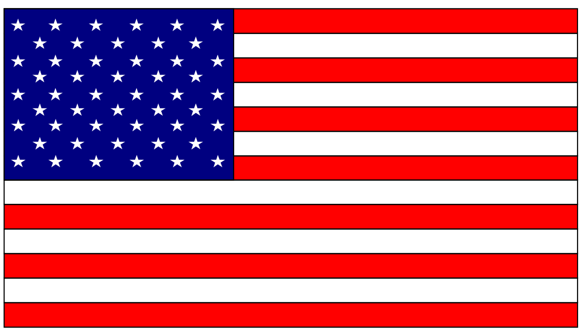
# Third Phase of the Binational Study Regarding the Presence of Toxic Substances in the Upper Portion of the Rio Grande/Rio Bravo Between the United States and Mexico




**Final Report, June 2004**

**(Field Data Collection Conducted November 1998)**

## AUTHORITY

This study and report were undertaken by the United States and Mexico pursuant to the International Boundary and Water Commission Minute No. 289 entitled "Observation of the Quality of the Waters along the United States and Mexico Border" dated November 13, 1992.

## PARTICIPATING AGENCIES

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National Park Service
United States Environmental Protection Agency
United States Bureau of Reclamation

### MEXICO

National Water Commission

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## FOREWORD

This report is a joint document issued by the Governments of the United States and Mexico through their respective Sections of the International Boundary and Water Commission, the United States Environmental Protection Agency - Region VI, and the National Water Commission of Mexico. The governments of both countries thank the Texas Commission on Environmental Quality formerly known as Texas Natural Conservation Commission, the National Park Service, and the United States Bureau of Reclamation for their cooperation in the collection of monitoring data and drafting of the various sections of the report.

Copies of this report in English may be obtained from the United States Section, International Boundary and Water Commission, 4171 North Mesa, Suite C-310, El Paso, Texas, 79902. The report in English may also be found on the Internet in Adobe® Portable Document Format (PDF) from the U.S. Environmental Protection Agency, Region VI, 1445 Ross Avenue, Suite 1200, Dallas, Texas 75202-2733 at http://www.epa.gov. Questions regarding the United States information contained in this report may be directed to Ms. Sylvia A. Waggoner at (915) 832-4740 or by email at sylviawaggoner@ibwc.state.gov.

Copies of this report in Spanish may be obtained from the Comisión Internacional de Límites y Aguas, Sección Mexicana, Ave. Universidad No.2180, Cd. Juárez, Chihuahua CP 32310, or from the Comisión Nacional del Agua, Subdirección General Técnica, Gerencia de Saneamiento y Calidad del Agua, Ave. San Bernabé #549, Col. San Jerónimo Lídice, México, D.F. CP 10200. Questions regarding the information from Mexico contained in this report may be directed to Ing. Luis A. Rascon M. at 011-52-1613-9942 or by email at arascon@cilamexeua.gob.mx.

## Table of Contents

## Table of Contents (cont)

## Table of Contents (cont)

## Table of Contents (cont)

## List of Tables

## List of Figures

## List of Figures (cont)

## LIST OF ABBREVIATIONS USED IN THE REPORT

| | |
|---|---|
| ALU | Aquatic Life Use |
| APHA | American Public Health Association |
| AVS | Acid Volatile Sulfide |
| BBNP | Big Bend National Park |
| BRBIBI | Benthic Macroinvertebrate Rapid Bioassessment Index of Biotic Integrity |
| CFR | Code of Federal Regulation |
| CNA | Comision Nacional Del Agua |
| CPOM | Course Particulate Organic Matter |
| DDD | 1,1-dichloro-2,2-bis(*p*-chlorophenyl) ethane |
| DDE | 1,1-dichloro-2,2-bis(*p*-chlorophenyl) ethylene |
| DDT | 1,1,1-trichloro-2,2-bis(*p*-chlorophenyl) ethane |
| EPT | Ephemeroptera-Trichoptera- Plecoptera Index |
| FPOM | Fine Particulate Organic Matter |
| HBI | Hilsenhoff Biotic Index |
| HQI | Habitat Quality Index |
| IBI | Index of Biotic Integrity |
| IBWC | International Boundary and Water Commission |
| ICI | Index of Community Integrity |
| MPS | Mean Point Score |
| NOAA | National Oceanic and Atmospheric Administration |
| PCA | Principal Components Analysis |
| PC1 | First Principal Component |
| PC2 | Second Principal Component |
| PC3 | Third Principal Component |
| PC4 | Fourth Principle Component |
| PEL | Probable Effects Level |
| QAPP | Quality Assurance Project Plan |
| RBA | Rapid Bioassessment Protocols |
| RWA | Receiving Water Assessment |
| RGTSS | Rio Grande/Rio Bravo Toxic Substance Study |

**LIST OF ABBREVIATIONS USED IN THE REPORT** (continued)

| | |
|---|---|
| SEM | Simultaneously Extracted Metals |
| SWQMPM | Surface Water Quality Monitoring Procedures Manual |
| TEL | Threshold Effects Level |
| TDH | Texas Department of Health |
| TDS | Total Dissolved Solids |
| TCEQ | Texas Commission on Environmental Quality (formerly the Texas Natural Resource Conservation Commission (TNRCC)) |
| TOC | Total Organic Carbon |
| TPWD | Texas Parks and Wildlife Department |
| TSS | Total Suspended Solids |
| TSWQS | Texas Surface Water Quality Standards |
| USEPA | United States Environmental Protection Agency |
| USFWS | United States Fish and Wildlife Service |
| USGS | United States Geological Survey |
| WWTP | Wastewater Treatment Plant |

# INTRODUCTION

In February 1992, the United States and Mexico issued the first stage of the Integrated Environmental Plan for the U.S.-Mexican Border Area (First Stage: 1992-1994; the subsequent plan is now called US-Mexico Border XXI Program). This plan set the stage for the two countries to work jointly in identifying and solving problems along the international border. On November 13, 1992, the United States and Mexican Sections of the International Boundary and Water Commission (IBWC) approved Minute No. 289, titled "Observation of the Quality of the Waters Along the United States-Mexico Border." This agreement resulted in the first phase of the Rio Grande/Rio Bravo Toxics Substance Study (RGTSS). These studies have been a binational multi-phase and multi-agency effort to characterize the extent of toxic contamination of the Rio Grande/Rio Bravo and its tributaries.

The original study (Phase I) was prompted by a widely held belief that the river was being contaminated by toxic substances originating from industrial and agricultural sources near the border. This concern has intensified in recent years with the increasing number of industrial facilities within the border region. Review of prior studies yielded limited information, and while some evidence of contamination from toxic substances was revealed, no environmental assessment was provided.

The overall objective of the multi-phase study was to determine if the suspected contamination of the Rio Grande/Río Bravo by toxic substances was, in fact, occurring. Three objectives were identified:

- to identify any sites and contaminants of potential concern;
- to assess the effects these toxic substances may have on fish and other aquatic organisms living in the river; and
- to identify potential sources at sites where toxic substances were found.

Due to the variety of activities occurring in the Rio Grande/Rio Bravo Basin, it has been difficult to pinpoint exact sources of a particular contaminant. Concerns identified in the multiple phases of this study have assisted in focusing resources on those sites and those contaminants most likely to impair water quality.

Due to the size of the Rio Grande/Rio Bravo, these objectives have been carried out in multiple phases. Each phase has not been a duplication of the initial phase but rather an ongoing process of refining the study based on data collected, and focusing on areas of concern.

## Phases I and II

Field work for Phase I was done from November 1992 through March 1993. During this intensive monitoring program, 45 sites were sampled under low flow conditions, including 19 on the mainstem, and 26 on tributaries (13 in Texas and 13 in Mexico) from El Paso/Ciudad Juárez to Brownsville/Matamoros. Most stations were located in areas where the likelihood for toxic chemical contamination was the greatest, primarily in the vicinities of the major border sister cities.

Phase I of the RGTSS identified areas with the highest probability of toxic contamination. During the second phase of intensive monitoring (May 1995-December 1995), samples were collected at 46 stations, including 27 mainstem sites and 19 tributary sites from El Paso/Ciudad Juárez to Brownsville/Matamoros identified during Phase I. Sites from Phase I which showed a low potential for impact were excluded from Phase II. Sixteen sites were added to Phase II in areas not covered in Phase I. Four of these new sites were located on International Falcon and Amistad Reservoirs. Additional work was done in areas where toxic effects were found in Phase I to develop a better understanding of contamination and associated effects.

Monitoring in Phase I and II consisted of:

- Laboratory analysis of water, sediment, and fish tissue samples to assess the occurrence of approximately 150 different toxic chemicals.
- Toxicity tests on water and sediment samples to observe any effects on the survival or reproduction of sensitive test organisms (fathead minnows and water fleas).
- Bioassessment of fish and benthic macroinvertebrate communities. Numbers and types of fish and benthic macroinvertebrates were used to evaluate relative aquatic ecosystem health.

## Phase III

El Paso/Ciudad Juárez-Big Bend National Park was chosen for Phase III because it was one of the main areas of concern and this reach of the Rio Grande/Rio Bravo offers a unique opportunity to assess a variety of factors over these three areas including: habitat alteration, land use, water/sediment quality, flow variations and biological communities. Since toxic impacts alone can not be cited as the cause for aquatic life deterioration, both point and nonpoint sources of pollution as well as habitat modification must be investigated to be able to accurately describe the water quality and aquatic life conditions in the river. These components can be brought together to identify key stressors on each of these areas. El Paso/Ciudad Juárez and Presidio/Ojinaga both represent sources of stress on the Big Bend National Park area and the protected areas in the states of Chihuahua and Coahuila Mexico, important and valued natural resources. Phase III was conducted in November 1998.

## Background

The Rio Grande/Rio Bravo, the fifth longest river in North America and among the top 20 in the world, was once a formidable river. The river extends 3,051 km (1,896 miles) from the San Juan Mountains in Colorado through New Mexico, Texas, and Mexico to the Gulf of Mexico. From El Paso/Ciudad Juárez to the Gulf of Mexico, approximately two-thirds of the total length of the river forms the 2,008 km (1,248 mile) international boundary between United States and Mexico (Figure 1).

The international portion of the Rio Grande/Rio Bravo has been significantly modified in order to support the lives of millions of inhabitants along the border. Diversion for agricultural and domestic/industrial water supplies, and receipt of treated and untreated domestic/industrial wastewaters and agricultural runoff, have reduced the quantity and quality of the Rio Grande/Rio Bravo. Diversion structures and dams impounding water on the Rio Grande/Rio Bravo have eliminated natural flow in the mainstem. As a result the Rio Grande/Rio Bravo is a very complex hydrologic system (TNRCC 1994a; Miyamoto *et al*. 1995; Collier *et al*. 1996).

The entire Rio Grande/Rio Bravo Basin drains a 868,945 $km^2$ (335,500 $mi^2$) area in the United States (Colorado, New Mexico and Texas), and Mexico (Chihuahua, Coahuila, Durango, Nuevo Leon and Tamaulipas). Not all of the basin drains to the Rio Grande. Half of the total area lies within closed basins (397,008 $km^2$ [153,285 $mi^2$]) where water either evaporates or soaks into the ground, never making it to the Rio Grande/Rio Bravo. The actual drainage area of the Rio Grande/Rio Bravo is 471,937 $km^2$ (182,215 $mi^2$). Approximately half is in the United States (230,427 $km^2$ [88,968 $mi^2$]) and the remaining half in Mexico (241,518 $km^2$ [93,250 $mi^2$]) (Miyamoto *et al*. 1995).

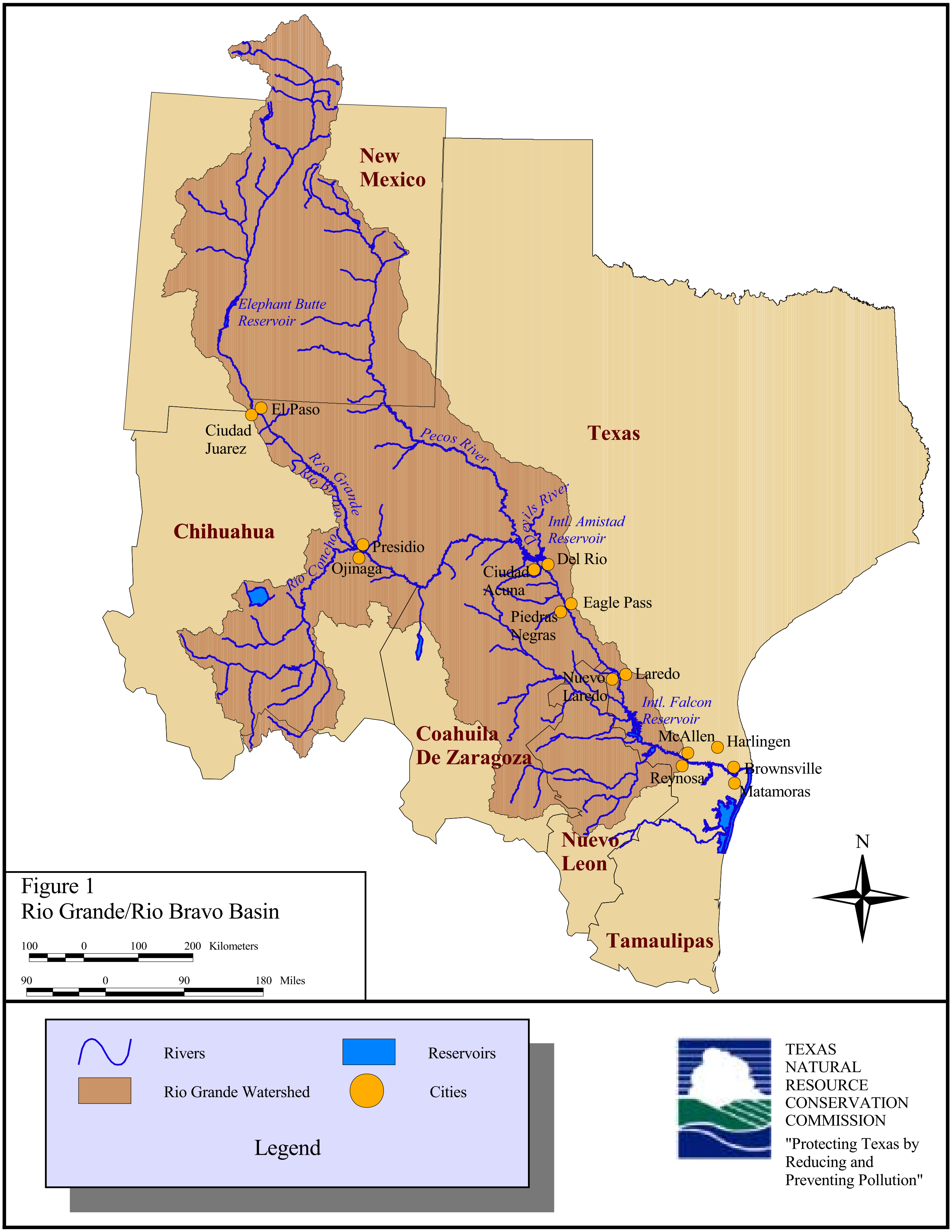


Figure 1
Rio Grande/Rio Bravo Basin

The study area for Phase III is located in a section of the Chihuahuan Desert ecosystem primarily comprised of arid to semi-arid biotic communities. The characteristic types of vegetation are shrubs which can form low closed thickets and short grass species that grow in association with creosote bush, yucca, gray thorn, various forbes and cacti (Border XXI 1996).

### El Paso/Ciudad Juárez to Presidio/Ojinaga

The majority of water flowing from Elephant Butte Reservoir through central New Mexico is redirected into canal systems in the El Paso area. A U.S. Geological Survey report refers to the Rio Grande as an "accidental river" between Elephant Butte Dam in New Mexico and Presidio, Texas/Ojinaga, Chihuahua. Elephant Butte Dam, located in New Mexico, was designed to retain all flow on the Rio Grande, releasing water only for irrigation purposes (Collier, *et al.* 1996). The Rio Grande/Rio Bravo in the El Paso/Ciudad Juárez area has been channelized and levies built to control flood waters.

Approximately 73% of the El Paso/Ciudad Juárez portion of the study area is considered rangeland; defined as grasses, grasslike plants, and shrubs. Another 10% of the area is classified as irrigated cropland; defined as cultivated fields, pastures, orchards, groves, and vineyards. The remaining 17 % is urban.

The area downstream of the Riverside Diversion Dam below El Paso/Ciudad Juárez extends 277.4 miles to the Rio Conchos confluence upstream of Presidio/Ojinaga. This area has been classified in Texas as Segment 2307. The limited U.S. irrigation return flows leaving the El Paso area are then used for irrigation in Hudspeth County. Channelization continues until Fort Quitman. The area from Fort Quitman to a point upstream of the Rio Conchos confluence can experience reduced flows. This section is part of the IBWC Preservation Project, where no channelization, rectification, bridges or sand-and-gravel mining has occurred in the 155 mile stretch.

### Presidio/Ojinaga to Big Bend National Park

The area around Presidio/Ojinaga is a combination of semi-urban, rangeland and a small amount of mining and industrial land uses. Some crop irrigation occurs upstream of Presidio/Ojinaga. The portion of the river downstream of Presidio/Ojinaga follows a winding channel through deep canyons separated by narrow valleys. The largest canyons are Santa Elena and Mariscal, both located within the boundaries of Big Bend National Park and Santa Elena and Del Carmen protected areas in Mexico. The Big Bend portion of Texas and adjacent portions of Mexico are the least populated portion of the study area. The land between Presidio/Ojinaga and Big Bend National Park is used for open range cattle grazing and recreation (Big Bend National Park, Rio Grande Wild and Scenic River, and Big Bend Ranch in the United States; Santa Elena and Del Carmen protected areas in Mexico) (National Park Service 1996). Historic mining activities are a potential concern of this area. Nonpoint source pollution originates from agricultural runoff, and urban runoff from the Presidio/Ojinaga area.

## Area Population

According to data from the 2000 census (United States and Mexico) there are roughly 4,440,461 residents living along the Texas and Mexico border. The majority of the border population reside in seven paired sister cities. Two of the seven sister cities are located within the study area, El Paso/Ciudad Juárez, Chihuahua and Presidio/Ojinaga, Coahuila. The populations of El Paso (679,622) and Ciudad Juárez (1,217,818) are the largest of the seven sister cities. The combined populations represent 43% of the total Texas/Mexico border population. In contrast, the populations of Presidio (4,167) and Ojinaga (24,313) are the smallest of the seven sister cities representing 0.64% of the total Texas/Mexico border population (Table1).

The remaining portion of the study area lies in Brewster County, and small rural communities in Chihuahua and Coahuila. The entire population of Brewster county is < 10,000. The majority of the residents reside in Alpine (± 6,000) and a lesser number in Marathon (±800). Exact numbers for the border area of Brewster County and adjacent area in Mexico are not reported, however, based on a few population numbers available, an approximate population estimate is < 1000 (Texas Almanac 1998-1999).

TABLE 1
POPULATIONS OF CITIES WITHIN THE PHASE III STUDY AREA

| City/Municipio, State | 1990 Population | 2000 Population | Percent Increase | Percent of Total Texas Border City Population | Percent of Total Mexico Border City Population |
|---|---|---|---|---|---|
| El Paso, Texas | 591,610 | 679,622 | 14.9 | 37.0 | |
| Ciudad Juarez, Chihuahua | 798,499 | 1,217,818 | 53 | | 46.8 |
| Presidio, Texas | 3,072 | 4,167 | 35.6 | 0.23 | |
| Ojinaga, Chihuahua | 23,910 | 24,313 | 2 | | 0.93 |
| Total Texas/Mexico Border Population- **Texas Cities** | 1,422,942 | 1,837,876 | 29.2 | | |
| Total Texas/Mexico Border Population- **Mexico Cities** | 1,758,448 | 2,602,585 | 48 | | |
| References: Texas State Data Center, http://txsdc.tamu.edu and Mexican National Institute of Statistics, Geography, and Informatics (INEGI) http://www.inegi.gob.mx | | | | | |

# Flow

## *El Paso/Ciudad Juárez to International Amistad Reservoir*

Flow to El Paso/Ciudad Juárez is controlled by irrigation releases from Elephant Butte Dam. Most of this flow is diverted for irrigation in the Mesilla Valley in New Mexico. The remainder is diverted at the American Dam (United States) and International Dam (Mexico) in El Paso/Ciudad Juárez for municipal use, and in the El Paso and Juárez Valleys for irrigation. This causes the Rio Grande/Rio Bravo flow to be intermittent in the area from below Riverside Diversion Dam to upstream of Fort Quitman. Occasional unscheduled releases from Elephant Butte Dam due to high runoff and stormwater runoff can replenish flow in this portion of the river. Flow below Fort Quitman to Presidio/Ojinaga is mainly municipal wastewater discharges, irrigation return flow and rainfall events (TNRCC 1994a; Miyamoto *et al*. 1995; Collier *et al*. 1996).

Other than the sources mentioned above, the only perennial source of flow into the Rio Grande/Rio Bravo below Fort Quitman comes from the Rio Conchos, a Mexican tributary located near Presidio/Ojinaga (454 km [284 miles] downstream of El Paso). The Rio Conchos adds about roughly an equal amount of flow to the river at this point. The contribution for flow from the Rio Conchos is significant. In the past few years, flow in the Río Conchos has been jeopardized by a severe drought and growth in northern Mexico, and the state of Chihuahua. Most of the smaller tributaries are intermittent, having defined channels but ceasing to flow during dry periods (Bowman 1993; TNRCC 1994a; Miyamoto *et al*. 1995). The next significant sources of inflow come 312 miles (500 km) downstream of El Paso/Ciudad Juárez where two major United States tributaries, the Pecos and Devils Rivers, flow into International Amistad Reservoir. Many smaller tributaries and springs also contribute to flow in the section of river downstream of Big Bend National Park.

## Climate

The upper portion of the Rio Grande/Rio Bravo flows through the northern Chihuahuan Desert and has an arid/semi-arid climate. As the river flows south, it becomes less arid and more tropical as it reaches the Gulf of Mexico. The Rio Grande/Rio Bravo region tends to be hot, warm and windy, and averages more 38°C (100° F) days from May to September than any part of Texas. Temperatures tend to be warmer in the lower portion of the basin than in the north. Seasonal rainfall (August to November) averages 19.8 cm (7.8 inches) at El Paso/Ciudad Juárez, the lowest in Texas (Miyamoto *et al.* 1995; TNRCC 1994a).

## Potential Sources of Chemical Contamination

An objective of the study was to determine potential sources of contaminants in the west Texas/Northern Chihuahua portion of the Rio Grande/Rio Bravo. The following are a few general categories associated with the Rio Grande/Rio Bravo basin.

### *Wastewater Sources*

Large volumes of treated and untreated municipal/industrial wastewater flow in to the Rio Grande/Rio Bravo daily. Industrial and municipal wastewater can contain thousands of chemicals with only a few causing aquatic toxicity (Rand 1995). Many components of water including total organic carbon (TOC), total suspended solids (TSS), pH, and hardness can have a strong effect on toxicity. Toxic effect is dependent upon the synergistic (total effect > sum of the individual effects), and antagonistic (interaction of two or more substances) activities of the toxic substances present. Wastewaters containing toxic substances are influenced by mixing, by effluent characteristics, and by receiving stream characteristics, all of which can produce toxicity levels different from pure compounds. These factors make wastewater toxicity difficult to determine by chemical analysis alone (Rand 1995).

### *Industrial Sources*

Prior to the 1900s, the border region was sparsely populated. With the construction of Elephant Butte Dam in New Mexico (1916), International Falcon Dam (1954) and International Amistad Dam (1968), the Rio Grande/Rio Bravo flood plain was transformed from a largely barren region into a major agricultural center for Texas and Mexico. In the 1950s the Rio Grande/Rio Bravo border population began to grow with increased employment opportunities in the textile and apparel industries. By the 1980s, manufacturing began to grow with the construction of industrial assembly plants in Mexico commonly referred to as maquiladoras. Maquiladoras have attracted mainly the electronic, automobile, petrochemical and textile manufacturing industries. More than 80% of the Mexican maquiladoras are located in the border region. Of the 1551 maquildoras along the Texas, Arizona and California borders, 614 (39.6%) are located between El Paso/Ciudad Juárez and Brownsville/Matamoros. Of the 614 maquiladoras, most are located in Ciudad Juárez, Nuevo Laredo, Reynosa and Matamoros (Miyamoto *et al.* 1995; USEPA 1996). By October 2001, there were 436 maquiladoras in Chihuahua and 275 in Coahuila (Banco de Informacion Economica, Mexican National Institute of Statistics, Geography, and Informatics (INEGI), http://www.inegi.gob.mx).

### *Nonpoint Source*

There are several major categories of nonpoint source pollution along the Rio Grande/Rio Bravo. In the heavily populated areas, the main source is urban runoff and storm sewers. In other areas, on-site disposal (septic systems), runoff from irrigated cropland, rangeland and natural erosion are the dominant nonpoint sources. The following are possible nonpoint source pollution categories for the upper Rio Grande/Rio Bravo.

| River Reach | Sources |
| --- | --- |
| **El Paso/Ciudad Juárez** | Urban Runoff/Storm Sewers; On-site Disposal (Septic Tanks); Irrigated Cropland Production; Erosion; Rangeland; Confined Animal Feeding Operations. Some of these sources may originate in New Mexico. |
| **Presidio/Ojinaga** | Irrigated Cropland Production; Urban Runoff; Municipal Point Sources; On-site Disposal (Septic Tanks); Erosion; Rangeland; Mining |
| **Big Bend National Park/Canyon de Santa Elena Protected Area** | Erosion; Rangeland; Mining |

# PROJECT DESCRIPTION

The study area begins upstream from the El Paso/Ciudad Juárez metropolitan area to the lower end of Big Bend National Park (Figures 2 and 3). Phases I and II identified the reach from El Paso/Ciudad Juárez to Presidio/Ojinaga as a high potential risk for toxic substance effects and a moderate potential for toxic substance effects at Big Bend National Park-Santa Elena Canyon. This section of the Rio Grande/Rio Bravo was also cited in Mexico's Phase II technical report as an area requiring further study due to increasing salinity.

Initial selection of Phase III sample sites was based on "hot spots" identified during Phase II. Other "hot spots" identified during Phase I and II were located in the areas of Del Rio, Eagle Pass, and Laredo. These areas are being addressed through other monitoring programs.

The primary goals of this project were:

- Better definition of problems identified in Phase I and Phase II with more intensive monitoring at fewer sites.
- Use multivariate analytical tools to identify which stressors (habitat, land use, physical/chemical water quality data) contribute to observed differences among sites.
- Determine the stressors that have the greatest effects on aquatic communities and human health.

All data is available to local, state and federal (United States and Mexico) agencies for use in setting priorities for wastewater treatment upgrades, nonpoint source best management practices and other potential mitigation practices.

## Study Area

The Phase III stations were located upstream and downstream of three very distinct areas; upstream/downstream of the El Paso/Ciudad Juárez metropolitan area, upstream/downstream of the Río Conchos confluence with the Rio Grande/Rio Bravo and sites at the upper and lower ends of Big Bend National Park. El Paso/Ciudad Juárez and Presidio/Ojinaga both represent sources of stress on the Big Bend National Park/Canyon de Santa Elena Protected Area, important and valued natural resources. This reach of the Rio Grande/Rio Bravo offers a unique opportunity to assess a variety of factors over these three areas including: habitat alteration, land use, water/sediment quality, flow variations and biological communities. These components can be brought together to identify key stressors on each of these areas.

| Sample Areas | General Land Use | General Degree of Impairment |
|---|---|---|
| El Paso/Ciudad Juárez | Heavily urbanized/ high agricultural use | Severe habitat alteration; degraded water quality |
| Presidio/Ojinaga | Moderately urbanized/high agricultural use | Moderate habitat alteration; moderate degree of impairment |
| Big Bend National Park/Canyon de Santa Elena Protected Area | Natural area/ recreational use/limited agricultural use/historic mining activities | Limited habitat alteration; low degree of impairment; impacted by upstream areas |

## Study Sites

| STATION No. | STATION DESCRIPTION (Figures 2 and 3) |
|---|---|
| 1 | **Rio Grande/Rio Bravo at Courchesne Bridge** (TNRCC Station ID 13272) Located near the Texas/New Mexico state line. The river at this site was shallow with 2 to 2.5 ft deep pools and exposed sand bars. The sediment was sandy with a light covering of silt. The vertical banks were 2 to 3 feet high and covered with grassy vegetation. Limited riparian vegetation, grasses and small shrubs. Influenced by urban/ agricultural runoff, and by flows coming from Elephant Butte Dam in New Mexico. The use of water for irrigation upstream contributes large volumes of irrigation return flow and agricultural runoff. El Paso Co., Texas/Chihuahua; Segment 2314. Latitude N 31° 48' 10"; Longitude W 106° 32' 25" |
| 2 | **Rio Grande/Rio Bravo at Zaragosa International Bridge** (TNRCC Station ID 13234) Located downstream of a significant part of El Paso/Ciudad Juárez. Strongly influenced by urban runoff. The moderately steep banks were 2 to 3 feet high, and sparsely covered with mowed grass on the U.S. bank and grass/shrubby vegetation on the Mexican bank. The surrounding area was disturbed with sparse vegetation. Heavily urbanized. Sediment was a grayish brown silt over sand. El Paso Co., El Paso, Texas/Ciudad Juarez, Chihuahua, Mexico. Segment 2307. Latitude N 31° 40' 20"; Longitude W 106° 20' 16". |
| 3 | **Rio Grande/Rio Bravo Upstream Rio Conchos Confluence** (TNRCC Station ID 13721) Located near Presidio/Ojinaga. The surrounding area is predominantly range land with some irrigated crops. Mainly influenced by rangeland/agricultural runoff. The banks were low. Riparian vegetation was mostly grass, shrubs and small trees. Levees are in place to prevent flooding. Presidio Co., Texas/Chihuahua, Mexico. Segment 2307. Latitude N 29° 36' 32"; Longitude W 104° 27' 23". |
| 4 | **Rio Grande/Rio Bravo Downstream Rio Conchos Confluence** (TNRCC Station ID 13229) Located downstream of Presidio/Ojinaga. Mainly influenced by rangeland/ agricultural runoff as well as urban runoff and wastewater discharges from Presidio/Ojinaga. Surrounding area is the start of the rocky mountainous terrain. Facing downstream the left bank rocky terrain with little flood plain while the right bank was low with grass and small shrubby vegetation and a wide flood plain. The river bottom was gravel with light brown silt. Presidio, Texas/Ojinaga, Chihuahua. Segment 2306. Latitude N 29° 32' 00"; Longitude W 104° 21' 00". |
| 5 | **Rio Grande/Rio Bravo at Santa Elena Canyon** (TNRCC Station ID 13228) Located at the canyon mouth in Big Bend National Park. U.S. bank was low with flood plain type vegetation. The Mexico bank was composed of the high Santa Elena Canyon wall with flood plain vegetation at the base. The area is 100% natural on both sides with limited grazing on the Mexican side and recreational use (hiking, rafting) on the U.S. side. The water was olive green. The sediment was a gray/brown silt. Brewster Co., Texas/Chihuahua, Mexico. Segment 2306. Latitude N 29° 10' 00"; Longitude W 103° 33' 15". |
| 6 | **Rio Grande/Rio Bravo at Boquillas Canyon** (TNRCC Station ID 16193) Located at the Boquillas Canyon head, downstream of Boquillas del Carmen, Coahuila, Mexico. The U.S. and Mexican banks were composed of high canyon walls with a narrow flood plains on both sides of the river. The area is 100% natural on both sides with limited grazing on the Mexican side and recreational use (hiking, rafting) on the U.S. side. The bottom was composed of cobble and light brown silt. Brewster Co., Texas/Coahuila, Mexico. Segment 2306. Latitude N 29° 12' 10"; Longitude W 102° 54' 00". |

## Study Participants

The Texas Commission of Environmental Quality (TCEQ) coordinated with the primary study participants, including the United States Environmental Protection Agency (USEPA), International Boundary and Water Commission-United States and Mexican Sections (IBWC) and the Comision Nacional del Agua (CNA). Various other aspects of the study (logistics and technical support) were accomplished through coordination with the United States National Park Service-Big Bend National Park (USNPS-BBNP). The United States Bureau of Reclamation (USBR) provided flow measurement support in the upper portion of the study area.

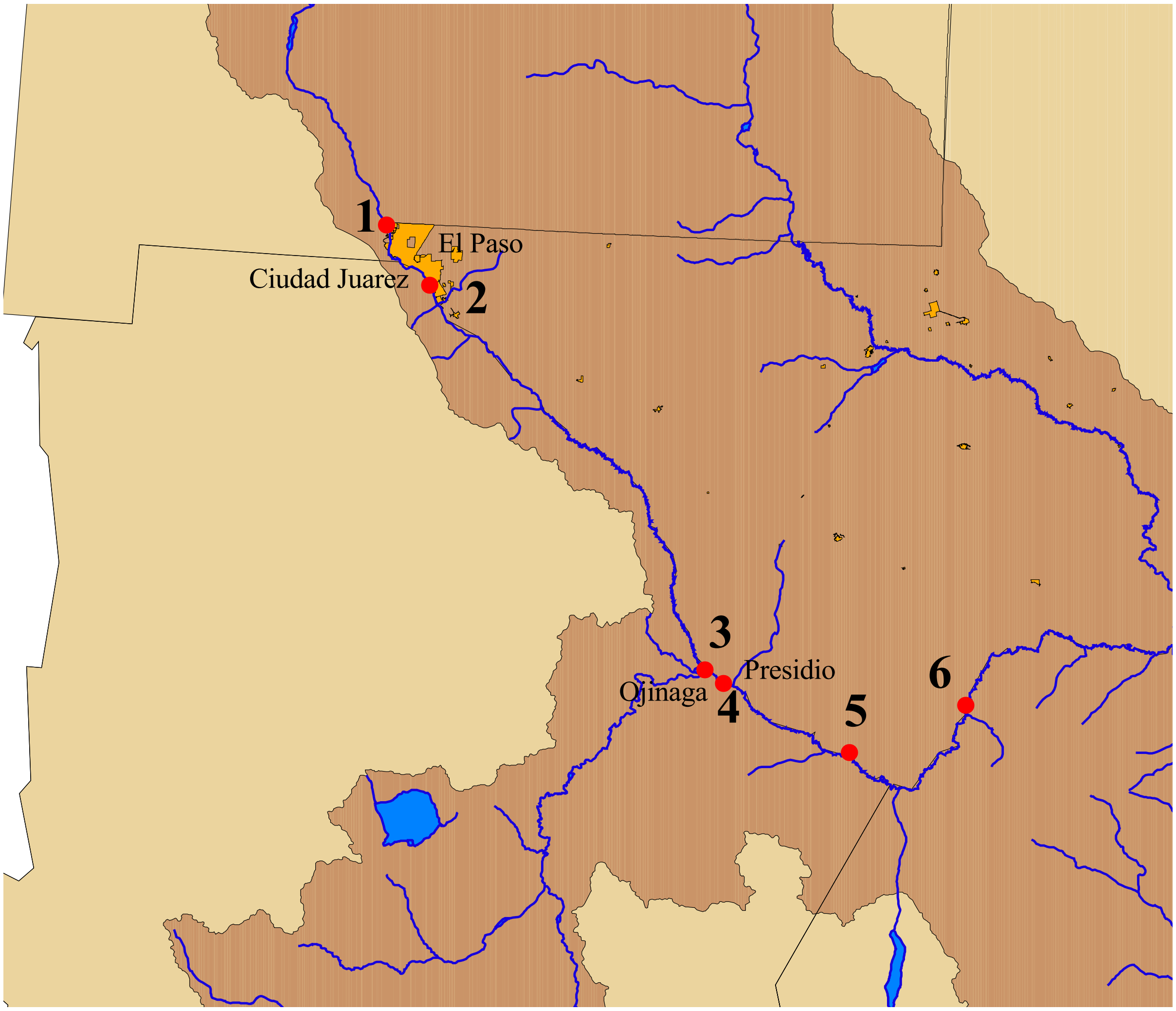



Figure 2
Monitoring Sites for Phase III of the
Rio Grande Toxic Substance Study 1998

40 0 40 80 Kilometers

30 0 30 60 Miles

N

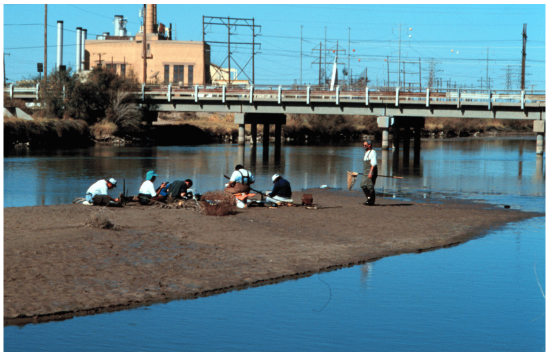
| | |
|---|---|
| Monitoring Sites | Reservoirs |
| Rivers | Rio Grande Watershed |

Legend

TEXAS
NATURAL
RESOURCE
CONSERVATION
COMMISSION
"Protecting Texas by
Reducing and
Preventing Pollution"

## Timing of Study

The project encompassed study sites in the upper border reach of the Rio Grande Basin from El Paso/Ciudad Juárez to Big Bend National Park. Irrigation season in the El Paso area causes high flows during normal low flow months (May through September). For the purpose of this study, sampling was conducted in the late fall, in an attempt to correspond to the short break in irrigation (November to January). The sampling was conducted from November 7 to 12, 1998.



Station 1- Courchesne Bridge

Station 2- Zaragosa Bridge

Station 3- Above Presidio/Ojinaga

Station 4- Below Presidio/Ojinaga

Station 5- Santa Elena Canyon

Station 6- Boquillas Canyon

Figure 3. Photographs of Study Sites

# METHODS

Water, sediment, tissue and biological data collection followed methods detailed in the TNRCC Surface Water Quality Monitoring Procedures Manual (SWQMPM). Chemical parameters analyzed were based on the findings of Phase II. The United States laboratory (TNRCC-Houston) conducted analyses for metals and selected organics in water, sediment and tissue (metals only) as well as conventional water quality parameters.

## Field and Laboratory Procedures

The following methods were used in the laboratory and field for the determination of physical, chemical and biological characteristics. All sampling, data collection and sample preservation procedures were done in accordance with standardized TNRCC Surface Water Quality Monitoring Procedures Manual (SWQMPM) (TNRCC 1999a). Laboratory analyses were done according to USEPA (1983) and American Public Health Association (APHA)(1989) guidelines. All water, sediment and tissue samples, for chemical analysis, were analyzed by the TNRCC Laboratory in Houston. Analytical methods used by the TNRCC are listed in APPENDIX A. Water and sediment toxicity samples were analyzed at the USEPA Laboratory in Houston. An attempt was made to collect all samples under the lowest flow conditions possible. Sampling under low flow conditions gives a better indication of impact from industrial/municipal discharges. Higher flows tend to have a dilution effect, reducing the ability to assess pollutant impacts.

### *Field Measurements*

Field instruments were calibrated and post-calibrated with each sampling event. All measurements were done in the field. Samples were collected according to methods detailed in Chapter 2 of the TNRCC SWQMPM.

| Parameter | Method |
|---|---|
| Temperature (°C) | Hydrolab Surveyor II |
| Dissolved Oxygen (mg/L) | Hydrolab Surveyor II |
| pH (s.u.) | Hydrolab Surveyor II |
| Conductivity (µmhos/cm) | Hydrolab Surveyor II |
| Instantaneous Flow | On-site measurements by US Bureau of Reclamation and USIBWC |

### *Flow*

Instantaneous flows were measured at the time of sample collection. Flow measurements were made by IBWC and US Bureau of Reclamation field staff from El Paso and Presidio.

### *Water Chemistry*

Water samples (conventional chemical) were needed to further assess elevated salinity. Salinity was identified as a potential stressor in Phase II, especially in Presidio/Ojinaga and Big Bend National Park/Canyon de Santa Elena Canyon. In Phase II, the highest chloride concentrations were found from El Paso/Ciudad Juárez to Big Bend National Park. Routine water samples were analyzed for total organic carbon (TOC), total suspended solids (TSS), total dissolved solids (TDS), total hardness, alkalinity, chloride, sulfate, total kjeldahl nitrogen, $NH_3$-N, $NO_3$-N + $NO_2$-N, total phosphorus, and orthophosphorus. Grab samples for all parameters were collected from mid-stream by submerging the container to a depth of one foot. Water sample specifications (volume, preservation and holding time) are summarized in Table 2.

TABLE 2
Summary of Water Sample Preservation,
Storage, and Handling Requirements-CONVENTIONAL

| Parameters | Recommended Containers | Sample Volume (ml) | Preservation | Maximum Holding Time |
|---|---|---|---|---|
| **CONTAINER 1** | | | | |
| **Alkalinity, TSS, Cl, $SO_4$, $NO_3 + NO_2$, $OPO_4$** See individual volumes and hold times required for parameters taken from Cubitainer 1 listed below | Cubitainer or glass | 1000 | Cool to 4°C, dark | |
| TSS (00530)/VSS (00535) | | 400 | " | 7 days |
| Chloride (Cl) (00940) | | 100 | " | 28 days |
| Sulfate ($SO_4$) (00945) | | 100 | " | 28 days |
| Orthophosphorus ($OPO_4$) ① (00671) | | 150 | " | Filter ASAP; 48 hrs until analysis |
| Nitrate + Nitrite (00630) ($NO_3 + NO_2$) ② | | 150 | " | 48 hours |
| **TDS** (70300) | | 250 | " | 7 days |
| **CONTAINER 2** | | | | |
| **$NH_3$, $TPO_4$, TOC** See individual volumes and hold times required for parameters taken from Cubitainer 2 listed below | cubitainer or glass | 1000 | 1-2 ml conc.$H_2SO_4$ to pH <2 and cool to 4°C, dark | |
| Ammonia ($NH_3$) (00610) | | 150 | " | 28 days |
| Total Phosphorus ($TPO_4$) (00665) | | 150 | " | 28 days |
| Total Organic Carbon (TOC) (00680) | | 100 | " | 28 days |

Dissolved metals-in-water samples were collected using ultra-clean procedures; a peristaltic pump was used to filter water directly from the stream through a 0.45 micron (μ) in-line filter and pre-treated Teflon tubing. The TNRCC Houston Laboratory used metals grade nitric acid to clean the tubing. Dissolved metals samples were collected in commercially pre-acidified one-quart plastic bottles containing metals grade nitric acid. Total metals-in-water were collected using the same ultra-clean method without the in-line filter (TNRCC 1999a). Samples were collected from a depth of one foot. Metals in water sample specifications (volume, preservation and holding time) are summarized in Table 3.

Organochlorine pesticides in water were collected at all sites. Samples were collected from a depth of one foot and containers were filled to the top leaving no head space. Organochlorine pesticide in water sample specifications (volume, preservation and holding time) are summarized in Table 4.

TABLE 3
Summary of Water Sample Collection Methods,
Preservation, Storage, and Handling Requirements-METALS

| Parameters | Recommended Containers | Sample Volume (ml) | Preservation | Maximum Holding Time |
|---|---|---|---|---|
| **Metals -In-Water** | | | | |
| **DISSOLVED** (except Hg) | $HNO_3$ cleaned plastic bottle | 1000 | Filter at sample site with 0.45 micron in-line filter into ultra-pure $HNO_3$ preacidified container to pH<2 | 6 months |
| **TOTAL** (except Hg) | $HNO_3$ cleaned plastic bottle | 1000 | Preacidified container with 5 ml ultra-pure $HNO_3$ to pH<2 | 6 months |
| **TOTAL MERCURY** (Hg) | $HNO_3$ cleaned glass or Teflon bottle | 250 | Preacidified with 1-2 ml ultra-pure $HNO_3$ to pH<2 | 28 days |
| **HARDNESS** (00900) | quart cubitainer | 250 | Cool to 4°C, dark **OR** | 48 hours |
| | | | Filtered and 2 ml conc $H_2SO_4$ or $HNO_3$ to pH < 2; Cool to 4°C, dark | 6 months |

TABLE 4
Summary of Water Sample Collection Methods,
Preservation, Storage, and Handling Requirements-ORGANICS

| Parameters | Recommended Containers | Sample Volume (ml) | Preservation | Maximum Holding Time |
|---|---|---|---|---|
| **Organics/Pesticides -In-Water** | | | | |
| **ORGANICS**<br><br>**PESTICIDES & HERBICIDES**<br>•Organophophorus Pesticides<br>•Organochlorine Pesticides<br>•Chlorinated Herbicides<br><br>**SEMI-VOLATILE ORGANICS** | 1- qt glass jar with teflon lined lid per sample type; must be prerinsed with hexane, acetone, or methylene chloride | 1000<br><br>**Each sample type requires 1000 ml in a separate container** | Cool to 4°C, dark<br><br>If chlorine is present, add 0.1g sodium thiosulfate | 7 days until extraction |

## *Sediment Chemistry*

Single composite sediment samples collected in Phase I and II indicated the presence of metals at all sites. These samples were all collected in a single general area at each site. In Phase III, a check for variability over a wider area was done by randomly collecting three replicate samples at each sample site. Sediment samples were collected with a stainless steel Ekman dredge or collected by hand with a Teflon scoop. The entire surface layer of fine grained most recently deposited sediment was used from each grab. Sediment was generally collected in slack water areas that allowed for sediment accumulation in the immediate vicinity of the designated sampling site. Where conditions allowed, sediment was collected from both the United States and Mexican portions of the river. Each replicate sediment sample was a composite with a minimum of three sub-samples. Sediment samples were analyzed for metals (aluminum, arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, and zinc), selected pesticides (DDD, DDE, DDT, aldrin, alpha BHC, beta BHC, delta BHC, dieldrin, endosulfan, endosulfan II, endosulfan sulfate, endrin, endrin aldehyde, gamma BHC, heptachlor, heptachlor epoxide, methoxychlor), particle size composition, TOC, and acid volatile sulfide. Sediment samples were collected according to methods detailed in Chapter 5 of the TNRCC SWQMPM. Sediment sample specifications (volume, preservation and holding time) are summarized in Table 5.

TABLE 5
Summary of Sediment Sample Collection Methods,
Preservation, Storage, and Handling Requirements-SEDIMENT

| Parameters | Recommended Containers | Sample Volume (grams) | Preservation | Maximum Holding Time |
|---|---|---|---|---|
| **Sediment** | | | | |
| **Metals** | 1- pint glass jar with Teflon lined lid; special treatment not required | 500 g | Cool to 4°C, dark | 28 day ① |
| **Organics** | 1-pint glass with Teflon lined lid; special treatment not required | 500 g | Cool to 4°C, dark | 14 days |
| **Conventionals** AVS, TOC, Grain Size, % Solids | 1-pint glass jar with Teflon lined lid | 500 g | Cool to 4°C, dark | 14 days ② |

① Holding time for mercury in sediment is 28 days. Other metals in sediment 180 days.
② Holding time for AVS is 14 days; for grain size, TOC, oil and grease, and percent solids (moisture content) 28 days.

## *Ambient Water and Sediment Toxicity Testing*

Sediment toxicity samples were collected in two one-quart glass jars using the same method described in sediment sampling for chemical parameters. Standard laboratory test procedures for *Ceriodaphnia dubia* (water flea) and *Pimephales promelas* (fathead minnow) and statistical data analyses are conducted by the USEPA Region 6 laboratory according to Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms (USEPA, 1994) and Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms (USEPA, 1993). The method for sediment testing is an adaptation of USEPA Corvallis methods and US Army Corp of Engineers drilling mud procedures developed by Terry Hollister and Able Uresti at the USEPA Houston Laboratory. Sediment elutriates are prepared by combining a subsample from the original sample with appropriate culture water. The sediment sample is mixed with culture water in a 1:4 volume-to-volume ratio with one part sediment and four parts culture water. After combining, the mixture is tumbled end-over-end for approximately 24 hours, after which the mixture is allowed to settle for an additional 24 hours at 3-4 °C. After settling, the elutriate (upper liquid portion) is siphoned off and filtered through a 1.5 micron glass fiber filter to remove background material. Standard laboratory tests and statistical data analyses are conducted according to the methods referenced above (USEPA 1993 and 1994; Howell *et al*. 1996).

Toxicity to *Ceriodaphnia dubia* (water flea) is tested using a seven-day survival and reproduction short-term chronic test observing mortality and number of offspring per female. Toxicity to *Pimephales promelas* (fathead minnow) is tested using a seven-day embryo-larval survival and teratogenicity; short-term chronic test observing mortality rate teratogenic effects, and/or abnormal swimming behavior. Toxicity sample specifications are summarized in Table 6.

TABLE 6
Summary of Sediment Sample Collection Methods,
Preservation, Storage, and Handling Requirements-TOXICITY

| Parameters | Recommended Containers | Sample Volume (grams) | Preservation | Maximum Holding Time |
|---|---|---|---|---|
| **Toxicity in Water** | Two 1-gallon cubitainers | 8000 ml | Cool to 4°C, dark | 7 days |
| **Toxicity in Sediment** | 1-quart glass jars | Two full jars | Cool to 4°C, dark | 7 days |

## Validity of Test Organisms

### Fathead Minnow (*Pimephales promelas*)

Currently, the fathead minnow (*Pimephales promelas*) is the most commonly used warm water species for acute and chronic toxicity tests. Fathead minnows belong to the carp/minnows family, Cyprinidae. The number of carp/minnow species makes it the most dominant freshwater family. Specifically, the fathead minnow thrives in ponds, lakes, ditches and slow moving muddy streams, feeding on anything from living invertebrates to detritus. Even though it is a tolerant species, the fathead minnow is an important part of the aquatic food chain, has a widespread distribution in North America and is easily cultured the laboratory (Rand 1995).

### Water Flea (*Ceriodaphnia dubia*)

Water fleas (*Ceriodaphnia dubia*) are freshwater microcrusteaceans in a group called Cladocerans. They are abundant throughout North America, inhabiting lakes, ponds and quiet sections of streams and rivers. Water fleas are important in the aquatic community because they represent a significant portion of the diet of numerous fish species (Rand 1995).

### Reliability of Sediment Toxicity Tests

In a ranking of freshwater chronic sediment toxicity tests, based on reliability, ecological relevance, exposure relevance, availability, interferences and chemical discrimination, fathead minnows had a rating of 11.5, and water fleas had a rating of 13.5 (highest rating was 15, lowest was 7.5) (American Petroleum Institute 1994). The sediment elutriate test is a useful way to represent exposure to chemicals, that occur in sediment, after sediments have been resuspended in the water column. This method is used to test for the toxic effect on organisms inhabiting the water column (plankton, fish). It does not relate to the effects on organisms living at or in the sediment. Testing of whole sediment was not within the scope of this project. For the majority of the Rio Grande/Rio Bravo this test procedure is appropriate due to resuspension of sediments under variable flow rates (American Petroleum Institute 1994).

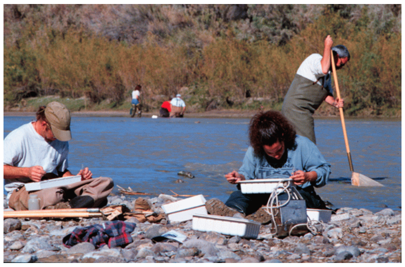
# Biological Community

Benthic macroinvertebrate and fish were collected for community assessments in Phase III. Biological sampling methods, located in Chapter 7 of the TNRCC SWQMPM, were used.

## *Benthic Macroinvertebrate Collection Methods*

### Kicknet/Snags

Benthic macroinvertebrate sampling followed standard procedures and protocols established by the TNRCC



SWQMPM (Chapter 7). In a riffle, a 5-minute kicknet sample was collected in a "zig-zag" pattern from downstream end of riffle to upstream end making sure to cover as much of the width of the riffle as possible. In a run/glide area, a 5-minute kicknet sample (if possible) was collected in a "zig-zag" pattern from the downstream end of run/glide to the upstream end. When the primary substrate in the stream was unsuitable (e.g., sand, bedrock) samples were collected from snag habitat. Snags are submerged woody debris (e.g., sticks, logs, roots, boulders, etc.) which are exposed to the current. Snags, 0.5 - 2.5 centimeters in diameter that were submerged in the stream for a minimum of two weeks were used. Moss, algae and/or fungal growth on the snags was used as evidence that the snag had been in the stream for an adequate time period to allow colonization by benthic macroinvertebrates. As with benthic macroinvertebrate samples collected from the stream bottom, snag samples were collected following rapid bioassessment protocols (RBA). Benthic samples were preserved in 10% formalin and were returned to the laboratory for processing.

Organisms were sorted, enumerated, and identified to the lowest possible taxonomic level. Specimens were identified and data analysis conducted according to the following taxonomic guidelines:

| | |
|---|---|
| • Insecta identified to genus | • Decapoda identified to genus |
| • Gastropoda identified to genus | • Oligochaeta identified to class (Oligochaeta) |
| • Pelecypoda identified to genus | • Nematoda identified to Phylum (Nematoda) |
| • Isopoda identified to genus | • Turbellaria identified to genus |
| • Ostracoda identified to subclass (Ostracoda) | • Hydracarina left at Hydracarina |
| • Amphipoda identified to genus | • Hirudinea identified to class (Hirudinea) |

### Pool Macrobenthic Communities

At each site, an Ekman dredge was used to sample 3 $ft^2$ of substrate. Subsamples were composited, rinsed in a sieve bucket, and preserved in 5% formalin. In the lab, pool macrobenthic samples were rinsed in a U.S. Standard No. 30 soil sieve, and organisms were sorted from debris at 10X magnification using a dissecting microscope. Specimens were enumerated and identified to the lowest taxonomic level possible, generally genus or species. Taxonomic counts were used to calculate values for 45 biological metrics. These metrics are discussed in the Data Evaluation section of this report.

## *Fish Community Collection Methods*

Fish community surveys were conducted using boat and/or backpack electrofishing unit(s) and seines at all sites. Electrofishing was conducted for 15-minutes with the primary objective being to collect a representative sample of fish species present in proportion to their relative abundances. An attempt was made to sample all major habitat types in a study reach. Seining was conducted using a fifteen-foot straight seine with 1/4 inch mesh. A minimum of six seine hauls were collected. Additional hauls were conducted according to available habitat and whether or not additional species were being added. Specimens were examined in the field for gross morphological pathologies, and the proportion of individuals, if any, that were diseased or had other physical abnormalities were recorded. Fishes not identified in the field were fixed in 10% formalin and later transferred to 75% ethanol.

## *Aquatic Community Health*

Based on data from Phase I and II, metals were the most common contaminant found in water and sediment. Algae (filamentous, if present), benthic macroinvertebrates (herbivores and predators), and fishes (forage and predators) were collected and analyzed for metals to determine if bioaccumulation is occurring. Availability of size and types of samples varied depending on the site. Fish and benthic macroinvertebrate collection methods used were similar to those described in the biological community section. However, sampling continued until enough organisms were collected to submit for chemical analysis. Samples were shipped to the lab in glass vials or ziplock bags. Tissue collection methods are detailed in Chapter 6 of the SWQMPM.

## *Human Health-Edible Fish Tissue*

The study attempted to further define potential human health risk by the analysis of the edible portion of fish tissue for metals and selected pesticides in target species (largemouth bass, catfish and/or carp). Tissue samples were also analyzed for percent lipid content. Fish tissue collection followed *The Texas Tissue Sampling Guidelines*, a consensus document prepared by state and federal agencies (TNRCC 1999a). Each tissue sample represents a composite of at least five individual organisms, except where fish were scarce and a smaller number was utilized. The number of individuals comprising each sample was documented and taken into account when evaluating the data. Two edible tissue samples were submitted from six sites on the Rio Grande/Rio Bravo. A concentrated effort was made to include a predatory species and a bottom-feeding species from each site. Tissue samples were analyzed for metals.

## *Fish Tissue Collection Methods*

Fish were collected with a boat-mounted electrofishing unit. The fish selected for analysis were kept in native water until processed. The total length of each fish was recorded along with any deformities, wounds or abnormalities. Both whole body and edible tissue samples were double wrapped in aluminum foil (dull side toward fish). Each fish in a composite sample was individually wrapped, labeled and placed in a plastic bag with the other individuals for that composite sample. Fish samples for edible tissue were prepared by the TNRCC Houston laboratory personnel.

The number of fish used in each composite sample ranged from one to six. The number of target species was limited, and varied widely in size at some locations. A decision was made to use fewer fish of similar size rather then more of varying size.

Target species were largemouth bass (*Micropterus salmoides*), channel catfish (*Ictalurus punctatus*), and common carp (*Cyprinus carpio*). The only target species collected was the common carp. Alternate species collected included blue catfish (*Ictalurus furcatus*) and flathead catfish *(Pylodictus olivaris)*.

## *Habitat Assessments*

Reach-based habitat assessments were conducted at eight sites in the Rio Grande Basin (Table 7). Two stations were not included in the Phase III sampling effort but added additional information to the data set. The TNRCC Receiving Water Assessments (RWA) protocols were employed at each site as well as the more qualitative habitat assessment protocols in the EPA's "Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers" (TNRCC 1999b;USEPA 1999).

For the RWA assessments, a sampling reach at each site was selected based on the areas of biological sample collection of both fish and benthic macroinvertebrates. Each sampling reach length was based on 40 times the average channel width within the area of biological sampling. The upper and lower reach boundaries were located based on this length and as an overlay of the biological collection area. Transects were located within the reach at regularly spaced intervals.

Channel, riparian, and flood plain characteristics associated with each sampling reach were measured according to RWA protocols. These attributes are ones which most influence the fish and benthic macroinvertebrate communities at each site. The Rapid Bioassessment Protocols (RBA) were used to provide additional information on the reach and to provide data on how RBA and RWA assessments compare on large river systems. The RBA assessment is comprised of rating 10 parameters which include such attributes as instream cover, substrate composition, bank stability, and riparian vegetative width. The RBA assessment generates a numerical score that can be used to compare physical and biological conditions of different streams with respect to a known reference condition in the same ecoregion. The RBA protocols provide for each of the numerical scores derived from each site to be compared to an eco-region reference site. Reference sites were not selected for this study as the entire Rio Grande Basin is in one eco-region and there are no other large rivers comparable to the Rio Grande in this ecoregion. Instead, the RBA scores from each site were compared to each other and to the RWA scores. The RBA protocols were not developed for large river systems, so it was expected that their use would be somewhat limited.

### Scoring Habitat Data

The habitat assessment scores used in this report were derived from the RWA metric set known as the Habitat Quality Index (HQI) and from the RBA scores derived directly from the EPA's RBA Habitat Assessment Field Data Sheets. For stations 1 and 2, the RBA "low gradient" field data sheets were used and for the remaining stations, the RBA "high gradient" sheets were used. Both HQI and RBA scores were represented as percent of maximum. While RBA scores were useful in comparison to HQI scores, the RBA assessment scores are typically used in comparison to reference conditions.

## Sampling Frequency

Types and frequency of samples collected for Phase III are summarized by station in Table 7.

## Sample Handling

Recommended storage and preservation requirements, and holding times were observed during shipping and analysis of water, sediment and tissue samples. Samples were shipped to the laboratories on ice in a sealed ice chest by overnight freight.

## Quality Assurance/Quality Control

The study was conducted in accordance with a USEPA approved quality assurance project plan (QAPP). The QAPP describes the quality assurance procedures in detail. An evaluation of specific data quality measures (field blanks, precision, accuracy, data completeness, comparability, and representativeness) is located in Appendix F.

TABLE 7
Phase III Study Stations and Summary of Sample Types

| Station Description | Station No. | Metals in Water | Metals in Sediment | Metals in Fish Tissue | Routine Water Quality | Organics/Pesticides in Water | Organics/Pesticides in Sediment | Organics/Pesticides in Fish Tissue✶ | Trophic Level Bioaccumulation of Metals (algae, benthics, fish) | Toxicity Testing (water & sediment) | Habitat | Benthics and Fish Communities |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rio Grande at Courchesne Bridge in El Paso, 2.7 km upstream of American Dam (river km 2,021) | 1 | X (1) | X (3) | X (2) | X (1) | X (1) | X (3) | X (2) | X (1 each) | X (1 each) | X (1) | X (1) |
| Rio Grande/Rio Bravo at Zaragosa International Bridge in El Paso/Ciudad Juárez (river km 1,992.8) | 2 | X (1) | X (3) | X (2) | X (1) | X (1) | X (3) | X (2) | X (1 each) | X (1 each) | X (1) | X (1) |
| Rio Grande/Rio Bravo 5 km upstream of Río Conchos confluence near Presidio/Ojinaga (river km 1,552.2) | 3 | X (1) | X (3) | X (2) | X (1) | X (1) | X (3) | X (2) | X (1 each) | X (1 each) | X (1) | X (1) |
| Rio Grande/Rio Bravo 14.4 km downstream of Río Conchos confluence near Presidio/Ojinaga (river km 1,528.5) | 4 | X (1) | X (3) | X (2) | X (1) | X (1) | X (3) | X (2) | X (1 each) | X (1 each) | X (1) | X (1) |
| Rio Grande/Rio Bravo at Colorado Canyon | 4.5 | | | | | | | | | | X ** (1) | |
| Rio Grande/Rio Bravo at mouth of Santa Elena Canyon (river km 1,424.7) | 5 | X (1) | X (3) | X (2) | X (1) | X (1) | X (3) | X (2) | X (1 each) | X (1 each) | X (1) | X (1) |
| Rio Grande/Rio Bravo at mouth of Boquillas Canyon | 6 | X (1) | X (3) | X (2) | X (1) | X (1) | X (3) | X (2) | X (1 each) | X (1 each) | X (1) | X (1) |
| Rio Grande/Rio Bravo at Black Gap Wildlife Management Area | 7 | | | | | | | | | | X** (1) | |

( ) indicates number of samples to be collected at each station; ✶ Samples collected but lost in shipping; ** Habitat assessments done apart from Phase III effort.

# Data Screening

The effects of any single chemical can vary in each type of sample (water, sediment, or fish tissue). It is important to note that the criteria/screening levels used to evaluate the toxics data will differ depending on the problem being evaluated. For example, a chemical concentration necessary to protect human health from the consumption of contaminated fish, is likely to be very different than the concentration to protect a drinking water source or that required to protect aquatic life.

# Water

## Texas Surface Water Quality Standards

Under Chapter 26.023 of the Texas Water Code, the TNRCC has the authority to make rules setting surface water quality standards for all state waters. Specific water uses and numerical criteria were developed by the TNRCC for each of the designated segments. The purpose of numerical criteria (temperature, pH, chloride, sulfate, total dissolved solids) is to protect water quality from the influence of point and nonpoint source pollution rather than the protection of a specific use. Table 12 lists the Title 30 Texas Administrative Code (TAC), Chapter 307, TSWQS uses and criteria for the segments included in this study (TNRCC 1999c).

### *Water Quality Criteria*

"*Criteria*" refers to specific numerical based concentrations for the protection of aquatic life and human health established by the TSWQS. Water quality criteria used to evaluate the RGTSS data are summarized in Table 8. Actual numerical concentrations are listed in Table 9. TSWQS for certain dissolved metals are site specific and based on hardness (TNRCC 1999c). Site specific criteria concentrations are located in Table 10. An exceedence of a human health criterion indicates a potential human health hazard if untreated water and/or fish from a water body were consumed on a regular, long-term basis. In the absence of TSWQS for a given pollutant, USEPA criteria for the protection of aquatic life and human health were used (USEPA 1986, 1995). USEPA proposes national standards that may be adopted by states. These standards tend to be lower than the TSWQS. State standards tend to be representative of conditions present within the state not represented by the national standards.

### *Water Quality Screening Levels*

"*Screening Levels*" are more general, and are mainly based on state and national 85$^{th}$ percentiles (TNRCC 2000; Greenpun and Taylor 1979). Eighty-fifth percentiles are screening values for given compounds that are higher than 85% of the values for similar areas; the four categories are freshwater stream, tidal stream, reservoir or estuary. Screening levels are used for pollutants without specific numerical criterion (nutrients) as a way to evaluate concerns. State and national screening levels represent a relatively high amount of a particular contaminant in water but do not necessarily have any toxicological significance. Values which exceed screening levels are termed "elevated." Water quality screening levels used to evaluate the RGTSS data are summarized in Table 8. Actual numerical concentrations are listed in Table 9.

### *Sediment Screening Levels*

The USEPA has developed procedures for generating criteria for only selected toxicants, and criteria have not been adopted. In the absence of specific numerical criteria for sediment, the TNRCC has relied on the use of 85$^{th}$ percentiles to screen sediment data. Sediment 85$^{th}$ percentiles are computed from values in the SWQM Database. The database was first screened for specific metals and organic substances with at least 25 observations statewide within four types of water bodies: freshwater streams, reservoirs, tidally influenced streams, and estuaries. This resulted in the selection of 12 metals and 131 organic substances (38 pesticides, 30 volatile organics, and 63 semivolatile organics). Until recently, only statewide 85$^{th}$ percentiles were used to assess sediment contaminant concentrations. State and national screening levels represent a relatively high amount of a particular contaminant in sediment but do not necessarily have any toxicological significance. Values which exceed screening levels are

TABLE 8
Summary of Criteria and Screening Levels

| SCREENING LEVEL/ CRITERIA | SOURCES | USES |
|---|---|---|
| **WATER** | | |
| **Human Health Criteria** | Surface Water Quality Standards | • State and Federal criteria for the consumption of FISH and WATER, and the consumption of FISH ONLY.<br>• Exceedence of these criteria indicate a potential human health hazard if untreated water and/or fish from a water body were consumed on a regular, long-term basis.<br>• Long-term exposure risk. |
| **Aquatic Life Criteria (Acute and Chronic)** | Surface Water Quality Standards | • State and Federal criteria for the protection of aquatic life.<br>• Exceedences of the criteria are indicators of potential short (acute) and long-term (chronic) effects on aquatic life. |
| **State and National 85th Percentiles** | Screening Level Only | • Represents a relatively high amount of a particular contaminant but does not have a direct toxicological meaning.<br>• Contaminants > the screening level are considered elevated.<br>• Used for contaminants without numerical criteria.<br>• Included in Guidance for Screening and Assessing Texas Surface and Finished Water Quality Data. |
| **SEDIMENT** | | |
| **State and National 85th Percentiles** | Screening Level | • Represents a relatively high amount of a particular contaminant but does not have a direct toxicological meaning.<br>• Contaminants > the screening level are considered elevated.<br>• Used for contaminants without criteria.<br>• Included in Guidance for Screening and Assessing Texas Surface and Finished Water Quality Data<br>• Limitations- The data used to calculated percentiles does not distinguish between contaminated and uncontaminated sites. Therefore, the data set tends to be skewed on the high side. |
| **National Oceanographic and Atmospheric Administration (NOAA) Sediment Screening Levels** | Screening Level (Aquatic Life) | • Threshold Effects Levels (TELs)-a value below which adverse effects are rarely expected.<br>• Probable Effects Levels (PELs)-a value above which adverse effects are frequently expected.<br>• Background concentrations-data collected from least contaminated sites. |
| **TISSUE** | | |
| **TNRCC Screening Levels** | Screening Levels (Human Health) | • Guidance for Screening and Assessing Texas Surface and Finished Water Quality Data. |
| **USEPA Guidance for Fish Advisories** | Screening Level (Human Health) | • Used for guidance in the issuance of fish consumption advisories. |
| **USFWS Predator Protection Limits** | Criteria (Aquatic Life) | • Used for the protection of predators. |
| **State, National 85$^{th}$ Percentiles** | Screening Level (Aquatic Life) | • Represents a relatively high amount of a particular contaminant but does not have a direct toxicological meaning.<br>• Contaminants > the screening level are considered elevated.<br>• Used for contaminants without other screening levels. |

termed "elevated." Sediment screening levels used to evaluate the RGTSS data are summarized in Table 8. Actual numerical concentrations are listed in Table 11. There are limitations to the 85$^{th}$ percentile values. The data used to calculate percentiles does not distinguish between contaminated and uncontaminated sites.

Much of the sediment monitoring in Texas is done on water bodies with the potential to be contaminated, rather than in least disturbed water bodies. Therefore, the data set tends to be skewed on the high side.

TABLE 9
Criteria and Screening Level Concentrations for Water Used in Phase III of the RGTSS

| PARAMETER | Screening Levels | | Human Health | | Aquatic Life | |
|---|---|---|---|---|---|---|
| | National ① 85th Percentile | State ② 85th Percentile | Consumption of Fish and Water | Consumption of Fish Only | Acute Value | Chronic Value |
| **CONVENTIONALS** (mg/L) | | | | | | |
| chloride | Segment Specific Criteria ③ *2306*-300; *2307*-300; *2308*-250; *2314*-340 | | | | 860 ④ | 230 ④ |
| sulfate | Segment Specific Criteria ③ *2306*-570; *2307*-550; *2308*-450; *2314*-600 | | | | - | - |
| total dissolved solids | Segment Specific Criteria ③ *2306*-1,550; *2307*-1,500; *2308*-1,400; *2314*-1,800 | | | | - | - |
| **METALS** (All dissolved except where noted) (µg/L) | | | | | | |
| aluminum | - | 60 | - | - | 991 ③ | 87 ④ |
| arsenic | 10 | 5.0 | 50 ③ | - | 360 ③ | 190 ③ |
| cadmium | 6.0 | 2.0 | 5.0 ③ | 10.0 ④ | SS ③ | SS ③ |
| chromium | 20 | 2.5 | 100 ③ | - | SS ③ | SS ③ |
| copper | 20 | 5.0 | 1300 ④ | - | SS ③ | SS ③ |
| lead | 20 | 5.0 | 5.0 ③ | 25.0 ③ | SS ③ | SS ③ |
| mercury (total) | 1.7 | 0.25 | 0.012 ② | 0.012 ② | 2.4 | 1.3 |
| nickel | 20 | 5.0 | 610 ④ | 4,600 ④ | SS ③ | SS ③ |
| selenium (total) | 8 | 2.5 | 50 ③ | - | 20.0 ③ | 5.0 ③ |
| silver | 10 | 1.0 | - | - | 0.92 | - |
| zinc | 80 | 20.0 | - | - | SS ③ | SS ③ |

①National 85th Percentiles (Greenspun and Taylor 1979)
④USEPA National Criteria (USEPA 1999)

②State 85th Percentile (TNRCC 2000)
③Texas Surface Water Quality Standards (TNRCC 1999c)
SS Site Specific

Equations for Calculating Aquatic Life Protection Criteria for Specific Metals
(All values calculated in µg/L)(Hardness concentrations are input as mg/L)

| Parameter | Acute | Chronic |
|---|---|---|
| Cadmium (d) | e (1.128[ln(hardness)] - 1.6774 | e (0.7852[ln(hardness)] - 3.490 |
| Chromium (Tri)(d) | e (0.8190)(ln(hardness)) + 3.688 | e (0.8190)(ln(hardness)) + 1.561 |
| Copper (d) | e (0.9422[ln(hardness)] - 1.3844 | e 0.8545[ln(hardness)] - 1.386 |
| Lead (d) | e (1.273 [ln(hardness)] - 1.460 | e (1.273 [ln(hardness)] - 4.705 |
| Nickel (d) | e (0.8460[ln(hardness)] + 3.3612 | e (0.8460[ln(hardness)] + 1.1645 |
| Zinc (d) | e (0.8473[ln(hardness)] + 0.8604 | e (0.8473[ln(hardness)] + 0.7614 |

TABLE 10
Site Specific Aquatic Life Criteria for Metals in Water Data

| **PhaseIII** | | | **Station** | | | |
|---|---|---|---|---|---|---|
| **Parameter** | **1** | **2** | **3** | **4** | **5** | **6** |
| Lead-Acute | 501.2 | 460.2 | 635.1 | 627 | 614.2 | - |
| Lead-Chronic | 19.5 | 17.9 | 24.7 | 24.4 | 23.9 | - |
| Zinc-Acute | - | 369.9 | - | - | - | 431.9 |
| Zinc-Chronic | - | 335.1 | - | - | - | 391.2 |
| **Phase II** | | | **Station** | | | |
| **Parameter** | **1** | **2** | **3** | **4** | **5** | |
| Copper-Acute | 83 | - | - | - | - | |
| Copper-Chronic | 48 | - | - | - | - | |
| Zinc-Acute | 436 | 383 | 529 | 550 | 521 | |
| Zinc-Chronic | 395 | 398 | 480 | 498 | 471 | |
| **Phase I** | | | **Station** | | | |
| Parameter | 1 | 2 | 3 | 4 | 5 | |
| Cadmium-Acute | - | 146 | - | - | - | |
| Cadmium-Chronic | - | 3.1 | - | - | - | |
| Copper-Acute | - | 65.2 | - | 65.8 | - | |
| Copper-Chronic | - | 38.8 | - | 39.1 | - | |
| Lead-Acute | 477 | - | 715 | - | 475 | |
| Lead-Chronic | 18.6 | - | 27.9 | - | 18.5 | |
| Nickel-Acute | - | - | 5,999 | 4,290 | 4,573 | |
| Nickel-Chronic | - | - | 667 | 477 | 508 | |
| Zinc-Acute | - | 351 | 496 | 355 | 378 | |
| Zinc-Chronic | - | 318 | 449 | 321 | 342 | |

Site specific criteria were calculated for stations with detected concentrations.

### ***Sediment Effects Screening Levels***

Multiple sediment screening levels, developed by the National Oceanic and Atmospheric Administration (NOAA), are used to evaluate wide spectrum of contaminant concentrations associated with various adverse aquatic life effects (Buchman 1999). Threshold Effects Levels (TELs) and Probable Effects Levels (PELs) are based on benthic community metrics and toxicity tests results. TELs are calculated using the geometric mean of the 15$^{th}$ percentile concentration of the toxic effects data set and the median of the no-effects data set. TELs (lower-threshold values) represent concentrations below a point where the occurrence of adverse biological effects are rarely expected. PELs are calculated as the geometric mean of 50% of impacted, toxic samples and 85% of the non-impacted samples. PELs (upper-threshold values) represent concentrations above a point where adverse biological effects are frequently expected. Since sediment screening levels have changed since Phases I and II, data from all three phases were re-evaluated as one data set using updated screening concentrations. In addition to the PELs and TELs, NOAA includes background concentrations. These concentrations are based on data collected at least contaminated sites (Table 11).

TABLE 11
Screening Level Concentrations for Sediment and Fish Tissue Used in Phase III

| PARAMETER | Freshwater Sediment Screening Levels | | | | Tissue Screening Levels | | |
|---|---|---|---|---|---|---|---|
| | Background Levels ⑧ | Threshold Effects Level (TEL) (mg/kg) ⑧ | Probable Effects Level (PEL) (mg/kg) ⑧ | National and State 85th Percentiles (mg/kg) ① ② | Whole Body National 85th Percentile ① (mg/kg) | Other Screening Levels (mg/kg) | Edible Tissue (Muscle) Value (mg/kg) |
| **METALS** | | | | | | | |
| **aluminum** | - | - | - | 16792 ② | - | - | - |
| **arsenic** | 1.1 | 5.9 | 17.0 | 14 ①; 6.32 ② | 0.20 | 0.20 ②; 3.0 ⑥;0.4-carp ⑦; 0.3-catfish ⑦ | 0.062 ④•;carp 0.2 ⑦; 0.3- catfish ⑦ |
| **barium** | 0.70 | - | - | 186 ② | - | - | - |
| **cadmium** | 0.10-0.30 | 0.596 | 3.53 | 6.6 ①; 1.0 ② | 0.30 | 0.20 ②;0.05⑦; 0.50 ⑥ | 10 ⑤ |
| **chromium** | 7.0-13.0 | 37.3 | 90.0 | 60 ①; 18.9 ② | 0.39 | 0.43 ②;100⑥; 0.2⑦ | - |
| **copper** | 10.0-25.0 | 35.7 | 18.7 | 52 ①; 15.9 ② | 2.2 | 1.45 ②; 1.0⑦;40 ⑥ | - |
| **lead** | 4.0-17.0 | 35.0 | 91.3 | 110 ①; 31.6 ② | 0.8 | 0.80 ②;0.22⑦; 1.25 ⑥ | - |
| **manganese** | 400 | | | 557 ② | - | - | - |
| **mercury** | 0.004-0.051 | 0.174 | 0.486 | 0.77 ①; 0.11 ② | 0.63 | 0.28 ②;1.0⑥; 1.0 ⑦ | 0.7⑤ |
| **nickel** | 9.9 | 18 | 35.9 | 44 ①; 14.2 ② | 0.60 | - | 215.4 ④ |
| **selenium** | 0.290 | - | - | 3.5 ①; 14.2② | 0.83 | 0.87 ②;2.0⑥; 0.5 ⑦ | 50 ⑤ |
| **silver** | < 0.50 | | | 3.0① ; 1.0 ② | 0.80 | - | - |
| **zinc** | 7.0-38.0 | 123.1 | 315 | 170 ①; 75.9 ② | 28 | 34.2 ⑦ | - |

① National 85th Percentiles (Greenspun and Taylor 1979)
② State 85th Percentiles (TNRCC 2000)
④ USEPA National Criteria
⑤ Guidance for Fish Advisories (USEPA 1993)
NA Not Applicable; No concentration detected
• Based on TNRCC $10^{-5}$ risk level, USEPA risk level is $10^{-6}$
⑥ Texas Department of Health Screening Levels/ TNRCC 305b Guidance Screening Levels
⑦ Wildlife Screening Level
⑧ NOAA 1999

### *SEM/AVS Ratios for Metals in Sediment*

Acid volatile sulfide has been recognized as an indicator of sediment metal toxicity. Simultaneously extracted metals (SEM)/acid volatile sulfides (AVS) ratios are used to predict the toxicity of metals in sediment. Simultaneously extracted metals (SEM) are the metals released during AVS analysis. Acid volatile sulfides (AVS) are defined as sediment sulfides that are soluble in hydrochloric acid. The ratio is referred to as the molar SEM/AVS ratio, where all metals and AVS values are converted from mg/kg to µmoles/kg (Howard and Evans 1993; Casas and Crecelius 1994; Ankley *et al*. 1996).

The SEM/AVS ratio is used with certain divalent cationic metals (arsenic, cadmium, chromium, copper, mercury, nickel, lead and zinc). These metals form insoluble metal sulfide solids (a dissolved metal replaces iron in ferrous sulfide) and are removed from the pore water by precipitation (Casas and Crecelius 1994; Pesch *et al*. 1995). Iron sulfides are formed by a reaction between hydrogen sulfide ($H_2S$) and ferrous iron in an anoxic (oxygen poor) environment. $H_2S$ is produced by the oxidation of organic matter by sulfide reducing bacteria (Casas and Crecelius 1995). The formation of these insoluble metal sulfides reduces the bioavailability to benthic organisms (Howard and Evans 1993).

If molar SEM/AVS ratio is less than 1.0, the majority of a metal is bound as a metal sulfate with little or no metal detected in the pore water. However, if the SEM/AVS ratio is greater than 1.0, excess metal may be available with a potential to be toxic to aquatic organisms.

### *Fish Tissue Screening Levels*

Screening level concentrations for fish tissue were developed from human health criteria in the TSWQS for 31 organics, and seven metals. Five of the metals, arsenic, cadmium, chromium, copper and selenium are based on Texas Department of Health (TDH) screening levels which are slightly lower than the levels used to issue consumption advisories (TNRCC 2000).

Tissue screening levels used to evaluate the Rio Grande/Rio Bravo Toxic Substance Study data are summarized in Table 8. Actual numerical concentrations are listed in Table 11.

USEPA Guidance for Fish Advisories include values used for guidance in the issuance of fish consumption advisories. These are used for screening edible tissue samples for the protection of human health (USEPA 1993).

US Fish and Wildlife Service (USFWS) wildlife screening levels are concentrations used to compare contaminant concentrations in whole body samples. Predator protection levels are maximum concentrations for fish and wildlife prey species. These levels, used to compare contaminant concentrations in prey species, are used as a protection measure for fish and wildlife predatory species consuming them (Irwin 1989).

State and national screening levels represent a relatively high amount of a particular contaminant in tissue but do not necessarily have any toxicological significance (Greenspun and Taylor 1979). Values which exceed screening levels are termed “elevated”.

## Assessment Criteria for Conventional Pollutants

Texas water quality criteria for water temperature, dissolved oxygen, pH, chloride, sulfate and total dissolved solids were established to protect surface water from the influence of point and nonpoint pollution sources. Segment specific criteria for these parameters are based on physical, chemical and biological characteristics of a stream (Table 12). Data for a five-year period (Texas Water Quality database) were used to determine compliance with the TSWQS. The guidance used in the assessment is that used to complete the State of Texas Water Quality Inventory (Section 305b of the Clean Water Act) (TNRCC 2000).

TABLE 12
Uses and Conventional Criteria for Segments of the Rio Grande/Rio Bravo Basin Included in Phase III

| Segment Number | RIO GRANDE BASIN<br>SEGMENT NAME | USE: Recreation | USE: Aquatic Life | USE: Public Water Supply | CRITERIA: Chloride (mg/L) | CRITERIA: Sulfate (mg/L) | CRITERIA: TDS (mg/L) | CRITERIA: Dissolved Oxygen (mg/L) | CRITERIA: pH (s.u.) | CRITERIA: Fecal Coliform (#/100 ml) | CRITERIA: Temperature (°F) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2306 | **Rio Grande Above International Amistad Reservoir**<br>Segment Description: from the headwaters of Amistad International Reservoir to the confluence of the Rio Conchos (Mexico) in Presidio County.<br>Segment Length: 503 km (313 miles) | CR | H | PS | 300 | 570 | 1550 | 5.0 | 6.5-9.0 | 200 | 93 |
| 2307 | **Rio Grande Below Riverside Diversion Dam**<br>Segment Description: from the confluence of the Rio Conchos (Mexico) to the Riverside Diversion Dam in El Paso County.<br>Segment Length: 357 km (222 miles) | CR | H | PS | 300 | 550 | 1500 | 5.0 ① | 6.5-9.0 | 200 | 93 |
| 2308 | **Rio Grande Below International Dam**<br>Segment Description: From the Riverside Diversion Dam to International Dam in El Paso County.<br>Segment Length: 24 km (15 miles) | NCR | L | | 250 | 450 | 1400 | 3.0 | 6.5-9.0 | 2000 | 95 |
| 2314 | **Rio Grande Above International Dam**<br>Segment Description: from International Dam to New Mexico State Line in El Paso County<br>Segment Length: 33 km (21 miles) | CR | H | PS | 340 | 600 | 1800 | 5.0 | 6.5-9.0 | 200 | 92 |

①The dissolved oxygen criteria in the upper reach of Segment 2307 (Riverside Diversion Dam to the end of the channel below Fort Quitman) shall be 3.0 mg/L when headwater flow over the Riverside Dam is less than $0.99 m^3/s$ ($35 ft^3/s$) (Texas Surface Water Quality Standards, 1997).

CR=contact recreation, NCR=noncontact recreation, H=high aquatic life use, L= limited aquatic life use, PS=public water supply.

The following are used to evaluate water temperature, pH and dissolved oxygen for general use support:

| Parameter | Minimum Number of Samples | Fully Supporting | Partially Supporting | Not Supporting |
|---|---|---|---|---|
| Dissolved Oxygen (mg/L) | 9 | 0-10% exceed criterion | 11-25% exceed criterion | Greater than 25% exceed criterion |
| pH (s.u.) | 9 | 0-10% do not meet criteria | 11-25% do not meet criteria | Greater than 25% do not meet criteria |
| Water Temperature (°C) | 9 | Segment average less than or equal to criterion | Partial support is not assessed | Segment average exceeds criterion |
| Chloride * (mg/L) | 9 | Segment average less than or equal to criterion | Partial support is not assessed | Segment average exceeds criterion |
| Sulfate * (mg/L) | 9 | Segment average less than or equal to criterion | Partial support is not assessed | Segment average exceeds criterion |
| Total Dissolved Solids * (mg/L) | 9 | Segment average less than or equal to criterion | Partial support is not assessed | Segment average exceeds criterion |

*All data collected in the five-year period, September 1993 to April 1999, were averaged for each of these three parameters. These averages are compared to segment criteria for chloride, sulfate and total dissolved solids (TNRCC 1999).

### Nutrient Screening Levels

State criteria do not exist for nutrients; therefore, nutrient data for fixed station monitoring events from September 1, 1993 to April 1999, were compared with screening levels used to evaluate pollutant concerns.

The following nutrient screening levels for freshwater streams were used (TNRCC 2000):

| Parameter | Screening Level | No Concern | Concern |
|---|---|---|---|
| ammonia ($NH_3$-N) | 0.16 mg/L | For any one parameter, 0-25% of the values exceed the screening level | For any one parameter, more than 25% of the values exceed the screening level |
| nitrite + nitrate ($NO_2$-N+$NO_3$-N) | 3.5 mg/L | | |
| orthophosphorus | 0.90 mg/L | | |
| total phosphorus | 1.10 mg/L | | |
| chlorophyll *a* | 30 µg/L | | |

## Biological

### *Benthic Macroinvertebrate Community*

Macrobenthic data evaluation employed widely-accepted methods commonly utilized in water quality studies. Standard indices of community organization and structure, including numerical density, species richness, diversity, trophic structure, and intercommunity similarity served as a basis for cross-sample comparisons. Use of a robust complement of metrics allowed for a thorough characterization of macrobenthic community integrity.

## Guidelines for Calculation of Metrics-Kick Net/Snags

Because of taxonomic difficulties for certain groups, and to promote consistency, the following taxonomic guidelines for commonly collected benthic macroinvertebrate taxa are proposed:

- Insecta, identify to Genus, except leave Chironomidae at Family
- Oligochaeta, leave at Oligochaeta
- Hirudinea, leave at Hirudinea
- Hydracarina, leave at Hydracarina
- Isopoda, identify to Genus
- Amphipoda, identify to Genus
- Nematoda, leave at Nematoda
- Ostracoda, leave at Ostracoda
- Palaemonidae, identify to Genus
- Cambaridae, leave at Cambaridae
- Gastropoda, identify to Genus
- Turbellaria, identify to Family
- Pelecypoda, identify to Genus

The following sections describe the rationale for each metric, calculation methods and how scoring categories were established.

### ***Taxa Richness*** **( = number of taxa)**

All macroinvertebrates are separated into appropriate taxonomic categories (see above), and the number of such categories are counted. In general, relatively lower taxa richness values reflect lower biotic integrity. Decreases in taxa richness may result from impairment of physico-chemical factors (e.g., dissolved oxygen, habitat heterogeneity).

### ***EPT*** **( = EPT richness)**

All Ephemeroptera, Plecoptera, and Trichoptera (EPT) are separated from the other macroinvertebrates. The number of distinct taxa (e.g., Genera) within these three orders are then counted. In general, this count tends to decrease with increasing impairment of physico-chemical factors as the majority of taxa in these orders are considered pollution sensitive.

### ***HBI*** **( = Hilsenhoff Biotic Index)**

Calculated as $\sum n_i t_i/N$ where $n_i$ is the number of individuals of a particular taxa (e.g., Genus, Family, etc.), $t_i$ is the tolerance value of that taxon, and N is the total number of organisms in a sample. Tolerance values are assigned to individual taxa on a scale of 0-10, with increasing tolerance values reflecting increasing tolerance to physico-chemical degradation. Note, N should include counts of organisms only from those taxa for which tolerance values can be determined. The index weights the relative abundance of each taxon in terms of its pollution tolerance in determining a community score, thus, in effect producing a weighted average tolerance value for a benthic sample. In general, as a result of the increase in the relative abundance of tolerant taxa, the value of the index increases as physico-chemical conditions degrade.

***% Chironomidae*** = (the ratio of the number of individuals in the family Chironomidae to the total number of individuals in the sample [N])*100)

Chironomidae are relatively ubiquitous in aquatic habitats. Although, the Chironomidae are often considered generally pollution tolerant, the variability in pollution tolerance at the species level is apparently quite large. This data set indicates that a small to moderate representation of the Chironomidae in kick net samples from minimally impacted streams is to be expected, with overly high or low proportions reflecting increasing physico-chemical impairment.

***% Dominant Taxon*** = (ratio of the number of individuals in the numerically dominant taxon to the total number of individuals [N])*100)

In general, a community dominated by relatively few species may indicate environmental stress, and a high percent contribution by one or two taxa represents an imbalance in community structure (Rosenberg and Resh, 1993, Plafkin et al., 1989). Thus, as this percentage increases, biotic integrity decreases.

***% Dominant Functional Group*** = (ratio of the number of individuals in the numerically dominant functional group to the total number of individuals [N])*100)

This metric is based on the well supported premise that physico-chemical impairment can result in modification of the resource base available to consumers in aquatic systems and subsequently cause an imbalanced trophic structure.

Aquatic macroinvertebrates are placed in functional groups according to Merritt and Cummins (1984) and the percentage of N represented by each group is calculated. The functional group classification places taxa in categories based on morpho-behavioral mechanisms of food acquisition (Merritt and Cummins 1984). Note that the functional classification is independent of taxonomy, i.e., one functional group may contain several taxa. Five functional feeding group categories are considered here:

| | |
|---|---|
| **Scrapers** (grazers) | benthic macroinvertebrates morpho-behaviorally adapted to utilize the fungal, bacterial, algal complex (= periphyton) closely attached to the substrate as the primary food resource. |
| **Collector-Gatherers** (deposit feeders) | benthic macroinvertebrates morpho-behaviorally adapted to utilize fine particulate organic matter (FPOM) deposited interstitially and/or on the surface of the substrate as the primary food resource. |
| **Filtering-Collectors** (suspension feeders) | benthic macroinvertebrates morpho-behaviorally adapted to utilize particulate organic matter suspended in the water column as the primary food resource. |
| **Predators** (engulfers) | benthic macroinvertebrates morpho-behaviorally adapted to utilize other living organisms (prey) as the primary food resource. |
| **Shredders** (living or dead plant material) | benthic macroinvertebrates morpho-behaviorally adapted to utilize coarse particulate organic matter (CPOM), especially leaf litter and associated algal, bacterial, fungal complex as the primary food resource. |

Note that the groups are not mutually exclusive, that is, one taxa may be considered a scraper/collector gatherer. In such a situation place half of the organisms from that taxa in the scraper category and half in the collector-gatherer category (i.e., four (4) individuals from the genus *Baetis* which is a scraper/collector-gatherers place two (2) in scraper category and two (2) in gatherer-collector category).

Scoring for the metric is based on the premise that relatively low to moderate percentages for all functional groups reflects a balanced trophic structure, while extremely high or low percentages reflect an imbalance, possibly due to physico-chemical perturbation.

***% Predator*** = (the ratio of the number of individuals in the Predator functional group to the total number of individuals [N])*100)

Variability in the percentage predators should be less correlated to resource base changes resulting from natural changes in habitat and more attuned to changes that cause significant reductions or increases in prey items (eg. Toxicity effects, nutrient effects). Further, most predators have relatively long aquatic life stages (usually >6 months) and thus reflect the integration of physicochemical conditions over longer periods of time than groups such as mayflies, some of which complete their aquatic existence in <2 weeks in Texas streams.

Scoring for the metric is based on the premise that relatively low to moderate percentages of predators reflect a balanced trophic structure, while extremely high or low percentages reflect an imbalance, possibly due to physicochemical perturbation.

***Ratio of Intolerant to Tolerant Taxa*** = (the ratio of the number of individuals in taxa with tolerance values < 6 to the number of individuals in taxa with tolerance values > 6)
This metric provides a measure of the relative contribution of tolerant and intolerant taxa to the composition of the community. The metric increases as the relative numbers of intolerant individuals increases and thus, higher values should reflect favorable physicochemical conditions.

***% of Total Trichoptera as Hydropsychidae*** = (ratio of the number of individuals in the family Hydropsychidae to the total number of individuals in the order Trichoptera)*100)
The Trichoptera are ubiquitous in Texas streams. Among the Trichoptera, the family Hydropsychidae is perhaps most commonly collected. Further, the Hydropsychidae tend to be among the most tolerant of Trichoptera. The metric is based on the observation that samples from reference streams in Texas typically contain representatives of Hydropsychidae as well as representatives from other families in the order Trichoptera. Thus, a high relative % of total Trichoptera accounted for by the Hydropsychidae, or a complete lack of Trichoptera likely reflect physico-chemical degradation.

***Number of Non-Insect Taxa***
This metric is based on the finding that kick net samples from reference streams in Texas typically include representatives from several non-insect taxa and that the number of non-insect taxa typically is lower in impaired streams. For calculation of the metric, because of taxonomic difficulties for certain groups, and to promote consistency, the following taxonomic guidelines for commonly collected non-insect taxa are proposed:

- Oligochaeta, leave at Oligochaeta
- Hirudinea, leave at Hirudinea
- Hydracarina, leave at Hydracarina
- Isopoda, identify to Genus
- Amphipoda, identify to Genus
- Nematoda, leave at Nematoda
- Ostracoda, leave at Ostracoda
- Palaemonidae, identify to Genus
- Cambaridae, leave at Cambaridae
- Gastropoda, identify to Genus
- Turbellaria, identify to Family
- Pelecypoda, identify to Genus

***% of N as Collector-Gatherers*** = ( ratio of the number of individuals in the collector-gatherer functional group to the total number of individuals in the sample [N] *100)
Collector-gatherers utilize fine particulate organic matter (FPOM) as the primary food resource. Physico-chemical impairment, especially organic enrichment, can cause an increase in the availability of FPOM via several mechanisms including direct input of FPOM and/or increased microbial activity. Thus, favoring the collector-gatherer functional group.

***% of N as Elmidae*** = (ratio of the number of the individuals from the family Elmidae to the total number of individuals in the sample [N])*100)
Riffle beetles are typically found in samples from reference streams in Texas. *Stenelmis* sp., perhaps the most commonly encountered genus, is relatively tolerant to pollution and thus apparently may become dominant in situations in which a moderate tolerance to organic enrichment confers an advantage. Thus, low scores for this metric are associated with either an extremely high percentage of or a complete absence of Elmidae.

## Total Scores and Establishment of Aquatic Life Use Categories

The overall integrity of the benthic macroinvertebrate community, as characterized by the sample, is expressed by the total score, obtained by summing the scores for the twelve individual metrics. Subsequently, the total score is used to place the water body in an aquatic life use category (Table 13). Each designated water body segment in Texas has been assigned an aquatic life use designation. Four categories are defined by the TSWQS as limited, intermediate, high, and exceptional aquatic life use (TNRCC 1999c).

TABLE 13
Metrics and Scoring Criteria for Kick Samples, Rapid
Bioassessment Protocol-Benthic Macroinvertebrates (Harrison 1996)

| **METRIC** | **SCORING CRITERIA** | | | |
|---|---|---|---|---|
| | **4** | **3** | **2** | **1** |
| Taxa Richness (s) | > 21 | 15-21 | 8-14 | < 8 |
| EPT Taxa Abundance | > 9 | 7-9 | 4-6 | < 4 |
| Biotic Index (HBI) | < 3.77 | 3.77-4.52 | 4.53-5.27 | > 5.27 |
| % Chironomidae | 0.79-4.10 | 4.11-9.48 | 9.49-16.19 | < 0.79 or > 16.19 |
| % Dominant Taxa | < 22.15 | 22.15-31.01 | 31.02-39.88 | > 39.88 |
| % Dominant Functional Feeding Group (FFG) | < 36.50 | 36.50-45.30 | 45.31-54.12 | > 54.12 |
| % Predators | 4.73-15.20 | 15.21-25.67 | 25.68-36.14 | < 4.73 or > 36.14 |
| Ratio of Intolerant:Tolerant Taxa | > 4.79 | 3.21-4.79 | 1.63-3.20 | < 1.63 |
| % of Total Trichoptera as Hydropsychidae | < 25.50 | 25.51-50.50 | 50.51-75.50 | > 75.50 or no trichoptera |
| # of Non-Insect Taxa | > 5 | 4.-5 | 2-3 | < 2 |
| % Collector-Gatherers | 8.00-19.23 | 19.24-30.46 | 30.47-41.68 | < 8.00 or > 41.68 |
| % of Total Number as Elmidae | 0.88-10.04 | 10.05-20.08 | 20.09-30.12 | < 0.88 or > 30.12 |

| **Aquatic Life Use Point Score Ranges** | |
|---|---|
| Exceptional | > 36 |
| High | 29-36 |
| Intermediate | 22-28 |
| Limited | < 22 |

# Guidelines for Calculation of Metrics-Pool Communities

The SWQM Team is developing an index of biotic integrity for pool macrobenthic communities of Texas streams, but it is not yet available. The SWQM Team has devised an interim assessment technique, described below, which has been employed in four studies since 1997, including a nonpoint source study in the Brazos-Colorado Coastal Basin, a biosurvey of Barton Creek, a retrospective bioassessment of Little Saline Creek, and biosurveys of seven additional Texas streams.

Aquatic life use attainment is determined using ten metrics representing diverse aspects of community structure and function. Of the 45 metrics that are routinely calculated for macrobenthic community assessments, these ten are considered the most meaningful for pool habitats. Five are positive, meaning that values are expected to decrease in response to disturbance (total taxa, EPT taxa, Diptera taxa, percent EPT taxa, intolerant taxa). The remainder are negative, with values expected to increase in response to disturbance (dominant functional feeding group, cumulative abundance of fine particulate organic matter feeders, three most abundant taxa, percent Oligochaeta, percent tolerant taxa). Aquatic life use ratings are derived by comparing metric values to descriptive statistics from TNRCC's statewide lotic-depositional data base (Table14). Values less than the 50th percentile for positive metrics, or greater than the 50th percentile for negative metrics, are considered unfavorable and are assigned a 'minus' sign. Values greater than the 85th percentile for positive metrics, or less than the 15th percentile for negative metrics, are regarded as favorable and are assigned a 'plus' sign. For each data set, the difference (delta) between numbers of 'plus' and 'minus' signs is then calculated (range of possible values, 10- to 10+). Delta value ranges, as they correspond to TNRCC aquatic life use subcategories, are: ≥ 3+, exceptional; 2+ to 2-, high; 3- to 4-, intermediate; and ≤ 5-, limited.

TABLE 14
Descriptive Statistics for Pool Macrobenthic Communities from the TNRCC data base (n=82)

| Metric * | minimum | maximum | mean | 15th percentile | 50th percentile | 85th percentile |
|---|---|---|---|---|---|---|
| **Total taxa** | 6.0 | 71.0 | 33.5 | 13.2 | 32.5 | 50.9 |
| Number of individuals/sq. m. | 174.0 | 60835.0 | 5288.8 | 965.4 | 2646.0 | 6095.3 |
| **EPT taxa** | 0.0 | 13.0 | 4.5 | 0.0 | 4.5 | 9.0 |
| No. of func. feeding groups | 2.0 | 6.0 | 5.5 | 5.0 | 6.0 | 6.0 |
| **Dominant func. feeding group (%)** | 23.9 | 99.6 | 60.7 | 35.3 | 58.6 | 84.5 |
| **Cum. abundance FPOM feeders (%)** | 13.2 | 99.6 | 74.1 | 57.0 | 76.4 | 92.9 |
| Grazers (%) | 0.0 | 34.3 | 6.0 | 0.0 | 4.2 | 11.8 |
| Gatherers (%) | 0.0 | 75.6 | 15.0 | 1.1 | 9.3 | 30.8 |
| Filterers (%) | 0.0 | 50.2 | 7.3 | 0.3 | 4.7 | 13.4 |
| Miners (%) | 1.7 | 99.6 | 51.8 | 19.0 | 54.3 | 84.5 |
| Shredders (%) | 0.0 | 23.9 | 3.4 | 0.1 | 1.7 | 6.3 |
| Predators (%) | 0.3 | 78.1 | 16.5 | 3.4 | 11.8 | 28.9 |
| Ephemeroptera taxa | 0.0 | 7.0 | 2.7 | 0.0 | 2.0 | 6.0 |
| Trichoptera taxa | 0.0 | 7.0 | 1.8 | 0.0 | 2.0 | 4.0 |
| **Diptera taxa** | 1.0 | 27.0 | 12.4 | 5.0 | 12.5 | 18.0 |
| Ephemeroptera (%) | 0.0 | 73.9 | 9.6 | 0.0 | 3.5 | 21.1 |
| Trichoptera (%) | 0.0 | 23.6 | 1.7 | 0.0 | 0.7 | 2.8 |
| Tanytarsini (%) | 0.0 | 24.4 | 2.7 | 0.0 | 0.5 | 6.0 |
| Coleoptera taxa | 0.0 | 11.0 | 2.1 | 0.0 | 2.0 | 4.0 |
| Chironomidae taxa | 1.0 | 26.0 | 10.3 | 4.0 | 11.0 | 17.0 |
| Non-insect taxa | 2.0 | 27.0 | 12.4 | 6.0 | 11.0 | 20.0 |
| Most abundant taxon (%) | 9.1 | 83.8 | 36.0 | 18.7 | 33.1 | 51.2 |
| Two most abundant taxa (%) | 18.1 | 97.7 | 51.7 | 31.9 | 51.9 | 68.9 |
| **Three most abundant taxa (%)** | 27.2 | 99.0 | 61.7 | 40.8 | 61.1 | 79.2 |
| Four most abundant taxa (%) | 35.9 | 99.5 | 68.5 | 48.5 | 68.0 | 86.6 |
| Five most abundant taxa (%) | 42.0 | 100.0 | 73.4 | 55.8 | 73.8 | 91.5 |
| Hydropsychidae/Trichoptera (%) | 0.0 | 100.0 | 6.5 | 0.0 | 0.0 | 0.0 |
| Coleoptera (%) | 0.0 | 42.1 | 3.0 | 0.0 | 0.9 | 4.6 |
| Oligochaeta taxa | 1.0 | 11.0 | 5.6 | 3.0 | 6.0 | 9.0 |
| **Oligochaeta (%)** | 0.1 | 99.2 | 40.4 | 4.5 | 37.8 | 78.3 |
| Chironomidae (%) | 0.0 | 91.8 | 23.8 | 4.4 | 15.9 | 47.6 |

TABLE 14 (cont)
Descriptive Statistics for Pool Macrobenthic Communities from the TNRCC data base (n=82)

| Metric * | minimum | maximum | mean | 15th percentile | 50th percentile | 85th percentile |
|---|---|---|---|---|---|---|
| Elmidae (%) | 0.0 | 40.4 | 2.7 | 0.0 | 0.4 | 3.8 |
| **EPT taxa (%)** | 0.0 | 74.9 | 11.3 | 0.0 | 4.5 | 23.6 |
| Grazers/filterers | 0.0 | 27.5 | 2.5 | 0.0 | 0.8 | 3.8 |
| Grazers/(grazers + filterers) (%) | 0.0 | 96.5 | 29.5 | 0.0 | 25.4 | 66.3 |
| **Intolerant taxa** | 0.0 | 10.0 | 2.4 | 0.0 | 2.0 | 5.0 |
| **Tolerant taxa (%)** | 2.6 | 100.0 | 46.9 | 11.5 | 45.0 | 84.4 |
| Orthocladiinae taxa | 0.0 | 4.0 | 0.6 | 0.0 | 0.0 | 1.8 |
| Tanytarsini taxa | 0.0 | 5.0 | 1.5 | 0.0 | 1.0 | 3.0 |
| Crustacea + Mollusca taxa | 0.0 | 13.0 | 4.5 | 1.0 | 4.0 | 9.0 |
| Odonata (%) | 0.0 | 28.2 | 1.5 | 0.0 | 0.5 | 2.3 |
| Diptera (%) | 0.4 | 92.4 | 31.1 | 7.0 | 21.7 | 62.6 |
| Orthocladiinae/Chironomidae (%) | 0.0 | 57.1 | 4.1 | 0.0 | 0.0 | 6.6 |
| Crustacea + Mollusca (%) | 0.0 | 54.6 | 10.0 | 0.4 | 5.8 | 17.5 |
| Tanytarsini/Chironomidae (%) | 0.0 | 53.3 | 10.5 | 0.0 | 5.3 | 24.9 |

* - metrics in bold were used in assessing aquatic life use attainment

## Similarity Index
A similarity index (Odum 1971) was employed as a measure of the similarity of species composition between two sampling sites. This index varies from zero, if no species are common between sites, to 1.0, if two sites share all species.

The equation for calculation of the similarity index is as follows:

$$S = 2C/(A+B)$$

where,

S = index of similarity,
A = number of species in sample A
B = number of species in sample B
C = number of species common to both samples.

## Fish Community
A community index derived from the Index of Biotic Integrity (IBI) as described by Karr *et al.* (1986) was utilized in the analysis of fish collections. The derivation of the index and rationale for individual metrics and scoring criteria are described in the Phase 1 report (Table 11)(USEPA/IBWC 1994). Nekton community evaluation procedures followed methods derived by Texas Parks and Wildlife Department (TPWD) for assessing nekton community integrity.

## Principal Components Analysis
Principal components analysis (PCA) is a statistical technique which is commonly used to describe differences between sampling sites as expressed by measurements of multiple variables at each site. PCA calculates the line (component) that extracts the maximum amount of statistical variance from a cloud of points (Karr and Wisseman 1996), in this case, each point represents a sample site. The number of dimensions through which the component passes is equal to the number variables measured.

MINITAB statistical software was used to conduct the PCA. Because some of the variables were measured by different scales, the correlation matrix was used to calculate the principal components. Results should be interpreted with caution because of the relatively small sample size available for the analysis.

# RESULTS AND DISCUSSION

## Water

### Routine Surface Water Quality Data Assessment

The following is an assessment of overall water quality in the river, and the level of support of designated uses and specific criteria listed in the TSWQS. This assessment was done using approximately five-years of routine fixed station surface water quality monitoring data (September 1993 to November 1999) from the State of Texas water quality data base, maintained by the TNRCC (TNRCC 1999).

#### Salinity (Chloride, Sulfate and TDS)

High concentrations of dissolved solids (chloride, sulfate) can cause water to be unusable for agriculture or too costly to treat for drinking water uses. Elevated dissolved solids concentrations can also affect the aquatic life use. Elevated dissolved solids, chloride and sulfate are a problem in the Rio Grande/Rio Bravo.

In the El Paso area, the salts tend to be lower during the irrigation season and higher during the off season. The standards for chloride, sulfate and total dissolved solids (TDS) are based on the segment average (Table15). These criteria do not reflect seasonal variation in chloride, sulfate and TDS values (Appendix E). When the data are grouped according to irrigation (March 15-September 15) and non-irrigation seasons (September 16-March 14) a general seasonal trend is evident (Miyamoto, *et al.*, 1995). Seasonally elevated chloride, sulfate and/or TDS can make the treatment of surface water more costly during periods of low flow. Data used to assess chloride, sulfate and TDS showed that concentrations at both the upstream (Courchesne Bridge-Station 1) and downstream (Zaragosa Bridge-Station 2) stations in the El Paso/Ciudad Juárez area were less than the criteria for the respective segments. An advantage El Paso has over the downstream areas is water from Elephant Butte Reservoir in Sierra County New Mexico. Even though the water coming from Elephant Butte is used for irrigation in New Mexico before reaching El Paso, it still maintains lower chloride, sulfate and TDS values than the downstream sites.

When compared to the other stations in this reach, the El Paso/Ciudad Juárez area does not have the salinity problems observed in the Fort Quitman-Big Bend areas. Five of the six stations in the reach from Fort Quitman to Amistad Reservoir have either chloride, sulfate and/or TDS average concentrations exceeding the criterion for the respective segments. The Presidio-Big Bend area experiences variable flows that are not influenced by irrigation but by rainfall and inflow from the Rio Conchos. In recent years, the Rio Conchos itself has been experiencing low flows due to drought conditions. The lower chloride and sulfate concentrations at sites downstream of Big Bend are the result of spring flow entering the river in the lower canyons area (between Black Gap Wildlife Management Area and Dryden), the lack of irrigation return flow and to a lesser extent inflow from local rains through Tornillo Creek and other small intermittent streams that drain Big Bend National Park. Salinity at the last site before Amistad Reservoir is not a problem.

Although, chloride, sulfate and total dissolved solids exceeded criteria in individual instances, the average of more than ten samples must exceed a criteria for a water body to be considered non-supporting (Table 15). These criteria are based on the average for the entire segment. Currently, Segment 2307 (which includes the reach from below the Riverside Diversion Dam in El Paso to the confluence of the Rio Conchos) is on the 303 (d) Impaired Waters List for exceeding the criteria for chloride, sulfate and TDS. This means that the general uses are not supported in this segment of the river.

#### *Nutrients*

Nutrients (total and orthophosphorus, nitrite-nitrogen, nitrate-nitrogen and ammonia-nitrogen) are important water quality indicators. Excessive nutrients can cause algal blooms which often result in depressed oxygen levels. Nearly all data indicated that dissolved oxygen and nutrient concentrations were not concerns. The exception was ammonia at two stations, downstream of El Paso/Ciudad Juárez and Presidio/Ojinaga.

TABLE 15
Chloride, Sulfate and Total Dissolved Solids Average
Values for the Area from El Paso to Amistad Reservoir.
(segment water quality criteria are included)

| **Rio Grande Stations** | **Chloride** | **Sulfate** | **TDS** |
|---|---|---|---|
| Segment 2314 Criteria | 340 | 600 | 1800 |
| Courchesne Bridge (El Paso) * | 173 | 297 | 933 |
| Segment Average ** | 173 | 297 | 933 |
| Number of Samples | 71 | 71 | 34 |
| Number > Criterion | 7 | 0 | 2 |
| Maximum Value | 610 | 594 | 2080 |
| Segment 2308 Criteria | 250 | 450 | 1400 |
| Zaragosa Bridge (El Paso) * | 159 | 269 | 882 |
| Segment Average ** | 159 | 269 | 882 |
| Number of Samples | 37 | 37 | 40 |
| Number > Criterion | 4 | 1 | 2 |
| Maximum Value | 309 | 452 | 2920 |
| Segment 2307 Criteria | 300 | 550 | 1500 |
| Neely Canyon South of Fort Quitman * | 699 | 615 | 2374 |
| Upstream of Rio Conchos (Presidio) * | 575 | 573 | 1911 |
| Segment Average ** | 630 | 592 | 2082 |
| Number of Samples | 70 | 70 | 84 |
| Number > Criterion | 63 | 37 | 68 |
| Maximum Value | 1410 | 1470 | 4410 |
| Segment 2306 Criteria | 300 | 570 | 1550 |
| Downstream of Rio Conchos (Presidio) * | 393 | 571 | 1572 |
| Santa Elena Canyon (Big Bend) * | 431 | 535 | 1621 |
| Gerstacker Bridge (FM 2627) * (Below Big Bend) | 247 | 472 | 1337 |
| Rio Grande at Foster Ranch West of Langtry * (last site before Amistad Reservoir) | 146 | 294 | 845 |
| Segment Average ** | 278 | 442 | 1341 |
| Number of Samples | 146 | 148 | 160 |
| Number > Criterion | 53 | 38 | 51 |
| Maximum Value | 644 | 881 | 2610 |

* Station Average; Standard applies to segment average **

Eighty-four percent of the ammonia concentrations (in 31 samples) exceeded the screening level (0.19 mg/L) at the Zaragosa Bridge site downstream of El Paso/Ciudad Juárez indicating a concern. Ammonia concentrations at this site ranged from 0.01-6.4 mg/L. At the second site downstream of Presidio/Ojinaga, 13% of the ammonia concentrations exceeded the screening level which indicates a potential concern.

One of the most common of the aquatic pollutants is **ammonia** ($NH_3$). The importance of ammonia is related to its highly toxic nature and widespread presence in surface waters. Ammonia is discharged in varying quantities from industrial, municipal and agricultural wastewaters (Rand and Petrocelli 1985). Ammonia, nitrite and nitrate are related by the process of nitrification, which is the oxidation of ammonia and nitrate. In the presence of oxygen, ammonia is oxidized by *Nitrosomonas* bacteria to nitrite, an intermediate product. Nitrite is then oxidized by *Nitrobacter* bacteria to form nitrate. Not only is ammonia toxic it is also an oxygen demanding substance. **Nitrite** ($NO_2^-$), like ammonia is extremely toxic to aquatic life, but is not considered an environmental problem because it occurs in relatively low concentrations. **Nitrate** ($NO_3^-$) is relatively nontoxic to aquatic organisms and is not considered an environmental problem (Note: Elevated nitrate concentrations are a problem in drinking water sources; eg. methemoglobinemia or blue babies). Acute (high concentrations over a short period) exposure to ammonia can cause death or at least damage to the organs and tissue of aquatic organisms. If the exposure to ammonia is chronic (sublethal concentrations over a longer period of time), aquatic organisms are more susceptible to disease, exhibit reduced reproduction/growth and several physiological functions show signs of deterioration (Boyd 1990; Rand and Petrocelli 1985).

## Metals

Of the 11 metals in water analyzed, aluminum, arsenic, lead, mercury, and zinc were found above the detection limits. Selenium, also above the detection limit, was found in the quality assurance field equipment blank so the data was not used in the assessment.

### Arsenic

| | |
|---|---|
| ***Sources*:** | Arsenic is a naturally occurring element, common in areas with volcanic activity. In addition to erosion, arsenic enters the environment mainly from use as a pesticide, industrial/municipal wastewater treatment plant effluent, mining, smelters, and emissions from coal fired power plants. Arsenic is released to the environment from natural sources (e.g., volcanoes, erosion from mineral deposits), but releases from anthropogenic (human) sources (e.g., metal smelting, chemical production and use, coal combustion, waste disposal) can lead to substantial environmental contamination. Most anthropogenic arsenic releases (pesticides or solid waste) are to land or soil but substantial amounts are also released to air and water. |
| ***Uses*:** | Mainly used to preserve wood; used in insecticides and weed killers; veterinary uses; used to make glass, cloth, and electrical semiconductors. |
| ***Environmental/ Health Effects*:** | Carcinogen; dissolves in water; changes from one form to another; persistent in water; can bioaccumulate in fish and shellfish tissue; enters environment mainly from use as a pesticide, industrial/ municipal WWTP effluent, and emissions from coal fired power plants; erosion; certain forms have a high acute and chronic toxicity in aquatic life (Eisler 1988; USDHHS 1993a). |

Dissolved arsenic in water was detected at all of the study sites. Concentrations did not exceed the acute or chronic aquatic life criteria (360 and 190 µg/L, respectively) or human health criterion (50 µg/L) established by the TSWQS but did exceed the state screening level of 5.0 µg/L (85$^{th}$ percentile) at Stations 3, 4, 5 and 6. Dissolved arsenic concentrations ranged from 5.2 to 8.9 µg/L at the four lower stations. Historical dissolved arsenic data, available for Stations 1, 2 and 4, show that average concentrations increase from upstream to downstream (Appendix E). At Station 1, the values ranged from < 2.0 to 8.74 µg/L with an average concentration of 5.1 and at Station 4 values ranged from 4.2 to 33.4 µg/L with an average concentration of 15 µg/L at Station 4. Because arsenic is a natural component of the earth's crust, low levels are found in all environmental media. Surveys of arsenic concentrations in rivers and lakes indicate that most values are below 10 µg/L, although higher values can occur near natural mineral deposits or man-made sources. The median arsenic concentration for surface water samples recorded in the EPA STORET database was 3 µg/L (USDHHS 1993a).

During the previous phases of the study arsenic was also detected at Stations 1 to 5. Concentrations were consistently lower at the upper stations near El Paso/Juárez and higher at the Presidio/Ojinaga and Big Bend area stations (Figure 4). Dissolved arsenic in water was also detected at all stations from El Paso/Juárez to Brownsville/Matamoros during Phases I and II, although the concentrations tended to be lower downstream of Amistad Reservoir.

The lower stations are influenced by agricultural runoff, irrigation return flow, urban runoff from Presidio/Ojinaga, inflow from the Rio Conchos and underlying mineral deposits from past volcanic activity. The upper stations (specifically Station 1) are influenced mainly by water released from Elephant Butte and Caballo Reservoirs and some irrigation return flow from New Mexico.

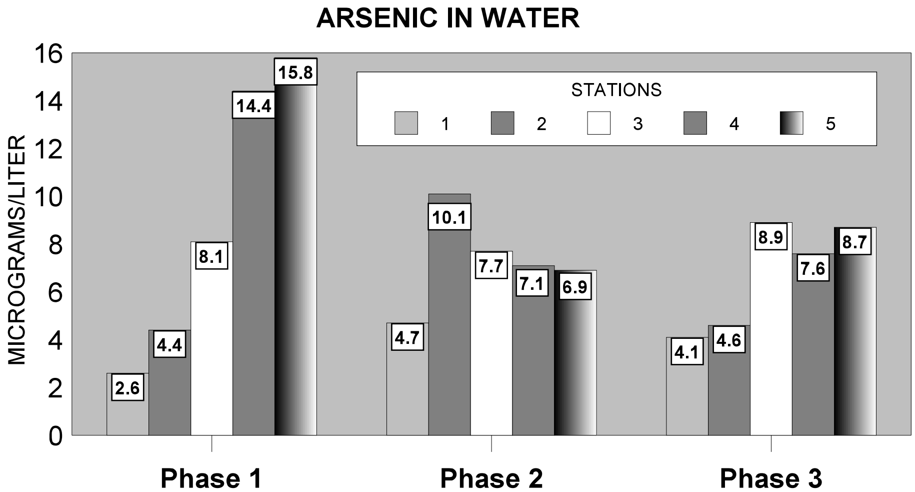



Figure 4. Arsenic in water for Phases I, II, and III of the RGTSS

## Mercury

***Sources*:** Occurs naturally, runoff from urban and industrial sources, municipal and industrial discharges

***Uses*:** Major use is as a cathode in the preparation of chlorine and caustic soda, electrical components, industrial control instruments (switches, thermometers, and barometers), pulp and paper manufacture, mining, pharmaceuticals, and general laboratory uses.

***Environmental / Health Effects*:** Several forms, ranging from elemental to dissolved organic and inorganic, occur in the environment; Certain microorganisms have the ability to convert the organic and inorganic forms to highly toxic methyl and dimethyl mercury has made all forms of mercury highly hazardous to the environment (USEPA 1980c; Eisler 1988; USDHHS 1993a).

Of all five metals detected in water, only mercury exceeded the human health criterion in two instances. Total mercury exceeded the human health criterion at the station above Presidio/Ojinaga (3) and at the Santa Elena Canyon (5) site in Big Bend. Duplicate samples collected during the study showed similar results with mercury detected above the human health criterion at Stations 3 and 5 in addition to the Boquillas Canyon (6) site. Mercury in water was not detected at any of the Phase III sites during Phases I or II of the study. Available historical metals in water data for total mercury is not available. Exceedence of these criteria indicate a potential human health hazard if untreated water and/or fish from a water body were consumed on a regular, long-term basis.

However, a caution is associated with the use of this data for any management or regulatory decision making.

Although the mercury concentrations in water exceeded the human health criterion, further investigation indicates that older mercury analysis methods used during this study were not adequately sensitive enough to assess ambient conditions. Recent samples, collected as part of a statewide metals in water survey were analyzed by the Texas A&M Trace Metals Laboratory using more accurate instrumentation. The results showed mercury was being detected at concentrations well below the human health criterion. New methods are being used that will improve the accuracy of monitoring for mercury-in-water. Older, less precise analytical instruments report erroneously elevated mercury concentrations that are more a reflection of the detection limit than actual instream concentrations.

### *Pesticides*

Analysis was done for a limited number of pesticides in water. Of the pesticides analyzed none were found above the detection limits in any of the samples. This was also true of the data collected at the same sites during Phases I and II of the study.

## Sediment

Many of the contaminants, natural and/or manmade (metals, pesticides, organics, and inorganics), introduced to surface waters will eventually accumulate in sediment. Information suggests that even in areas where surface water quality criteria are met, organisms in or on sediment can be adversely impacted by contaminants in sediment. Surface water quality criteria, developed to protect organisms inhabiting the water column, were not derived to protect benthic organisms (Rand 1995). The bioavailablity of organic contaminants in sediment is thought to be dependent upon the amount of organic carbon present and metals dependent on the presence of acid volatile sulfides; increases in organic carbon and acid volatile sulfides concentrations cause bioavailability of a contaminant to decrease (Pesch *et al*. 1995). The most commonly detected metals during Phase III were arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc (Table 16). The same metals were also common during Phases I and II of the study (Appendix D). Of the metals detected in sediment, the majority were less than any of the screening levels (Appendix B).

The two metals which were detected at concentrations exceeding screening levels at three or more stations were arsenic and chromium.

### *Sediment Effects Screening Levels*

Threshold Effects Levels (TELs), developed by NOAA, are based on benthic community metrics and toxicity tests results. TELs (lower-threshold values) represent concentrations below a point where the occurrence of adverse biological effects are rarely expected (Buchman 1999). Of the TELs available for metals in sediment, only arsenic and cadmium exceeded the screening concentrations.

TABLE 16
Contaminants in Sediment that
Exceeded Screening Levels in Phase III

| Contaminant | Sediment Screening Level Exceeded (Stations) |
|---|---|
| ●Arsenic | ●State 85th percentile (3, 4, 5 and 6)<br>●TEL (3, 4, 5 and 6) |
| ●Cadmium | ●TEL (2) |
| ●Chromium | ●State 85th percentile (3, 4 and 5) |
| ●Copper | ●State 85th percentile (2) |
| ●Nickel | ●State 85th percentile (4 and 5) |

### *SEM/AVS Ratios for Metals in Sediment*

An indicator of the bioavailability of certain metals in sediment to aquatic organisms is the ratio of simultaneously extracted metals and acid volatile sulfate (SEM/AVS). If SEM/AVS ratio is less than 1.0, the majority of a metal is unavailable to aquatic organisms. However, if the SEM/AVS ratio is greater than 1.0, excess metal may be readily available to aquatic organisms.

The SEM/AVS ratios can be compared with arsenic, cadmium, chromium, copper, mercury, nickel, lead and zinc. The SEM/AVS ratios calculated for the Phase III sites were all less than one. Although all of these metals were detected at various concentrations during Phase III, the SEM/AVS ratios indicate that none of these metals were readily available to aquatic organisms (Figure 5).

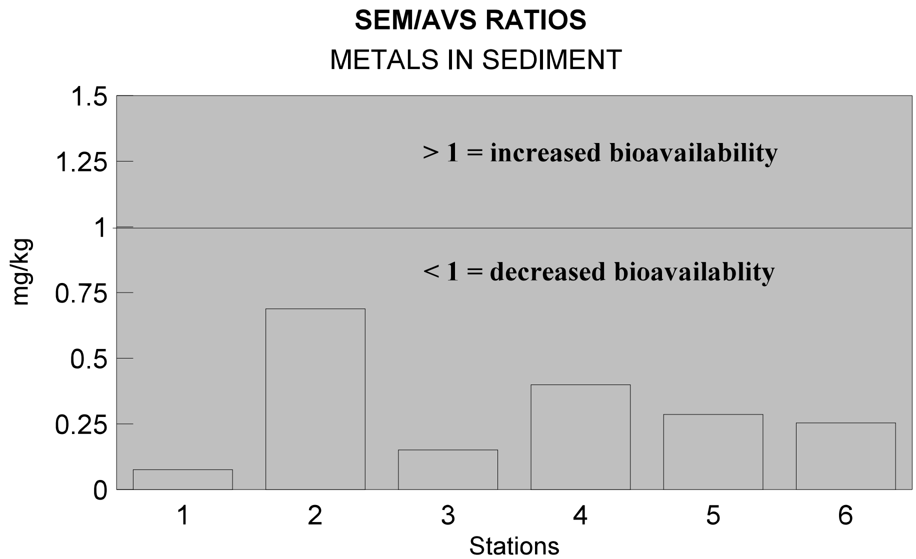



Figure 5. SEM/AVS Ratios for Phase III stations

### Arsenic

Arsenic in sediment was detected at all of the Phase III study sites. Concentrations exceeded both the state screening (85th percentile) level (6.32 mg/kg) and the Threshold Effects Level (TEL) concentration (5.9 mg/kg) at Stations 3, 4, 5 and 6 (Table 17). TELs (lower-threshold values) represent concentrations below a point where the occurrence of adverse biological effects are rarely expected. Arsenic concentrations ranged from 7.2 to 8.9 mg/kg at the four lower stations.

During the previous phases of the study arsenic was also detected at Stations 1 to 5 (Figure 6). Concentrations were consistently lower at the upper stations near El Paso/Juárez and higher at the Presidio/Ojinaga and Big Bend area stations. The arsenic concentrations detected at the lower stations during Phases I and II also exceeded the state and TEL screening levels. Arsenic in sediment was also detected at all stations from El Paso/Juarez to Brownsville/Matamoros during Phases I and II, although the concentrations tended to be lower downstream of Amistad Reservoir.

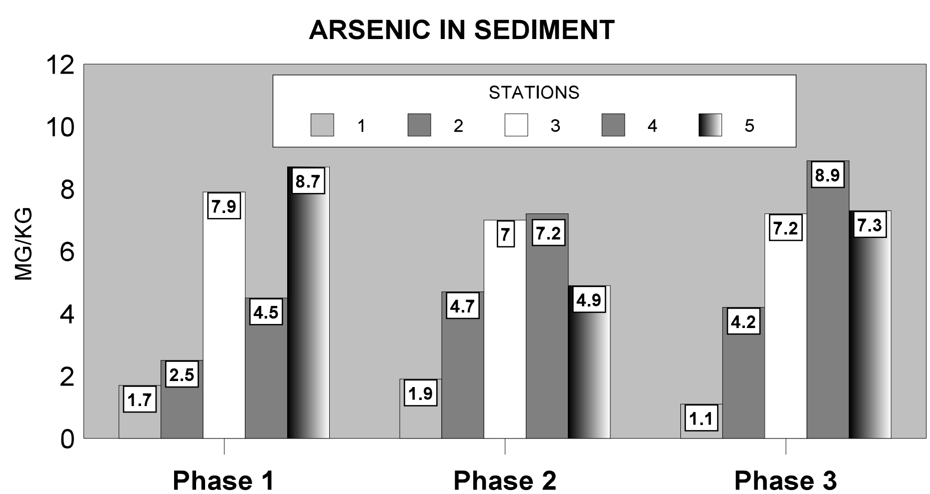
The background concentration for arsenic in sediment reported by NOAA is 1.1 mg/kg (Buchman 1999). Only Station 1 had a concentration at background levels. Areas of west Texas, dominated by volcanic rock and mineral-rich geologic deposits are the primary reason for higher arsenic concentrations in the Rio Grande/Rio Bravo.

TABLE 17
Summary of Screening Level Concentrations,
Background Levels and Data for Metals Detected in Sediment-Phase III

| METALS IN SEDIMENT | Arsenic | Cadmium | Chromium | Copper | Lead | Mercury | Nickel | Zinc | SEM/AVS |
|---|---|---|---|---|---|---|---|---|---|
| TEL Concentration | 5.9 | 0.596 | 37.3 | 35.7 | 35.0 | 0.174 | 18.0 | 123.1 | - |
| State 85th % Concentration | 6.32 | 1.0 | 18.9 | 15.9 | 31.6 | 0.11 | 14.2 | 75.9 | - |
| Background Concentrations* | 1.1 | 0.10-0.30 | 7.0-13.0 | 10.0-25.0 | 4.0-17.0 | 0.004-0.051 | 9.9 | 7.0-38.0 | - |
| Station 1 | 1.1 | 0.025 | 5.6 | 2.6 | 4.1 | 0.002 | 3.3 | 14.3 | 0.076 |
| Station 2 | 4.2 | **0.73** | 12.9 | **45.3** | 28.6 | 0.025 | 6.7 | 55 | 0.688 |
| Station 3 | **7.2** | 0.23 | **19.4** | 10.5 | 6.1 | 0.009 | 12.6 | 46.8 | 0.151 |
| Station 4 | **8.9** | 0.27 | **24.1** | 13.2 | 8.9 | 0.020 | **14.9** | 65.4 | 0.399 |
| Station 5 | **7.3** | 0.36 | **21.3** | 12.9 | 9.4 | 0.029 | 11.3 | 66.5 | 0.286 |
| Station 6 | **6.96** | 0.275 | 18.35 | 10.8 | 11.05 | 0.025 | 11.05 | 63.0 | 0.254 |

See Table 10 for a list of all sediment screening concentrations
* NOAA background levels (Buchman 1999)

Figure 6. Arsenic in Sediment Detected During All Phases of the RGTSS



## *Chromium*

***Sources*:** Naturally occurring element in rocks, plants, animals, volcanic dust, and gases; manufacturing, disposal of products or chemicals containing chromium or burning of fossil fuels release chromium to the air, soil, and water. Chromium (III) occurs naturally and is an essential nutrient required by the human body. Chromium (VI) and chromium (0) are generally produced by industrial processes.

***Uses*:** Making steel and other alloys, electroplating, bricks in furnaces, dyes and pigments, chrome plating, textile manufacturing, leather tanning, and wood preserving.

***Environmental/ Health Effects*:** Carcinogen and Mutagen; a small amount dissolves in water; rest settles to the bottom; chromium does not accumulate in fish tissue; very persistent in water; more toxic in soft water than hard; chromium (III) has a moderate acute toxicity and high chronic toxicity to aquatic life and chromium (VI) has high acute and chronic toxicity to aquatic life. Soluble chromium compounds can remain in water for years before settling to the bottom. In addition, deposition of airborne chromium is also a significant nonpoint source of chromium in surface water (USEPA 1980g;Eisler 1986a; USDHHS 1993e).

Chromium in sediment was detected at all of the Phase III study sites. Chromium exceeded the state 85$^{th}$ percentile (18.9 mg/kg) at Stations 3, 4 and 5 with concentrations ranging from 19.4 to 24.1 mg/kg (Table 17). The range of background concentrations for chromium in sediment reported by NOAA is 7.0 to 13.0 mg/kg (Buchman 1999). With the exception of the three instances where chromium exceeded the TEL at Stations 3, 4 and 5, during Phase 3, all other chromium concentrations (Phases I, II and III) were less than the upper limit of the range of background concentrations.

## Cadmium

***Sources*:** Natural element in the earth's crust; usually found as a mineral combined with other elements; all soils and rocks, including coal and mineral fertilizers contain some cadmium.

***Uses*:** Cadmium does not corrode easily and has many uses in industry and consumer products; batteries, pigments, photoelectric cells, process engraving, electroplating, metal alloys, metal coatings, and plastics.

***Environmental/ Health Effects*:** Carcinogen; enters the air from mining, industry and the burning of coal and household waste; enters water from metal plating industry effluent and municipal WWTP effluent; doesn't break down in the environment, very persistent in water; bioaccumulates in tissue; high acute and chronic toxicity to aquatic life (USEPA 1985;Eisler 1985; USDHHS 1993c).

Cadmium in sediment was detected at all of the Phase III study sites. Cadmium exceeded the TEL concentration (0.596 mg/kg) at Station 2 only with a concentration of 0.73 mg/kg (Table17). The remaining cadmium concentrations were all less than 0.36 mg/kg. Data from Phase I and II showed similar results. During Phase II, cadmium was also detected at all stations but exceeded the TEL only at Station 4 (0.69 mg/kg). All other cadmium concentrations from Phases I and II were less than 0.37 mg/kg.

The range of background concentrations for cadmium in sediment reported by NOAA is 0.10 to 0.30 mg/kg (Buchman 1999). With the exception of the two instances where cadmium exceeded the TEL at Stations 2 and 4, all other cadmium concentrations fell within or slightly above the range of background concentrations.

## Copper

***Sources*:** Extremely common in rocks and soil; corrosion of brass and copper pipes and tubes, industrial/ municipal WWTP discharges, the use of copper compounds as aquatic algicides.

***Uses*:** Smelting and refining industries, copper wire mills, coal burning industries, and iron and steel production.

***Environmental/ Health Effects*:** Not a carcinogen. Copper is necessary for good health. Too much copper can have some adverse health effects. One of the most common contaminants of urban runoff; enters natural waters by runoff; industrial/municipal WWTP effluent or by atmospheric fallout from industry; rainfall may be a significant source of copper to the aquatic environment in industrial and mining areas; industrial and municipal discharges (USEPA 1980h).

Copper, detected at all Phase III stations, exceeded screening levels at Station 2 only. Concentrations exceeded both the state 85$^{th}$ percentile (15.9 mg/kg) and the TEL concentration (35.0 mg/kg) at Station 2 (Table17). During Phase II, copper was also detected at all stations but exceeded the TEL only at Station 2 ( 26.7 mg/kg). The elevated copper concentrations downstream of El Paso/Juárez, in large part, can be attributed to urban runoff.

During all phases of this project, copper concentrations were all less than the upper limit of the background concentrations with the exception of Station 2. The range of background concentrations for copper in sediment reported by NOAA is 10 to 25 mg/kg (Buchman 1999).

## Nickel

***Sources:*** Weathering of rocks, rainfall and runoff; 24$^{th}$ most abundant mineral and can be found in all soils.

***Uses*:** Nickel is combined with other metals to form alloys; the most common alloy is nickel-iron used to make stainless steel; other alloys are used to make coins, jewelry, plumbing, and heating equipment, gas-turbine engines and electrodes; nickel compounds are also used in plating, to color ceramics, and to make some batteries.

***Environmental/ Health Effects*:** Carcinogen; one of the most common metals in surface water; burning of coal and other fossil fuels; discharges from industry (electroplating and smelting); does not bioaccumulate in fish tissue; nickel common in air and is washed out by rain or snow; most ends up attached to soil or sediment particles; high acute and chronic toxicity in aquatic life (USEPA 1986a;USDHHS 1993h).

Nickel, also detected at all Phase III stations, exceeded a screening level at Stations 4 and 5. Concentrations at Stations 4 and 5 exceeded the state 85$^{th}$ percentile (14.2 mg/kg) (Table 17). Nickel concentrations were greater than the background concentration (9.9 mg/kg) at all stations except Stations 1 and 2 (Buchman 1999).

During Phases I and II of this project, nickel concentrations were also less than the background concentration at Stations 1 and 2. None of the nickel concentrations found at Stations 3, 4 and 5 were greater than any of the screening levels. However, all but one were greater than the background concentration of 9.9 mg/kg (Appendix D).

**Lead, Mercury and Zinc**: Lead, mercury and zinc were detected at all sites during Phases I, II and III but concentrations did not exceed any of the screening levels (Appendix D). During all phases of the project, ***mercury*** concentrations were all less than the upper limit of the background concentration range (Buchman

1999). ***Zinc*** was greater than background concentration range at Phase I, II and III stations with the exception of Station 1. Zinc is one of the earths most common elements; found in air, soil, and water and is present in all foods. ***Lead*** was within the normal range of background concentrations at all stations with the exception of Station 2 (Table 17). Elevated lead can be attributed to urban runoff, and both industrial and municipal wastewater treatment plant discharges.

### Lead

| | |
|---|---|
| ***Sources:*** | Lead is a major constituent of > 200 identified minerals. Only three are found in sufficient abundance to form mineral deposits. |
| ***Uses*:** | Lead pipe, lead lined containers for corrosive gases and liquids, paint, pigments, alloys used in metallurgy, storage batteries, ceramics, electronic devices, and plastics. |
| ***Environmental/ Health Effects*:** | Teratogen; reaches the aquatic environment through rainfall; fallout of lead dust; urban runoff and both industrial and municipal WWTP discharges (USEPA 1980k; USDHHS 1993g). |

### Zinc

| | |
|---|---|
| ***Sources:*** | One of the earths most common elements; found in air, soil, and water and is present in all foods. |
| ***Uses*:** | Many commercial uses; as coating to prevent rust; in dry cell batteries; mixed with other metals to make alloys like brass and bronze; zinc compounds are widely used to make paint, rubber, dye, wood preservatives, and ointments. |
| ***Environmental/ Health Effects*:** | Not a carcinogen. Zinc is an essential dietary element. Too little zinc can cause health problems, but too much zinc is also harmful. Enters the environment by natural processes in addition to activities like mining, steel production, coal burning and waste burning; builds up in fish and other organisms; readily transported in most natural waters-groundwater, lakes, streams and rivers (USEPA 1980r; USDHHS 1995f). |

### *Pesticides*

Analysis was done for a limited number of pesticides in sediment. Three replicate samples and one duplicate sample were collected at each site. Pesticides were not detected in any of the 24 sediment samples collected. Comparison of data from the three phases of the study shows that of the pesticides analyzed in Phase III, only two pesticides were detected in sediment during Phase II; DDE and alpha BHC were detected at Station 2. A smaller set of pesticides was chosen for Phase III because other pesticides were not commonly detected during Phases I or II.

## Metals in Tissue

An attempt was made to collect tissue samples from various levels of the food chain. This was achieved with varying degrees of success due to high flow, habitat limitations, reduced sampling equipment performance, and/or access to sites. Overall, tissue samples from each site included combinations of the following: whole and edible fish (large), pan size fish, minnow size fish, benthic macroinvertebrates (predator species, Chironomids, mayflies, caddisflies, beetles, worms, trichoptera species, blackflies, dragonflies) and algae. Due to a problem with laboratory contamination, chromium, copper and lead data were invalid for most of the tissue samples with the exception of whole fish. Benthics tissue results are reported as dry weight (dw) and fish tissue results reported as wet weight (ww).

### *Arsenic*

Arsenic was detected in fish tissue at all stations and in benthic macroinvertebrate tissue at five of six stations (Table18). Overall, the concentration of arsenic in tissue was greater in the invertebrates than in the fishes (Figure 7). Among the fish tissue samples, the highest value was 4.3 mg/kg wet weight (ww) reported for a whole catfish sample collected at Station 3. The highest concentration for the benthic macroinvertebrate samples was 28.6 mg/kg ww in oligochaetes collected at Station 1. In order to allow comparison of our results to studies reporting

TABLE 18

TISSUE DATA Rio Grande/Rio Bravo Toxic Substance Study-Phase III

STATION 1-Rio Grande/Rio Bravo at Courchesne Bridge

| Parameter (mg/kg) | Whole Fish Carp | Edible Fish Carp | Whole Fish Pan Size | Whole Fish Minnow Size | Benthics Dragonflies | Benthics Caddisflies | Benthics Worms | Algae |
|---|---|---|---|---|---|---|---|---|
| Arsenic, Total (ICP) | 2.53 | < 7.02 | < 2.07 | 7.46 | < 12.3 | 5.48 | 28.6 | 15.0 |
| Cadmium, Total (ICP) | < 0.365 | < 1.17 | < 0.345 | < 0.940 | < 2.06 | < 0.689 | < 2.37 | < 1.06 |
| Chromium, Total (ICP) | 0.773 | * | 3.47 | * | * | * | * | * |
| Copper, Total (ICP) | 4.49 | * | 277 | * | * | * | * | * |
| Lead, Total (ICP) | < 1.83 | < 5.85 | 12.1 | * | * | * | * | * |
| Mercury, Total (ICP) | 0.133 | 0.577 | 0.151 | 0.128 | 0.114 | 0.008 | 0.040 | 0.032 |
| Selenium, Total (ICP) | 2.52 | < 7.02 | 5.07 | < 5.64 | < 12.3 | < 4.13 | < 14.2 | < 6.37 |
| Tin, Total (ICP) | 21.0 | 6.62 | 12.2 | * | * | * | * | * |

* NOT REPORTED - did not meet all QC criteria; [Benthics reported as dry weight (dw)/Fish reported in wet weight (ww)]

STATION 2-Rio Grande/Rio Bravo at Zaragosa Bridge

| Parameter (mg/kg) | Whole Fish Carp | Edible Fish Carp | Edible Fish Carp (Duplicate) | Whole Fish Minnow Size | Benthics Trichoptera Filter Feeders | Benthics Chironomids | Benthics Predators |
|---|---|---|---|---|---|---|---|
| Arsenic, Total (ICP) | 3.05 | < 6.69 | < 7.00 | < 7.24 | < 13.0 | 19.0 | < 10.1 |
| Cadmium, Total (ICP) | < 0.389 | < 1.12 | < 1.17 | < 1.21 | < 2.16 | 4.29 | 1.73 |
| Chromium, Total (ICP) | 0.832 | * | * | * | * | * | * |
| Copper, Total (ICP) | 6.11 | * | * | * | * | * | * |
| Lead, Total (ICP) | < 1.94 | < 5.58 | < 5.84 | * | * | * | * |
| Mercury, Total (ICP) | 0.119 | 0.231 | 0.230 | 0.174 | 0.081 | 0.164 | 0.083 |
| Selenium, Total (ICP) | 3.49 | < 6.69 | < 7.00 | < 7.24 | < 13.0 | < 10.4 | < 10.1 |
| Tin, Total (ICP) | 23.0 | 5.23 | 9.44 | * | * | * | * |

TABLE 18 (cont)
TISSUE DATA Rio Grande/Rio Bravo Toxic Substance Study-Phase III

STATION 3-Rio Grande/Rio Bravo 5.0 km Upstream from Rio Conchos Confluence

| Parameter (mg/kg) | Whole Fish Catfish | Whole Fish Minnow Size | Benthics Predators | Benthics Blackflies | Benthics Mayflies | Algae (Filamentous) |
|---|---|---|---|---|---|---|
| Arsenic, Total (ICP) | 4.33 | < 7.46 | < 15.3 | 16.5 | < 14.5 | 14.3 |
| Cadmium, Total (ICP) | < 0.448 | < 1.24 | < 2.55 | < 1.60 | < 2.41 | < 1.88 |
| Chromium, Total (ICP) | 4.79 | * | * | * | * | * |
| Copper, Total (ICP) | 630 | * | * | * | * | * |
| Lead, Total (ICP) | 28.6 | * | * | * | * | * |
| Mercury, Total (ICP) | 0.507 | 0.339 | 0.145 | 0.146 | 0.142 | 0.059 |
| Selenium, Total (ICP) | 8.38 | < 7.46 | < 15.3 | < 9.61 | < 14.5 | < 11.3 |
| Tin, Total (ICP) | 14.9 | * | * | * | * | * |

STATION 4-Rio Grande/Rio Bravo Downstream of Rio Conchos Confluence

| Parameter (mg/kg) | Whole Fish Carp | Edible Fish Catfish | Whole Fish Minnow Size | Benthics Predators | Benthics Chironomids | Benthics Mayflies | Benthics Caddisflies |
|---|---|---|---|---|---|---|---|
| Arsenic, Total (ICP) | 3.41 | < 8.22 | < 7.08 | < 12.4 | 24.6 | 19.4 | < 12.7 |
| Cadmium, Total (ICP) | < 0.370 | < 1.37 | < 1.18 | < 2.07 | < 2.38 | < 1.75 | < 2.12 |
| Chromium, Total (ICP) | 1.02 | * | * | * | * | * | * |
| Copper, Total (ICP) | 5.09 | * | * | * | * | * | * |
| Lead, Total (ICP) | < 1.85 | < 6.85 | * | * | * | * | * |
| Mercury, Total (ICP) | 0.553 | 0.679 | 0.328 | 0.103 | 0.041 | 0.096 | 0.094 |
| Selenium, Total (ICP) | 5.69 | < 8.22 | 8.72 | < 12.4 | < 14.3 | < 10.5 | < 12.7 |
| Tin, Total (ICP) | 67.2 | < 5.48 | * | * | * | * | * |

STATION 5 - Rio Grande/Rio Bravo at Santa Elena Canyon

| Parameter (mg/kg) | Whole Fish Flathead Catfish | Whole Fish Carp | Edible Fish Catfish | Whole Fish Minnow Size | Benthics Predators | Benthics Mayflies |
|---|---|---|---|---|---|---|
| Arsenic, Total (ICP) | 4.28 | 3.36 | < 7.48 | 7.16 | < 12.5 | < 13.8 |
| Cadmium, Total (ICP) | < 0.448 | < 0.386 | < 1.25 | < 0.896 | < 2.08 | < 2.29 |
| Chromium, Total (ICP) | 0.979 | 1.52 | * | * | * | * |
| Copper, Total (ICP) | 3.45 | 3.45 | * | * | * | * |
| Lead, Total (ICP) | < 2.24 | < 1.93 | < 6.24 | * | * | * |
| Mercury, Total (ICP) | 2.65 | 1.00 | 1.18 | 0.591 | 0.208 | 0.092 |
| Selenium, Total (ICP) | 6.51 | 5.71 | < 7.48 | 8.8 | < 12.5 | < 13.8 |
| Tin, Total (ICP) | 43.3 | 98.9 | 8.88 | * | * | * |

TABLE 18 (cont)
TISSUE DATA Rio Grande/Rio Bravo Toxic Substance Study-Phase III

| STATION 6- Rio Grande/Rio Bravo at Boquillas Canyon | | | | |
|---|---|---|---|---|
| Parameter (mg/kg) | Whole Fish Flathead Catfish | Benthics Beetles | Benthics Predators | Benthics Mayflies |
| Arsenic, Total (ICP) | 3.94 | < 27.4 | < 11.1 | 17.7 |
| Cadmium, Total (ICP) | < 0.493 | < 4.57 | < 1.85 | 1.97 |
| Chromium, Total (ICP) | 4.26 | * | * | * |
| Copper, Total (ICP) | 126 | * | * | * |
| Lead, Total (ICP) | 4.64 | * | * | * |
| Mercury, Total (ICP) | 0.873 | 0.054 | 0.127 | 0.115 |
| Selenium, Total (ICP) | 7.0 | < 27.4 | < 11.1 | 12.1 |
| Tin, Total (ICP) | 14.8 | * | * | * |

concentrations per unit wet weight, we used data provided by the laboratory which quantifies the solid fraction of each sample, to convert the dry weight concentration of arsenic in tissue to wet weight concentrations. In every case where arsenic was detected in fish tissue, carp at Stations 1, 2, 4 and 5, shiners at Stations 1 and 5, channel catfish at Station 3, and flathead catfish at Stations 5 and 6 the concentrations exceeded the national 85$^{th}$ percentile (0.2 mg/kg ww; Figure 8). Arsenic levels in tissue for carp at Stations 1, 2, 4, and 5, shiners at Stations 1 and 5, channel catfish at Station 3, and flathead catfish at Stations 5 and 6 exceeded the maximum value (0.33 mg/kg ww) reported by Irwin (1989) in his summary of toxic chemicals in wildlife at Big Bend (Table 18 ). These values also exceed the predator protection level reported by Irwin (1989)(Figure 9). All values were below the TDH screening levels.

There are little comparative data available on arsenic concentrations in invertebrate tissue in the Rio Grande/Rio Bravo other than in the lower portion of the basin in tidal and marine environments. The maximum concentration noted in our study, 28.6 mg/kg dw in oligochaetes collected at Station 1, exceeds the maximum reported by Mora and Wainwright (1997), 26.9 mg/kg dw for grass shrimp collected in the lower Laguna Madre.

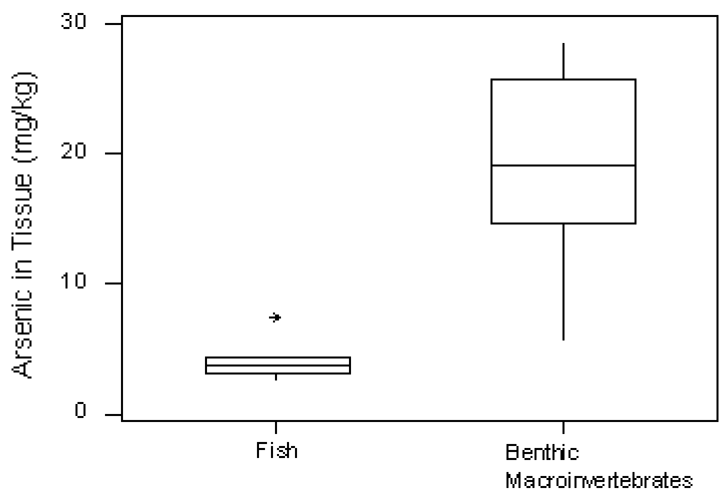



Figure 7. Comparison of Arsenic Concentrations in Fish and Benthic Macroinvertebrate Tissue Samples Collected from Six Stations During Phase III. Note: The upper and lower vertical lines represent the Upper and Lower Limits, respectively. The Upper Limit is defined as $Q_3$ +1.5 ($Q_3$-$Q_1$) and the lower limit as $Q_1$-1.5 ($Q_3$-$Q_1$). The upper, middle and lower horizontal lines of the box represent the Third Quartile($Q_3$), the Median, and the First Quartile ($Q_1$). The "*" represents outliers, those points outside the lower and upper limits.

At each station there is some indication of bioaccumulation of arsenic, especially at the lower trophic levels. The tissue concentration of arsenic in primary producers (algae), invertebrate collector-gatherers/deposit feeders such as mayflies, and oligochaetes was greater than in sediment (Figures 6 and 8). However, this was not as evident in higher trophic levels. In invertivorous (insect eating) fishes, the arsenic concentrations in tissue were greater than sediment concentrations, but lower than concentrations found in the invertebrate samples (Figure 7). This is consistent with findings reported in Quality Criteria for Water (USEPA 1986) indicating that arsenic does not bioconcentrate to a high degree but that invertebrates may accumulate higher arsenic residues than fish. It should be noted that, in his report on Toxic Chemicals in Fish and Wildlife at

Big Bend National Park, Texas (USFWS 1989), R.J. Irwin indicates that arsenic is one of the few metals that tends to concentrate in the axial muscles of fish. Arsenic was detected in fish tissue at all six sites (Figure 9) in concentrations which exceeded that in sediment. Arsenic levels in tissue for shiners exceeded the maximum values which were reported by Mora and Wainright (1997) in their review of contaminants in biota of the Rio Grande/Rio Bravo. The elevated tissue concentration of arsenic in the insectivorous shiners detected at Stations 1 and 5 may reflect bioaccumulation. Irwin suggests that potential sources for arsenic include air pollution from fossil fuel combustion and soil erosion as well as from pesticides and industrial sources.

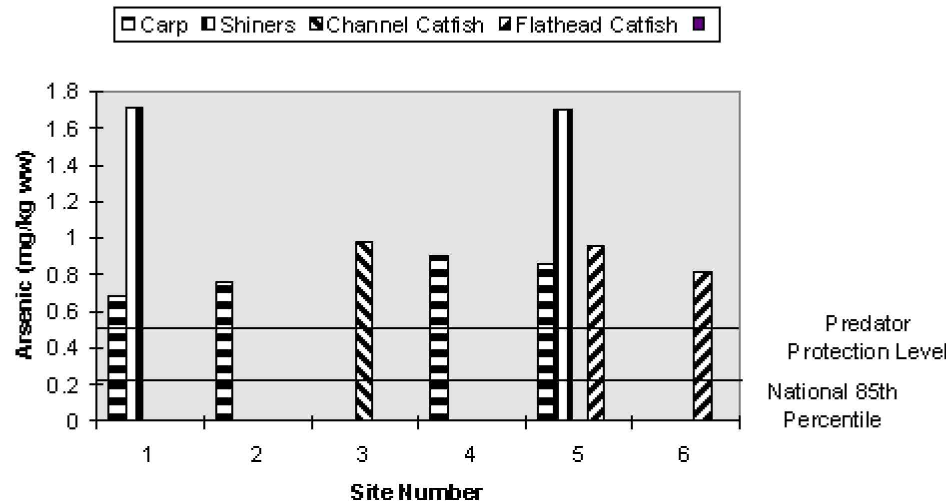



Figure 8. Summary of Arsenic Concentrations in Fish Tissue Samples Collected from Six Stations During Phase III

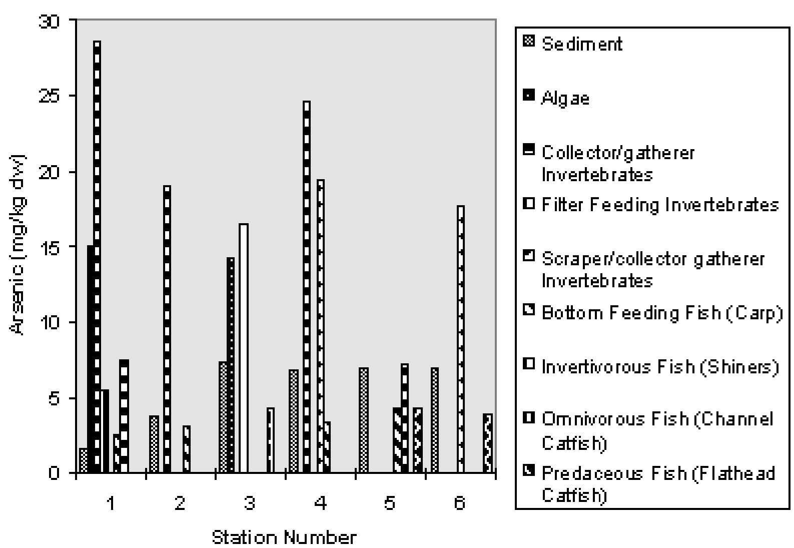



Figure 9. Summary of Arsenic in Tissue Samples Collected During Phase III.

### Mercury

At all six stations, total mercury was detected in fish and benthic macroinvertebrate tissue samples (Table 18). The four highest values detected, 2.65 mg/kg ww in flathead catfish, 1.0 mg/kg ww in carp, 1.18 mg/kg ww in catfish collected at Station 5, and 0.873 mg/kg ww in flathead catfish from Station 6 exceeded all but one of the values reported by Mora and Wainwright (1997). Interestingly, that value (8.70 mg/kg dw) was also for a predator long nose gar (*Lepisosteus osseus*) collected from the Rio Grande/Rio Bravo in Big Bend National Park/Canyon de Santa Elena Protected Area.

The wet weight (ww) tissue concentration for mercury exceeded the state 85$^{th}$ percentile in a flathead catfish sample collected at Station 5 (Figure 10). Values for carp at Station 4, shiners at Station 5, channel catfish at Station 3, and flathead catfish at Stations 5 and 6 exceed the predator protection level (0.1 mg/kg ww) cited by Irwin (1989)(Figure 10). All wet weight values are lower than the 1.0 mg/kg ww human health screening concentrations (TNRCC 2000).

Dry weight tissue concentrations of mercury in benthic macroinvertebrates ranged from 0.008 mg/kg in filter feeding caddisflies collected at Site 1 to 0.208 mg/kg in dragonfly larvae collected at Station 5 (Figures 11-16). These values are in good agreement with those reported by Mora and Wainwright (1997) in their report which cites a range of 0.001 mg/kg to 0.32 mg/kg mercury in aquatic invertebrate tissue in the Rio Grande/Rio Bravo Basin. All results reported by Mora and Wainwright for aquatic invertebrates are from tidal waters and/or the Laguna Madre, and so are not directly comparable to our samples of freshwater aquatic macroinvertebrates collected from the river. Khan and Richerson (1982) reported values of mercury in tissue ranging from 1 to 35.6 ug/g dw for terrestrial arthropods collected around Terlingua Creek.

Mercury in the sediments can enter the aquatic food web via several pathways, primary among these is methylation by micro-organisms (Twidwell 2000). Subsequent consumption by invertebrate deposit feeders and collector-gatherers, such as some of the mayfly and chironomid larvae as well as oligochaetes, utilize organic matter in the sediments, including fecal matter from other invertebrates and vertebrates as food items (Khan and Richerson 1982).

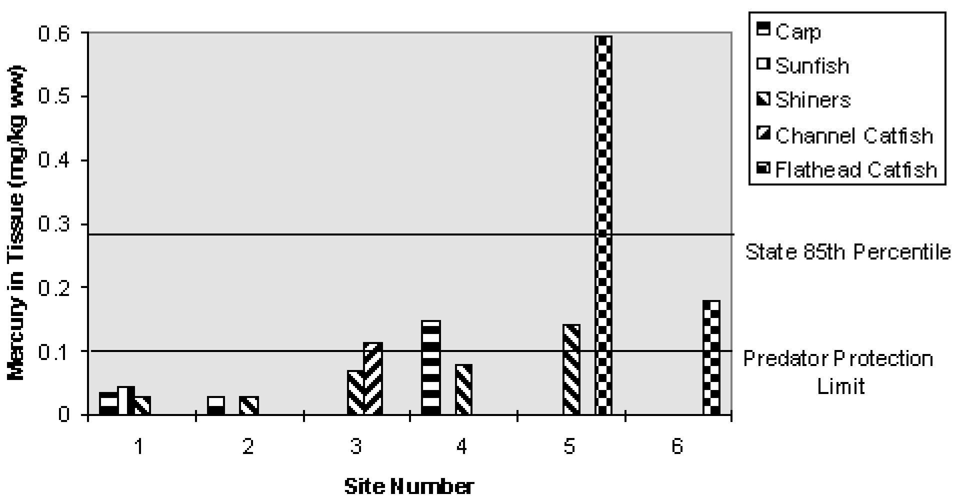



Figure 10. Summary of Mercury Concentrations in Fish Tissue Samples Collected from Six Stations During Phase III.


Figure 11. Summary of Mercury Concentrations in Tissue of Different Trophic Levels for Samples Collected at Station 1 During Phase III.

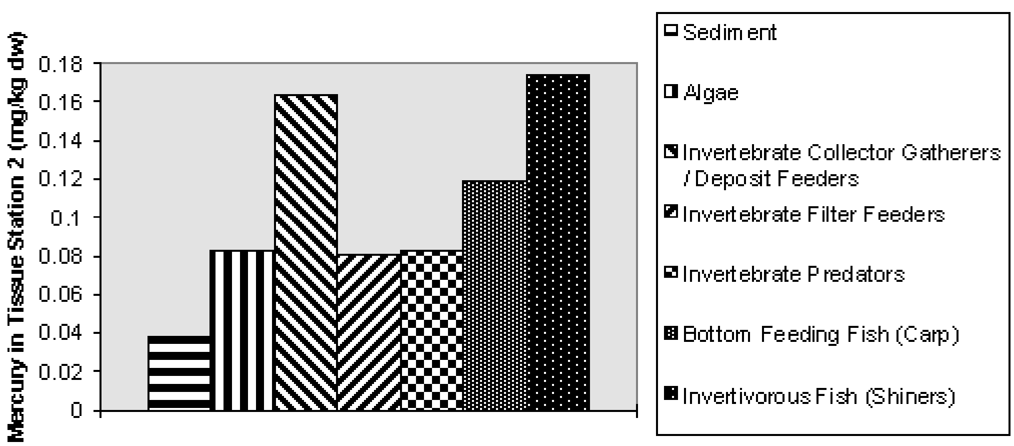



Figure 12. Summary of Mercury Concentrations in the Tissue of Different Trophic Levels for Samples Collected from Station 2 During Phase III.

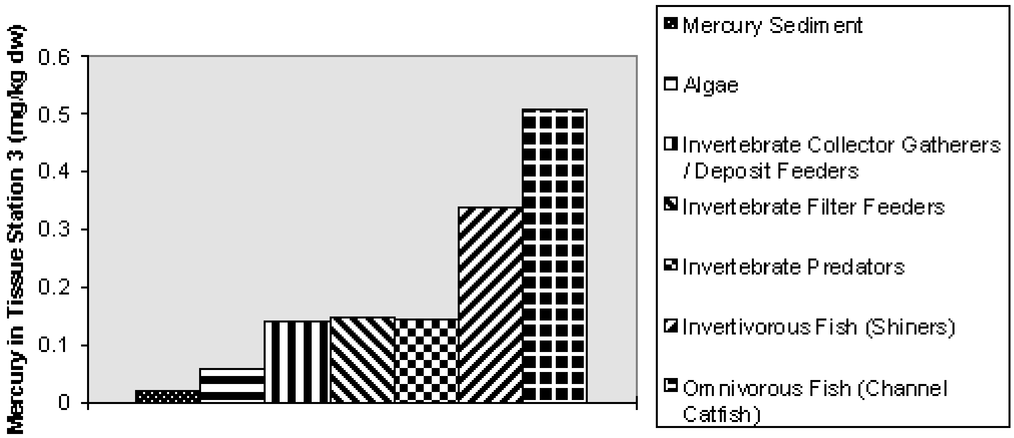



Figure 13. Summary of Mercury Concentrations in the Tissue of Different Trophic Levels for Samples Collected from Station 3 During Phase III.

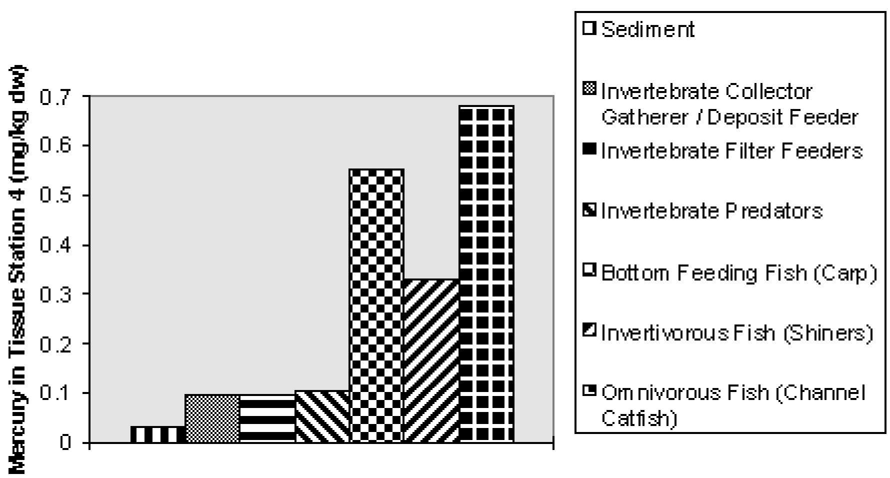



Figure 14. Summary of Mercury Concentrations in the Tissue of Different Trophic Levels for Samples Collected from Station 4 During Phase III.

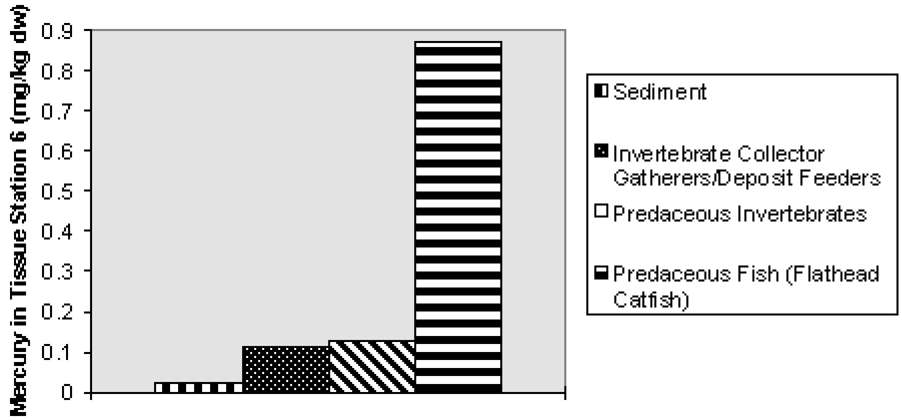



Figure 15. Summary of Mercury Concentrations in the Tissue of Different Trophic Levels for Samples Collected from Station 5 During Phase III.

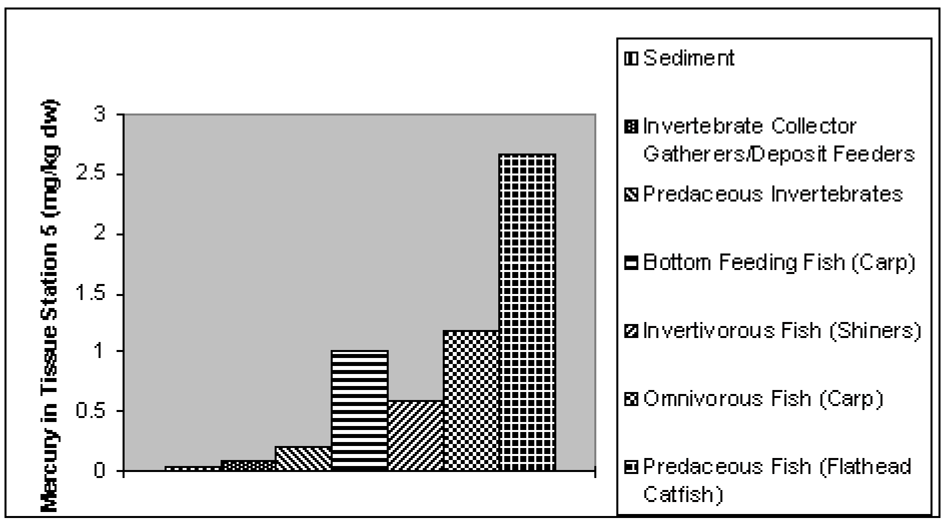



Figure 16. Summary of Mercury Concentrations in the Tissue of Different Trophic Levels for Samples Collected from Station 6 During Phase III.

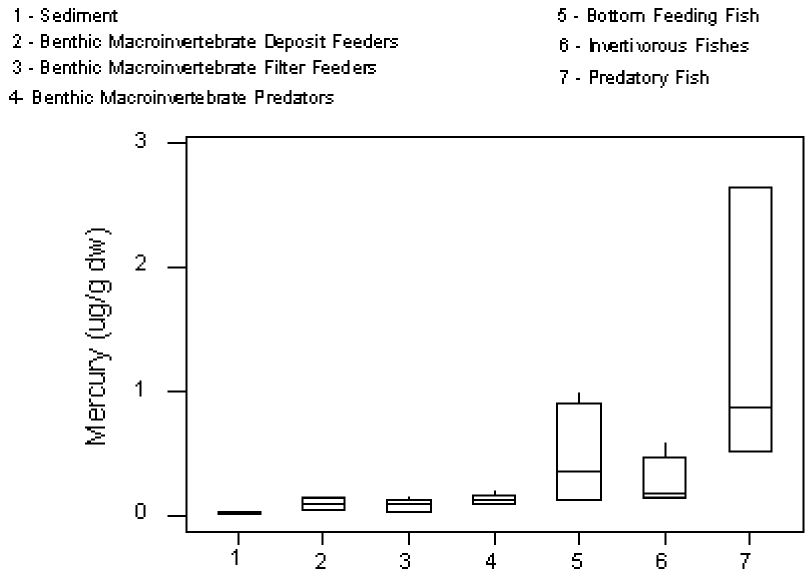



Figure 17. Boxplot Relating Mercury Tissue Concentrations for Each Trophic Level Across All Six Stations. Note: The upper and lower vertical lines represent the Upper and Lower Limits, respectively. The Upper Limit is defined as $Q_3 + 1.5 (Q_3 - Q_1)$ and the lower limit as $Q_1 - 1.5 (Q_3 - Q_1)$. The upper, middle and lower horizontal lines of the box represent the Third Quartile($Q_3$), the Median, and the First Quartile ($Q_1$). The "*" represents outliers, those points outside the lower and upper limits.

Consumption of these groups as prey items by invertebrate predators such as dragonfly larvae as well as vertebrate predators such as shiners, and top predators such as flathead catfish results in the movement of mercury from the sediments to top predators. Mercury, usually in the form of methyl-mercury (MeHg), tends to biomagnify in aquatic food webs because of progressively increasing concentrations of mercury at each successive level in the food web (Twidwell 2000).

This tendency for total mercury to bioaccumulate is evident in our results both when data are pooled across all stations (Figure 17) and at individual stations (Figures 11 to16). For example, at Station 5 the increase in mercury concentrations showed a relatively uniform increase across trophic levels. The lowest concentration were observed in the sediment, the highest in the predaceous fish and intermediate concentrations in the invertebrates and invertivorous fishes (Figure 17). A similar pattern was observed at all stations. Mercury body burdens in top predators such as the flathead catfish exceeded predator protection level at Stations 5 and 6.

Because both aquatic invertebrates and vertebrates are potential prey items for terrestrial predators bioaccumulation of mercury in aquatic environments may also contribute to elevated levels of mercury in terrestrial organisms. Khan and Richerson (1982) found elevated levels of mercury in terrestrial invertebrates collected from around Terlingua Creek located in Brewster County, Texas in and adjacent to Big Bend National Park. Their findings, coupled with ours indicate that mercury in the Rio Grande/Rio Bravo may be contributing to elevated levels of mercury in terrestrial organisms.

At stations downstream of Terlingua Creek, these findings may be related to historic mining activities. It is unclear what, other than aerial deposition might contribute to elevated levels detected in tissue samples from stations upstream of Terlingua Creek.

## Other Metals

### *Fish*

**Chromium**

Chromium was detected in the tissue of carp at Stations 1 - 5, sunfish at Station 1, flathead catfish at Stations 5 and 6 (Figure18). Tissue concentrations exceeded the national 85th percentile in carp collected at Station 3, sunfish collected at Station 1, and flathead catfish collected at Station 6. Chromium body burdens exceeded the predator protection limit in sunfish collected at Station 1, carp collected at Stations 3, 4, and 5 and in flathead catfish collected at Stations 5 and 6. All values were below the Texas Department of Health (TDH) Screening level (Table11).

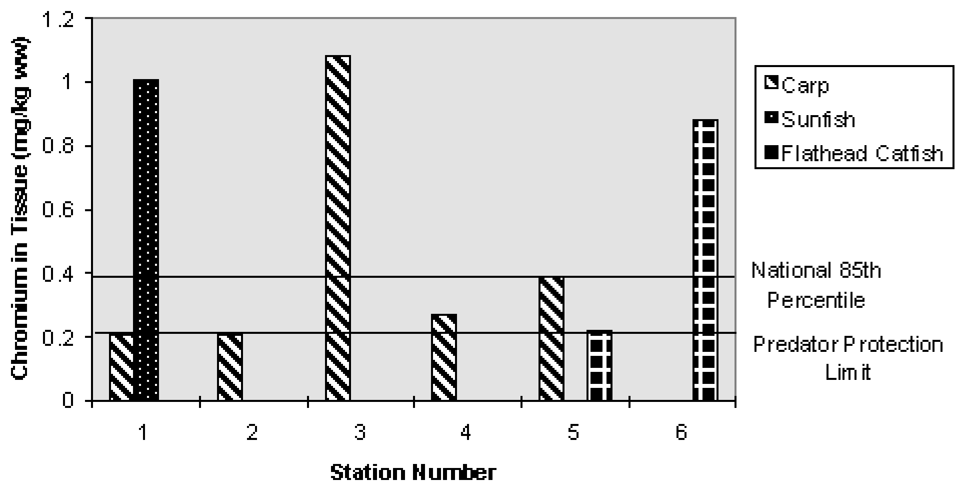



Figure 18. Summary of Chromium Concentrations in Fish Tissue for Samples Collected from Six Stations During Phase III.

**Copper**

Copper was detected in tissue samples from carp collected at Stations 1, 2, 4, and 5 as well as in sunfish collected at Station 1, channel catfish from Station 3 and flathead catfish collected at Stations 5 and 6. Copper body burdens exceeded the national 85th percentile in sunfish collected at Station 1, channel catfish collected at Station 3, and flathead catfish collected at Station 6. The TDH screening level was exceeded in sunfish collected at Station 1, and channel catfish collected at Station 3 (Figure 19).

**Lead**

Lead was detected in tissue samples from sunfish collected at Station 1, channel catfish collected at Station 3, and flathead catfish collected at Station 6. The concentration of lead for each of these samples exceeded the predator protection limit as well as the TDH screening level. The national 85th percentile lead in fish tissue concentration was exceeded in sunfish collected at Station 1, and channel catfish collected at Station 3 (Figure 19).

**Selenium**

Selenium was detected in tissue samples from carp collected at Stations 1, 2, 4, and 5, sunfish collected at Station 1, shiners collected at Stations 3 and 4, channel catfish collected at Station 3, and flathead catfish collected at Stations

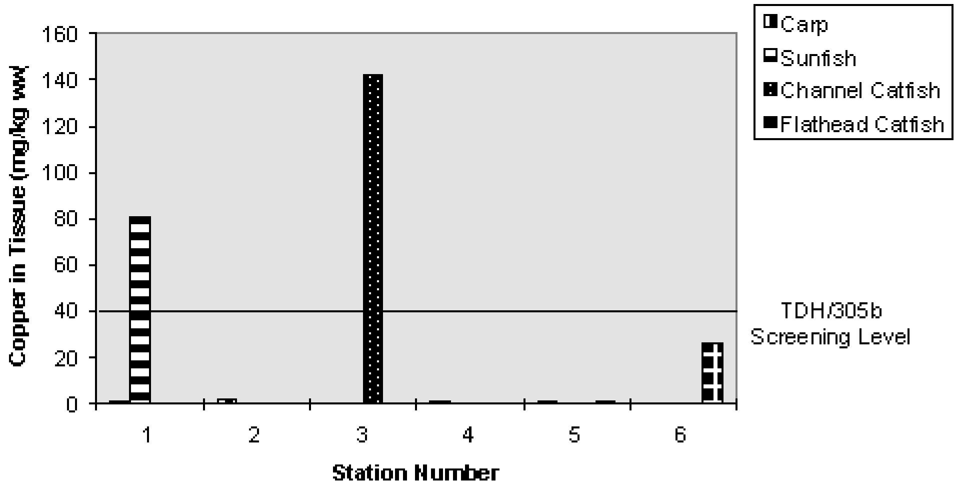



Figure 19 . Summary of Copper Concentrations in Fish Tissue for Samples Collected from Six Stations During Phase III.

5 and 6. The concentration of selenium in all of these samples exceeded the predator protection level (Figure 21). The national 85th percentile selenium tissue concentration was exceeded in sunfish collected at Station 1, carp collected at Stations 2 and 4, channel catfish collected at Station 3, shiners collected at Station 4, and in flathead catfish collected at Stations 5 and 6. The body burden of selenium in shiners collected at Station 4 exceeded the TDH screening level.

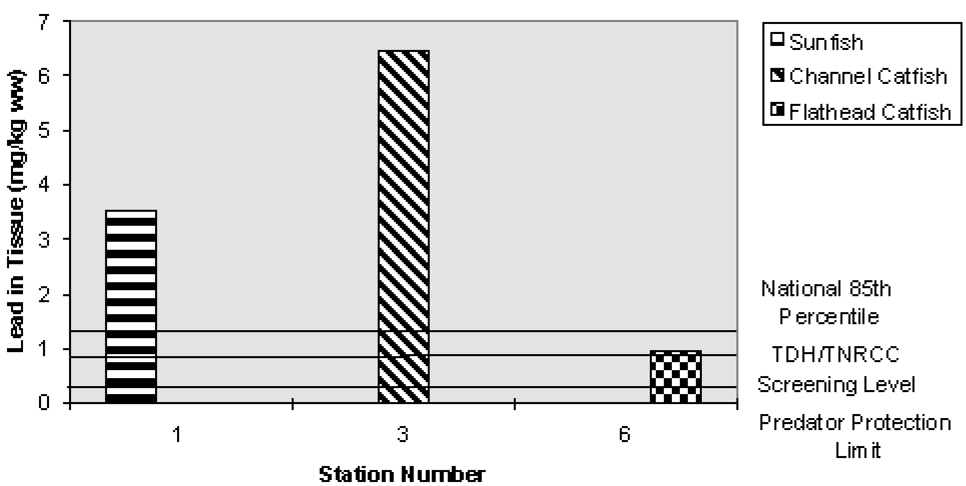



Figure 20. Summary of Lead Concentrations in Fish Tissue for Samples Collected from Six Stations During Phase III.

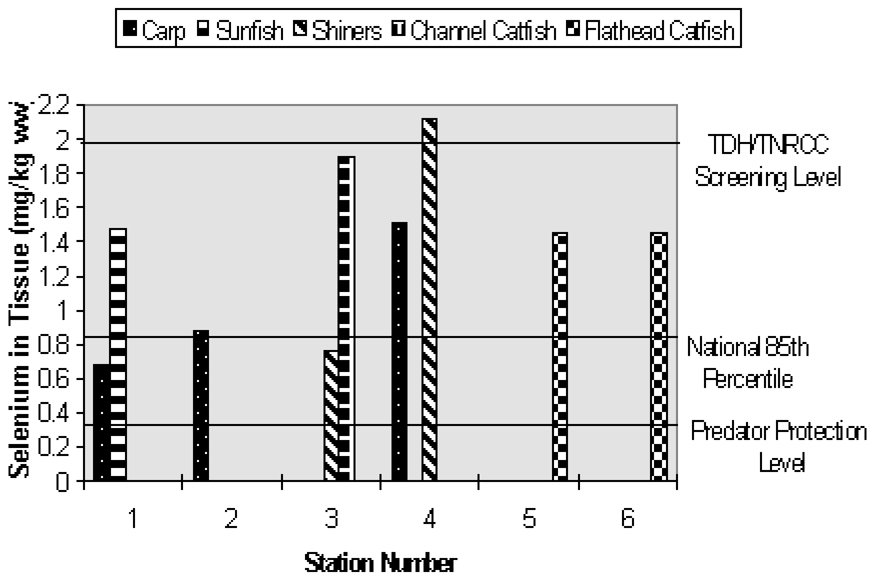



Figure 21. Summary of Selenium Concentrations in Fish Tissue for Samples Collected from Six Stations During Phase III.

### *Benthic Macroinvertebrates*

Cadmium and selenium were the only other metals detected in benthic macroinvertebrates. Cadmium was detected in the tissue of predators at Station 2 (1.73 mg/kg dw) and in the tissue of collector gatherers/deposit feeders at Stations 2 (4.29 mg/kg dw) and 6 (1.97 mg/kg dw). All values except at station 2, are below 2 mg/kg dw, the value which has been proposed as the threshold for predator protection (Irwin 1989).

Selenium was detected in collector gatherers/deposit feeders (0.88 mg/kg ww; 0.14 mg/kg dw) at Station 6. This value is well within the range (0.002-3 mg/kg dw) reported by Mora and Wainwright (1997) but exceeds 0.5 mg/kg ww, the value which has been proposed as the threshold for predator protection (Irwin 1989).

## Toxicity in Water and Sediment

### Water

During Phase II, toxicity in water was found between Presidio/Ojinaga (Station 4) and Big Bend National Park (Station 5). These were the only two mainstem sites, of the 37 sampled, that exhibited ambient water toxicity. Only water fleas were affected at Stations 4 and 5. At Station 4 (downstream of Presidio/Ojinaga) and Station 5 (Santa Elena Canyon in Big Bend National Park), water fleas exhibited a reduction in the number of young per female. The two most obvious contributing factors were elevated chloride and total dissolved solids concentrations. Elevated TDS and chloride levels are a common problem in the Rio Grande/Rio Bravo (TNRCC 1994a; TNRCC 1994b; Miyamoto *et al*. 1995). Use and reuse of river water for irrigation, oil and gas wells, industrial and municipal wastewater discharges, and the natural occurrence of salts in surrounding soils contribute to this problem.

Approximately one month following sample collection a fish kill in the Big Bend National Park portion of the river was reported to Texas Parks and Wildlife. No definite cause was identified, however, a bloom of toxic algae (*Prymnesium parvum*) was considered a potential cause. In the past, *Prymnesium parvum* has been cited as a cause of fish kills on the Pecos River, and is usually associated with increased salinity (personal communication, TPWD). This may have contributed to the significant effect noted on the water flea toxicity test. The ambient water toxicity tests run on samples collected during Phase III showed no significant effects on test organisms (Tables 19 and 20).

## Sediment

Sediment samples collected for toxicity during Phase II, showed significant effect to fathead minnows at Station 2. Station 2, located downstream of El Paso/Juárez at Zaragosa Bridge, was the only mainstem station where significant effects occurred in sediment samples. Copper, lead, nickel and zinc were elevated in sediment at Station 2, which is influenced by wastewater discharges and urban stormwater runoff. Any one and/or combination of metals found could have caused a toxic effect. Arsenic and nickel have high acute and chronic toxicity to aquatic life, while silver has high chronic toxicity which is dependent on pH (University of Virginia database).

The sediment elutriate toxicity tests run on samples collected during Phase III showed no significant effects on test organisms (Table 20).

TABLE 19
Summary of Ambient Water Toxicity Data for
Fathead Minnows (*Pimephales promelas)*, Phase III

| Station | Control (%) | Site (%) | Significant Effect * | Control (%) | Site (%) | Significant Effect * |
|---|---|---|---|---|---|---|
| | **WATER** | | | **SEDIMENT** | | |
| 1 | 3 | 0 | NO | 3 | 3 | NO |
| 2 | 3 | 0 | NO | 3 | 3 | NO |
| 3 | 3 | 0 | NO | 3 | 0 | NO |
| 4 | 3 | 10 | NO | 3 | 0 | NO |
| 5 | 0 | 3 | NO | 3 | 0 | NO |
| 6 | 0 | 10 | NO | 3 | 0 | NO |

-* Significantly different (P > 0.95) from the control.
-Significant effects for *P. promelas* include number of dead embryos (unhatched) and abnormal growth or swimming behaviors of larvae.

TABLE 20
Summary of Ambient Water Toxicity Data
for Water Fleas (*Ceriodaphnia dubia*), Phase III

***WATER***

| Station | Control Mortality (%) | Site Mortality (%) | Control YPF | Site YPF | Significant Effect * |
|---|---|---|---|---|---|
| 1 | 0 | 0 | 17.9 | 19.9 | NO |
| 2 | 0 | 0 | 17.9 | 20.0 | NO |
| 3 | 0 | 0 | 17.9 | 17.8 | NO |
| 4 | 0 | 0 | 17.9 | 18.2 | NO |
| 5 | 0 | 3 | 18.4 | 20.4 | NO |
| 6 | 0 | 10 | 18.4 | 17.6 | NO |

-* Significantly different (P > 0.95) from the control.
-**YPF** = YOUNG PER FEMALE
-Significant effects for *C. dubia* include survival and number of young per female (YPF).
-Bioassay results taken from EPA Lab Reports.

TABLE 21
Summary of Sediment Toxicity Data
for Water Fleas (*Ceriodaphnia dubia*), Phase III

***SEDIMENT***

| Station | Control Mortality (%) | Site Mortality (%) | Control YPF | Site YPF | Significant Effect * |
|---|---|---|---|---|---|
| 1 | 0 | 0 | 17.9 | 19.9 | NO |
| 2 | 0 | 0 | 17.9 | 20.0 | NO |
| 3 | 0 | 0 | 18.4 | 20.0 | NO |
| 4 | 0 | 0 | 18.4 | 20.8 | NO |
| 5 | 0 | 0 | 18.4 | 20.0 | NO |
| 6 | 0 | 0 | 18.4 | 18.6 | NO |

-* Significantly different (P > 0.95) from the control.
-**YPF** = YOUNG PER FEMALE
-Significant effects for *C. dubia* include survival and number of young per female (YPF).
-Bioassay results taken from EPA Lab Reports.

## Benthic Macroinvertebrate Community Assessment: Erosional Zones

A total of 998 individuals representing 32 taxa were collected from the six stations (Table22). Overall, the most abundant taxon was the mayfly *Traverella* sp. which accounted for approximately 18.3% of the total number of individuals collected at the six stations. Collectively, two leptophlebiid mayflies *Traverella* sp., and *Choroterpes* sp. along with the hydropsychid caddisfly *Smicridea* sp. comprised approximately 49% of the total number of individuals. In terms of spatial distribution, two taxa, *Fallceon* sp., and *Simulium* sp. were collected at all stations. Among the least common taxa in the collections were *Hydroptila* sp., *Hetaerina* sp., *Dicrotendipes* sp., *Hydrobaenus* sp., *Rheotanytarsus* sp., and *Corbicula* sp.. Each of these taxa was represented by only one individual.

Comparative data are sparse for benthic macroinvertebrate samples from the Rio Grande/Rio Bravo. Data are available for kicknet samples collected at Stations 1 to 4 during Phase II. If the comparison is restricted to Stations 1 to 4 the results are quite similar with 633 individuals from 26 taxa collected in Phase III from these four stations and 643 individuals from 28 taxa collected in Phase II (TNRCC 1997). Whereas the hydropsychid caddisflies *Smicridea* sp., and *Cheumatopsyche* sp. were the dominant group in the overall collection from the four stations in Phase III, accounting for 28.4% of the individuals collected, the chironomidae were numerically dominant in Phase II, accounting for 46.8% of the individuals collected.

Taxa richness ranged from nine at Station 1 to 15 at Station 4 (Figure 22). Where sample stations bracketed urban areas, benthic macroinvertebrate taxa richness was greater at the downstream station. In El Paso/Ciudad Juarez, taxa richness was nine at Station 1, upstream, and 14 at the downstream station. For the stations bracketing Presidio/Ojinaga, taxa richness was 11 at Station 3, upstream and 14 at the downstream Station 4. This is similar to the results observed for the fish community. Increasing taxa richness is often taken as an indicator of improving water quality. However, in this case, results are a bit deceiving in that the increase in the number of taxa is largely attributed to tolerant taxa and likely reflect water quality degradation due to the effects of the urban areas at the downstream stations. At Presidio/Ojinaga, of the seven taxa collected at the downstream station, five are tolerant (tolerance value $\geq$6) These same taxa were not collected at the upstream station. Even though the number of benthic macroinvertebrate taxa was greater at the stations downstream of El Paso/Ciudad Juárez and Presidio/Ojinaga, in both cases the percentage of individuals considered tolerant (tolerance value $\geq$6) was much greater at the downstream station (Figure 23). More heterogeneous and higher quality habitat at the station below Presidio/Ojinaga likely contributes to these findings.

Results of the analysis of benthic macroinvertebrate data collected during Phase II were similar and in the case of the stations bracketing Presidio/Ojinaga, more marked. Taxa richness for RBA samples collected in Phase II increased from 10 at Station 1 upstream of El Paso/Ciudad Juárez to 12 at the downstream Station 2. At Station 4, downstream of Presidio/Ojinaga, taxa richness was 21 while at Station 3, upstream, taxa richness was 7. In Phase I, in which benthic macroinvertebrate samples were collected and processed using quantitative protocols (TNRCC 1999) in lieu of RBA protocols employed in Phases II and III, taxa richness declined from 42 to 32 respectively from Station 1 to Station 2, and increased from 19 to 50 respectively from Station 3 to Station 4.

Overall, individuals from tolerant taxa, those taxa with tolerance values $\geq$ 6, accounted for 15.5% of the total number of individuals collected (Figure 23) in Phase III. The percentage of individuals as tolerant ranged from 2.5% at station 1 to 28.7% at Station 2. In Phase II approximately 9.9% of the total number of individuals collected were from tolerant taxa (TNRCC 1997). At individual stations, the percentage of the collection comprised of tolerant individuals ranged from zero at Station 3 to 33.9% at Station 4. The percentage of individuals from tolerant taxa was greater at the stations located downstream of El Paso/Ciudad Juárez and Presidio/Ojinaga relative to the upstream stations (Figure 23). At Station 1 upstream of El Paso/Ciudad Juárez, only 2.5% of the individuals in the collection were from tolerant taxa. This percentage increased by more than a factor of 10 at Station 2, and thirty-five percent of these tolerant individuals were from highly tolerant taxa, taxa with a tolerance value of ten. In Phase II the relative

TABLE 22
Summary of Benthic Macroinvertebrate Collections Made During Phase III

| **Taxon** | **Functional Feeding Group** | **Tolerance** | **1** | **2** | **3** | **4** | **5** | **6** |
|---|---|---|---|---|---|---|---|---|
| Camelobaetidius sp. | SCR/CG | 4 | | | 3 | 1 | 1 | 31 |
| Fallceon sp. | SCR/CG | 4 | 8 | 1 | 10 | 21 | 2 | 1 |
| Farrodes sp. | SCR/CG | 2 | | | | 1 | 6 | |
| Choroterpes sp. | SCR/CG | 2 | | | 59 | 68 | 25 | 4 |
| Thraulodes sp. | SCR/CG | 2 | | | | | | 18 |
| Traverella sp. | FC | 2 | | | 2 | 1 | 124 | 56 |
| Brachycercus sp. | CG | 3 | | | 5 | | | 1 |
| Tricorythodes sp. | CG | 5 | 4 | 13 | | | | |
| Chematopsyche sp. | FC | 6 | | 3 | 9 | 19 | | |
| Smicridae sp. | FC | 4 | 70 | 76 | | 2 | 2 | |
| Hydroptila sp. | SCR | 2 | | 1 | | | | |
| Corydalus sp. | P | 6 | | | | | 3 | |
| Helichus sp. | SCR/CG | 4 | | | | | 2 | 7 |
| Postelichus sp. | SCR/CG | 4 | | | | | 2 | |
| Erpetogomphus sp. | P | 1 | | | 1 | 8 | 1 | 2 |
| Argia sp. | P | 6 | | | 3 | 8 | 2 | 18 |
| Hetaerina sp. | P | 6 | | | | 1 | | |
| Ambrysus sp. | P | | | | | 3 | 12 | |
| Chironmus sp. | CG/SHR | 10 | | 35 | | | | |
| Dicrotendipes sp. | CG/FC | 7 | | 1 | | | | |
| Polypedilum sp. | SHR/CG/P | 6 | | | 1 | | 1 | |
| Orthocladius sp. | CG | 4 | 20 | 21 | | | | |
| Hydrobaenus sp. | SCR/CG | 10 | | 1 | | | | |
| Thienemanniella sp. | CG | 2 | 2 | 1 | | | | |
| Natarsia sp. | P | 10 | | 4 | | | | |
| Pentaneura sp. | CG/P | 5 | 3 | | | | | |
| Thienemannimyia sp. | P | 6 | | | | 2 | | |
| Rheotanytarsus sp. | FC | 6 | | 1 | | | | |
| Tanytarsus sp. | CG/FC | 7 | 3 | 1 | 1 | 1 | | |
| Simulium sp. | FC | 4 | 51 | 1 | 72 | 3 | 6 | 8 |
| Corbicula sp. | FC | 6 | | | | | | 1 |
| Oligochaeta | CG | 8 | 1 | | | 9 | | 26 |
| n= | CG=collector gatherer; FC= filterer collector; SHR=shredder; P=predator; SCR=scrapper | | 162 | 160 | 166 | 148 | 189 | 173 |
| Taxa Richness = | | | 6 | 14 | 11 | 15 | 14 | 12 |

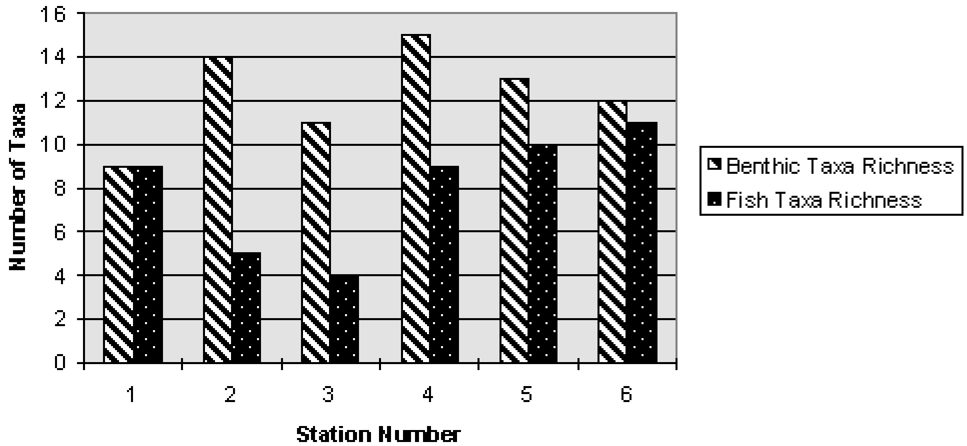



Figure 22. Comparison of Taxa Richness Values for Benthic Macroinvertebrate and Fish Surveys Conducted at Six Stations During Phase III.

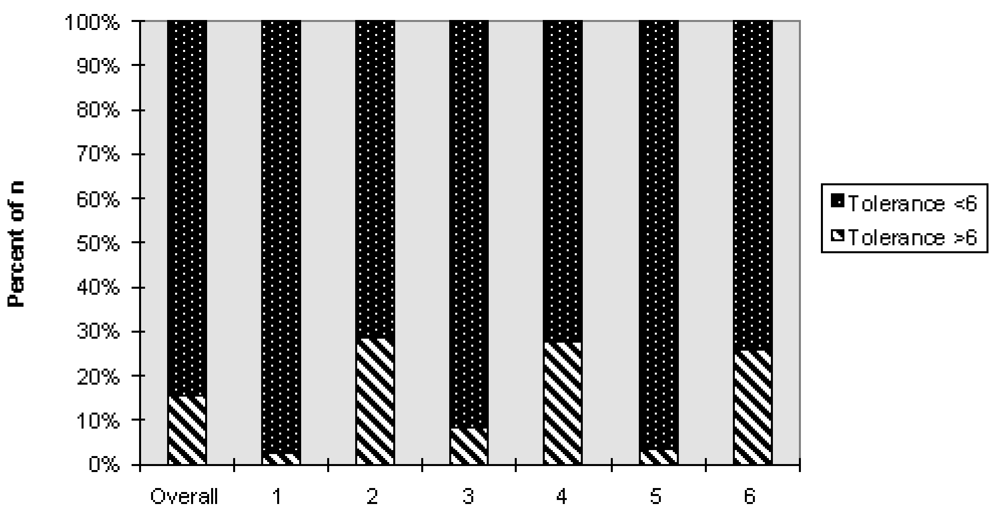



Figure 23. Summary of the Percentage of Tolerant and Intolerant Individuals in Benthic Macroinvertebrate Samples Collected from Six Stations during Phase III.

abundance of individuals from tolerant taxa was also greater at the downstream station, but the difference was not as pronounced. The percentage of tolerant individuals in the collection increased from 8.4% upstream of Presidio/Ojinaga to 27.6% at the downstream station. The difference in the relative abundance of tolerant taxa upstream and downstream of Presidio/Ojinaga in Phase II was even greater than that noted in Phase III. Tolerant taxa were not present in the kicknet sample from the upstream station, but tolerant taxa accounted for approximately 34% of individuals in the collection from the station downstream from Presidio/Ojinaga.

Unexpectedly, individuals from tolerant taxa comprised 26% of the benthic community at Station 6, located in Boquillas Canyon in Big Bend National Park. At first look, this value is comparable to that noted at the Stations downstream of El Paso/Ciudad Juárez and Presidio/Ojinaga. However, upon closer analysis it becomes clear that, especially relative to Station 2, the composition of the tolerant proportion of the community is quite different at Station 6. At Station 2 *Chironomus* sp., *Hydrobaenus* sp., and *Natarsia sp.* collectively accounted for 25% of the individuals in the collection. All three of these taxa are highly tolerant, especially to low dissolved oxygen resulting from organic enrichment (Resh and Rosenberg 1984) and have tolerance value of 10, the highest possible. Station 2 is the only station where these taxa were present in the sample. At Station 6, the relatively high percentage of individuals as tolerant is largely due to the presence of several individuals from the taxon *Argia* sp., a damselfly with a tolerance value of six, the lower end of the range of values considered as tolerant. The only relatively highly tolerant individuals in the collection from Station 6 were oligochaetes which are assigned a tolerance value of eight and accounted for only 15% of the collection. Further, a number of individuals from highly intolerant taxa such as the gomphid dragonfly *Erpetogomphus* which is assigned a tolerance value of 1, the lowest possible, as well as the leptophlebiid mayflies *Choroterpes*, *Thraulodes*, and *Traverella* all of which have tolerance values of two, were collected at Station 6. In fact, individuals from these highly intolerant taxa collectively comprised approximately 46.2% of the collection at Boquillas Canyon. At Station 2 individuals from taxa considered to be highly intolerant comprised only 1.2% of the collection. The predominance of highly tolerant individuals at Station 2 is reflected in the value of the biotic index, 5.6, which was the highest among the six stations, and exceeds the 90th percentile for the HBI in the statewide database for RBA samples. This compared to biotic index values of 2.3 and 2.96, the two lowest values obtained in Phase III, for the collections from Stations 5 and 6 in Big Bend National Park.

Overall, the collections were dominated by the filtering collectors, primarily the mayfly *Traverella* sp., the caddisfly *Smicridea* sp., and the blackfly *Simulium* sp. which collectively accounted for 51.1% of the total number of individuals collected. Collector-gatherers such as *Tricorthodes* sp., and *Orthocladius* sp., were the second most abundant functional group accounting for approximately 26.3% of the total number of individuals collected. Scrapers and scraper-collectors were the next most abundant functional group, predators and shredders were less abundant. These three groups accounted for 13.7%, 7.0%, and 1.8% respectively of the total number of individuals collected. In both Phase II and Phase III, the collector-gatherers and the filtering collectors were the most abundant functional groups in the collections from Stations 1 to 4, the only stations for which benthic macroinvertebrate kick net data are available for both Phases. Overall, at these four stations, these two groups comprised 59.2% and 30.8% respectively of the total collection in Phase II and 29.3% and 49.5% respectively of the total collection in Phase III.

Among individual stations, the filtering collectors were dominant, in terms of relative numbers, at five stations (1,2, 3, 5, and 6). At Station 4, the collector-gatherers were dominant (Figure 24). The highest percentages of filtering-collectors were noted at Stations 1 and 5 where the filtering-collectors comprised 75.6 % and 69.8 %, respectively. These values exceed the 95th percentile for the TNRCC data set from kick net samples collected from minimally impacted streams statewide (Harrison 1996). This seems to indicate an imbalanced trophic structure at each of these two stations. The filtering-collectors were also the most abundant groups in benthic surveys conducted at Station 1 in Phases I and II (TNRCC 1992 and 1997) though not to the degree as observed in Phase III. In Phase I the filtering-collectors comprised 37 % of the community at Station 1, and 49.6 % of the community in Phase II.

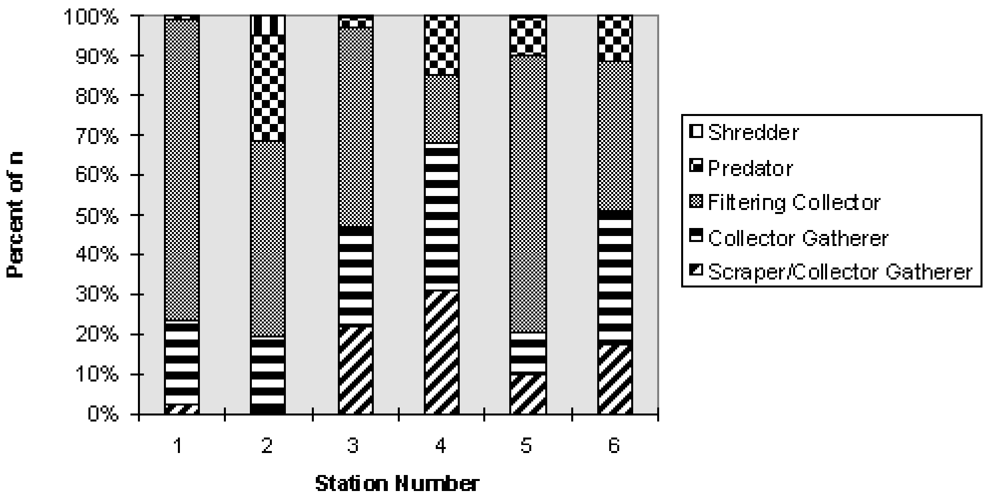



Figure 24. Summary of the Percentage of Individuals in Each Functional Group for Benthic Macroinvertebrate Samples Collected at Six Stations During Phase III.

Scraper-collectors, the next most abundant functional group, were relatively common at Stations 3 to 6 comprising greater than 10% of the individuals in the collection at each station (Figure 24). At Stations 1 and 2, the scraper- collectors accounted for only 2.5% and 0.6% respectively of the individuals collected. Similarly, in Phases I and II, the scrapers (= grazers in TNRCC 1992) were essentially absent at these two stations. Scrapers made up only 2.4 % and 3.5 % of the community at Stations 1 and 2 in Phase I. Only 0.3 % of the community at Station 1 were scrapers, and representatives of this functional group were not collected at Station 2 in Phase II. Habitat factors limit the abundance of scraper/collectors at these two stations, as they are adapted to scrape and/or graze on periphyton from the surface of stable substrate such as large gravel, and cobble for at least a portion of their energy needs (Merritt and Cummins 1995; Allan 1995). As a result of channelization and channel maintenance activities, this type of habitat is essentially absent at these two stations. The scraper-collector mayfly *Fallceon* sp. was the only representative of this functional group which was collected at both stations, but was relatively rare accounting for only a small proportion of the community.

## Benthic Macroinvertebrate Rapid Bioassessment Index of Biotic Integrity (BRBIBI)

Total scores for the benthic macroinvertebrate rapid bioassessment index of biotic integrity (BRBIBI) ranged from 18 to 28 out of a possible 48 (Table 23). Finding the lowest BRBIBI score at Station 2 is consistent with expectations as this score corresponds to the designated ALU for Segment 2308 (Limited) and each of the other five stations are located in segments with high aquatic life use designations. As pointed out in Phase I (TNRCC 1992) effluent from the El Paso Haskell Street wastewater treatment plant dominated the flow in Segment 2308, especially during periods of low flow and, as a result of channelization, the physical habitat is poor (Note: This is no longer the case, as of April 1999, the El Paso Haskell Street wastewater treatment plant no longer discharges to Segment 2308 causing this segment to be primarily intermittent). These factors are reflected in the low overall BRBIBI score for Station 2 and for the individual metrics (Table 24). The benthic community at Station 2 received the lowest possible score for eight of twelve metrics. The Hilsenhoff Biotic Index (HBI) for Station 2 was the highest among all stations and exceeds the 85th percentile for the HBI among all kicknet samples from minimally impacted streams in the TNRCC database (Harrison 1996), reflecting the degraded physico-chemical conditions at this station. Results from Phase II at this station were similar in that the benthic community was found to be of relatively low integrity but to meet the designated limited aquatic life use. In Phase I the benthic community at Station 2 was found to partially attain a high aquatic life use based on the scores for the TNRCC Mean Point Scores (MPS) and the Ohio Index of

Community Integrity (ICI) which rated the community high and intermediate respectively.

TABLE 23
Summary of ALU Designations, RBA Scores and ALU Determinations for Benthic Macroinvertebrate RBA Samples Collected During Phase III

| Station | Segment | Designated ALU Category | BRBIBI Score | ALU Category Indicated by BRBIBI |
|---|---|---|---|---|
| 1 | 2314 | High | 19 | Limited |
| 2 | 2308 | Limited | 18 | Limited |
| 3 | 2307 | High | 26 | Intermediate |
| 4 | 2307 | High | 28 | Intermediate |
| 5 | 2306 | High | 26 | Intermediate |
| 6 | 2306 | High | 26 | Intermediate |

At the other five stations (1, 3, 4, 5, 6), the BRBIBI scores indicate that the designated aquatic life use, at least as expressed by the benthic community, is not being attained (Table 23). The designated aquatic life use for each of these stations is high. BRBIBI scores for four of the sites (3, 4, 5, and 6) fell in the upper intermediate aquatic life use category and the score for Station 1 fell in the limited aquatic life use category.

## El Paso/Ciudad Juárez

Station 1 is located upstream of the El Paso/Ciudad Juárez urban area and was originally selected in Phase I to serve as an upstream station of comparison relative to Station 2 which is located downstream. However, as noted above, the BRBIBI score for Station 1 indicates that the benthic community is not meeting the designated aquatic life use and scores for nine of the twelve individual metrics fell in the lowest BRBIBI category. The number of EPT taxa, as well as the percent Chironomidae and the percent predator metrics were the lowest among any of the stations. The BRBIBI for the RBA snag sample collected in Phase II was one point lower than that for Phase III, also falling in the limited aquatic life use category. Quantitative snag samples were also collected in Phase II and the TNRCC MPS fell in the intermediate aquatic life use category. Results from Phase I were mixed in that by one measure of benthic integrity, the TNRCC MPS, the designated high aquatic life use was being attained, and by the other measure used, the Ohio ICI, the benthic community was rated as attaining an intermediate aquatic life use (TNRCC 1992). Thus, four benthic macroinvertebrate samples have been collected at Station 1 over three Phases and for three of these the measures of benthic community integrity have indicated that the high aquatic life use is not being attained. For the one sample that did indicate attainment, the results are not unequivocal as one analytical tool, the TNRCC MPS indicated attainment while the other measure used, the Ohio ICI reflected non-attainment.

Although Station 1 is located upstream of El Paso/Ciudad Juárez, there are several factors which potentially contribute to the apparently impaired benthic community. As pointed out in Phase I, there is some tendency for snag samples to slightly underrate macrobenthic integrity. Snag habitat is often less than optimal in that, depending on the characteristics of the individual snag, heterogeneity is often considerably lower than that provided by cobble, gravel type substrates. This factor can significantly restrict the richness and integrity of the snag community. At Station 1, personal observation indicates that snags tend to be less than optimal, often consisting of small salt cedar saplings which are relatively smooth and provide little habitat heterogeneity. Also, due to channelization, Station 1 is characterized by monotonous shifting sandy substrate. Thus, availability of snags as an alternative habitat becomes

TABLE 24
Summary of Metric Values for Benthic Macroinvertebrate
RBA Samples Collected from the Rio Grande/Rio Bravo

| | Stations | | | | | |
|---|---|---|---|---|---|---|
| **METRICS** | **1** | **2** | **3** | **4** | **5** | **6** |
| **Taxa Richness (s)** | 7 | 7 | 10 | 14 | 14 | 12 |
| **EPT Taxa Abundance** | 4 | 5 | 6 | 7 | 6 | 6 |
| **Biotic Index (HBI)** | 4.05 | 5.64 | 3.39 | 3.55 | 2.30 | 2.96 |
| **% Chironomidae** | 43.39 | 40.62 | 1.20 | 2.03 | 0.53 | 0.00 |
| **% Dominant Taxa** | 43.39 | 47.50 | 43.37 | 45.94 | 65.61 | 32.37 |
| **% Dom. Functional Group (FFG)** | 50.00 | 49.06 | 50.30 | 37.16 | 69.84 | 37.57 |
| **% Predators** | 0.88 | 26.87 | 2.61 | 14.86 | 9.70 | 11.56 |
| **Ratio of Intolerant:Tolerant Taxa** | 20.00 | 0.70 | 10.86 | 2.62 | 28.50 | 2.84 |
| **% of Total Trichoptera as Hydropsychidae** | 100 | 98.75 | 100 | 100 | 100 | 100 |
| **# of Non-Insect Taxa** | 1 | 0 | 0 | 1 | 0 | 2 |
| **% Collector-Gatherers** | 48.50 | 18.75 | 25.20 | 37.16 | 10.23 | 33.24 |
| **% of Total Number as Elimidae** | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total** | **19** | **18** | **26** | **28** | **26** | **26** |

an especially critical limiting factor for benthic integrity. In such situations, compounding the simple scarcity of suitable habitat, competitive interactions intensify and an equilibrium community structure, if at all attainable, becomes far less stable. Further aggravating the situation at Station 1, is the complete containment of flow within the channel. This area is also highly erosional and characterized by episodic scour and depositional events which can be especially detrimental to snag communities.

## Presidio/Ojinaga

BRBIBI scores for the benthic communities at both Stations 3 and 4, the stations bracketing Presidio/Ojinaga, both fell in the intermediate category. The score at Station 4 is the highest possible score in the intermediate category and the score at Station 3, upstream of Presidio/Ojinaga was only two points lower. Habitat limitations at the upstream station where the river has been channelized and contained in levees contributes to the lower score. In both Phase I and Phase II the TNRCC MPS for the Surber samples collected at Station 3 was the lowest possible in the intermediate category. Similarly, the BRBIBI score for a kicknet collected at Station 3 in Phase II indicated an intermediate aquatic life use. In Phases I and II, the MPSs for Surber samples collected at Station 4 fell in the high and intermediate categories respectively.

## Big Bend National Park

Both stations in the Big Bend National Park (5 and 6), scored 26 for the BRBIBI, indicating an intermediate aquatic life use. BRBIBI scores for kicknet samples collected during Phase II as well as while assisting the USGS with a study in progress in 1999 at Station 5 both indicated intermediate aquatic life use. The results for the Surber samples collected at Station 5 during Phase I reflected high aquatic life use based on the TNRCC MPS method and intermediate aquatic life use based on the Ohio ICI. At Station 6 in Phase I, both the TNRCC MPS and the Ohio ICI indicated exceptional aquatic life use. For the kicknet collected during the USGS survey in 1999, Station 6 was categorized as intermediate.

### Summary

The median score for the BRBIBI for all collections made in the reach upstream of International Falcon Reservoir, one of three "faunal reaches" suggested in Phase I, is 17. Both benthic rapid bioassessment samples collected from Station 2 fell in the lower quartile. Scores for Station 3 fell below the median for both benthic macroinvertebrate RBA samples. At Station 4, one of two RBA scores fell below the median and the other in the third quartile. Of the two RBA collections made at Station 5, one during Phase III and the other in 1999 while we were assisting USGS with an on-going study, one approximated the median and the other was one-half point greater. The BRBIBI scores for both RBA samples which have been collected at Station 6 were equal and are above the median.

## Pool Benthic Macroinvertebrate Community Assessment

The TNRCC SWQM Team has been evaluating macrobenthic communities of pool habitats for several years. This biological component was incorporated into monitoring protocols for the following reasons. (1) Certain types of impact may be manifested initially, or exclusively, in pools (effects of depressed dissolved oxygen, fine sediment deposition, or toxicant accumulation in sediment). If only riffle communities are evaluated, as has often been the case in Texas stream studies, an incomplete picture of environmental condition may be generated. (2) Pools are the predominant habitat in lowland streams, streams with low base flow, and seasonally intermittent streams, stream types which occur across the state. If only erosional zones are targeted for sampling, the major habitat type within such streams is overlooked, and sampling cannot be conducted at all during periods of no flow.

The interim assessment technique was applied to data from pool macrobenthic communities at four sites on the Rio Grande/Rio Bravo in conjunction with Phase III (Table 25). Data from the four sites were used to evaluate aquatic life use attainment. Based on the results, one site was assigned an intermediate aquatic life use rating (Courchesne Bridge), and the other three, a limited rating (Rio Grande/Rio Bravo at Zaragosa International Bridge, Rio Grande/Rio Bravo below Presidio, and Rio Grande/Rio Bravo below Santa Elena Canyon) (Table 25).

TABLE 25
Aquatic Life Use Evaluations Based on Depositional Macrobenthic Communities for Four Phase III Sites

| **STATION DESCRIPTION** | Station 1 | Station 2 | Station 4 | Station 5 |
|---|---|---|---|---|
| **Metric** | | | | |
| Total taxa | | (-) | (-) | (-) |
| EPT taxa | (-) | (-) | (-) | (-) |
| Dominant functional feeding group (%) | (-) | (-) | (-) | |
| Cumulative abundance FPOM feeders (%) | (-) | (-) | (-) | (-) |
| Diptera taxa | (+) | (-) | | (-) |
| Three most abundant taxa (%) | | (-) | (-) | (-) |
| Oligochaeta (%) | | (-) | (+) | (-) |
| EPT taxa (%) | (-) | (-) | (-) | |
| Intolerant taxa | | | | |
| Tolerant taxa (%) | (-) | (-) | (-) | (-) |
| **Statistic** | | | | |
| Number of 'minuses' | 5- | 9- | 7- | 7- |
| Number of 'pluses' | 1+ | 0+ | 1+ | 0+ |
| Delta value | 4- | 9- | 6- | 7- |
| **Aquatic life use rating** | **intermediate** | **limited** | **limited** | **limited** |

## Fish Community Assessment

A total of 1,628 individuals representing 18 species from 7 families were collected from the six stations over the period 11/07/1998 - 11/11/1998 (Table 26). These findings are consistent with results reported from other surveys of the El Paso/Ciudad Juárez to Big Bend Reach of the Rio Grande/Rio Bravo. In Phase I, 2730 individuals representing 21 species from 11 families were collected from the reach of the Rio Grande/Rio Bravo from El Paso/Ciudad Juárez to Big Bend/Canyon de Santa Elena Protected Area. In addition, 199 individuals representing 15 species from 7 families were collected during Phase II from the stations located in the international reach of the Rio Grande/Rio Bravo from El Paso/Ciudad Juárez to Big Bend /Canyon de Santa Elena Protected Area. In a more intensive effort in which they visited 21 mainstem stations in the reach from El Paso/Ciudad Juárez to Big Bend/Canyon de Santa Elena Protected Area, Bestgen and Platania (1988) reported collecting 22 species from seven families.

In terms of spatial occurrence, commonly collected taxa include *Cyprinella lutrensis* which was the only species collected at all six stations and *Pylodictus olivaris* which was collected at five of the six stations. Four species, *Carpiodes carpio, Cyprinus carpio, Ictalurus punctatus,* and *Ictalurus furcatus* were collected at four of the six stations.

The only species collected by Bestgen and Platania which was not collected during at least one of the three phases of the Toxic Substances Study was the Mexican stoneroller (*Campostoma ornatum*). *C. anomalum* was also not collected in a survey of the reach conducted by the U.S. Geological Survey (USGS; J.B. Moring personal communication) in March of 1999 when fish surveys were conducted at five stations along the river from Big Bend Ranch State Park (west of the Big Bend/Canyon de Santa Elena Protected Area ) to Black Gap Wildlife Management Area (east of the Big Bend/Canyon de Santa Elena Protected Area). Both Big Bend Ranch State Park and the Black Gap Wildlife Management area are maintained by the Texas Parks and Wildlife Department. Hubbs 1991 describes this taxon as occurring primarily in Mexico, ranging into Texas only in the Rio Grande/Rio Bravo drainage in Brewster and Presidio counties. Hubbs also considers the Mexican stoneroller as threatened. The finding that, at least according to these records, *C. anomalum* has not been collected in this reach of the river since 1988 may indicate a need for a more intense effort to reevaluate its status as Hubb's threatened designation indicates a species likely to become endangered.

Overall, in terms of relative abundance, the cyprinids were dominant, collectively accounting for 89.6% of the total number of individuals collected. Seven species of cyprinids were collected, the most species of any single family. The red shiner (*Cyprinella lutrensis*) was the most abundant cyprinid, accounting for 86.9% of the total number collected. *C. lutrensis* was the only taxon which was collected at all six stations and was the dominant taxon at four of the six stations (1, 3, 4, and 5) comprising >65% of the total number of individuals collected. Cyprinids comprised approximately 49.9% and 46.7% respectively, of the collections made in the El Paso/Ciudad Juárez to Big Bend/Canyon de Santa Elena Protected Area reach during Phase I and Phase II. Platania (1990), in his survey of the fishes of the Rio Grande/Rio Bravo drainage in Texas and Mexico between Boquillas and San Ygnacio located downstream from the City of Laredo, reported that the red shiner was the most abundant taxon in his collections, comprising 39.7% of the total number of individuals collected. Similarly, in their survey of the fishes of the Rio Grande/Rio Bravo between the New Mexico-Texas border and Big Bend National Park/Canyon de Santa Elena Protected Area, Bestgen and Platania (1988) reported that *C. lutrensis* comprised 55.2% of the total number of individuals collected. Occurring in far lower numbers than the cyprinidae, the sunfishes (Centrarchidae) were the next most abundant family. The centrarchids were represented by two species, *Micropterus salmoides* and *Lepomis megalotis*, which together comprised 3.6% of the total number of individuals collected. In previous surveys in this reach of the river, the sunfishes were also collected in relatively low numbers accounting for approximately 0.2% of the collection in RGTSS Phase I, approximately 1% In TSS Phase II, and approximately 3.9% of the collections made by Bestgen and Platania (1988). Additional sunfish taxa collected in previous surveys include the green sunfish (*Lepomis cyanellus*), collected by Bestgen and Platania (1988), and bluegill sunfish (L. *macrochirus*) collected in Phase I.

TABLE 26
Summary of Fish Collected from the Rio Grande/Rio Bravo During Phase III

| | | | | Station | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Scientific Name** | **Common Name** | **Trophic-Group** | **Tolerance** | **1** | **2** | **3** | **4** | **5** | **6** |
| Mircorpterus salmoides | Largemouth Bass | P | | 1 | | | | | |
| Lepomis megalotis | Longear Sunfish | IF | | 57 | | 1 | | | |
| Carpiodes carpio | River Carpsucker | O | T | 2 | | | 15 | 12 | 1 |
| Cycleptus elongatus | Blue Sucker | IF | I | | | | 5 | | |
| Ictiobus bubalus | Smallmouth Buffalo | O | | | | | 7 | | 8 |
| Cyprinus carpio | Common Carp | O | T | 6 | 11 | | 5 | 8 | |
| Extrarius aestivalis | Speckled Chub | IF | | | | | | 17 | 1 |
| Cyprinella lutrenis | Red Shiner | IF | T | 362 | 2 | 46 | 651 | 209 | 6 |
| Notropis amabilis | Texas Shiner | IF | | | | | | | 10 |
| Notropis braytoni | Tamaulipas Shiner | IF | | | | | | 7 | 50 |
| Notropis chihuahua | Chihuahua Shiner | IF | | | | | | 47 | 19 |
| Pimphales vigilax | Bullhead Minnow | IF | | 1 | 1 | | | | |
| Ictalurus punctatus | Channel Catfish | O | T | 3 | | | 1 | 5 | 1 |
| Ictalurus furcatus | Blue Catfish | P | | | | 5 | 7 | 1 | 1 |
| Pylodictus olivaris | Flathead Catfish | P | | 1 | | 5 | 2 | 2 | 4 |
| Gambusia affinis | Mosquitofish | IF | T | | 8 | | | 1 | |
| Astyanax mexicanus | Mexican Tetra | IF | | | | | 4 | | 1 |
| Dorosoma cepedianum | Gizzard Shad | O | T | 7 | 1 | | | | |

O=Omnivore; IF= Invertivore Feeder; P=Predator

A couple of species worth noting were observed in our collections. The Chihuahua shiner (*N. chihuahua)*, is considered by Hubbs et al. (1991) as threatened., likely to become endangered in the near future. According to Hubbs et al. the distribution of this species is restricted to the Rio Grande/Rio Bravo drainage in the Big Bend region of southwestern Texas, and in northern Mexico, primarily in the Rio Conchos Basin. *N. chihuahua,* was collected only in the Big Bend National Park/Canyon de Santa Elena Protected Area at Stations 5 and 6, and was not collected in either Phase I or Phase II. Bestgen and Platania (1988) found *N. chihuahua* in three of 24 collections made in the Rio Grande/Rio Bravo in the reach from the New Mexico-Texas border to Big Bend National Park. Two of the stations where Bestgen and Platania collected *N. chihuahua* were located on the Rio Grande/Rio Bravo upstream and downstream of Presidio, the other station was located on Alamito Creek near Presidio. The finding that the Chihuahua shiner apparently ranged in the mainstem at least into the reach around Presidio/Ojinaga as recently as 1988 but has not been noted in this reach in our surveys in 1992, 1995, 1998 may reflect further restriction of the range of this species. *Cycleptus elongatus*, the blue sucker, is considered by Hubbs et al. as being of Special Concern, a taxon of which the abundance or range has been reduced to the degree that it may be threatened with extinction. *C. elongatus* was collected only at Station 4 in Phase III and was also collected in both Phase I at Stations 4 and 5 and Phase II at Stations 3 and 5, of the RGTSS. The USGS collected *C. elongatus* at four of five sites in and around Big Bend during their 1999 survey (J.B. Moring personal communication). The only taxon considered by Hubbs (1991) as being introduced to Texas waters, which was collected was the common carp (*Cyprinus carpio*) which was collected at Stations 1, 2, 4, and 5. This taxon was abundant in collections made in both Phases I and II, as well as in the surveys conducted by Bestgen and Platania (1988). The bullhead minnow

(*Pimphales vigilax*), is considered to be introduced to the upper Rio Grande/Rio Bravo (Hubbs 1991). Bestgen and Platania (1988) collected the bullhead minnow, reporting that it was restricted to the reach upstream of the confluence with the Rio Conchos. This is consistent with our findings in Phases I, II, and III as, among mainstem stations in the reach from El Paso/Ciudad Juárez to Big Bend National Park/Canyon de Santa Elena Protected Area, *P. vigilax* was collected only at Stations 1 and/or 2. Among tributary stations in this reach, the bullhead minnow was collected on the Rio Conchos in Phase II (TNRCC 1997).

Hubbs et al. (1977) identified seven species (*Dorosoma cepedianum, Cyprinus carpio, Notropis lutrensis, Carpiodes carpio, Ictalurus punctatus, Gambusia affinis, and Lepomis cyanellus*) which he considers common in the international reach of the Rio Grande/Rio Bravo from El Paso/Ciudad Juárez to the confluence with the Pecos River in Texas. Of these, only the green sunfish (*L. cyanellus*) was not collected during Phase III.

Bestgen and Platania (1988) noted distinct differences in their collections from sites upstream and downstream of the confluence of the Grande/Río Bravo and the Rio Conchos. They reported that the discharge of the Rio Conchos completely changed the character of the Grande/Río Bravo relative to upstream of the confluence. Based on their nekton samples they concluded that the ichthyofauna of the Grande/Río Bravo downstream of the Rio Conchos was reduced in abundance and diversity relative to upstream reaches. They collected 537 specimens/collection and 155 specimens/collection upstream and downstream respectively of the Rio Conchos. With respect to abundance and diversity, our results also indicate differences in the reaches, however the relationship is different. We collected 173 specimens/collection in the upstream reach and 369 specimens/collection in the reach downstream of the Rio Conchos. On closer inspection, it becomes clear that the results are not strictly comparable in that their study included 16 stations upstream whereas we only sampled three stations upstream. The results are more similar when using only their data for three upstream stations located in the same river reaches as where we collected samples for Phase III. Using this approach, they collected 127 specimens/collection in the upstream reach and 177 specimens/collection in the downstream reach.

From the three upstream stations noted above, Bestgen and Platania (1988) collected 7 species and they collected 11 taxa from the three stations downstream of the Rio Conchos. Species that they collected at the three upstream stations but not at the downstream stations were *Cyprinus carpio, Pimphales vigilax, Rhinichthys cataractae, Ictalurus punctatus, Lepomis cyanellus* and *Lepomis megalotis*. Taxa collected from the three downstream stations but not from the three upstream stations were *Campostoma ornatum, Extrarius aestivalis, Notropis braytoni*, and *Notropis chihuahua.* Our results were similar in that we collected 11 species from the three stations upstream of the Rio Conchos and 14 species from the three stations downstream. Species that we collected at the three upstream stations but not downstream were *Micropterus salmoides, Lepomis megalotis, Pimphales vigilax,* and *Dorosoma cepedianum*. Collected downstream but not upstream were *Cycleptus elongatus, Ictiobus bubalus, Extrarius aestivalis, Notropis amabilis, Notropis braytoni, Notropis chihuahua,* and *Astyanax mexicanus.*

We noted little difference in the relative abundance of tolerant taxa in collections from above and below the confluence with the Rio Conchos. For the three stations upstream of the confluence, the percentage of individuals in the collections considered tolerant was 86.1%, for the three stations downstream of the confluence, the collection was comprised of 82.6%.

Our results also suggest distinct differences in the reaches upstream and downstream of the Rio Conchos confluence with respect to taxonomic composition. The similarity matrix revealed that similarity is greater among the fish assemblages within each reach than when the comparison is made across reaches (Table 27). This is quite clear for the comparisons among the three stations in the downstream reach. For these three stations the mean similarity value (0.70) was nearly twice the mean value for inter-reach comparisons (0.40). In the upstream reach, the mean similarity value among the three stations (0.41) was only slightly greater than that for the inter-reach comparisons.

Taxa richness ranged from four at Station 3 to 12 at Station 6 (Table 26; Figure 22). Species richness dropped from nine in the collection from Station 1, upstream of El Paso/Ciudad Juárez, to five at the downstream station (Station 2). Elevated levels of ammonia likely contribute to the lower species richness at Station 2 relative to Station 1 as 84% of the 31 water samples which have been collected from Station 2 contained ammonia concentrations which exceed the screening level. In a discussion of ammonia toxicity in the report Quality Criteria for Water (USEPA 1986) the authors suggest that some of the species potentially most sensitive to chronic ammonia toxicity are from the families Cyprinidae, Centrarchidae, Catostomidae and Ictaluridae. Our findings lend some support to such a premise as two species of Centrarchidae, the largemouth bass (*Micropterus salmoides*), and the longear sunfish (*Lepomis megalotis*), as well as two species from the family Ictaluridae, the channel catfish (*Ictalurus punctatus*), and the flathead catfish (*Pylodictus olivaris*) and one species from the family Catostomidae, the river carpsucker (*Carpiodes carpio*) were present in the collection from the upstream station but not at the downstream station.

TABLE 27
Similarity Matrix for Fishes Collected from
the Rio Grande/Rio Bravo During Phase III

| | Station Number | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | 1.00 | | | | | |
| 2 | 0.57 | 1.00 | | | | |
| 3 | 0.46 | 0.20 | 1.00 | | | |
| 4 | 0.55 | 0.28 | 0.46 | 1.00 | | |
| 5 | 0.53 | 0.40 | 0.43 | 0.63 | 1.00 | |
| 6 | 0.40 | 0.13 | 0.40 | 0.70 | 0.76 | 1.00 |

The mosquitofish (*Gambusia affinis*), a species generally considered to be highly tolerant of poor water quality, was the only taxon which was collected at the downstream station but not at the upstream station. At the stations bracketing Presidio/Ojinaga (Stations 3 and 4), species richness was greater downstream than upstream (Figure 22). A finding which is likely related to the more favorable habitat at the downstream station as indicated by the lower RBA habitat score at the upper station (117) relative to that for the lower station (131). The lower quality habitat at the upstream station is due to channelization which reduces available cover, lowers the heterogeneity of velocity and depth regimes, decreases the prevalence of riffles and lowers the vegetative buffer zone relative to the downstream station. *C. carpio*, blue sucker (*Cycleptus elongatus*), smallmouth buffalo (*Ictiobus bubalus*), common carp (*Cyprinus carpio*), *I. punctatus*, and Mexican tetra (*Astyanax mexicanus*) were collected at the downstream station but not at the upstream station. *L. megalotis* is the only species which was collected at the upstream station but not at the lower station.

Overall, tolerant taxa accounted for 83.7% of the total number of individuals collected. Six tolerant species, *Carpiodes carpio*, *Cyprinus carpio, Cyprinella lutrensis, Ictalurus punctatus, Gambusia affinis,* and *Dorosoma cepedianum* collectively accounted for 83.7% of the total collection (Table 26). The only species collected which is generally considered to be intolerant was the blue sucker which was collected only at Station 4. Among mainstem stations upstream of Amistad Reservoir, *C. elongatus* was collected at Stations 4 and 5 in Phase I and at Stations 3 and 5 in Phase II. This finding is consistent with the caveat expressed in the Phase I report (TNRCC 1992) that the Rio Grande/Rio Bravo basin presents an intrinsically harsh environment. Due to this, the Phase I report recommends that metrics related to tolerance be eliminated. However, even though these conditions, for example elevated salinity and extreme flow fluctuations, are, to a large extent, naturally occurring they are, to varying degrees, exacerbated by anthropogenic activities such as irrigation withdrawals and return flows, reservoirs, and point and nonpoint sources. Also, the tolerance value assigned to a particular taxon is often primarily a measure of tolerance to low dissolved oxygen concentrations rather than those conditions such as elevated salinity and flow fluctuation which are intrinsic to the Rio Grande/Rio Bravo. Thus, the relative differences in the representation of tolerant taxa among stations is likely to reflect, at least to some extent, differences in environmental conditions caused by anthropogenic activities.

Among individual stations, the highest proportion of tolerant individuals was noted in the collection from Station 4 where 93.4% of the individuals were red shiners, a taxon which is generally considered to be tolerant to harsh environmental conditions. This station is located downstream of Presidio/Ojinaga. At the upstream station (Station 3), 80.7% of the collection was comprised of individuals from tolerant taxa. A similar relative change was noted for the Stations bracketing El Paso/Ciudad Juarez where the percentage of tolerant individuals was greater at the downstream station (95.6%) than at the upstream station (86.4%). The lowest percentage of individuals as tolerant was in the collection from Station 6, near Boquillas Canyon in Big Bend Park where only 7.8% of the individuals collected belong to tolerant taxa. The blue sucker (*Cycleptus elongatus*) was the only species collected which is considered intolerant. Only five blue suckers were collected and all were collected at Station 4, downstream from Presidio.

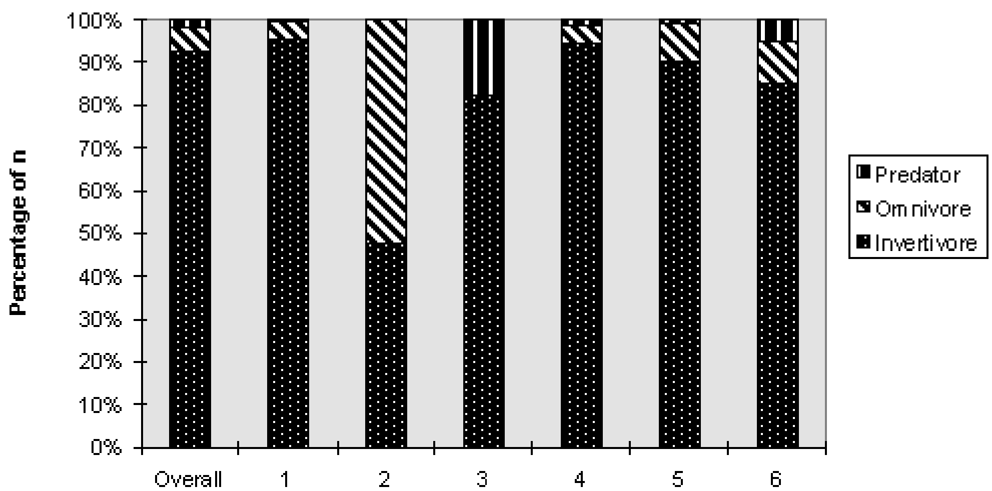



Figure 25. Summary of Trophic Composition of Fish Community as Indicated by Surveys Conducted at Six Stations During Phase III.

## Index of Biotic Integrity (IBI)

Index of Biotic Integrity (IBI) scores ranged from 12 at Station 2 to 20 at Stations 5 and 6, out of a possible 30 points (Table 27). Three of the six stations sampled during Phase III had equal IBI scores. However, there were differences in the values/scores for the individual metrics among these three stations. The primary difference was species richness, as nine species were collected at both Stations 1 and 4, while at Station 3, only four taxa were collected. Also, only one species of minnow was collected at Stations 3 and 4 and two species of minnows were collected at Station 1. The red shiner (*Cyprinella lutrensis*) is the only minnow species collected at all three of these stations. Two stations (5 and 6) had IBI equal scores. Individual metrics which differed include the percentage of individuals in the most abundant species, 67.6% at Station 5 and 49% at Station 6, as well as the number of individuals in the sample.

A decrease of six points in the IBI score, from 18 to 12, was noted from Station 1 upstream of El Paso/Ciudad Juárez, to Station 2 the downstream station (Table 28). The lower score at the downstream station was attributable to lower species richness, a lower number of individuals in the collection, and a higher percentage of non-native species relative to the upstream station. As noted for the decrease in species richness at Station 2, elevated levels of ammonia likely contribute to the apparent low overall integrity of the fish community at Station 2. Eighty-four percent of the 31 water samples which have been collected from

Station 2 contained ammonia concentrations which exceed the screening level. The overriding effect of water chemistry and water availability (diversions and lack of return flows) on the lower integrity noted at Station 2 is reflected in the higher RBA Habitat Score at the downstream station (82) relative to that for the upstream station (68). The IBI score was 18 for the collections from both of the stations bracketing Presidio/Ojinaga, Stations 3 and 4. The higher scores at Stations 5 and 6 were due to higher species richness, a higher number of minnow species, and a relatively low representation of non-native species. Higher quality habitat at these stations, as indicated by the RBA habitat assessment scores (Table 32), is the primary factor for the relatively high IBI scores.

TABLE 28
Summary of Metric Values for Fish Collections from
Six Stations on the Rio Grande/Rio Bravo (TPWD Phase 1 Fish IBI)

| Site Number | Taxa Richness | Total Number of Minnow Species | Percent of Individuals in Most Abundant Species | Number of Individual s in Sample | Percent of n with Disease or Anomaly | Percent of Individuals as non-native species | Total Score |
|---|---|---|---|---|---|---|---|
| **1** | 9 | 2 | 82.3 | 440 | 0 | 1.4 | 18 |
| **2** | 5 | 2 | 47.8 | 23 | 0 | 47.8 | 12 |
| **3** | 4 | 1 | 80.7 | 57 | 0 | 0 | 18 |
| **4** | 9 | 1 | 93.4 | 697 | 0 | 0.72 | 18 |
| **5** | 10 | 5 | 67.6 | 309 | 0 | 2.6 | 20 |
| **6** | 11 | 5 | 49.02 | 102 | 0 | 0 | 20 |

Based on an analysis of faunal patterns, the Phase I report (TNRCC 1992) suggested that the Rio Grande/Rio Bravo fish community is characterized by two fundamental species associations, one upstream and one downstream of International Falcon Reservoir. Considering all 32 fish collections from all three phases of the Toxic Substances Survey, at stations in the reach upstream of International Falcon Reservoir, the median IBI score was 17.5 (Figure 26). Among the IBI scores for the six fish collections made during Phase III in this reach, only that for Station 2 fell below the median and, in fact, in the lower quartile. Two out of the three collections from Station 2 (Phases II and III) fell in the lower quartile, indicating that the fish community at this station is stressed. IBI scores for fish collections from Stations 1, 3, and 4 made during Phase III were just above the median and the scores for Stations 5 and 6 were in the upper quartile.

## Synthesis: *Bioassessment*

In general, the fish and benthic macroinvertebrate assemblages showed similar patterns of interstation variation. Both assemblages showed decreased overall integrity, as expressed by the fish IBI and the BRBIBI for the benthics, between Stations 1 and 2 then overall improvement at Stations 3 to 6 (Figure 27). Though the decrease in the BRBIBI between Stations 1 and 2 was not near nearly as great as for the fish. The highest overall scores for the fish were observed at Stations 5 and 6. For the benthics, the scores at Stations 3, 5, and 6 were within one point of the highest score which was observed at Station 4. Benthic macroinvertebrate measures of community integrity for samples collected in depositional zones suggest that these habitats are more degraded than the erosional zones (Table 24 and 25).

For both assemblages, between station comparisons of taxonomic composition, as indicated by the similarity index, lend support to the idea of the Rio Conchos confluence constituting a fundamental faunal division. This is especially clear for the intra-reach comparisons between stations downstream of the confluence. The similarity matrix revealed that, for both the fish and benthic macroinvertebrate assemblages, sites within this reach were clearly more similar to each other than were assemblages in different reaches (Table27). In the upstream reach, within reach similarity was approximately equal to the respective inter-reach site comparisons for both the fish and the benthic

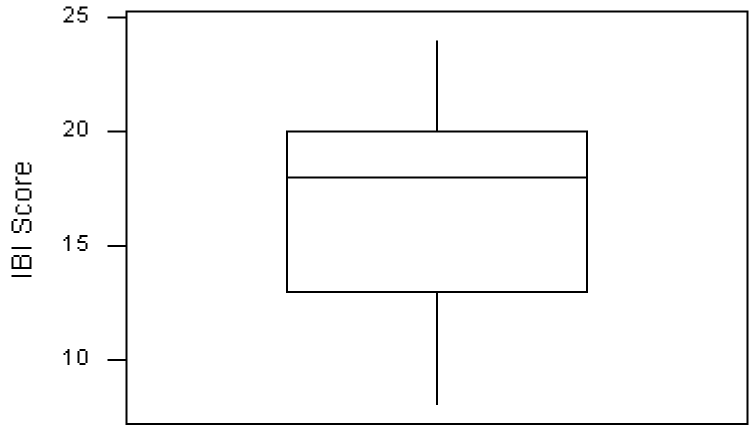



Figure 26. Boxplot of IBI Scores for Fish Collections from the Faunal Region of the Rio Grande/Rio Bravo Upstream of International Falcon Reservoir During Phases I, II and III of the RGTSS (n=37).

macroinvertebrates. This clear contrast in the degree of similarity among biotic communities upstream and downstream of the confluence with the Rio Conchos reflects the instability imposed by habitat modifications and urban influences on water quality and quantity in the upstream reach.

Habitat quality is one of five major categories of factors identified by Karr *et al.* (1986) which influence the overall biotic integrity of aquatic communities. In the Rio Grande/Rio Bravo, habitat quality clearly plays an important role in the changes in the character and overall integrity of the benthic macroinvertebrate and fish assemblages along the reach from El Paso/Ciudad Juárez to Big Bend National Park/Canyon de Santa Elena Protected Area (Figures 28 and 29). The other four major categories identified by Karr are water quality, flow regime, energy source and biotic interactions. The later two, energy source and biotic interactions were not analyzed for this study. Water quality and flow regime are discussed within other parts of the report.

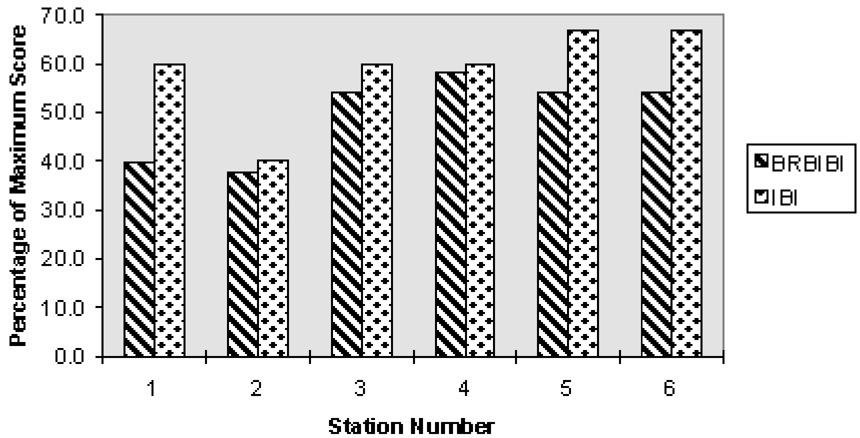



Figure 27. Comparison of Benthic BRBIBI and Fish IBI Scores, Expressed as a Percentage of the Maximum Possible Score, at Six Stations for Surveys Conducted During Phase III.

For the benthic macroinvertebrates, the relationship between habitat quality and biotic integrity, as measured by the Habitat Quality Index (HQI) the BRBIBI respectively, is relatively clear (Figure 28). Habitat quality at Stations 1 and 2, as measured by the HQI, fell in the limited aquatic life use subcategory, as does the integrity of the benthic macroinvertebrate assemblage.

At Stations 4 - 6 habitat quality is more conducive to the development of aquatic communities with high integrity, as indicated by higher HQI scores for these three stations which fell in the high aquatic life use subcategory. The higher quality habitat at these stations is reflected in the scores for the BRBIBI which are in the upper intermediate

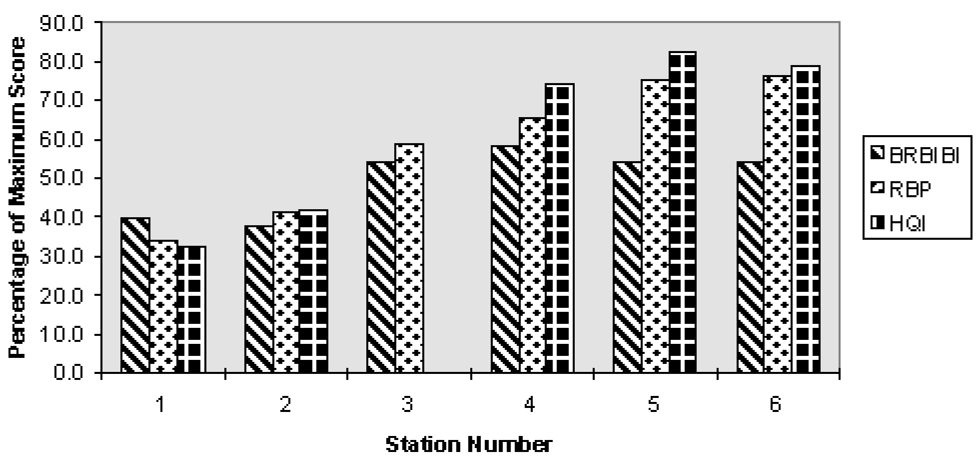



Figure 28. Comparison of BRBIBI Scores for Benthic Macroinvertebrate Kicknet Samples and Habitat Scores for Surveys Conducted at Six Stations During Phase III of the RGTSS.

range at all three stations. The overriding effects of degraded habitat at Stations 1 and 2 are evident in that

BRBIBI scores from both Phase II and Phase III fell in the lower 25th percentile for all BRBIBI scores from all stations in the reach from El Paso/Ciudad Juárez to International Falcon Reservoir. Conversely, at Stations 5 and 6 for the benthic samples collected during Phase III, as well as for the samples collected during the USGS survey in 1999, the BRBIBI scores were above the median. At Station 4, that the potential provided by the relatively high quality habitat is confounded by the effects of the Presidio/Ojinaga urban area upstream, is evidenced by the variability of the BRBIBI score. For Phase III , the score was within one point of the high aquatic life use category and in the upper 25th percentile of all scores in the reach from El Paso/Ciudad Juárez to International Falcon Reservoir, in Phase II on the other hand the BRBIBI score was well below the median and indicated attainment of limited aquatic life use.

For the fish assemblage the relationship between habitat quality and biotic integrity was a bit less clear. Increasing HQI scores clearly reveal improving habitat quality at Stations 4 to 6 relative to Stations 1 and 2. Higher IBI scores at Stations 4 to 6 relative to Station 2 reflect the higher quality habitat (Figure 29). However, the IBI for Station 1, where the HQI score is actually lower than at Station 2, was comparable to the IBI scores at Stations 4 to 6 where the habitat is of much higher quality. Because of inherently harsh conditions in the Rio Grande/Rio Bravo, some natural, some man induced, the fish community in the Rio Grande/Rio Bravo is likely not able to attain the integrity potential set by the habitat. Because of inherently harsh conditions in the Rio Grande/Rio Bravo, some natural, some man induced, the fish community in the Rio Grande/Rio Bravo may not be able to attain the integrity potential set

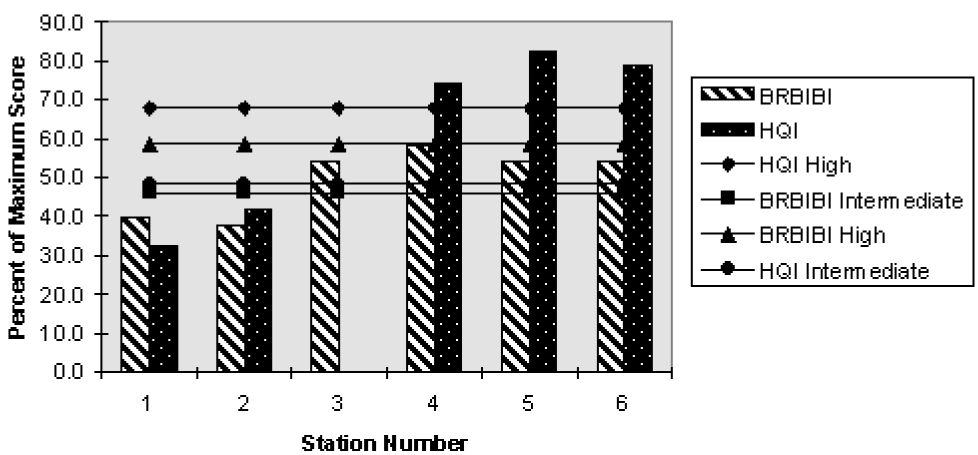



Figure 29. Summary of Benthic BRIBI Scores, HQI Scores, and Aquatic Life Use Category Scores (plotted as a percentage of the maximum possible score) for Benthic Macroinvertebrate Samples Collected During Phase III.

by the habitat. The higher quality habitat in the more natural reaches, such as the portion of the river downstream of Presidio/Ojinaga to International Amistad Reservoir, has a fish assemblage that is below the potential one would expect. The probable cause of a less optimal fish assemblage is a highly variable flow regime which varies naturally and is further exacerbated by man induced flow fluctuations. The effects of elevated flows are heightened by established stands of salt cedar along the river banks which limit stream meandering and habitat variability, and increase stream incision. The combination of natural and man induced flow variations results in a highly variable and overall highly unnatural flow regime with which the fish assemblage must cope. In addition the salinity regime is a product of natural and man induced elevated salinities which often exceed the USEPA aquatic life criterion (TNRCC 1997). These factors coupled with the bioaccumulation of heavy metals to levels which exceed predator protection limits, interact to depress the biotic integrity potential below that set by the physical habitat. Thus, because biotic integrity is limited in reaches of higher quality habitat by these confounding factors, the fish assemblage in habitat limited reaches such as that around Station 1, can attain levels of biotic integrity comparable to those in more natural reaches.

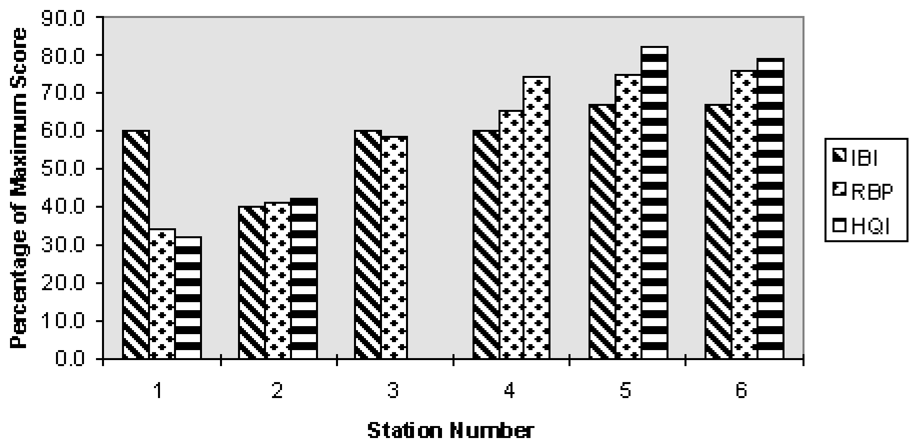



Figure 30. Comparison of IBI Scores for Fish Collections with Habitat Scores for Surveys Conducted at Six Stations During Phase III.

Both the fish and benthic macroinvertebrate assemblages were of lower overall integrity, as indicated by the IBI and the BRBIBI, at Station 2 relative to the other stations (Figure 27). However, the relative difference between Stations 1 and 2 was much more pronounced for the fish. Among water chemistry variables, elevated ammonia levels at Station 2, seem to be one of the most notable differences between the two stations. Eighty-four percent of the 31 water samples which have been collected from Station 2 contained ammonia concentrations which exceed the TNRCC screening level (Appendix D; TNRCC 1999). And the finding that the benthic community does not seem to be affected as negatively as the fish is consistent with findings as reported by EPA (USEPA 1986) that indicate that invertebrates are generally more tolerant than fishes to acute as well as chronic ammonia toxicity. Thus, in this case differences between benthic community integrity might be expected to primarily reflect habitat differences. And since habitat, especially as it relates to benthic macroinvertebrate community integrity, is degraded at both stations, primarily as a result of channelization, it follows that the relative change in benthic integrity between stations due to habitat differences should be small.

Overall, characteristics of ecological communities such as the number of taxa, types of taxa present, and trophic structure tend to respond in a relatively predictable manner to perturbation. However, characteristics intrinsic to individual components of the aquatic community such fish and benthic macroinvertebrate assemblages may result in differential responses of each assemblage to perturbation. Fish tend to be more mobile, and may move in and out of a particular habitat thus maintaining long term biotic integrity despite periodic or infrequent perturbations. Benthic macroinvertebrates, on the other hand, are much less mobile and re-establishing community equilibrium following perturbation is often a much slower process, dependent on recolonization via egg deposition by winged adults from other habitats, or downstream drift of aquatic stages. Given repeated periodic disturbance, the benthic community may never attain its potential biotic integrity. Also, fish may be more exposed to water column perturbations whereas, because the benthics maintain intimate contact within and on the bottom sediments they may be more subject to the accumulation of toxicants in the sediment.

As expressed by several measures of community structure, aquatic communities in the Rio Grande/Rio Bravo are clearly stressed. In general, although there is some variability among communities in terms of the relative abundance of each taxon, a stressed community is indicated by an overabundance of one or a very few taxa. The percent dominant taxon in the benthic assemblage at five of six of the stations (1, 2, 3, 4, 5) exceeds the 85$^{th}$ percentile among all reference stream kicknet samples in the TNRCC database (Harrison 1996). At Station 5, the percent dominant benthic taxon exceeds the maximum in the database. Considering the three most dominant benthic taxa, the imbalance is even more clear. At four of the six stations (1, 2, 3, 5) the percentage exceeds the maximum found by Davis (1997) in his data set which included 95 benthic samples from the bioregion which includes the Southern Deserts Ecoregion. At the remaining station (6) the percentage exceeds the 75$^{th}$ percentile reported by Davis. Similarly, an imbalance in functional feeding groups, resulting from relatively unstable food dynamics, reflects stressed conditions (USEPA 1999). At Stations 1 and 5 the percentage of individuals in the dominant functional group exceeds the 95$^{th}$ percentile reported by Harrison (1996). And at Station 1, the percentage exceeds the maximum for kicknet samples from reference streams in Texas (Harrison 1996). The percentage at Station 1 exceeds the 75$^{th}$ percentile among 141 benthic samples collected statewide as reported by Davis (1997). Invertivorous fishes account for approximately 95% of the collection at two stations (1 and 4). And, at Station 2, over 50% of the individuals in the collection are considered omnivores. Karr et al. (1986) point out that the prevalence of omnivorous fishes is an indicator of highly degraded streams. This is a result of the advantage conferred on omnivores as their opportunistic foraging habits make them more successful than more specialized groups as specific components of the food base become more unreliable.

Several factors potentially contribute to the community imbalance noted. Perhaps the overriding factor, is that physico-chemical conditions collectively inhibit the establishment of stable equilibrium community structure. Unnatural flow regimes, resulting from irrigation withdrawals and return flows coupled with impoundment release and withholding patterns which are geared primarily to agricultural activities. Habitat modifications such as channelization reduce overall habitat heterogeneity. At several of the stations in the channelized reaches, the only available habitat are snags and woody debris jams. Even these microhabitats are of relatively low quality as most consist of young salt cedar saplings with relatively smooth and homogeneous surfaces. In these reaches, reduced and fluctuating habitat availability contributes to more intense biotic interactions. Thus, flow variability, homogeneous channelized habitat with even microhabitats of low quality offer little opportunity for the aquatic biological community to reach a stable equilibrium. The imbalance noted in both the fish and benthic macroinvertebrate communities is also likely related to the bioaccumulation of heavy metals which, as noted by Wiederholm (1984), can reduce the abundance and species richness of aquatic insects and change the proportional abundance of different groups. Our findings clearly reveal the bioaccumulation of heavy metals, including arsenic, mercury, lead and selenium each of which exceeded predator protection levels at one or more stations.

## Multivariate Analysis

Principal components analysis (PCA) was used in an effort to better understand the relationships and contribution of multiple water quality variables to differences among sites. Routine water chemistry, sediment metals, and biological assessment data from ten stations in the reach from Station 1 just upstream of El Paso to Station 12 downstream of Laredo/Nuevo Laredo were used. In each case, the means for all samples from each station across all three phases were used in the analysis.

### Water Quality

The PCA of four routine water quality variables, ammonia, total dissolved solids (TDS), chloride and sulfate samples produced two “significant” components which together explained 98% of the variation among stations (Table 29). The first principal component (PC1) explained approximately 73% of the variance and seems to represent a gradient of TDS, chloride and sulfate each of which had relatively high negative loadings. PC1 separates stations with high concentrations of these parameters, such as Stations 3, 4, and 5 from Stations which are characterized by lower concentrations such as 7, 8, 10, and 12 (Figure 31). Separation of these two groups of stations along PC1 is a reflection of the effects of International Amistad Reservoir in combination with the changing geomorphic environment as the river flows from the Southern Deserts ecoregion into the South Texas Plains ecoregion. Amistad reservoir effectively acts as a sink for the elevated TDS, chloride and sulfate which characterize the Rio Grande/Rio Bravo partly as a result of upstream irrigation withdrawal and return flows and partly because of the more arid conditions in the Southern Deserts ecoregion. The second principal component explained an additional 26% of the variation and represents a gradient of ammonia which had a high negative loading. The separation of Station 2 from all of the other stations along this component clearly reflects the effects of the discharge from the City of El Paso Haskell Street wastewater treatment plant which discharged directly to the Rio Grande/Rio Bravo at the time of the study. As of April 1999, the Haskell Street wastewater treatment plant no longer discharges directly to the Rio Grande/Rio Bravo.

TABLE 29
Summary of Loadings and Explained Variances of the First Four Principal Components (PC) of Interstation Variation in Ammonia, Total Dissolved Solids (TDS), Chloride and Sulfate

| **Variable** | **PC1** | **PC2** | **PC3** | **PC4** |
|---|---|---|---|---|
| **Ammonia** | -0.023 | -0.995 | -0.071 | 0.059 |
| **TDS** | -0.584 | -0.014 | -0.254 | -0.771 |
| **Chloride** | -0.577 | 0.087 | -0.535 | 0.611 |
| **Sulfate** | -0.571 | -0.034 | 0.803 | 0.168 |
| **Proportion of Variance** | 0.726 | 0.252 | 0.020 | 0.002 |
| **Cumulative Proportion** | 0.726 | 0.978 | 0.998 | 1.00 |

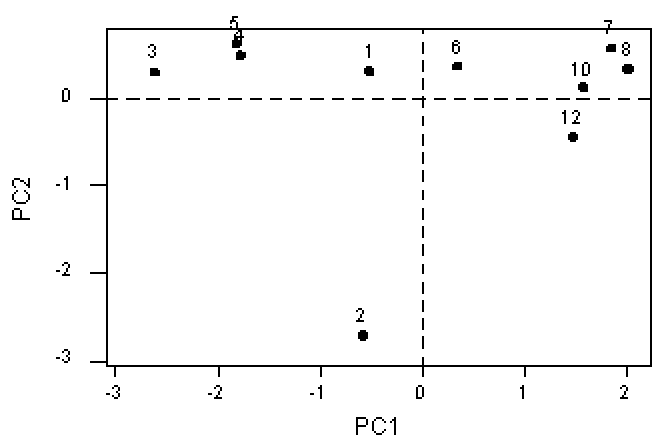



Figure 31. First and Second Principal Components Reflecting Ammonia,
Total Dissolved Solids, Chloride, and Sulfate at Ten Stations on the Rio Grande/Rio Bravo.

## Sediment

Four components explained nearly 95% of the variation among stations for the PCA of sediment metals data (Table 30). PC1 explained 46% of the variance. Zinc, arsenic, nickel, chromium and cadmium contributed most significantly to PC1 as each had a relatively high negative loading on this component indicating higher relative concentrations of these metals on the left side of the graph. Accordingly, the component appears to contrast Stations 2, 3, 4, 5, and 6 with Stations 7, 8, 10, 12 and especially Station 1 suggesting higher relative concentrations of these five metals at Stations 2, 3, 4, 5, and 6. PC2 seems to represent a gradient of lead, cadmium, copper and mercury each of which had a relatively high negative loading. Thus, stations on the lower negative end of this component, such as Station 2 are characterized by higher relative concentrations of lead, cadmium, copper and mercury and contrasted with Stations such as 1, 3, and 6 which the analysis would indicate have similar characteristics with respect to the concentration of these four metals in the sediments. The apparent contrast between Stations 1 and 2 along both components (Figure 32) is further indication of the effects of the urban area which lies between the two along the Rio Grande/Rio Bravo. These effects include sediments at Station 2 which are characterized by elevated concentrations of zinc, arsenic, cadmium, chromium, nickel, lead, copper and mercury relative to Station 1 which is located upstream of the urban area. The effects of both anthropomorphic and natural factors can be seen in the similarity between Stations 2, 3, 4, 5, and 6 relative to the sediment concentration of zinc, arsenic, nickel, chromium and cadmium indicated by the similar location of these five Stations along PC1. For example, in Phase I, it was noted that high levels of arsenic have occurred in effluent from the El Paso Haskell Street wastewater treatment plant, upstream of Station 2, as well as in the Ciudad Juárez sewage discharge canal upstream of Station 3. At Station 4, the similarity to Station 2 is related to inputs from the urban area around Presidio/Ojinaga and inputs from the Rio Conchos which includes agriculturally derived arsenical pesticides. The similarity of Stations 5, and 6 which are located in a more natural reach of the river to the other three stations is related to geological inputs via the weathering of ore bearing rocks in the region, historical mining activities as well as inputs from further upstream.

TABLE 30
Summary of Loadings and Explained Variances of the First Four Principal Components (PC) of Interstation Variation in Sediment Metals

| Variable | PC1 | PC2 | PC3 | PC4 |
|---|---|---|---|---|
| **Arsenic** | -0.462 | 0.234 | 0.031 | 0.388 |
| **Cadmium** | -0.360 | -0.415 | -0.143 | 0.226 |
| **Chromium** | -0.403 | 0.268 | 0.127 | -0.737 |
| **Copper** | -0.212 | -0.386 | -0.607 | -0.184 |
| **Lead** | -0.183 | -0.557 | 0.053 | -0.090 |
| **Mercury** | -0.010 | -0.399 | 0.726 | 0.101 |
| **Nickel** | -0.443 | 0.287 | -0.046 | 0.408 |
| **Zinc** | -0.469 | -0.012 | 0.251 | -0.191 |
| **Proportion of variance** | 0.461 | 0.316 | 0.131 | 0.040 |
| **Cumulative Proportion** | 0.461 | 0.777 | 0.908 | 0.948 |

## Fish

For the PCA of fish data, four components explained 96% of the variance among sites (Table 31). The first component explained 53% of the variance and represented a contrast between the total IBI score, total number of minnow species, and taxa richness, each of which had relatively high positive loadings with the percent of individuals as non-native which had a relatively high negative loading. The component contrasted stations with low total IBI scores, low numbers of minnow species, low total taxa richness and a high proportion of non-native taxa such as Stations 7 and 2 with Stations 6, 9, 10, and 11 which exhibit the opposite characteristics (Figure 33). The clear separation of Stations 2 and 7 from the other sample sites along this component in the PCA are related to upstream influences. Station 2 is downstream of the El

Paso/Ciudad Juárez urban areas and Station 7 is just downstream of International Amistad Reservoir. PC2 contrasted the proportion of individuals with disease or anomalies, which had relatively high positive loading with proportion of the community in the most abundant species which had a relatively high negative loading. Along this component, Stations 7 and 9 were clearly separated from the rest of the sample sites as a result of the relatively high proportion of diseased individuals in the collections at these sites. Species richness contributed less strongly to this component but contributed to the position of Station 7. Atypical conditions imposed by the dam at International Amistad Reservoir upstream of Station 7 contribute to the low taxa richness.

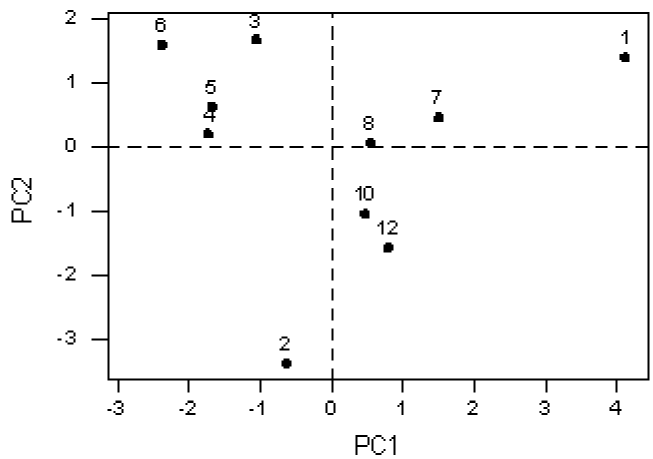



Figure 32. First and Second Principal Components Reflecting Sediment Metals at Ten Stations on the Rio Grande/Rio Bravo.

TABLE 31
Summary of Loadings and Explained Variances of the First Four Principal Components (PC) of Interstation Variation in Measures of the Biotic Integrity of the Fish Assemblage

| Variable | PC1 | PC2 | PC3 | PC4 |
|---|---|---|---|---|
| Species Richness | 0.477 | 0.324 | 0.020 | 0.037 |
| Number of Minnow Species | 0.486 | -0.052 | -0.226 | -0.159 |
| Percent of individuals in Dominant Species | -0.247 | -0.665 | 0.057 | -0.093 |
| Percent Diseased/Physical Anomalies | -0.278 | 0.594 | 0.470 | -0.178 |
| Percent of individuals as Non-Native Species | -0.364 | 0.312 | -0.843 | 0.023 |
| Total IBI score | 0.515 | -0.028 | -0.120 | 0.583 |
| Proportion of Variance | 0.531 | 0.279 | 0.096 | 0.055 |
| Cumulative Proportion | 0.531 | 0.809 | 0.905 | 0.960 |

## Benthic Macroinvertebrates

Approximately 98% of the variance among stations in terms of seven benthic macroinvertebrate metrics was explained by four components (Table32). PC1 explained 62% of the variance and seems to represent a contrast between the percent dominant taxon, percent dominant functional group, and the percent chironomidae, all of which had relatively high negative loadings, with taxa richness, EPT, and the number of non-insect taxa, each of which had relatively high positive loadings on this component. Reflecting high percent dominant taxon, high percent dominant functional group and a relatively high percentage of chiromidae in the assemblage, Station 2 is again clearly separated from the rest of the Stations along this component (Figure 34). Stations 8, 10, and 12 have the opposite characteristics with respect to these variables as well as higher relative taxa richness, EPT and numbers of non-insect taxa. PC2 explains an additional 20% of the variance and represents a contrast between EPT and the biotic index with relatively high positive and negative loadings respectively. Along this component, Stations 3, 4, 5, 6, 10 and 12, each of which has relatively high EPT, are sharply contrasted with Station 8 which has low EPT and a high biotic index.

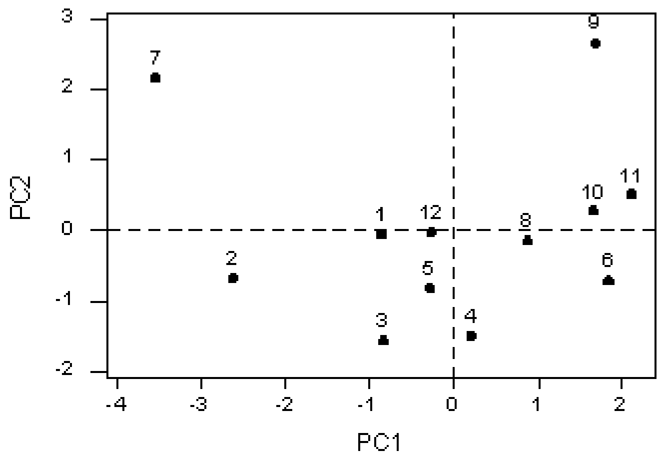



Figure 33. First and Second Principal Components Reflecting Measures of Fish Biotic Integrity at Ten Stations on the Rio Grande/Rio Bravo.

TABLE 32
Summary of Loadings and Explained Variances of the First Four Principal Components (PC) of Interstation Variation in Measures of the Biotic Integrity of the Benthic Macroinvertebrate Assemblage

| Variable | PC1 | PC2 | PC3 | PC4 |
|---|---|---|---|---|
| **Taxa Richness** | 0.398 | 0.318 | -0.430 | 0.134 |
| **EPT** | 0.364 | 0.490 | -0.265 | 0.127 |
| **Biotic index** | 0.231 | -0.695 | -0.269 | -0.036 |
| **Percent of Individuals as Chironomidae** | -0.334 | -0.107 | -0.802 | 0.011 |
| **Percent of Individuals in Dominant Taxon** | -0.424 | -0.085 | -0.016 | 0.771 |
| **Percent of Individuals in Dominant Functional Group** | -0.429 | 0.134 | -0.166 | -0.606 |
| **Number of Non-Insect Taxa** | 0.425 | -0.372 | -0.039 | -0.049 |
| **Proportion of Variance** | 0.619 | 0.206 | 0.107 | 0.046 |
| **Cumulative Proportion** | 0.619 | 0.825 | 0.932 | 0.978 |

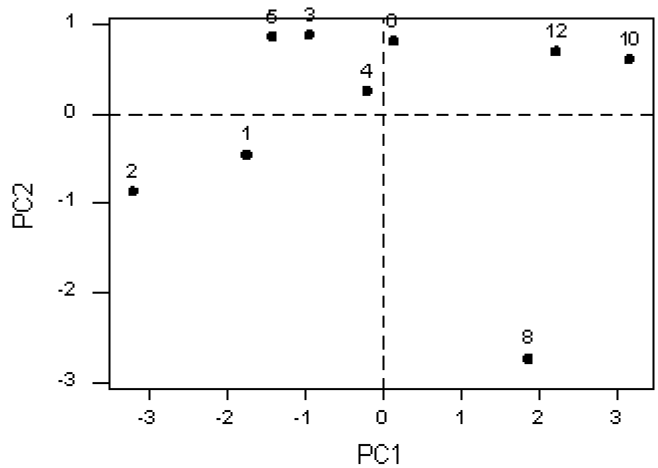



Figure 34. First and Second Principal Components Reflecting Measures of Benthic Macroinvertebrate Biotic Integrity at Ten Stations on the Rio Grande/Rio Bravo.

## Summary of PCAs

Collectively, the PCAs of routine water chemistry, sediment metals, and measures of biotic integrity revealed several commonalities. Stations 2, 3, and 4 were separated from the other Stations along components in the direction indicating degraded conditions in three of the four PCAs. Station 2 stands out as being located farthest in the direction of degraded conditions in each case (Figures 31, 32, 33, and 34). This finding is consistent with results in Phase II which indicated a high concern for potential effects of toxic chemicals for Stations 2, 3, and 4. In Phase I, Station 2 was judged to have a high potential for toxic chemical impact. Stations 3 and 4 were rated as having slight to moderate and little or no potential for toxic chemical impact respectively.

Conversely, Stations 1, 8, 10, and 12 were located along the components in the direction indicating less degraded conditions in three of the four PCAs and Station 6 was located along the component in the direction indicating less degraded conditions in all four PCAs (Figures 31, 32, 33, and 34). The results for Stations 1, 6, 8, and 10 are consistent with those cited in Phase I as these four stations were considered to have no to moderate potential for toxic chemical impact in that report. Station 12, however, was found to have a high potential for toxic chemical impact in Phase I. In Phase II, Stations 1 and 12 were found to have low and slight concern respectively. Station 6 was not sampled in Phase II and Stations 8, and 10 were not ranked because of inadequate data.

The PCAs, seem to contribute to interpretation of results with respect to land use patterns and habitat modification. Stations 1, 2, and 3 have the most significantly altered physical habitats among these ten stations. Station 2 stands out in having both a significantly degraded habitat and being located immediately downstream of a large urban area. The consistent separation of Station 2 from the others in the PCA results reflect the integrated effects of this combination of degraded physical conditions and chemical factors. On the other hand, Stations 1 and 3 with habitat conditions similar to that at Station 2, but with less degraded conditions in terms of water and sediment chemistry variables, tended to group with Stations in areas with more natural habitats in the PCAs, especially with respect to measures of biological integrity (Figures 31 and 32). Further, the PCAs indicate that stations with more natural habitats, even if located downstream of urban areas, such as Stations 4, 8, 10, and 12 tend to be more similar to stations located in areas with relatively undisturbed habitats which are relatively distant from urban influences such as Stations 5 and 6, again, especially with respect to measures of biotic integrity.

# Habitat Assessments

The Rio Grande/Rio Bravo is a river dramatically influenced by the activities of man in the watershed. With regards to habitat availability, the most influential aspect affecting the river is flow. The dominant anthropogenic influences to the riverine structure in this area are regulated flows through diversions and returns related to agricultural practices and reservoir development, dredging, channelization, loss of riparian habitat, point and nonpoint source discharges, and partially and untreated wastewater discharges. In general, streams with significant urban development and/or heavy agricultural activities in the watershed usually exhibit highly variable flows, channel incision, increased sediment loads, and increased rates of bank erosion, increased channelization and loss of stable woody vegetation in the riparian and flood plain zones.

## Habitat Assessment Summary

Table 33 shows the breakdown of metric scores that produced each of the HQI scores.

**Station 1 - Courchesne Bridge in El Paso:** This station was the uppermost station on the Rio Grande. The channel is sand dominated with extensive shifting bar development. The channel is also fairly well channelized at this station although there was some pool development. This station scored the lowest in terms of riparian buffer vegetation and channel sinuosity.

**Station 2 - Zaragosa International Bridge in El Paso/Ciudad Juárez:** Zaragosa Bridge is a major point of entry between the U.S. and Mexico and has considerable foot vehicle traffic. The river is more channelized at this station than at any other station in the study. The substrate was dominated by fine shifting sand and was fairly uniform in depth across each transect, resulting in a run dominated reach with no pools present, hence little to no variability in flow regimes. Comparisons between HQI and RBA scores and between HQI and study IBI scores were the closest at this site.

**Station 3 - Upstream of Presidio/Ojinaga:** This site was located approximately five (5) km upstream of the confluence with the Rio Conchos, a Mexican tributary. At the time of the field visit, the flow was up considerably due to recent rainfall upstream and irrigation return flows, therefore, field measurements for the RWA protocols could not be made. The RBA assessment was conducted and as many RWA attributes as possible were derived from that assessment. The river at this site is very constricted, with places where the width is only about 10 meters. On both sides of the river, most of the native riparian vegetation is burned on a regular basis causing grasses to make up the stabilizing bank vegetation. This results in a lowering of the bank stability attributes. There is some cobble and gravel present and the stream is not as channelized in this area.

**Station 4 - Downstream of Presidio/Ojinaga:** Downstream of Presidio/Ojinaga, the river exhibits a much more natural stream profile and becomes much wider. Instream cover and the presence of cobble and gravel greatly increases which increases the HQI score. The only metric which decreases is channel flow status. This is in part due to the widening of the channel in this area to a more natural, unchannelized state even though the flow actually increases slightly from the upstream site. Although still very comparable, this site had the widest separation between HQI and RBA scores.

**Station 4.5 Colorado Canyon:** The Colorado Canyon site is on the Big Bend Ranch State Park which is managed by the Texas Parks and Wildlife Department (TPWD) and is perhaps the closest to reference conditions that can be found on the Rio Grande/Rio Bravo. The channel is in a very natural state and riparian disturbance is minimal. Channel flow status at this site scored lower than at any other site due to the fact that it was measured four months after Stations 1 through 6 and the flow had dropped. The site had a good mixture of habitat types and was the only site which had boulders and water falls present. Colorado Canyon had the highest RBA score. There is a good mixture of gravel, cobble, sand, and silt at this site.

**Station 5- Santa Elena Canyon:** Santa Elena Canyon is the first station in Big Bend National Park/Canyon de Santa Elena Protected Area and had the highest HQI score. Santa Elena Canyon did have a relatively low bank stability score compared to the other more natural sites (Stations 4 through 7), due to multiple factors, including higher bank angles at this site even though erosion potential was lower, and a lack of trees on either bank. Trees do provide much more stability to steeper banks than do shrubs and grasses. This site was equal with Colorado Canyon in having good pool development. Seventy-six percent of the substrate in this reach was gravel size or larger.

**Station 6- Boquillas Canyon:** Boquillas Canyon is the most downstream site in Big Bend National Park/Canyon de Santa Elena Protected Area. This site scored as high aquatic life use and probably could have scored out much higher, however, only four transects out of six could be conducted on the day of the study. With additional measurements, it is probable that this site could have scored out at least as high, if not higher, than Santa Elena Canyon. Bottom substrate stability and available instream cover were equally as good in the four transects measured as they were at Santa Elena. Channel sinuosity was second to that of Colorado Canyon. Seventy-one percent of the substrate at this station was gravel size or larger.

**Station 7- Black Gap Wildlife Management Area:** Black Gap Wildlife Management Area (WMA) is the furthest down stream site and was assessed as part of the Southern Deserts Ecoregion study conducted in July, 2000 by the TNRCC. This site is also classified as high aquatic life use with regards to the HQI. This site had considerably less available instream cover than at either Boquillas Canyon or Santa Elena Canyon, but had one more riffle than Boquillas and the same number as Santa Elena. Black Gap WMA is managed by the TPWD and is used for game hunting, fishing and some cattle grazing. It is a very scenic portion of the river with less evidence of human activity than is present at either of the Big Bend Park/Canyon de Santa Elena Protected Area sites. Eighty-seven percent of the substrate at Black Gap was gravel size or larger, which was the highest percentage in the study.

Table33
HQI Scores by Individual Metrics

| Station | Available Instream Cover | Bottom Substrate Stability | Number of Riffles | Dimensions of Largest Pool | Channel Flow Status | Bank Stability | Channel Sinuosity | Riparian Buffer Vegetation | Aesthetics of Reach | Total Score |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 3 | 2 | 1 | 0 | 0 | 1 | 10 |
| 2 | 1 | 1 | 1 | 1 | 3 | 2 | 0 | 1 | 1 | 11 |
| 3 | ** | ** | ** | ** | 3 | ** | ** | 1 | 1 | |
| 4 | 3 | 4 | 3 | 3 | 2 | 2 | 1 | 3 | 2 | 23 |
| 4.5 | 3 | 4 | 3 | 4 | 1 | 2 | 2 | 3 | 3 | 25 |
| 5 | 4 | 4 | 3 | 4 | 2 | 1.5 | 1 | 3 | 3 | 25.5 |
| 6 | 4 | 4 | 2 | 2.5 | 2 | 2 | 2 | 3 | 3 | 24.5 |
| 7 | 3 | 4 | 3 | 3.5 | 2 | 2 | 1 | 3 | 3 | 24.5 |

** Data not collected due to high flow-stream was not wadeable

## Phase III Significant Findings

- Arsenic was detected in all water and sediment samples collected during Phase III. Areas of west Texas and northern Chihuahua, dominated by volcanic rock and mineral-rich geologic deposits, are the primary reason for elevated arsenic levels in the Rio Grande/Rio Bravo.

- Arsenic levels in water did not exceed the water quality criteria for either the protection of aquatic life or human health.

## Phase III Significant Findings cont'd

- In addition to arsenic, cadmium, chromium, copper and nickel also exceeded the screening levels used to assess metals in sediment. Cadmium and copper were elevated at Station 2 while arsenic, chromium and nickel were above screening levels at the lower stations (Stations 3, 4, 5, 6).

- Mercury in sediment was detected within the range of background concentrations, at all stations. None of the sediment concentrations exceeded screening levels.

- Increasing dissolved solids, chloride and sulfate continue to be a problem in the Rio Grande/Rio Bravo (downstream gradient). Elevated dissolved solids concentrations have negative effects on domestic drinking water and agricultural water supplies and on aquatic life. The highest levels of chloride, sulfate and total dissolved solids are found from Fort Quitman to the lower end of the Big Bend area.

- The water and sediment toxicity tests run on samples collected during Phase III showed no significant effect on test organisms.

- The fish IBI and benthic macroinvertebrate BRBIBI seem to indicate similar inter-station responses of each assemblage to changes in physical habitat and water chemistry.

- The BRBIBI indicates that, with the exception of Station 2 which is classified as Limited Aquatic Life Use, none of the segments in the study reach are meeting the designated use. Benthic macroinvertebrate samples collected in depositional zones reflect even lower biotic integrity.

- For both assemblages (fish and benthic macroinvertebrates), between station comparisons of taxonomic composition, as indicated by the similarity index, results lend support to the idea of the Rio Conchos confluence constituting a fundamental faunal division.

- Benthic macroinvertebrate community structure is imbalanced as indicated by such factors as percent dominant taxon in the benthic macroinvertebrate assemblage which exceeded the Texas statewide $85^{th}$ percentile, and the percentage of individuals in the dominant benthic macroinvertebrate functional group which exceeded Texas statewide $95^{th}$ percentile.

- Degraded habitat and water chemistry is reflected in the abundance of tolerant taxa, as indicated by the Hilsenhoff Biotic Index at Station 2 which exceeded the $90^{th}$ percentile for the Texas statewide database of RBA samples.

- The effects of habitat degradation are clearly evident in changes in benthic macroinvertebrate community integrity along the study reach.

- Biomagnification of heavy metals is evident to the extent that tissue levels at several of the sample sites exceed predator protection levels.

- All wet weight values for mercury in tissue were less than the human health screening level of 1.0 mg/kg for edible tissue.

- The effects of the two major urban areas in the study reach are evident in the responses of both the fish and benthic macroinvertebrate assemblages in stations bracketing El Paso/Ciudad Juárez, and Presidio/Ojinaga. As exemplified by relative changes in the relative dominance of tolerant taxa as measured by the HBI, and the intolerant to tolerant ratio for the benthics and the relative dominance of tolerant individuals in the fish collections.

## Recommendations

Although the completion of the Phase III Binational Toxics Substances Study marks the end to the multiphase synoptic assessments (1992 -present), it is recommended that further assessments be performed along the Rio Grande/Rio Bravo Watershed. Due to the scale and international nature of the Rio Grande/Rio Bravo Watershed data gaps still exist. In consideration of the good results obtained via the multiphase efforts, the following recommendations are proposed.

- Under the framework already established by the IBWC Minute No. 289, it is proposed that a binational routine monitoring program be established to help fill the data gaps that currently exist. The routine monitoring program would be modeled under the current USIBWC Texas Clean Rivers Program;

- Collect additional biological community data to refine and enhance existing biological criteria in order to develop binational biological standards for the Rio Grande/Rio Bravo. Biological criteria for the Rio Grande Watershed can be used to further refine the data obtained through the multiphase Binational Toxics Substances Studies. Biological criteria can be used by government agencies in both the United States and Mexico to help them assess stream health in relation to water quality information.

- Develop a routine binational biological monitoring program for the Rio Grande/Rio Bravo Watershed to assist in identifying changes in water quality through the biological community and enhance the use of available resources for advanced studies.

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**APPENDIX A**
**Rio Grande Toxic Substance Study-Phase III**
**WATER DATA**

| **Stations** | **1** | **2** | **3** | **4** | **5** | **6** |
|---|---|---|---|---|---|---|
| **Date** | 11/07/98 | 11/07/98 | 11/10/98 | 11/09/98 | 11/12/98 | 11/11/98 |
| **Time** | 1542 | 855 | 945 | 938 | 1015 | 1055 |
| **Segment Number** | 2314 | 2308 | 2307 | 2306 | 2306 | 2306 |
| **FIELD PARAMETERS** | | | | | | |
| **Water Temperature (°C)** | 17.4 | 14.2 | 15.1 | 15 | 16.6 | 19.5 |
| **pH (s.u.)** | 8.4 | 7.9 | 8.3 | 8.2 | 8.4 | 8.1 |
| **Dissolved Oxygen (mg/L)** | 8.8 | 6.8 | 9.5 | 9.9 | 9.9 | 9.4 |
| **Conductivity (µmhos/cm)** | 1953 | 1857 | 2436 | 2336 | 2344 | 2207 |
| **Flow (cfs)** | 225 | 206 | 332 | 398 | 392 | 392 |
| **CONVENTIONAL PARAMETERS** | | | | | | |
| **Ammonia Nitrogen** | 0.06 | 0.94 | < 0.05 | < 0.05 | < 0.05 | < 0.05 |
| **Total Kjeldahl Nitrogen** | 0.49 | 1.91 | 1.18 | 0.97 | 1.16 | 0.86 |
| **Total Phosphorus** | 0.15 | 0.52 | 0.77 | 0.5 | 0.38 | 0.13 |
| **Orthophosphate** | 0.15 | 0.5 | 0.23 | 0.21 | < 0.06 | < 0.06 |
| **Nitrate + Nitrite Nitrogen** | 1 | 2.1 | 1.64 | 1.25 | 1 | 0.35 |
| **Chlorophyll *a*** | < 1.0 | < 1.0 | 9.6 | < 1.0 | 29.1 | 6.41 |
| **Pheophytin *a*** | 6.58 | 12.6 | < 1.0 | 42.4 | < 1.0 | 9.29 |
| **Total Organic Carbon** | 5 | 6 | 9 | 7 | 10 | 11 |
| **Alkalinity, Total** | 256 | 236 | 260 | 260 | 260 | 176 |
| **Total Dissolved Solids** | 586 | 1150 | 1550 | 1630 | 1670 | 1340 |
| **Chloride** | 222 | 222 | 411 | 366 | 360 | 330 |
| **Sulfate** | 424 | 380 | 452 | 489 | 500 | 503 |
| **Total Suspended Solids** | 38 | 89 | 448 | 293 | 324 | 150 |
| **Volatile Suspended Solids** | 5 | 8 | 24 | 25 | 29 | 16 |
| **METALS (µg/L)** | | | | | | |
| **Aluminum** | 24.5 | < 15.0 | 16.4 | 21.3 | 22.5 | < 15.0 |
| **Arsenic** | 4.05 | 4.55 | 8.92 | 7.59 | 8.73 | 5.21 |
| **Cadmium** | < 5.0 | < 5.0 | < 5.0 | < 5.0 | < 5.0 | < 5.0 |
| **Chromium** | < 5.0 | < 5.0 | < 5.0 | < 5.0 | < 5.0 | < 5.0 |

| Stations | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| | | | **METALS (µg/L) (cont)** | | | |
| **Copper** | < 3.0 | < 3.0 | < 3.0 | < 3.0 | < 3.0 | < 3.0 |
| **Lead** | 1.76 | 1.42 | 1.9 | 2.81 | 3 | < 1.0 |
| **Mercury** ** | 0.011 | < 0.010 | 0.015 | 0.011 | 0.02 | < 0.010 |
| **Nickel** | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 |
| **Selenium** ** | < 1.11 | < 1.11 | < 5.5 | < 1.11 | < 5.5 | < 5.5 |
| **Silver** | < 0.25 | < 0.25 | < 0.25 | < 0.25 | < 0.25 | < 0.25 |
| **Zinc** | < 5.0 | 7.4 | < 5.0 | < 5.0 | < 5.0 | 5.61 |
| **Calcium-Dissolved** | 123 | 116 | 145 | 149 | 148 | 136 |
| **Magnesium-Dissolved** | 26.1 | 24.4 | 31.2 | 29.9 | 28.9 | 31.3 |
| **Hardness-Dissolved** | 416 | 389 | 501 | 496 | 488 | 467 |
| | | | **PESTICIDES (µg/L)** | | | |
| **DDD** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **DDE** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **DDT** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Aldrin** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Alpha BHC** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Beta BHC** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Delta BHC** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Dieldrin** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Endosulfan** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Endosulfan II** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Endosulfan Sulfate** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Endrin** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Endrin Aldehyde** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Endrin Ketone** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Gamma BHC** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Heptachlor** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Heptachlor Epoxide** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Methoxychlor** | < 0.030 | < 0.030 | * | < 0.030 | * | * |

*Not analyzed  * *Total

**Rio Grande Toxic Substance Study-Phase III**
**WATER DATA**

| DUPLICATES | | | | | | |
|---|---|---|---|---|---|---|
| **Stations** | **1** | **2** | **3** | **4** | **5** | **6** |
| **Date** | 11/07/98 | 11/07/98 | 11/10/98 | 11/09/98 | 11/12/98 | 11/11/98 |
| **Time** | 1545 | 855 | 950 | 942 | 1055 | 1055 |
| **CONVENTIONAL PARAMETERS (mg/L)** | | | | | | |
| **Ammonia Nitrogen** | 0.06 | < 0.05 | < 0.05 | 0.05 | < 0.05 | < 0.05 |
| **Total Kjeldahl Nitrogen** | 0.56 | 1.69 | 1.28 | 1.02 | 1.08 | 0.85 |
| **Total Phosphorus** | 0.14 | 0.55 | 0.78 | 0.5 | 0.38 | 0.16 |
| **Orthophosphate** | < 0.06 | 0.46 | 0.27 | 0.22 | < 0.06 | < 0.06 |
| **Nitrate + Nitrite Nitrogen** | 1 | 2.1 | 1.65 | 1.25 | 1.71 | 0.34 |
| **Chlorophyll *a*** | 2.85 | < 1.0 | < 1.0 | 4.27 | 19.9 | 6.41 |
| **Pheophytin *a*** | 2.63 | 1.36 | 50.9 | 6.19 | < 1.0 | 8.54 |
| **Total Organic Carbon** | 4 | 6 | 9 | 6 | 7 | 11 |
| **Alkalinity, Total** | 260 | 240 | 262 | 256 | 254 | 178 |
| **Total Dissolved Solids** | 580 | 1150 | 1540 | 1520 | 1660 | 1580 |
| **Chloride** | 221 | 223 | 409 | 367 | 364 | 328 |
| **Sulfate** | 422 | 383 | 449 | 491 | 508 | 500 |
| **Total Suspended Solids** | 37 | 95 | 413 | 355 | 304 | 148 |
| **Volatile Suspended Solids** | 4 | 11 | 23 | 27 | 26 | 15 |
| **METALS (µg/L)** | | | | | | |
| **Aluminum** | < 15.0 | < 15.0 | 26.8 | 15.3 | < 15.0 | < 15.0 |
| **Arsenic** | 4.44 | 5.08 | 9.09 | 7.83 | 8.99 | 5.04 |
| **Cadmium** | < 5.0 | < 5.0 | < 5.0 | < 5.0 | < 5.0 | < 5.0 |
| **Chromium** | < 5.0 | < 5.0 | < 5.0 | < 5.0 | < 5.0 | < 5.0 |
| **Copper** | < 3.0 | < 3.0 | < 3.0 | < 3.0 | < 3.0 | < 3.0 |
| **Lead** | 1.25 | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 |
| **Mercury** ** | < 0.010 | < 0.010 | 0.014 | < 0.010 | 0.015 | 0.017 |
| **Nickel** | < 10.0 | < 10.0 | < 10.0 | < 10.0 | < 10.0 | < 10.0 |
| **Selenium** ** | 1.7 | 1.32 | < 5.5 | < 5.5 | < 5.5 | < 5.5 |
| **Silver** | < 0.25 | < 0.25 | < 0.25 | < 0.25 | < 0.25 | < 0.25 |
| **Zinc** | < 5.0 | 6.5 | < 5.0 | < 5.0 | < 5.0 | < 5.0 |
| **Calcium-Dissolved** | 124 | 116 | 145 | 150 | 147 | 131 |
| **Magnesium-Dissolved** | 26.4 | 24.5 | 31.4 | 29.9 | 28.9 | 31 |
| **Hardness-Dissolved** | 418 | 391 | 492 | 497 | 487 | 455 |

| DUPLICATES | | | | | | |
|---|---|---|---|---|---|---|
| **Stations** | **1** | **2** | **3** | **4** | **5** | **6** |
| | | | **PESTICIDES (µg/L)** | | | |
| **DDD** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| | | | **PESTICIDES (µg/L)** | | | |
| **DDE** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **DDT** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Aldrin** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Alpha BHC** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Beta BHC** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Delta BHC** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Dieldrin** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Endosulfan** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Endosulfan II** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Endosulfan Sulfate** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Endrin** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Endrin Aldehyde** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Endrin Ketone** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Gamma BHC** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Heptachlor** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Heptachlor Epoxide** | < 0.030 | < 0.030 | * | < 0.030 | * | * |
| **Methoxychlor** | < 0.030 | < 0.030 | * | < 0.030 | * | * |

*Not analyzed  * *Total

**APPENDIX B**
**Rio Grande Toxic Substance Study-Phase III**
**SEDIMENT DATA**

| | | | | | | |
|---|---|---|---|---|---|---|
| **SEDIMENT REPLICATE 1** | | | | | | |
| **Stations** | **1** | **2** | **3** | **4** | **5** | **6** |
| **Date** | 11/07/98 | 11/07/98 | 11/10/98 | 11/09/98 | 11/12/98 | 11/11/98 |
| **Time** | 1610 | 1000 | 1045 | 1045 | 1050 | 1010 |
| **METALS (mg/kg)** | | | | | | |
| **Aluminum** | 2480 | 10600 | 20000 | 19200 | 18100 | 22500 |
| **Arsenic** | 1.17 | 4.94 | 7.25 | 4.71 | 6.13 | 6.47 |
| **Barium** | 32.1 | 121 | 158 | 245 | 200 | 182 |
| **Cadmium** | 0.03 | 0.9 | 0.22 | 0.16 | 0.29 | 0.29 |
| **Chromium** | 6.05 | 14.4 | 18.3 | 14.1 | 16.4 | 17.7 |
| **Copper** | 1.98 | 55.5 | 9.99 | 7.58 | 9.71 | 9.54 |
| **Lead** | 3.87 | 33.7 | 4.56 | 8.07 | 6.96 | 10.3 |
| **Manganese** | 126 | 235 | 273 | 347 | 343 | 336 |
| **Mercury** | 0.002 | 0.024 | 0.008 | 0.012 | 0.022 | 0.023 |
| **Nickel** | 3.12 | 7.6 | 12 | 8.25 | 11.5 | 11.5 |
| **Selenium** | < 0.08 | 0.28 | < 1.48 | 0.39 | < 0.75 | < 0.71 |
| **Silver** | < 0.241 | < 0.308 | < 0.222 | < 0.350 | < 0.451 | < 0.426 |
| **Zinc** | 14.1 | 65.4 | 44.4 | 49.3 | 55 | 55.8 |
| **SEDIMENT CONVENTIONALS** | | | | | | |
| **SEM-AVS** | 0.05 | 0.806 | 0.155 | 0.185 | 0.214 | 0.251 |
| **AVS (mg/kg)** | < 0.10 | 2.44 | 0.16 | 0.68 | 0.33 | 0.56 |
| **TOC (mg/kg)** | 2390 | 51800 | 30600 | 29200 | 44800 | 28900 |
| **%Solids** | 66.46 | 71.37 | 72.18 | 56.24 | 66.6 | 64.17 |
| **% Clay** | 0 | 2.38 | 9.6 | 20.06 | 32.46 | 21.59 |
| **% Gravel** | 0 | 0 | 0 | 0 | 0 | 0 |
| **% Sand** | 99.4 | 78.96 | 67.21 | 69.52 | 23.06 | 35.23 |
| **% Silt** | 0.6 | 18.66 | 23.19 | 10.43 | 44.48 | 43.18 |
| **PESTICIDES (µg/kg)** | | | | | | |
| **DDD** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **DDE** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **DDT** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Aldrin** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Alpha BHC** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Beta BHC** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Delta BHC** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Dieldrin** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |

| SEDIMENT REPLICATE 1 | | | | | | |
|---|---|---|---|---|---|---|
| **Stations** | **1** | **2** | **3** | **4** | **5** | **6** |
| | | | **PESTICIDES (µg/kg)** | | | |
| **Endosulfan II** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Endosulfan Sulfate** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Endrin** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Endrin Aldehyde** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Endrin Ketone** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Gamma BHC** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Heptachlor** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Heptachlor Epoxide** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Methoxychlor** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |

**Rio Grande Toxic Substance Study-Phase III**
**SEDIMENT DATA**

| SEDIMENT REPLICATE 2 | | | | | | |
|---|---|---|---|---|---|---|
| **Stations** | **1** | **2** | **3** | **4** | **5** | **6** |
| **Date** | 11/07/98 | 11/07/98 | 11/10/98 | 11/09/98 | 11/12/98 | 11/11/98 |
| **Time** | 1615 | 1030 | 1045 | 1055 | 1100 | 1020 |
| **METALS (mg/kg)** | | | | | | |
| **Aluminum** | 1860 | 8010 | 21000 | 64000 | 18100 | 11800 |
| **Arsenic** | 0.92 | 4.22 | 7.29 | 16.9 | 6.64 | 6.08 |
| **Barium** | 38.2 | 103 | 169 | 256 | 249 | 178 |
| **Cadmium** | 0.01 | 0.67 | 0.24 | 0.45 | 0.34 | 0.21 |
| **Chromium** | 5.7 | 11.1 | 19.4 | 44.1 | 16.5 | 10.2 |
| **Copper** | 1.59 | 42.9 | 10.6 | 22.5 | 11.2 | 6.98 |
| **Lead** | 4.19 | 29 | 5.63 | 8.98 | 9.45 | 11.4 |
| **Manganese** | 107 | 190 | 281 | 494 | 374 | 327 |
| **Mercury** | 0.002 | 0.023 | 0.011 | 0.032 | 0.032 | 0.022 |
| **Nickel** | 3.12 | 6.14 | 12.6 | 25.6 | 13.6 | 7.23 |
| **Selenium** | < 0.078 | 0.21 | < 1.44 | 0.62 | < 0.68 | < 0.69 |
| **Silver** | < 0.235 | < 0.276 | < 0.216 | < 0.409 | < 0.393 | < 0.414 |
| **Zinc** | 14.1 | 49.4 | 47.7 | 100 | 62.2 | 54.1 |
| **SEDIMENT CONVENTIONALS** | | | | | | |
| **SEM-AVS** | 0.07 | 0.619 | 0.147 | 0.939 | 0.261 | 0.209 |
| **AVS (mg/kg)** | < 0.01 | 0.25 | 0.22 | 0.93 | 0.25 | 0.24 |
| **TOC (mg/kg)** | 1420 | 8600 | 30100 | 46100 | 45200 | 37900 |
| **%Solids** | 77.91 | 79.36 | 71.86 | 41.61 | 67.77 | 67.5 |
| **% Clay** | 2 | 1.99 | 9.18 | 62.03 | 18.33 | 11.53 |
| **% Gravel** | 0 | 0 | 0 | 0 | 0 | 0 |
| **% Sand** | 94.8 | 79.65 | 64.19 | 0 | 68.91 | 75.35 |
| **% Silt** | 3.2 | 18.35 | 26.62 | 37.97 | 12.76 | 13.12 |
| **PESTICIDES (µg/kg)** | | | | | | |
| **DDD** | < 2.8 | < 3.2 | < 3.1 | < 8.5 | < 4.4 | < 3.6 |
| **DDE** | < 2.8 | < 3.2 | < 3.1 | < 8.5 | < 4.4 | < 3.6 |
| **DDT** | < 2.8 | < 3.2 | < 3.1 | < 8.5 | < 4.4 | < 3.6 |
| **Aldrin** | < 2.8 | < 3.2 | < 3.1 | < 8.5 | < 4.4 | < 3.6 |
| **Alpha BHC** | < 2.8 | < 3.2 | < 3.1 | < 8.5 | < 4.4 | < 3.6 |
| **Beta BHC** | < 2.8 | < 3.2 | < 3.1 | < 8.5 | < 4.4 | < 3.6 |
| **Delta BHC** | < 2.8 | < 3.2 | < 3.1 | < 8.5 | < 4.4 | < 3.6 |

| SEDIMENT REPLICATE 2 | | | | | | |
|---|---|---|---|---|---|---|
| **Stations** | **1** | **2** | **3** | **4** | **5** | **6** |
| **Dieldrin** | < 2.8 | < 3.2 | < 3.1 | < 8.5 | < 4.4 | < 3.6 |
| | | | | | | |
| | | | | | | |
| **PESTICIDES (µg/kg)** | | | | | | |
| **Endosulfan** | < 2.8 | < 3.2 | < 3.1 | < 8.5 | < 4.4 | < 3.6 |
| **Endosulfan II** | < 2.8 | < 3.2 | < 3.1 | < 8.5 | < 4.4 | < 3.6 |
| **Endosulfan Sulfate** | < 2.8 | < 3.2 | < 3.1 | < 8.5 | < 4.4 | < 3.6 |
| **Endrin** | < 2.8 | < 3.2 | < 3.1 | < 8.5 | < 4.4 | < 3.6 |
| **Endrin Aldehyde** | < 2.8 | < 3.2 | < 3.1 | < 8.5 | < 4.4 | < 3.6 |
| **Endrin Ketone** | < 2.8 | < 3.2 | < 3.1 | < 8.5 | < 4.4 | < 3.6 |
| **Gamma BHC** | < 2.8 | < 3.2 | < 3.1 | < 8.5 | < 4.4 | < 3.6 |
| **Heptachlor** | < 2.8 | < 3.2 | < 3.1 | < 8.5 | < 4.4 | < 3.6 |
| **Heptachlor Epoxide** | < 2.8 | < 3.2 | < 3.1 | < 8.5 | < 4.4 | < 3.6 |
| **Methoxychlor** | < 2.8 | < 3.2 | < 3.1 | < 8.5 | < 4.4 | < 3.6 |

Rio Grande Toxic Substance Study-Phase III
SEDIMENT DATA

| SEDIMENT REPLICATE 3 | | | | | | |
|---|---|---|---|---|---|---|
| **Stations** | **1** | **2** | **3** | **4** | **5** | **6** |
| **Time** | 11/07/98 | 11/07/98 | 11/10/98 | 11/09/98 | 11/12/98 | 11/11/98 |
| **Date** | 1637 | 1100 | 1045 | 1100 | 1050 | 1030 |
| **METALS (mg/kg)** | | | | | | |
| **Aluminum** | 3380 | 6310 | 21000 | 33300 | 36500 | 34600 |
| **Arsenic** | 1.33 | 2.64 | 7.35 | 9.36 | 8.05 | 8.33 |
| **Barium** | 59.2 | 78.9 | 160 | 185 | 215 | 211 |
| **Cadmium** | 0.04 | 0.42 | 0.22 | 0.32 | 0.39 | 0.3 |
| **Chromium** | 6.87 | 12.2 | 20.3 | 25 | 27.2 | 28 |
| **Copper** | 5.2 | 27.6 | 11.1 | 15.3 | 15.6 | 16 |
| **Lead** | 4.89 | 17.8 | 6.63 | 9.1 | 10.7 | 11.7 |
| **Manganese** | 157 | 178 | 291 | 345 | 424 | 459 |
| **Mercury** | 0.003 | 0.014 | 0.009 | 0.024 | 0.032 | 0.032 |
| **Nickel** | 3.98 | 6.03 | 13.5 | 17.9 | 17 | 14.6 |
| **Selenium** | < 0.07 | < 0.09 | < 1.74 | < 2.13 | < 0.99 | < 0.98 |
| **Silver** | < 0.209 | < 0.310 | < 0.261 | < 0.319 | < 0.596 | < 0.587 |
| **Zinc** | 18.3 | 41.3 | 48.4 | 68.8 | 76.1 | 81.6 |
| **SEDIMENT CONVENTIONALS** | | | | | | |
| **SEM-AVS** | 0.141 | 0.433 | 0.159 | 0.31 | 0.327 | 0.301 |
| **AVS (mg/kg)** | 0.03 | 0.3 | 0.2 | 4.09 | 0.79 | 1.36 |
| **TOC (mg/kg)** | 3970 | 8460 | 31200 | 39100 | 49500 | 47000 |
| **%Solids** | 78.02 | 71.42 | 71.98 | 52.31 | 48.79 | 50.54 |
| **% Clay** | 5.96 | 3.97 | 11.36 | 31.66 | 10.39 | 43.62 |
| **% Gravel** | 0 | 0 | 0 | 0 | 0 | 0 |
| **% Sand** | 89.27 | 83.7 | 63.57 | 23.86 | 66.41 | 12.76 |
| **% Silt** | 4.77 | 12.29 | 25.07 | 44.48 | 23.19 | 43.62 |
| **PESTICIDES (µg/kg)** | | | | | | |
| **DDD** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **DDE** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **DDT** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Aldrin** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Alpha BHC** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Beta BHC** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Delta BHC** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |

| SEDIMENT REPLICATE 3 | | | | | | |
|---|---|---|---|---|---|---|
| **Stations** | **1** | **2** | **3** | **4** | **5** | **6** |
| **Dieldrin** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Endosulfan** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **PESTICIDES (µg/kg)** | | | | | | |
| **Endosulfan II** | < 3.0 | < 4.0 | < 3.1 | < 6.7 | < 9.0 | < 5.8 |
| **Endosulfan Sulfate** | < 3.0 | < 4.0 | < 3.1 | < 6.7 | < 9.0 | < 5.8 |
| **Endrin** | < 3.0 | < 4.0 | < 3.1 | < 6.7 | < 9.0 | < 5.8 |
| **Endrin Aldehyde** | < 3.0 | < 4.0 | < 3.1 | < 6.7 | < 9.0 | < 5.8 |
| **Endrin Ketone** | < 3.0 | < 4.0 | < 3.1 | < 6.7 | < 9.0 | < 5.8 |
| **Gamma BHC** | < 3.0 | < 4.0 | < 3.1 | < 6.7 | < 9.0 | < 5.8 |
| **Heptachlor** | < 3.0 | < 4.0 | < 3.1 | < 6.7 | < 9.0 | < 5.8 |
| **Heptachlor Epoxide** | < 3.0 | < 4.0 | < 3.1 | < 6.7 | < 9.0 | < 5.8 |
| **Methoxychlor** | < 3.0 | < 4.0 | < 3.1 | < 6.7 | < 9.0 | < 5.8 |

**Rio Grande Toxic Substance Study-Phase III**
**SEDIMENT DATA**

| SEDIMENT REPLICATE 4 | | | | | | |
|---|---|---|---|---|---|---|
| **Stations** | **1** | **2** | **3** | **4** | **5** | **6** |
| **Date** | 11/07/98 | 11/07/98 | 11/10/98 | 11/09/98 | 11/12/98 | 11/11/98 |
| **Time** | 1610 | 1000 | 1045 | 1045 | 1050 | 1010 |
| **METALS (mg/kg)** | | | | | | |
| **Aluminum** | 2000 | 10300 | 20200 | 17400 | 33000 | 23300 |
| **Arsenic** | 0.92 | 5.09 | 7.05 | 4.58 | 8.21 | 7.23 |
| **Barium** | 36.6 | 117 | 156 | 187 | 185 | 196 |
| **Cadmium** | 0.02 | 0.91 | 0.23 | 0.14 | 0.4 | 0.3 |
| **Chromium** | 3.6 | 14 | 19.4 | 13.1 | 25 | 17.5 |
| **Copper** | 1.63 | 55 | 10.2 | 7.27 | 15.2 | 10.7 |
| **Lead** | 3.56 | 33.8 | 7.37 | 9.28 | 10.5 | 10.8 |
| **Manganese** | 103 | 229 | 275 | 322 | 412 | 363 |
| **Mercury** | < 0.001 | 0.037 | 0.009 | 0.01 | 0.029 | 0.022 |
| **Nickel** | 2.94 | 6.95 | 12.4 | 7.91 | 17.8 | 11.9 |
| **Selenium** | < 0.066 | 0.27 | < 1.42 | < 1.84 | < 0.97 | < 0.75 |
| **Silver** | < 0.198 | 0.33 | < 0.214 | < 0.276 | < 0.580 | < 0.448 |
| **Zinc** | 10.7 | 63.9 | 46.5 | 43.3 | 72.8 | 60.6 |
| **SEDIMENT CONVENTIONALS** | | | | | | |
| **SEM-AVS (mg/kg)** | 0.042 | 0.895 | 0.144 | 0.161 | 0.342 | * |
| **AVS (mg/kg)** | < 0.01 | 1.21 | 0.19 | 1.92 | 0.81 | 0.33 |
| **TOC** | 1040 | 21500 | 30900 | 20400 | 51700 | 39100 |
| **%Solids** | 79.13 | 74.07 | 80.06 | 68.14 | 47.93 | 62.38 |
| **% Clay** | 0 | 8.02 | 15.49 | 17.54 | 10.1 | 19.46 |
| **% Gravel** | 0 | 0 | 0 | 0 | 0 | 0 |
| **% Sand** | 99.21 | 73.54 | 59.08 | 69.71 | 63.28 | 37.27 |
| **% Silt** | 0.79 | 18.44 | 25.43 | 12.75 | 26.62 | 43.28 |
| **PESTICIDES (µg/kg)** | | | | | | |
| **DDD** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **DDE** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **DDT** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Aldrin** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Alpha BHC** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Beta BHC** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Delta BHC** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Dieldrin** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Endosulfan** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |

| PESTICIDES (µg/kg) | | | | | | |
|---|---|---|---|---|---|---|
| **Endosulfan II** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |

| SEDIMENT REPLICATE 4 | | | | | | |
|---|---|---|---|---|---|---|
| **Stations** | **1** | **2** | **3** | **4** | **5** | **6** |
| **Endosulfan Sulfate** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Edrin** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Endrin Aldehyde** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Endrin Ketone** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Gamma BHC** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Heptachlor** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Heptachlor Epoxide** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |
| **Methoxychlor** | < 2.5 | < 4.4 | < 3.0 | < 4.0 | < 3.5 | < 4.2 |

## APPENDIX C-SUMMARIZED WATER QUALITY DATA FROM PHASES I, II AND III OF THE RIO GRANDE TOXIC SUBSTANCE STUDY

| | Station 1 | | | Station 2 | | | Station 3 | | | Station 4 | | | Station 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Phase** | **I** | **II** | **III** | **I** | **II** | **III** | **I** | **II** | **III** | **I** | **II** | **III** | **I** | **II** | **III** |
| **Date** | 11/12/92 | 12/3/95 | 11/7/98 | 11/11/92 | 12/3/95 | 11/7/98 | 11/13/92 | 12/5/95 | 11/10/98 | 11/14/92 | 12/5/95 | 11/9/98 | 11/15/92 | 12/6/95 | 11/12/98 |
| **Time** | 900 | 830 | 1542 | 1000 | 1500 | 855 | 1000 | 910 | 945 | 900 | 1500 | 938 | 900 | 1040 | 1015 |
| **FIELD MEASUREMENTS** | | | | | | | | | | | | | | | |
| **Water Temperature (°C)** | 8.4 | 9.8 | 17.4 | 15.1 | 15.1 | 14.2 | 12.5 | 11.1 | 15.1 | 13.9 | 13.4 | 15 | 14.5 | 14.6 | 16.6 |
| **pH** | 8.6 | 8.1 | 8.4 | 7.7 | 8.4 | 7.9 | 8.4 | 8.6 | 8.3 | 8.2 | 8.2 | 8.2 | 8.4 | 8.5 | 8.4 |
| **Dissolved Oxygen** | 9.8 | 9.7 | 8.8 | 6.8 | 7.9 | 6.8 | 8.9 | 8.2 | 9.5 | 8.8 | 11.4 | 9.9 | 9.3 | 11 | 9.9 |
| **Conductivity (µmhos/cm)** | 1700 | 2500 | 1953 | 1760 | 2130 | 1857 | 2640 | 3020 | 2436 | 1620 | 3010 | 2336 | 1680 | 2940 | 2344 |
| **Flow (cfs)** | 185 | 176 | 225 | 186 | 144 | 206 | 278 | 283 | 332 | 798 | 295 | 398 | 722 | 329 | 392 |
| **CONVENTIONALS (mg/L)** | | | | | | | | | | | | | | | |
| **Ammonia Nitrogen** | 0.09 | 0.05 | 0.06 | < 0.02 | 1.1 | 0.94 | 0.19 | 0.07 | < 0.05 | < 0.02 | 0.09 | < 0.05 | < 0.02 | < 0.01 | < 0.05 |
| **Total Kjeldahl Nitrogen** | - | 0.8 | 0.49 | - | 1.9 | 1.91 | - | 1 | 1.18 | - | 0.61 | 0.97 | - | 1.1 | 1.16 |
| **Total Phosphorus** | - | 0.14 | 0.15 | - | 0.55 | 0.52 | - | 0.89 | 0.77 | - | 0.7 | 0.5 | - | 0.22 | 0.38 |
| **Orthophosphate** | - | 0.07 | 0.15 | - | 0.3 | 0.5 | - | 0.77 | 0.23 | - | 1 | 0.21 | - | 0.1 | < 0.06 |
| **Nitrate + Nitrite Nitrogen** | - | 1.16 | 1 | - | 2 | 2.1 | - | 3.7 | 1.64 | - | 3 | 1.25 | - | 1.1 | 1 |
| **Total Organic Carbon** | 5 | 5 | 5 | 6 | 7 | 6 | 11 | 6 | 9 | 7 | 6 | 7 | 8 | 7 | 10 |
| **Total Dissolved Solids** | 1200 | 1600 | 586 | 1240 | 1460 | 1150 | 1820 | 2045 | 1550 | 1120 | 2100 | 1630 | 1190 | 2010 | 1670 |
| **Chloride** | 202 | 346 | 222 | 238 | 297 | 222 | 500 | 559 | 411 | 227 | 523 | 366 | 237 | 527 | 360 |

## APPENDIX C-SUMMARIZED WATER QUALITY DATA FROM PHASES I, II AND III OF THE RIO GRANDE TOXIC SUBSTANCE STUDY

| | Station 1 | | | Station 2 | | | Station 3 | | | Station 4 | | | Station 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Phase** | **I** | **II** | **III** | **I** | **II** | **III** | **I** | **II** | **III** | **I** | **II** | **III** | **I** | **II** | **III** |
| **Sulfate** | 445 | 497 | 424 | 406 | 456 | 380 | 510 | 536 | 452 | 368 | 593 | 489 | 386 | 580 | 500 |
| **Total Suspended Solids** | 54 | 33 | 38 | 120 | 32 | 89 | 358 | 127 | 448 | 97 | 50 | 293 | 109 | 28 | 324 |
| **METALS (µg/L)** | | | | | | | | | | | | | | | |
| **Aluminum** | < 20 | 11.7 | 24.5 | < 20 | 4.8 | < 15.0 | < 20 | 5.4 | 16.4 | < 20 | 5.2 | 21.3 | < 20 | < 4.7 | 22.5 |
| **Arsenic** | 2.6 | 4.7 | 4.05 | 4.4 | 10.1 | 4.55 | 8.1 | 7.7 | 8.92 | 14.4 | 7.1 | 7.6 | 15.8 | 6.9 | 8.73 |
| **Cadmium** | < 0.10 | < 0.40 | < 5.0 | 0.21 | < 0.40 | < 5.0 | < 0.10 | < 0.40 | < 5.0 | < 0.10 | < 0.40 | < 5.0 | < 0.10 | < 0.40 | < 5.0 |
| **METALS (µg/L)** | | | | | | | | | | | | | | | |
| **Chromium** | < 3.6 | < 1.4 | < 5.0 | < 3.6 | < 1.4 | < 5.0 | < 3.6 | < 1.4 | < 5.0 | < 3.6 | < 1.4 | < 5.0 | < 3.6 | < 1.4 | < 5.0 |
| **Copper** | < 1.6 | 5.5 | < 3.0 | 4.2 | < 5.2 | < 3.0 | < 1.6 | < 5.2 | < 3.0 | 2.4 | < 5.2 | < 3.0 | < 1.6 | < 5.2 | < 3.0 |
| **Lead** | 1.1 | < 2.0 | 1.76 | < 1.0 | < 1.0 | 1.42 | 1.6 | < 2.0 | 1.9 | < 1.0 | < 2.0 | 2.81 | 1.8 | < 2.0 | 3 |
| **Mercury **** | < 0.13 | < 0.13 | 0.011 | < 0.13 | < 0.13 | < 0.010 | < 0.13 | < 0.13 | 0.015 | < 0.13 | < 0.13 | 0.011 | < 0.13 | < 0.13 | 0.02 |
| **Nickel** | < 4.7 | < 3.2 | < 10 | < 4.7 | < 3.2 | < 10 | 15.4 | < 3.2 | < 10 | 19.6 | < 3.2 | < 10 | 10.6 | < 3.2 | < 10 |
| **Selenium **** | < 2.4 | < 0.60 | < 1.11 | < 2.4 | 1.9 | < 1.11 | < 2.0 | 1.2 | < 5.5 | < 2.4 | 0.9 | < 1.11 | 3 | 1 | < 5.5 |
| **Silver** | < 1.0 | < 5.1 | < 0.25 | < 1.0 | < 5.1 | < 0.25 | < 1.0 | < 5.1 | < 0.25 | < 1.0 | < 5.1 | < 0.25 | < 1.0 | < 5.1 | < 0.25 |
| **Zinc** | < 5.0 | 2.9 | < 5.0 | 9.7 | 5.3 | 7.4 | 5.2 | 3.4 | < 5.0 | 14 | 2.5 | < 5.0 | 7.6 | 2.8 | < 5.0 |
| **Hardness-Dissolved** | 400 | 472 | 416 | 366 | 405 | 389 | 550 | 594 | 501 | 370 | 621 | 496 | 399 | 582 | 488 |
| **PESTICIDES (µg/L)** | | | | | | | | | | | | | | | |
| **DDD** | < 0.15 | < 0.15 | < 0.03 | < 0.15 | < 0.15 | < 0.03 | < 0.15 | < 0.15 | - | < 0.15 | < 0.15 | < 0.03 | < 0.15 | < 0.15 | - |
| **DDE** | < 0.10 | < 0.10 | < 0.03 | < 0.10 | < 0.10 | < 0.03 | < 0.10 | < 0.10 | - | < 0.10 | < 0.10 | < 0.03 | < 0.10 | < 0.10 | - |
| **DDT** | < 0.15 | < 0.15 | < 0.03 | < 0.15 | < 0.15 | < 0.03 | < 0.15 | < 0.15 | - | < 0.15 | < 0.15 | < 0.03 | < 0.15 | < 0.15 | - |
| **Aldrin** | < 0.20 | < 0.20 | < 0.03 | < 0.20 | < 0.20 | < 0.03 | < 0.20 | < 0.20 | - | < 0.20 | < 0.20 | < 0.03 | < 0.20 | < 0.20 | - |

**APPENDIX C-SUMMARIZED WATER QUALITY DATA FROM PHASES I, II AND III OF THE RIO GRANDE TOXIC SUBSTANCE STUDY**

| | Station 1 | | | Station 2 | | | Station 3 | | | Station 4 | | | Station 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Phase** | **I** | **II** | **III** | **I** | **II** | **III** | **I** | **II** | **III** | **I** | **II** | **III** | **I** | **II** | **III** |
| **Alpha BHC** | < 0.03 | < 0.04 | < 0.03 | < 0.03 | < 0.04 | < 0.03 | < 0.03 | < 0.03 | - | < 0.03 | < 0.03 | < 0.03 | < 0.03 | < 0.03 | - |
| **Beta BHC** | < 0.03 | < 0.04 | < 0.03 | < 0.03 | < 0.04 | < 0.03 | < 0.03 | < 0.03 | - | < 0.03 | < 0.03 | < 0.03 | < 0.03 | < 0.03 | - |
| **Delta BHC** | < 0.03 | < 0.04 | < 0.03 | < 0.03 | < 0.04 | < 0.03 | < 0.03 | < 0.03 | - | < 0.03 | < 0.03 | < 0.03 | < 0.30 | < 0.30 | - |
| **Dieldrin** | < 0.10 | < 0.10 | < 0.03 | < 0.10 | < 0.10 | < 0.03 | < 0.10 | < 0.10 | - | < 0.10 | < 0.10 | < 0.03 | < 0.10 | < 0.10 | - |
| **Endosulfan** | < 0.20 | < 0.20 | < 0.03 | < 0.20 | < 0.20 | < 0.03 | < 0.20 | < 0.20 | - | < 0.20 | < 0.20 | < 0.03 | < 0.20 | < 0.20 | - |
| **Endosulfan II** | < 0.20 | < 0.20 | < 0.03 | < 0.20 | < 0.20 | < 0.03 | < 0.20 | < 0.20 | - | < 0.20 | < 0.20 | < 0.03 | < 0.20 | < 0.20 | - |
| **Endosulfan Sulfate** | < 0.20 | < 0.20 | < 0.03 | < 0.20 | < 0.20 | < 0.03 | < 0.20 | < 0.20 | - | < 0.20 | < 0.20 | < 0.03 | < 0.20 | < 0.20 | - |
| **Endrin** | < 0.20 | < 0.20 | < 0.03 | < 0.20 | < 0.20 | < 0.03 | < 0.20 | < 0.20 | - | < 0.20 | < 0.20 | < 0.03 | < 0.20 | < 0.20 | - |
| **PESTICIDES (µg/L)** | | | | | | | | | | | | | | | |
| **Endrin Aldehyde** | < 0.20 | < 0.20 | < 0.03 | < 0.20 | < 0.20 | < 0.03 | < 0.20 | < 0.20 | - | < 0.20 | < 0.20 | < 0.03 | < 0.20 | < 0.20 | - |
| **Gamma BHC** | < 0.03 | < 0.04 | < 0.03 | < 0.03 | < 0.04 | < 0.03 | < 0.03 | < 0.04 | - | < 0.03 | < 0.04 | < 0.03 | < 0.03 | < 0.04 | - |
| **Heptachlor** | < 0.02 | < 0.02 | < 0.03 | < 0.02 | < 0.02 | < 0.03 | < 0.02 | < 0.02 | - | < 0.02 | < 0.02 | < 0.03 | < 0.02 | < 0.02 | - |
| **Heptachlor Epoxide** | < 0.06 | < 0.06 | < 0.03 | < 0.06 | < 0.06 | < 0.03 | < 0.06 | < 0.06 | - | < 0.06 | < 0.06 | < 0.03 | < 0.06 | < 0.06 | - |
| **Methoxychlor** | < 0.50 | < 0.50 | < 0.03 | < 0.50 | < 0.50 | < 0.03 | < 0.50 | < 0.50 | - | < 0.50 | < 0.50 | < 0.03 | < 0.50 | < 0.50 | - |

**** Phases I and II results are dissolved; Phase III results are total.**

## APPENDIX D- SUMMARIZED SEDIMENT QUALITY DATA FROM PHASES I, II AND III OF THE RIO GRANDE TOXIC SUBSTANCE STUDY

| | Station 1 | | | Station 2 | | | Station 3 | | | Station 4 | | | Station 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Phase** | **I** | **II** | **III** | **I** | **II** | **III** | **I** | **II** | **III** | **I** | **II** | **III** | **I** | **II** | **III** |
| **Date** | 11/12/92 | 12/3/95 | 11/7/98 | 11/11/92 | 12/3/95 | 11/7/98 | 11/13/92 | 12/5/95 | 11/10/98 | 11/14/92 | 12/5/95 | 11/9/98 | 11/15/92 | 12/6/95 | 11/12/98 |
| **CONVENTIONALS** | | | | | | | | | | | | | | | |
| **TOC (mg/kg)** | 2200 | 2700 | 2205 | 2780 | 5860 | 22590 | 4600 | 3880 | 30700 | 5400 | 3940 | 33700 | 6500 | 4440 | 47800 |
| **AVS (mg/kg)** | 51 | < 1.0 | 0.03 | 79 | < 1.0 | 1.1 | 83 | < 1 | 0.19 | 34 | < 1 | 1.9 | 91 | 66 | 0.55 |
| **Particle Size (% dry wt.)** | | | | | | | | | | | | | | | |
| **Clay ( < 0.0039 mm)** | 5 | 5 | 2 | 8 | 5 | 4.1 | 26 | 13 | 11.4 | 5 | 14 | 32.8 | 28 | 20 | 17.8 |
| **Silt (0.0039-0.0625 mm)** | 6 | 13 | 2.3 | 10 | 23 | 16.9 | 66 | 42 | 25.1 | 15 | 44 | 26.4 | 64 | 57 | 26.8 |
| **Sand (0.0625-2.0 mm)** | 90 | 82 | 95.7 | 82 | 72 | 79 | 8 | 45 | 63.5 | 80 | 41 | 40.8 | 8 | 23 | 55.4 |
| **Gravel (> 2.0 mm)** | < 1 | < 1 | 0 | < 1 | < 1 | 0 | < 1 | < 1 | 0 | < 1 | < 1 | 0 | < 1 | < 1 | 0 |
| **METALS (mg/kg)** | | | | | | | | | | | | | | | |
| **Aluminum** | 3560 | 5510 | | 5340 | 8250 | | 12000 | 11400 | | 5990 | 10500 | | 15100 | 13900 | |
| **Arsenic** | 1.73 | 1.9 | 1.1 | 2.54 | 4.7 | 4.2 | 7.93 | 7 | 7.2 | 4.47 | 7.2 | 8.9 | 8.74 | 4.9 | 7.3 |
| **Cadmium** | 0.1 | 0.13 | 0.025 | 0.35 | 0.37 | 0.73 | 0.37 | 0.14 | 0.23 | 0.26 | 0.69 | 0.27 | 0.37 | 0.28 | 0.36 |
| **Chromium** | 4.79 | < 0.42 | 5.6 | 5.32 | 0.68 | 12.9 | 9.64 | < 0.58 | 19.4 | 6.66 | < 0.65 | 24.1 | 10.4 | < 0.49 | 21.3 |
| **Copper** | 4.61 | 7.9 | 2.6 | 12.5 | 26.7 | 45.3 | 12 | 10.3 | 10.5 | 6.13 | 8.4 | 13.2 | 10.1 | 10.3 | 12.9 |
| **Lead** | 4.2 | 9.4 | 4.1 | 7.8 | 19.7 | 28.6 | 10.4 | 12.3 | 6.1 | 7.8 | 19 | 8.9 | 10.7 | 13.5 | 9.4 |
| **Mercury** | 0.02 | 0.02 | 0 | 0.06 | 0.03 | 0.025 | 0.02 | 0.03 | 0.009 | 0.05 | 0.03 | 0.02 | 0.04 | 0.03 | 0.029 |
| **Nickel** | 3.34 | 6 | 3.3 | 4.05 | 8.4 | 6.7 | 12.5 | 11.9 | 12.6 | 6.21 | 10.1 | 14.9 | 11.6 | 12 | 15 |
| **Selenium** | 0.7 | 0.11 | < 0.74 | 1.11 | 0.23 | 0.25 | 1.75 | 0.28 | < 1.5 | 1.47 | 0.21 | 0.51 | 2.28 | 0.37 | < 0.85 |
| **Silver** | < 0.08 | < 0.50 | < 0.22 | 0.61 | < 0.53 | 0.33 | < 0.07 | < 0.55 | < 0.23 | < 0.07 | < 0.51 | < 0.34 | < 0.08 | < 0.54 | < 0.51 |

**APPENDIX D- SUMMARIZED SEDIMENT QUALITY DATA FROM PHASES I, II AND III OF THE RIO GRANDE TOXIC SUBSTANCE STUDY**

| | Station 1 | | | Station 2 | | | Station 3 | | | Station 4 | | | Station 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Phase** | I | II | III | I | II | III | I | II | III | I | II | III | I | II | III |
| **Date** | 11/12/92 | 12/3/95 | 11/7/98 | 11/11/92 | 12/3/95 | 11/7/98 | 11/13/92 | 12/5/95 | 11/10/98 | 11/14/92 | 12/5/95 | 11/9/98 | 11/15/92 | 12/6/95 | 11/12/98 |
| **Zinc** | 15.3 | 23.7 | 14.3 | 33.2 | 44.7 | 55 | 48.3 | 43.6 | 46.8 | 43 | 68.2 | 65.4 | 50.4 | 51.6 | 66.5 |
| **PESTICIDES (µg/kg)** | | | | | | | | | | | | | | | |
| **DDD** | < 6.0 | < 5.3 | < 2.75 | < 6.0 | < 6.4 | < 4.0 | < 6.0 | < 54.6 | < 3.1 | < 6.0 | < 5.6 | < 5.8 | < 6.0 | < 6.3 | < 5.9 |
| **DDE** | < 3.0 | < 5.3 | < 2.75 | < 3.0 | 3.6 | < 4.0 | < 3.0 | < 21.8 | < 3.1 | < 3.0 | < 2.8 | < 5.8 | < 3.0 | < 3.1 | < 5.9 |
| **DDT** | < 6.0 | < 2.7 | < 2.75 | < 6.0 | < 6.4 | < 4.0 | < 6.0 | < 5.6 | < 3.1 | < 6.0 | < 5.6 | < 5.8 | < 6.0 | < 6.3 | < 5.9 |
| **Aldrin** | < 1.0 | < 1.1 | < 2.75 | < 1.0 | < 1.3 | < 4.0 | < 1.0 | < 1.1 | < 3.1 | < 1.0 | < 1.1 | < 5.8 | < 1.0 | < 1.3 | < 5.9 |
| **Alpha BHC** | < 1.0 | < 1.1 | < 2.75 | < 1.0 | 3 | < 4.0 | < 1.0 | < 1.1 | < 3.1 | < 1.0 | < 1.1 | < 5.8 | < 1.0 | < 1.1 | < 5.9 |
| **Beta BHC** | < 1.0 | < 1.1 | < 2.75 | < 1.0 | < 1.3 | < 4.0 | < 1.0 | < 1.1 | < 3.1 | < 1.0 | < 1.1 | < 5.8 | < 1.0 | < 1.3 | < 5.9 |
| **Delta BHC** | < 1.0 | < 1.1 | < 2.75 | < 1.0 | < 1.3 | < 4.0 | < 1.0 | < 1.1 | < 3.1 | < 1.0 | < 1.1 | < 5.8 | < 1.0 | < 1.3 | < 5.9 |
| **Dieldrin** | < 2.0 | < 3.2 | < 2.75 | < 2.0 | < 3.8 | < 4.0 | < 2.0 | < 3.4 | < 3.1 | < 2.0 | < 3.4 | < 5.8 | < 2.0 | < 3.8 | < 5.9 |
| **Endosulfan** | < 2.5 | < 2.7 | < 2.75 | < 2.5 | < 3.2 | < 4.0 | < 2.5 | < 2.8 | < 3.1 | < 2.5 | < 2.8 | < 5.8 | < 2.5 | < 3.1 | < 5.9 |
| **Endosulfan II** | < 2.5 | < 2.7 | < 2.75 | < 2.5 | < 3.2 | < 4.0 | < 2.5 | < 2.8 | < 3.1 | < 2.5 | < 2.8 | < 5.8 | < 2.5 | < 3.1 | < 5.9 |
| **Endosulfan Sulfate** | < 3.0 | < 5.3 | < 2.75 | < 3.0 | < 6.4 | < 4.0 | < 3.0 | < 5.6 | < 3.1 | < 3.0 | < 5.6 | < 5.8 | < 3.0 | < 6.3 | < 5.9 |
| **Endrin** | < 3.0 | < 3.2 | < 2.75 | < 3.0 | < 3.8 | < 4.0 | < 3.0 | < 3.4 | < 3.1 | < 3.0 | < 3.4 | < 5.8 | < 3.0 | < 3.8 | < 5.9 |
| **Endrin Aldehyde** | < 3.0 | ND | < 2.75 | < 3.0 | ND | < 4.0 | < 3.0 | < 2.3 | < 3.1 | < 3.0 | < 2.3 | < 5.8 | < 3.0 | < 2.5 | < 5.9 |
| **Gamma BHC** | < 1.0 | < 1.1 | < 2.75 | < 1.0 | < 1.3 | < 4.0 | < 1.0 | < 1.1 | < 3.1 | < 1.0 | < 1.1 | < 5.8 | < 1.0 | < 1.3 | < 5.9 |
| **Heptachlor** | < 0.5 | < 1.1 | < 2.75 | < 0.5 | < 1.3 | < 4.0 | < 0.5 | < 1.1 | < 3.1 | < 0.5 | < 1.1 | < 5.8 | < 0.5 | < 1.3 | < 5.9 |
| **Heptachlor Epoxide** | < 1.0 | < 2.1 | < 2.75 | < 1.0 | < 2.5 | < 4.0 | < 1.0 | < 2.3 | < 3.1 | < 1.0 | < 2.3 | < 5.8 | < 1.0 | < 2.5 | < 5.9 |
| **Methoxychlor** | < 10 | < 16 | < 2.75 | < 10 | < 19 | < 4.0 | < 10 | < 17 | < 3.1 | < 10 | < 17 | < 5.8 | < 10 | < 19 | < 5.9 |

**Phase III data is reported in this table as an average of four samples collected at each site.**

## APPENDIX E

Historical TNRCC Routine Monitoring Program Data for Conventional Parameters

**Rio Grande at Courchesne Bridge (Station 1)**

| Date | Chloride | Sulfate | TDS | $NH_3$-N | $NO_2$+$NO_3$ | O-P | T-P |
|---|---|---|---|---|---|---|---|
| 06/17/93 | 100 | 240 | | | | | |
| 09/16/93 | 97 | 220 | | | | | |
| 09/28/93 | 125 | 302 | 805 | 0.04 | 0.45 | 0.11 | 0.26 |
| 10/21/93 | 150 | 360 | | | | | |
| 11/09/93 | 174 | 408 | 1105 | 0.16 | 0.76 | 0.13 | 0.15 |
| 12/16/93 | 220 | 430 | | | | | |
| 01/21/94 | 160 | 310 | | | | | |
| 02/22/94 | 136 | 260 | 770 | 0.03 | 0.36 | 0.04 | 0.06 |
| 03/14/94 | 110 | 220 | | | | | |
| 03/15/94 | 93 | 244 | 580 | 0.04 | 0.35 | < 0.01 | 0.34 |
| 04/22/94 | 140 | 270 | | | | | |
| 05/10/94 | 119 | 280 | 748 | 0.04 | 0.32 | 0.03 | 0.17 |
| 05/26/94 | 110 | 240 | | | | | |
| 06/16/94 | 76 | 170 | | | | | |
| 08/18/94 | 86 | 200 | | | | | |
| 08/30/94 | 90 | 198 | 654 | 0.02 | 0.1 | 0.03 | 0.13 |
| 09/15/94 | 140 | 300 | | | | | |
| 09/26/94 | 128 | 290 | 820 | 0.04 | 0.3 | 0.02 | 0.16 |
| 11/08/94 | 256 | 404 | 1190 | 0.23 | 1.04 | 0.08 | 0.12 |
| 02/14/95 | 180 | 326 | 980 | 0.3 | 0.7 | 0.08 | 0.15 |
| 03/08/95 | 141 | 302 | 780 | 0.05 | 0.52 | 0.07 | 0.23 |
| 05/10/95 | 72 | 193 | 684 | 0.03 | 0.28 | 0.04 | 0.18 |
| 06/01/95 | 110 | 210 | | | | | |
| 06/22/95 | 80 | 180 | | | | | |
| 07/20/95 | 96 | 170 | | | | | |
| 08/16/95 | 132 | 81 | 1300 | 0.07 | 0.44 | 0.29 | 1.38 |
| 08/17/95 | 160 | 250 | | | | | |
| 09/19/95 | 179 | 311 | 1260 | 0.04 | 0.34 | 0.07 | 0.09 |
| 09/19/95 | 419 | 452 | 1890 | 0.73 | 1.08 | 0.58 | 0.64 |
| 09/21/95 | 190 | 300 | | | | | |
| 10/19/95 | 130 | 260 | | | | | |
| 11/15/95 | 230 | 421 | 1190 | 0.05 | 0.86 | 0.06 | 0.13 |
| 11/30/95 | 330 | 460 | | | | | |
| 12/14/95 | 360 | 500 | | | | | |
| 01/16/96 | 272 | 430 | 1170 | 0.03 | 1 | 0.04 | 0.18 |
| 01/18/96 | 190 | 280 | | | | | |
| 02/15/96 | 220 | 340 | | | | | |
| 03/13/96 | 122 | 189 | | | | | 0.27 |
| 03/21/96 | 92 | 180 | | | | | |
| 04/18/96 | 110 | 210 | | | | | |
| 05/08/96 | 115 | 212 | 1100 | < 0.01 | | | 0.19 |
| 05/16/96 | 150 | 270 | | | | | |
| 06/20/96 | 100 | 210 | | | | | |
| 07/18/96 | 120 | 210 | | | | | |
| 08/22/96 | 98 | 200 | | | | | |

| Rio Grande at Courchesne Bridge (Station 1)(cont) | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Date** | **Chloride** | **Sulfate** | **TDS** | **$NH_3$-N** | **$NO_2$+$NO_3$** | **O-P** | **T-P** |
| 08/26/96 | 100 | 225 | 688 | 0.02 | | | 0.23 |
| 09/23/96 | 138 | 308 | 844 | 0.02 | | | 0.38 |
| 09/26/96 | 140 | 290 | | | | | |
| 10/10/96 | 160 | 340 | | | | | |
| 10/17/96 | 210 | 400 | | | | | |
| 10/31/96 | 290 | 440 | | | | | |
| 11/20/96 | 610 | 580 | | | | | |
| 11/21/96 | 470 | 580 | | | | | |
| 12/11/96 | 397 | 594 | 2080 | 0.05 | 1.18 | 0.16 | 0.24 |
| 12/12/96 | 410 | 530 | | | | | |
| 12/16/96 | 370 | 500 | | | | | |
| 03/18/97 | 98 | 155 | 568 | 0.04 | | | 0.56 |
| 06/05/97 | 100 | 210 | 828 | < 0.05 | | | 0.21 |
| 02/19/98 | 144 | 231 | | | | | |
| 03/16/98 | 86 | 159 | 484 | < 0.05 | | | 0.51 |
| 06/17/98 | 87 | 188 | 680 | 0.06 | | | 0.19 |
| 10/08/98 | 115 | 250 | 768 | < 0.05 | | | 0.19 |
| 12/15/98 | 226 | 432 | 1140 | 0.08 | | | 0.25 |
| 02/03/99 | 132 | 189 | 636 | 0.06 | | | 0.34 |
| 04/22/99 | 121 | 241 | 808 | 6.9 | | | 0.26 |
| 06/29/99 | 91 | 197 | 672 | 0.06 | | | 0.32 |
| 10/07/99 | 160 | 211 | 608 | 0.03 | | | |
| 10/14/99 | 120 | 175 | 734 | 0.02 | | | |
| 10/21/99 | 175 | 440 | 982 | 0.11 | | | |
| 10/28/99 | 190 | 399 | 1054 | 0.19 | | | |
| 11/18/99 | 230 | 346 | 1105 | 0.14 | | | |
| | | | | | | | |
| Number of Samples | 71 | 71 | 34 | 34 | 17 | 17 | 30 |
| Mean | 173 | 297 | 933 | | | | |
| Criterion | 340 | 600 | 1800 | | | | |
| Screening Level | | | | 0.19 | 3.54 | 0.93 | 1.12 |
| # > Screening level | | | | 1 | 0 | 0 | 1 |
| % Exceeding Screening Level | | | | 2.9 | 0 | 0 | 3.3 |

| Historical TNRCC Routine Monitoring Program Data for Conventional Parameters<br>**Rio Grande at Zaragosa International Bridge (Station 2)** | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| **Date** | **Chloride** | **Sulfate** | **TDS** | **$NH_3$-N** | **$NO_2$+$NO_3$** | **O-P** | **T-P** |
| 06/08/93 | 95 | 223 | 616 | 0.48 | 0.44 | 1.84 | 1.91 |
| 06/21/93 | | | 664 | | | | |
| 07/20/93 | 95 | 180 | 568 | 0.58 | 0.49 | 0.2 | 0.63 |
| 08/24/93 | 309 | 219 | 694 | 0.54 | 0.75 | 0.25 | 0.58 |
| 09/28/93 | 134 | 270 | 797 | 1.04 | | | |
| 11/09/93 | 226 | 369 | 1176 | 1.53 | 0.87 | 0.41 | 0.82 |
| 11/30/93 | | | 122 | | 1.48 | 0.4 | 0.47 |
| 02/22/94 | 142 | 238 | 760 | 2.25 | 0.76 | 0.25 | 0.77 |
| 02/23/94 | | | 936 | | | | |
| 03/15/94 | 90 | 180 | 597 | 0.7 | 0.5 | < 0.01 | 0.48 |
| 05/11/94 | 123 | 199 | 724 | 0.48 | 0.84 | 0.05 | 0.27 |
| 06/06/94 | 85 | 186 | 1580 | 0.5 | 0.52 | 0.07 | 0.36 |
| 09/26/94 | 118 | 242 | 724 | 0.29 | 0.62 | 0.03 | 0.25 |
| 11/08/94 | 223 | 392 | 996 | 1.23 | 1.46 | 0.18 | 0.24 |
| 02/14/95 | 172 | 346 | 920 | 2.19 | 1.8 | 0.37 | 0.46 |
| 03/08/95 | 111 | 187 | 676 | 0.65 | 0.86 | 0.14 | 0.38 |
| 05/10/95 | 86 | 182 | 600 | 0.44 | 0.63 | 0.09 | 0.36 |
| 06/12/95 | 71 | 138 | 696 | 0.12 | 0.29 | 0.07 | 0.29 |
| 09/19/95 | 120 | 282 | 972 | 0.41 | 0.54 | 0.19 | |
| 11/28/95 | 282 | 439 | 1180 | 2.8 | 1.44 | 0.44 | 0.53 |
| 01/16/96 | 237 | 418 | 1100 | 1.38 | | | 0.61 |
| 03/13/96 | 138 | 280 | 664 | 0.32 | | | 0.37 |
| 05/08/96 | 90 | 175 | 731 | 0.21 | | | 0.31 |
| 06/25/96 | 88 | 184 | 604 | 0.27 | | | 0.31 |
| 09/23/96 | 184 | 308 | 912 | 0.36 | | | 0.53 |
| 01/23/97 | 288 | 452 | 1160 | 4.25 | | | 1.13 |
| 03/18/97 | 97 | 152 | 554 | 0.33 | | | 0.59 |
| 09/23/97 | 86 | 174 | 568 | 0.22 | | | 1.47 |
| 12/17/97 | 247 | 432 | 2920 | 2.99 | | | 0.59 |
| 05/12/98 | 126 | 191 | 820 | 6.39 | | | 1.03 |
| 11/12/98 | 244 | 408 | 1330 | 0.84 | | | 0.58 |
| 12/15/98 | 237 | 375 | 984 | 2.66 | | | 0.61 |
| 01/19/99 | 256 | 396 | 1120 | 3.49 | | | 1.13 |
| 03/03/99 | 136 | 168 | 849 | 4.38 | | | 0.98 |
| 06/29/99 | 85 | 174 | 714 | 0.31 | | | 0.37 |
| 10/07/99 | 140 | 164 | 688 | 0.17 | | | |
| 10/14/99 | 110 | 171 | 576 | 0.01 | | | |
| 10/21/99 | 180 | 327 | 1064 | 0.16 | | | |
| 10/28/99 | 200 | 368 | 898 | 0.07 | | | |
| 11/18/99 | 250 | 349 | 1028 | 0.10 | | | |
| | | | | | | | |
| Number of Samples | 37 | 37 | 40 | 37 | 17 | 17 | 31 |
| Mean | 159 | 269 | 882 | | | | |
| Criterion | 250 | 450 | 1400 | | | | |
| Screening Level | | | | 0.19 | 3.54 | 0.93 | 1.12 |
| # > Screening level | | | | 31 | 0 | 1 | 3 |
| % Exceeding Screening Level | | | | 84 | 0 | 5.9 | 9.7 |

| Historical TNRCC Routine Monitoring Program Data for Conventional Parameters<br>**Rio Grande at Neely Canyon, South of Fort Quitman** | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| **Date** | **Chloride** | **Sulfate** | **TDS** | **$NH_3$-N** | **$NO_2$+$NO_3$** | **O-P** | **T-P** |
| 07/21/93 | 412 | 433 | 1625 | 0.10 | 0.83 | 0.26 | 1.40 |
| 08/24/93 | 672 | 498 | 1618 | 0.05 | 1.14 | 0.22 | 0.80 |
| 09/08/93 | 443 | 440 | 1462 | | | | 0.73 |
| 09/29/93 | 493 | 611 | 1839 | 0.02 | 1.79 | 0.29 | 0.52 |
| 11/08/93 | 558 | 502 | 1924 | 1.28 | 2.25 | 0.78 | 1.79 |
| 12/07/93 | 601 | 1470 | 1995 | 1.59 | 1.20 | 1.17 | 1.48 |
| 03/14/94 | 1270 | 968 | 3670 | 0.13 | 0.73 | 0.08 | 0.27 |
| 05/24/94 | 799 | 681 | 2550 | 0.04 | 0.96 | 0.06 | 0.56 |
| 06/06/94 | 518 | 462 | 4410 | 0.05 | 0.97 | 0.18 | 0.68 |
| 09/26/94 | 401 | 466 | 1540 | 0.03 | 1.20 | 0.20 | 0.76 |
| 11/08/94 | 602 | 567 | 2000 | 1.31 | 2.08 | 0.70 | 0.91 |
| 12/19/94 | 571 | 428 | 1650 | 6.60 | 1.33 | 1.33 | 1.84 |
| 03/27/95 | 1320 | 598 | 3480 | 0.66 | 0.87 | 0.39 | 0.55 |
| 05/10/95 | 789 | 604 | 2620 | 0.37 | 1.10 | 0.14 | 0.47 |
| 06/12/95 | 246 | 250 | 892 | 0.04 | 0.56 | 0.14 | 0.16 |
| 11/28/95 | 607 | 512 | 2070 | 2.62 | 1.90 | 1.19 | 1.25 |
| 12/11/95 | 613 | 552 | 2600 | 3.30 | 1.49 | 1.18 | 1.36 |
| 03/13/96 | 769 | 600 | 2400 | 0.02 | 0.51 | 0.13 | 0.40 |
| 05/08/96 | 906 | 740 | 3000 | 0.02 | 0.37 | 0.09 | 0.54 |
| 06/25/96 | 1410 | 1150 | 4400 | 0.02 | 0.15 | 0.03 | 0.12 |
| 09/24/96 | 701 | 596 | 2980 | 0.06 | 0.97 | 0.35 | 0.53 |
| 01/23/97 | 950 | 752 | 2970 | 0.81 | 1.71 | 0.51 | 0.66 |
| 05/08/97 | 925 | 788 | 2700 | < 0.05 | 0.23 | 0.04 | 0.30 |
| 09/23/97 | 277 | 294 | 1100 | 0.25 | | | 2.01 |
| 12/17/97 | 546 | 474 | 2020 | 6.79 | 1.21 | 2.32 | 2.50 |
| 05/12/98 | 693 | 458 | 2310 | < 0.05 | 0.63 | 0.05 | < 0.01 |
| 08/04/98 | 658 | 588 | 2360 | < 0.05 | 0.93 | 0.11 | 0.63 |
| 09/09/98 | 677 | 627 | 2140 | < 0.05 | | | 0.24 |
| 01/19/99 | 653 | 631 | 1990 | 2.9 | | | 1.18 |
| 05/26/99 | 876 | 734 | 2930 | < 0.05 | | | 0.46 |
| 07/28/99 | 721 | 604 | 2360 | < 0.05 | | | 0.67 |
| | | | | | | | |
| Number of Samples | 31 | 31 | 31 | 30 | 25 | 25 | 31 |
| Mean | 699 | 615 | 2374 | | | | |
| Criterion | 300 | 550 | 1550 | | | | |
| Screening Level | | | | 0.19 | 3.54 | 0.93 | 1.12 |
| # > Screening level | | | | 12 | 0 | 5 | 9 |
| % Exceeding Screening Level | | | | 40 | 0 | 20 | 29 |

| Historical TNRCC Routine Monitoring Program Data for Conventional Parameters<br>**Rio Grande Upstream Rio Conchos Confluence near Presidio/Ojinaga (Station 3)** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Date** | **Chloride** | **Sulfate** | **TDS** | **$NH_3$-N** | **$NO_2$+$NO_3$** | **O-P** | **T-P** |
| 06/15/93 | 466 | 566 | 2002 | 0.03 | | | |
| 10/11/93 | 467 | 505 | 1664 | 0.02 | 0.15 | 0.03 | 0.24 |
| 12/28/93 | | | 1144 | | | | |
| 01/25/94 | 741 | 617 | 1760 | 0.05 | 0.68 | 0.18 | 0.32 |
| 02/23/94 | | | 2015 | | | | |
| 03/22/94 | | | 2008 | | | | |
| 04/27/94 | 729 | 668 | 2390 | 0.02 | | | 0.5 |
| 04/28/94 | | | 2346 | | | | |
| 05/24/94 | | | 1306 | | | | |
| 06/22/94 | | | 1482 | | | | |
| 07/11/94 | 192 | 456 | 988 | | 0.09 | 0.07 | |
| 08/24/94 | | | 1391 | | | | |
| 09/20/94 | | | 1625 | | | | |
| 10/10/94 | 467 | 543 | 1760 | 0.04 | 0.12 | 0.15 | 0.15 |
| 11/22/94 | | | 1262 | | | | |
| 12/21/94 | | | 1232 | | | | |
| 01/23/95 | 659 | 539 | 1990 | < 0.01 | 1.38 | 0.42 | 0.67 |
| 02/22/95 | | | 1224 | | | | |
| 03/27/95 | | | 1261 | | | | |
| 04/17/95 | 1170 | 800 | 3530 | < 0.01 | 0.07 | 0.06 | 0.26 |
| 07/17/95 | 323 | 312 | 1480 | 0.04 | 0.1 | 0.49 | 0.67 |
| 10/16/95 | 465 | 487 | 1650 | 0.04 | < 0.01 | 0.19 | |
| 02/26/96 | 634 | 473 | 2220 | 0.07 | 0.01 | 0.2 | 0.79 |
| 04/08/96 | 993 | 856 | 3220 | 0.01 | 0.01 | 0.1 | 0.26 |
| 07/29/96 | 482 | 370 | 1970 | 0.05 | 0.57 | 0.09 | 0.56 |
| 10/29/96 | 587 | 556 | 2530 | < 0.01 | 0.62 | 0.23 | 0.36 |
| 11/13/96 | 600 | 582 | 1980 | 1.72 | | | < 0.133 |
| 12/18/96 | 699 | 561 | 2320 | < 0.244 | | | |
| 02/25/97 | 769 | 660 | 2320 | < 0.01 | < 0.01 | 0.06 | 0.23 |
| 03/18/97 | 799 | 657 | 2410 | < 0.244 | | | |
| 04/15/97 | 1010 | 735 | 2530 | < 0.01 | < 0.01 | 0.08 | 0.33 |
| 05/27/97 | | | 2197 | | | | |
| 06/17/97 | 241 | 255 | 1200 | | | | |
| 07/14/97 | 291 | 483 | 1570 | < 0.05 | 0.26 | 0.12 | 1.68 |
| 08/25/97 | | | 1794 | | | | |
| 10/22/97 | 484 | 525 | 1920 | < 0.05 | 0.66 | 0.11 | 0.39 |
| 01/13/98 | 577 | 520 | 1819 | < 0.244 | | | |
| 02/23/98 | 574 | 524 | 1930 | < 0.05 | 0.59 | | 0.38 |
| 03/17/98 | 828 | 667 | 2373 | < 0.75 | | | |
| 04/27/98 | 640 | 748 | 2350 | < 0.05 | 0.02 | 0.3 | 0.51 |
| 05/19/98 | 635 | 663 | 2123 | < 0.275 | | | |
| 07/14/98 | 742 | 1020 | 2800 | < 0.05 | 0.02 | | 0.12 |
| 08/19/98 | 159 | 380 | 1051 | 0.275 | | | |
| 10/13/98 | 440 | 550 | 1830 | < 0.05 | | | 0.40 |
| 11/17/98 | 423 | 485 | 1781 | < 0.28 | | | |
| 12/15/98 | 401 | 474 | 1770 | < 0.28 | | | |
| 01/19/99 | 593 | 601 | 2052 | < 0.28 | | | |
| 02/18/99 | 561 | 499 | 1730 | < 0.05 | | | |

| Rio Grande Upstream Rio Conchos Confluence near Presidio/Ojinaga (Station 3) (cont) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| **Date** | **Chloride** | **Sulfate** | **TDS** | **$NH_3$-N** | **$NO_2+NO_3$** | **O-P** | **T-P** |
| 03/16/99 | 825 | 775 | 2721 | < 0.28 | | | |
| 04/27/99 | 516 | 710 | 2220 | < 0.05 | | | |
| 07/14/99 | 210 | 493 | 1400 | < 0.05 | | | 0.54 |
| 10/27/99 | 484 | 486 | 1800 | 0.10 | | | 0.30 |
| 11/16/99 | 549 | 549 | 1820 | 0.20 | | | 0.82 |
| | | | | | | | |
| Number of Samples | 39 | 39 | 53 | 37 | 19 | 17 | 23 |
| Mean | 575 | 573 | 1911 | | | | |
| Criterion | 300 | 550 | 1550 | | | | |
| Screening Level | | | | 0.19 | 3.54 | 0.93 | 1.12 |
| # > Screening level | | | | 3 | 0 | 0 | 1 |
| % Exceeding Screening Level | | | | 8.1 | 0 | 0 | 4.3 |

Historical TNRCC Routine Monitoring Program Data for Conventional Parameters

**Rio Grande Downstream Rio Conchos Confluence near Presidio/Ojinaga (Station 4)**

| Date | Chloride | Sulfate | TDS | $NH_3$-N | $NO_2+NO_3$ | O-P | T-P |
|---|---|---|---|---|---|---|---|
| 06/15/93 | 62 | 310 | 851 | < 0.01 | 0.75 | 0.03 | 0.2 |
| 08/10/93 | | | 910 | | | | |
| 10/11/93 | 183 | 396 | 1079 | 0.02 | 0.62 | 0.02 | 0.14 |
| 12/28/93 | | | 689 | | | | |
| 01/25/94 | 271 | 435 | 780 | 0.06 | 0.84 | 0.06 | 0.16 |
| 02/23/94 | | | 1339 | | | | |
| 03/22/94 | | | 1410 | | | | |
| 04/28/94 | 121 | 372 | 1040 | 0.05 | | | 0.17 |
| 05/24/94 | | | 903 | | | | |
| 06/22/94 | | | 1274 | | | | |
| 07/11/94 | 202 | 431 | 1118 | 0.01 | 0.43 | 0.04 | 0.37 |
| 08/24/94 | | | 1098 | | | | |
| 09/20/94 | | | 1073 | | | | |
| 10/10/94 | 326 | 542 | 1391 | 0.04 | 0.22 | 0.04 | 0.11 |
| 11/22/94 | | | 1098 | | | | |
| 12/21/94 | | | 1115 | | | | |
| 01/23/95 | 487 | 544 | 1780 | < 0.01 | 0.98 | 0.21 | |
| 02/22/95 | | | 1209 | | | | |
| 03/27/95 | | | 1240 | | | | |
| 04/17/95 | 622 | 754 | 2220 | < 0.01 | 0.19 | 0.04 | 0.19 |
| 07/17/95 | 345 | 421 | 1440 | 0.04 | 0.17 | 0.51 | |
| 10/16/95 | 444 | 524 | 1550 | 0.04 | 0.04 | 0.15 | 0.29 |
| 02/26/96 | 615 | 562 | 2250 | 0.06 | 0.14 | 0.16 | 0.29 |
| 04/08/96 | 880 | 880 | 3370 | < 0.01 | 0.02 | 0.12 | 0.26 |
| 07/29/96 | 364 | 495 | 1810 | 0.05 | 0.39 | 0.06 | 0.29 |
| 10/29/96 | 360 | 556 | 2080 | < 0.01 | 0.63 | 0.09 | 0.18 |
| 11/13/96 | 478 | 621 | 1900 | 0.314 | | | < 0.133 |
| 12/18/96 | 591 | 600 | 2200 | < 0.244 | | | |
| 02/25/97 | 583 | 691 | 1800 | < 0.01 | 0.1 | 0.06 | 0.2 |
| 03/18/97 | 591 | 694 | 2120 | 0.281 | | | |
| 04/15/97 | 567 | 756 | 2120 | < 0.01 | < 0.01 | 0.07 | 0.26 |
| 05/20/97 | 137 | 393 | 996 | < 0.244 | | | 0.313 |
| 06/17/97 | 122 | 329 | 860 | < 0.13 | | | < 0.13 |
| 07/14/97 | 176 | 440 | 1190 | < 0.05 | | | 0.34 |
| 08/25/97 | 431 | 570 | 1443 | | | | |
| 10/22/97 | 528 | 568 | 1930 | < 0.05 | 0.53 | 0.1 | 0.33 |
| 01/13/98 | 376 | 584 | 1750 | < 0.244 | | | |
| 02/23/98 | | | 1810 | | | 0.18 | |
| 03/17/98 | 514 | 710 | 1930 | < 0.275 | | | < 1.63 |
| 04/27/98 | 363 | 667 | 2040 | < 0.05 | 0.08 | 0.22 | 0.44 |
| 05/19/98 | 337 | 710 | 1833 | < 0.75 | | | |
| 08/19/98 | 38 | 344 | 784 | 0.275 | | | |
| 09/22/98 | 366 | 881 | 2093 | 0.275 | | | |
| 10/13/98 | 360 | 620 | 2090 | < 0.05 | | | |
| 11/12/98 | 366 | 489 | 1630 | | | | |
| 11/17/98 | 369 | 536 | 1724 | < 0.28 | | | |

| Rio Grande Downstream Rio Conchos Confluence near Presidio/Ojinaga (Station 4) (cont) | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Date** | **Chloride** | **Sulfate** | **TDS** | **$NH_3$-N** | **$NO_2$+$NO_3$** | **O-P** | **T-P** |
| 12/15/98 | 339 | 526 | 1770 | < 0.28 | | | |
| 01/19/99 | 495 | 659 | 1995 | < 0.28 | | | |
| **Date** | **Chloride** | **Sulfate** | **TDS** | **$NH_3$-N** | **$NO_2$+$NO_3$** | **O-P** | **T-P** |
| 02/18/99 | 511 | 607 | 1710 | < 0.05 | | | 0.30 |
| 03/16/99 | 515 | 827 | 2248 | < 0.28 | | | |
| 04/27/99 | 271 | 663 | 1600 | < 0.05 | | | 0.29 |
| 07/14/99 | 130 | 536 | 1510 | < 0.05 | | | 0.62 |
| 10/27/99 | 436 | 556 | 1810 | < 0.1 | | | 0.20 |
| 11/16/99 | 498 | 613 | 1870 | 0.30 | | | 0.60 |
| | | | | | | | |
| Number of Samples | 40 | 41 | 54 | 39 | 17 | 18 | 26 |
| Mean | 393 | 571 | 1572 | | | | |
| Criterion | 300 | 570 | 1550 | | | | |
| Screening Level | | | | 0.19 | 3.54 | 0.93 | 1.12 |
| # > Screening level | | | | 5 | 0 | 0 | 0 |
| % Exceeding Screening Level | | | | 13 | 0 | 0 | 0 |

Historical TNRCC Routine Monitoring Program Data for Conventional Parameters

**Rio Grande at Mouth of Santa Elena Canyon (Station 5)**

| Date | Chloride | Sulfate | TDS | $NH_3$-N | $NO_2$+$NO_3$ | O-P | T-P |
|---|---|---|---|---|---|---|---|
| 06/16/93 | 63 | 321 | 858 | 0.03 | 0.71 | 0.05 | 0.37 |
| 10/12/93 | 224 | 388 | 1079 | < 0.01 | 0.51 | 0.03 | 0.07 |
| 01/26/93 | 298 | 443 | 1070 | 0.02 | 0.78 | 0.01 | 0.15 |
| 04/28/94 | 128 | 342 | 1060 | 0.02 | | | 0.43 |
| 07/12/94 | 130 | 326 | 840 | 0.06 | 0.78 | 0.13 | 0.56 |
| 10/11/94 | 249 | 571 | 1380 | 0.02 | 0.1 | 0.1 | 0.21 |
| 01/24/95 | 412 | 553 | 1580 | < 0.01 | 0.67 | 0.19 | 0.33 |
| 04/18/95 | 460 | 804 | 1930 | < 0.01 | 0.03 | 0.06 | 0.08 |
| 07/18/95 | 372 | 402 | 1690 | 0.01 | 0.27 | 0.48 | |
| 10/17/95 | 433 | 600 | 1720 | 0.01 | 0.03 | 0.05 | 0.08 |
| 02/27/96 | 478 | 510 | 1740 | 0.02 | < 0.01 | 0.05 | 0.16 |
| 04/09/96 | 644 | 796 | 4590 | < 0.01 | 0.02 | 0.12 | 0.24 |
| 07/30/96 | 154 | 423 | 1270 | 0.05 | | | 0.11 |
| 10/30/96 | 373 | 586 | 2100 | 0.01 | 0.03 | 0.08 | 0.11 |
| 02/25/97 | 210 | 510 | 1140 | 0.03 | | | 0.32 |
| 04/15/97 | 605 | 811 | 2160 | < 0.01 | < 0.01 | 0.07 | 0.17 |
| 07/14/97 | 90 | 493 | 1090 | 0.05 | | | |
| 10/22/97 | 438 | 585 | 1930 | 0.24 | 0.02 | 0.12 | 0.18 |
| 02/23/98 | 520 | 568 | 1720 | < 0.05 | 0.01 | | |
| 07/14/98 | 9 | 125 | 348 | < 0.05 | | | 1.34 |
| 10/13/98 | 360 | 680 | 1920 | < 0.05 | | | 0.30 |
| 02/18/99 | 435 | 545 | 1580 | < 0.05 | | | 0.27 |
| 04/27/99 | 520 | 934 | 2610 | < 0.05 | | | 0.36 |
| 07/14/99 | 222 | 443 | 1250 | < 0.05 | | | 2.38 |
| 11/22/99 | 498 | 624 | 1880 | 0.10 | 1.0 | | 0.30 |
| | | | | | | | |
| Number of Samples | 24 | 25 | 25 | 25 | 16 | 14 | 22 |
| Mean | 333 | 535 | 1621 | | | | |
| Criterion | 300 | 570 | 1550 | | | | |
| Screening Level | | | | 0.19 | 3.54 | 0.93 | 1.12 |
| # > Screening level | | | | 1 | 0 | 0 | 2 |
| % Exceeding Screening Level | | | | 4 | 0 | 0 | 9.1 |

| Historical TNRCC Routine Monitoring Program Data for Conventional Parameters<br>**Rio Grande at FM 2627 (Gerstacker Bridge) Downstream of Big Bend (below Station 6)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Date** | **Chloride** | **Sulfate** | **TDS** | **$NH_3$-N** | **$NO_2$+$NO_3$** | **O-P** | **T-P** | **Chl *a*** |
| 07/28/93 | 84 | 289 | 741 | 0.03 | 0.48 | 0.08 | 0.76 | 33.5 |
| 10/12/93 | 155 | 354 | 953 | 0.02 | 0.43 | 0.04 | 0.17 | < 1.0 |
| 01/26/94 | 231 | 421 | 940 | 0.02 | 0.08 | 0.03 | 0.23 | 22.7 |
| 04/28/94 | 174 | 395 | 1200 | 0.04 | | | 0.4 | 77.7 |
| 07/12/94 | 207 | 428 | 1120 | 0.02 | < 0.11 | 0.02 | 0.76 | 22.4 |
| 10/11/94 | 231 | 537 | 1360 | 0.02 | 0.11 | 0.16 | 0.22 | 22.4 |
| 01/24/95 | 332 | 448 | 1380 | < 0.01 | 0.79 | 0.13 | 0.28 | 1.2 |
| 04/18/95 | 190 | 558 | 1340 | < 0.01 | 0.08 | 0.08 | 0.12 | 3.2 |
| 07/18/95 | 334 | 400 | 1900 | < 0.01 | 0.01 | 0.41 | | 3.66 |
| 10/17/95 | 405 | 540 | 1570 | 0.01 | < 0.01 | 0.09 | 0.09 | 9.52 |
| 02/27/96 | 378 | 441 | 1640 | 0.02 | < 0.01 | 0.04 | 0.11 | 8.86 |
| 04/09/96 | 350 | 549 | 1700 | < 0.01 | < 0.01 | 0.07 | 0.07 | < 1.0 |
| 07/30/96 | 142 | 485 | 1240 | 0.01 | | | 0.19 | < 1.0 |
| 10/30/96 | 270 | 496 | 1380 | < 0.01 | | | 0.08 | 10.2 |
| 02/25/97 | 219 | 360 | 1110 | < 0.01 | | | 0.49 | 9.8 |
| 04/15/97 | 465 | 658 | 1790 | < 0.01 | < 0.01 | < 0.01 | 0.15 | 2.94 |
| 07/14/97 | 89 | 330 | 720 | 0.06 | | | | 2.61 |
| 10/22/97 | 205 | 415 | 1160 | < 0.05 | | | 0.02 | 4.81 |
| 02/23/98 | 402 | 532 | 1580 | < 0.05 | 0.01 | | 0.05 | 30.4 |
| 04/27/98 | 291 | 637 | 1710 | < 0.05 | 0.02 | 0.12 | 0.25 | 8.9 |
| 07/14/98 | 93 | 365 | 880 | < 0.05 | | | 0.12 | 1.6 |
| 10/13/98 | 260 | 613 | 2060 | < 0.05 | | | 0.11 | < 1.0 |
| 02/18/99 | 395 | 573 | 1510 | < 0.05 | | | 0.27 | 2.1 |
| 04/27/99 | 92 | 360 | 892 | < 0.05 | | | 0.09 | 2.0 |
| 07/14/99 | 173 | 611 | 1540 | < 0.05 | | | 4.16 | < 1.0 |
| | | | | | | | | |
| Number of Samples | 25 | 25 | 25 | 25 | 14 | 13 | 23 | 25 |
| Mean | 247 | 472 | 1337 | | | | | |
| Criterion | 300 | 570 | 1550 | | | | | |
| Screening Level | | | | 0.19 | 3.54 | 0.93 | 1.12 | 16.1 |
| # > Screening Level | | | | 0 | 0 | 0 | 1 | 6 |
| % Exceeding Screening Level | | | | 0 | 0 | 0 | 4.3 | 24 |

Historical TNRCC Routine Monitoring Program Data for Conventional Parameters

**Rio Grande at Foster Ranch West of Langtry**

| Date | Chloride | Sulfate | TDS | $NH_3$-N | $NO_2$+$NO_3$ | O-P | T-P | Chl *a* |
|---|---|---|---|---|---|---|---|---|
| 08/17/93 | 120 | 330 | 852 | | | < 0.01 | < 0.01 | |
| 10/28/93 | 171 | 394 | 933 | 0.03 | 0.41 | 0.03 | 0.10 | 2.54 |
| 11/17/93 | 160 | 330 | 944 | | | < 0.01 | < 0.01 | |
| 01/19/94 | 190 | 350 | 1060 | | | | | |
| 03/02/94 | 176 | 352 | 1170 | 0.02 | 0.42 | < 0.01 | 0.08 | |
| 05/18/94 | 75 | 320 | 788 | | | < 0.01 | 0.16 | |
| 06/15/94 | 163 | 377 | 992 | 0.01 | 0.32 | 0.01 | 0.20 | 2.27 |
| 08/02/94 | 130 | 340 | 886 | | | < 0.01 | 0.15 | |
| 09/28/94 | 130 | 338 | 840 | 0.03 | | | 0.47 | 45.7 |
| 11/29/94 | 210 | 370 | 1080 | | | < 0.01 | 0.05 | |
| 12/07/94 | 201 | 322 | 1260 | 0.01 | 0.36 | < 0.01 | 0.12 | 6.84 |
| 02/07/95 | 200 | 310 | 986 | | | < 0.01 | < 0.01 | |
| 03/29/95 | 134 | 314 | 842 | 0.01 | 0.70 | 0.06 | 0.08 | < 1.0 |
| 05/24/95 | 35 | 110 | 318 | | | < 0.01 | 0.06 | |
| 06/06/95 | 88 | 218 | 564 | 0.11 | 0.71 | 0.03 | 0.08 | < 1.0 |
| 08/15/95 | 210 | 280 | 980 | | 0.02 | 0.07 | | |
| 09/20/95 | 22 | 310 | 604 | | | < 0.01 | 7.5 | |
| 10/11/95 | 322 | 487 | 1250 | 0.06 | 0.61 | 0.38 | | < 1.0 |
| 10/25/95 | 250 | 330 | 1120 | | | < 0.01 | 0.02 | |
| 01/24/96 | 283 | 369 | 1100 | 0.05 | | | 0.08 | 2.16 |
| 02/21/96 | 300 | 380 | 1190 | | | 0.001 | 0.09 | |
| 03/05/96 | 214 | 324 | 924 | 0.01 | | | 0.10 | 12.9 |
| 03/20/96 | 210 | 320 | 1000 | | | 0.001 | 0.05 | |
| 04/01/96 | 210 | 320 | 992 | | | 0.001 | 0.06 | |
| 04/16/96 | 160 | 280 | 834 | | | < 0.001 | 0.03 | |
| 05/01/96 | 160 | 290 | 882 | | | 0.001 | 0.04 | |
| 05/29/96 | 62 | 160 | 513 | | | 0.001 | 0.03 | |
| 06/26/96 | 39 | 153 | 564 | 0.03 | | | 0.33 | < 1.0 |
| 06/27/96 | 38 | 130 | 438 | | | 0.003 | 0.07 | |
| 07/30/96 | 63 | 250 | 626 | | | 0.001 | < 0.01 | |
| 08/15/96 | 190 | 350 | 940 | | | < 0.001 | 0.10 | |
| 08/20/96 | 27 | 120 | 398 | | | 0.008 | 1.2 | |
| 08/30/96 | 42 | 200 | 484 | | | < 0.001 | 0.12 | |
| 09/11/96 | 78 | 300 | 706 | | | 0.011 | 0.37 | |
| 10/10/96 | 291 | 456 | 1470 | 0.06 | 0.65 | 0.59 | 1.76 | < 1.0 |
| 12/18/96 | 240 | 380 | 1130 | | | < 0.001 | < 0.001 | |
| 01/29/97 | 250 | 380 | 1140 | | | | | |
| 03/11/97 | 120 | 300 | 804 | | | | | |
| 03/25/97 | 195 | 316 | 1030 | 0.01 | | | 0.07 | 11.8 |
| 04/01/97 | 133 | 294 | 815 | | | | | |
| 04/15/97 | 231 | 394 | 1151 | | | | | |
| 05/22/97 | 51 | 169 | 449 | | | | | |
| 05/28/97 | 46 | 323 | 683 | | | | | |
| 07/01/97 | 33 | 123 | 404 | | | | | |
| 07/16/97 | 49 | 286 | 660 | | | | | |
| 08/07/97 | 65 | 271 | 788 | | | | | |

| Rio Grande at Foster Ranch West of Langtry (contd) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Date** | **Chloride** | **Sulfate** | **TDS** | **$NH_3$-N** | **$NO_2$+$NO_3$** | **O-P** | **T-P** | **Chl *a*** |
| 09/10/97 | 109 | 246 | 719 | | | | | |
| 11/19/97 | 230 | 335 | 1058 | | | | | |
| 01/28/98 | 229 | 338 | | | | | | |
| 03/04/98 | 256 | 344 | 1070 | 0.01 | | | | |
| 03/11/98 | 222 | 314 | 998 | | | | | |
| 04/29/98 | 140 | 281 | 820 | | | | | |
| 05/27/98 | 55 | 129 | 458 | | | | | |
| 06/23/98 | 58 | 167 | 526 | | | | | |
| 07/29/98 | 46 | 208 | 555 | | | | | |
| 08/21/98 | 145 | 393 | 998 | | | | | |
| 09/01/98 | 48 | 199 | 541 | | | | | |
| | | | | | | | | |
| Number of Samples | 57 | 57 | 56 | 14 | 9 | 31 | 34 | 12 |
| Mean | 146 | 294 | 845 | | | | | |
| Criterion | 300 | 570 | 1550 | | | | | |
| Screening Level | | | | 0.19 | 3.54 | 0.93 | 1.12 | 16.1 |
| # > Screening Level | | | | 0 | 0 | 0 | 3 | 1 |
| % Exceeding Screening Level | | | | 0 | 0 | 0 | 9 | 8 |

## DISSOLVED METALS

| Historical TNRCC Routine Monitoring Program Data for Metals<br>**Rio Grande at Courchesne Bridge (Station 1)**<br>**DISSOLVED METALS** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Date** | **Ar** | **Cd** | **Cr** | **Cu** | **Pb** | **Ni** | **Ag** | **Zn** |
| 09/28/93 | 5.5 | < 0.10 | < 3.6 | 3 | < 4.0 | < 5.0 | < 0.5 | < 5.0 |
| 11/30/93 | 8.74 | < 4.0 | < 2.0 | < 1.0 | < 1.0 | < 10 | < 0.5 | < 3.0 |
| 02/23/94 | 4.37 | < 4.0 | < 2.0 | < 1.0 | < 1.0 | < 10 | < 0.5 | 59 |
| 05/10/94 | 3.51 | < 4.0 | < 2.0 | < 1.0 | < 1.0 | < 10 | < 0.5 | 62 |
| 11/08/94 | 5.65 | < 4.0 | < 3.0 | < 4.0 | < 1.0 | < 9.0 | < 0.5 | < 3.0 |
| 02/14/95 | 6.79 | < 4.0 | < 3.0 | < 4.0 | < 1.0 | < 9.0 | < 0.5 | 38 |
| 03/08/95 | 4.42 | < 4.0 | < 3.0 | < 4.0 | < 1.0 | < 9.0 | < 0.5 | 66 |
| 05/10/95 | 3.45 | < 4.0 | < 3.0 | < 4.0 | < 1.0 | < 9.0 | < 0.5 | 26 |
| 08/16/95 | 4.99 | < 4.0 | < 3.0 | < 4.0 | < 1.0 | < 9.0 | < 0.5 | 25 |
| 11/15/95 | 6.82 | < 4.0 | < 3.0 | < 4.0 | < 1.0 | < 9.0 | 0.85 | < 3.0 |
| 01/16/96 | < 2.0 | 6 | < 3.0 | < 4.0 | < 1.0 | < 9.0 | < 0.5 | < 3.0 |
| 03/13/96 | 4.57 | < 4.0 | < 3.0 | < 4.0 | < 1.0 | < 9.0 | < 0.5 | < 3.0 |
| 05/08/96 | 5.77 | < 4.0 | < 3.0 | < 4.0 | < 1.0 | < 9.0 | < 0.5 | < 3.0 |
| 08/26/96 | 5.29 | < 4.0 | < 3.0 | < 4.0 | < 1.0 | < 9.0 | < 0.5 | < 3.0 |
| 12/11/96 | 5.99 | < 4.0 | < 3.0 | < 4.0 | < 1.0 | < 9.0 | < 0.5 | < 3.0 |
| 03/18/97 | 5.13 | < 5.0 | < 3.0 | < 3.0 | < 1.0 | < 11.0 | < 10 | < 4.0 |
| | | | | | | | | |
| Number of Samples | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |
| Mean | 5.1 | | | | | | | |

| Historical TNRCC Routine Monitoring Program Data for Metals<br>**Rio Grande at Zaragosa Bridge (Station 2)**<br>**DISSOLVED METALS** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Date** | **Ar** | **Cd** | **Cr** | **Cu** | **Pb** | **Ni** | **Ag** | **Zn** |
| 6/21/93 | 5.0 | < 0.1 | < 3.6 | < 1.6 | < 1.0 | < 5.0 | < 10 | 9.9 |
| 07/20/93 | 6.9 | < 0.1 | < 3.6 | 2.6 | < 1.0 | 7.4 | < 10 | 11.4 |
| 09/28/93 | < 4.0 | < 4.0 | 5.1 | 4.9 | < 1.0 | < 5.0 | < 0.05 | < 5.0 |
| 11/30/93 | 10.11 | < 4.0 | < 2.0 | < 1.0 | < 1.0 | < 10 | < 0.05 | < 3.0 |
| 02/23/94 | 4.37 | < 4.0 | < 2.0 | < 1.0 | < 1.0 | < 10 | < 0.05 | 62 |
| 05/11/94 | 2.14 | < 4.0 | < 2.0 | 3 | < 1.0 | < 10 | < 0.05 | 64 |
| 06/06/94 | < 2.0 | < 4.0 | 9 | 9 | < 1.0 | < 10 | < 0.05 | 85 |
| 11/08/94 | 6.45 | < 4.0 | < 3.0 | < 4.0 | < 1.0 | < 9.0 | < 0.05 | < 3.0 |
| 02/14/95 | 10.1 | < 4.0 | < 3.0 | 5 | < 1.0 | < 9.0 | < 0.05 | 34 |
| 03/08/95 | 2.99 | < 4.0 | < 3.0 | < 4.0 | < 1.0 | < 9.0 | < 0.05 | 55 |
| 05/10/95 | 2.13 | < 4.0 | < 3.0 | < 4.0 | < 1.0 | < 9.0 | < 0.05 | 28 |
| 06/12/95 | 4.22 | < 4.0 | < 3.0 | < 4.0 | < 1.0 | < 9.0 | < 0.05 | 31 |
| 11/28/95 | 7.51 | < 4.0 | < 3.0 | < 4.0 | < 1.0 | < 9.0 | < 0.05 | < 3.0 |
| 01/16/96 | < 2.0 | < 4.0 | < 3.0 | < 4.0 | < 1.0 | 11 | < 0.05 | < 3.0 |
| 03/13/96 | 3.82 | < 4.0 | < 3.0 | < 4.0 | < 1.0 | < 9.0 | < 0.05 | < 3.0 |
| 06/25/96 | 2.99 | < 4.0 | < 3.0 | < 4.0 | < 1.0 | < 9.0 | < 0.05 | < 3.0 |
| 03/18/97 | 4.5 | < 5.0 | < 3.0 | < 3.0 | < 1.0 | < 11 | < 0.05 | < 4.0 |
| | | | | | | | | |
| Number of Samples | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 |
| Mean | 4.5 | | | | | | | |

| Historical TNRCC Routine Monitoring Program Data for Metals<br>**Rio Grande at Below Rio Conchos Confluence near Presidio/Ojinaga (Station 4)**<br>**DISSOLVED METALS** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Date** | **Ar** | **Cd** | **Cr** | **Cu** | **Pb** | **Ni** | **Ag** | **Zn** |
| 08/10/93 | 24.1 | < 0.10 | < 3.6 | 4 | < 1.0 | < 5.0 | < 10 | 7.3 |
| 10/11/93 | 21 | < 1.6 | < 1.0 | 5.9 | < 4.0 | 1.7 | | < 12 |
| 01/25/94 | 26.89 | < 4.0 | < 2.0 | < 1.0 | < 1.0 | < 10 | < 0.5 | 107 |
| 04/28/94 | 33.4 | < 4.0 | 3 | < 1.0 | < 1.0 | < 10 | < 0.5 | 73 |
| 07/11/94 | 15.4 | < 4.0 | < 3.0 | 13 | < 1.0 | < 9.0 | < 0.5 | 53 |
| 10/10/94 | 23.8 | < 4.0 | 4 | < 4.0 | < 1.0 | < 9.0 | < 0.5 | < 3.0 |
| 01/23/95 | 6.79 | < 4.0 | < 3.0 | 5 | < 1.0 | < 9.0 | < 0.5 | 27 |
| 04/17/95 | 6.95 | < 4.0 | < 3.0 | < 4.0 | < 1.0 | < 9.0 | < 0.5 | 31 |
| 07/17/95 | 7.16 | < 4.0 | < 3.0 | < 4.0 | < 1.0 | < 9.0 | < 0.5 | 35 |
| 10/16/95 | 5.35 | < 4.0 | < 3.0 | 6 | < 1.0 | < 9.0 | < 0.5 | < 3.0 |
| 02/26/96 | 10 | < 4.0 | < 3.0 | < 4.0 | < 1.0 | < 9.0 | < 0.5 | 22 |
| 04/08/96 | < 33 | < 4.0 | < 3.0 | < 4.0 | < 1.0 | < 9.0 | < 0.5 | < 3.0 |
| 07/29/96 | 7.89 | < 4.0 | < 3.0 | < 4.0 | < 1.0 | < 9.0 | < 0.5 | < 3.0 |
| 07/14/97 | 4.22 | < 5.0 | < 3.0 | < 3.0 | < 1.0 | < 11.0 | < 0.5 | < 4.0 |
| | | | | | | | | |
| Number of Samples | 14 | 14 | 14 | 14 | 14 | 14 | 13 | 14 |
| Mean | 15 | | | | | | | |

## APPENDIX F
## QUALITY ASSURANCE MEASURES

The study was conducted in accordance with a quality assurance project plan (QAPP) approved by USEPA Region 6 (TNRCC 1998). The QAPP describes the quality assurance procedures in detail. The following is an evaluation of specific data quality measures.

### Field Blanks

Field blanks were analyzed at a frequency of 100% which equaled one blank for each metals in water sample collected. Blanks were made up of type 2 deionized water provided by the TNRCC laboratory in Houston. Containers of type 2 deionized water were carried to the field, and handled by the same protocols used for ambient water samples. Blanks were analyzed for conventional parameters, dissolved metals and pesticides.

The results are included in the following table:

**FIELD BLANK DATA SUMMARY**

| Stations | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Date | 11/07/98 | 11/07/98 | 11/10/98 | 11/09/98 | 11/12/98 | 11/11/98 |
| Time | 1630 | 1130 | 1015 | 1005 | 1130 | 1330 |
| **CONVENTIONAL PARAMETERS (mg/L)** | | | | | | |
| Ammonia Nitrogen | < 0.05 | < 0.05 | < 5.0 | < 0.05 | < 0.05 | < 0.05 |
| Total Kjeldahl Nitrogen | < 0.10 | < 0.10 | < 0.10 | < 0.10 | < 0.05 | < 0.05 |
| Total Phosphorus | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| Orthophosphate | < 0.06 | < 0.06 | < 0.06 | < 0.06 | < 0.06 | < 0.06 |
| Nitrate + Nitrite Nitrogen | < 1.0 | < 0.10 | 0.35 | < 0.10 | < 0.10 | < 0.10 |
| Chlorophyll *a* | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 |
| Pheophytin *a* | < 1.0 | 3.63 | < 1.0 | < 1.0 | < 1.0 | < 1.0 |
| Total Organic Carbon | < 1.0 | <1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 |
| Alkalinity, Total | < 5.0 | < 5.0 | < 5.0 | < 5.0 | 2 | 2 |
| Total Dissolved Solids | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 |
| Chloride | 1 | 1 | 1 | 1 | < 1.0 | < 1.0 |
| Sulfate | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 |
| Total Suspended Solids | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 |
| Volatile Suspended Solids | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 |
| **METALS (µg/L)** | | | | | | |
| Aluminum | < 15 | < 15 | < 15 | < 15 | < 15 | < 15 |
| Arsenic | < 0.05 | < 0.5 | < 0.5 | < 0.50 | < 0.50 | < 0.50 |
| Cadmium | < 5.0 | < 5.0 | < 5.0 | < 5.0 | < 5.0 | < 5.0 |
| Chromium | < 5.0 | < 5.0 | < 5.0 | < 5.0 | < 5.0 | < 5.0 |
| Copper | < 3.0 | < 3.0 | < 3.0 | < 3.0 | < 3.0 | < 3.0 |
| Lead | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 | < 1.0 |
| Mercury ** | < 0.010 | < 0.010 | < 0.010 | < 0.010 | < 0.010 | < 0.010 |
| Nickel | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 |
| Selenium ** | 1.18 | 1.17 | < 5.5 | < 5.5 | < 5.5 | < 5.5 |
| Silver | < 0.25 | < 0.25 | < 0.25 | < 0.25 | < 0.25 | < 0.25 |
| Zinc | < 5.0 | < 5.0 | < 5.0 | < 5.0 | < 5.0 | < 5.0 |

**FIELD BLANK DATA SUMMARY**

| Stations | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| **METALS (µg/L)** | | | | | | |
| Calcium-Dissolved | 0.103 | 0.0272 | 0.0285 | <0.020 | 0.0218 | 0.02 |
| Magnesium-Dissolved | 0.0185 | < 0.01 | 0.0155 | < 0.010 | < 0.010 | < 0.010 |
| Hardness-Dissolved | 0.333 | < 0.08 | 0.135 | < 0.08 | 0.081 | < 0.08 |
| **PESTICIDES (µg/L)** | | | | | | |
| DDD | < 0.030 | < 0.030 | * | * | * | * |
| DDE | < 0.030 | < 0.030 | * | * | * | * |
| DDT | < 0.030 | < 0.030 | * | * | * | * |
| Aldrin | < 0.030 | < 0.030 | * | * | * | * |
| Alpha BHC | < 0.030 | < 0.030 | * | * | * | * |
| Beta BHC | < 0.030 | < 0.030 | * | * | * | * |
| Delta BHC | < 0.030 | < 0.030 | * | * | * | * |
| Dieldrin | < 0.030 | < 0.030 | * | * | * | * |
| Endosulfan | < 0.030 | < 0.030 | * | * | * | * |
| Endosulfan II | < 0.030 | < 0.030 | * | * | * | * |
| Endosulfan Sulfate | < 0.030 | < 0.030 | * | * | * | * |
| Endrin | < 0.030 | < 0.030 | * | * | * | * |
| Endrin Aldehyde | < 0.030 | < 0.030 | * | * | * | * |
| Endrin Ketone | < 0.030 | < 0.030 | * | * | * | * |
| Gamma BHC | < 0.030 | < 0.030 | * | * | * | * |
| Heptachlor | < 0.030 | < 0.030 | * | * | * | * |
| Heptachlor Epoxide | < 0.030 | < 0.030 | * | * | * | * |
| Methoxychlor | < 0.030 | < 0.030 | * | * | * | * |

* *Total *Not analyzed

Pesticides were not detected in two of the blanks, the other three blanks were not analyzed due to lab error. However, there were no detects in any of the ambient water samples analyzed for pesticides.

Only one metal, total selenium, was detected in the blanks associated with Stations 1 and 2 (El Paso/Ciudad Juarez). The value, 1.2 µg/L in both blanks, was less than the detection limit of 5.5 µg/L.

Possible sources of metals in the blanks include (1) pre-contamination of the type 2 deionized water furnished by the laboratory; (2) laboratory contamination during analysis; (3) leaching of metals from tubing, in-line filters, or from sample containers walls; (4) contamination from gloves of sample collectors; (5) atmospheric contamination; and/or (6) pre-contamination of the samples bottles pre-preserved by the supplier with metals grade nitric acid.

## Precision

Data precision was evaluated using analytical data from duplicate water and sediment samples. Duplicated water samples were analyzed at a frequency of 100% which equaled one duplicate per station. Duplicate sediment samples were analyzed at a frequency of 100% which equaled one duplicate per station. In addition, three sediment replicate samples were collected at each station. Duplicates were collected, handled and preserved using standard procedures. Duplicates were analyzed for metals, volatile/semi-volatile organics and pesticides. Field duplicate water samples were collected as grab samples, and sediment duplicates were collected from a single composite. This would cause the sediment duplicates to have less variability than the water duplicates. The precision was acceptable for the purposes of this study.

Six metals were the only parameters in water that occurred above detection limits. Coefficients of variation for duplicate samples generally exceeded the target levels. However, the precision target levels were meant for laboratory duplicates and not the field duplicates used in this study. Since field duplicates are expected to have more variability, the coefficients of variation tend to be higher than the target values.

### Analytical Data-Duplicate Water Samples Summary

| Parameter ② | Duplicates | | Mean | Standard Deviation | Coefficient of Variation (%) ③ | Target Coefficient of Variation ④ |
|---|---|---|---|---|---|---|
| | 1 | 2 | | | | |
| **El Paso/Ciudad Juárez (Station 1)** | | | | | | |
| Aluminum | 24.5 | < 15.0 ① | 19.75 | 4.75 | 24.3 | ± 6.0 |
| Arsenic | 4.05 | 4.44 | 4.25 | 0.195 | 4.6 | ± 11.2 |
| Lead | 1.76 | 1.25 | 1.51 | 0.255 | 16.9 | ± 5.8 |
| Selenium | < 1.11 ① | 1.7 | 1.41 | 0.295 | 20.9 | ± 6.8 |
| **El Paso/Ciudad Juárez (Station 2)** | | | | | | |
| Arsenic | 4.55 | 5.08 | 4.775 | 0.225 | 4.7 | ± 11.2 |
| Lead | 1.42 | < 1.0 ① | 1.21 | 0.21 | 17.3 | ± 5.8 |
| Selenium | < 1.11 ① | 1.32 | 1.215 | 0.105 | 8.6 | ± 6.8 |
| Zinc | 7.4 | 6.5 | 6.95 | 0.45 | 6.5 | ± 3.3 |
| **Presidio/Ojinaga (Station 3)** | | | | | | |
| Aluminum | 16.4 | 26.8 | 21.6 | 5.2 | 24.1 | ± 6.0 |
| Arsenic | 8.92 | 9.09 | 9.005 | 0.085 | 0.94 | ± 11.2 |
| Lead | 1.9 | < 1.0 ① | 1.45 | 0.45 | 31 | ± 5.8 |
| Mercury | 0.015 | 0.014 | 0.0145 | 0.0005 | 3.4 | ± 10 |
| **Presidio/Ojinaga (Station 4)** | | | | | | |
| Aluminum | 21.3 | 15.3 | 18.3 | 3.0 | 16.7 | ± 6.0 |
| Arsenic | 7.59 | 7.83 | 7.71 | 0.12 | 1.6 | ± 11.2 |
| Lead | 2.81 | < 1.0 ① | 1.905 | 0.905 | 47.5 | ± 5.8 |
| Mercury | 0.011 | < 0.010 | 0.0105 | 0.0005 | 4.8 | ± 10 |
| **Big Bend National Park (Station 5)** | | | | | | |
| Aluminum | 22.5 | < 15.0 ① | 18.75 | 3.75 | 20 | ± 6.0 |
| Arsenic | 8.73 | 8.99 | 8.86 | 0.13 | 1.47 | ± 11.2 |
| Lead | 3.0 | < 1.0 ① | 2.0 | 1.0 | 50 | ± 5.8 |
| Mercury | 0.02 | 0.015 | 0.0175 | 0.0025 | 14.5 | ± 10 |

| Parameter ② | Duplicates | | Mean | Standard Deviation | Coefficient of Variation (%) ③ | Target Coefficient of Variation ④ |
|---|---|---|---|---|---|---|
| | 1 | 2 | | | | |
| **Big Bend National Park (Station 6)** | | | | | | |
| Arsenic | 5.21 | 5.04 | 5.125 | 0.085 | 1.66 | ± 11.2 |
| **Big Bend National Park (Station 6) cont** | | | | | | |
| Mercury | < 0.010 ① | 0.017 | 0.0135 | 0.0035 | 25.9 | ± 10 |
| Zinc | 5.61 | < 5.0 ① | 5.305 | 0.305 | 5.7 | ± 3.3 |

① Detection limit used in calculation
② Only parameters that occurred above the detection limit are included in the table
③ Calculated as standard deviation/mean x 100
④ Target coefficients of variation are the precision limits of laboratory duplicates in the SWQM QAPP.

## Accuracy

Laboratory blanks, spikes and quality control samples were analyzed according to USEPA requirements for accredited laboratories as described in the QAPP. Results of the laboratory quality control samples were not reported by the laboratory, but any problems were noted on the analytical results sent by the laboratory.

## Data Completeness

A target of 90% completeness was established in the QAPP. As shown in the following table, the target level was achieved, with a margin of +3.7%.

**Data Completeness Summary**

| | WATER | | SEDIMENT | | TISSUE ① | | BENTHICS | | NEKTON | |
|---|---|---|---|---|---|---|---|---|---|---|
| | P | A | P | A | P | A | P | A | P | A |
| (A) # of Stations | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| (B) # of Samples | 6 | 6 | 18 | 18 | 12 | 11 | 6 | 6 | 6 | 6 |
| (C) # of Parameters | 51 | 51 | 39 | 39 | 8 | 8 | 1 | 1 | 1 | 1 |
| (D) # Data Points | 306 | 252 | 702 | 702 | 96 | 80② | 6 | 6 | 6 | 6 |
| (E) Total # of data points planned = 1116 | | | | | | | | | | |
| (F) Total # of data points achieved = 1046 | | | | | | | | | | |
| OVERALL COMPLETENESS = (F)/(E) x 100 = 93.7 % | | | | | | | | | | |
| P= planned; A= achieved | | | | | | | | | | |

① Includes only whole and edible fish tissue samples. Trophic level tissue samples were not included in this analysis since it was unknown if enough of anyone species would be found to attain the required weight required for analysis.

②Number of data points does not include pesticides in tissue. Samples sent to the EPA lab in Cincinnati were lost in shipment. The analysis of tissue for organics was added on after the data collection.

## Comparability

Data comparability was maintained through the use of standard field and laboratory techniques described in the QAPP. Analytical methods were obtained from USEPA approved lists published in the *Federal Register*. Procedures were used consistently throughout the study with a few exceptions where conditions required slight modifications. Any modifications are described in the Methods Section. None of the modifications affected data comparability between stations. The procedures used in Phase 3 are the same as those used in both Phases 1 and 2, making data from both studies comparable.

## Representativeness

Station locations, collection of multi-media samples (water, sediment, fish tissue and biological) and approved field and laboratory methods were used to ensure that data was a representation of actual stream conditions. Data from Phases 1and 2 identified areas with highest probability of contamination. This information was used to select appropriate sample sites for Phase 3.