in the WCA Project; other crops grown here include sorghum, alfalfa hay, oats, barley, and peanuts. The project surrounds the city of Altus and irrigation canals belonging to the project run through the city. The topography of the area consists mostly of level plains, with very slight changes in elevation. Minor ranges of small bluffs are scattered along the riverine corridors in the area.

The WCA Project is bordered on the east by the North Fork of the Red River and on the west by the Salt Fork of the Red River. Water for the project is supplied by Altus Reservoir to the north via a series of canals. ~~The project is drained by two natural creeks;~~ on the east by Stinking Creek, which flows southeasterly into the North Fork, and on the west by Bitter Creek, which flows southwesterly into the Salt Fork. Drainage of the project is accomplished primarily via these creeks; consequently, water movement through the project consists mainly of one inflow and two outflows. Water was originally passed once across each field in the district, and the excess was collected in the return flow system. In 1989, the USDA Soil Conservation Service adopted a new water conservation plan, which offered operators the option of on-field impoundment and subsequent reuse of return flow water.

Because of the intensive agricultural practices within the project area, high-quality fish and wildlife habitat is relatively scarce. However, there is riparian habitat along both forks of the Red River and both Stinking and Bitter Creeks, as well as wetlands and uplands adjacent to the upper and lower regions of the watershed. Native vegetation is comprised mostly of low scrub-shrub, with stands of cottonwoods and other opportunistic trees along the rivers and creeks. Wetland habitat within a representative section of the project area was estimated from National Wetland Inventory maps using planimetry. An arbitrary corridor of one mile on either side of the North Fork at the mouth of Stinking Creek was examined, for a distance of two miles upstream and two miles downstream of the confluence. An additional 2-mile-wide corridor extending two miles upstream along Stinking Creek was also examined. A comparable area was measured at the confluence of the lower Salt

Fork and Bitter Creek. In the vicinity of the lower North Fork/Stinking Creek confluence, riverine and palustrine wetlands account for about 20 percent of the total acreage, with about 99 percent of the available wetlands associated with water courses (Table 1). In the vicinity of the lower Salt Fork/Bitter Creek, wetlands account for about 12 percent of the total acreage, with about 96 percent of available wetlands connected to water courses. The same general trend regarding this wetland composition occurs in the rest of the project area. Therefore, only a fraction of available aquatic habitat in the project area, generally in the form of farm ponds, is free from potential contaminants transported in drainage water.

DOI trust resources which can be found in the WCA Project area include a large number of migratory bird species, some of which are of special concern to the FWS. The federally-listed endangered whooping crane, interior least tern, peregrine falcon, and bald eagle, and candidate species such as the ferruginous hawk, loggerhead shrike, western snowy plover, and white-faced ibis appear in the area. Other migratory birds found in the area include the great blue heron, green heron, sandhill crane, Bells' vireo, northern harrier, and ladder-backed woodpecker. Most of these species, along with waterfowl that nest and forage in the project area, are largely confined to water courses, natural and ~~manmade. Consequently, the possibility of trust resources coming~~ into direct contact with, and consuming aquatic resources from, irrigation drainwater is highly probable. This situation, coupled with the relative scarcity of available habitat in the WCA Project area, makes it imperative that the quality of such habitat is maintained in good condition.

#### METHODS

Native small fish were collected by seining during August and October 1992 (in this study, small fish refer to adult and young-of-year specimens of forage fish species such as red shiners and minnows). Sampling was conducted above and below Bitter Creek and Stinking Creek in the Salt Fork and the North Fork of the Red River, respectively, and in Bitter Creek and Stinking Creek (Figure 2). Efforts in both creeks included areas about one-quarter to two miles upstream of the confluences with their respective rivers. Fish collected in the field were immediately placed on wet ice. In the FWS lab, all fish were counted and composited by species, weighed, wrapped, labeled, and stored in a commercial freezer. Finally, all fish samples were shipped on dry ice to a FWS contract analytical chemistry laboratory where they were analyzed for OC pesticide residues and 19 elements (Table 2).

Native channel catfish (CCF) were collected with gill nets during August and October 1992 in Bitter Creek and Stinking Creek (Figure 2). Efforts in both creeks were about one-quarter to one-half mile

upstream of the confluences with their respective rivers. Each fish was weighed and measured, and placed in separate bags on wet ice along with fillets taken from the left lateral muscle tissue of each fish. In the FWS lab, all fish and fillet samples were wrapped, labeled, frozen, and stored in a commercial freezer. Finally, all fish and fillet samples were shipped on dry ice to a FWS contract laboratory for OC analysis.

To assess the potential for uptake of contaminants by channel catfish in specific locations within the project area, cages were constructed to hold test fish during the exposure period. The cages were fabricated from stainless steel hoop frames, 400 mm in diameter and 750 mm long. Stainless steel wire mesh was bound to the frames with stainless steel wire, with a cross-section partition dividing each cage into half. A small stainless steel door in the top of each cage afforded access to each partition. Channel catfish, 175 to 250 mm long, were acquired from the J. A. Manning State Fish Hatchery near Lawton, Oklahoma. Eight fish, selected at random, were placed in each cage, four in each partition, and a cage was set out at each of six sites: the upper Salt Fork, Bitter Creek, the lower Salt Fork; the upper North Fork, Stinking Creek, and the lower North Fork (Figure 2). Eight additional fish, randomly selected, were divided into two composite samples and analyzed for initial concentrations of OCs. These samples were weighed, labeled, and frozen. All cages were set out ~~in June and removed in August 1992 for a total exposure of 49 days.~~ The fish were fed intermittently during the exposure period with commercial pellet food. All surviving fish were then composited by location, weighed, labeled, wrapped, and frozen. All samples were then shipped on dry ice to the contract laboratory for OC analysis.

Water samples were collected during June and August 1992 where caged catfish were located. There were two samples from each of six sites (Figure 2). Two field blanks per sampling date were created using distilled water, for a total of 14 samples per date. Each sample consisted of approximately 500 ml of water collected in chemically cleaned, 1-liter plastic containers which were rinsed once with sample water. The water at most sites was only a few centimeters deep, so collection depth was not a factor. Samples and blanks were filtered through an HA millipore filter and preserved with 5 ml of concentrated nitric acid, then labeled and shipped to a contract laboratory for elemental analyses.

Sediment samples were collected during September 1992 from seven sites within both the Bitter Creek and Stinking Creek drainages (Figure 2). Sites were located at strategic points within the streams, or at the mouths of large irrigation drains, in an attempt to isolate major contributing areas within the Bitter Creek and Stinking Creek watersheds. Two additional samples were collected from a site just upstream from the confluence of the Salt Fork and Bitter Creek, and upstream from the confluence of the North Fork and Stinking Creek. Each sediment sample consisted of

approximately one liter of material, collected by scraping the top 5 cm of sediment into a chemically cleaned wide-mouth jar. Samples were labeled and placed on wet ice in the field. In the FWS lab, samples were stored in a commercial freezer. Finally, all samples were shipped to a contract laboratory for OC and elemental analyses, and analyses for total organic carbon and texture.

SPMDs consisted of extracted, layflat polyethylene tubing filled with 5 ml of triolein. Each SPMD was suspended on stainless steel bolts within a protective section of copper pipe (50 mm diameter by 600 mm long) free-mounted on a fencing stake. Six SPMDs were submerged in this manner at each of six sites comparable to caged catfish sites: upper Salt Fork, Bitter Creek, lower Salt Fork; upper North Fork, Stinking Creek, and lower North Fork (Figure 2). SPMDs were exposed for a period of about 30 days on each of two occasions, one in June and one in August 1992. One additional SPMD per site was stored in holding containers for control purposes. Following exposure, all SPMDs were collected, cleaned of accumulated detritus, and returned to the MSC for pretreatment and dialysis into organic solvents before being submitted to the contract laboratory for OC analyses.

All samples except the second round of water samples were sent to Hazleton Environmental Services (HES), Inc. of Madison, WI. Due to ~~miscommunication, the second set of water samples was sent to~~ Research Triangle Institute (RTI) of Research Triangle Park, NC.

HES submitted all samples to be analyzed for OCs to silica gel cleanup and separation, if necessary. Then gas chromatography-electron capture (GC-EC) methods were used to assess for the presence and concentrations of OCs in samples. Both HES and RTI conducted analyses for elements with the use of graphite furnace atomic absorption (GFAA), cold vapor atomic absorption (CVAA), and inductively couple plasma (ICP) determination.

HES confirmed the identity of selected OCs with GC-mass spectrophotometry in samples which generally contained unusually high levels of these OCs. Duplicate aliquots of these samples were also analyzed to assess the precision of the measurements; relative differences between initial and duplicate results usually fell between 0 and 10 percent. Procedural blanks were also analyzed to confirm the accuracy of measurements; all results came back with zero values. Spike recoveries were conducted to further quantify the accuracy of measurements; the majority of the recovery values fell between 95 and 100 percent for elements and between 80 and 120 percent for OCs.

RTI used GFAA, GVAA, and ICP to analyze samples for elements. Procedural blanks were run for all elements included in the analysis; most values fell between 0 and 0.05  $\mu\text{g}$ , with outliers ranging up to 0.22  $\mu\text{g}$ . Duplicate analyses resulted in relative differences of zero for all elements except iron (22 percent) and

magnesium (92 percent). Spike recoveries on reference materials resulted in a general recovery range of 93 to 123 percent; the same procedure on sample aliquots resulted in a general recovery range of 95 to 105 percent, with outliers extending from 67 percent (magnesium) to 119 percent (aluminum). In general, RTI estimates appeared to run a little higher than HES estimates for elements in water samples.

## RESULTS AND DISCUSSION

### SMALL FISH - ORGANOCHLORINES

Twenty-seven samples of small fish were submitted for analysis. Species included red shiners, plains minnows, fathead minnows, plains killifish, and mosquitofish.

Fish were analyzed for 20 OCs (Table 2). Three OCs were detected in more than 75 percent of the samples: dieldrin (78 percent); toxaphene (96 percent) and p,p'-DDE (100 percent) (Table 3). The frequency of occurrence of other OCs varied from 0 to 45 percent. Spatial distribution of concentrations of less frequently detected OCs were scattered throughout the project area, indicating that these OCs were not a widespread concern. Of the 26 small fish samples, 16 were composed of red shiners, which were the most abundant and widespread species in this study (Table 4). The three most common OCs in small fish are discussed below.

#### Dieldrin

Dieldrin, a relatively persistent cyclodiene pesticide, is listed among the top 25 hazardous substances thought to pose the most significant potential threat to human health at Superfund sites (U.S. Department of Health and Human Services and U.S. EPA 1987). Once widely used to control soil-dwelling insects on cotton, all uses of dieldrin were voluntarily cancelled by 1987 (U.S. EPA 1992). Dieldrin is known to be toxic to fish, and also readily bioaccumulates in animal tissue (Rompala et al. 1984) because it is strongly apolar and has a high affinity for animal fats (U.S. EPA 1980a). Ten of 16 red shiner samples, mostly from Bitter Creek and the lower Salt Fork, had concentrations of dieldrin which exceeded the predator protection level of 0.1 ppm suggested by the National Academy of Sciences (NAS 1973). This indicates that while dieldrin concentrations may not be acutely toxic to red shiners, predators feeding on them may accumulate this chemical to concentrations that are potentially harmful.

Dieldrin concentrations in red shiners collected from Bitter Creek and the lower Salt Fork were more than seven times higher than those in red shiners collected from Stinking Creek and the lower North Fork (Table 4). Among species, fathead minnows appeared to accumulate more dieldrin than red shiners in Stinking Creek. The

same was true of plains minnows versus red shiners in Bitter Creek. Since lipid levels were about the same among plains minnows, fathead minnows, and red shiners from these areas, the feeding biology of these fishes is the probable cause. Plains minnows and fathead minnows are primarily herbivores, feeding on bottom algae, while red shiners feed largely on invertebrates throughout the water column. Given dieldrin's affinity for binding to organic sediments, it appears that plains minnows and fathead minnows are more likely to accumulate dieldrin than red shiners. The data for mosquitofish varied. Dieldrin concentrations in mosquitofish were lower than in red shiners collected from the lower North Fork, but the opposite was true in fish collected from Stinking Creek. Feeding habits of the two species may be similar enough that any differences in dieldrin accumulation may be a result of random variation, especially with a small number of samples.

Dieldrin has been a major cause of pesticide poisoning of raptors in the U.S. For example, dieldrin was the cause of death in 15 bald eagles from 18 midwestern states from 1963 to 1985, and a major factor in the deaths of four more bald eagles from the same area (Wiemeyer 1991). Since bald eagles and other piscivorous birds are found within the project area, it is likely that such birds are at risk of being adversely affected by consuming fish containing dieldrin residues.

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#### DDE

P,p'-DDE is a breakdown product of DDT and is the most persistent form of all DDT metabolites. Although DDT was banned in the U.S. in 1972, its metabolites, especially DDE, persist in the environment. DDE is generally prevalent in DDT-contaminated fish tissue. DDE in one study constituted 50 to 90 percent of the DDT analogs found in fish (Jarvinen et al. 1977). DDE is also readily bioaccumulated in fish. Hamelink and Waybrant (1976) calculated the bioconcentration factor (BCF) in bluegill sunfish to be as high as 110,000. All 26 samples of small fish collected in the WCA Project area had detectable levels of p,p'-DDE. Wet-weight (ww) concentrations in 21 samples exceeded the 1984 National Contaminant Biomonitoring Program (NCBP) geometric mean of 0.19 ppm ww (Schmitt et al. 1990). P,p'-DDE concentrations in 6 samples also exceeded the 1984 national maximum residue concentration reported in Schmitt et al. (1990). Sixteen of the 26 samples had concentrations of p,p'-DDE which exceeded the suggested 1.0 ppm ww total DDT predator protection standard (NAS 1973). This is significant because of the well-documented biomagnification potential of DDT metabolites by successively higher trophic levels. For example, Niethammer et al. (1984) found averages of 0.51 ppm ww DDE in primary consumers such as crayfish (e.g., *Cambarus* spp.), 2.46 ppm ww in secondary consumers such as mosquitofish and bullfrogs (*Rana* spp.), and 11.20 ppm ww in tertiary consumers such as herons, spotted gar, and channel catfish. Two of three mosquitofish samples collected in the WCA Project area had wet-weight concentrations of p,p'-DDE

which fell within the range reported for mosquitofish in Niethammer et al. (1984). The presence of a similar biomagnification profile within the WCA Project area, given the abundant evidence of past DDT-induced population declines of fish-eating birds across the country, would be significant. Concentrations of p,p'-DDE in red shiners were slightly higher in Bitter Creek than in Stinking Creek (Table 4). Contamination by p,p'-DDE did not appear confined to the project area. Red shiners taken from the upper Salt Fork had an average concentration of 0.75 ppm ww, which exceeds the 1984 national geometric mean. Concentrations of p,p'-DDE in fathead minnows were also higher than in red shiners from the same locations, which points to differences in feeding habits as the cause, since p,p'-DDE is very strongly sorbed to soils (U.S. EPA 1992).

### Toxaphene

Toxaphene is a pesticide used in emergency treatments of cotton and small grains where stocks of the chemical exist, but its registration has otherwise been cancelled. It is oncogenic and causes acute toxicity in aquatic organisms as well as chronic problems in wildlife (U.S. EPA 1990). Toxaphene has been shown to persist in soils and water under certain conditions, with documented half-times of 9 to 11 years. It also readily bioaccumulates in aquatic organisms, with BCFs of up to 52,000 in fathead minnows (Eisler and Jacknow 198

Toxaphene concentrations in 25 of the 26 small fish samples exceeded the 1984 NCBP geometric mean (0.14 ppm ww; Schmitt et al. 1990). 11 of the samples also exceeded the 1984 NCBP national maximum residue concentration (Schmitt et al. 1990). Furthermore, a study of fathead minnows found that after 150 days of exposure to 55 ng/L of toxaphene in water ( $5.5 \times 10^{-5}$  ppm), exposed fathead minnows had more fragile spines and were significantly smaller than control minnows (Mehrle and Mayer 1975). Using published BCFs as a rough guide, the two samples of fathead minnows collected from Stinking Creek indicate that they may have been living in water with toxaphene concentrations around  $7 \times 10^{-4}$  ppm, an order of magnitude higher than the concentration reported in Mehrle and Mayer (1975). In an acute toxicity test, Johnson and Julin (1980) reported a 96-hour LC50 value of 5.0  $\mu\text{g/L}$  (0.005 ppm) toxaphene for fathead minnows. This converts into a whole-body concentration of 260 ppm, well above the values obtained from the WCA Project. Based on this report, fathead minnows within the project area might bioaccumulate toxaphene without lethal consequences; however, concentrations of toxaphene in irrigation drainwater within the project area may be chronically rather than acutely toxic to fish. Thus, amounts of toxaphene which do not approach acutely toxic levels within the project area may still cause chronic toxicity and/or physiological problems not only to fathead minnows but also other fish and piscivorous predators. For example, the LD50 acute oral toxicity of toxaphene to sandhill cranes was as low as 100

ppm, with lower lethal dosages for smaller-sized birds (Eisler and Jacknow 1985). Sandhill cranes are numerous in Greer and Jackson Counties during their migrations, and are known to eat crayfish and surface-feeding forage fish such as mosquitofish and topminnows.

Red shiners collected from Bitter Creek and the lower Salt Fork had toxaphene concentrations about twice that in red shiners collected from Stinking Creek (Table 4). This observation, plus the fact that toxaphene concentrations in red shiners collected from the upper Salt Fork were equal to those in red shiners from Stinking Creek, appear to indicate that toxaphene contamination extends beyond the limits of the WCA Project area, up into the Salt Fork watershed. Based on two red shiner samples and one plains minnow sample, toxaphene contamination of the upper North Fork does not seem to be significant. As with dieldrin and p,p'-DDE, toxaphene concentrations tended to be higher in fathead minnows and plains minnows than in red shiners at sampling areas common to these species. Feeding biology is suggested as the probable cause.

With toxaphene concentrations as high as 35 ppm in forage fish collected from the WCA Project area, it is reasonable to assume that piscivorous birds are at risk of consuming sublethal doses of toxaphene by feeding on contaminated fish within the project area, with subsequent effects on survival and reproduction.

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#### SMALL FISH - ELEMENTS

Twenty-three of the small fish samples were analyzed for 19 potentially toxic elements (Table 2). No detectable concentrations of any of the following elements were found in more than one fish sample: beryllium, cadmium, molybdenum, and lead. Concentrations of the following elements did not appear to be highly elevated: boron (Hoffman et al. 1990, U.S. EPA 1986); chromium (U.S. EPA 1980b); mercury (Eisler 1987); manganese (U.S. EPA 1986); and nickel (Winger et al. 1990). Concentrations of aluminum, barium, iron, magnesium, strontium, and vanadium did not appear highly elevated (Table 5), but definite conclusions regarding these elements, especially vanadium, are hampered by the scarcity of relevant literature on toxicity in fishes (S. Finger and C. Schmitt, Midwest Science Center, Columbia, MO, pers.comm. 1994). Concentrations of the remaining four elements, arsenic, copper, selenium, and zinc, appeared to be elevated above normal background levels within tissues of fish collected in the project area (Table 6), and these are discussed below.

#### Arsenic

Arsenic concentrations in most samples (Table 6) exceeded the 85th percentile in a national survey (Schmitt and Brumbaugh 1990), and half exceeded the predator-protection level of 0.5 ppm wet weight ww proposed by Walsh et al. (1977). Within the latter group, most

of these elevated concentrations came from the upper as well as the lower regions of the Salt Fork, which indicates that the situation is not directly attributable to irrigation practices within the project area. However, almost all tissue residues were less than the biota protection level proposed by Eisler (1994). Therefore, any effects of arsenic concentrations on fish and wildlife in the project area are probably chronic and/or indirect.

#### Copper

Copper concentrations in most samples (Table 6) exceeded the 85th percentile in a national survey (Schmitt and Brumbaugh 1990). However, water samples collected within the project area indicate that copper concentrations in irrigation drainwater might not be high enough to cause significant damage to fish (U.S. EPA 1983).

#### Selenium

Selenium concentrations in 22 of 23 fish samples (Table 6) exceeded the predator protection level of 0.5 ppm ww recommended by Walsh et al. (1977). A biological effects threshold of 4  $\mu\text{g/g}$  (ppm dry weight [dw]) has been proposed for whole-body residues in freshwater fish to protect their health and reproductive success. Tissue damage and mortality begin to occur when concentrations reach 4 to 16 ppm dw (Lemly 1993). Selenium concentrations in 15 of the samples exceeded this threshold by as much as 3.1 ppm. However, Lemly's synopsis (1993) also indicated that certain forage fishes such as fathead minnows and mosquitofish may accumulate high concentrations of selenium without adverse effects. However, birds and other higher trophic level predators feeding on such fish could receive harmful doses of selenium due to bioconcentration of this potentially toxic element in fish tissue.

Lemly (1993) has proposed a dietary toxicity threshold for fish and wildlife of 3  $\mu\text{g/g}$  (dw), with a toxic effects threshold of 10  $\mu\text{g/g}$  in bird liver tissue. Selenium concentrations in 21 of 23 forage fish samples exceeded 3  $\mu\text{g/g}$ , which indicates potential poisoning of foraging species within the project area. Selenium concentrations in several fish samples also approached 10  $\mu\text{g/g}$ , which infers the possibility of sublethal effects in piscivorous birds. Elevated concentrations of selenium, which occur in southwestern Oklahoma, may be caused by weathering of selenium-laden soils rather than anthropogenic activities. However, irrigation return flows within the project area may contribute to this phenomenon by causing accelerated leaching of selenium salts from the soil (Lemly 1993, Lemly and Smith 1987) since the highest concentrations of selenium in the project area were found in fish collected from Bitter Creek and Stinking Creek (Table 2).

## Zinc

Zinc concentrations in all but one sample (Table 6) exceeded the national geometric mean (Schmitt and Brumbaugh 1990), but most concentrations were below the 85th percentile, and none appeared particularly toxic (Eisler 1993). Zinc-related risks to fish and wildlife in the project area are probably slight.

Red shiners were the only species collected at all sampling sites. The highest concentrations of elements in these fish were generally found in the upper North Fork (Table 7). There were no marked differences in elemental concentrations between red shiners collected from Stinking Creek and those collected from Bitter Creek, except for strontium. Aluminum and iron concentrations were considerably higher in red shiners collected from the lower Salt Fork than from the upper Salt Fork. Magnesium and manganese concentrations were also markedly higher in red shiners collected from the upper North Fork than in the lower North Fork. Arsenic concentrations were lowest in red shiners collected from Stinking Creek and Bitter Creek. Selenium was highest in red shiners collected from Bitter Creek and Stinking Creek, and the upper Salt Fork, which indicates that irrigation practices may indeed elevate concentrations of selenium. However, more definitive conclusions cannot be made because of the small number of data points and the ~~varied distribution of element concentrations.~~

## NATIVE CHANNEL CATFISH - ORGANOCHLORINES

Eleven native CCF, five from Bitter Creek and six from Stinking Creek, were analyzed individually for whole-body and fillet residues. Three OCs, dieldrin, toxaphene, and p,p'-DDE, were detected in all whole-body samples (Table 8). Other OCs were detected in varying frequencies in fish, ranging from no detected concentrations, to detected concentrations in less than half of the samples. The three commonly occurring OCs are discussed below.

### Dieldrin

As mentioned previously, dieldrin bioconcentrates readily in animal tissues. Bioconcentration factors for dieldrin in dorsal muscles of CCF ranged from 2,385 to 2,993 (U.S. EPA 1980a). Whole-body BCFs probably would be higher due to dieldrin's affinity for fatty tissue. Dieldrin concentrations in fillets in this study were generally lower than in corresponding whole-body samples (Table 8). Five of the CCF collected in this study had whole-body concentrations of dieldrin which exceeded the suggested predator protection level of 0.1 ppm ww (NAS 1973). There was no significant difference in CCF dieldrin concentrations between Stinking Creek and Bitter Creek (t-test:  $t = -0.4$ ,  $df = 9$ ,  $\alpha > 0.05$ ).

### DDE

All CCF samples collected in the WCA Project area had detectable concentrations of p,p'-DDE (Table 8). Fillets taken from native CCF generally exhibited concentrations of p,p'-DDE lower than those of whole-body CCF samples. This reflects DDE's tendency to concentrate in the liver, bile, and in fatty deposits, rather than in the axial muscles of fish from which fillets are taken. Wet-weight concentrations in all 11 CCF whole-body samples exceeded the 1984 national geometric mean (0.19 ppm ww, Schmitt et al. 1990) by up to 55 times. Even though larger CCF may not be frequently taken as prey, all 11 CCF samples had wet-weight concentrations of p,p'-DDE which exceeded the NAS (1973) 1.0 ppm ww total DDT predator protection standard. One CCF sample collected in the WCA Project area also had a p,p'-DDE concentration of 11 ppm ww, which equals the concentration found in the Niethammer et al. (1984) study. This suggests that a serious biomagnification profile of DDT metabolites may be occurring within the WCA Project area. These concentrations also indicate either a recent, illegal use of DDT or an older, persistent source. As with dieldrin, there was no significant difference in CCF p,p'-DDE concentrations between Stinking Creek and Bitter Creek (t-test:  $t = 0.18$ ,  $df = 9$ ,  $\alpha > 0.05$ ).

### Toxaphene

All CCF samples collected within the project area had detectable concentrations of toxaphene (Table 8). Toxaphene is readily bioconcentrated in aquatic organisms, with BCFs of up to 22,000 in adult CCF (Eisler and Jacknow 1985). The U.S. Food and Drug Administration's action level for toxaphene in fish tissue to be consumed by humans is 5.0 ppm ww (U.S. DHHS and U.S. EPA 1987). Wet-weight concentrations in 2 of 11 CCF fillet samples exceeded this level. All 11 whole-body CCF samples also exceeded the 1984 NCBP national geometric mean of 0.14 ppm ww for whole-body concentrations of toxaphene in fish (Schmitt et al. 1990), by a factor of at least 10. Back-calculation of water concentrations of toxaphene in the project area using published CCF BCFs and toxaphene concentrations in native CCF would yield a theoretical value of about 0.0012 ppm. In acute toxicity tests, Johnson and Julin (1980) found a 96-hour  $LC_{50}$  value of 0.8  $\mu\text{g/L}$  (0.0008 ppm) toxaphene for CCF. Using these values, CCF would hypothetically be harmed by waterborne concentrations of toxaphene present in the project area. As with dieldrin and p,p'-DDE, there was no significant difference in CCF toxaphene concentrations between Stinking Creek and Bitter Creek (t-test:  $t = -0.1$ ,  $df = 9$ ,  $\alpha > 0.05$ ).

### CAGED CHANNEL CATFISH - ORGANOCHLORINES

Six cages of CCF were set out as described above, during the summer of 1992. During the course of the exposure period, the cages

located in the upper North Fork, upper Salt Fork, and lower Salt Fork were buried in shifting sand or stolen, and all fish were lost. Thus, composite samples were obtained only from three sites: the lower North Fork, Bitter Creek, and Stinking Creek. The number of CCF in each cage was also diminished, presumably due to starvation, toxicity, and/or cannibalism, since skeletons were found in each cage. Results were similar to those of native CCF in that significant concentrations were detected in caged CCF for three OCs, dieldrin, p,p'-DDE, and toxaphene.

### Dieldrin

Dieldrin concentrations in caged CCF from Bitter Creek and Stinking Creek were twice as high as in native CCF collected from each of these respective areas (Table 8). This suggests that dieldrin bioconcentration in CCF is perhaps largely a function of direct uptake from the water, since caged CCF were confined to each creek and had access only to pelleted fish food and detritus drifting into the cages. Native CCF were able to forage more efficiently for natural food sources and to move into the comparatively unpolluted Salt Fork and North Fork. The data also suggests a possible, localized release of dieldrin either during or immediately prior to the caged CCF study. Dieldrin concentrations in all caged CCF were higher than the suggested predator protection level of 0.1 ppm ww (NAS 1973). Dieldrin concentrations in caged CCF were also similar between Bitter Creek and Stinking Creek.

### DDE

Average concentrations of p,p'-DDE in native CCF collected in Stinking Creek and Bitter Creek were about three and five times higher, respectively, than in caged CCF (Table 8). Because the primary food source of the caged CCF was pellet feed rather than potentially contaminated natural forage, these data along with literature (e.g., Johnson and Finley, 1980) suggest that CCF bioaccumulate p,p'-DDE more through diet than through direct absorption from the water medium. CCF concentrations of p,p'-DDE were slightly higher in Stinking Creek than in Bitter Creek.

### Toxaphene

Toxaphene concentrations in caged CCF kept in Stinking and Bitter Creeks were about three times higher than in native CCF taken from each area (Table 8). This suggests that uptake of toxaphene, like that of dieldrin, is not as dependent on dietary habits as it is on exposure to the water medium. As with p,p'-DDE, toxaphene concentrations in caged CCF were slightly higher in Stinking Creek than in Bitter Creek. Using the published BCF of 22,000 (Eisler and Jacknow 1985) as a guide, caged catfish in Stinking Creek theoretically would have been exposed to a (constant) water concentration of about 4  $\mu\text{g/L}$ . While this concentration is less than the concentration reported for acute toxicity (13.1  $\mu\text{g/L}$ ,

Johnson and Finley, 1980), a 49-day exposure to such a concentration might contribute to elevated stress and subsequent death of caged catfish. Since dieldrin, p,p'-DDE, and toxaphene concentrations in caged CCF from the lower North Fork were lower than in Stinking Creek, irrigation drainwater emptying into Bitter Creek and Stinking Creek might appear to be the source of these OCs. However, more data would be needed to form a more definitive picture of the distribution of toxaphene and other OCs within and around the project area.

The 1989 pre-reconnaissance survey also indicated the presence of dieldrin, toxaphene, and p,p'-DDE in the project area. This suggests that contamination of the natural resources in the area by tainted drainwater is an ongoing problem. Exposure and leaching of OCs from previously buried, contaminated soil by heavy summer rains may also be a factor. Although data in the 1989 survey are limited, there are indications that contaminant levels may be rising, not falling, in native fish living in downstream reaches of the project area, despite restrictions placed on the use of these three OCs. Whether these levels may exhibit cyclic or linear trends cannot be determined from the available data.

#### WATER - ELEMENTS

Element concentrations in water samples were below detection limits ~~in most or all samples for the following elements: beryllium,~~ cadmium, chromium, lead, mercury, and nickel. Concentrations of the following elements generally were not elevated: arsenic, barium, boron, iron, and magnesium (Flora et al. 1984); copper and zinc (U.S. EPA 1991); manganese and selenium (Lillebo et al., 1986); and molybdenum (Eisler 1989). Concentrations of three elements were elevated: aluminum, strontium, and vanadium (Table 9). These three elements are discussed below.

##### Aluminum

An upper limit of 250 ppb aluminum in water was suggested for protection of aquatic life (McKee and Wolf 1963). Six of the 12 first-round samples and 5 second-round samples exceeded this concentration. Generally, samples with high concentrations were collected during the second round, when discharge levels were lower than in the first round (Table 9). The decreased volume of water at this time may have contributed to the elevated concentrations, which also occurred in water taken from above as well as below the project area. Given the small number of samples taken, no definitive conclusions can be drawn other than the source of aluminum appears not to be attributable solely to irrigation practices. The highest concentrations of aluminum were found in the lower Salt Fork; concentrations were also slightly higher in Stinking Creek than in Bitter Creek.

### Strontium

Strontium concentrations in water samples were elevated compared to values contained in U.S. Geological Survey (USGS) records (Hem 1985). However, the cause of these concentrations could be geographical, because strontium concentrations in other, relatively unimpacted areas of the southwest U.S. are comparable with those in the project area. Strontium is also an important contributor to water hardness in such regions (U.S. EPA 1986). The impacts of strontium on fish and wildlife resources are also poorly understood, since compounds, rather than the pure form, of strontium appear to be toxicologically more significant. As with aluminum, strontium concentrations were higher among the second round samples, during a period of low water flows. The highest concentrations were found in the upper Salt Fork, which is probably attributable to background concentrations since the anthropogenic sources of strontium are specialized industrial operations, which generally do not exist along the sampled area of the upper Salt Fork. Strontium concentrations were also slightly higher in Stinking Creek than in Bitter Creek.

### Vanadium

Vanadium is relatively stable in water in three oxidation states (+3 to +5), and is deposited primarily as fallout from air pollution (Jenkins 1981). Compared to USGS records of median concentrations of vanadium in large North American rivers (Jenkins 1981), all samples collected in the project area had elevated concentrations. These concentrations were higher in the lower reaches of the Salt Fork and the North Fork, and especially in Bitter and Stinking Creeks. However, vanadium bioconcentration and bioaccumulation in birds and fish are thought to be limited (Jenkins 1981); the low concentrations of vanadium present in all fish samples support this theory. Vanadium contamination of the Lugert Altus watershed appears to be due largely to emissions from road and air traffic along the highways and around the Altus Air Force Base, and not solely as a result of irrigation practices. The higher concentrations of vanadium in the first round of sampling, during high water flows, suggests precipitation and runoff of vanadium into water courses, when airborne particles of this element may have come into contact with droplets of water during rainstorms.

### SEDIMENTS - ORGANOCHLORINES

Only one OC, p,p'-DDE, was detected in a large number of sediment samples (14 of 16 samples). The average concentration of p,p'-DDE was 0.07 and 0.17 ppm dw for Stinking Creek and Bitter Creek, respectively. The Effects Range - Median (ER-M) value for p,p'-DDE, proposed by Long and Morgan (1990), above which effects were routinely or always observed in a variety of bioassays and other studies, was 0.015 ppm. All but two of the WCA Project samples had

p,p'-DDE concentrations which exceeded the ER-M value by up to 23 times. Furthermore, Niethammer et al. (1984) reported an average value of 0.029 ppm ww total DDE in sediment from a Louisiana lake suspected of DDT contamination; the averaged wet-weight concentration of p,p'-DDE alone in sediment samples collected in the WCA Project area was 0.078 ppm. These comparisons indicate that p,p'-DDE is a definite and well-established hazard to natural resources within the project area. The samples collected from the Salt Fork and the North Fork had non-detectable concentrations of p,p'-DDE, which suggest that the source of DDT metabolites in the watershed is located within the project area. Concentrations of p,p'-DDE were significantly higher in Bitter Creek than in Stinking Creek (t-test:  $t = -2.61$ ,  $df = 12$ ,  $\alpha = 0.05$ ).

#### SEDIMENTS - ELEMENTS

Concentrations of the following elements did not appear highly elevated (Table 10): aluminum (U.S. EPA 1988); barium (soils, Brown et al. 1983); beryllium, boron, and vanadium (Jenkins 1981); magnesium (U.S. EPA 1986); manganese (Beyer 1990); molybdenum (Eisler 1989); and arsenic, cadmium, chromium, copper, mercury, nickel, lead, and zinc (Long and Morgan 1990). Iron and strontium, while elevated, appear to be related to water quality and hardness (U.S. EPA 1986). Selenium concentrations ranged from 0.51 to 2.2 ppm, which fell within the range of 0 to 3.6 ppm reported in a previous hydrogeochemical study conducted in the area (Union Carbide 1978). However, no sample concentrations of selenium exceeded the value of 4 ppm dw proposed as the level of concern for impacts on fish and waterfowl (Lemly and Smith 1987). In general, there were no significant differences in element concentrations between creeks; however, concentrations of several elements were much higher in the North Fork than in the Salt Fork. The very low clay and silt content of the Salt Fork sediment sample is the probable reason for this discrepancy, since sediments with higher organic content (i.e., higher silt and clay percentages) tend to retain contaminants more readily than sandy sediments.

#### SPMDS - ORGANOCHLORINES

Due to vandalism, high water, siltation, and weathering, SPMDS were lost or rendered unusable at each of the following locations during the first round: all six from the upper North Fork and three each from the lower North Fork, upper Salt Fork, and lower Salt Fork. All SPMDS were recovered from the Stinking Creek and Bitter Creek sites. During the second round, the following SPMDS were lost or rendered unusable: three each from the lower North Fork, upper Salt Fork, lower Salt Fork, and Bitter Creek; and all six from Stinking Creek. OC Concentrations were reported in wet weight. At the time of this study, it was not possible to calculate dry weight concentrations. As a result, comparisons of OC concentrations between SPMDS and fish would not be meaningful. SPMD data are

included in this report primarily to qualitatively assess presence and distribution of OCs within the project area.

No detectable concentrations were found for the following OCs: HCB, PCB-total,  $\alpha$ -BHC,  $\beta$ -BHC,  $\sigma$ -BHC,  $\sigma$ -chlordane, mirex, or oxychlordane. Less than twenty percent of samples had detectable concentrations for the following OCs: heptachlor epoxide, o,p'-DDD, o,p'-DDT, and trans-nonachlor. The remaining OCs are presented in Table 11. P,p'-DDE and toxaphene were the most commonly occurring OCs. The highest concentrations recorded for each of these OCs generally occurred in Bitter Creek and Stinking Creek, although high concentrations of toxaphene were also found in the lower North Fork. Concentrations of OCs were greater during the first round of sampling in both the lower North Fork and the lower Salt Fork, while they remained relatively consistent in Bitter Creek and Stinking Creek. OC concentrations were also higher in the lower reaches than in the upper reaches of the Salt Fork and the North Fork, and slightly higher in Bitter Creek than in Stinking Creek. As a result, the presence of OCs in the watershed appears to be linked to irrigation practices within the project area. The presence of toxaphene in the first round of sampling on the upper Salt Fork may have been caused by recent surface runoff from agricultural operations in that area, especially since no toxaphene was detected in the area during the ~~second, drier round of sampling.~~ SPMDs also appeared to be a fairly sensitive indicator of the presence of a wide variety of DDT metabolites in water. A possible reason for this may be that, unlike fish, SPMDs do not metabolize DDT metabolites once these (and other) OCs are picked up from the water.

SPMDs were included in this study to corroborate the uptake of OC contaminants in fish. Their limited success was due largely to mechanical and logistical problems. Losses due to vandalism, fluctuating water levels, and shifting substrates could be alleviated by altering the design. The fencing stakes used in this study could be shortened to lower the profile of the copper pipes. This would render them less visible to passersby and minimize torsional forces exerted by high water flows. Placing the SPMDs in more remote sites, using available debris and vegetation for camouflage, would decrease the chances of unwanted discovery. Using larger-diameter pipe could alleviate debris accumulation within each pipe and ease the subsequent restriction of water flow over SPMDs. Finally, bottom-mounted SPMD assemblies probably were not ideal for use in the project area, where river substrates were composed of fine sand which was easily shifted by river currents. This problem was also encountered during deployment of the bottom-resting fish cages, where some caged catfish were smothered by shifting sand. This type of design is probably more suited to use in rivers and lakes with slow, stable water flows or in rivers with solid, non-shifting substrates.

## CONCLUSIONS

Data collected in this study confirm the suspicions of the 1989 pre-reconnaissance survey, that fish in the WCA Project area are highly contaminated with a variety of OC pesticides, including dieldrin, DDT metabolites, and toxaphene. Although no information is available for terrestrial resources, it is reasonable to assume that any trust resources which utilize aquatic biota present in the watershed are affected by these OCs. Further studies should be conducted to assess potential effects of OC residues on piscivorous and insectivorous birds, fish recruitment, and aquatic insect production.

Data in this study indicate that OC contamination within the project area is concentrated in Bitter Creek and Stinking Creek. However, the presence of OCs, especially toxaphene, in upper reaches of rivers such as the Salt Fork indicate that agricultural practices upstream of the project area may also contribute to the OC burden found in fish collected in the vicinity. This contribution could be either intentional (recent, deliberate use of OCs) or unintentional (leaching of previously-treated soils). Soil concentrations of most DDT metabolites begin decreasing after application, with the exception of p,p'-DDE. In one study, soil concentrations of p,p'-DDE increased over the first few years after an application, then leveled off or decreased (Beyer and Gish 1980). ~~Because of the non-linear nature of p,p'-DDE degradation,~~ it is difficult to determine the age of DDE residues in soils or sediments based on ratios of DDT and DDE concentrations. As a result, follow-up studies should be conducted to further assess changes over time of concentrations of DDE and other OCs in the W. C. Austin project area. Further work should also be done to pinpoint the sources of these OCs.

The problem of selenium seems to be related to naturally elevated levels in soils within the project area. Irrigation practices probably exacerbate the situation by accelerating the leaching of selenium from exposed soils. Whether this occurs throughout the project area cannot be determined from the limited data, however. The highest levels of selenium found within the project area in the Union Carbide study (1978) appear to be concentrated around Bitter and Stinking Creeks. However, a dedicated collection and analysis of a project-wide array of sediment samples would help determine the extent of the contribution of irrigation practices to the selenium problem.

The choice of sampling media in this study was geared towards obtaining a general overview of the pathway of contaminants through a "limited" aquatic ecosystem. Contaminants were examined in passage through water (initial medium), sediment (long-term storage medium), native small fish (lower-level food chain item), and predatory gamefish (higher-level food chain item). Our data indicate a general biomagnification profile throughout this

ecosystem, with concentrations of some organic contaminants reaching potentially harmful levels within each sampling medium. Extrapolation of this biomagnification trend suggests that organisms higher up on the food chain (for example, piscivorous birds and humans) would also be exposed to potentially harmful concentrations of these contaminants. Furthermore, the spatial distribution of organochlorine concentrations appears to suggest that water flowing into Bitter Creek and Stinking Creek is the primary source of pesticide contamination in the study area. Spatial distribution of inorganic contamination of the study area was not as well-defined and was probably due in greater part to non-agricultural sources and natural background concentrations within the area's soils.

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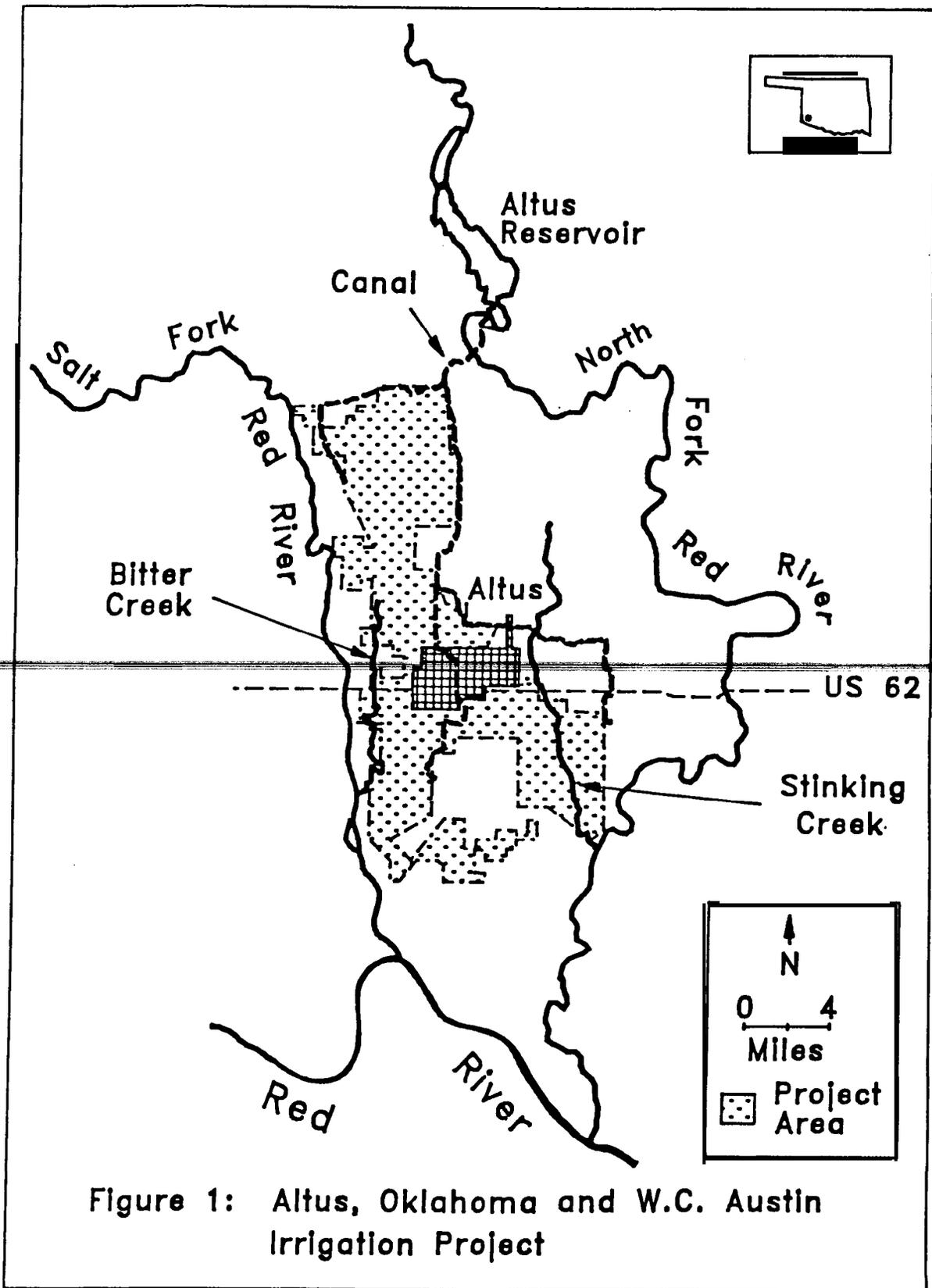


Figure 1: Altus, Oklahoma and W.C. Austin Irrigation Project

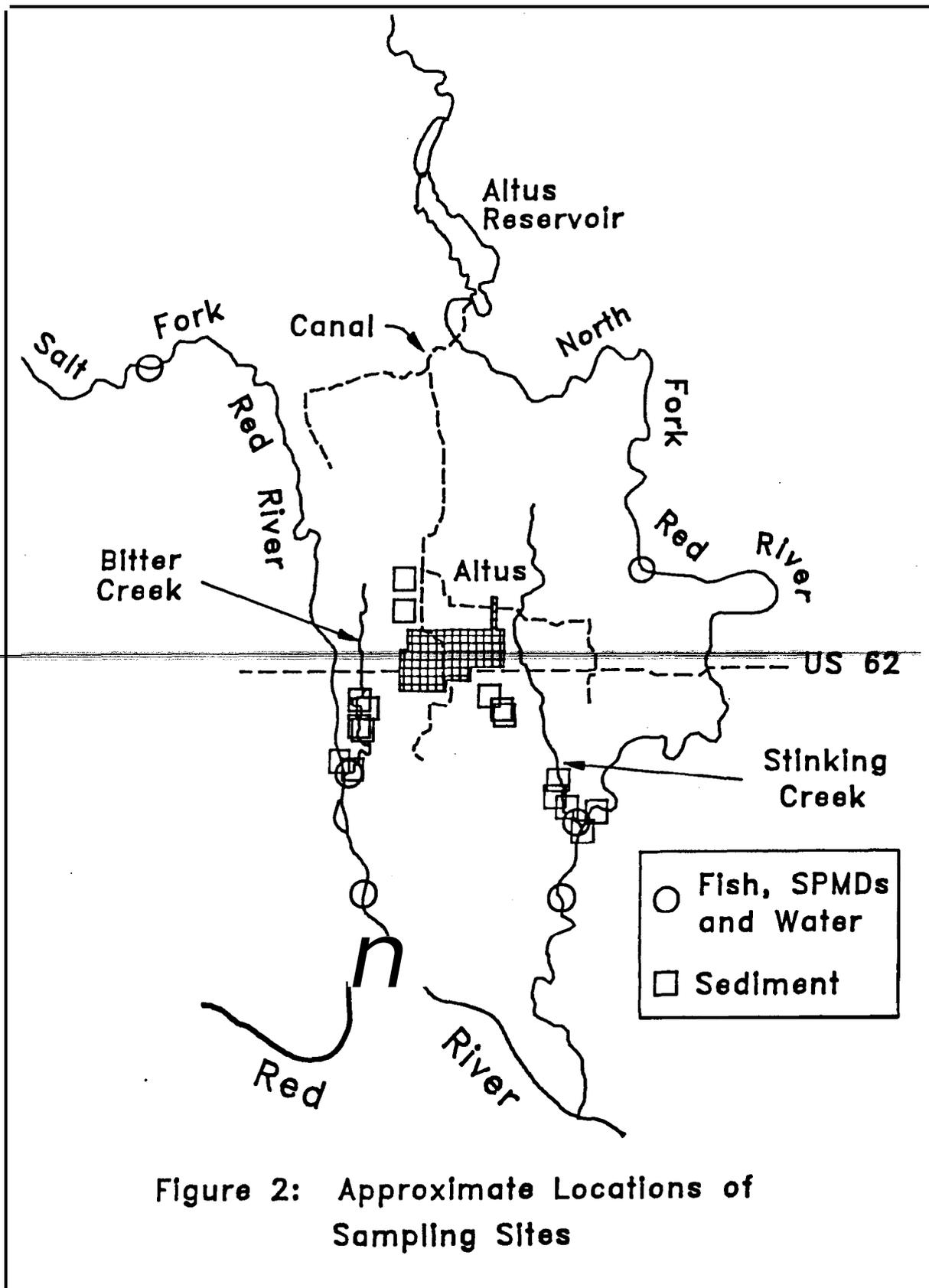


Figure 2: Approximate Locations of Sampling Sites

TABLE 1: Approximate acreages of wetlands at selected sites within the  
W.C. Austin Project area, 1992

Site(1)	Total Acreage	Wetland Acreage	% Acreage in Wetlands	% Wetlands Riverine(2)
BC/LSF	4600	930	20	99
SC/LNF	5300	650	12	96

(1) BC/LSF = Confluence of Bitter Creek and Lower Salt Fork;  
SC/LNF = Confluence of Stinking Creek and Lower North Fork;  
values are based on a corridor one mile wide on either side of each river,  
two miles upstream and two miles downstream of the confluence with  
the corresponding creek, plus a similar corridor two miles up each  
creek from their respective confluences

(2) Includes palustrine wetlands connected to riverine habitat

TABLE 2: List of organochlorines and elements included for analysis

a- Benzene Hexachloride (alpha BHC)	Aluminum
beta BHC	Arsenic
gamma BHC	Barium
alpha Chlordane	Beryllium
gamma Chlordane	Boron
Dieldrin	Cadmium
Endrin	Chromium
Heptachlor epoxide	Copper
Hexachlorobenzene (HCB)	Iron
Mirex	Lead
o,p'-DDD	Magnesium
o,p'-DDE	Manganese
o,p'-DDT	Mercury
Oxychlordane	Molybdenum
Polychlorinated Biphenyls (PCB-total)	Nickel
p,p'-DDD	Selenium
p,p'-DDE	Strontium
p,p'-DDT	Vanadium
Toxaphene	Zinc
trans - Nonachlor	

TABLE 3: Concentrations of dieldrin, p,p'-DDE, and toxaphene (ppm dry wt) in small fish collected from various locations within the WC Austin Project area, 1992

SPECIES	SITE	NO.(1)	Dieldrin	p,p'-DDE	toxaphene
Fathead Minnow	Stinking Creek	20	0.26	18	34
Fathead Minnow	Stinking Creek	20	0.35	20	35
Mosquitofish	Lower North Fork	86	0.14	2.6	5.8
Mosquitofish	Lower Salt Fork	169	0.18	6.5	5.7
Mosquitofish	Stinking Creek	143	0.16	7.0	7.0
Plains Killifish	Upper Salt Fork	60	< 0.04	0.40	0.55
Plains Killifish	Upper Salt Fork	100	< 0.04	0.71	0.62
Plains Killifish	Upper Salt Fork	100	< 0.04	0.58	0.97
Plains Minnow	Bitter Creek	9	0.85	8.14	41
Plains Minnow	Upper North Fork	23	< 0.04	0.30	0.90
Red Shiner	Bitter Creek	200	0.70	11	22
Red Shiner	Bitter Creek	94	0.21	8.5	7.8
Red Shiner	Bitter Creek	220	0.43	6.8	7.5
Red Shiner	Lower North Fork	223	0.20	9.0	8.1
Red Shiner	Lower Salt Fork	200	0.30	6.7	13
Red Shiner	Lower Salt Fork	140	0.76	5.8	20
Red Shiner	Lower Salt Fork	200	0.31	7.3	13
Red Shiner	Lower Salt Fork	200	0.37	8.7	16
Red Shiner	Lower Salt Fork	165	0.71	6.7	20
Red Shiner	Stinking Creek	80	0.05	5.1	5.8
Red Shiner	Stinking Creek	80	0.07	9.0	7.2
Red Shiner	Upper North Fork	170	< 0.04	0.22	< 0.42
Red Shiner	Upper North Fork	140	< 0.04	0.24	< 0.44
Red Shiner	Upper Salt Fork	115	0.07	2.7	9.0
Red Shiner	Upper Salt Fork	120	0.07	2.3	6.9
Red Shiner	Upper Salt Fork	135	0.10	3.5	11

(1) Samples were whole-body composites consisting of the number shown

TABLE 4: Concentrations of dieldrin, p,p'-DDE, and toxaphene (ppm dry wt) in red shiners collected from various locations within the W.C. Austin Project area, 1992

SITE	NO.(1)	Dieldrin	p,p'-DDE	toxaphene
Bitter Creek	200	0.70	11	22
Bitter Creek	94	0.21	8.5	7.8
Bitter Creek	220	0.43	6.8	7.5
average		0.45	8.7	13
Lower North Fork	223	0.20	3.0	8.1
Lower Salt Fork	200	0.30	6.7	13
Lower Salt Fork	140	0.76	5.8	20
Lower Salt Fork	200	0.31	7.3	13
Lower Salt Fork	200	0.37	8.7	16
Lower Salt Fork	165	0.71	6.7	20
average		0.49	7.1	16
Stinking Creek	80	0.07	9.0	7.2
Stinking Creek	80	0.05	5.7	5.8
average		0.06	7.1	6.5
Upper North Fork	170	< 0.04	0.24	< 0.44
Upper North Fork	140	< 0.04	0.22	< 0.42
average			0.23	
Upper Salt Fork	115	0.07	2.7	9.0
Upper Salt Fork	120	0.07	2.3	6.9
Upper Salt Fork	135	0.10	3.5	11
average		0.08	2.8	8.9

(1) Samples were whole-body composites consisting of the number shown

TABLE 5: Concentrations of five elements (ppm dry wt.) in small-fish samples collected at various locations within the W.C. Austin Project area, 1992

SPECIES	SITE	ANALYTE					V
		Al	Ba	Fe	Mg	Sr	
Fathead Minnow	Stinking Creek	2400	25	1800	1800	160	9.7
Fathead Minnow	Stinking Creek	860	21	720	1400	160	6.3
Mosquitofish	Lower North Fork	430	20	330	1400	130	2.8
Mosquitofish	Lower Salt Fork	260	14	210	1400	140	1.4
Plains Killifish	Upper Salt Fork	230	17	350	1478	110	2.2
Plains Killifish	Upper Salt Fork	670	21	810	1600	100	3.3
Plains Killifish	Upper Salt Fork	340	18	450	1500	110	2.3
Plains Minnow	Upper North Fork	11	3.6	63	1000	51	0.67
Red Shiner	Bitter Creek	39	2.6	65	1200	140	1.5
Red Shiner	Bitter Creek	210	4.6	180	1300	140	2.1
Red Shiner	Lower North Fork	740	18	640	1600	140	5.6
Red Shiner	Lower Salt Fork	540	15	440	1700	160	3.5
Red Shiner	Lower Salt Fork	670	14	590	1200	120	8.1
Red Shiner	Lower Salt Fork	720	15	560	1700	170	4.0
Red Shiner	Lower Salt Fork	1700	17	1300	1600	130	11
Red Shiner	Lower Salt Fork	1600	18	1100	1900	180	6.4
Red Shiner	Stinking Creek	70	3.7	89	1400	240	2.2
Red Shiner	Upper North Fork	1100	27	910	2500	190	7.5
Red Shiner	Upper North Fork	1100	28	950	2300	160	7.7
Red Shiner	Upper Salt Fork	370	11	510	1400	140	4.7
Red Shiner	Upper Salt Fork	400	11	520	1400	140	5.1
Red Shiner	Upper Salt Fork	210	12	340	1400	160	4.7

TABLE 6: Concentrations of selected elements (ppm dry wt) in small-fish samples collected at various locations within the W.C. Austin Project area, 1992

SPECIES	SITE	ANALYTE			
		As	Cu	Se	Zn
Fathead Minnow	Stinking Creek	2.4	4.1	6.2	88
Fathead Minnow	Stinking Creek	1.4	4.5	7.1	82
Mosquitofish	Lower North Fork	1.7	7.3	3.9	110
Mosquitofish	Lower Salt Fork	2.2	6.7	5.8	120
Plains Killifish	Upper Salt Fork	3.6	6.5	5.4	100
Plains Killifish	Upper Salt Fork	2.9	7.4	5.9	110
Plains Killifish	Upper Salt Fork	4.9	11	5.8	110
Plains Minnow	Upper North Fork	0.74	1.7	1.0	78
Red Shiner	Bitter Creek	1.2	3.3	4.8	140
Red Shiner	Bitter Creek	1.1	4.0	6.1	140
Red Shiner	Lower North Fork	2.0	7.7	3.4	120
Red Shiner	Lower Salt Fork	1.6	4.3	5.1	160
Red Shiner	Lower Salt Fork	5.6	3.7	3.6	73
Red Shiner	Lower Salt Fork	1.5	5.1	4.8	170
Red Shiner	Lower Salt Fork	3.8	4.2	3.6	90
Red Shiner	Lower Salt Fork	2.5	4.5	3.6	170
Red Shiner	Stinking Creek	0.86	3.5	6.8	180
Red Shiner	Upper North Fork	2.0	6.1	3.0	150
Red Shiner	Upper North Fork	2.2	5.3	2.5	140
Red Shiner	Upper Salt Fork	3.0	4.0	5.4	120
Red Shiner	Upper Salt Fork	3.2	3.6	4.8	110
Red Shiner	Upper Salt Fork	1.7	3.8	4.9	130

TABLE 7: Concentrations of elements (ppm dry wt) in red shiners collected from various locations within the W.C. Austin Project area, 1992

SITE	ANALYTE									
	Al	As	B	Be	Be	Cd	cr	cu	Fe	Hg
Upper Salt Fork	370	3.0	1.7	11	< 0.06	< 0.23	2.0	4.0	510	0.19
Upper Salt Fork	400	3.2	2.1	11	< 0.08	< 0.23	1.6	3.6	520	0.16
Upper Salt Fork	210	1.7	1.5	12	< 0.08	< 0.22	1.9	3.6	340	0.16
<b>average</b>	<b>327</b>	<b>2.64</b>	<b>1.70</b>	<b>11.5</b>	<b>&lt; 0.06</b>	<b>&lt; 0.23</b>	<b>1.91</b>	<b>3.76</b>	<b>456.7</b>	<b>0.16</b>
Bitter Creek	39	1.2	< 1.3	2.6	< 0.07	< 0.20	1.1	3.3	65	0.15
Bitter Creek	210	1.1	2.1	4.6	< 0.07	< 0.21	1.3	4.0	160	0.11
<b>average</b>	<b>125</b>	<b>1.1</b>	<b>&lt; 1.7</b>	<b>3.6</b>	<b>&lt; 0.07</b>	<b>&lt; 0.21</b>	<b>1.22</b>	<b>3.83</b>	<b>122.5</b>	<b>0.13</b>
Lower Salt Fork	<b>540</b>	1.6	2.4	15	< 0.08	< 0.23	<b>1.9</b>	4.3	440	<b>0.19</b>
Lower Salt Fork	<b>670</b>	5.6	1.8	14	< 0.07	< 0.21	1.6	3.7	<b>590</b>	0.08
Lower Salt Fork	<b>720</b>	1.5	2.0	15	< 0.08	< 0.23	2.0	5.1	560	0.16
Lower Salt Fork	<b>1700</b>	3.0	3.2	17	< 0.07	< 0.21	2.7	4.2	<b>1300</b>	0.11
Lower Salt Fork	<b>1600</b>	2.5	4.1	16	< 0.07	< 0.22	2.7	4.5	<b>1100</b>	0.16
<b>average</b>	<b>1046</b>	<b>3.0</b>	<b>2.9</b>	<b>16</b>	<b>&lt; 0.07</b>	<b>&lt; 0.22</b>	<b>2.16</b>	<b>4.34</b>	<b>798</b>	<b>0.14</b>
Upper North Fork	<b>1100</b>	2.0	3.7	27	4 0.08	< 0.26	2.6	6.1	<b>910</b>	<b>0.21</b>
Upper North Fork	<b>1100</b>	2.2	3.7	28	< 0.06	< 0.24	2.5	5.3	<b>950</b>	<b>0.20</b>
<b>average</b>	<b>1100</b>	<b>2.11</b>	<b>3.74</b>	<b>27.6</b>	<b>&lt; 0.08</b>	<b>&lt; 0.25</b>	<b>2.55</b>	<b>5.71</b>	<b>930</b>	<b>0.2</b>
Stinking Creek	<b>70</b>	0.86	2.2	3.7	< 0.07	< 0.22	1.5	a.5	89	<b>0.23</b>
Lower North Fork	<b>740</b>	2.0	<b>2.1</b>	<b>18</b>	< 0.08	< 0.26	1.9	7.7	640	<b>0.12</b>
		<b>Mg</b>	<b>Mn</b>	<b>Mo</b>	<b>Ni</b>	<b>Pb</b>	<b>se</b>	<b>Sr</b>	<b>V</b>	<b>Zn</b>
Upper Salt Fork	<b>1400</b>	42	< 1.5	0.86	< <b>1.9</b>	5.4	140	4.7	<b>120</b>	
Upper Salt Fork	1400	u	< 1.5	0.63	< <b>1.9</b>	4.6	140	5.1	110	
Upper Salt Fork	1400	51	< 1.5	1.3	< 1.8	4.9	160	4.7	130	
<b>average</b>	<b>1400</b>	<b>45.0</b>	<b>&lt; 1.50</b>	<b>0.91</b>	<b>&lt; 1.9</b>	<b>5.00</b>	<b>147</b>	<b>4.82</b>	<b>120</b>	
Biker Creek	<b>1200</b>	13	< 1.3	< 0.40	< 1.7	4.6	140	1.5	<b>140</b>	
Bitter Creek	<b>1300</b>	17	< 1.4	< 0.43	< 1.6	6.1	140	2.1	140	
<b>average</b>	<b>1250</b>	<b>14.5</b>	<b>&lt; 1.38</b>	<b>&lt; 0.42</b>	<b>&lt; 1.73</b>	<b>5.45</b>	<b>140</b>	<b>1.8</b>	<b>139.9</b>	
Lower Salt Fork	1700	U	< 1.6	0.93	< 1.9	5.1	160	3.5	160	
Lower Salt Fork	1200	43	< 1.4	1.0	< 1.7	3.8	120	8.1	73	
Lower Salt Fork	1700	u	< 1.6	0.05	< 1.9	4.8	170	4.0	170	
Lower Salt Fork	1600	52	< 1.4	1.4	< 1.8	3.6	130	11	<b>90</b>	
Lower Salt Fork	<b>1900</b>	46	< 1.5	1.4	< 1.8	3.6	180	6.4	170	
<b>average</b>	<b>1620</b>	<b>48.1</b>	<b>&lt; 1.48</b>	<b>1.13</b>	<b>&lt; 1.85</b>	<b>4.13</b>	<b>152</b>	<b>6.59</b>	<b>132.5</b>	
Upper North Fork	2500	93	< 1.8	<b>1.7</b>	< 2.2	3.0	<b>190</b>	7.5	150	
Upper North Fork	2300	97	< 1.6	1.7	< 2.0	2.5	160	7.7	<b>140</b>	
<b>average</b>	<b>2400</b>	<b>94.8</b>	<b>&lt; 1.69</b>	<b>1.73</b>	<b>&lt; 2.11</b>	<b>2.75</b>	<b>175</b>	<b>7.57</b>	<b>145.1</b>	
Stinking Creek	1400	<b>19</b>	< 1.5	< 0.45	< <b>1.9</b>	6.8	240	2.2	160	
Lower North Fork	1600	41	< 1.8	0.89	< 2.2	3.4	140	5.8	120	

TABLE 8: Averages and ranges of selected organochlorine concentrations (ppm dry wt) in channel catfish (CCF) collected from the W.C. Austin Project area, 1992

MATRIX	SITE	No. of samples (1)	Dieldrin	p,p'-DDE	toxaphene
Caged CCF	Stinking Creek	2 C	1.1	6.7	87
			1.1	6.5 - 6.8	83 - 90
Caged CCF	Bitter Creek	2 C	1.3	3.8	70
			0.93 - 1.6	2.7 - 4.9	55 - 85
Caged CCF	Lower North Fork	2 C	0.16	0.59	7.6
			0.15 - 0.17	0.49 - 0.68	6.5 - 8.6
Wild CCF	Stinking Creek	6 S	0.32	19	30
			0.10 - 0.71	10 - 37	6.6 - 62
Wild CCF	Bitter Creek	5 S	0.57	20	24
			0.09 - 1.1	8.1 - 35	7.6 - 37
Fillets of CCF	Stinking Creek	6 S	< 0.13	9.2	10
			< 0.06 - 0.34	3.4 - 17	2.6 - 24
Fillets of CCF	Bitter Creek	5 S	0.30	13	15
			8.5	0.1 - 0.57	-

(1) C = composite, S = single fish

TABLE 9: Concentrations of selected elements (ppb) in wafer collected from various locations around the W.C. Austin Project area, 1992

Site	Discharge(l)	Al	As	B	Ba	Fe	Mg	Mn	Sr	V
Upper Salt Fork, 1st Round	434	97	3.0	220	54	34	34000	3.0	1300	9.0
Upper Salt Fork, 2nd Round	6	290	7.0	510	36	< 22	120000	83	5500	< 4.4
Stinking Creek, 1st Round	- -	67	5.0	600	120	27	59000	11	1500	14
Stinking Creek, 2nd Round	- -	440	8.0	450	43	110	120000	25	3700	13
Lower Salt Fork, 1st Round	1280	540	4.0	350	92	320	510m	9.0	1700	14
Lower Salt Fork, 2nd Round	170	270	8.0	380	92	29	87000	5.0	2800	9.0
Upper North Fork, 1st Round	2060	17	5.0	250	110	31	36000	3.0	1400	9.0
Upper North Fork, 2nd Round	17	270	6.0	500	110	140	92000	17	2700	< 4.4
Bitter Creek, 1st Round	- -	74	5.0	490	160	25	64000	26	1800	15
Bitter Creek, 2nd Round	- -	290	7.0	370	77	29	99000	6.0	3100	10
Lower North Fork, 1st Round	2760	92	4.0	180	120	36	33000	3.0	980	12
Lower North Fork, 2nd Round	161	270	7.0	430	140	85	90000	9.0	3000	8.0
Field Blank	- -	28	< 1.0	26	< 4.0	28	< 20	< 2.0	< 1.0	< 1.0
Field Blank	- -	45	< 1.0	27	< 4.0	32	220	< 2.0	5.0	< 1.0
Field Blank	- -	< 22	< 6.0	< 3.0	< 1.0	180	30	< 2.2	< 22	< 4.4
Field Blank	- -	28	< 6.0	< 3.0	< 1.0	< 22	< 22	< 2.2	< 22	< 4.4

(1) Water discharge (cfs) for the respective site and time (Blazs et al. 1993)

TABLE 10: Element concentrations (ppm dry wt) in sediment samples collected from various locations in the W.C. Austin Project area, 1992

ANALYTE	Bitter Creek(1)			Stinking Creek(2)			ER-L (5)
	Average	Coefficient of Variation	Salt Fork(3)	Average	Coefficient of Variation	North Fork(4)	
<b>Al</b>	<b>16143</b>	<b>0.18</b>	<b>1600</b>	<b>15614</b>	0.35	27000	--
As	<b>1.82</b>	0.42	2.4	<b>1.85</b>	0.42	4.3	33
B	23.4	0.22	3.5	23.8	0.31	37	--
<b>Ba</b>	143	0.23	33	217	0.30	<b>190</b>	--
Be	0.64	0.13	0.09	0.65	0.28	<b>1</b>	--
<b>Cd</b>	<b>0.22</b>	<b>0.09</b>	<b>0.18</b>	0.25	0.18	0.23	5
<b>Cr</b>	<b>15.1</b>	<b>0.14</b>	2.6	15	0.28	23	80
cu	9.06	0.12	<b>1.4</b>	<b>9.38</b>	<b>0.33</b>	16	70
Fe	<b>12114</b>	<b>0.11</b>	2500	12500	0.26	<b>19000</b>	--
<b>Hg</b>	0.02	<b>0.11</b>	<b>0.01</b>	0.02	0.24	0.02	0.15
<b>Mg</b>	4800	0.09	1700	5729	0.18	9900	--
Mn	381	0.59	210	443	0.40	590	--
Mo	1.46	0.09	1.2	1.7	0.18	1.5	--
Ni	10.8	0.11	2.1	12	0.22	17	30
<b>Pb</b>	5.95	<b>0.18</b>	<b>1.5</b>	7.5	0.18	7.7	35
<b>Se</b>	1.23	0.21	0.51	1.3	0.34	1	--
Sr	92.3	0.44	80	127	0.26	200	--
v	53.5	0.13	8.7	55	0.24	79	--
<b>Zn</b>	<b>30.53</b>	<b>0.17</b>	<b>4.7</b>	<b>32</b>	<b>0.32</b>	<b>46</b>	<b>120</b>

- (1) Averaged soil parameters: % Total Organic Carbon=0.87; % Sand=44; % Silt=37; % Clay=19  
(2) Averaged soil parameters: % Total Organic Carbon=0.86; % Sand=49; % Silt=28; % Clay=23  
(3) Soil parameters: % Total Organic Carbon=1.55; % Sand=24; % Silt=42; % Clay=34  
(4) Soil parameters: % Total Organic Carbon=0.24; % Sand=90; % Silt=6; % Clay=4  
(5) Effects Range - Low (Long and Morgan 1990); -- = not available

TABLE 11: Concentrations of selected organochlorines @pm wet wt) In SPMDs set out In the W.C. Austin Project area, 1992

SITE	ROUND	ANALYTE							
		a-Chlordane	Dieldrin	Endrin	o,p'-DDE	p,p'-DDD	p,p'-DDE	p,p'-DDT	toxaphene
Upper Salt Fork	1	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.04	< 0.02	0.83
Upper Salt Fork	2	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.20
	average						< 0.03		< 0.42
Bitter Creek	1	0.00	0.53	0.30	0.15	0.29	1.5	0.38	6.5
Bitter Creek	1	0.09	0.54	0.28	0.02	0.33	1.9	0.41	8.2
Bitter Creek	2	0.07	0.43	0.29	0.02	0.43	1.5	0.58	10
	average	0.08	0.5	0.29	0.07	0.35	1.63	0.46	8.23
Lower Salt Fork	1	< 0.02	0.09	0.08	< 0.02	0.07	0.35	0.13	2.7
Lower Salt Fork	2	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.02	< 0.02	< 0.20
	average	< 0.02	< 0.06	< 0.05	< 0.02	< 0.04	0.19	< 0.08	< 1.45
Upper North Fork	2	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.20
Upper North Fork	2	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.20
Stinking Creek	1	0.05	0.30	0.20	0.02	0.16	1.3	0.24	3.8
Stinking Creek	1	0.06	0.39	0.23	0.13	0.18	1.7	0.24	4.5
	average	0.06	0.35	0.22	0.08	0.17	1.5	0.24	4.15
Lower North Fork	1	< 0.02	0.26	0.30	< 0.02	0.51	0.86	0.87	11
Lower North Fork	2	< 0.02	0.05	0.04	< 0.02	0.05	0.18	0.08	2.1
	average	< 0.02	0.15	0.17	< 0.02	0.28	0.53	0.48	6.55

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## APPENDIX A: Organochlorine concentrations (ppm dry wt) in fish collected from the W.C. Austin Project, 1992

		ANALYTE										
MATRIX(1)	SITE(2)	% Moisture	HCB	PCB - TOT	a-BHC	a-Chlordane	b-BHC	Dieldrin	Endrin	g-BHC	g-Chlordane	Heptachlor Epoxide
CAGECCF	CTRL	73.6	< 0.04	< 0.32	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
CAGE CCF	S C	so.5	< 0.05	< 0.52	< 0.05	< 0.05	< 0.05	1.1	< 1.2	< 0.05	< 0.05	< 0.08
CAGECCF	SC	50.1	< 0.05	< 0.50	< 0.05	< 0.05	< 0.05	1.1	< 1.1	< 0.05	< 0.05	0.07
CAGE CCF	LNF	75.0	0.05	< 0.45	< 0.05	< 0.05	< 0.05	0.17	< 0.15	< 0.05	< 0.05	< 0.05
CAGECCF	LNF	75.5	< 0.04	< 0.41	< 0.04	< 0.04	< 0.04	0.15	< 0.14	< 0.04	< 0.04	< 0.04
CAGECCF	BC	75.4	< 0.04	< 0.42	< 0.04	< 0.04	< 0.04	0.83	< 0.47	< 0.04	< 0.04	< 0.08
CAGECU	BC	77.7	< 0.05	< 0.45	< 0.05	< 0.05	< 0.05	1.8	< 0.21	< 0.05	< 0.05	< 0.12
CAGECCF	CTRL	73.4	< 0.04	< 0.32	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
PLM	UNF	71.3	4 0.04	< 0.35	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
RSH	UNF	75.4	< 0.04	< 0.42	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
RSH	UNF	77.1	< 0.04	< 0.44	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
PLM	BC	70.5	0.05	< 0.34	< 0.03	< 0.03	< 0.03	0.85	< 0.03	< 0.03	< 0.03	< 0.03
RSH	BC	70.1	< 0.03	< 0.33	< 0.03	< 0.03	< 0.03	0.70	< 0.03	< 0.03	< 0.03	< 0.03
CCF	SC	75.2	< 0.04	< 0.42	< 0.04	< 0.04	< 0.04	0.71	< 0.04	< 0.04	< 0.04	< 0.04
CCF	SC	70.2	< 0.03	< 0.34	< 0.03	< 0.03	< 0.03	0.70	< 0.03	< 0.03	0.06	< 0.03
CCF	SC	81.0	< 0.05	< 0.54	< 0.05	< 0.05	< 0.05	0.10	< 0.05	< 0.05	< 0.05	< 0.05
CCF	SC	72.0	< 0.05	< 0.47	< 0.05	< 0.05	< 0.05	0.14	< 0.05	< 0.05	< 0.05	< 0.05
CCF	SC	70.0	< 0.05	< 0.47	< 0.05	< 0.11	< 0.05	0.10	< 0.05	< 0.05	< 0.06	< 0.05
CCF	SC	80.3	< 0.05	< 0.51	< 0.05	0.12	< 0.05	0.18	< 0.10	< 0.05	< 0.05	< 0.05
CCF(F30)	SC	22.4	< 0.05	< 0.57	< 0.02	< 0.08	< 0.08	0.16	0.10	< 0.05	< 0.08	< 0.08
CCF(F31)	S C	50.7	< 0.05	< 0.52	< 0.05	0.10	< 0.05	0.34	0.13	a m	< 0.05	< 0.05
CCF(F32)	S C	25.4	< 0.08	< 0.59	< 0.08	< 0.03	< 0.08	0.02	< 0.05	< 0.05	< 0.08	< 0.05
CCF(F33)	S C	85.5	< 0.07	< 0.70	< 0.07	< 0.07	< 0.07	< 0.07	< 0.07	< 0.07	< 0.07	< 0.07
CCF(F34)	SC	23.7	< 0.08	< 0.81	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08	4 0.08
CCF(F35)	SC	24.4	< 0.08	< 0.84	< 0.08	< 0.05	< 0.05	< 0.08	< 0.08	< 0.05	< 0.08	< 0.05
FHM	SC	88.0	< 0.03	< 0.31	< 0.03	0.12	0.04	0.25	0.22	< 0.03	< 0.03	< 0.03
FHM	SC	88.8	< 0.03	< 0.32	< 0.03	0.12	0.05	0.35	0.30	< 0.03	< 0.03	< 0.03
RSH	SC	72.3	< 0.04	< 0.38	< 0.04	< 0.04	< 0.04	0.04	0.04	< 0.04	< 0.04	< 0.04
MGF	LNF	77.2	< 0.05	< 0.45	< 0.05	< 0.05	< 0.05	0.14	0.12	< 0.05	< 0.05	< 0.05
RSH	LNF	76.5	< 0.04	< 0.43	< 0.04	< 0.04	< 0.04	0.20	0.20	< 0.04	< 0.04	< 0.04
ASH	USF	72.2	< 0.04	< 0.38	< 0.04	< 0.04	< 0.04	0.07	< 0.04	< 0.04	< 0.04	< 0.04
RSH	USF	74.0	< 0.04	< 0.39	< 0.04	< 0.04	< 0.04	0.07	< 0.04	< 0.04	< 0.04	< 0.04
RSH	USF	74.2	< 0.04	< 0.39	< 0.04	< 0.04	< 0.04	0.10	< 0.04	< 0.04	< 0.04	< 0.04
PLK	USF	74.7	< 0.04	< 0.40	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
PLK	USF	75.2	< 0.04	< 0.42	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
PLK	USF	74.3	< 0.04	< 0.39	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
RSH	SC	72.4	< 0.04	< 0.38	< 0.04	< 0.04	< 0.04	0.07	0.08	< 0.04	< 0.04	< 0.04
MGF	SC	71.3	< 0.04	< 0.35	< 0.04	< 0.04	< 0.04	0.18	0.07	< 0.04	< 0.04	< 0.04
CCF	BC	79.1	< 0.05	< 0.48	< 0.05	< 0.05	< 0.05	0.89	< 0.12	< 0.08	< 0.08	< 0.08
CCF	BC	79.0	< 0.05	< 0.45	< 0.06	< 0.05	< 0.05	0.09	< 0.25	< 0.05	< 0.05	< 0.05
CCF	BC	77.4	< 0.04	< 0.44	< 0.04	< 0.01	< 0.04	0.89	< 0.33	< 0.04	< 0.04	0.07
CCF	BC	73.8	< 0.04	< 0.35	< 0.04	< 0.04	< 0.04	1.1	< 0.88	< 0.04	< 0.04	0.10
CCF	BC	74.3	< 0.04	< 0.39	< 0.04	< 0.04	< 0.04	0.70	< 0.70	< 0.04	< 0.04	0.02
CCF(F55)	BC	54.5	< 0.07	< 0.88	< 0.07	< 0.07	< 0.07	0.10	< 0.13	< 0.07	< 0.07	< 0.07
CCF(F56)	BC	24.1	< 0.08	< 0.53	< 0.08	< 0.05	< 0.08	0.15	< 0.18	< 0.08	< 0.05	0.05
CCF(F57)	BC	52.3	< 0.08	< 0.57	< 0.08	< 0.08	< 0.08	0.57	< 0.32	< 0.05	< 0.08	0.08
CCF(F58)	BC	50.2	< 0.05	< 0.51	< 0.05	< 0.05	< 0.05	0.35	< 0.37	< 0.05	< 0.05	0.02
CCF(F59)	BC	80.0	< 0.05	< 0.50	< 0.05	< 0.05	< 0.05	0.31	< 0.37	< 0.05	< 0.05	0.09
RSH	BC	70.6	< 0.03	< 0.34	< 0.03	< 0.03	< 0.03	0.21	< 0.03	< 0.03	< 0.03	< 0.03
---	BC	74.1	< 0.04	< 0.39	< 0.04	< 0.04	0.05	0.43	< 0.04	< 0.04	< 0.04	< 0.04
RSH	BC	72.2	< 0.04	< 0.35	< 0.04	< 0.04	0.04	0.43	< 0.04	< 0.04	< 0.04	< 0.04
RSH	LSF	73.3	< 0.04	< 0.35	< 0.04	< 0.04	< 0.04	0.30	< 0.34	< 0.04	< 0.04	< 0.04
RSH	LSF	72.4	< 0.04	< 0.35	< 0.04	< 0.04	0.08	0.78	< 0.54	< 0.04	< 0.04	< 0.04
RSH	LSF	75.4	< 0.04	< 0.41	< 0.04	< 0.04	< 0.04	0.31	< 0.34	< 0.04	< 0.04	< 0.04
RSH	LSF	74.2	< 0.04	< 0.40	< 0.04	< 0.04	< 0.04	0.37	< 0.39	< 0.04	< 0.04	< 0.04
RSH	LSF	71.2	< 0.04	< 0.35	< 0.04	< 0.04	< 0.04	0.71	< 0.53	< 0.04	< 0.04	< 0.04
MGF	LSF	75.3	< 0.04	< 0.41	< 0.04	< 0.04	< 0.04	0.12	< 0.15	< 0.04	< 0.04	< 0.04

(continued)

APPENDIX A (cont.)

			ANALYTE									
MATRIX(1)	SITE(2)	% Moisture	Mirex	o,p'-DDD	o,p'-DDE	o,p'-DDT	oxychlorane	p,p'-DDD	p,p'-DDE	p,p'-DDT	toxaphene	trans-nonachl
CAGE CCF	CTRL	73.6	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.38	< 0.04
CAGECCF	SC	80.8	< 0.05	< 0.05	< 0.05	0.08	< 0.06	< 0.05	6.8	< 3.9	83	< 0.05
CAGE CCF	S C	80.1	< 0.05	< 0.05	< 0.05	0.09	< 0.05	< 0.05	5.5	< 3.2	90	< 0.05
CAGE CCF	LNF	78.0	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.68	< 0.40	8.6	< 0.05
CAGE CCF	LNF	75.5	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	0.40	< 0.33	6.5	< 0.04
CAGE CCF	S C	76.4	< 0.04	< 0.55	< 0.04	< 0.04	< 0.04	< 0.04	2.7	< 2.1	55	< 0.04
CAGECCF	S C	77.7	< 0.05	< 1.1	< 0.05	0.05	< 0.05	< 0.05	4.9	< 3.8	65	< 0.05
CAGECCF	CTRL	73.4	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.38	< 0.04
PLM	UNF	71.3	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	0.30	< 0.04	0.90	< 0.04
RSH	UNF	76.4	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	0.22	< 0.04	< 0.42	< 0.04
RSH	UNF	77.1	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	0.24	< 0.04	< 0.44	< 0.04
PLM	SC	70.5	< 0.03	< 0.54	< 0.03	< 0.03	< 0.03	< 1.8	5.14	< 0.03	41	< 0.03
RSH	SC	70.1	< 0.03	< 0.03	0.04	< 0.03	< 0.03	< 1.2	11	< 0.03	22	< 0.03
CCF	SC	75.8	< 0.04	< 0.04	< 0.04	0.07	< 0.04	< 0.71	26	< 3.4	62	< 0.04
CCF	SC	70.2	< 0.03	< 0.03	0.09	0.07	< 0.03	< 0.03	37	< 3.7	54	< 0.03
CCF	SC	81.6	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.08	10	< 0.65	9.2	< 0.05
CCF	SC	72.0	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.07	12	< 0.05	6.8	< 0.05
CCF	SC	72.0	< 0.05	< 0.13	< 0.05	< 0.05	< 0.05	< 0.14	14	< 0.85	13	< 0.05
CCF	SC	80.3	< 0.06	0.27	< 0.05	< 0.05	< 0.05	< 0.05	16	< 1.7	32	< 0.05
CCF (F30)	SC	22.4	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08	0.22	7.4	0.74	11	< 0.08
CCF (F31)	S C	50.7	< 0.05	< 0.05	< 0.05	0.07	< 0.05	0.57	17	1.8	24	< 0.05
CCF (F32)	SC	55.4	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	8.1	0.48	8.1	< 0.06
CCF (F33)	S C	85.0	< 0.07	< 0.07	< 0.07	< 0.07	< 0.07	< 0.07	14	0.35	5.1	< 0.07
CCF (F34)	S C	53.7	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	3.4	0.13	2.5	< 0.06
CCF (F35)	SC	54.4	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	4.2	0.36	6.4	< 0.06
FHM	SC	68.0	< 0.03	0.50	0.15	0.30	< 0.03	0.75	18	1.7	34	< 0.03
FHM	SC	68.6	< 0.03	< 0.03	0.17	0.39	< 0.03	0.74	20	1.7	35	< 0.03
RSH	SC	72.3	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	0.13	5.1	0.25	5.e	< 0.04
MQF	LNF	77.8	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.11	2.8	0.37	5.0	< 0.05
RSH	LNF	75.5	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	3.0	0.47	(1.1)	< 0.04
RSH	USF	72.2	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	0.22	2.7	0.54	0.0	< 0.04
RSH	USF	74.0	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	0.33	2.3	0.42	6.9	< 0.04
RSH	USF	74.2	< 0.04	0.14	< 0.04	0.05	< 0.04	0.38	3.5	0.66	11	< 0.04
PLK	USF	74.7	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	0.40	< 0.04	0.55	< 0.04
PLK	USF	75.9	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	0.12	0.71	0.09	0.02	< 0.04
PLK	USF	74.3	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	0.18	0.50	0.08	0.07	< 0.04
RSH	SC	72.4	< 0.04	0.11	< 0.04	0.04	< 0.04	0.24	9.0	0.40	7.2	< 0.04
MQF	SC	71.3	< 0.04	0.00	< 0.04	< 0.04	< 0.04	0.21	7.0	0.80	7.0	< 0.04
CCF	SC	79.1	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.42	0.1	< 0.01	7.8	< 0.05
CCF	BC	78.0	< 0.05	< 0.05	0.07	< 0.05	< 0.05	< 0.65	21	< 1.9	15	< 0.05
CCF	BC	77.4	< 0.04	< 0.38	0.06	0.18	< 0.04	< 2.28	35	< 3.8	37	0.07
CCF	SC	73.8	< 0.04	< 0.50	0.07	0.07	< 0.04	< 2.0	26	< 2.0	35	0.05
CCF	BC											
CCF (F55)	BC	74.8	< 0.04	< 0.07	< 0.04	0.07	< 0.04	< 0.40	11	0.13	< 0.04	< 0.04
CCF (F56)	SC	84.1	< 0.06	< 0.10	< 0.00	0.08	< 0.06	< 0.50	17	< 1.2	13	< 0.06
CCF (F57)	SC	82.3	< 0.06	< 0.27	< 0.06	0.09	< 0.06	< 1.3	21	< 2.4	28	< 0.06
CCF (F58)	SC	30.2	< 0.05	< 0.17	< 0.05	< 0.05	< 0.05	< 0.71	9.1	< 1.1	12	< 0.05
CCF (F59)	SC	80.0	< 0.05	< 0.15	< 0.05	< 0.05	< 0.05	< 0.65	7.0	< 1.1	13	< 0.05
RSH	BC	70.0	< 0.03	< 0.16	0.06	0.05	< 0.03	< 0.44	8.5	< 0.58	7.5	< 0.03
-	SC	74.1	< 0.04	< 0.22	0.08	< 0.04	< 0.04	< 0.48	11	< 0.82	a.5	< 0.04
RSH	SC	72.2	< 0.04	< 0.16	0.06	< 0.04	< 0.04	< 0.43	8.8	< 0.58	7.5	< 0.04
RSH	LSF	73.3	< 0.04	< 0.04	0.08	0.12	< 0.04	< 0.60	5.7	< 0.75	13	< 0.04
RSH	LSF	72.4	< 0.04	< 0.04	0.06	0.15	< 0.04	< 0.96	5.8	< 1.3	20	< 0.04
RSH	LSF	75.4	< 0.04	< 0.04	0.06	0.11	< 0.04	< 0.69	7.3	< 1.0	13	< 0.04
RSH	LSF	74.9	< 0.04	< 0.04	0.07	0.15	< 0.04	4 0.68	8.7	< 0.82	13	< 0.04
RSH	LSF	71.2	< 0.04	< 0.04	0.05	0.12	< 0.04	< 1.0	5.7	< 1.5	20	< 0.04
MQF	LSF	75.3	< 0.04	< 0.11	0.05	< 0.04	< 0.04	< 0.24	6.5	< 0.49	5.7	< 0.04

(1) Caged CCF = Caged Channel Catfish; CCF = Channel Catfish; CCF (Fxx) = Filet of Catfish No. xx; FHM = Fathead Minnow; PLK = Plains Killifish; PLM = Plains Minnow; RSH = Red Shim  
 (2) BC = Bitter Creek; CTRL = Control; LNF = Lower North Fork; LSF = Lower Salt Fork; SC = Stinking Creek; UNF = Upper North Fork; USF = Upper Salt Fork

## APPENDIX B: Concentrations of elements (ppm dry wt) in fish samples collected from the W. C. Austin Project area, 1992

			ANALYTE											
SPECIES(1)	SITE(2)	% Moisture	Al	As	B	Ba	Be	cd	cr	Cu	Fe			
PLM	UNF	72.6	11	0.74	< 1.5	3.6	< 0.07	< 0.22	1.3	1.7	63			
RSH	UNF	75.6	1100	2.2	3.7	26	< 0.06	< 0.24	2.5	5.3	950			
RSH	UNF	77.5	1109	2.0	3.7	27	< 0.09	< 0.25	2.6	5.1	910			
FHM	SC	56.9	2400	2.4	7.0	25	0.06	< 0.19	4.0	4.1	1800			
FHM	SC	50.9	660	1.4	4.6	21	< 0.07	< 0.20	2.2	4.5	720			
RSH	SC	73.1	70	0.66	2.2	3.7	< 0.07	< 0.22	1.5	3.5	69			
MQF	LNF	79.3	430	1.7	< 1.9	20	< 0.09	< 0.26	1.9	7.3	330			
RSH	LNF	77.2	740	2.0	2.1	16	< 0.09	< 0.26	1.9	7.7	540			
RSH	UBF	73.6	210	1.7	1.5	12	< 0.06	< 0.22	1.9	3.6	340			
RSH	USF	73.9	370	3.0	1.7	11	< 0.08	< 0.23	2.0	4.0	510			
RSH	USF	74.3	400	3.2	2.1	11	< 0.06	< 0.23	1.1	3.6	520			
PLK	USF	75.1	340	4.9	1.7	16	< 0.06	< 0.24	2.5	11	450			
PLK	USF	74.9	230	3.6	< 1.5	17	< 0.06	< 0.24	2.3	6.5	350			
PLK	USF	74.3	570	2.9	2.2	21	< 0.06	< 0.23	2.0	7.4	610			
RSH	BC	70.5	39	1.2	< 1.3	2.6	< 0.07	< 0.20	1.1	3.3	65			
--	BC	75.2	160	1.5	< 1.6	5.4	< 0.06	< 0.24	1.4	6.6	150			
RSH	BC	72.4	210	1.1	2.1	4.6	< 0.07	< 0.21	1.3	4.0	160			
RSH	LSF	73.1	1600	2.5	4.1	16	< 0.07	< 0.22	2.7	4.5	1100			
RSH	LSF	71.3	570	5.6	1.6	14	< 0.07	< 0.21	1.6	3.7	590			
RSH	LSF	74.4	540	1.8	2.4	15	< 0.06	< 0.23	1.9	4.3	440			
RSH	LSF	74.5	720	1.5	2.9	15	< 0.06	< 0.23	2.0	5.1	560			
RSH	LSF	72.5	1700	3.6	3.2	17	< 0.07	< 0.21	2.7	4.2	1300			
MQF	LSF	75.6	250	2.2	< 1.6	14	< 0.05	< 0.24	1.5	5.7	2	1	0	

SPECIES(1)	SITE(2)	% Moisture	Hg	Mg	Mn	Mo	Ni	Pb	Se	Br	v	Zn
PLM	UNF	72.6	< 0.04	1000	7.5	< 1.5	< 0.44	< 1.6	1.0	51	0.67	76
RSH	UNF	75.6	0.20	2300	97	< 1.6	1.7	< 2.0	2.5	160	7.7	140
RSH	UNF	77.5	0.21	2500	93	< 1.6	1.7	< 2.2	3.0	190	7.5	150
FHM	SC	56.9	0.14	1800	52	< 1.3	2.1	< 1.6	5.2	160	9.7	66
FHM	SC	69.9	0.09	1400	47	< 1.3	1.5	< 1.6	7.1	160	6.3	82
RSH	SC	73.1	0.23	1400	18	< 1.5	< 0.45	< 1.8	6.3	240	2.2	100
MQF	LNF	79.3	0.21	1400	35	< 1.8	0.73	< 2.3	3.9	130	2.6	110
RSH	LNF	77.2	0.12	1500	41	< 1.1	0.69	< 2.2	3.4	140	5.5	120
RSH	USF	73.6	0.16	1400	51	< 1.5	1.3	< 1.8	4.9	160	4.7	130
RSH	USF	73.9	0.19	1400	42	< 1.5	0.66	< 1.0	5.4	140	4.7	120
RSH	USF	74.3	0.16	1400	44	< 1.5	0.63	< 1.9	4.6	140	5.1	110
PLK	USF	75.1	0.20	1500	86	< 1.1	1.1	< 2.0	5.6	110	2.3	110
PLK	USF	74.9	0.16	1476	60	< 1.6	0.99	4 2.0	5.4	110	2.2	100
PLK	USF	74.3	0.15	1600	72	< 1.5	0.69	< 1.9	5.9	100	3.3	110
RSH	BC	70.6	0.15	1200	13	< 1.3	< 0.40	< 1.7	4.6	140	1.5	140
--	BC	75.2	0.11	1300	12	< 1.5	< 0.46	< 2.0	5.2	160	1.6	100
RSH	BC	72.4	0.11	1300	17	< 1.4	< 0.43	< 1.6	6.1	140	2.1	140
RSH	LSF	73.1	0.16	1900	46	< 1.5	1.4	< 1.6	3.5	180	6.4	170
RSH	LSF	71.3	0.06	1200	43	< 1.4	1.0	< 1.7	3.6	120	6.1	73
RSH	LSF	74.4	0.19	1700	44	< 1.5	0.93	< 1.8	5.1	160	3.5	150
RSH	LSF	74.5	0.16	1700	44	< 1.6	0.95	< 1.9	4.6	170	4.0	170
RSH	LSF	72.5	0.11	1600	52	< 1.4	1.4	< 1.6	3.6	130	1.1	90
MQF	LSF	75.6	0.31	1400	46	< 1.6	< 0.49	< 2.0	5.6	140	1.4	120

(1) FHM = Fathead Minnow; MQF = Mosquitofish; PLK = Plains Killifish; PLM = Plains Minnow; RSH = Red Shiner

(2) BC = Bitter Creek; LNF = Lower North Fork; LSF = Lower Salt Fork; SC = Stinking Creek; UNF = Upper North Fork; USF = Upper Salt Fork

## APPENDIX C: Concentrations of elements (ppb) in water samples collected from the W. C. Austin Project area, 1992

SITE(1)	ANALYTE																		
	Al	As	B	Ba	Be	Cd	Cr	cu	Fe	Hg									
BL	20	<	1.0	26	<	4.0	<	1.0	<	2.0	2.0	20	<	02					
UNF	77		5.0	250		110	<	1.0	<	1.0	c	2.0	5.0	31	<	02			
SC	07		5.0	600		120	<	1.0	<	1.0	<	2.0	5.0	27	<	02			
LNF	92		4.0	180		120	c	1.0	<	1.0	<	2.0	5.0	30	<	02			
USF	97		3.0	220		54	<	1.0	<	1.0	<	2.0	2.0	34	<	02			
BC	74		5.0	490		160	<	1.0	<	1.0	<	2.0	4.0	25	<	02			
LSF	540		4.0	350		92	<	1.0	<	1.0	<	2.0	4.0	320	<	02			
BL	45	<	1.0	27	<	4.0	<	1.0	<	1.0	<	2.0	<	2.0	32	<	02		
BL	<	22	<	6.0	<	3.0	<	1.0	<	0.6	<	0.6	<	5.6	<	5.6	180	<	1.1
UNF	270		6.0	500		110	<	0.6	<	0.6	<	5.5	<	5.5	140	<	1.1		
SC	440		6.0	450		43	<	0.6	<	0.6	<	5.5	<	5.5	110	<	1.1		
LNF	270		7.0	430		140	c	0.6	<	0.6	<	5.5	<	5.5	05	<	1.1		
USF	290		7.0	510		36	<	0.6	<	0.6	<	5.6	<	5.6	<	22	<	1.1	
BC	290		7.0	370		77	<	0.6	<	0.6	<	5.5	<	5.5	20	<	1.1		
LSF	270		6.0	300		92	<	0.6	<	0.6	<	5.6	<	5.6	20	<	1.1		
BL	20	<	6.0	<	3.0	<	1.0	<	0.6	<	0.6	<	5.6	<	5.6	<	22	<	1.1

SITE(1)	Mg	Mn	Mo	Ni	Pb	Se	Sr	V	Zn									
BL	<	20	<	2.0	<	0.0	<	2.0	<	10	<	2.0	<	1.0	<	1.0	4	0
UNF	36000		3.0	<	8.0	<	2.0	<	10	<	2.0	1400	9.0	<				4.0
SC	59000		11	<	0.0						2.0							6.0
LNF	33000		3.0	<	0.0	<	2.0	<	10	10	5	2.0	1980		12			5.0
USF	34000		3.0	<	0.0	<	3.0	<	10	<		1300	9.0	<				4.0
BC	64000		26	<	0.0	<	2.0	<	10	<	2.0	1800	15	5				0
LSF	51000		9.0	<	0.0	<	2.0	<	10	3	0	1700	14	6				0
BL	220	<	2.0	<	8.0	<	2.0	<	10	<	2.0	5.0	<	1.0	<			4.0
BL	30	<	22	<	4.4	<	5.6	<	5.6	<	6.6	<	22	<	4.4	<		11.1
UNF	92000		17		5.0	<	5.5	<	5.5	<	5.6	2700	<	4.4	<			11.1
SC	120000		25		5.0	<	5.5	<	5.5	<	5.6	3700	13	<				11.1
LNF	90000		9.0	6.0	<	5.5	<	5.5	<	5.5	3000	0.0	<					11.1
USF	120000		83	<	4.4	<	5.6	<	5.6	<	5.5	5500	<	4.4	<			11.1
BC	99000		6.0	<	4.4	<	5.5	<	5.5	<	5.6	3100	10	<				11.1
LSF	87000		5.0	<	4.4	<	5.6	<	5.6	<	5.6	7.0	2800	9.0	<			11.1
BL		<	2.2	<	4.4	<	5.6	<	5.6	<	5.5	<	2.2	<	4.4	<		11.1

(1) BL=Blank; BC=Bitter Creek; LNF=Lower North Fork; LSF=Lower Salt Fork; SC=Stinking Creek; UNF=Upper North Fork; USF=Upper Salt Fork

APPENDIX D: Concentrations of organochlorines (ppm dry wt) in sediment sampler collected from the W.C. Austin Project area, 1992

ANALYTE											
Site (1)	% Moisture	HCB	PCB-TOT	a-BHC	a-Chlordane	b-BHC	Dieldrin	Endrin	g-BHC	g-Chlordane	Heptachlor Epoxide
SC	35	< 0.03	< 0.15	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.03	< 0.02
SC	46	< 0.02	< 0.19	< 0.02	< 0.02	0.02	< 0.02	< 0.02	< 0.02	< 0.03	< 0.02
SC	43	< 0.02	< 0.18	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
NF	36	< 0.02	< 0.18	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
SC	28	< 0.03	< 0.13	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
SC	26	< 0.01	< 0.13	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
SC	34	< 0.03	< 0.15	< 0.02	< 0.02	< 0.02	< 0.02	< 0.03	< 0.02	< 0.02	< 0.02
47		< 0.03	< 0.19	< 0.02	< 0.02	< 0.02	< 0.02	< 0.03	< 0.02	< 0.02	< 0.02
BC	42	< 0.02	< 0.17	< 0.02	< 0.03	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
BC	27	< 0.01	< 0.14	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
BC	28	< 0.01	< 0.14	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
BC	28	4 0.01	< 0.14	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
BC	43 37	< 0.02	< 0.16	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
		< 0.02	< 0.17	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
BC	35	< 0.02	< 0.11	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
SF	23	< 0.01	< 0.13	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

Site (1)	% Moisture	Mirex	o,p'-DDD	o,p'-DDE	o,p'-DDT	oxychlordane	p,p'-DDD	p,p'-DDE	p,p'-DDT	toxaphene	trans-nonachlor
SC	35	< 0.02	< 0.03	< 0.02	< 0.02	< 0.02	< 0.02	0.03	< 0.02	< 0.02	< 0.02
SC	46	< 0.02	< 0.03	< 0.02	< 0.02	< 0.02	< 0.02	0.06	< 0.02	< 0.02	< 0.02
SC	43	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.05	< 0.02	< 0.02	< 0.02
NF	36	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
SC	23	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.09	< 0.01	< 0.01	< 0.01
SC	26	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.06	< 0.01	< 0.01	< 0.01
SC	24	< 0.03	< 0.02	< 0.03	< 0.02	< 0.02	< 0.02	0.05	< 0.02	< 0.02	< 0.02
SC	47	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.13	< 0.02	< 0.02	< 0.02
BC	42	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.23	< 0.02	< 0.02	< 0.02
BC	27	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.18	< 0.01	< 0.01	< 0.01
BC	28	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.13	< 0.01	< 0.01	< 0.01
BC	28	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.12	< 0.01	< 0.01	< 0.01
BC	37	< 0.03	< 0.03	< 0.02	< 0.02	< 0.02	< 0.02	0.35	0.02	< 0.02	< 0.02
BC	42	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.16	< 0.02	< 0.02	< 0.02
BC	35	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.05	< 0.02	< 0.02	< 0.02
SF	22	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.03	< 0.01	< 0.01	< 0.01

(1) BC = Bitter Creek; NF = North Fork; SC = Stinking Creek; SF = Salt Fork

APPENDIX E: Concentrations of elements (ppm dry wt) in sediment samples collected from the W. C. Austin Project area, 1992

		ANALYTE										
SITE(1)	% Moisture	Al	As	B	Ba	Be	Cd	Cr	Cu	Fe	Hg	
SC	35	8300	3.2	13	200	0.47	< 0.22	9.3	6.0	8900	< 0.02	
SC	46.3	22000 15000	2.4 2.3	25	360 160	0.09	< 0.30	19	11	16000	< 0.62	
				28		0.01	< 0.26	15	14	12000	0.03	
NF	36	27000	4.3	37	190	1.0	< 0.23	23	16	19000	0.02	
SC	23	13000	0.08	20	200	0.52	< 0.19	13	6.6	10000	< 0.01	
SC	20	SOW	1.5	16	150	0.42	< 0.21	9.7	5.5	8600	< 0.01	
SC						0.77	< 0.26	10	10	15000	< 0.02	
SC	34.47	22000 20000	0.90 1.0	20 36	210 240	0.88	< 0.33	21	12	17000	< 0.02	
BC	42	16000	2.7	25	140	0.02	< 0.22	15	8.9	12000	< 0.02	
BC	27	19000	2.7	30	150	0.70	< 0.22	17	10	13000	< 0.02	
BC	20	12000	0.00	14	110	0.61	< 0.20	12	9.6	11000	< 0.01	
BC	20	19000	2.2	20	190	0.71	< 0.21	17	9.7	13000	0.02	
BC						0.73	< 0.21	10	9.9	14000	< 0.01	
BC	37.42	18000 16000	0.71 2.2	27 23	180 110	0.60	< 0.26	15	a.7	12000	< 0.62	
BC	30	12000	1.2	10	110	0.40	< 0.20	12	6.8	9800	< 0.01	
SF	22	1600	2.4	3.5	33	0.08	< 0.10	2.6	1.4	2500	< 0.01	

SITE (1)	% Moisture	Mg	Mn	Mo	Ni	Pb	Se	Sr	V	Zn
SC					e m					
SC	35.40	7300 5000	440 410	<< 2.0 1.5	9.0 15	8.0 0.4	1.5 1.3	130 120	42 07	0 19
SC	43	5600	700	< 1.7	11	0.0	1.0	140	54	34
		9900	590	< 1.5	17	7.7	1.0	200	78	40
NF	36									
SC	23.20	4300 4800	210 220	<< 1.3 1.4	9.0 0.6	5.2 5.7	0.62 1.2	120 62	42 39	20 19
SC										
SC	34.47	6200 6900	680 480	<< 2.2 1.7	15 14	0.1 0.5	2.2 1.5	140 100	71 m	30 45
BC	42	4700	330	< 1.5	10	6.5	1.7	110	51	40
BC	27	5200	280	< 1.5	11	7.2	1.3	170	02	31
BC	20	4700	240	< 1.4	11	6.9	1.3	110	57	20
BC	20	5100	290	< 1.4	12	6.0	1.4	62	56	32
BC	37	5300	300	< 1.4	12	6.2	0.83	53	58	33
BC	42	4700	930	< 1.8	10	4.8	1.2	99	50	27
BC	35	3900	300	< 1.3	8.5	4.1	0.90	52	40	22
SF	22	1700	210	< 1.2	2.1	< 1.5	0.51	80	8.7	4.7

(1) BC=Bitter Creek; NF=North Fork; SC=Stinking Creek; SF=Salt Fork

APPENDMF: Concentrations of organochlorines @pm wet wt) In SPMDs set out in the W. C. Austin Project area, 1992

		ANALYTE									
MATRIX(1)	SITE(2)	HCB	PCB-TOT	a-BHC	a-Chlordane	b-BHC	Dieldrin	Endrin	g-BHC	g-Chlordane	Heptachlor Epoxide
SPMD	CONTROL	< 0.02	< 0.20	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
SPMD	CONTROL	< 0.02	< 0.20	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
SPMD(1)	BLANK	< 0.02	< 0.20	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.03	< 0.02	< 0.02
SPMD(1)	BLANK	< 0.02	< 0.30	< 0.03	< 0.02	< 0.02	< 0.03	< 0.03	< 0.02	< 0.02	< 0.02
SPMD(1)	BLANK	< 0.02	< 0.20	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
SPMD(3)	SC	< 0.02	< 0.20	< 0.02	0.06	< 0.02	0.39	0.33	< 0.02	< 0.02	0.43
SPMD(3)	SC	< 0.02	< 0.20	< 0.02	0.05	< 0.03	0.30	0.20	< 0.02	< 0.02	0.02
SPMD(3)	LNF	< 0.02	< 0.20	< 0.02	< 0.02	< 0.02	0.26	0.30	< 0.02	< 0.02	0.02
SPMD(4)	USF	< 0.02	< 0.20	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
SPMD(3)	BC	< 0.02	< 0.20	< 0.03	0.08	< 0.02	0.53	0.30	< 0.02	< 0.02	< 0.02
SPMD(3)	BC	< 0.02	< 0.20	< 0.02	0.09	< 0.02	0.54	0.26	< 0.02	< 0.02	< 0.02
SPMD(3)	LSF	< 0.02	< 0.20	< 0.02	< 0.02	< 0.02	0.09	0.08	< 0.02	< 0.03	< 0.02
SPMD(1)	BLANK	< 0.02	< 0.20	< 0.02	< 0.02	< 0.02	< 0.03	< 0.02	< 0.02	< 0.03	< 0.02
SPMD(1)	BLANK	< 0.02	< 0.20	< 0.03	< 0.02	< 0.02	< 0.02	< 0.02	< 0.03	< 0.02	< 0.02
SPMD(1)	BLANK	< 0.02	< 0.20	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
SPMD(1)	BLANK	< 0.02	< 0.20	< 0.03	< 0.03	< 0.03	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
SPMD(3)	U N	< 0.02	< 0.20	< 0.02	< 0.02	< 0.02	< 0.03	< 0.02	< 0.03	< 0.02	< 0.02
SPMD(3)	UNF	< 0.02	< 0.20	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
SPMD(3)	LNF	< 0.02	< 0.20	< 0.02	< 0.02	< 0.02	0.05	0.04	< 0.02	< 0.02	< 0.02
SPMD(3)	USF	< 0.02	< 0.20	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
SPMD(3)	BC	< 0.02	< 0.20	< 0.02	0.07	< 0.02	0.43	0.20	< 0.02	< 0.02	0.04
SPMD(3)	LSF	< 0.02	< 0.20	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
SPMD(1)	BLANK	< 0.02	< 0.20	< 0.02	< 0.03	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
SPMD(1)	BLANK	< 0.02	< 0.20	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
SPMD(1)	BLANK	< 0.02	< 0.30	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02

MATRIX(1)	SITE(2)	Mirex	o,p'-DDD	o,p'-DDE	o,p'-DDT	oxychlordane	p,p'-DDD	p,p'-DDE	p,p'-DDT	toxaphene	trans-nonachlor
SPMD	CONTROL	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.20	< 0.02
SPMD	CONTROL	< 0.02	< 0.02	< 0.03	< 0.02	< 0.02	< 0.03	< 0.02	< 0.02	< 0.20	< 0.02
SPMD(1)	BLANK	< 0.02	< 0.02	< 0.03	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.20	< 0.02
SPMD(1)	BLANK	< 0.02	< 0.03	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.20	< 0.02
SPMD(1)	BLANK	< 0.02	< 0.02	< 0.03	< 0.02	< 0.03	< 0.02	< 0.02	< 0.02	< 0.20	< 0.02
SPMD(3)	SC	< 0.02	< 0.02	0.13	< 0.02	< 0.03	0.18	1.7	0.24	4.6	< 0.02
SPMD(3)	SC	< 0.02	0.14	0.03	< 0.02	< 0.02	0.18	1.3	0.24	3.3	< 0.02
SPMD(3)	LNF	< 0.02	< 0.02	< 0.02	0.07	< 0.02	0.51	0.88	0.87	11	0.04
SPMD(4)	USF	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.04	< 0.02	0.63	< 0.02
SPMD(3)	BC	< 0.02	< 0.02	0.18	< 0.02	< 0.02	0.29	1.5	0.29	4.5	< 0.02
SPMD(3)	LSF	< 0.02	< 0.02	0.02	< 0.02	< 0.03	0.33	1.0	0.41	8.2	< 0.03
SPMD(3)	LSF	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.07	0.35	0.13	2.7	< 0.02
SPMD(1)	BLANK	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.20	< 0.02
SPMD(1)	BLANK	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.20	< 0.02
SPMD(1)	BLANK	< 0.02	< 0.02	< 0.02	< 0.03	< 0.02	< 0.02	< 0.02	< 0.03	< 0.30	< 0.02
SPMD(3)	U N	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.20	< 0.02
SPMD(3)	U N	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	4	0.02	< 0.02	< 0.02	< 0.02
SPMD(3)	L N F	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.06	0.13	0.08	2.1	< 0.02
SPMD(3)	USF	< 0.02	< 0.02	< 0.03	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.20	< 0.02
SPMD(3)	USF	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.20	< 0.02
SPMD(3)	LSF	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	1.5	0.58	10	< 0.02
SPMD(3)	LSF	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.20	< 0.02
SPMD(1)	BLANK	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.20	< 0.02
SPMD(1)	BLANK	< 0.02	< 0.02	< 0.03	< 0.02	< 0.03	< 0.02	< 0.02	< 0.03	< 0.20	< 0.02
SPMD(1)	BLANK	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.03	< 0.02	< 0.02	< 0.20	< 0.02

(1) SPMD = Semipermeable Membrane Device; SPMD(x) = x number of SPMD's in the sample;

(2) BC = Bitter Creek; Control = Lab Control; LNF = Lower North Fork; LSF = Lower Salt Fork; SC = Stinking Creek; UNF = Upper North Fork; USF = Upper Salt Fork