

**Angostura Irrigation District
Contract Renewals**

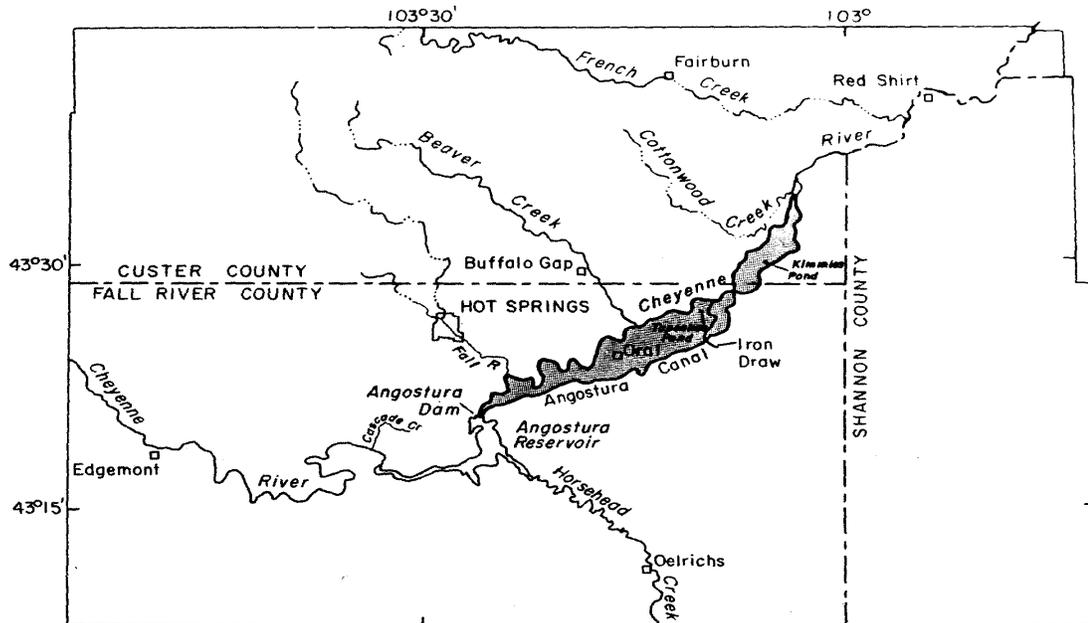
South Dakota

**Water Quality and Sediment in the
Cheyenne River Basin in Relation to the
Angostura Contract Renewals**

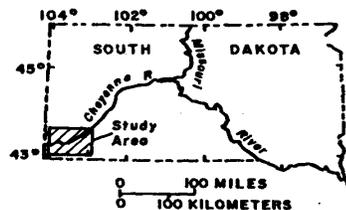
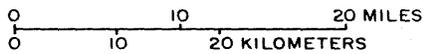
March 1999

**United States Department of the Interior
Bureau of Reclamation**





Base from U.S. Geological Survey
1:500,000, 1963



LOCATION MAP

EXPLANATION

 APPROXIMATE BOUNDARY OF
ANGOSTURA RECLAMATION
UNIT LANDS

Frontispiece: Angostura Irrigation District Contract Renewals Primary Study Area
(adapted from Greene et al., 1991)

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Introduction

The purpose of this report is to discuss the water quality of the Cheyenne River from an historical perspective and as it relates to the renewal of the Angostura Irrigation District (AID) water service contract. The study area will encompass the Cheyenne River basin from upstream from Angostura Reservoir to its mouth at Lake Oahe on the Missouri River. The first section will relate to the water quality of Angostura Reservoir based on historic data from the Environmental Protection Agency's (EPA) STORET data base. Data from the same source will be used to report on a basin-wide salt budget and to discuss water quality on the basis of total dissolved solids (TDS).

There are several water quality studies that have a bearing on the Angostura Water Contracting environmental statement process. In 1988, the National Irrigation Water Quality Program (NIWQP) of the Department of the Interior (DOI) conducted a study of the Angostura Unit and its effects on the water quality of the Cheyenne River and its biota (Greene *et al.*, 1990). The NIWQP collected 1 to 4 seasonal water samples at 9 sites during 1988 along with one set of sediment samples at the same sites between October 31 and November 2, 1988. In 1994, the NIWQP did a follow-up or verification study on the water quality aspects of the 1988 study; this study has not yet been published but the data are available from the EPA STORET data base. The laboratory results for the set of sediment samples collected during the study have been provided for use in this study (Joyce E. Williamson, personal communication, March 17, 1999). The data from these 2 studies are to be used to characterize the existing status of water quality and sediment within the Angostura Unit.

The Oglala Sioux Tribe (OST) has also been concerned about the water quality of the Cheyenne River. The OST has monitored the water quality of the Cheyenne River in the vicinity of Red Shirt Village since 1993. The data have been published in Hoof (1998). The OST has provided their monitoring data for use in the Angostura Unit EIS. The OST monitoring data will be used to supplement the NIWQP data.

The OST also collected one sediment sample from the Cheyenne River near Red Shirt during October 1996 (McGlaughlin, Personal Communication, July 2, 1997). These samples were analyzed at the Bureau of Reclamation's Soil and Water Laboratory in Bismarck, North Dakota. This sample was collected from the same site as one of the NIWQP samples and will be used to evaluate sediment at that site as it may have changed over an 8-year interval.

The Cheyenne River Sioux Tribe (CRST) has also been concerned about the water quality of the Cheyenne and Moreau rivers; only the Cheyenne River is a concern to the Angostura Unit contract renewals. The CRST sponsored a study of water quality trends in the Cheyenne and Moreau rivers by the USGS (Heakin, 1998). Water quality and fish were sampled during July and August 1997 (Plateau, 1997). These data have

also been provided to Reclamation. Under the sponsorship of the EPA, the CRST has also undertaken a sediment monitoring project in the Cheyenne and Moreau rivers (CRST, 1997); the contaminants data from that project have also been provided to Reclamation for use in the EIS preparation. All of the sediment data will be presented in a separate report.

Reclamation sampled water and sediment in the Cheyenne River and Angostura Reservoir during 1997. The Reclamation samples included sites on the river from upstream of Angostura reservoir to the Cheyenne River Indian Reservation. The data from all of the above sources will be integrated into a data set and will be used to characterize the water quality of the Cheyenne River as a baseline for the Angostura contract renewals.

Angostura Reservoir

Angostura Reservoir was surveyed in 1974 by EPA's National Eutrophication Survey (NES), by the USGS in 1988, and by the State in 1978 and again in 1989-95. All of the data show similar conditions in the reservoir, *i.e.* elevated nitrogen, phosphorus, and chlorophyll, indicative of eutrophication; dissolved oxygen depression, but not complete depletion, in late summer at depth; and relatively saline water, EC > 2000 $\mu\text{mho}/\text{cm}$.

NES profiles for Angostura Reservoir are shown in Figure 1. The profiles were measured at the deepest station in the reservoir, which was located near the dam. There were three other sites where profiles were measured, but the deeper ones are representative of the conditions of most importance to evaluating water quality.

The reservoir was relatively well-mixed (showed little or no difference in temperature with depth) during April 1974 and dissolved oxygen (D.O.) was near saturation throughout the water column. By July thermal stratification (due density differences as the surface warms) was strongly established at depths between 30 and 40 feet. There was a large drop-off in D.O. coincident with the drop-off in temperature (the layer of rapid temperature change is the thermocline, which also exhibits coincident density differences that restricts exchange with the atmosphere [*i.e.* reaeration]). The bottom D.O. was 2 mg/L. The September profiles show a nearly fully-mixed temperature profile, although there is lingering depression in D.O. The temperature difference from surface to bottom is less than 1°C, but most of the change (0.4°C) occurred in the 5-foot depth interval between 15 and 20 feet. The coincident density difference was apparently sufficient to limit, but not completely eliminate, reaeration.

The South Dakota Department of Environment and Natural Resources (DENR) has sampled Angostura Reservoir each year since 1989, with the exception of 1990. The available data include temperature and D.O. profiles, Secchi depths, a measure of

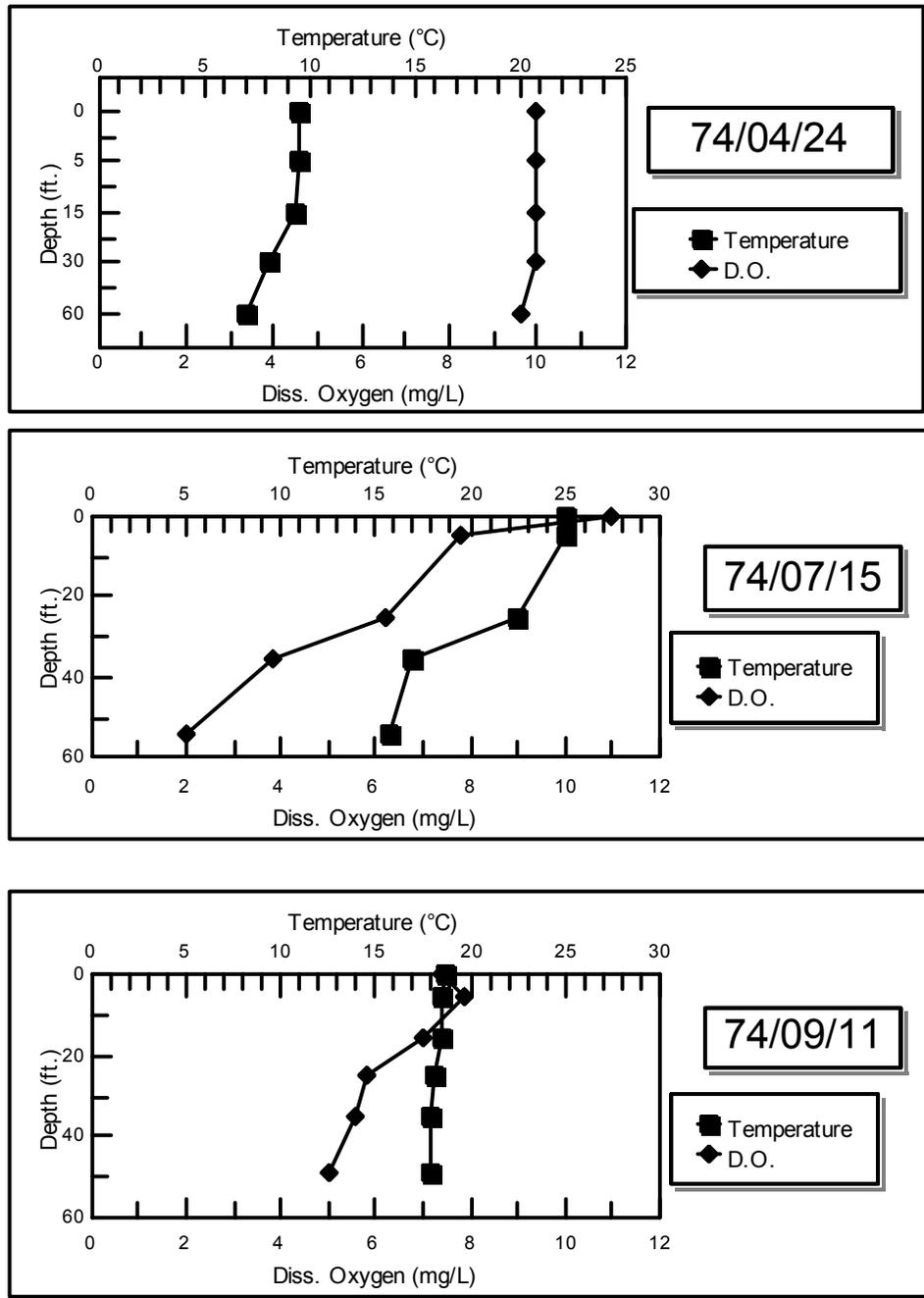


Figure 1: NES Temperature and D.O. profiles measured during 1974

water clarity, and surface and bottom samples of nutrient (nitrogen and phosphorus) species and total suspended solids. Surface and bottom temperature and D.O. measurements are shown on Figure 2. The DENR has published the complete set of water clarity, and surface and bottom samples of nutrient (nitrogen and phosphorus)

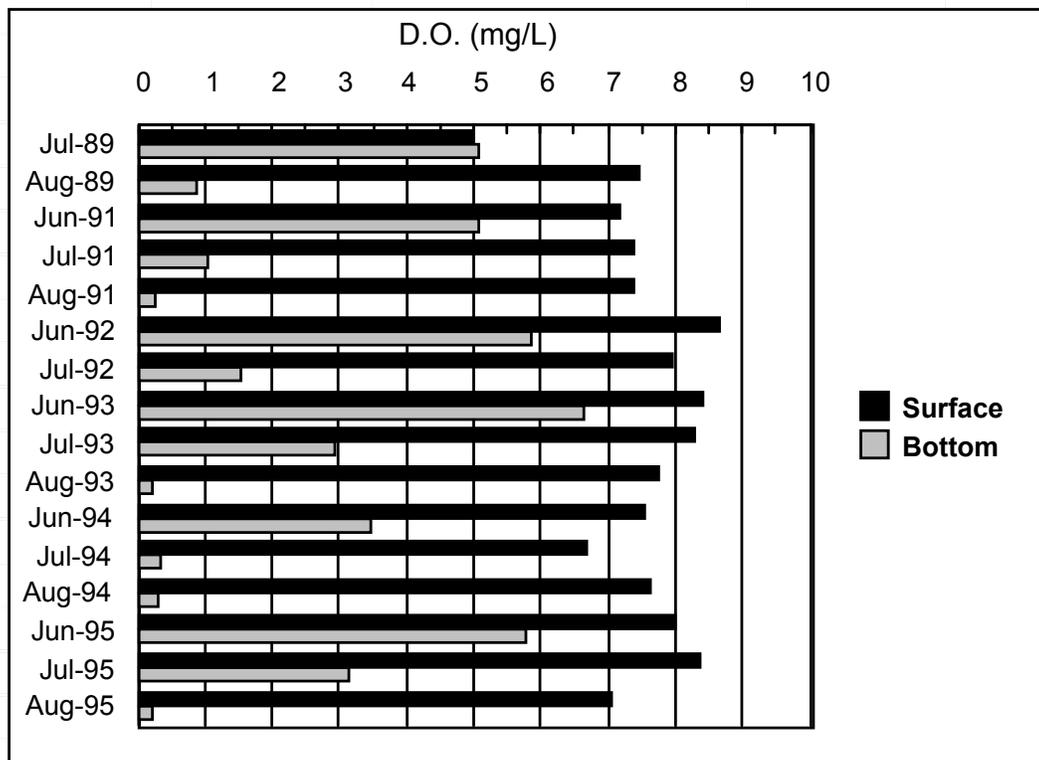
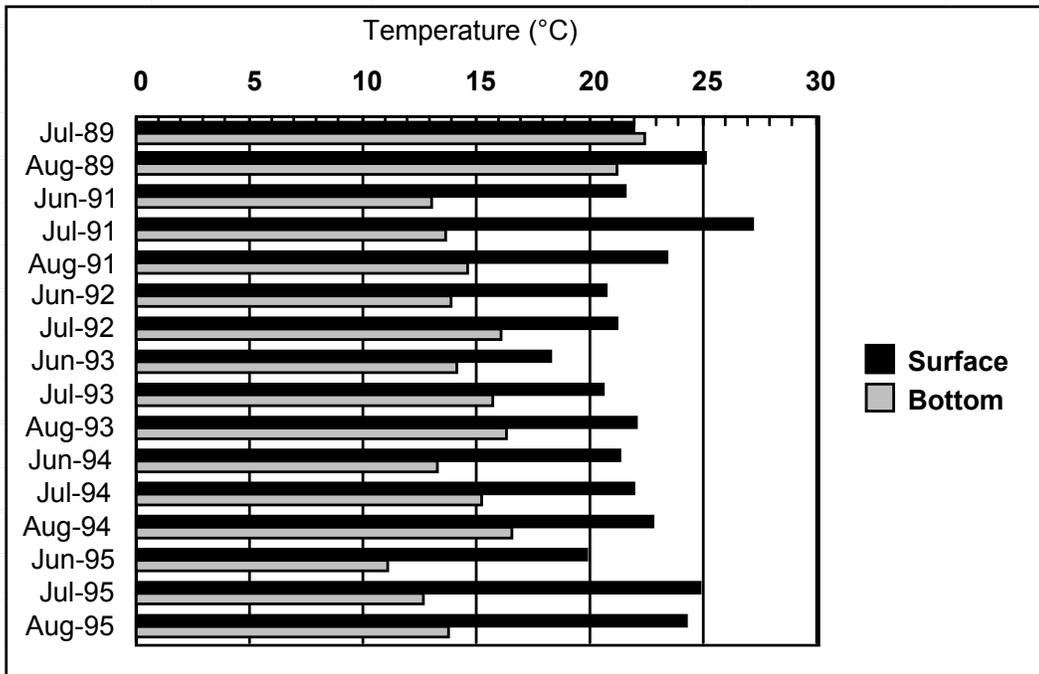


Figure 2: Surface and bottom temperature and D.O. measurements during the summer months of 1989 through 1995 by the South Dakota Department of Environment and Natural Resources

species and total suspended solids. Surface and bottom temperature and D.O. measurements are shown on Figure 2. The DENR has published the complete set of temperature and D.O. profiles measured during 1991 through 1995 (Stueven and Stewart, 1996). Unlike in other years, the July 1989 temperature profile indicates that temperature and D.O. profiles measured during 1991 through 1995 (Stueven and Stewart, 1996). Unlike in other years, the July 1989 temperature profile indicates that the temperature profile was isothermal from top to bottom through the water column. In the other years, the profiles measured in July show stratification to be at its maximum strength. This generalization includes 1974 (Figure 1). Alternatively the minimum bottom D.O. has been observed during August of each of the sampled years (Figure 2). Each of the August D.O. measurements shows less than 1 mg/L of D.O. The years when the D.O. does not fall below 1 mg/L include only 1974 and 1992, in which years there were no August measurements. A further set of temperature and D.O. profiles made in August 1979 indicate relatively strong stratification and D.O. less than 1 mg/L at the bottom of the profile. The data indicate that the reservoir tends to be stratified during most years during the months of June through August with fall overturn (the breakdown of thermal stratification) occurring during early to mid-September.

The DENR (1996) evaluates lakes and reservoirs in the State based on Carlson's trophic state index (TSI - Carlson, 1977). The most recent DENR (1996) evaluation categorized Angostura Reservoir as mesotrophic with a degrading trend in water quality. The major pollution sources for the reservoir are categorized as natural. However, a trend line in the Clean Lakes report, which is based on the TSI's for the last 10 years, indicates a trend toward oligotrophy or improving water quality, at least from the perspective of trophic status.

Basin-wide Total Dissolved Solids (TDS)

One of the simplest and most meaningful measures of water quality is electrical conductivity (EC). The majority of EC data used in this report are measurements made by the USGS and are corrected to 25°C. The measurement is actually called specific conductance. Reclamation uses the less specific term, electrical conductivity and the abbreviation, EC, for all measures. As used in this report, EC has been corrected to 25°C in all measurements, including the ones made by Reclamation. The parameter retrieved from STORET was number 95, Conductivity at 25°C.

EC is a measure of the amount of electricity that water will conduct, which is proportional to the concentration of electrolytes (ions) dissolved in the water. There is a linear relationship between EC and TDS. Hem (1985) indicates that EC can be converted to TDS using the formula:

$$KA=S$$

where K is specific conductance in $\mu\text{mho}/\text{cm}$, S is TDS in mg/L , and A is the slope of a regression line. A usually has a value between 0.55 and 0.75 (*ibid.*); a typical value is 0.64 (McCutcheon *et al.*, 1993).

TDS is also a relatively good measure of the effects of irrigation on water quality. Irrigation water is consumed by evaporation and by plants (crops) through transpiration. In both processes the majority of the salts in the irrigation water are left behind. To successfully maintain productivity, the salts must be moved through the soil profile. The salts therefore become concentrated in irrigation return flows. The effects of irrigation can be measured by increases in TDS downstream from an irrigated area.

Table 1. Total Annual Flow and Salt (TDS) Loads in the Cheyenne Basin during 1979 and 1980

A. Flow [acre-feet]

Site Name	Mainstem		Tributaries	
	1979	1980	1979	1980
Cheyenne at Edgemont	61,100	32,800		
Cheyenne at Dam	20,000	17,900		
Fall River			16,000	15,400
Beaver Creek			5,700	4,300
Cheyenne at Buffalo Gap	66,368	55,171		
Rapid Creek			33,300	28,500
Cheyenne at Wasta	168,500	96,500		
Belle Fourche River			160,200	79,000
Cheyenne at Plainview	322,700	174,000		
Cheyenne at Cherry Creek	350,400	184,000		

B. Salt Load [tons]

Site Name	Mainstem		Tributaries	
	1979	1980	1979	1980
Cheyenne at Edgemont	134,420	119,850		
Cheyenne at Dam	44,380	45,870		
Fall River			21,160	21,690
Beaver Creek			15,550	12,030
Cheyenne at Buffalo Gap	170,850	160,280		
Rapid Creek			27,440	24,380
Cheyenne at Wasta	292,190	196,450		
Belle Fourche River			319,400	193,830
Cheyenne at Plainview	588,520	358,080		
Cheyenne at Cherry Cr.	731,980	428,260		

A salt budget was developed for the Cheyenne River basin in the study area. The budget was based on data for 1979 and 1980. These two years have the most complete geographic data available for the study area. After 1980, the gage on the Cheyenne River near Buffalo Gap, which was the only mainstem Cheyenne River gage within the AID, was discontinued. It should be noted that the gage was located 5.8 miles upstream from the mouth of Cottonwood Creek and near the downstream end of the AID. After 1980, the nearest downstream gage would be the one near Wasta, which is located downstream from Rapid Creek, which greatly influences the water quality of the river.

The annual water and salt budgets for the available monitoring sites during 1979 and 1980 are summarized in Table 1. There is a net gain in flow in both years between the Edgemont gage and the Buffalo Gap gage during both years (Table 1.A.). The increase in flow is small in the wetter year, 1979, and amounts to a little over 5,000 acre feet. This is less than the flow of the reach tributaries, the Fall River and Beaver Creek. This should reflect, at least in part, the depletion due to Project irrigation. In 1980, which is the drier year, there is a much larger gain between the Edgemont gage and the Buffalo Gap gage; the flow at the downstream gage is nearly twice that of the upstream gage. The gain between the two river gages is much greater than the inflow from the reach tributaries. The large gain during the drier year may reflect withdrawals from carry-over storage in the reservoir or discharge from ground water, either from seepage or due to return flows from pumping for irrigation.

Table 1.B. shows the salt loads associated with the flows. The salt load in the drier year (1980) is only slightly smaller than in the wetter year at most gage sites. This is well illustrated in figure 3, which shows the salt (TDS) loads at each of the gages during 1979 and 1980. The only gage that shows a decrease in the load is the gage below Angostura Dam. The decrease reflects the water diverted into the Angostura Canal. The return flows from the diverted water along with any gains from ground water would be included in the difference between the 3 inflows, *i.e.* the flow at the dam, Fall River and Beaver Creek, and the flow at the Buffalo Gap gage. The same would be true of the salt loads. These values are shown in Table 2. The gain in flow is smaller in the drier year than in the wetter year, but the salt gain is also smaller. The flow and the salt load can be used to calculate a TDS concentration in the return flows. These are also shown in Table 2. These calculated TDS concentrations represent a normalized concentration that is not subject to the hydrologic effects due to seasonality of flow. The normalized calculated TDS also represents an integrated TDS from all sources between the 2 Cheyenne River gages, less the

Table 2: Seepage gains between Angostura Dam and the USGS Gage near Buffalo Gap

	1979	1980
Flow [Ac. Ft.]	24,468	17,608
Salt Load [tons]	89,760	80,690
TDS [mg/L]	2,700	3,370

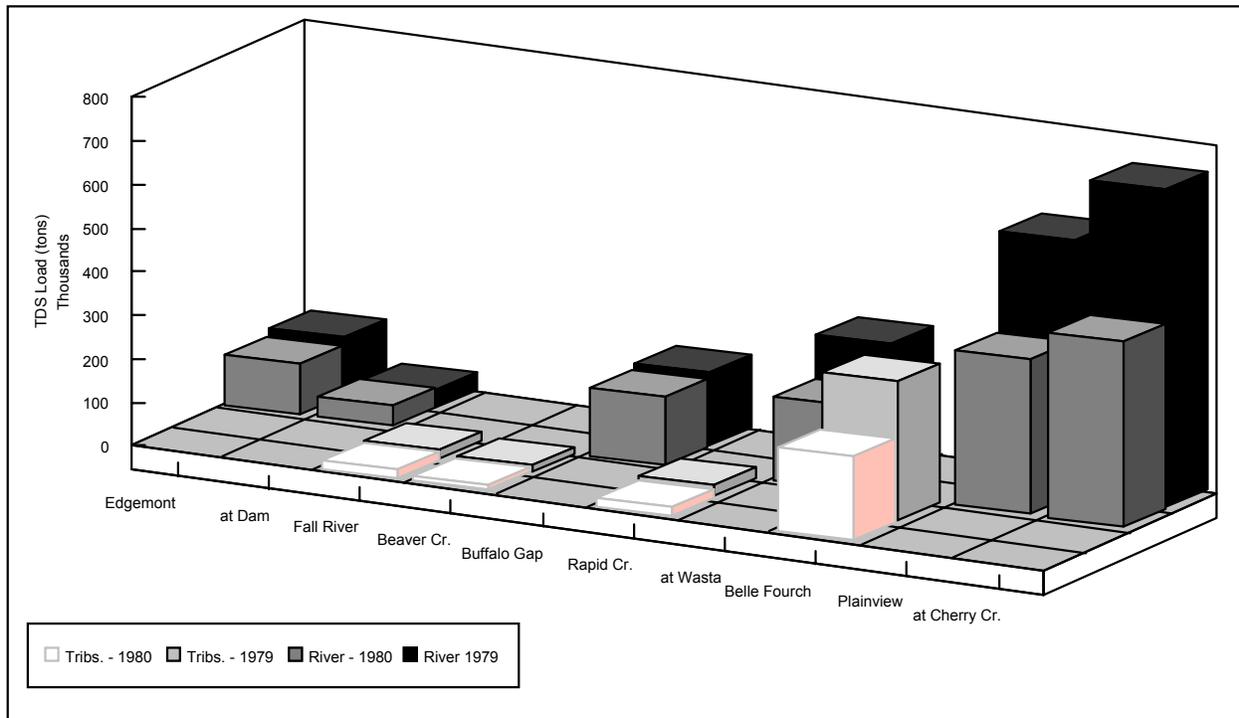


Figure 3: Salt Loads in the Cheyenne Basin during 1979 and 1980

TDS of the Fall River and Beaver Creek. At a minimum these sources include native ground water seepage and surface and subsurface return flows from the AID. None of the sources can be individually isolated based on the available data.

The seasonality that affects both flow and TDS creates a skewed data set. Because of the skew in the data, the arithmetic mean may not be a representative statistic. For this reason a geometric mean is usually used to represent the data. Although the geometric mean is somewhat normalized, it frequently maintains some skew. The geometric means and the flow-weighted mean as used in Table 2 are shown in Table 3 for each of the gages. The nearer the two values, the less skew there is in the data.

The Edgemont gage is located upstream from Angostura Reservoir. The flow above the gage is not controlled and the seasonality in flow and TDS is at its maximum. The flow-weighted mean and the geometric mean TDS differ by at least several hundred mg/L at Edgemont (Table 3). Alternatively at the gage below Angostura Dam, the difference is closer to 100 mg/L in each of the years. The reservoir itself will serve as a mechanism to flow-weight the TDS. The flows that accrue over several months will be mixed in the reservoir. The highest flows have the lowest TDS and will constitute the majority of each year's storage. As a consequence, the flow-weighted mean is an arithmetic approximation of what is physically occurring in the reservoir.

The Fall River is also an uncontrolled stream. However, the flow-weighted means and the geometric means for both 1979 and 1980 are virtually identical (Table 3). While there are no significant artificial controls on the Fall River, the flow is mostly composed of ground water. Because of this there is very little seasonality. The flow in the river is nearly constant year round. The TDS is likewise relatively constant. This will be discussed in more detail later in this report.

Table 3 . Comparison of Flow-weighted and Geometric Mean TDS at Sites in the Cheyenne River Basin

Flow-weighted Mean TDS [mg/L]				
Site Name	Mainstem		Tributaries	
	1979	1980	1979	1980
Cheyenne at Edgemont	1,617	2,690		
Cheyenne at Dam	1,628	1,882		
Fall River			963	1,039
Beaver Creek			2,004	2,065
Cheyenne at Buffalo Gap	1,893	2,136		
Rapid Creek			605	630
Cheyenne at Wasta	1,275	1,497		
Belle Fourche River			1,466	1,803
Cheyenne at Plainview	1,341	1,510		
Cheyenne at Cherry Creek	1,536	1,712		

Mean (measured) TDS [mg/L]				
Site Name	Mainstem		Tributaries	
	1979	1980	1979	1980
Cheyenne at Edgemont	2,300	2,996		
Cheyenne at Dam	1,705	1,767		
Fall River			962	1,025
Beaver Creek			2,041	2,165
Cheyenne at Buffalo Gap	1,973	2,124		
Rapid Creek			604	646
Cheyenne at Wasta	1,396	1,500		
Belle Fourche River			1,945	2,085
Cheyenne at Plainview	1,436	1,599		
Cheyenne at Cherry Creek	1,782	1,883		

The same phenomenon attributable to the Fall River also appears to apply to the TDS of Beaver Creek and Rapid Creek. Both of the creeks show little difference between the geometric and flow-weighted means (Table 3). However, there are controls on the flows in Rapid Creek from impoundments and controlled tributaries, e.g. sewage treatment plant discharge. Diffuse irrigation return flows, such as subsurface drainage, also serve as contributions to base flow (ground water inflows). The remaining gages,

with the possible exception of the Belle Fourche River during 1979, do not show quite the difference in the two means as was the case at Edgemont.

National Irrigation Water Quality Program (NIWQP)

The NIWQP study was based on up to 4 sets of water quality samples collected in 1988. Samples were collected upstream from and downstream from Angostura Reservoir. Upstream samples included both the Cheyenne River (see above) and Horsehead Creek. However Horsehead Creek carried no flow on 3 of 4 sampling dates; when a sample was collected during May 1988, the flow was only 0.1 ft³/s. According to Greene *et al.* (1990), 1988 was a drought year. Poorer than normal water quality is expected during drought conditions. The concentrations and predominant constituents were similar in Horsehead Creek to those in the Cheyenne River. Neither the Cheyenne River above Angostura Reservoir nor Horsehead Creek carried what would be considered harmful concentrations of trace elements.

The most comprehensive set of trace element and on the Cheyenne River and tributaries downstream from Angostura Dam are those from 1988 collected during the NIWQP study of the Angostura Unit (Greene *et al.*, 1990). The results indicated that there were elevated trace elements in several tributaries to the Cheyenne River within the Angostura Unit irrigated area. Concentrations that would be considered at levels of concern and the sites at which they were observed are as follows:

Cd	5.0 µg/L	Cheyenne River above Buffalo Gap;
Hg	5.3 µg/L	Cheyenne River above Buffalo Gap;
U	44 µg/L	Iron Draw near Buffalo Gap; and
Se	16 µg/L	Cottonwood Creek near Buffalo Gap (Nov. 1988). A

sample collected earlier in the spring from Cottonwood Creek at the same site had Se of 13 µg/L; 2 other samples in the summer showed Se to be ≤ 5 µg/L. At the time the samples were collected in Cottonwood Creek, the maximum discharge was 0.24 ft³/s; consequently loadings to the Cheyenne River were very small with a maximum of 0.3 ounces Se per day during 1988. It should be noted that Cottonwood Creek was a background site in the NIWQP study.

There was no consistency or pattern to the elevated trace element results. The conclusion reached by Greene *et al.* (1988) during the study was: "Because the majority of trace element concentrations were within baseline ranges, there is probably no significant accumulation of trace element concentrations due to irrigation." No further study or other action was recommended by the Department of the Interior.

Reclamation did a follow-up sampling of many of the same sites as were sampled during the NIWQP study. In addition, the NIWQP collected follow-up samples during 1994 at several of the original sites that were sampled during 1988. As was noted

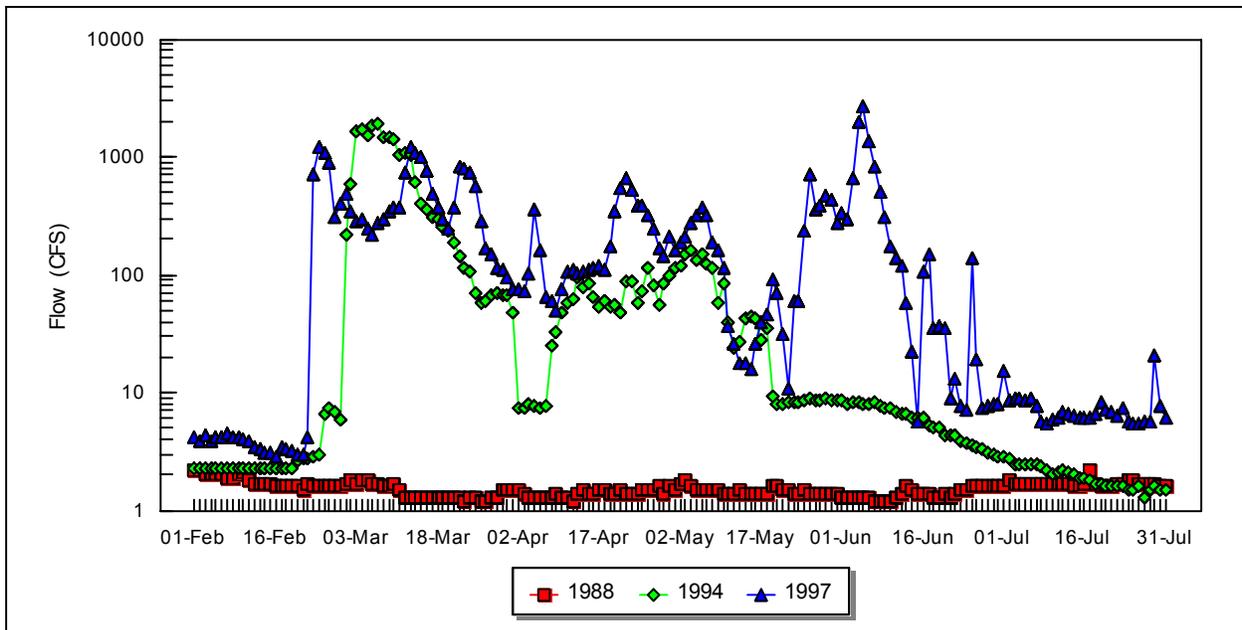


Figure 4: Mean daily discharge of the Cheyenne River (0.15 mi.) downstream from Angostura Dam during the spring and early summer of 1988, 1994, and 1997

above, 1988 was a drought year. Figure 4 shows the relative level of flow in 1988 in comparison to the other sample years. It should be noted that since water year 1978 the gage record for the gage downstream from Angostura Dam only includes data for the period from February 1 through July 31 each year. That period is plotted on Figure 4 for 1988, 1994, and 1997, which are the years in which the water quality samples of concern to this discussion were collected.

Water year 1988 had no high flows (Figure 4). Each of the other sample years show peak flows greater than 1000 ft³/s (note the logarithmic scale on Figure 4); there were also several other flows during the year that exceeded 100 ft³/s (Figure 4). The average flow for the period shown on Figure 4 was over 100 ft³/s during 1994 and over 200 ft³/s during 1997. The peak flow during 1988 was only 2.2 ft³/s during the period shown and the average flow for the 6 month period was only 1.5 ft³/s. This would be expected to have a great effect on water quality relative to that in the other 2 years. The concentration of dissolved substances tends to be more concentrated (higher) during low flow or dry years. Consequently 1988 may be something of a "worst case" representation of conditions in the study area.

Irrigation releases from Angostura Dam are made to the Angostura Canal. Except for flood-control releases during the spring and early runoff periods, there are usually no releases to the Cheyenne River from Angostura Dam during the irrigation season (May through September - Greene *et al.*, 1990). Most of the flow in the 4.5 mile river reach between Angostura Dam and the Fall River consists primarily of seepage from the dam and leakage from the radial gates (*ibid.*). The data in Figure 4 indicate that there were

significant releases from the dam during both 1994 and 1997, but no releases during 1988. There were no NIWQP water quality sampling sites between Angostura Dam and the mouth of the Fall River. Therefore the flow and quality of the Fall River must also be considered when evaluating possible differences in the NIWQP data and follow-up samples from different years at sites in the Cheyenne River.

The discharge from the Fall River during the same periods as shown for the Cheyenne River below Angostura Dam are shown on Figure 5. Unlike Figure 4, which was plotted on a log scale, Figure 5 is on a linear scale. This is because there is so little spread in the data. There is very little year-to-year difference in the Fall River flows; similarly there is very little seasonal difference in flows. Most of the flows from the Fall River originate from several large springs in and above the town of Hot Springs (Greene *et al.*, 1990). The peak flows would represent the contribution from the limited surface drainage in the basin while the low flows would reflect the contribution from the springs. The important point is that during much of 1988, samples collected downstream from Angostura Dam included increasing percentages of tributary water. Even at the first NIWQP site downstream from the dam, the water would be mostly from the Fall River. The effect of irrigation return flows would be lowest when the amount of water available for dilution is greatest; this would occur when the releases from the reservoir are the greatest.

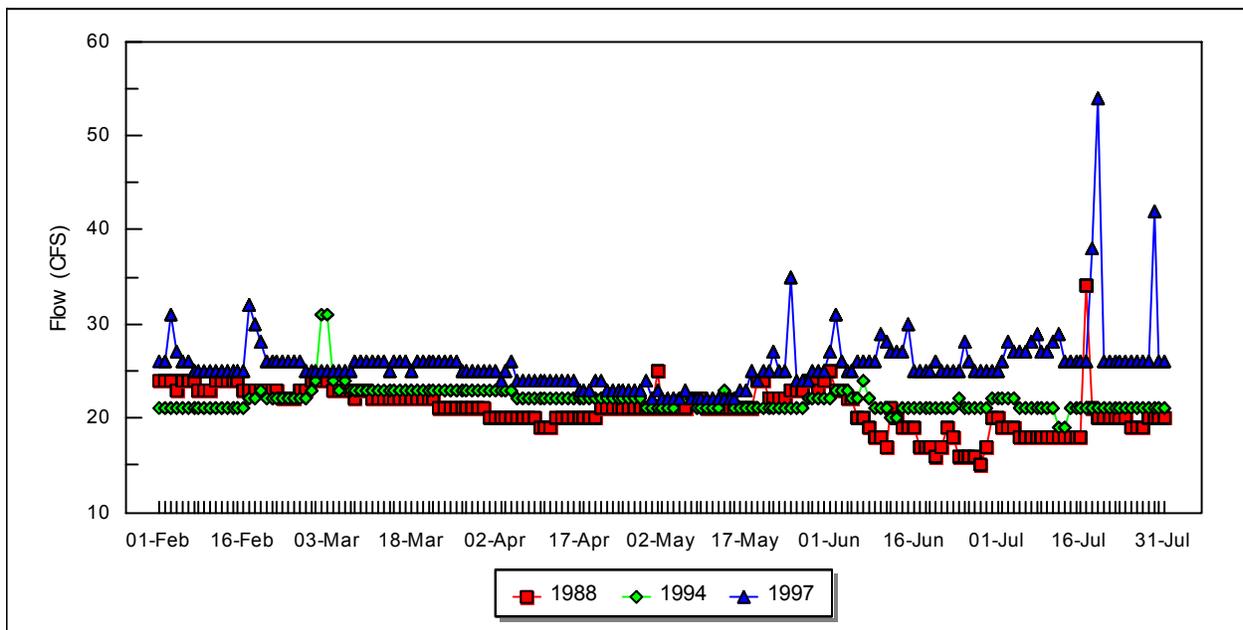


Figure 5: Mean daily discharge of the Fall River near the mouth during the spring and early summer of 1988, 1994, and 1997

The releases from the dam vary greatly from year to year. The geometric mean and maximum flows for each of the years since the beginning of the NIWQP studies in 1986 through the most recent year available (1997) are plotted on Figure 6. In each of the

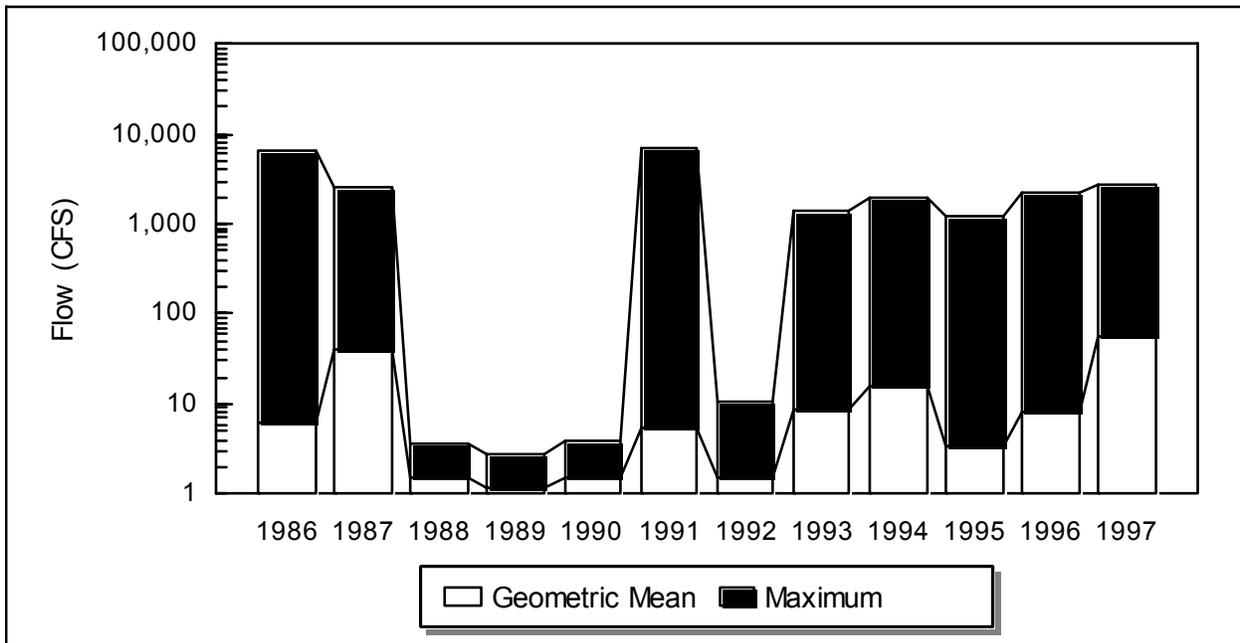


Figure 6: Mean and maximum flows during the period February 1 through July 31 at the USGS gage downstream from Angostura Dam

years in which the peak flow was less than 10 ft³/s, the average flow for the 6 month period was less than 2 ft³/s at the gage. The more recent samples by the NIWQP and Reclamation have been collected in a period when the peak flows have been relatively constant from year to year (Figure 6). The peak flows have ranged from a low of 1250 ft³/s in 1995 to a maximum of 2710 ft³/s in 1997. The peak flow was 1920 ft³/s in 1994 (3rd of the 5 years in rank) when the NIWQP verification samples were collected (Figure 6).

The dam releases would be reflected in the quality of the water in the Angostura Canal; however, the water in the canal would come from a higher level in the reservoir than most of the seepage or releases to the river. In addition seepage may also be affected by laterally inflowing ground water from other sources. The inflowing ground water may increase or decrease the concentration of dissolved solids in the seepage as it moves to the river. The quality of the laterally flowing ground water can also be affected by hydrologic conditions. During wet years when there is greater precipitation, there will be greater recharge and a greater amount of dilution by the recharge; the ground water itself will have a lower concentration of dissolved solids in wetter years.

Comparison between Reclamation's 1997 Samples and the NIWQP Data

Table 4 shows the range for each of the measurements made during the NIWQP study conducted by Greene *et al.* (1990) and, where available, data for the verification study. The Reclamation results are shown above the NIWQP minimum values. The Reclamation results are expected to lower than those of the NIWQP in most instances involving dissolved substances. This is obvious in the EC and TDS at the Hot Springs gage above Angostura Reservoir (Table 4), where the EC in 1997 was about ½ the minimum EC in 1988 and the TDS in 1997 was much less than ½ the minimum TDS in 1988. Oddly enough, in 1988, the maximum EC and TDS were observed in May, coinciding with the highest flow when of any of the samples was collected; the minimum EC and TDS were observed in August, coinciding with the lowest flow when any of the samples were collected.

The NIWQP samples at the Cheyenne River site below Angostura Dam were collected during 1994 rather than in 1988. During 1988, Greene *et al.* (1990) collected biological samples downstream from the dam, but at a site farther upstream. The 1994 samples show EC and TDS that are similar to those of 1997. As was noted above, that should be expected based on the flows during 1994 and 1997 (Figure 4). The pattern for EC and TDS is consistent at the other sites in the study area. When the NIWQP samples were collected during 1988, the Reclamation 1997 samples are less than the NIWQP minimum. When the NIWQP samples were collected in 1994, the Reclamation 1997 sample is with the range of the NIWQP samples (Table 4). Oddly enough, in the one case where the NIWQP collected samples in both 1988 and 1994, *i.e.* near Fairburn, the Reclamation sample is outside their range (Table 14). Furthermore, the Fairburn sample shows a decrease in both EC and TDS from what had been observed upstream at the county road bridge site; the NIWQP samples all showed an increase between the sites. Apparently in 1997, there was some source of dilution between the sites that had not been observed previously.

The major ions, *i.e.* those that make up the majority of the TDS, include the cations, Ca, Mg, Na, K; and the anions SO₄ and Cl, along with the bicarbonate (HCO₃) and carbonate (CO₃) ions, which are represented in Table 4 by alkalinity. The water is predominantly a CaSO₄-type of water above Angostura Reservoir. As the water proceeds downstream, it becomes more of a Ca-Na-SO₄ type of water (Table 4). For the most part the pattern exhibited by the EC and TDS data is also shown by the major ions. One noteworthy exception is at the site downstream from the dam where the Reclamation 1997 sample was slightly greater than the NIWQP maximum for Na, Cl, and SO₄ (Table 4).

Several nitrogen species, including nitrate, nitrite, ammonium, and total Kjeldahl nitrogen (includes organic nitrogen and ammonium - samples from Angostura Reservoir only) were analyzed in the Reclamation samples; the NIWQP samples were analyzed

Table 4. Comparison of Reclamation's 1997 Water Quality Sample with the Range of NIWQP Results

Site		Dates	Water Temp. (°C)	E.C. at 25°C µmho/cm	TDS (mg/L)	pH Field	D.O. (mg/L)	NO ₂ +NO ₃ (mg/L)
Near Hot Springs	BR 8/97		ND	1470	1139	8.09	ND	0.7
	GS - Min	May-88	15.5	2800	2640	8.00	7.20	0.1
	- Max	Nov-88	28	3550	3160	8.26	8.80	0.2
			NA	*	*		NA	*
¼ Mi. Downstream of Dam	BR 8/97		19.9	2080	1624	7.95	ND	0.5
	GS - Min	Apr-94	ND	1996	1490	8.01	8.3	ND
	- Max	Sep-94	ND	2250	1670	8.43	11.8	ND
						*	NA	*
Angostura Canal	BR 8/97		20.7	1980	1580	7.69	ND	0.6
	GS - Min	May-88	14	2520	2000	8.10	8.2	< 0.1
	- Max	Aug-88	23	2610	2120	8.33	8.2	0.2
				*	*	*	NA	*
Iron Draw near Buffalo Gap	BR 8/97		20.3	2630	2159	8.01	ND	3.4
	GS - Min	May-88	14	2950	2440	8.13	7.90	2.4
	- Max	Nov-88	27	3090	2480	8.32	8.10	4.3
				*	*	*	NA	*
Nr Custer Co. Rd. 656	BR 8/97		ND	2360	1826	8.08	ND	0.8
	GS - Min	Apr-94	ND	2260	1760	8.03	8.8	ND
	- Max	Sep-94	ND	2550	2010	8.23	9.2	ND
River near Fairburn	BR 8/97		26.1	1830	1407	8.10	ND	0.54
	GS - Min	May-88	9.5	2320	1830	8.18	6.6	0.2
	- Max	Sep-94	31	2750	2240	8.33	11.0	1.3
				*	*	*	NA	
At Cherry Creek	BR 8/97		26.4	1690	1215	8.24	ND	1.2
	GS - Min	Jan-88	-0.2	911	620	7.22	7.2	< 0.1
	- Max	Aug-95	25.5	3420	3030	8.39	8.2	4.0
			*				NA	

[* Indicates BR 1997 sample outside GS 1988-95 Range]
 ND - No Data; NA - Not Applicable

Table 4 (continued)

		Calcium Ca, Diss. (mg/L)	Magne- sium, Mg (mg/L)	Potassi- um, K (mg/L)	Sodium Na, Diss. (mg/L)	Alkalinity as CaCO ₃ (mg/L)	Chloride Cl, diss. (mg/L)	Sulfate SO ₄ (mg/L)
Near Hot Springs	BR 8/97	107	43	13	189	ND	109	598
	GS - MIN	410	92	6.8	100	166	82	1600
	- MAX	530	100	9.1	320	169	160	1900
		*	*	*		NA		*
¼ Mi. Downstream Dam	BR 8/97	198	66	10.7	215	ND	135	911
	GS - MIN	180	53	8.7	190	166	96	790
	- MAX	240	81	12	210	166	110	890
					*	NA	*	*
Angostura Canal	BR 8/97	186	62	11	216	ND	135	889
	GS - MIN	200	75	9	240	141	140	1100
	- MAX	270	84	11	260	141	140	1300
		*	*		*	NA	*	*
Iron Draw Nr Buffalo Gap	BR 8/97	287	79	31	284	ND	152	1166
	GS - MIN	280	81	14	290	274	130	1300
	- MAX	360	100	28	300	275	140	1400
			*	*	*	NA	*	*
Nr Custer Co. Br. 656	BR 8/97	251	81	17	213	ND	105	1026
	GS - MIN	230	69	11	200	206	110	930
	- MAX	250	80	18	230	206	130	1100
		*	*			NA	*	
River Nr Fairburn	BR 8/97	187	61	15	186	ND	75	757
	GS - MIN	230	74	10	210	135	110	970
	- MAX	270	92	17	260	203	170	1300
		*	*		*	NA	*	*
At Cherry Creek	BR 8/97	105	53	13	206	ND	33	701
	GS - MIN	36	6.7	0.7	94	91	15	270
	- MAX	340	130	18	410	326	150	1900
						NA		

[* Indicates BR 1997 sample outside GS 1988-95 Range]
 ND - No Data; NA - Not Applicable

Table 4 (continued)

Site		Arsenic As,diss (µg/L)	Boron B,diss (µg/L)	Cadmium Cd, diss. (µg/L)	Chromium Cr, diss. (µg/L)	Copper Cu, diss. (µg/L)	Lead Pb, diss. (µg/L)
Near Hot Springs	BR 8/97	2	221	0.2	4	4	2
	GS - MIN	< 1	190	< 1	< 1	< 1	< 5
	- MAX	1 *	270	1	4	1 *	< 5
¼ Mi. Downstream Dam	BR 8/97	1	193	0.2	1	1	1
	GS - MIN	< 1	160	< 1	< 1	1	< 1
	- MAX	2	180 *	1	1	1	1
Angostura Canal	BR 8/97	1.2	209	0.2	1	1	1
	GS - MIN	1	200	< 1	< 1	1	< 5
	- MAX	1 *	210	1	3	11	11
Iron Draw Nr Buffalo Gap	BR 8/97	< 1	352	0.2	< 1	< 1	< 1
	GS - MIN	< 1	320	< 1	< 1	< 1	< 5
	- MAX	1	360	1	2	1	< 5
Nr Custer Co. Br. 656	BR 8/97	1	359	0.2	< 1	1.6	< 1
	GS - MIN	< 1	240	< 1	< 1	< 1	< 1
	- MAX	1	340 *	1	1	< 1 *	< 1
River Nr Fairburn	BR 8/97	2	280	0.2	< 1	2	1
	GS - MIN	< 1	240	< 1	< 1	< 1	< 1
	- MAX	1 *	370	1	2	2	6
At Cherry Creek	BR 8/97	6	309	0.2	4	9	5
	GS - MIN	1	No Data	< 1	< 1	< 1	< 1
	- MAX	13	No Data	10	3 *	6 *	1 *

[* Indicates BR 1997 sample outside GS 1988-95 Range]

ND - No Data; NA - Not Applicable

Table 4 (continued)

Site		Mercury Hg,diss (µg/L)	Molybdenum Mo, diss. (µg/L)	Selenium Se, diss. (µg/L)	Uranium U-nat (µg/L)	Vanadium V, diss. (µg/L)	Zinc Zn,diss. (µg/L)
Near Hot Springs	BR 8/97	< 0.2	2	1	8	7	11
	GS - MIN	< 0.1	12	2	7	2	< 10
	- MAX	< 0.1	16	3	12	3	20
			*	*		*	
¾ Mi. Downstream Dam	BR 8/97	0.2	6	2	8	1	5
	GS - MIN	< 0.1	5	2	7.6	2	5
	- MAX	0.1	8	4	9.2	3	10
		*		*		*	
Angostura Canal	BR 8/97	0.2	6	1	8	1	5
	GS - MIN	< 0.1	8	1	9	1	< 10
	- MAX	0.1	10	2	11	2	150
		*	*		*		
Iron Draw Nr Buffalo Gap	BR 8/97	< 0.2	1.6	2	34	1	6
	GS - MIN	< 0.1	< 1	4	22	< 1	< 10
	- MAX	0.1	4	6	44	2	20
				*			
Nr Custer Co. Br. 656	BR 8/97	< 0.2	8	2.1	13	1.4	11
	GS - MIN	< 0.1	7	2	11	3	< 10
	- MAX	< 0.1	8	3	13	4	< 10
					*	*	
River Nr Fairburn	BR 8/97	< 0.2	5	< 1	1	4	6
	GS - MIN	< 0.1	< 6	< 1	10	< 1	< 10
	- MAX	0.2	8	4	15	4	50
				*			
At Cherry Creek	BR 8/97	< 0.2	< 1	2	6	21	20
	GS - MIN	< 0.1	< 2	< 1	ND	< 1	< 3
	- MAX	0.2	13	7	ND	12	14
					*	*	

[* Indicates BR 1997 sample outside GS 1988-95 Range]
 ND - No Data; NA - Not Applicable

for combined nitrate and nitrite only. The only Reclamation sample that had measurable nitrite (> 0.02 mg/L - N) was collected from Iron Draw, where the nitrite concentration was 0.03 mg/L. None of the samples had measurable Kjeldahl nitrogen, but the detection limit was relatively high (1 mg/L).

Table 4 shows a comparison of the NIWQP nitrate plus nitrite data with that in the Reclamation samples. The Reclamation 1997 samples were higher in nitrite plus nitrate than the NIWQP 1988 samples at the more upstream sites, but within the range of the NIWQP samples farther downstream (Table 4). The consistently greatest nitrogen concentration was in samples collected from Iron Draw in both sets of samples. The only other site where the nitrogen concentration exceeded 1 mg/L was at the NASQAN site at Cherry Creek.

A potentially toxic form of nitrogen that is sometimes found in water that has a heavy load of organic matter is ammonia, which may be a dissolved solid (ammonium ion - NH_4^{+1}) or a dissolved gas (ammonia - NH_3). The gaseous form of ammonia is toxic at higher concentrations. The various forms are determined by the equilibrium chemistry of ammonia, which is temperature and pH dependent. Figure 7 shows the total ammonia in filtered samples, *i.e.* the total dissolved ammonia. The unionized ammonia at each of the Reclamation sample sites, except for the one upstream from Angostura Reservoir, is also shown on Figure 7. There was no temperature measurement at the upstream site to use in the unionized ammonia calculation.

The y-axis (Figure 7) that shows the unionized ammonia is one-tenth of the y-axis showing the total dissolved ammonia. The unionized ammonia is therefore only a small percentage of the total. This should be noted in particular for the site near Cherry Creek, where the unionized bar appears to be as large as that for the total dissolved ammonia (Figure 7).

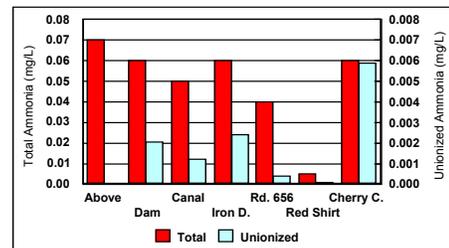


Figure 7: Total and unionized ammonia in samples collected by Reclamation at various sites in the Angostura study area during August 1997 - **NOTE scale difference on the 2 y-axes**

The toxic concentration of ammonia is also temperature dependent (EPA, 1996). Consequently the harmful concentration at each of the sites will vary with temperature. Although the toxic concentration of ammonia is not shown on Figure 7, it is well above the concentrations shown on Figure 7. At the time the samples were collected during August 1997, ammonia was well below toxic concentrations at all of the sites.

Trace elements with the possible exception of the most soluble would not be expected to show the same pattern as the EC, TDS, and major ions. Many of the trace element data are affected by the detection limits of the instruments or analytical methods used in the laboratories doing the analyses. This is evident in Table 4, where many of the data points from both the NIWQP and Reclamation are shown as "<" values. These are present in all of the trace element data except those for boron and uranium (Table 4), although there are only a few of the values for molybdenum, selenium, and vanadium that are below ("<") the detection limit.

The site on the Cheyenne River at Cherry Creek is not part of the NIWQP; however, Reclamation collected a sample at the site during August 1997. The USGS data for the site are included as a basis for comparison with the Reclamation sample. The site is a long-term USGS NASQAN (National Stream Quality Accounting Network) monitoring site with a record that extends from 1971 through 1995, when it was discontinued. For consistency with the NIWQP, only the range of data for the site that include the period beginning in 1988 are summarized in Table 4. The NASQAN monitoring data at the site do not include analyses for boron or uranium, but there are data for each of the other trace elements sampled by the NIWQP. With the much longer period of record at the NASQAN site, the range would be expected to be much greater. However, the 1997 sample is outside the historic range of values for 5 of the 10 trace elements for which there are data at the NASQAN site (Table 4). The trace elements for which the 1997 sample exceeded the historic (1988-95) maximum value include Cr, Cu, Pb, V, and Zn. In the case of the last 4 trace elements, the 1997 value is well in excess of the earlier maximum (Table 4). None of the trace elements were below the 1988-95 minimum for the Cherry Creek NASQAN site.

The water quality at sites downstream from Angostura Dam represents that of return flows from the irrigation district. The data for Iron Draw show the ionic composition of water nearest the source, while the site near Custer Co. Road 656 shows a mixture of irrigation return flows and tributary flows. The EC at the river site near road 656 is slightly lower than that in Iron Draw indicating that there is dilution occurring. The most distinctive characteristic of the water quality of Iron Draw is a relatively high uranium concentration. The EPA MCL (primary drinking water standard) for uranium is 20 µg/L. The water in Iron Draw is not suitable for drinking for other reasons, but it also well above the uranium MCL. All of the other sites shown in Table 4 have uranium concentrations well below the MCL; this would indicate that the high concentration of uranium in the water in Iron Draw is due to a localized source. The uranium concentration in the river downstream from Iron Draw (at the county road site) is only slightly greater than that above Iron Draw, which shows that Iron Draw has little effect on the river. The flow in Iron Draw when the samples were collected ranged from 1.4 to 3.2 ft³/s (Greene *et al.*, 1990).

Numerous pesticides in water were also sampled and analyzed by the NIWQP in 1988; there were no pesticide samples collected during 1994. The NIWQP results are summarized in Table 5. All of the samples that were above detection limits were herbicides, including three triazine herbicides (atrazine, cyanazine, and simazine), metolachlor, and prometone (*sic* = prometon).

The most commonly observed of the triazines was atrazine, which was above the detection limit of 0.1 µg/L in nearly ½ the samples (9 of 19 - Table 5); the maximum observed atrazine concentration during 1988 was 0.2 µg/L, which is only a little above the detection limit. As a point of reference, the atrazine MCL is 3 µg/L (EPA, 1996), a concentration that was not approached in 1988 at the NIWQP sampling sites. Atrazine is highly soluble, but is readily decomposed by UV light (Ahrens, 1994). Atrazine is a selective herbicide that can be applied pre- or post-plant to control many broadleaf weeds in corn or sorghum (Ahrens, 1994). Atrazine is toxicity class III (slightly toxic) and is a restricted use pesticide due to its potential for ground water contamination (EXTOXNET, 1996).

Four of the 8 samples that had measurable atrazine were collected during May. The samples originated from Horsehead Creek, a tributary to Angostura Reservoir; the Cheyenne River above Buffalo Gap; Iron Draw; and the Cheyenne River near Fairburn (a.k.a., near Red Shirt - see Greene *et al.*, 1990: Table 21). The maximum observed concentration of atrazine was in the May sample from the Fairburn site. All 3 of the samples collected from Iron Draw and all 4 of the samples from the Fairburn site contained measurable atrazine during 1988. Each of these sites, except for Horsehead Creek would be expected to carry irrigation return flows from the AID (Angostura Irrigation District). Atrazine should be an herbicide to consider as originating from agricultural activities associated with the delivery of Project irrigation water.

Cyanazine was observed in 2 samples collected during May 1988 (Table 5). The samples were collected from the Cheyenne River near Hot Springs and from Horsehead Creek (see Greene *et al.* 1990: Table 21). Both of these sites are inflow sites to Angostura Reservoir. Cyanazine was not measured at any of the sites that reflect return flows from the AID. Cyanazine enters the reservoir, but it either remains in the reservoir or is lost elsewhere during use. Based on the NIWQP data, cyanazine does not appear to be in the return flows from the Project. It does not seem that the contract renewals should have any effect on cyanazine concentrations in the Cheyenne River or its tributaries.

Simazine was also observed in 2 of the 19 NIWQP samples collected during 1988 (Table 5). Both of the measurable simazine samples were collected during May. The sample collected from the Cheyenne River above Buffalo Gap contained 0.3 µg/L of simazine, while the sample collected near Fairburn had a simazine concentration of 0.1 µg/L (see Greene *et al.*, 1990: table 21). The drinking water standard for simazine is

Table 5: Summary of the results of the NIWQP pesticide sampling during 1988 (19 samples, except metribuzin and metolachlor, 17 samples) and that of Reclamation in 1997 (6 samples) of the Cheyenne River

	Alachlor Total	Ametryne Gesapax Total	Atrazine Whole Sample	Cyanazine Whole Water	Methomyl Whole water	Metribuzin Water Tot. Rec.	Metolachlor Water Total
NIWQP Detection Limit (µg/L)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.5	< 0.1	< 0.1
Number > Detection Limit	0	0	9	2	0	0	0
Reclamation Detection Limit (µg/L)	< 0.1	< 0.1	< 0.1	< 0.1	< 2.0	< 0.1	< 0.1
	Prometon Whole water	Prometryne Whole water	Propazine Total	Propham Whole water	Sevin Whole Sample	Simazine Whole water	Simetryne Whole water
NIWQP Detection Limit (µg/L)	< 0.1	< 0.1	< 0.5	< 0.5	< 0.5	< 0.1	< 0.1
Number > Detection Limit	2	0	0	0	0	2	0
Reclamation Detection Limit (µg/L)	< 0.1	< 0.1	< 0.1	---	---	< 0.1	< 0.1
	Treflan Water	Aldicarb Sulfone Total	Aldicarb Sulfoxide Tot. Rec.	Carbaryl Water Total	Carbofuran Water Tot. Rec.	Oxamyl Total water	
NIWQP Detection Limit (µg/L)	< 0.5	---	---	---	---	---	
Number > Detection Limit	0	---	---	---	---	---	
Reclamation Detection Limit (µg/L)	---	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	

4 µg/L (EPA, 1996). Simazine is also in EPA toxicity class VI (practically nontoxic), but a special review of its status was begun in 1994 (EXTOXNET, 1996).

Prometon was observed at concentrations above the reporting limit at 2 sites (Greene *et al.* 1990). The samples that were above the reporting limit of 0.1 µg/L were from the Cheyenne River above Buffalo Gap (1 µg/L) and from the river near Fairburn (0.2 µg/L). According to Ahrens (1994) and NACA (1994), prometon is a non-selective herbicide applied pre- or post-emergence on noncrop land (industrial sites, railroad rights-of-way, recreation areas, highway medians, along guard rails and around fuel tanks, among others). One of the prometon formulations includes simazine. None of the uses listed for prometon include crops, but it may be used for other purposes in the Project area or on the Project. EPA (1996) shows a drinking water health advisory for long-term exposure for a 10 Kg. child of 0.2 mg/L (= 200 µg/L). Both of the observed concentrations are well below this minimum, potentially harmful concentration.

Greene *et al.* (1990) also indicated in Table 15 that metolachlor was observed at one site. However, the raw data in Table 21, and the same data retrieved from both STORET and the NIWQP website, indicate that all of the samples were < 0.1 µg/L. Williamson (1999, personal communication) also indicates that 4 herbicides were detected, not the 5 listed in Greene *et al.* (1990). It appears that Table 15 is in error.

Reclamation sampled 6 of the NIWQP sites for pesticide concentrations in water. The sites included the Cheyenne River near Hot Springs (NIWQP site 2), Iron Draw near Buffalo Gap (NIWQP site 10), the Cheyenne River near County Road 656 (NIWQP site 12), and the Cheyenne River near Fairburn (NIWQP site 14). Samples were also collected from 2 ponds from which the NIWQP collected biological samples (NIWQP sites 9 and 11); the county road site was also a biological sampling site for the NIWQP. The list of pesticides for which analyses were performed on the August 1997 samples are also shown on Table 5. No measurable pesticides were present in any of the samples collected during 1997. Whether these differences between the NIWQP and the 1997 Reclamation samples are due to the above described wet year/dry year effect is unknown. Nevertheless, there does not appear to be a water quality problem associated with pesticides in the Project area. There are no instream water quality standards for any of the 3 triazine herbicides observed in the area by the NIWQP in 1988.

Oglala Sioux Tribe (OST) Data

The OST have collected seasonal (high-flow and low-flow) water quality samples from the Cheyenne River near Red Shirt Village since 1993. As was shown in Figure 6 above, the flows during the period February 1 through July 31 during those years showed much less year-to-year variation than was the case of the 3 years during which the NIWQP and Reclamation sampled the river (Figure 4). The data for site CRI, which is located near Red Shirt Village, include the period 1993 through 1997; no data were collected during 1994. The data were provided by the OST Water Resource Department for use in the preparation of the Environmental Statement for the Angostura Contract Renewals (Joe Amiotte, Personal Communication, February 18, 1998). During 1997, a second site (CRII) was added. CRII is located east of Davidson Flat (Hoof, 1998).

The OST data are shown in Table 6. The high flow samples have been collected during the months of May, June, and July, and the low flow samples have been collected during September, October, and December. Samples for other purposes have been collected at other times, but those data are not included in Table 6. Those results will be discussed later.

One of the main reasons for monitoring the water quality of the Cheyenne River by the OST relates to the extensive occurrence of lesions on the fish in the river in the vicinity of the Pine Ridge Reservation (Hoof, 1998). The lesions have been attributed to bacterial infections associated with stress due to either parasitism by leeches or poor water quality. The data in Table 6 indicate that periodically there is low dissolved oxygen (D.O.) in the river; the data for 12/93 and 5/96 show D.O. at 10 and 8 percent of saturation respectively. The 12/93 D.O. would correspond to about 1.5 mg/L, while that for 5/96 would correspond to a D.O. concentration of about 0.8 mg/L. This would be sufficient to cause at least short term stress to fish, and may be fatal to some if such a condition persisted for very long. For example, EPA (1986) recommends an instantaneous minimum D.O. of 3 mg/L for adult warmwater fish. The 9/96 sample also showed a reduced D.O. of about 33 percent of saturation, which would correspond to a D.O. concentration of about 2.8 mg/L, which is also below the EPA recommended minimum. There is no way to estimate a frequency of low D.O. conditions in the river from the available data. However, if the data in Table 6 are representative of ambient conditions, then low D.O. could be expected to be present about half the time. Even if this estimate is way off (too high), stressful conditions for fish could still be expected to be present rather often.

In addition to low D.O., the 12/93 sample also showed a nitrite concentration of 0.43 mg/L, which is very high for surface waters and indicates that reducing conditions (from a chemical perspective) were present. The 5/96 sample shows that about 50 percent of any ammonia present in the water would be in the highly toxic unionized form; there are

Table 6: Major Ions and Total Metals in the Cheyenne River near Red Shirt during High Flow and Low Flow Periods of 1993 - 1997 (Data from OST Records)

SITE ID	DATE	TEMP. (°C)	pH	D.O. % Sat.	Alkalinity (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Sodium (mg/L)
CRI	06/23/93	---	---	---	140	92	0.49	0.10	0.01	186
CRI	12/12/93	2.2	8.5	10.1	180	121	0.51	3.22	0.43	203
CRI	05/25/95	15.1	8.7	87.1	146	60	0.44	0.22	0.01	106
CRI	09/28/95	---	---	---	180	136	0.48	0.95	0.01	214
CRI	05/15/96	20.5	9.4	8.0	170	130	0.60	0.40	0.01	216
CRI	09/30/96	22.2	10.7	32.8	186	140	0.40	1.20	0.01	247
CRI	07/01/97	24.3	8.1	90.5	---	113	0.60	0.19 ¹	---	250
CRI	10/16/97	13.4	9.0	82.0	208	113	0.44	1.31 ¹	---	250
CRII	07/16/97	27.8	8.5	71.9	170	115	0.51	0.54 ¹	---	240
CRII	10/01/97	19.2	9.0	86.9	194	128	0.45	1.03 ¹	---	240

SITE ID	DATE	Ortho-P (mg/L)	Total P (mg/L)	Sulfate (mg/L)	Arsenic (mg/L)	Barium (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)
CRI	06/23/93	0.03	0.16	728	0.013	0.14	0.0005	0.010	0.011
CRI	12/12/93	0.01	0.07	1130	0.005	0.07	< 0.0005	0.009	< 0.005
CRI	05/25/95	0.03	0.17	610	0.052	0.83	---	0.016	0.014
CRI	09/28/95	0.01	0.02	1120	0.005	0.05	---	< 0.005	< 0.005
CRI	05/15/96	0.01	0.32	990	0.005	0.17	---	0.010	0.024
CRI	09/30/96	0.02	0.02	1100	0.005	0.05	---	< 0.005	0.005
CRI	07/01/97	0.02	0.03	987	0.005	< 0.10	< 0.0005	< 0.010	< 0.010
CRI	10/16/97	0.01	0.01	1050	0.005	0.04	< 0.0005	< 0.010	< 0.010
CRII	07/16/97	0.10	0.11	1010	0.005	0.08	< 0.0005	< 0.005	0.007
CRII	10/01/97	0.01	0.02	1100	0.005	0.04	< 0.0005	< 0.010	< 0.010

SITE ID	DATE	Iron (mg/L)	Lead (mg/L)	Man- ganese (mg/L)	Mercury (mg/L)	Nickel (mg/L)	Selenium (mg/L)	Silver (mg/L)	Zinc (mg/L)
CRI	06/23/93	4.99	0.005	0.15	0.0005	0.007	0.003	0.003	0.04
CRI	12/12/93	2.22	< 0.005	0.09	< 0.0002	0.006	0.002	0.004	0.06
CRI	05/25/95	19.80	0.006	0.35	0.0008	---	---	---	0.09
CRI	09/28/95	0.65	< 0.005	0.04	0.0019	---	---	---	0.03
CRI	05/15/96	6.40	0.003	0.28	0.0018	---	---	---	216.00
CRI	09/30/96	0.66	< 0.002	0.05	0.0003	---	---	---	0.05
CRI	07/01/97	0.70	< 0.002	0.07	0.0003	< 0.030	0.005	< 0.005	< 0.02
CRI	10/16/97	0.42	0.003	0.04	< 0.0002	< 0.030	0.005	< 0.010	< 0.02
CRII	07/16/97	3.00	0.003	0.10	< 0.0002	< 0.005	0.005	< 0.005	< 0.02
CRII	10/01/97	0.54	< 0.002	0.05	< 0.0002	< 0.030	0.005	< 0.010	< 0.02

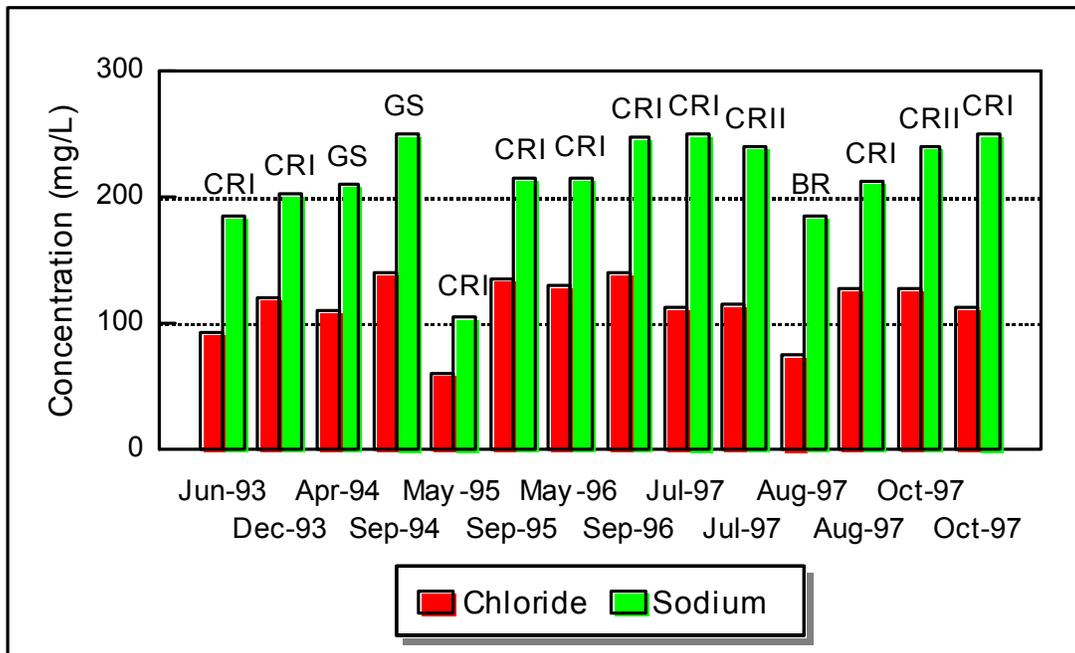
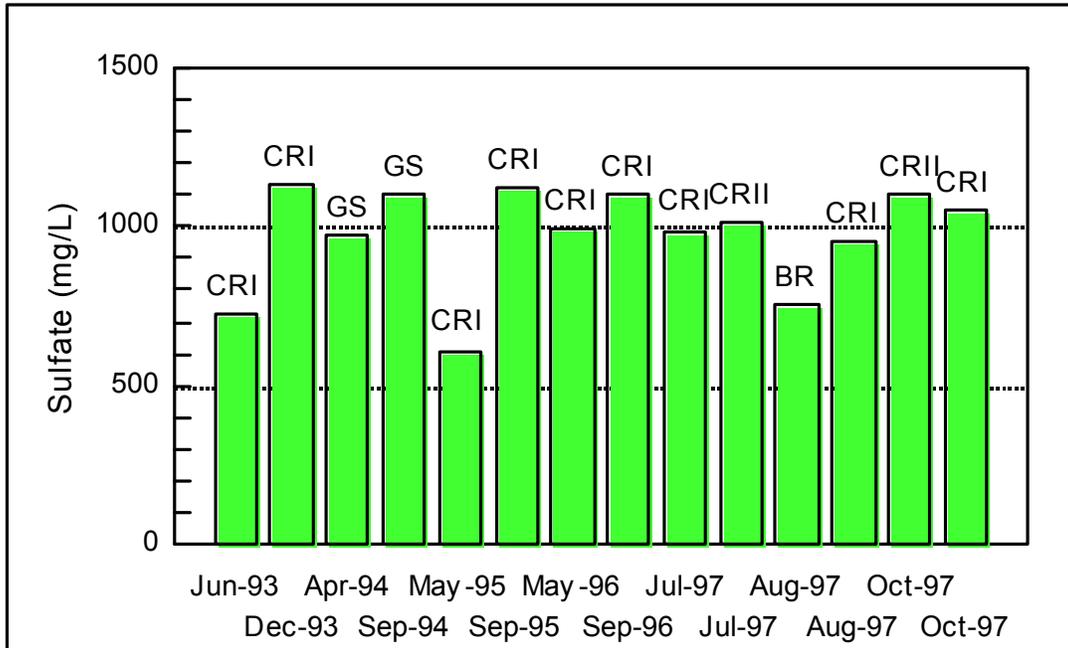
¹ NO₂ + NO₃

no ammonia data for that sample date to evaluate the potential for fish toxicity, including sublethal effects (stress).

Fish samples were collected for bacterial and parasitic analysis by the OST on August 21, 1997 (Byrne, 1997). At the same time one water sample was collected. The water sample contained 0.18 mg/L of ammonia-nitrogen (*ibid.*). The data reported for the sample did not include water temperature, which is necessary to calculate the unionized ammonia fraction. However, if the temperature is assumed to be the same as it was when Reclamation collected a sample from the same site in early August, the unionized ammonia (the toxic form) concentration would have been 0.008 mg/L; the toxic concentration under those same conditions would be 0.043 mg/L. Ammonia toxicity would not be a concern. However, if the total ammonia concentration were 0.18 mg/L on May 15, 1996 when the sample would have had about 50 percent unionized ammonia, then the unionized fraction would be about 0.09 mg/L; the toxic concentration under the same conditions would be 0.05 mg/L, based on the table of 4-day average ammonia criteria for nonsalmonid/nonsensitive species presented in EPA (1986). If these conditions were to occur, stress on fish from ammonia would occur.

The OST has collected samples during the high-flow and low-flow periods. In addition to year-to-year effects on water quality, the instantaneous flow will also affect water quality. There are no flow, EC, or TDS data in Table 6, but the flow effect can be qualitatively illustrated using sulfate, the predominant anion, as a surrogate for EC and TDS. For example, all of the high-flow sulfate concentrations at site CRI are less than 1,000 mg/L, while all of the low-flow sulfate concentrations are greater than 1,000 mg/L (Table 6, Figure 8). This same flow effect is also evident in the NIWQP 1994 verification data, which are plotted on Figure 8 with the OST and Reclamation data. The same effect cannot be shown in the OST data for site CRII, but that site is located farther downstream. In other words the 1,000 mg/L cut-off only holds for sulfate at the Red Shirt site.

The flow effect also seems to show in the sodium and chloride data (Table 6, Figure 8) and in the alkalinity data (Table 6). In the case of alkalinity, there appears to be a cut-off between high-flow and low-flow concentrations like that for sulfate between 170 and 180 mg/L, at least during the type of water years represented by the period 1993 through 1997. Alternatively there is no obvious cut-off for sodium and chloride among years, but the high-flow sample is consistently lower than the low-flow sample for samples collected within each year (Table 6). For example, the high-flow chloride in 1996 is lower than that for the low-flow, but higher than the low-flow chloride in 1993 (Table 6). There is no difference in the high-flow and low-flow chloride in 1997. The same scenario applies to sodium to sodium as that for chloride (Table 6).



Legend:

- BR Bureau of Reclamation at Red Shirt
- CRI Oglala Sioux Tribe at Red Shirt
- CRII Oglala Sioux Tribe east of Davidson Flat
- GS US Geological Survey near Fairburn

Figure 8: Comparison of OST major ion data and those of DOI agencies during 1993 through 1997

Another anion that shows very distinct seasonality related to flow is nitrate. The low-flow samples are all well in excess of 0.5 mg/L and all but one is greater than 1 mg/L (Table 6). All of the high-flow samples are less than 0.5 mg/L.

The flow-effect was evaluated statistically based on a series of Mann-Whitney tests on each of the variables. The results indicate that there is a significant difference in alkalinity, sulfate, and nitrate between high and low flow periods. The apparent differences between sodium and chloride are not statistically significant.

The trace elements shown in Table 6 are all total concentrations. Any relationship to flow will be dependent on the form of the element. If the trace element is predominantly dissolved, any relationship to flow will tend to be inverse. In other words dilution of inflows will dominate. If the trace element is mostly suspended, then a positive relationship is more likely to dominate. The transport of suspended material, such as sediment, increases as flow increases. This also tends to show that the major source of the trace element is erosion, since higher flows are associated with higher runoff from either rainstorms or snow melt. Alternatively if the mechanisms are of near equal importance in determining the concentration of a trace element, there will be no correlation with flow. The trace element data are shown in plots like those for major ions on Figure 9.

There is a statistically significant difference between high and low flow iron and manganese concentrations. In both cases concentrations during high flows are much greater than during low flows. For example, the median high-flow iron concentrations is 5 mg/L, while the median low-flow concentration is 0.7 mg/L; similarly for manganese, the high-flow median is 0.15 mg/L, while that for the low-flow period is 0.045 mg/L. There are no significant differences in the high-flow and low-flow concentrations of the other trace elements.

The set of water samples collected in conjunction with fish sampling in August 1997 were analyzed at Colorado State University in Fort Collins, Colorado. The analyses included both dissolved and total concentrations. The results are shown in Table 7. In addition to the analytical results, Table 7 includes a calculated chronic aquatic life criterion that applies to the dissolved fraction of the total concentration; the table also includes the analytical fraction that is dissolved, as a percent of the total.

Only chromium exceeded its aquatic life criterion (Table 7). It should be noted that the chromium criterion is based on the Cr^{VI} ionic form (chromate or CrO_4^{-2}). The analytical result is based on all ionic forms that pass through a 0.45 μm filter. To further evaluate the speciation of chromium, the analytical results were entered into the equilibrium chemical code, WATEQ4F (Ball *et al.*, 1987). The results of the computer simulation indicate that all of the measurable chromium would be in the form of the Cr^{VI} ion. The comparison shown in Table 7 is considered reasonable.

Table 7: Cheyenne River samples collected at site CRI on 8/21/97 (source: Byrne, 1997)

Trace element	Observed Concentration (mg/L)	Dissolved Fraction (%)	Chronic Criterion (mg/L)
ALUMINUM, DISSOLVED	< 0.10		NA
ALUMINUM, TOTAL	0.02	< 50.0%	NA
ANTIMONY, DISSOLVED	0.09		NA
ANTIMONY, TOTAL	0.12	75.0%	NA
ARSENIC, DISSOLVED	< 0.001		0.19
ARSENIC, TOTAL	< 0.001	≤ 100.0%	NA
BARIUM, DISSOLVED	0.04		NA
BARIUM, TOTAL	0.07	57.1%	NA
BORON, DISSOLVED	0.01	NA	NA
CADMIUM, DISSOLVED	< 0.005		0.0021
CADMIUM, TOTAL	< 0.005	≤ 100.0%	NA
CHROMIUM, DISSOLVED	0.05		0.01
CHROMIUM, TOTAL	0.08	62.5%	NA
COPPER, DISSOLVED	0.01		0.1043
COPPER, TOTAL	0.25	4.0%	NA
IRON, DISSOLVED	0.16		NA
IRON, TOTAL	0.72	22.2%	NA
LEAD, DISSOLVED	< 0.05		0.0164
LEAD, TOTAL	< 0.05	≤ 100.0%	NA
MANGANESE, DISSOLVED	0.01		NA
MANGANESE, TOTAL	0.03	33.3%	NA
MERCURY, DISSOLVED	< 0.001		0.00001
MERCURY, TOTAL	< 0.001	≤ 100.0%	NA
MOLYBDENUM, DISSOLVED	< 0.01		NA
MOLYBDENUM, TOTAL	0.06	< 16.7%	NA
NICKEL, DISSOLVED	0.01		NA
NICKEL, TOTAL	0.05	20.0%	0.9213
SELENIUM, DISSOLVED	< 0.001		5
SELENIUM, TOTAL	0.001	< 100.0%	NA
SILVER, DISSOLVED	< 0.01		0.0034
SILVER, TOTAL	0.02	< 50.0%	NA
THALLIUM, DISSOLVED	< 0.01		NA
THALLIUM, TOTAL	0.07	< 14.3%	NA
ZINC, DISSOLVED	< 0.01		0.1821
ZINC, TOTAL	0.01	< 100.0%	NA

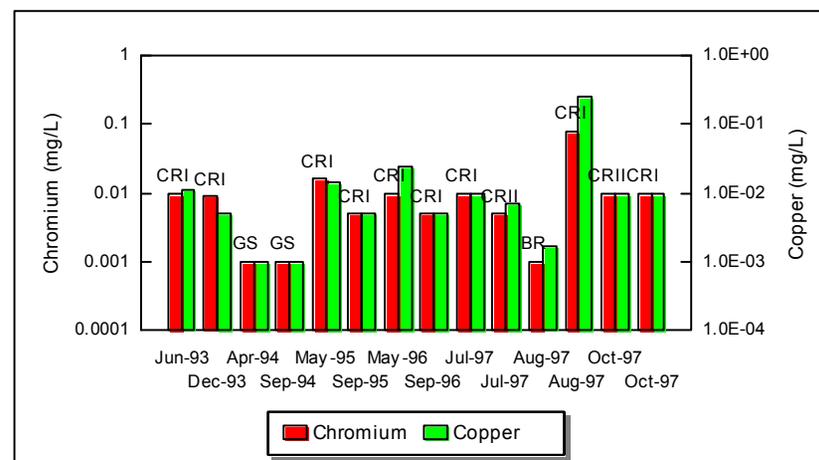
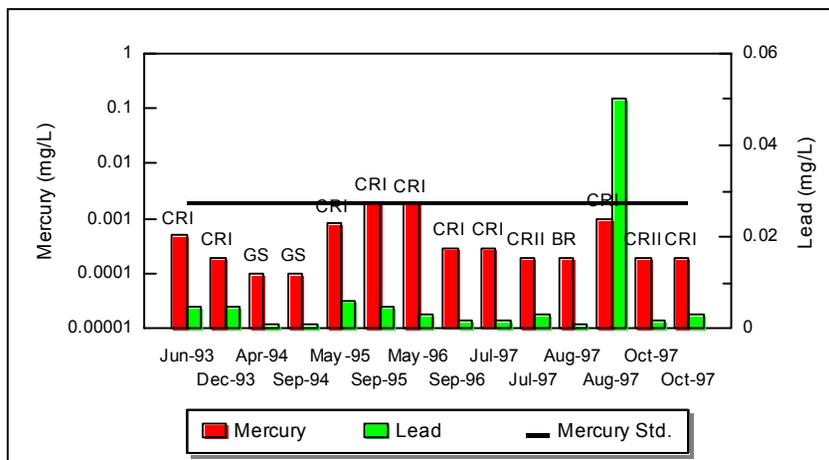
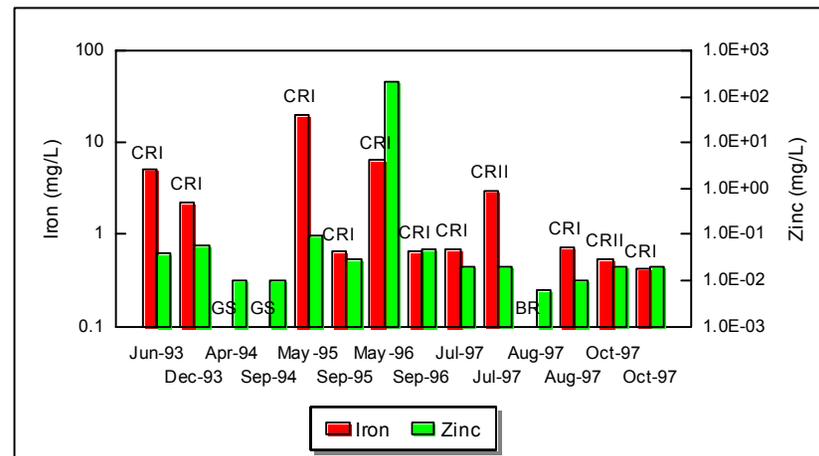
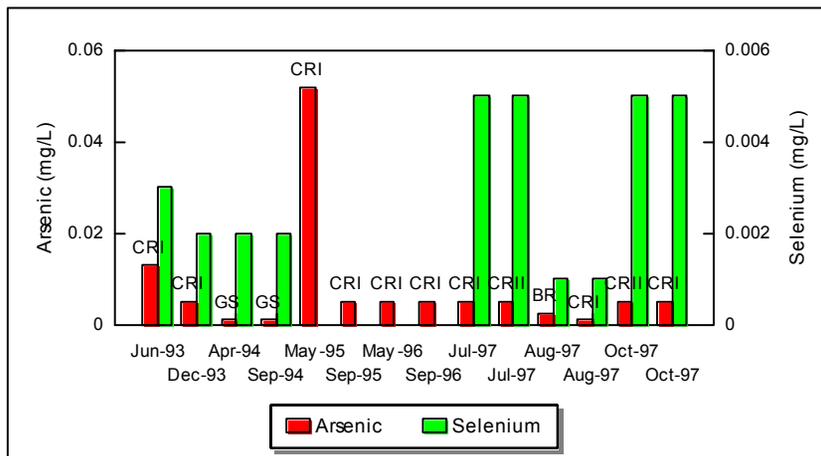


Figure 9: Trace element concentrations in the Cheyenne River near Red Shirt during 1993 through 1997

The data collected by Reclamation and the NIWQP (collectively the DOI data) were to be compared to the OST data. The DOI data consist of the dissolved fraction only. Based on the data in Table 7, the DOI results would represent a small fraction of the total concentration of several of the trace elements, in particular this would apply to copper and lead, both of which are plotted with the OST data on Figure 9. In other words the DOI results would be expected to be lower than the OST data. The difference in copper concentrations is rather obvious in Figure 9, but the difference in lead is not readily apparent. The other trace elements, *i.e.* arsenic, selenium, zinc, and mercury, cannot be evaluated based on the data in Table 7. The dissolved and total concentrations are both at or below their detection limits, and the results can only indicate that the fraction dissolved is less than or equal to 100 percent.

A major concern of the NIWQP was selenium contamination due to irrigation with DOI supplied water. The NIWQP selenium data are summarized in Table 4. The maximum dissolved selenium concentration near Red Shirt (near Fairburn) observed by Greene *et al.* (1990) during 1988 was 4 µg/L. As was noted above, 1988 was a relatively low water year and the concentrations of dissolved solids (including selenium) would be higher than usual. The concurrent DOI and OST selenium data (1993-97) are plotted on Figure 9. The earlier OST data (1993-94) show 2-3 µg/L of total selenium. There are no data for 1995-96. The 1997 data are somewhat variable. In July and October 1997, there was 5 µg/L total selenium. The Reclamation sample in August (Table 4 and Figure 9) and the OST sample in August (Table 7) had < 1 µg/L dissolved selenium (1 µg/L = 0.001 mg/L); there was 1 µg/L total selenium (Table 7 and Figure 9). On the whole the selenium data from the different sources seem consistent. None of the observed concentrations exceed the EPA chronic aquatic life criterion for selenium of 5 µg/L.

Figure 9 shows a plot of the recent mercury data. The plot also shows the primary drinking water standard for mercury (or MCL [maximum contaminant level] = 2 µg/L). The samples for September 1995 and May 1996 approach the MCL (Table 3). The other data are well below the MCL. The 1995 and 1996 data may also represent a case where the suspended concentration is somewhat high. Since the data represent the total mercury concentration, a comparison to the MCL (dissolved concentration) is not totally appropriate. The aquatic life standard for mercury is 0.012 µg/L; the form is a total recoverable concentration, which is assumed to be the biologically available fraction. The mercury aquatic life standard is also well below the detection limit of any of the samples shown in this report. Because of this, there is quite a bit of uncertainty in reporting mercury results. The aquatic life standard is based on the bioaccumulation of mercury to the FDA action level of 1 ppm in fish flesh. Fish samples collected by the DOI and the State of South Dakota do not show elevated mercury. This would indicate that elevated mercury in the water is not excessively bioavailable.

Cheyenne River Sioux Tribe (CRST) Data

The CRST has sponsored two recent studies in the Cheyenne and Moreau rivers (Heakin, 1998; Plateau, 1997). Heakin (1998) is strictly a water quality study that focused on temporal trends and the relationship between ambient concentrations and water quality standards. The Plateau (1997) study encompassed both fish and water quality and reported on the relationship between fish, water quality, and physical habitat in the rivers. The Cheyenne River water quality aspects of both studies are pertinent to the Angostura EIS.

The Cheyenne River in the CRST study area is classified for water quality purposes for warmwater permanent fish life propagation, immersion recreation, and limited contact recreation. Heakin (1998) used water quality criteria for those beneficial uses as well as domestic water supply (primary and secondary maximum contaminant levels [MCL's and SMCL's]), wildlife propagation and stock watering, and irrigation in his study. Heakin (1998) indicates that no MCL's were exceeded, but the SMCL for sulfate (500 mg/L) was exceeded frequently and those for TDS (1,000 mg/L), fecal coliform bacteria, pH (6 - 9), and manganese (50 µg/L) were exceeded with varying frequency. [NOTE - there is no standard for fecal coliforms; the raw water standard of 5,000 total coliform colonies/100mL for waters designated for domestic use was compared to fecal coliform counts.] For irrigation water the sodium adsorption ratio (SAR), for which the standard is 10, was exceeded once in the Cheyenne River at Cherry Creek and the standard for EC (2,500 µmho/cm) was exceeded frequently. The standards for wildlife propagation and stock water were generally met. The suspended solids and ammonia standards for fish propagation were frequently exceeded.

It was noted above that selenium was a major concern of the NIWQP. Heakin (1998) indicates that the chronic toxicity standard for fisheries propagation (5 µg/L) was frequently exceeded. A review of the selenium data for the site indicates that the standard has been exceeded in about 11 percent of the samples collected since 1974. The data set is shown plotted against time in Figure 10. There has only been one time since 1990 that the standard has been exceeded. It appears that the higher concentrations of selenium have decreased in frequency. A plot of the data by Heakin (1998 - see Figure 32) also shows that the maximum selenium values were observed in the mid-1980's. That plot also indicates that the peak selenium concentrations observed since 1990 are lower than those in the previous decade. The associated trend analysis on the Heakin's plot indicates that there is no significant trend. However, the distribution of the data prior to 1980 are similar to the data since 1990, which could mask any recent trend.

Heakin (1998) did find significant trends in the data sets for several measures of water quality in the Cheyenne. There were both increasing trends and decreasing trends. The significant increasing trends were exhibited by TDS, sulfate, and chloride. The latter 2 of which are major components of the TDS and are to a great extent

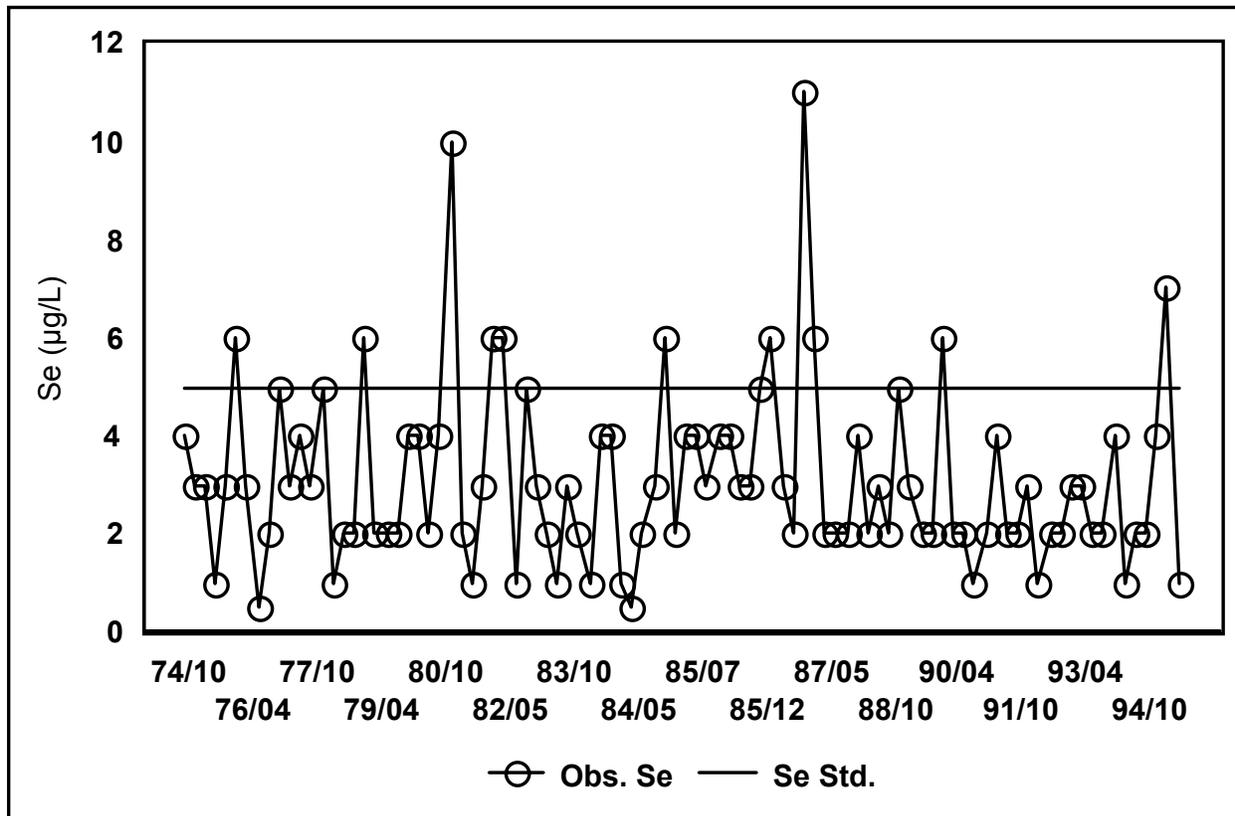


Figure 10: Dissolved selenium in the Cheyenne River at Cherry Creek

responsible for the increasing trend in TDS. The significant decreasing trends are shown by arsenic and manganese. The decrease in arsenic was attributed to the better methods for the disposal of mine tailings that was initiated in 1977 (Heakin, 1998). This may also be true of the manganese decrease as well.

Plateau (1997) collected fish, invertebrate, and water samples between July 28 and August 3, 1997. Water samples were collected from 4 sites in the Cheyenne River for a broad range of chemical analyses (Table 8). The water quality sample sites were located upstream from Bull Creek (CR1), just downstream from Bull Creek (CR2), at the Cherry Creek gage (CR3), and downstream from Little Cottonwood Creek (CR4). The invertebrate and fish samples were collected for enumeration and population analysis; there were no contaminant analyses on any of the biological samples.

Plateau (1997) noted that the water at the time of sampling was highly turbid; this is evident in Table 8. The turbidity increased from 1294 to 3740 NTU (Nephelometric Turbidity Units). The turbidity is a reflection of the high concentrations of total suspended solids (TSS) at each of the sites; these are also shown in Table 8. [Plateau (1997) also attributed the high turbidity to high TDS, but turbidity has nothing to do with TDS.]

TABLE 8. Results of water quality analyses conducted for samples collected at stations on Cheyenne River between July 28 and August 3, 1997.

Parameter	CR1	CR2	CR3	CR4
Water Temperature (°C)	21.0	26.0	24.0	26.0
Dissolved Oxygen (mg/L)	9.0	9.1	11.8	10.5
Biochemical Oxygen Demand (mg/L)	3	3	4	<2
Carbon Dioxide (mg/L)	48.0	39.8	37.0	48.0
Carbonate (mg/L)	<0.1	<0.1	<0.1	<0.1
Bicarbonate (mg/L)	149.4	143.1	151.2	157.3
pH	7.2	7.3	7.3	7.3
Specific Conductance (µmho/cm)	1,190	1,180	1,250	1,250
Chlorophyll <i>a</i> (mg/m ³)	0.4	5.8	3.0	7.5
Turbidity (NTU)	1,294	1,870	2,560	3,740
Total Dissolved Solids (mg/L)	1,007	980	1,011	1,026
Total Suspended Solids (mg/L)	4,636	4,798	12,002	9,678
Ammonia, total (mg/L)	0.80	<.01	0.50	0.64
Ammonia, unionized (mg/L)	0.004	< 0.001	0.004	0.006
Ammonia Nitrogen (mg/L)	0.62	<.01	0.39	0.50
Nitrite, total (mg/L)	<.01	<.01	<.01	<.01
Nitrite Nitrogen (mg/L)	<.01	<.01	<.01	<.01
Nitrate, total (mg/L)	2.20	1.80	2.20	2.20
Nitrate Nitrogen (mg/L)	0.50	0.40	0.50	0.50
Total Kjeldahl Nitrogen (mg/L)	2.67	2.62	3.15	3.03
Alkalinity, total (as CaCO ₃ ; mg/L)	122	117	124	129
Hardness, total (as CaCO ₃ ; mg/L)	448	403	437	450
Calcium (mg/L)	124.5	122.3	129.1	127.4
Fluoride (mg/L)	0.40	0.40	0.30	0.30
Magnesium (mg/L)	33.0	30.8	32.2	31.6
Phosphorus, total (mg/L)	6.70	5.90	6.90	6.20
Phosphorus, dissolved (mg/L)	0.10	0.10	0.10	0.10
Ortho-phosphate (mg/L)	0.02	0.02	0.03	0.02
Potassium (mg/L)	8.00	8.00	8.30	8.20
Sodium (mg/L)	121.0	123.9	122.8	131.9
Chloride (mg/L)	14.6	5.6	16.7	16.1
Sulfate (mg/L)	555.9	545.5	550.0	553.1
Aluminum, total (mg/L)	0.10	<0.1	<0.1	<0.1
Aluminum, dissolved (mg/L)	<0.1	<0.1	<0.1	0.10
Antimony, total (mg/L)	0.91	0.93	0.89	0.93
Antimony, dissolved (mg/L)	0.36	0.24	0.22	0.25
Arsenic, total (mg/L)	<0.1	<0.1	0.10	0.10
Barium, total (mg/L)	0.08	0.08	0.07	0.07
Barium, dissolved (mg/L)	0.08	0.08	0.07	0.07
Boron, total (mg/L)	0.18	0.18	0.19	0.19
Boron, dissolved (mg/L)	0.16	0.17	0.19	0.19
Cadmium, total (mg/L)	<0.01	<0.01	<0.01	<0.01
Cadmium, dissolved (mg/L)	<0.01	<0.01	<0.01	<0.01
Chromium, total (mg/L)	0.03	0.03	0.04	0.03
Chromium, dissolved (mg/L)	0.03	0.02	0.02	0.03
Copper, total (mg/L)	<0.01	0.01	0.01	0.01
Copper, dissolved (mg/L)	<0.01	<0.01	<0.01	<0.01
Iron, total (mg/L)	0.40	0.11	0.02	0.03
Iron, dissolved (mg/L)	0.15	0.01	0.01	0.01
Lead, total (mg/L)	<0.05	<0.05	<0.05	<0.05

TABLE 8. Results of water quality analyses conducted for samples collected at stations on Cheyenne River between July 28 and August 3, 1997.

Parameter	CR1	CR2	CR3	CR4
Lead, dissolved (mg/L)	<0.05	<0.05	<0.05	<0.05
Manganese, total (mg/L)	0.01	0.01	0.01	0.01
Manganese, dissolved (mg/L)	0.01	0.01	0.01	<0.01
Mercury, total (mg/L)	<0.001	<0.001	<0.001	<0.001
Mercury, dissolved (mg/L)	<0.001	<0.001	<0.001	<0.001
Molybdenum, total (mg/L)	0.01	0.01	0.20	0.01
Molybdenum, dissolved (mg/L)	0.01	0.01	0.01	0.01
Nickel, total (mg/L)	0.01	0.02	0.02	0.01
Nickel, dissolved (mg/L)	0.01	0.02	0.01	0.01
Selenium, total (mg/L)	0.017	0.006	0.006	0.007
Silicon, total (mg/L)	11.9	10.3	10.7	11.1
Silicon, dissolved (mg/L)	9.3	9.3	10.3	10.1
Silver, total (mg/L)	0.06	0.05	0.06	0.06
Silver, dissolved (mg/L)	0.01	<0.01	<0.01	<0.01
Thallium, total (mg/L)	0.23	0.19	0.22	0.25
Zinc, total (mg/L)	<0.01	<0.01	<0.01	<0.01
Zinc, dissolved (mg/L)	<0.01	<0.01	<0.01	<0.01

¹ Calculated from dissolved ammonia, temperature, and pH data

Plateau (1997) also noted that the ammonia concentration (dissolved) at CR1 was high (0.62 mg/L - see Table 8) and exceeded the water quality standard proposed by the CRST. The water quality standards proposed by the CRST are shown in Table 9. The proposed standards for ammonia are based on the total dissolved fraction. The standards shown indicate that the chronic standard is 0.80 mg/L (as N), which is higher than the acute standard of 0.52 mg/L (as N). Since the acute standard is the concentration at which fatal toxicity is expected, it should be higher than the chronic standard, which is based on long-term exposure and usually sub-lethal effects. Since the latter effects are insidious and require the longer exposure, lower concentrations will bring about those effects. For example, EPA (1986) has 1-hour (acute) and 4-day (chronic) criteria tables for ammonia at various combinations of temperature and pH. The acute ammonia nitrogen criterion at the temperature and pH of the CR1 sample (Table 8) would be 15.8 mg/L, while the chronic criterion would be 1.7 mg/L. It would therefore appear that the ammonia values have been reversed in Plateau (1997).

Plateau (1997) also noted that the sulfate concentration was high in all samples. The sulfate concentration at all 4 sites was 550 mg/L and is the predominant anion in the Cheyenne River. Nevertheless, this is a much lower sulfate concentration than in samples farther upstream and well within the normal range of USGS samples from the gage at Cherry Creek (see Table 7).

The CRST proposed standards for the 5 trace elements shown in Table 9 differ from the State water quality standards for the Cheyenne River. For the most part the CRST proposed standards are either more conservative (lower) than the State's standards or consist of contaminants for which the State has no standard. For example, the State has no standard for aluminum or thallium, but the CRST proposed standards include

Table 9. - Proposed standards for selected water quality parameters for aquatic resources on the Cheyenne River Indian Reservation, South Dakota [from Plateau (1997), Appendix A, Table A-3].

Parameter	Aquatic Life		Fish Consumption
	Acute	Chronic	
Ammonia Nitrogen (mg/L)	0.52	0.80	--
Aluminum (µg/L)	750	87	--
Arsenic (µg/L)	360	150	0.02
Chromium (µg/L)	16	11	3,400
Selenium (µg/L)	20	2	9,000
Thallium (µg/L)	--	15	61

both an acute and chronic value for aluminum and a chronic value for thallium (Table 9). The State's chronic standard for arsenic is 190 µg/L, which is slightly higher than the CRST proposed standard (Table 9). The State's acute and chronic standards for chromium are each 1 µg/L higher than the CRST proposals, while the State standard for selenium is 3 µg/L higher than the CRST proposal.

The proposed standards for fish consumption are standards for water that are designed to prevent the bioaccumulation of the contaminant in question to a concentration in fish that is considered harmful to humans. The State has no fish consumption standards for either chromium or selenium. The State's fish consumption standard for arsenic is 0.14 µg/L, which is well above the CRST proposed standard, while the State's fish consumption standard for thallium is 6.3 µg/L, which is well below the CRST proposal.

Plateau (1997) compared the results of the July-August 1997 water sampling effort to the CRST proposed standards and indicated that each of the proposed standards shown in Table 9 was exceeded at least one site (compare tables 5 and 6). The aluminum at CR1 exceeded the proposed aquatic life standard. Selenium exceeded the proposed chronic aquatic life standard at all sites and approached the proposed acute standard at site CR1. Chromium exceeded both the proposed acute and chronic standard at all sites. The minimum dissolved chromium was 0.02 mg/L or 20 µg/L, which is within rounding error of the standard (Table 8). The minimum total chromium concentration was 0.03 mg/L or 30 µg/L. Thallium exceeded its proposed aquatic life standard at each of the sites except CR2, where the standard was matched. Plateau (1997) also indicated that arsenic at sites CR3 and CR4, which were each stated to be 100 µg/L, approached the proposed chronic standard of 150 µg/L; however, both results were actually reported at 0.1 mg/L, which is equal to the detection limit. The arsenic at both sites CR1 and CR2 was reported to be < 0.1 mg/L (Table 8). The numerical error associated with results near the detection limit tends to be large on a percentage basis. Consequently the "high concentrations" of arsenic noted by Plateau (1997) may be an artifact of the laboratory analytical method and/or instrumentation.

Sediment

There are two aspects of sediment to consider from a water quality perspective. The first is sediment as a pollutant in and of itself. For example, the DENR (1996) has listed suspended solids, equivalent to total suspended sediment (TSS), as the greatest cause of water quality impairment in the Cheyenne River basin between Angostura Reservoir and the mouth of the Belle Fourche River. The other aspect of suspended sediment relates to its vehicle for the transport of contaminants. Both aspects of sediment will be addressed in this section.

Much of the TSS that is responsible for water quality impairment is attributed to erosion off the Badlands via Sage Creek (DENR, 1996), which empties into the Cheyenne River downstream from the AID. One of the characteristics of a reservoir is that it traps sediment. The accumulation of sediment in the reservoir has been addressed elsewhere. From a water quality perspective, the reservoir removes sediment from the river. There are few TSS data available for the river downstream from Angostura Dam. The only TSS samples were collected during the summer of 1950; all of the data are shown in Table 10. Samples were also collected from a site upstream from the reservoir; contemporary samples from upstream are also included in Table 10.

Table 10. Angostura Reservoir Inflow and Outflow and Suspended Sediment during the Summer of 1950

CHEYENNE R NEAR HOT SPRINGS					BELOW ANGOSTURA DAM		
Average Date	No. of Obs.	No. of Days	Stream Flow, Inst-cfs	Susp Sed Conc mg/L	Date	Stream Flow, Inst-cfs	Susp Sed Conc mg/L
07/11	5	6	846	60,600	07/11/50	109	42
07/18	1	1	105	10,200	07/18/50	125	66
07/24	8	4	789	21,550	07/26/50	197	79
08/05	4	14	1,238	19,575	08/08/50	116	86
08/15	1	1	332	14,200	08/15/50	79	19
08/25	2	20	436	19,400	08/29/50	55	10
09/05	5	3	2,864	31,100	09/19/50	28	12

Most of the upstream samples were not collected on the same dates as the downstream samples. The upstream data represent an average for a period that precedes or includes the date of the downstream sample. In Table 10 the number of observations is the number of samples in the average, while the number of days is the period that was included in the average. The comparison is somewhat complicated by the fact that there is a variable travel time through the reservoir. The travel time is affected by the flow and by the reservoir content. In addition stratification within reservoir can dictate the formation of currents that can short-circuit travel through the reservoir. High concentrations of TSS will also affect the density of the inflowing water; this can also affect the way in which the water is routed through the reservoir. What all of this means is that the comparison in Table 10 is something of an oversimplification of

a complex situation. Nevertheless Table 10 provides an example of what happens in the reservoir.

There are two mechanisms that can affect the TSS concentration in the reservoir. The first is settling. When the flowing water enters the reservoir, the velocity declines significantly as the inflow mixes with the water already in the reservoir. The ability to transport sediment is greatly affected by velocity. As the velocity declines, the ability to transport sediment decreases, depositing the sediment. The deposition is related to the size and composition of the particles. In general, the larger particles are deposited first, while the finer particles are transported farther in the reservoir. Some particles may be carried through the reservoir to the river downstream. This is reflected in the sediment concentrations in Table 10.

The complete inflow TSS data set is shown on Figure 11. The plot shows the inflow TSS for the period prior to sample collection downstream from the dam. The plot is on semi-log axes because the variation in the inflow TSS concentration and difference between the inflow and outflow TSS are so large. It should be noted that there are still only 7 samples below the dam; there appear to be more on figure 11 because of interpolation between adjacent points in the data set. Since Figure 11 is only intended as a qualitative illustration, this should not be a problem.

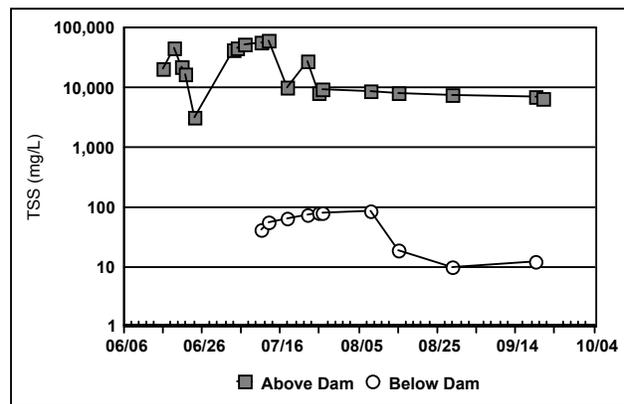


Figure 11: Inflow and outflow TSS at Angostura Reservoir during 3 months in 1950

There are several orders of magnitude of difference between the TSS of the inflow and outflow of Angostura Reservoir (Table 10; Figure 11). For design purposes, Reclamation assumes that 100 percent of the inflowing sediment will be retained in the reservoir. The average inflow TSS concentration for the data in Figure 11 is 24,800 mg/L; the average TSS in the outflow is 52 mg/L. If these are representative data, then 99.8 percent of the sediment was being retained in the reservoir.

The appearance imparted to water by suspended material is more of a consideration to most than the actual concentration of TSS in the water. The measure of the visual effect of TSS is turbidity. Turbidity data for the Cheyenne River are shown in Table 11. Table 11 also includes all of the TSS data collected at the inflow site for Angostura Dam. The samples were collected between 1949 and 1967. The turbidity samples shown as "Above Dam" were collected at two sites by the TVA (Tennessee Valley Authority) between 1983 and 1989. The sample sites were above and below the Edgemont Uranium Mill UMTRA cleanup, but both above the reservoir. There are a large number of samples. The sample design involved hourly samples for 24 hours

Table 11. Suspended Solids and Turbidity at Three Sites on the Cheyenne River

	Above Dam		Below Dam		Near Mouth	
	Susp Sed Conc mg/L	Turbidity FTU	Susp Sed Conc mg/L	Turbidity NTU	Susp Sed Conc mg/L	Turbidity JTU & NTU
Minimum	8	< 1	10	< 1	< 1	< 1
Median	14,000	17	42	10	390	61
Maximum	68,200	14,625	86	25	53,900	12,000
# of Obs.	162	1503	7	7	184	144

FTU - Formazin Turbidity Unit

JTU - Jackson Turbidity Unit

NTU - Nephelometric Turbidity Unit

either once a month or following storms. Consequently the samples are in sets of 24 that are internally aggregated; in other words they are not independent samples in a statistical sense. From that perspective, there are considerable fewer than the 1500 samples shown in Table 11. There are no concurrent TSS samples in the TVA data set.

The turbidity data that are also included in Table 11 have 3 different measurement units their equivalent abbreviations are also shown in the table. The original measure of turbidity was the Jackson candle turbidimeter (APHA, 1992); turbidity was measured in JTU. The minimum turbidity that the Jackson candle could measure was about 25 JTU (APHA, 1992), a value that would be characteristic of clear pond water (McKee and Wolfe, 1963). The currently preferred method is to use a turbidimeter (or nephelometer). The turbidimeter is standardized against a suspension of formazin polymer. An FTU is any turbidity measure against a formazin standard. The NTU is an FTU as measured on a nephelometer, which can measure down to 0.1 NTU. The drinking water standard for turbidity is 1 NTU, which is assumed to indicate the presence of bacteria. The NTU (= FTU) is equal to a JTU at 40 units. The measures will deviate from each other as one moves away from 40 units depending on the instrument used; they are nevertheless considered equivalent (Fishman and Friedman, 1989).

Table 11 contains both TSS and turbidity data for a third site near the mouth of the Cheyenne River. Specifically the site is at the USGS gage at Cherry Creek Village. Of the 144 turbidity samples collected at the third site, there are 78 with concurrent TSS data. The turbidity and TSS data show a relatively good correlation ($r^2 = 0.65$). However, when an obvious pair of outliers is dropped from the data set, the r^2 improved to 0.95. The equation without the outliers is:

$$\text{Turb.} = (0.3201 * \text{TSS}) - 3.0294$$

Based on this equation, turbidity is about a the TSS.

It should be noted that turbidity only relates in part to the TSS concentration. The turbidity is also affected by the shape and distribution of particles within the sample.

The r^2 of 0.95 would indicate that the sediments are comparatively uniform in size from sample to sample and fine enough to be similarly dispersed throughout the samples.

The turbidity data shown in Table 11 for the site below the dam are not actual turbidity measurements. The turbidity data were developed using the above turbidity equation. How accurate this might be is unknown since the relationship reflects conditions well downstream from the dam. If it is accurate, then the dam releases would have a turbidity of 25 NTU or less. This is consistent with the type of clear water release that is characteristic of dams.

The TSS samples at the site at Cherry Creek were collected between June 1972 and August 1995. Obviously this is later than the TSS samples near the reservoir, but it includes the period during which the TVA samples were collected. The range of TSS in the samples collected at the site upstream from the reservoir is somewhat greater than that at the Cherry Creek gage (Table 11). The turbidity range is also much larger at the upstream site. Since the reservoir is between the two sites, most of the sediment at the Cherry Creek gage would be expected to have originated from inflows downstream from the dam.

The Cheyenne River gage near Wasta also has limited data on both turbidity and TSS. The Wasta gage is nearest gage downstream from the project area, but it is also downstream from the Sage Creek confluence. The 7 turbidity and TSS samples are shown in Table 12 along with stream flows and sample dates. The turbidity samples were collected in less than a year during 1969-70, while the TSS samples were collected over a 4-year period during 1983-87 (Table 12). The turbidity samples were collected over a relatively small range of flow (42-188 ft³/s) and show a comparably small range. The TSS samples on the other hand were collected over a very broad range of flow (64-20,300 ft³/s) and show an appropriately broad TSS range. The TSS data are consistent with the effects of storm runoff with erosion as the sediment source. It is also consistent with the DENR (1996) characterization of sediment sources and patterns downstream from Angostura Dam.

Table 12. Flow, Turbidity, and TSS in the Cheyenne River near Wasta

Sample Date	Stream Flow ft ³ /s	Turbidity (JTU)	Sample Date	Stream Flow, Inst-ft ³ /s	TSS mg/L
08/27/69	68	73	06/09/83	127	108
09/24/69	90	32	09/26/83	108	13
10/30/69	115	45	01/04/84	64	35
12/16/69	102	10	06/10/86	20,300	39,200
02/10/70	66	40	03/07/87	3,460	15,429
03/10/70	42	40	06/23/87	125	475
06/10/70	188	35	08/31/87	112	451

The relationships between flow and TSS, for each of the above discussed gages on the Cheyenne River, along with one for turbidity at the Cherry Creek gage, are illustrated by the regressions in Table 13. All of the regressions are statistically significant at an of level less than or equal to 0.01; the turbidity and flow data presented in Table 12 for the gage near Wasta do not produce a statistically significant regression ($r^2 = 0.26$). The two seemingly best regression relationships shown in Table 13 are for the gages below Angostura Dam and near Wasta; however, both are based on only 7 observations. Because of the limited data sets on which these are based, the relationships represent a limited range of conditions and cannot be used as predictive tools. Alternatively, the r^2 -values for the other regressions are less than 0.5, indicating that the regressions explain less than 50 percent of the variation in the dependent variable (*i.e.*, TSS or turbidity). Because of the small r^2 -values, these regressions are not good predictive tools either. As a generality the regressions indicate that there is a relationship between the TSS concentration, but it is more complex than what can be quantified by a simple linear regression.

Table 13. Summary of Regressions of TSS on Flow (Q) and Turbidity on Flow at USGS Gages on the Cheyenne River

	Hot Springs below Dam		near Wasta	at Cherry Creek	
	TSS - Q	TSS - Q	TSS - Q	TSS - Q	Turb - Q
r^2	0.386	0.764	0.829	0.358	0.468
r	0.621	0.874	0.911	0.598	0.684
<i>d.f.</i>	160	5	5	177	138
b_1	0.745	1.248	1.229	0.975	1.260
b_0	4.712	-2.076	-1.066	0.765	-2.909
Begin date	10/20/49	07/11/50	06/09/83	07/05/72	10/03/74
End Date	08/01/67	09/19/50	08/31/87	08/28/95	08/28/95

NOTE - the above regressions are fitted to an equation of the form:

$$TSS = \exp([b_1 \cdot \ln\{Q\}] + b_0)$$

Ten different fractions based on particles sizes have been sampled over the years at the Hot Springs gage near the reservoir inflow. The different fractions have been sampled with varying frequencies over the years. Table 14 shows the regressions of the concentrations as a function of flow; the regressions are in the same form as those in Table 13. What is interesting about the regressions based on particle size fractions is that, in general, the r^2 improves as the size of the particles increases for particle sizes up to 0.125 mm. The slope of the regression line also increases up to the same point. This is a reflection of the fact that the smaller particles are transported independent of flow. In other words, most any flow is high enough to carry the very finest particles. As the particles increase in size, transport becomes a factor; *i.e.* larger flows are needed to carry the larger particles.

Table 14. Regression of Size Fractions of Suspended Solids on Flow

Particle Size	r ² [%]	r	d.f.	Prob. > r	b ₁	b ₀
<2µm	6.1%	0.247	96	< 0.05	0.284	6.802
2-4µm	8.1%	0.285	142	< 0.01	0.369	5.518
4-8µm	25.2%	0.502	81	< 0.01	0.557	3.821
8-16µm	19.9%	0.446	141	<< 0.01	0.654	3.966
16-31µm	32.9%	0.573	67	<< 0.01	0.824	1.338
31-62µm	14.3%	0.378	144	<< 0.01	0.618	3.658
62-125µm	58.4%	0.764	63	<< 0.01	1.236	-2.687
0.125-0.25mm	77.2%	0.879	20	<< 0.01	1.309	-2.495
0.25-0.5 mm	67.4%	0.821	53	<< 0.01	1.242	-2.917
0.5-1 mm	63.8%	0.799	28	<< 0.01	1.030	-1.995

The regressions shown in Table 14 are plotted individually against flows between 1 to 6,500 ft³/s on Figure 12A. The relationships are somewhat confounded by the varying number of samples in each of the particle data subsets (Table 15). The problem is that the data are published as cumulative frequency distributions. The concentrations for the individual size fractions were calculated from the total concentration by multiplying the TSS by the cumulative frequency for a fraction and subtracting the similar value for the previous fraction. Where a fraction is missing, then the calculated concentration is actually the concentration of two or more size fractions, depending on the intervening number that were not reported. Since this is not a sediment transport study, but an environmental impact analysis, this problem is not considered critical to the results.

Most of the curves on Figure 12A are similar in form. There is a rapid increase at lower flows, followed by an attenuated increase as the flow increases beyond 1,000 ft³/s. The two exceptions are the 8-16 µm (10⁻³ mm) fraction and the 0.125-0.25 mm fraction. The 8-16 µm fraction shows a nearly linear increase continuously to the 6,500 ft³/s maximum shown on the figure. The 0.125-0.25 mm fraction increases at an increasing rate at flows beyond about 2,500 ft³/s. Neither of these trends is sustainable. Each of the regressions is based on a maximum flow of 6,540 ft³/s with the lone exception of the 0.125-0.25 mm fraction, which had a maximum flow of only 3420 ft³/s. The plot of the fraction is being extended well beyond the maximum observed. In this case such an extrapolation is inappropriate. Alternatively the reason for the anomaly for the 8-16 µm fraction cannot be explained based on the data. This may be a reflection of the much smaller number of samples in the previous size fraction. The smaller data set has the effect of increasing some of the data in 8-16 µm fraction. For example the median for the 8-16 µm fraction is much larger than medians for the adjacent fractions (Table 15).

Figure 12B shows a comparison of the sum of the concentrations in the various size fractions from Figure 12A and the concentrations from the TSS-flow regression shown in Table 13. The results are similar at the lower flows, although the summed TSS increases somewhat more rapidly. This is a reflection of the effect of the very fine sediment fraction (< 2 µm), which shows a very rapid increase at flows less than 1,000

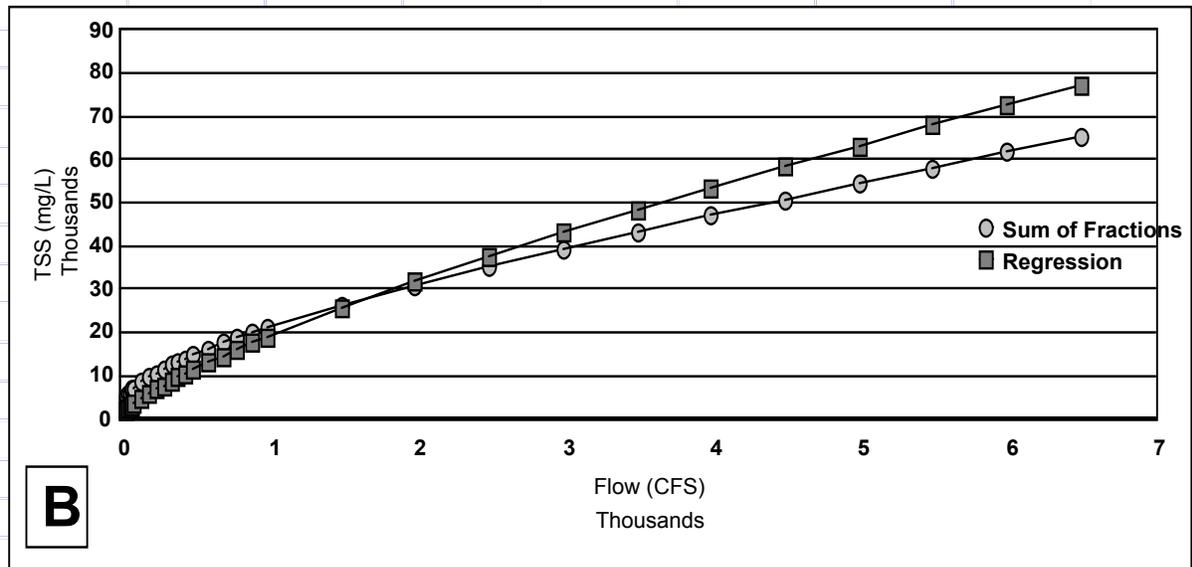
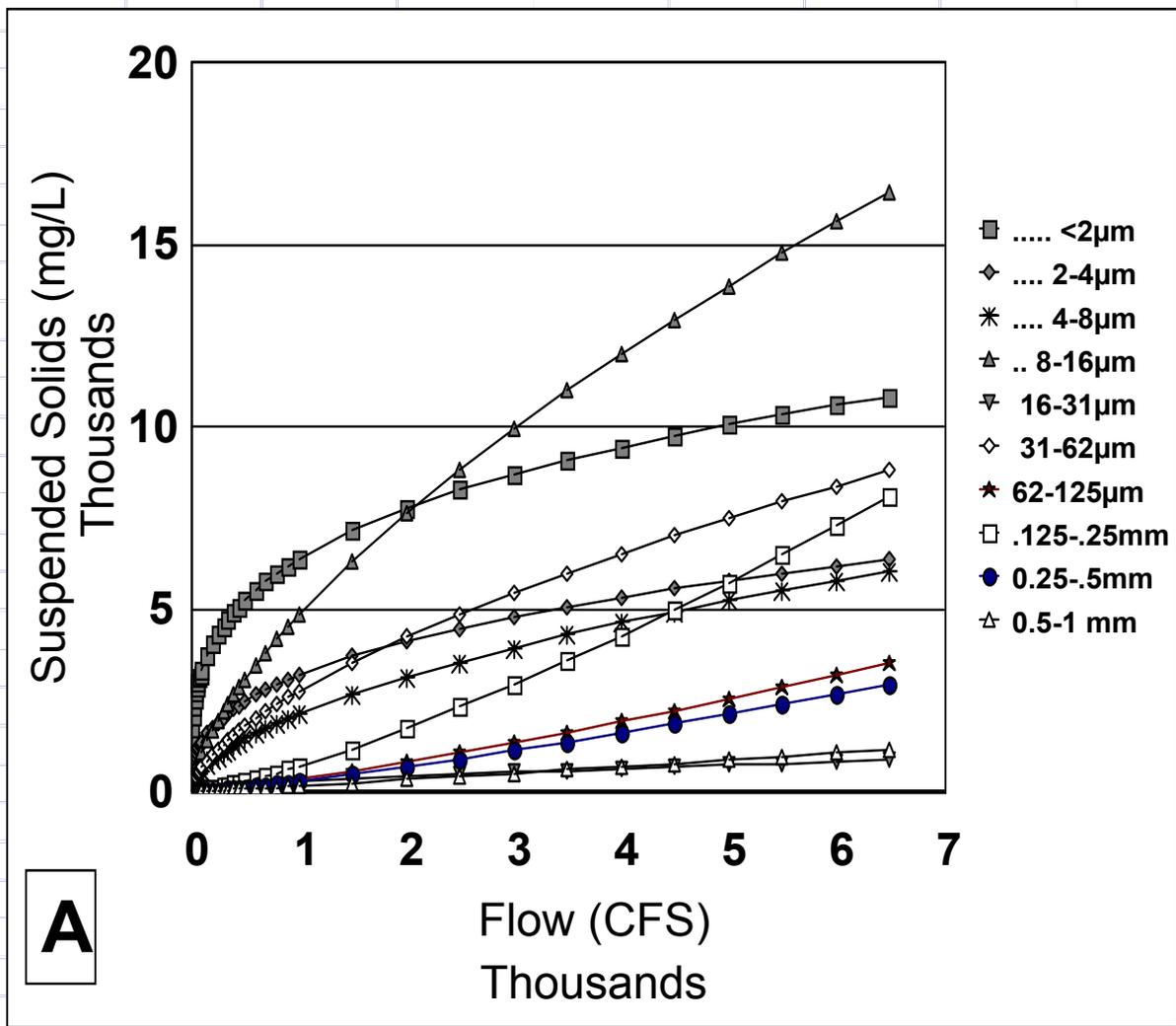


Figure 12 :Total and individual suspended solids fractions as a function of flow

Table 15. Summary Statistics for Flow and Suspended Solids (mg/L) Regressions

	Stream Flow, ft ³ /s	Total Susp Sed Conc	Stream Flow, ft ³ /s	Susp Sed Part. Size <2µm	Stream Flow, ft ³ /s	Susp Sed Part. Size 2-4µm
Minimum	18	8	32	124	18	66
Median	413	14,000	443	6,449	443	2,497
Maximum	6,540	68,200	6,540	38,190	6,540	39,476
# of Obs.	162	162	98	98	144	144

	Stream Flow, ft ³ /s	Susp Sed Part. Size 4-8µm	Stream Flow, ft ³ /s	Susp Sed Part. Size 8-16µm	Stream Flow, ft ³ /s	Susp Sed Part. Size 16-31µm
Minimum	32	46	18	10	32	12
Median	484	1,444	455	3,146	608	651
Maximum	6,540	12,060	6,540	53,932	6,540	63,426
# of Obs.	83	83	143	143	69	69

	Stream Flow, ft ³ /s	Susp Sed Part. Size 31-62µm	Stream Flow, ft ³ /s	Susp Sed Part. Size 62-125µm	Stream Flow, ft ³ /s	Susp Sed Part. Size .125-.25mm
Minimum	18	8	42	3	88	12
Median	453	1,452	669	246	1,040	670
Maximum	6,540	56,745	6,540	30,987	3,420	2,096
# of Obs.	146	146	65	65	22	22

	Stream Flow, ft ³ /s	Susp Sed Part. Size .25-.5mm	Stream Flow, ft ³ /s	Susp Sed Part. Size 0.5-1 mm
Minimum	24	1	24	3
Median	653	216	1,040	143
Maximum	6,540	3,808	6,540	1,245
# of Obs.	55	55	30	30

ft³/s (Figure 12A). The two curves diverge greatly at higher flows and differ by about 12,000 mg/L at 6,500 ft³/s. At higher flows the sum of the fractions gives a much better estimate of the TSS than does the regression equation. The measured maximum TSS was 68,000 mg/L (Table 15). The maximum TSS from the sum of the fractions is 65,200 mg/L, while the TSS-Q regression gives a TSS of over 77,000 mg/L.

The above provides the basis for the evaluation of the effects of the various contract renewal alternatives. Alternatives that increase the storage, and consequently the

amount of time that the water remains in the reservoir, relative to existing conditions, the more TSS will be removed from the water. The reverse will also be true and alternative that decrease the storage will increase the TSS in the releases relative to existing conditions. However, as long as the dam remains in place, some sediment would still be removed relative to the TSS of a free-flowing river.

Contaminants

Reclamation collected bed sediment samples on August 4, 1997. The NIWQP had only sampled bed sediments on 1 date during the 1988 reconnaissance study of the Angostura Unit, and no sediments were sampled during the 1994 verification study. The purpose of sampling the Cheyenne River sediments in 1997 was to update and expand the database developed by the NIWQP. The NIWQP database include 9 sites between the Edgemont gage and Red Shirt (see Greene *et al.*, 1990; Table 23). Reclamation resampled 4 of the NIWQP sites, and sampled 3 other NIWQP sites where water or biotic samples had been collected, but no sediment sample. Sample locations and site numbers, which were assigned their NIWQP equivalent where appropriate, are as follows:

- 4a. Angostura Reservoir - Inflow Site
- 4b. Angostura Reservoir - Horsehead Creek Arm
- 4c. Angostura Reservoir near Dam
- 6 Angostura Canal
- 6S Angostura Canal - split
- 9 Topeska's Pond
- 10 Iron Draw
- 11 Kimmie's Pond
- 12 Cheyenne River near Custer County Road 656 Bridge
- 14 Cheyenne River near Fairburn (Red Shirt)
- CRRC Cheyenne River at Rapid Creek
- CRCC Cheyenne River at Cherry Creek

The two additional sites (CRRC and CRCC) that were sampled downstream from the NIWQP study area were added to supplement the data and extend the study area to near the confluence with the Missouri River. The complete set of Reclamation results are shown in Table 16.

The NIWQP evaluated sediment contamination by comparing the sample data against a baseline for Western U.S. soils that was published by Shacklette and Boerngen (1984). The rationale for this is that most of the stream and lake sediments were derived from eroded soils and the chemical composition of the sediment should reflect that origin. The baseline is shown in Table 17 for the elements analyzed in any samples that are to be used in this report, including those collected by the NIWQP, Reclamation, the OST, and the CRST. The Shacklette and Boerngen (1984) baseline does not include all of the elements that were analyzed in the above referenced studies, *e.g.* cadmium was not included.

Table 16. Sediment Samples - Cheyenne River and Angostura Reservoir during 1997 (All in ppm, unless otherwise noted)

	4a	4b	4c	6	6S	9	10	11	12	14	CRRC	CRCC
Wet Wgt. [g.]	16.30	14.28	15.73	18.52	18.52	16.65	14.81	14.59	16.13	17.61	15.73	12.10
Dry Wgt. [g.]	6.72	3.43	4.87	13.53	13.53	5.23	9.97	9.78	13.45	10.90	9.14	8.32
TOC [%]	1.26	0.78	1.31	0.55	0.62	3.19	0.39	1.13	0.09	0.31	0.66	0.41
Arsenic	5.1	7.2	16.4	13.0	10.3	10.2	6.4	10.8	21.7	4.9	15.9	104.3
Boron	20	27	19	6	5	23	4	14	9	12	12	7
Barium	192	146	232	81	47	88	84	157	615	436	561	403
Cadmium	1.3	1.5	1.4	0.6	0.6	0.7	0.3	0.7	0.2	0.6	0.5	1.9
Chromium	23.0	27.0	21.0	4.0	4.0	7.0	6.0	17.0	2.0	10.0	14.0	12.0
Copper	20.0	26.0	29.0	7.0	7.0	8.0	9.0	19.0	4.0	12.0	24.0	19.0
Lead	19	< 48	< 62	< 146	< 146	< 63	< 135	< 135	< 167	21	< 116	< 138
Molybdenum	5.9	7.3	7.5	4.0	3.0	3.9	1.9	5.4	6.9	3.4	4.7	3.9
Nickel	26.0	28.0	39.0	14.0	12.0	14.0	11.0	23.0	20.0	13.0	31.0	23.0
Selenium	1.0	0.4	1.9	0.3	0.4	1.0	0.9	0.5	0.7	0.2	0.5	0.8
Vanadium	25.0	43.0	46.0	12.0	11.0	16.0	12.0	30.0	19.0	19.0	24.0	21.0
Zinc	59.0	97.0	95.0	28.0	24.0	71.0	36.0	317.0	52.0	40.0	91.0	63.0
Mercury	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Thorium	11.5	15.7	13.3	7.0	9.3	9.2	8.1	10.8	4.8	10.6	11.9	10.0
Uranium	4.2	5.1	5.8	2.8	3.2	17.8	2.5	3.3	2.7	3.2	3.4	3.2
Calcium	81,297	22,709	57,734	83,481	77,696	23,348	8,196	13,901	17,437	27,619	13,860	23,286
Magnesium	22,426	10,716	6,117	4,723	3,344	2,930	1,912	6,077	1,036	4,716	6,313	5,760
Sodium	711	1,419	936	271	261	704	341	593	152	1,000	854	654
Potassium	5,802	7,120	4,338	801	632	1,507	837	2,992	308	4,039	2,522	2,051

NOTE: TOC is Total Organic Carbon.

Wet weight is the weight of the sample as received from the field.

Dry weight is the weight of the sample after drying, but before grinding.

Table 17: Various baselines for evaluating Cheyenne River sediments [all in ppm]

Element	-----Western States----- Soils Baseline			Crustal & Sedimentary Rock Abundance Values				
	Lower C.L.	Mean	Upper C.L.	Earth's Crust [CAV]	Clays & shales	Shales	Sandstones	Carbonate rocks
Arsenic	1.2	5.5	22	1.8	6.6	13	1	1
Boron	5.8	23	91	9.0	100	100	35	20
Barium	200	580	1,700	390	800	580	< 10	10
Calcium	1,900	18,000	170,000	46,600	25,300	22,100	39,100	302,300
Cadmium	No Data	No Data	No Data	0.2	0.3	0.3	< 0.1	0.035
Chromium	8.5	41	200	122	100	90	35	11
Copper	4.9	21	90	68	57	45	< 1	4
Mercury	0.0085	0.046	0.25	0.086	0.4	0.4	0.03	0.04
Potassium	3,800	18,000	32,000	18,400	22,800	26,600	10,700	2,700
Magnesium	1,500	7,400	36,000	27,600	13,400	15,000	7,000	47,000
Molybdenum	0.18	0.85	4.0	1.2	2	2.6	0.2	0.4
Sodium	2,600	9,700	37,000	22,700	6,600	9,600	3,300	400
Nickel	3.4	15	66	99	95	68	0.2	20
Lead	5.2	17	55	13.0	20	20	7	9
Selenium	0.039	0.23	1.4	0.05	0.6	0.6	0.05	0.08
Thorium	4.1	9.1	20	8.1	11	12	1.7	1.7
Uranium	1.2	2.5	5.3	2.3	3.2	3.7	0.45	2.2
Vanadium	18	70	270	136	130	130	20	20
Zinc	17	55	180	76	80	95	16	20

Sources: Western States Baseline: Shacklette and Boerngen, 1984.

C.A.V.: Fortescue, 1992.

Sedimentary rock values: Parker, 1967.

A baseline that is used in exploration geochemistry is based on crustal abundance values (CAV). These are average concentrations in the earth's crust; concentrations that are greatly above these average CAV's are indicative of mineralized areas. In the Cheyenne Basin, many of the tributaries to the river originate in the Black Hills, which are predominantly dolomite [$\text{CaMg}(\text{CO}_3)_2$]. Other parts of the drainage basin are composed of a variety sedimentary rocks. For this reason abundance values for a variety of sedimentary rocks are also included in Table 17. Table 17 also illustrates the variability in the chemical composition of natural materials.

The comparison to the Western soils baseline indicates that more often than not, concentrations in the samples were below the lower confidence limit, rather than above the upper confidence limit. This is particularly true of barium and chromium among the trace elements and sodium and potassium among the more common elements; each of these elements were below the soils baseline at a majority of the sites.

There has been uranium mining and milling upstream from Angostura Reservoir. Erosion of mine and mill tailings has been implicated in loading of uranium to the reservoir sediments (Rahn *et al.*, 1996; NRC, 1982). Uranium exceeded the upper confidence limit of the soils baseline at only one of the sites in the reservoir, the site nearest the dam (site 4c). This would indicate that the uranium was associated with the finest sediments; coarser particles would settle more quickly and be deposited nearer the inflow area of the reservoir. The baseline was exceeded by the greatest margin in the only other site where the sample exceeded the uranium baseline, site 9 (Topeska's Pond), which is located off the river. The sample exceeded the upper limit of the baseline by a factor of slightly more than 3 (tables 10 and 11) The source for the uranium in the pond is unknown, but it seems unlikely that it came from the river or the reservoir.

Molybdenum (Mo) is the only other trace element that is elevated at more than one sample site. Mo is above the upper limit of the soils baseline at each of the reservoir sites. The sediments in the reservoir originate from areas upstream from Angostura Reservoir. Webb and Rahn (1994) indicate that the Inyan Kara Group is known to contain anomalously high concentrations of molybdenum associated with uranium deposits, some of which are adjacent to the Cheyenne River. The molybdenum could originate from either uranium mining or natural weathering of these rocks.

The reservoir sediment sample collected from the reservoir near Angostura Dam had a high concentration of selenium. Webb and Rahn (1994) also indicate that the same rocks that had the high concentration of molybdenum, contained high concentrations of selenium. The selenium could originate from the same source as the molybdenum, but in apparently finer material, since it was not deposited in the upper areas of the reservoir.

Arsenic and zinc were also above the upper confidence limit for Western soils at one site each. The elevated arsenic was observed in the sample collected from the site at

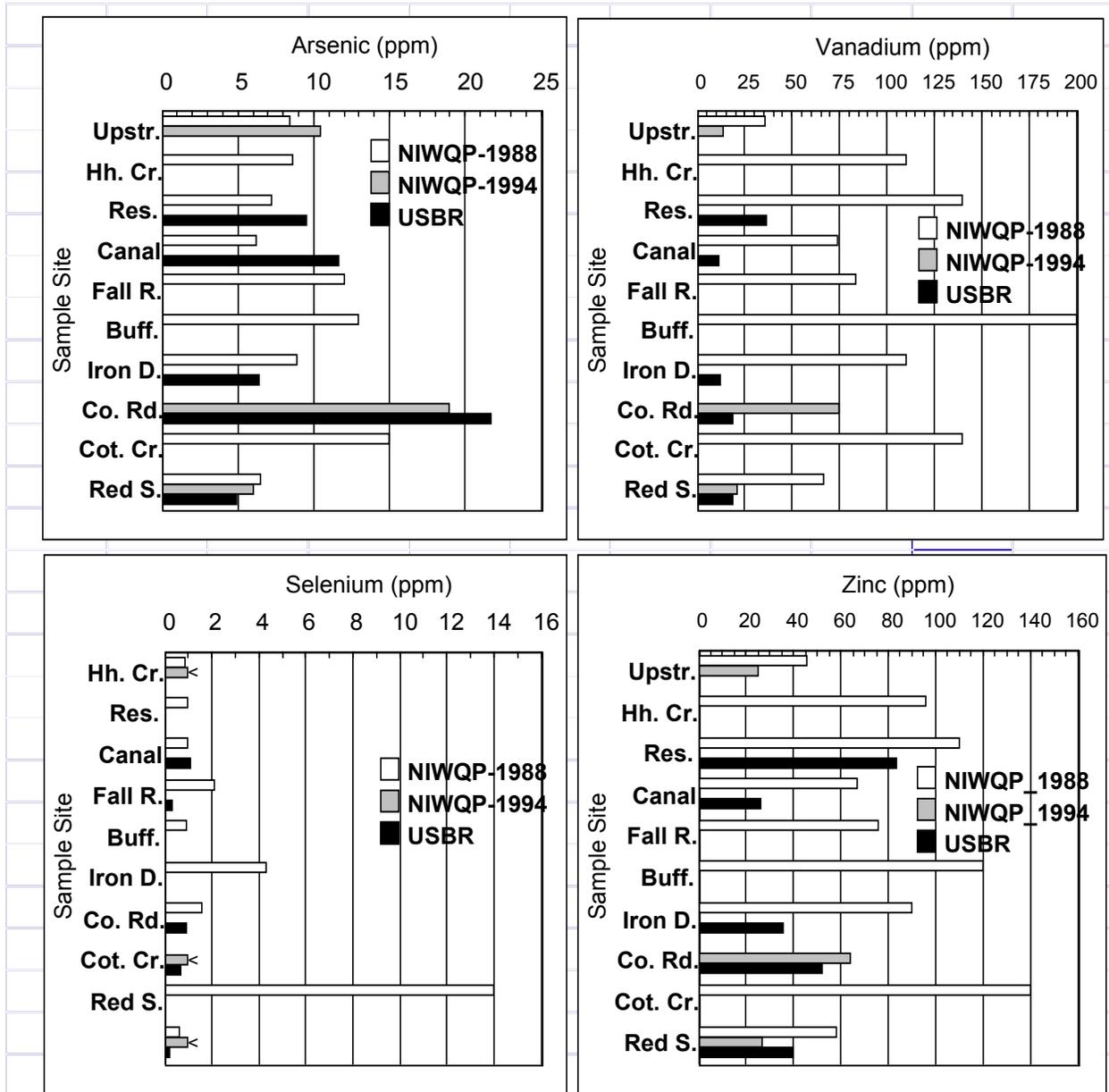
Cherry Creek, which is located downstream from the mouth of the Belle Fourche River. Arsenic is a significant pollutant in the former gold fields of the Whitewood Creek basin. An estimated 100 million metric tons of finely ground gold-mill tailings were discharged to Whitewood Creek near Lead between 1876 and 1977 (Goddard *et al.*, 1987). The primary contaminant is arsenic derived from, or still present as arsenopyrite (FeAsS), a gangue mineral common to the gold deposits around Lead (*ibid.*). Other elements identified in the tailings are antimony, cadmium, copper, iron, manganese, mercury, and silver (*ibid.*). Whitewood Creek is a tributary to the Belle Fourche River at the probable source of the arsenic in the sample from the site near Cherry Creek.

Zinc was elevated relative to the soils baseline in the sample collected from Kimmie's Pond (site 11). This site is located off stream; the site was chosen by the NIWQP as potentially receiving irrigation return flows. No water or sediment samples were collected from the site by the NIWQP, but biological samples were collected. Zinc was not elevated at the site (Greene *et al.*, (1990).

The CAV values shown in Table 17 are based on an assumed average crustal composition that is predominantly igneous rock (95 percent - see Clarke and Washington, 1924). In an environment such as that of the AID, this may not be particularly appropriate. In the Project area, the reservoir, much of its drainage basin, and the Cheyenne River to a point a couple of miles downstream from Angostura Dam, are underlain by Mesozoic sedimentary rocks, predominantly shales and limestones (Greene *et al.*, 1990). Most of the remainder of the Project area is underlain by Pierre Shale. Igneous rocks are confined to an area to the north of the Project area in the headwaters of Beaver Creek (see Greene *et al.*, 1990 - Figure 2). If the sediments in the Cheyenne River are derived from the rocks in the drainage basin, the chemical composition should represent a mix of shale and limestone. Based on the data in tables 10 and 11, the sediments are principally derived from the shales. This is consistent with the conclusion of Greene *et al.* (1990) that their samples were similar in trace element composition to Department of Energy samples from Foxhills Sandstone and Pierre Shale surface exposures.

The purpose for sampling the sediments in this study was to expand the NIWQP data base and to compare the more recent samples. Selected elements from the 1988 and 1994 NIWQP samples and the 1997 Reclamation samples are shown on Figure 13. In 1988, the NIWQP sampled several areas in the reservoir, but the samples were composited into one sample for analysis in the laboratory; the reservoir was not sampled in 1994. Reclamation sampled three sites in the reservoir. For purposes of comparison, the geometric mean of the three Reclamation samples is plotted on Figure 13.

Arsenic in the reservoir was somewhat higher in the Reclamation sediment sample than in the NIWQP composite sample (Figure 13). The sediment samples from the tributaries to Angostura Reservoir showed approximately the same arsenic concentration in 1988 and 1994, but were intermediate between the NIWQP and Reclamation sediment



Site Name	Site	NIWQP-1988 Number
CHEYENNE RIVER NEAR HOT SPRINGS	Upstr.	2
HORSEHEAD CREEK AT CELRICHS	Hh. Cr.	3
ANGOSTURA RESERVOIR NEAR HOT SPRINGS	Res.	4
ANGOSTURA CANAL NEAR HOT SPRINGS	Canal	6
FALL RIVER AT MOUTH NEAR HOT SPRINGS	Fall R.	7
CHEYENNE RIVER ABOVE BUFFALO GAP	Buff.	8
IRON DRAW NEAR BUFFALO GAP	Iron D.	10
RIVER NEAR CLUSTER COUNTY ROAD 656 BRIDGE	Co. Rd.	12
COTTONWOOD CREEK NEAR BUFFALO GAP	Cot. Cr.	13
CHEYENNE RIVER NEAR FAIRBURN	Red S.	14

Figure 13 : Comparison of concentrations of four elements in samples collected from the Cheyenne River and its tributaries by the NIWQP in 1988 and 1994 and Reclamation in 1997

samples for the reservoir (Figure 13). (The 1988 NIWQP upstream sample in Figure 13 is the average of 3 QC samples - sample [11] + split [7.6] + replicate [6.6] and the 1994 sample was collected from Edgemont, rather than Hot Springs, and is also a replicate QA sample [< 10 and 12 ppm].) The Reclamation sample from the Angostura Canal was about twice as high in arsenic as the NIWQP 1988 sample. The highest arsenic in any sample was the Reclamation sample from the county road 656 bridge, but it was only slightly higher than the NIWQP 1994 sample (Figure 13). In 1994, the NIWQP collected a sample from the site $\frac{3}{4}$ mile downstream from Angostura Dam; that sample had an arsenic concentration of 12 ppm, which is the same as the arsenic concentration in the 1988 sample from the site near Buffalo Gap. This would indicate that there is an arsenic source between the site near Buffalo Gap and the one at the county road bridge. There were no samples collected from the river between the dam and the bridge site in 1997 that could help identify the source.

The maximum arsenic in the NIWQP samples was collected from Cottonwood Creek, which had been sampled as a background site. Cottonwood Creek is downstream from the county road bridge site and could not be the source of the sediment arsenic. Arsenic in samples from the remaining two sites located in Iron Draw and the Cheyenne River near Fairburn are similar in the two sample sets (Figure 13). At each of these sites, the Reclamation samples are slightly lower in arsenic than NIWQP samples. Overall the sediments appear to have had a higher concentration of arsenic in 1997 than was the case in 1988.

In 1988, the Cheyenne River showed an increase in selenium in the downstream direction as far as Buffalo Gap (Figure 13). All of the selenium samples collected in 1994 were below the detection limit of 1 ppm. (Most of the samples collected in 1988 and 1997 were also less than 1 ppm, but the detection limits were also below 1 ppm). As was the case for arsenic, the maximum selenium concentration in the 1988 NIWQP sediment samples was observed in Cottonwood Creek. Selenium then declined at the site near Red Shirt, despite the inflow from Cottonwood Creek upstream from the site. In 1997, the results appear to be similar, although fewer sites were sampled. Selenium was barely measurable at the site near Red Shirt in 1997.

The final two elements shown on Figure 13 are vanadium and zinc. Both showed relatively high maximum concentrations in 1988, although both remained within the soils baseline. The reason for including the data in Figure 13 is to illustrate how much lower the concentrations are in 1997 than they were in 1988. This was what was expected because the 1988 samples were collected during a relatively significant drought period. This makes the above discussed arsenic results even more perplexing.

Figure 14 shows the uranium data for the NIWQP's 1988 study and the Reclamation samples collected during 1997. The NIWQP verification study 1994 samples were all reported as < 100 ppm, which is well in excess of any of the 1988 or 1997 results. The NIWQP 1988 and Reclamation's 1997 do not show any pattern between the two years.

There is an interspersed of results with some of the 1988 samples greater than the 1997 samples at half the common sites (Figure 14). The mean of the Reclamation samples from the reservoir is twice the concentration in the 1988 NIWQP composite. On the other hand the NIWQP canal and Iron Draw samples have a greater uranium concentration than the Reclamation samples. At Red Shirt the Reclamation sample once again shows the higher uranium concentration (Figure 14). About all that can be said of uranium based on the two sets of samples collected in the study area during 1988 and 1997 is that it is highly variable among the various samples sites. There is no clear pattern of uranium distribution. There is also no evidence of widespread contamination.

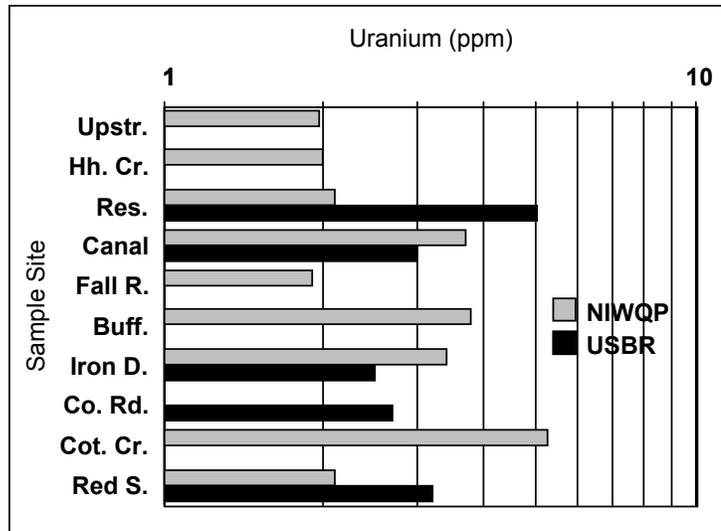


Figure 14: Uranium concentrations in the Cheyenne Basin sediments in 1988 (NIWQP) and 1997 (USBR)

The OST collected sediment samples from the Cheyenne River at Red Shirt in 1996. Those data along with the NIWQP 1988 and 1994 and the Reclamation 1997 data for that site are plotted on Table 14. The plots are shown on a logarithmic scale. There are two plots on Figure 15 to maintain a maximum of four log cycles (orders of magnitude) per plot. The upper plot (Figure 15A) includes elements with concentrations that were less than 100 ppm and ranged from a low of 0.02 ppm for mercury to a maximum of 56 ppm for boron. The lower plot (Figure 15B) includes elements that had concentrations between 10 ppm (chromium) and 1200 ppm (barium). A comparison to Table 17 shows that only the Reclamation molybdenum sample is above its respective upper 95 percent confidence limit for Western soils (15 ppm and 4 ppm).

Of the four sampled years shown on Figure 15, 1988 was one of the driest (based on the Wasta gage record), 1994 was fairly average, 1996 is another rather wet year, and 1997 was the overall wettest year in the 66 years for which there are data. If there is any relationship between mean annual flow (or particle size) and bed sediment concentrations of the elements shown, 1988 (NIWQP) should have the highest concentration and 1997 (USBR) should have the lowest. This is true for each of the elements in Figure 15B (Reclamation did not analyze the sample for manganese), but, with the exception of nickel, and possibly mercury, it is not true for any of the elements in Figure 15A. Reclamation did analyze the sample for mercury, but the analytical reporting limit was 0.1 ppm, which is greater than either of the other results shown in Figure 15A. Some of the other elements shown in Figure 15A also are affected by reporting limits. For example, the NIWQP results for both cadmium and molybdenum are actually reported as less than 2 ppm, which, in the case of cadmium, is greater than either of the other results. In this instance the actual concentrations may be greater than those of either the OST or Reclamation, but there is no way to determine this for sure.

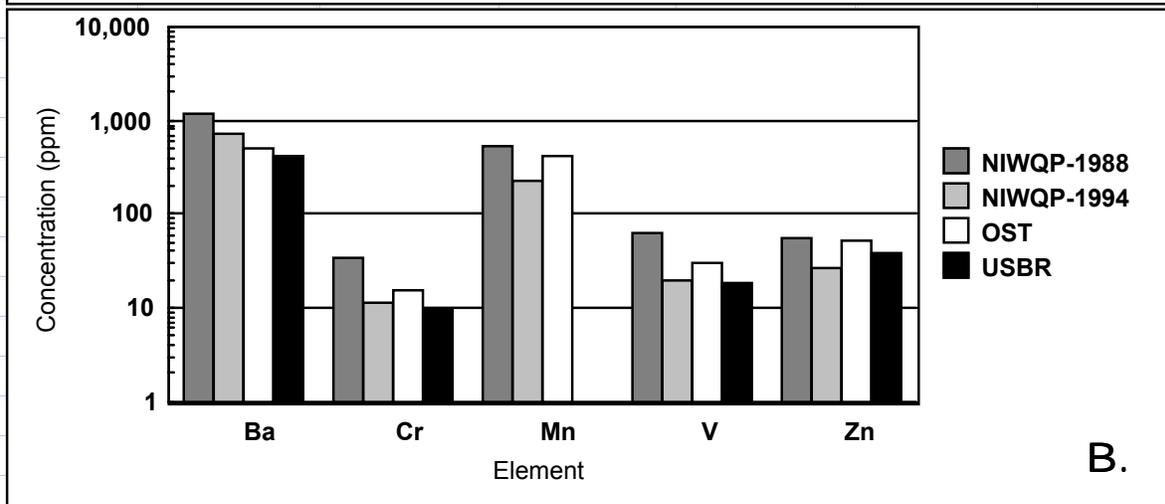
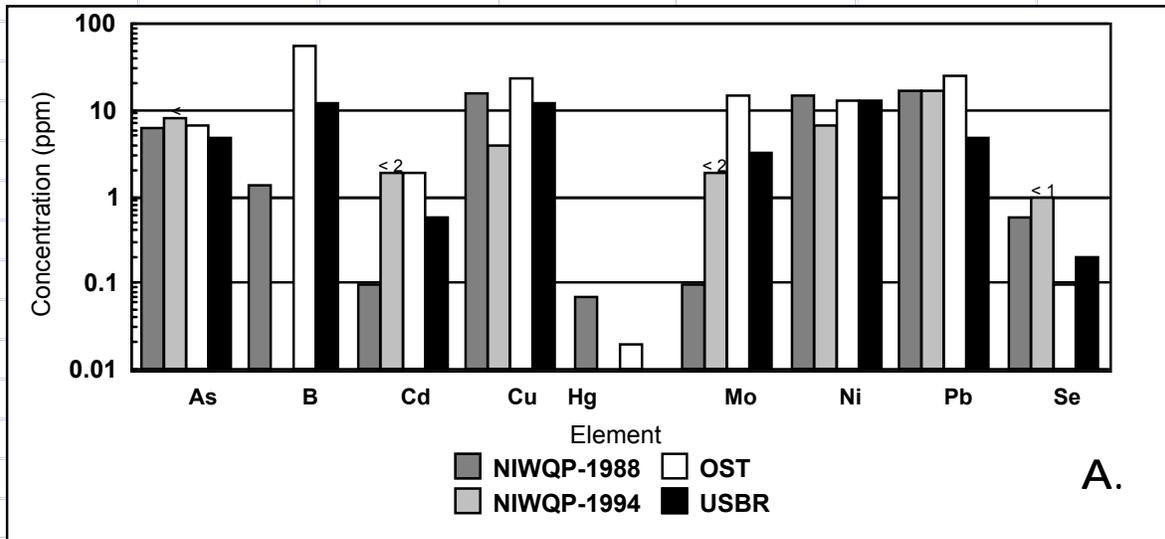


Figure 15: Comparison of sediment samples collected from the Cheyenne River at Red Shirt during four different years (NIWQP, 1988 and 1994; OST, 1996; USBR, 1997)

Alternatively, the molybdenum is definitely less than either of the other results.

The CRST initiated a sediment monitoring project in 1994 (CRST, undated). Results for stations in the vicinity of Cherry Creek are shown in Table 18. The Reclamation sample collected in 1997 at approximately the same site as CR-40 is also included in Table 18 for comparison. The CRST used clean-up criteria developed by the Washington Department of Ecology (DoE, 1995) for Puget Sound as evaluation criteria. The criteria include a "no adverse effect" level and a "minor adverse effect level." These are used by the DoE to evaluate whether cleanup is needed in contaminated areas of Puget Sound. None of the CRST samples from the Cheyenne River in the vicinity of Cherry

Table 18. Sediment Criteria and CRST and Reclamation sediment data for the Cheyenne River in the vicinity of Cherry Creek

Element (Dry Weight Units)	Sediment Quality Criteria		Cheyenne River Sioux Tribe					USBR
	Wash. DoE ¹ No effect	Minor effect	CR-21	CR-38	CR-40	CR-20	CR-39	CRCC
As, ppm	57	93	23.8	44.47	17.31	17.44	21.47	104.3
Cd, ppm	5.1	6.7	0.79	1.17	0.40	0.63	0.60	1.9
Cr, ppm	260	270	16.6	29	20.5	2	7.16	12.0
Cu, ppm	390	390	16.99	27.78	27.66	11.75	10.19	19.0
Fe, %	---	---	2.7	3.26	3	5.5	2	---
Hg, ppm	0.41	0.59	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Mn, ppm	---	---	332.9	552.9	516.5	2639.9	496.6	---
Ni, ppm	---	---	17.3	29.8	28.8	25.4	13.5	23.0
Pb, ppm	450	530	13.9	19.7	17.8	15.7	9.4	< 10.0
Zn, ppm	410	960	67.0	97.0	103.0	68.0	44.5	63.0
% solids			92.51	91.78	85.46	82.34	77.40	68.76

Sample Site Locations	Site No.	Date
CHEYENNE RIVER ABOVE CONFLUENCE OF CHERRY CREEK	CR-21	23-Aug-94
CHEYENNE RIVER ABOVE CONFLUENCE OF CHERRY CREEK	CR-38	31-Aug-94
CHEYENNE RIVER AT CHERRY CREEK	CR-40	31-Aug-94
CHEYENNE RIVER BELOW CONFLUENCE OF CHERRY CREEK	CR-20	23-Aug-94
CHEYENNE RIVER BELOW CONFLUENCE OF CHERRY CREEK	CR-39	31-Aug-94
CHEYENNE RIVER AT CHERRY CREEK	CRCC	04-Aug-97

¹ Puget Sound Sediment Quality Chemical Criteria, Washington Department of Ecology

Creek exceeded the DoE sediment standards (CRST, undated). The Reclamation sample collected in 1997 did exceed the DoE criterion for arsenic, but was well below each of the other criteria (Table 18).

The primary reason that the CRST sampled the sediments in streams on their reservation was to evaluate the effect of floods that occurred throughout the summer of 1993 (CRST, undated). The Reclamation sample is somewhat higher than the CRST results for arsenic and cadmium, but within the range shown for the other elements (Table 18). There is no indication whether the CRST samples were sieved prior to analysis; the Reclamation sample represents only the < 0.062 mm fraction. If the CRST samples represent the total sediment, that could account for some of the difference. For example, Severson *et al.* (1991) observed differences among the way different elements were partitioned in different size-fractions of sediment. Arsenic was tightly clustered about the 45° line of equal distribution between fine and coarse sediments at lower concentrations, but showed a great deal of scatter at higher concentrations (> 20 ppm) of arsenic (*ibid.*). Despite the one excessive arsenic concentration, the sediments do not appear to be contaminated with any inorganic substances.

The partitioning of elements by size fractions is important to any flow relationship. Higher flows are capable of transporting larger sized sediments than lower flows. If an element is adsorbed to finer particles, such as clays, then it will tend to be concentrated in the fines. During periods of low flow, these elements would tend to constitute a larger part of the suspended sediments, and when deposited, a larger part of the surface layer of bed sediments. When higher flows are present in wetter years, larger particles with lower concentrations of the adsorptive elements will be present. These larger particles are less easily transported, and thus more readily deposited. The deposition of the larger particles with lower concentrations of the adsorptive elements will dilute the sediment concentrations. This is the reason that higher concentrations of some elements are expected following dry periods.

The CRST also analyzed 5 sediment samples for pesticides. No measurable pesticides were found in any of the samples, but only one of the samples was from the mainstem of the Cheyenne River (CRST, undated, Table 3). The NIWQP analyzed 5 sediment samples for atrazine and carbofuran. Samples were collected from the Cheyenne River upstream from Angostura Reservoir, above Buffalo Gap, and near Fairburn; samples were also collected from Iron Draw and Cottonwood Creek. All of the results were reported as < 0.1 ppm (Greene *et al.*, 1990).

Special Topic - Edgemont Uranium Mill Decommissioning

The Tennessee Valley Authority (TVA) purchased a uranium processing mill during 1974 (NRC, 1982). The mill was never operated by TVA. The mill site was located upstream from Angostura Reservoir. In 1978, Congress Passed the Uranium Mill Tailings Radiation Control Act. Although the Act did not specifically include the Edgemont Uranium Mill, TVA decided to decommission the mill. A final Environmental Statement was published in 1982 (NRC, 1982).

The site consisted of a processing mill and mill tailings, along with 8 settling ponds. The site layout is shown on Figure 2.9 of the FES (page 2-15; NRC, 1982). All contaminated material [mill buildings, equipment, tailings, stream sediment from Cottonwood Creek, and pond residues [slimes] - see Table 2.2, page 2-16 of FES for listing) was entombed at a site located at the headwaters of an ephemeral drainage 2 miles southeast of the mill site.

Cottonwood Creek through the mill sites was also cleaned up. The creek was diverted and contaminated bed sediments and bank materials were removed to the disposal site.

The mill had a significant effect on Cottonwood Creek before the cleanup. This is illustrated in Figure 16, which shows uranium concentrations in the creek upstream

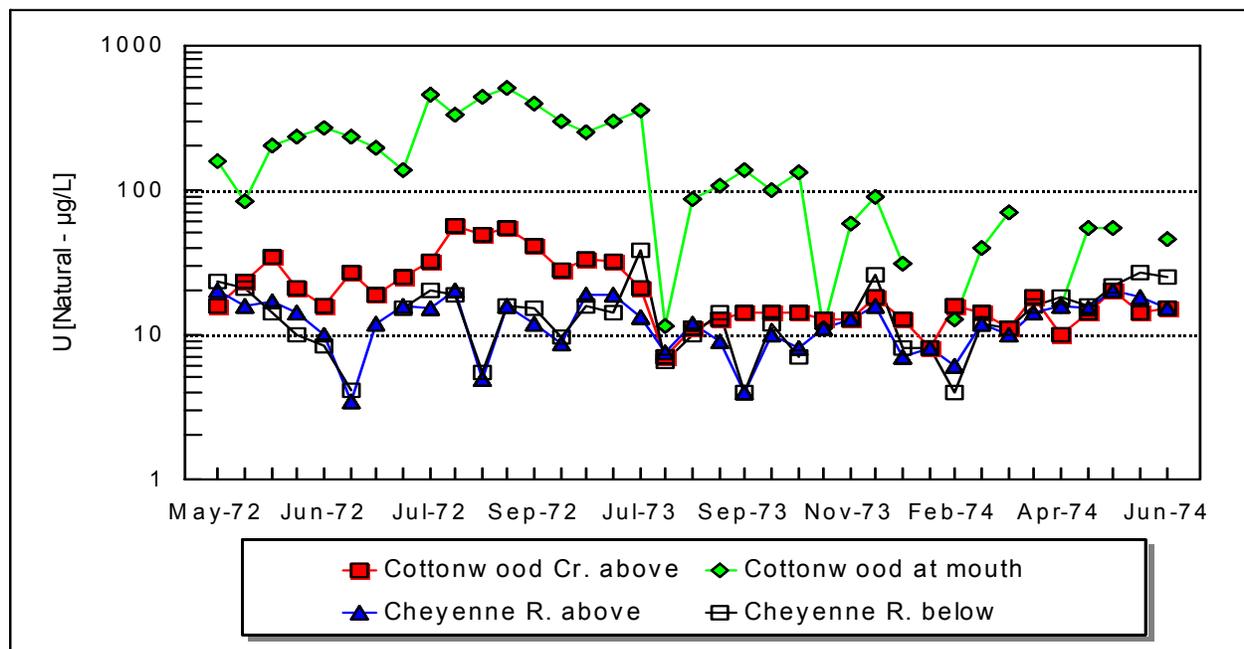


Figure 16: Uranium Concentrations in Cottonwood Creek and the Cheyenne River during 1972 through 1974 [NOTE: semi-log scale]

from and at the mill site. By far the largest uranium concentrations were in Cottonwood Creek within the mill site, which occupied the area at the mouth of the creek. The downstream concentrations of uranium were typically 10 times those at the upstream

site. Even at the upstream end of the reservoir, the uranium concentration exceeded 50 µg/L on 2 occasions during 1972 (Figure 16), but the downstream concentration was over 500 µg/L at the same time. During both 1973 and 1974, the uranium concentrations were much lower than they were during 1972 both upstream and downstream from the mill site (Figure 16). According to the FES (page 1-2), the mill ceased operations in 1972. The decline may represent the effects of natural processes once the mill quit operating.

The Cheyenne River showed a general increase above and below Cottonwood Creek, although there were both increases and decreases in uranium during the 3 years that the sites were monitored (Figure 16). When the data are averaged for the individual years, the largest increase was during 1973, which was the wettest of the 3 years monitored, based on records at the Edgemont gage. The average percent increase in the Cheyenne River was smallest (2 percent) during 1972, when the highest uranium concentrations were observed in Cottonwood Creek.

There are very few recent monitoring data for uranium in the Cheyenne River reach affected by the mill since the cleanup. The available data for the Cheyenne River are summarized in Table 19. The USGS has sampled the river for uranium at 2 sites in the last 10 years. Four samples were collected at Hot Springs during 1988 and 2 samples were collected at the Edgemont gage in 1994.

Table 19: Summary of the Recent Uranium Data in the Cheyenne River at 2 Sites

	<u>Hot Springs</u>	<u>Edgemont</u>
	1988	1994
Average	8.2	20.5
Maximum	12	25
# of Obs.	4	2

Uranium was much higher at the Edgemont gage during 1994 than at Hot Springs during 1988. The Edgemont gage is a background site; it is located upstream from both Cottonwood Creek and the mill site. The Hot Springs site is located well downstream from the mill site, but it should be relatively representative of the Angostura inflow. The 1988 data would indicate that the inflow to the reservoir in recent years is not affected by any remnant effects of the uranium mill operation. In 1988, both the average and the maximum were below the EPA uranium drinking water standard. Actually the uranium concentration may have been as high at the Edgemont gage during 1988 as it was in 1994 at Hot Springs. In 1988, the flow in the river increased on the average by a factor of eleven between the 2 sites at the time the samples were collected. There is more than enough dilution water entering the river between the 2 sites to lower the uranium concentration at the Hot Springs site. Based on the data in Table 19, it would appear that there are still sources of uranium in the basin upstream from Edgemont.

Conclusions

1. The most recent DENR (1996) evaluation classified Angostura Reservoir as mesotrophic with a degrading trend in water quality. The major pollution sources for the reservoir are categorized as natural. However, a trend line in the Clean Lakes report, which is based on trophic state indices for the last 10 years, indicates a trend toward oligotrophy or improving water quality, at least from the perspective of trophic status.
2. Temperature and D.O. profiles measured by EPA, NIWQP, and South Dakota DENR indicate that the reservoir tends to be stratified during most years during the months of June through August with fall overturn (the breakdown of thermal stratification) occurring during early to mid-September. The minimum bottom D.O. has been observed during August of each of the sampled years with August measurements. Each of the August measurements shows less than 1 mg/L of D.O. The years when the D.O. did not fall below 1 mg/L include only 1974 and 1992, in which years there were no August measurements.
3. There is a large decrease in flow and salt load below Angostura Dam Due to diversions through the Angostura Canal. The flow and salt load in the Cheyenne River increases downstream from the AID. TDS decreases from upstream of the AID to the Cherry Creek gage on the Cheyenne River near its mouth. The decrease is due to mixing of dilute high flows with more concentrated low flows in Angostura Reservoir and the effect of more dilute downstream tributary flows. Although there is a large depletion in flow due to the AID, there is no apparent increase in TDS due to the Angostura Unit.
4. A study conducted by the Department of the Interior's NIWQP in 1988 concluded that toxic levels of selenium or other trace elements or pesticides in water did not appear to be a persistent problem within the Project area or downstream of irrigation return flows. Follow-up samples collected in 1994 by the NIWQP and in 1997 by Reclamation supported the 1988 conclusion.
5. Three triazine herbicides, including atrazine, cyanazine, and simazine, were the only pesticides observed above detectable concentrations by the NIWQP, but all were below water quality standards. Atrazine is the only one of the above pesticides that is reportedly used in the AID and therefore could potentially be affected by contract renewals. Reclamation samples collected during August 1997 showed no measurable pesticides.
6. Water quality data collected by the OST indicate that the most serious problem for aquatic life in the Cheyenne River in the vicinity of the Pine Ridge Reservation is low D.O., and/or possibly excessive unionized ammonia. There have been concerns related to lesions on fish; these have been shown to be associated with bacterial infections and parasites. Stress due to poor water quality has been cited as an underlying factor in the infections. Stress is consistent with the effects of low D.O. and excessive ammonia.

7. The OST water quality data also indicate that trace elements are not a water quality problem in the Cheyenne River in the vicinity of the Pine Ridge Reservation.

8. The CRST has sponsored two recent water quality related studies. The USGS evaluated historic data in relation to water quality standards in the vicinity of the Cheyenne River Indian Reservation. The USGS study results indicate that the most significant water quality problems in the lower Cheyenne River were excessive TDS, suspended solids, and ammonia, the latter two of which were specifically related to aquatic life. The water quality data collected during a fish study, which also included habitat data, indicated that suspended solids (or turbidity) and ammonia were significant problems in the lower Cheyenne River. Several trace elements were reported to have exceeded standards that have been proposed by the CRST at one or more of the sample sites; these included proposed standards for aluminum, arsenic chromium, selenium, and thallium. However, many of these interpretations suffer from data quality differences relating to laboratory reporting limits.

9. Sediment samples collected by the NIWQP, Reclamation, the OST, and the CRST, except for the Reclamation uranium samples, do not indicate any serious contamination with trace elements or uranium. Elevated concentrations of molybdenum, selenium, arsenic, and zinc, were observed at a minimum of one site, but only molybdenum was elevated at more than one site when compared to a baseline for Western soils. Comparison to criteria for the protection of aquatic life indicates that the sediments are not contaminated to potentially harmful concentrations.

10. Sediment samples collected in the Cheyenne River by the NIWQP, Reclamation, the OST, and the CRST indicate that the sediments are not contaminated with pesticides.

11. A former uranium mill in Edgemont contributed a large amount of contamination to the Cheyenne River upstream from Angostura Reservoir between 1952 and 1972, when it was closed. Uranium data collected since the site was cleaned up by the TVA indicate that there is no longer any significant contamination to Angostura Reservoir from the site.

Literature Cited

Ahrens, William H. (Ed.). 1994. Herbicide Handbook, Seventh Edition - 1994. Weed Society of America, Champaign, Illinois. 352 pp.

Amiotte, Joe. 1998. Personal Communication: Letter of February 18, 1998, from Director, Oglala Sioux Tribe, Oglala Lakota Nation Water Resource Department, Pine Ridge, South Dakota, to James Yahnke, Bureau of Reclamation, Denver, Colorado.

American Public Health Association, American Water works Association, and Water Environment Federation. 1992. Standard Methods for the Examination of Water and Wastewater. APHA, Washington, D.C. Paged by Chapter.

Ball, James W., D. Kirk Nordstrom, and Dieter W. Zachmann. 1987. WATEQ4F--A Personal Computer FORTRAN Translation of the Geochemical Model WATEQ2 with Revised Data Base. U.S. Geological Survey Open File Report 87-50. USGS, Menlo Park, CA. 108 pp.

Byrne, Anthony T. 1997. Letter report - results of fish and water examinations, Cheyenne River from Plateau Ecosystems Consulting, Inc., Arvada, Colorado, to OST Water Resource Department, Pine Ridge, South Dakota. 5 pp. (in Hoof, 1998.)

Carlson, R.E. 1977. A Trophic State Index of Lakes. *Limnol. Oceanog.* 22(2): 361-69.

Cheyenne River Sioux Tribe. Undated. Sediment Monitoring Project, Volume 1: Project Report. Cheyenne River Indian Reservation, Eagle Butte, South Dakota. 36 pp. + App.

Clarke, F. W., and H.S. Washington. 1924. The composition of the earth's crust. U.S. Geological Survey Professional Paper 127. U.S. Government Printing Office, Washington, D.C. 117 pp. (Cited in Parker, 1967).

Environmental Protection Agency. 1986. Quality Criteria for Water 1986. EPA 440/5-86-001. EPA, Office of Water, Washington, D.C. Unn.

Environmental Protection Agency. 1996. Drinking Water Standards and Health Advisories. EPA 822-B-96-002, Office of Water, Washington, D.C. 11 pp.

EXTOXNET. 1996. Atrazine/Cyanazine/Simazine. Extension Toxicology Network, Pesticide Information Profiles, Oregon State University website - <http://ace.ace.orst.edu/info/extoxnet/pips/>

Fishman, Marvin J., and Linda C. Friedman. 1989. Methods for the Determination of Inorganic Substances in Water and Fluvial Sediments. Techniques of Water-Resources Investigations of the United States Geological Survey, Book 5, Chapter A1. US Government Printing Office, Washington, D.C. 545 pp.

Fortescue, John A.C. 1992. Landscape geochemistry: retrospect and prospect—1990. *Applied Geochemistry* 7:1-53.

Greene, Earl A., Charles L. Sowards, and Eugene W. Hansmann. 1990. Reconnaissance Investigation of Water Quality, Bottom Sediment, and Biota Associated with Irrigation Drainage in the Angostura Reclamation Unit, Southwestern, South Dakota, 1988-89. Water-Resources Investigation Report 90-4152, U.S. Geological Survey, Rapid City, South Dakota. 75 pp.

Goddard, Kimball E., Arthur J. Horowitz, and Charles E. Shearer. 1987. Distribution of Solid-Phase Arsenic and Trace Elements in Bottom and Suspended Sediments, Whitewood Creek and the Belle Fourche and Cheyenne Rivers, Western South Dakota. In: U.S. Geological Survey Toxic Substances Hydrology Program – Surface-Water Contamination: Proceedings of the Technical Meeting, Denver, Colorado, February 2-4, 1987. Open-file Report 87-764, USGS, Reston, Virginia. Pp 13-17.

Heakin, Allen J. 1998. Water-Quality Trends for the Cheyenne and Moreau Rivers, Cheyenne River Indian Reservation, South Dakota, 1972-94. Water-Resources Investigations Report 98-4092, U.S. Geological Survey, Rapid City, South Dakota. 56 pp.

Hem, John D. 1985. Study and Interpretation of the Chemical Characteristics of Natural Water. United States Geological Survey Water-Supply Paper 2254. U.S. Government Printing Office, Washington, D.C. 263 pp. + 3 Plates.

Hoof, Mary M. 1998. Cheyenne River Impact Study, Pine Ridge Reservation, Pine Ridge, South Dakota. Oglala Lakota Nation Water Resource Department, Pine Ridge, South Dakota. Unn.

McGlaughlin, Gerald. 1997. Faxogram of July 2, Subject: Water Quality Lab Reports. Water Resources Department, Oglala Sioux Tribe, Pine Ridge, South Dakota. 11 pp.

McCutcheon, Steve C., James L. Martin, and Thomas O. Barnwell. 1993. Water Quality. In: Handbook of Hydrology, David R. Maidment (ed.). Mc Graw-Hill, Inc. New York, NY. Numbered by Chapter.

National Agricultural Chemicals Association. 1994. Crop Protection Chemicals Reference. Chemical and Pharmaceutical Press, New York, NY. 1948 pp.

Parker, Raymond L. 1967. Data of Geochemistry, Sixth Edition, Chapter D. Composition of the Earth's Crust. Geological Survey Professional Paper 440—D, U.S. Government Printing Office, Washington, D.C. 19 pp.

Plateau Ecosystems Consulting, Inc. 1997. Aquatic Ecological Surveys of the Moreau and Cheyenne Rivers, South Dakota, 1997. Plateau Ecosystems Consulting, Inc., Arvada, Colorado. Paginated by chapter.

Rahn, P.H., A.D. Davis, C.J. Webb, and A.D. Nichols. 1996. Water quality impacts from mining in the Black Hills, South Dakota, USA. *Environmental Geology* 27: 38-53.

Severson, R.C., K.C. Stewart, and Thelma F. Harms. 1991. Partitioning of Elements Between Two Size Fractions in Samples from Nineteen Areas of the Western United States. U.S. Geological Survey, Open-File Report 91-381, USGS, Denver, Colorado. 18 pp.

Shacklette, Hansford T., and Josephine G. Boerngen. 1984. Element concentrations in Soils and Other Surficial Materials of the Conterminous United States. U.S. Geological Survey Professional Paper 1270, U.S. Government Printing Office, Washington, D.C. 105 pp.

South Dakota Department of Environment and Natural Resources. 1996. South Dakota Water Quality - Water Years 1994-1995: The 1996 Report to Congress of the United States by the State of South Dakota pursuant to Section 305(b) of the Federal Water Pollution Control Act. DENR, Pierre, South Dakota. 253 pp.

Stueven, Eugene, and William C. Stewart. 1996. 1995 South Dakota Lakes Assessment Final Report. South Dakota Department of Environment and Natural Resources, Pierre, South Dakota.

U.S. Nuclear Regulatory Commission. 1982. Final Environmental Statement related to the decommissioning of the Edgemont Uranium Mill. Tennessee Valley Authority Docket No. 40-1341. NRC, Washington, D.C. Paged by Chapter.

Washington Department of Ecology. 1995. Sediment Management Standards, Chapter 173-204 WAC, (<http://www.wa.gov/ecology/sea/smu/173-204.htm>), DoE, Seattle, Washington. 49 pp.

Webb, Cathleen J., and Perry H. Rahn. 1994. Final Report: Potential Chemical and Environmental Hazards at Abandoned Mining Sites in the Black Hills. Report to the University of South Dakota, Vermillion, South Dakota. 117 pp.

Williamson, Joyce E. 1999. Personal communication: Letter of March 17, 1999, from Information Management Section, U.S. Geological Survey, Rapid City, South Dakota, to James Yanke, Bureau of Reclamation, Denver, Colorado.

**Angostura Irrigation District
Contract Renewals**

South Dakota

**Trace Elements and Organic Contaminants
in Fish in the Cheyenne River
during August 1997**

August 1998

**Bureau of Reclamation
Denver, Colorado**

Trace Elements and Organic Contaminants in Fish in the Cheyenne River during 1997

Introduction

The Bureau of Reclamation (Reclamation) collected fish samples from two sites in the Cheyenne River during August 1997. The purpose of the sampling was to perform a follow-up to the sampling and analysis conducted under the NIWQP (National Irrigation Water Quality Program) in 1988 (Greene *et al.*, 1990). The NIWQP did a follow-up to the 1988 study in 1994, but only water samples were collected. A report on this verification study is in preparation. The 1997 sampling by Reclamation was conducted on a much reduced scale in comparison to that of Greene *et al.* (1990) and was meant to supplement the NIWQP verification study.

The Reclamation samples were analyzed for 8 trace elements and variety of organic contaminants, including herbicides, insecticides, and several polychlorinated biphenyl (PCB) isomers. This report will focus primarily on trace elements. The vast majority of the organic analyses yielded results that were below detectable concentrations. A brief discussion of those results appears at the end of the report.

Greene *et al.* (1990) noted a number of problems related to the variability of trace element and organic concentrations in organisms. Because of these inherent problems, interpretation of the results must be made with caution. The same type of approach to evaluating the results that was used by Greene *et al.* (1990) will be used here. Greene *et al.* (1990) compared their results to the 85th percentile of the NCBP (National Contaminants Biomonitoring Program), as presented in Lowe *et al.* (1985). Since the time of Greene *et al.* (1990), further NCBP results have been published (Schmitt and Brumbaugh, 1990). The results of Schmitt and Brumbaugh (1990) will be used as the primary basis for comparison in this report. A comparison of the NCBP 85th percentile data from Lowe *et al.* (1985) and Schmitt and Brumbaugh (1990) are presented for comparison in Table 1. As can be seen, any differences are small and not really of any consequence.

It should be noted that the 85th percentile of the NCBP database is not a contaminant level that is indicative of harm to a consumer of the fish. It is the upper limit of what should be considered an uncontaminated background. Fish consumption advisories are issued by the states when potentially harmful concentrations of contaminants are found. EPA has compiled a listing of fish consumption advisories nationwide. There are no fish consumption advisories in South Dakota (EPA, 1998).

A further purpose of this report is to compare the Reclamation 1997 results to those of Greene *et al.* (1990). This is somewhat complicated by the fact that Greene *et al.* (1990) did not collect samples at the same sites as Reclamation. Greene *et al.* (1990) sampled fish from 4 sites in the Cheyenne River: near Edgemont (upstream

Table 1: Ambient Metal Concentrations Used for Comparison with Cheyenne River Data

Concentrations in mg/Kg wet weights	NCBP Geometric Mean ¹	NCBP 85th Percentile 1990 ¹	NCBP 85th Percentile 1985 ²	Other Levels	
				Level Used	Source
Aluminum (Al)	---	---	---	100 ³	4-100 ppm. - Animals in General
Arsenic (As)	0.16	0.24	0.23	---	
Beryllium (Be)	---	---	---	0.6	³ 50-600 ppb. - Animals in General
Copper (Cu)	0.72	1.00	1.02	---	
Mercury (Hg)	0.11	0.17	0.18	---	
Selenium (Se)	0.45	0.71	0.71	---	
Thallium (Tl)	---	---	---	0.10 0.19	³ Animals in General ⁴ Fish in Minimata Bay, Japan, a Contaminated Site
Zinc (Zn)	22.3	40.2	43.23	---	

¹ Schmitt, Christopher J. and William G. Brumbaugh. 1990. Arch. Environ. Contam. Toxicol. 19:731-747. Average of samples collected in 1978-79, 1980-81, & 1984 (see Table 2 of reference)

² Lowe, T.P., T.W. May, W.G. Brumbaugh, and D.A. Kane. 1985. Arch. Environ. Contam. Toxicol. 14:363-388. Used in NIWQP Report; average of 1978-89 & 1980-81 samples.

³ Pais, Istvan, and J. Benton Jones. 1997. The Handbook of Trace Elements. St. Lucie Press, Boca Raton, Florida. 223 pp.

⁴ Fish in Minimata Bay: from Ivan C. Smith and Bonnie L. Carson. 1977. Contaminants in the Environment, Vol. 1 - Thallium. Ann Arbor Science, Ann Arbor, Michigan.

from Angostura Reservoir), $\frac{3}{4}$ of a mile downstream from Angostura Dam, near the Custer County Road 656 Bridge, and near Fairburn (Red Shirt). Reclamation collected samples near Oral and Red Shirt. The Fairburn and Red Shirt sites are one and the same. Reclamation's Oral site was located about 1 mile downstream from Angostura Dam, but also downstream from the mouth of the Fall River. Greene *et al.* (1990) presented trace element data on fish collected from a site near Oral by the Fish and Wildlife Service (the Service) in 1986; this sample was made up of only 5 fish of different species from the Reclamation sample collected near Oral. This will be addressed in more detail when the results are presented later in the report.

Methods

Fish Collection

Fish specimens for tissue analysis were collected during August and September of 1997. Staff from Reclamation's Newell Field Office, Oglala Sioux Tribe, and South Dakota State University participated in the field sampling. Three species of fish were collected at two sampling sites on the Cheyenne River within or near the Angostura Irrigation District. The two sampling sites were Oral and Red Shirt. Species collected for analysis were; Channel Catfish - *Ictalurus punctatus*, Goldeye - *Hiodon alosoides*, and White sucker - *Catostomus commersonii*.

At each sampling site seines, trap nets, and hoop nets were used to collect fish. Seine sampling was discontinued in September due to higher flows in the Cheyenne River. Seine hauls were conducted in a downstream direction either from bank to bank or from bank to middle of the channel. Seining was completed during daylight hours. Trap and hoop nets were placed with the mouth facing downstream and a lead attached to the cod end toward the deeper part of the channel. The trap and hoop nets were deployed in the evening and left for 12 hours. Fish species not needed for analysis were returned to the river.

Fish were held in a holding pen until they could be processed. Fish were sorted by species into water-filled buckets and anesthetized with compressed carbon dioxide. Each species at each sampling site was then sorted, packaged individually, and tagged for pesticide or metal analysis. Species packaged for pesticide analysis were wrapped in aluminum foil and placed in zip-locked bags. Species packaged for metal analysis were placed in zip-locked bags. Weights and measurements were completed by the contract laboratory, Northern Lake Services, Crandon, Wisconsin. After the packaging was completed, the specimens were placed on ice in two 48-quart coolers. Each cooler only contained fish from each sampling site and was tagged accordingly. Upon completion of each sampling period, the

Table 2: Fish Species Collected for Contaminants Analysis				
	Oral		Red Shirt	
	Pesticide	Metal	Pesticide	Metal
Channel Catfish	3	0	7	9
Goldeye	4	5	4	4
White Sucker	4	5	4	2
Total	11	10	15	15
Grand Total: 51				
NOTE: In addition to the above, 4 short head redhorse and several small channel catfish collected at the Red Shirt site were discarded at the laboratory (NLS, 1998). One of the fish collected for pesticide analysis was analyzed for metals.				

specimens were placed in frozen storage until shipment to Northern Lake Services. Table 2 shows the number of specimens collected and packaged for analysis. On December 4, 1997, the specimens were sent frozen in two 48 quart coolers via Federal Express to Northern Lake Services for processing and analysis. Each cooler was tagged identifying sampling sites and only contained fish from those sites. Northern Lake Services received the two coolers on December 5, 1997 and placed them in frozen storage until analysis could be completed.

Methods and quality assurance-quality control results for the fish chemical analyses are presented in NLS (1998). A complete set of laboratory analytical reports was included with NLS (1998). All are on file with Reclamation. Trace elements were reported in mg/Kg (ppm) and organics were reported in µg/Kg (ppb); all results were reported on a wet weight basis, but the percent solids was provided to enable to convert to dry weight concentrations if necessary, *i.e.*:

Dry Weight = Wet Weight * percent solids;

Percent solids = 1 - percent moisture

Percent moisture = (wet weight - dry weight)/wet weight

The quality assurance results indicated that the determination of all trace elements except mercury were within acceptable analytical error. The spike recoveries of mercury ranged from 44 to 67 percent (average recovery of 52 percent). Consequently the mercury data should be considered low, probably by about ½ of the actual value. The laboratory reported that there had been some contamination of the samples with zinc from the grinder used in sample preparation (NLS, 1998). The zinc results should therefore be considered high.

Statistical analysis of the data were performed using the statistical package, SYSTAT, Version 7 (SPSS, 1997). Because of the inherent skew in the data, only nonparametric procedures were used. The comparisons were made using either the Mann-Whitney test, a nonparametric equivalent to an unpaired t-test, or the Kruskal-Wallis oneway analysis of variance (ANOVA), a nonparametric ANOVA. Statistical significance was noted when the probability associated with a test statistic was less than or equal to 0.05.

Results

Trace Elements

Complete results for the trace element analyses of fish tissue are shown in Attachment A (see Table A-1), which also shows a statistical summary of the data (Table A-2). The trace elements included in the analyses were aluminum (Al), arsenic (As), beryllium (Be), copper (Cu), mercury (Hg), selenium (Se), thallium (Tl), and zinc (Zn). There was no detectable Tl in any of the fish samples. Measurable As was only present in 2 of the fish, and measurable Hg was only observed in 2 fish, although this may be more of an analytical problem than a true reflection of conditions in the river. For the statistical analysis, the As, Hg, and Tl data could not be used.

Table 3 summarizes the comparison to the baseline concentrations (85th percentiles) previously presented in Table 1. At the Oral site fish samples are above the previously presented background concentration for Cu, Se, and Zn. Se was the most frequently observed (over 80% - Table 3) above its background concentration. Cu and Zn were above the background concentration in over 50 percent of the samples.

Table 3: Summary Comparison of Metals Concentrations in Cheyenne River Fish to Background Concentrations					
Trace Element	ORAL SITE (n = 11)		RED SHIRT (n = 12)		Total
	No. > Norm.	% > Norm.	No. > Norm.	% > Norm.	% > Norm.
Aluminum	0	0.0%	0	0.0%	0.0%
Arsenic	0	0.0%	2	16.7%	8.7%
Beryllium	0	0.0%	0	0.0%	0.0%
Copper	6	54.5%	3	25.0%	39.1%
Mercury	0	0.0%	0	0.0%	0.0%
Selenium	9	81.8%	5	41.7%	60.9%
Thallium	0	0.0%	0	0.0%	0.0%
Zinc	6	54.5%	0	0.0%	26.1%

The frequency of exceeding the background declined at the Red Shirt site (Table 3) for each of the trace elements that exceeded the baseline at the Oral site. Copper

and selenium had only ½ the percentage of samples that exceeded the baseline at the Red Shirt site, and zinc did not have any samples greater than the baseline at the Red Shirt site. This would indicate that the zinc contamination did not affect the samples at the Red Shirt site to the degree that the samples were above the baseline. Alternatively, the samples from the Oral site that were above the baseline could have been above the baseline without the contamination. Despite the contamination in the zinc data, there is a decline in zinc exceedences, as well as those of copper and selenium, from the upper Angostura service area to below it. A statistical comparison of the data from the two sites shows that only the differences in the concentrations of selenium and zinc are statistically significant (see Table A-3).

Arsenic did not exceed the baseline at the Oral site, but showed 2 samples that exceeded the baseline at the Red Shirt site. It should be noted that both of the samples that exceeded the baseline had arsenic concentrations that were below the reporting limit (and the only 2 above the detection limit); this is a statistical region near the detection limit where the data are questionable because the percent analytical error is high. The arsenic baseline is 0.23 µg/g (ppm); the NCBP determined arsenic by hydride generation AA and had a detection limit of at least 0.02 µg/g based on the most recent published data (see Schmitt and Brumbaugh, 1990; Appendix A).

Based on the declining trace element concentrations in fish below the Angostura Unit in comparison to those above the Unit, it appears that the Unit is not having an adverse effect on the fish, at least for trace element contamination.

Lowe *et al.* (1985) noted greater variability in trace element content between species of fish than there was among stations in samples collected nationwide. There appeared to be differences in size and some of the trace element concentrations among the species in the Reclamation data. This could have implications for the comparison with the NIWQP data, and it will be explored. A summary of the Reclamation data by species is presented in Table 4; only those trace elements that were mostly above the detection limit are included.

Table 4 indicates that the goldeye were generally heavier than the other two species, although the heaviest individual fish was a channel catfish (the lone channel cat from the Oral site that was analyzed for metals [see Table A-1]). The white sucker samples were all intermediate in weight between the other two species. There is no statistically significant difference among the weights of the three species. However, there are statistically significant differences in all of the other variables, except beryllium, based on the results of nonparametric oneway analysis of variance (see Table A-4 for results). Based on the data in Table 4, it would appear that the white sucker were significantly higher in aluminum, copper, and selenium than the other species, while it appears that the channel catfish were

Table 4: Summary of 1997 Physical and Chemical (ppm) Data by Fish Species

		Weight (grams)	Length (cm)	Al	Be	Cu	Se	Zn
Channel Catfish	Minimum	56.0	20.0	2.80	<0.0037	0.670	0.508	8.8
	Median	210.0	31.0	6.70	0.0038	0.970	0.660	17.0
	Maximum	482.1	39.4	38.00	0.0520	1.084	0.810	20.0
Goldeye	Minimum	280.0	32.5	0.91	<0.0034	0.530	0.330	17.0
	Median	310.0	33.9	3.00	0.0082	0.740	0.732	24.0
	Maximum	460.0	42.3	6.80	0.3200	0.970	1.200	28.0
White Sucker	Minimum	120.0	23.0	3.00	<0.0033	1.100	0.560	17.0
	Median	250.0	30.0	28.00	0.0120	1.700	1.100	20.0
	Maximum	370.0	33.0	86.00	0.1500	2.300	1.600	32.0

significantly lower in zinc than the other species. Because of the differences in trace element concentrations among species, a comparison to the NIWQP data (Greene *et al.*, 1990) without correcting for the species effect could be misleading.

Greene *et al.* (1990) did not sample the Oral area during the study in 1988, but did collect fish from the river near the Custer Co. Road 656 bridge and at the site near Fairburn (Red Shirt). Samples were collected in April and September 1988. There were differences in the fish species collected between the two sites (Table 5). There were also seasonal differences in the fish sampled at the two sites. Black crappie and sauger were only taken in April, while flathead chub, river carpsucker, and smallmouth bass were only collected in September. The most common species collected during 1988 was the shorthead redhorse (Table 5). Reclamation collected four shorthead redhorse in 1997, but these were discarded by the laboratory (NLS, 1998) and were not analyzed for trace element content. White sucker were collected during 1997, but none were collected during the 1988 study. The only common species in the two time periods were channel catfish and goldeye. The comparison between the NIWQP 1988 data and the Reclamation 1997 data will focus on those two species.

A comparative summary of the NIWQP data of Greene *et al.* (1990) by site and by species and the 1997 data for channel catfish and goldeye is shown in Table A-5. The data collected at the site near the county road bridge were entered under the assumption that there would be little difference between that site and the site near Red Shirt. This is true in most cases but there are also some differences there as well. Statistically the channel catfish show a significant difference in aluminum and copper between the 2 sites, and goldeye show a significant difference in selenium. When the species are lumped together, there are significant differences in copper and selenium between the two sites. Statistical analyses were performed with the data for the bridge and Red Shirt sites lumped and for the Red Shirt site taken

Species	Custer Co. Road 656		Red Shirt	
	Number	Size Range (cm)	Number	Size Range (cm)
Black crappie	3	15.0 - 20.2	0	---
Common carp	14	17.4 - 49.1	6	27.8 - 46.8
Channel catfish	11	19.3 - 31.8	7	15.1 - 28.5
Flathead chub	1	12.7	4	9.8 - 14.8
Goldeye	7	33.1 - 36.8	7	32.4 - 35.3
Shorthead Redhorse	17	18.7 - 40.3	10	22.0 - 33.8
Green sunfish	0	---	3	8.4 - 10.5
River carpsucker	0	---	4	16.1 - 24.4
Sauger	0	---	2	38.2 - 51.3
Smallmouth bass	0	---	1	18.2

alone. In order to do the latter, the species were lumped to give enough observations to make a valid comparison. Obviously lumping the data expands the ranges of a given variable when there is significant difference between the groups being lumped together. This reduces the probability of showing a difference. It was necessary to either lump sites or lump species. The latter was chosen, but the white sucker were not included in the data set that was used in the comparison.

Table 6 shows the comparison of the NIWQP and Reclamation data from 1988 and 1997 respectively for the site near Red Shirt. The comparison was performed using the Mann-Whitney test. The results for the Oral site showed no significant differences in any of the variables tested even though there appear to be very large differences in a number of variables (see Table A-5), *e.g.* aluminum and copper. The problem is that the sample sizes are too small for differences to be statistically significant. The results for Red Shirt on the other hand indicate that there is a significant difference ($p < 0.05$) in the size of fish sampled (weight and length), as well as in concentrations of aluminum, copper, selenium, and zinc (Table 6). Both the goldeye and the channel catfish sampled in 1997 were much larger than what had been sampled in 1988 (see Table A-5). It should be noted that the similar set of Mann-Whitney tests using the lumped bridge and Red Shirt data from the NIWQP gave the same results, but the associated probabilities were somewhat lower.

Table 6: Statistical Comparison of 1988 and 1997 Samples from the Red Shirt Site based on Physical Characteristics and Trace Elements in Channel Catfish and Goldeye

Variable	Mann-Whitney U	Probability	X²	Median 1986-88	Median 1997
Weight (g.)	131.5	0.404	0.697	279.0	310.0
Length (cm)	129.0	0.360	0.837	33.1	34.0
Aluminum	200.0	0.173	1.860	5.98	4.30
Beryllium	101.0	0.070	3.288	0.003	0.006
Copper	52.5	0.001	11.359	0.538	0.798
Selenium	237.0	0.011	6.507	0.921	0.732
Zinc	292.0	0.000	18.652	28.0	20.0

The trace element differences show that there has been a significant decrease in aluminum, selenium, and zinc, and an increase in copper between the 2 sets of samples (see Tables 6 and A-5). If the results are interpreted with caution, the tendency would be to factor in all of the other differences among the data that were shown above, particularly differences between species. Another set of similar Mann-Whitney tests for the channel catfish and goldeye individually was also performed to control for species differences (See tables A-6 and A-7). Those results indicate that there was no significant difference in the size of the channel catfish in the two samples (Table A-6), despite the very large difference in the median weights. The goldeye in the 1997 data are significantly heavier, although not longer, than those in the 1988 data set. The channel catfish showed the same results for trace elements as are shown in Table 6, but the associated probabilities are much more significant using the combined data (Table 6). The goldeye only showed a significant decline in zinc (Table A-7). The results therefore indicate that the changes in aluminum, copper, and selenium may be species specific, but the decrease in zinc was shown across specific lines and could be true of fish in general.

Organic Contaminants

Reclamation's 1997 samples were also submitted to NLS for analysis for organic contaminants. The total list of 41 analytes and their detection limits is shown in Table A-8. The list comprises 14 herbicides, 20 insecticides, and 7 PCB's (polychlorinated biphenyls). Of these, 1 herbicide and 7 insecticides (inclusively pesticides) were observed at detectable concentrations. No PCB's were found at measurable concentrations in any of the fish samples (Table A-8).

The complete list of fish and the observed concentrations of pesticides that exceeded the detection limit are shown in Table A-9. Of the 24 fish samples analyzed for organic contaminants, 5 had none present in detectable concentrations. The remaining 19 fish had between 1 and 5 pesticides in measurable concentrations (Table A-9). The fish with the greatest number of measurable pesticides (5) was a goldeye from the Red Shirt site, followed by two goldeye from the Oral site, one with 4 and another with 3. The remaining 16 fish had 1 or 2 of the organic contaminants present in measurable concentrations. The majority of fish samples had measurable organic contaminants.

Many of the measurable concentrations of pesticides were present at what would be less than reportable concentrations. There are two limits usually listed on laboratory reports. The first is the instrument detection limit (IDL [or LOD, limit of detection in NLS, 1998]). The second is the limit of quantitation (LOQ), also known as the reporting limit. The LOQ is the area of uncertainty above the LOD, but within the standard error of the analytical method. Results below the LOQ are frequently reported as "less than" by laboratories. NLS (1998) presented numerically complete results, but flagged results that were less than the LOQ. Of the 34 measurable concentrations of pesticides in the 1997 fish samples, *i.e.* those greater than the LOD, 25 were less than the LOQ and could just as well be reported as a censored or "less than" result. For purposes of this report, all 34 results will be numerically retained, based on the assumption that the instrument estimate is better than using something like $\frac{1}{2}$ the LOQ.

The 1997 results are statistically summarized in Table 7. The most frequently observed pesticide, DDE, is not really a pesticide, but a decomposition product of both DDT and DDD, both of which were insecticides banned in 1972 and have not been used legally in the U.S. in over 20 years. DDD is also a decomposition product of DDT as well as being an insecticide in its own right. Aldrin and dieldrin, which were observed in a small percentage of the samples, are also organochlorine insecticides like DDT. Also like DDT their use in the U.S. has been banned (EPA, 1997). Two forms of BHC (benzene hexachloride) were also observed in fish samples (Table 7); α -BHC was the second most frequently observed pesticide in the fish. BHC has also been banned for use in the U.S. (EPA, 1997).

Table 7: Summary of Pesticide Results - 1997: Number of Samples Greater than the LOD (= n), Geometric Mean, and Maximum Concentrations

Pesticide	Oral			Red Shirt			Total
	n	Mean	Max.	n	Mean	Max.	
4,4-DDD	1	2.5	2.5	1	1.3	1.3	2
4,4-DDE	8	4.4	16.0	6	3.5	5.9	14
Alachlor	2	472	530	1	220	220	3
Aldrin	1	2.4	2.4	0	---	---	1
α-BHC	3	1.7	2.5	5	2.0	2.7	8
δ-BHC	1	1.2	1.2	0	---	---	1
Dieldrin	0	---	---	1	3.4	3.4	1
Methoxychlor	3	0.71	0.83	1	0.96	0.96	4

Alachlor and methoxychlor are the only 2 compounds in Table 7 that are not on EPA's list of banned pesticides. In other words these are the only pesticides that have a realistic potential for contamination of fish by future actions. Alachlor is an herbicide that is used to control a variety of annual grasses and certain broadleaf plants in corn and beans (Ahrens, 1994). For purposes of environmental impact assessment for the Angostura Unit contract renewals, alachlor appears to be the only pesticide that may need to be considered for future aquatic impacts. According to records provided by the Angostura Irrigation District, of the 2 pesticides only alachlor has been used recently (for weed control on corn fields). Alachlor is a restricted use herbicide because it has been shown to cause liver tumors (oncogenicity) in rats (Ahrens, 1994). Methoxychlor is a general use organochlorine insecticide of low toxicity (EXTOXNET, 1996). The Angostura Irrigation District is not aware of any methoxychlor use.

There is no baseline for pesticides that is quite as good as the NCBP for inorganic contaminants. In the late-1960's through the early 1980's, the Fish and Wildlife Service did participate in a companion program, the National Pesticide Monitoring Program (NPMP) that gathered periodic data on organochlorine contaminants (Schmitt *et al.*, 1985). The geometric means and maximum concentrations for samples gathered during 1976-77, 1978-79, and 1980-81 (see Table A-10) have been published by Schmitt *et al.* (1985). Comparison to the NPMP means would indicate if results are above the national average, but would not provide any indication of contamination. If a value exceeded the NPMP maximum, that would be a strong indicator of potentially harmful level of contamination. A comparison to the pesticide data shown in Table A-9 indicated that neither the means or maximum values of the samples shown in Table 7 exceeded their respective NPMP geometric means (NOTE - the data in Table A-10 are in ppm and Table 7 is in ppb; multiply the data in Table A-10 by 1,000 to get comparable concentrations). Only 4 of the

pesticides that were above the LOD in the 1997 samples, DDD, DDE, α -BHC, and dieldrin, were included in the entire period of the NPMP. Methoxychlor was included in 1980-81, but the majority of concentrations were below detection and a geometric mean could not be calculated (Table A-10); the published value (< 0.01 ppm [= < 10 ppb]) does not provide a basis for comparison.

The NIWQP sampled pesticides and PCB's in fish in 1988 (Green *et al.*, 1990). That data set is shown in Table A-11 (once again in ppm). The LOD's for the 1988 samples were much higher than those for the 1997 samples. Still, Green *et al.* (1990) found measurable concentrations of DDD and DDE in 5 of 5 fish samples at their Fairburn site (Table A-11). Dieldrin was observed in 1 fish sample. All of the samples shown in Table A-11 are lower than the comparable NPMP data (Table A-10). Only one of the 1997 samples, a goldeye collected from the Oral site, had a concentration of any pesticide greater than the 1988 detection limit (16 vs. 10 ppb DDE). It should be noted, however, that there are differences in species between the two data sets. There was only one common species in the NIWQP and Reclamation data sets for the Red Shirt site, channel catfish. The lone channel catfish specimen in the NIWQP data set showed no measurable pesticides. The lower concentrations in the 1997 samples may be a reflection of differences in the species sampled rather than a reflection of conditions in the river.

Both the NIWQP and the Reclamation fish data show lower organochlorine pesticide concentrations than the NPMP data base. The NPMP data base encompasses a broad spectrum of species from throughout the U.S. The fish in the Cheyenne River appear to show lower levels of pesticide contamination than would be found in a cross-section of U.S. streams. Whether differences in the species composition in the two data bases has any effect on the result is unknown.

Conclusions

1. At the Oral site fish samples are above background concentrations for copper, selenium, and zinc. Selenium was the most frequently observed (over 80 %) above its background concentration. Copper and zinc were above the background concentration in over 50 percent of the samples. The frequency of exceeding the background at the Red Shirt site for each of the trace elements that exceeded the baseline at the Oral site was much lower. There were only $\frac{1}{2}$ the percentage of copper and selenium samples at the Red Shirt site that had exceeded the baseline at the Oral site, while there were no zinc samples greater than the baseline at the Red Shirt site. Based on the declining trace element concentrations in fish below the Angostura Unit in comparison to those above the Unit, it appears that the Unit is not having an adverse effect on the fish, at least for trace element contamination.

2. The laboratory noted that the samples were contaminated with zinc during preparation. The absence of results that were greater than the baseline at the Red Shirt site would indicate that the zinc contamination did not significantly affect the samples at the downstream site.
3. The analytical recovery of mercury spikes was low, ranging from 44 to about 65 percent. The low mercury recovery probably accounts for the absence of mercury in the fish samples. Only 3 of 23 samples had measurable mercury, and all 3 of these were less than 0.1 mg/Kg, the reporting limit.
4. There is a significant difference in the trace element concentrations among the three fish species sampled in the Cheyenne River. The white sucker were significantly higher in aluminum, copper, and selenium than the goldeye or channel catfish, while it appears that the channel catfish were significantly lower in zinc than either of the other species.
5. The channel catfish showed a significant decrease in the tissue concentrations of aluminum, selenium, and zinc, and a significant increase in the copper concentration between the 1988 and 1997 samples. The goldeye only showed a significant decrease in zinc. The results therefore indicate that the changes in aluminum, copper, and selenium may be species specific, but the decrease in zinc was shown across specific lines and could be true of fish in general.
6. A total of 23 fish were sampled for organic chemicals tissue analysis; the analytes included 20 insecticides, 14 herbicides, and 7 PCB's. Of these 7 insecticides, 1 herbicide, and no PCB's were found in measurable concentrations in the fish. Six of the 7 insecticides are currently banned from further use in the United States and should represent residues from past use; all are persistent organochlorines. The remaining insecticide, methoxychlor, is not known to be used on Angostura Irrigation District lands. The 1 herbicide observed in fish samples, alachlor, is used in the District, but the tissue residue is lower downstream from the District than upstream.
7. The fish in the Cheyenne River exhibit lower tissue residues of organochlorines than has been shown in a representative sample of U.S. streams.

References

- Ahrens, William H. (Ed.). 1994. Herbicide Handbook, Seventh Edition - 1994. Weed Society of America, Champaign, Illinois. 352 pp.
- Environmental Protection Agency. 1998. Fact Sheet - Update: Listing of Fish and Wildlife Advisories. EPA-823-F-98-009, EPA Office of Water, Washington, D.C. 6 pp.
- EXTOXNET. 1996. Methoxychlor. Extension Toxicology Network, Pesticide Information Profiles, Oregon State University website - <http://ace.orst.edu/cgi-bin/mfs/01/pips/methoxyc.htm?150#mfs>
- Greene, Earl A., Charles L. Sowards, and Eugene W. Hansmann. 1990. Reconnaissance Investigation of Water Quality, Bottom Sediment, and Biota Associated with Irrigation Drainage in the Angostura Reclamation Unit, Southwestern South Dakota, 1988-89. Water-Resources Investigation Report 90-4152, U.S. Geological Survey, Rapid City, South Dakota. 75 pp.
- Lowe, T.P., T.W. May, W.G. Brumbaugh, and D.A. Kane. 1985. National Contaminant Biomonitoring Program: Concentrations of Seven Elements in Freshwater Fish, 1978-81. Arch. Environ. Contam. Toxicol. 14: 363-388.
- Northern Lake Service, Inc. 1998. Fish Tissue Analysis for Selected Metals and Pesticides, Project Summary. NLS, Crandon, Wisconsin. 5 pp. + attachments.
- Pais, Istvan, and J. Benton Jones. 1997. The Handbook of Trace Elements. St. Lucie Press, Boca Raton, Florida. 223 pp.
- Schmitt, Christopher J., and William G. Brumbaugh. 1990. National Contaminant Biomonitoring Program: Concentrations of Arsenic, Cadmium, Copper, Lead, Mercury, Selenium, and Zinc in U.S. Freshwater Fish, 1976-84. Arch. Environ. Contam. Toxicol. 19: 731-747.
- Schmitt, Christopher J., Jim L. Zajicek, and Michael A. Robick. 1985. National Pesticide Monitoring Program: Residues of Organochlorine Chemicals in Freshwater Fish, 1980-81. Arch. Environ. Contam. Toxicol. 14: 225-260.
- Smith, Ivan C., and Bonnie L. Carson. 1977. Contaminants in the Environment, Vol. 1 - Thallium. Ann Arbor Science, Ann Arbor, Michigan. 394 pp.
- SPSS, Inc. 1997. SYSTAT 7.0 User Manual. SPSS, Inc., Chicago, Illinois. 5 Vols.

U.S. Environmental Protection Agency. 1997. List of Pesticides Banned and Severely Restricted in the U.S. EPA, Office of Pesticide Programs Website - <http://www.epa.gov/oppfead/international/piclist.htm>

ATTACHMENT A

MISCELLANEOUS TABLES FOR FISH TISSUE SAMPLES FROM TWO SITES ON THE CHEYENNE RIVER

Table A-1: Physical Data and Trace Element Concentrations in Fish Samples Collected during August 1997 at 2 Sites on the Cheyenne River

SITE	Species	WEIGHT (grams)	SOLIDS %	LENGTH (cm)	Al [mg/Kg]	As [mg/Kg]	Be [mg/Kg]	Cu [mg/Kg]	Hg [mg/Kg]	Se [mg/Kg]	Tl [mg/Kg]	Zn [mg/Kg]
ORAL	Channel Cat	482.1	20.8	39.4	3.05	< 0.28	<0.0037	1.084	< 0.014	0.508	< 0.46	8.8
	Goldeye	310.0	32.5	34.0	2.20	< 0.26	0.0065	0.710	< 0.022	1.200	< 0.43	28.0
	Goldeye	310.0	32.7	33.0	2.80	< 0.27	0.0580	0.798	0.062	1.100	< 0.45	24.0
	Goldeye	420.0	35.8	38.0	3.00	< 0.22	<0.0034	0.769	0.027	0.690	< 0.37	27.0
	Goldeye	280.0	36.2	36.0	5.40	< 0.27	0.0650	0.970	< 0.024	0.732	< 0.45	24.0
	Goldeye	310.0	32.5	34.0	4.30	< 0.27	<0.0036	0.740	< 0.022	0.910	< 0.45	25.0
	White Sucker	240.0	25.6	28.0	31.00	< 0.28	0.1500	2.200	< 0.018	1.600	< 0.45	18.3
	White Sucker	120.0	23.7	23.0	3.00	< 0.28	<0.0033	1.700	< 0.016	1.100	< 0.40	23.0
	White Sucker	370.0	27.2	33.0	86.00	< 0.28	0.0230	1.300	< 0.018	1.200	< 0.46	32.0
	White Sucker	330.0	25.9	32.0	64.00	< 0.28	0.0450	1.100	< 0.017	1.200	< 0.43	20.0
	White Sucker	310.0	28.8	30.0	28.00	< 0.28	0.0110	1.400	< 0.019	0.983	< 0.46	21.0
RED SHIRT	Channel Cat	320.0	28.8	35.0	13.00	< 0.24	0.0034	0.930	< 0.019	0.660	< 0.40	20.0
	Channel Cat	240.0	27.4	32.0	11.00	< 0.25	0.0310	0.670	< 0.018	0.620	< 0.43	15.0
	Channel Cat	210.0	27.6	31.0	38.00	0.28	0.0045	0.810	< 0.019	0.800	< 0.43	19.0
	Channel Cat	84.0	25.6	22.0	6.70	< 0.25	0.0035	0.970	< 0.017	0.740	< 0.41	17.0
	Channel Cat	79.0	26.1	22.0	5.70	< 0.22	0.0038	1.000	< 0.017	0.630	< 0.36	15.0
	Channel Cat	56.0	26.4	20.0	2.80	< 0.27	0.0520	0.970	< 0.018	0.810	< 0.46	19.0
	Goldeye	430.0	40.9	37.0	6.80	0.47	0.3200	0.880	< 0.027	0.950	< 0.42	19.0
	Goldeye	460.0	42.3	37.0	2.70	< 0.25	0.0082	0.530	< 0.029	0.330	< 0.43	17.0
	Goldeye	370.0	33.9	36.0	0.91	< 0.26	0.0200	0.570	< 0.023	0.650	< 0.43	20.0
	Goldeye	280.0	33.3	33.0	3.60	< 0.26	<0.0035	0.700	< 0.022	0.430	< 0.44	24.0
	White Sucker	250.0	21.9	30.0	28.00	< 0.24	<0.0037	2.300	0.055	0.950	< 0.46	19.0
	White Sucker	160.0	24.9	26.0	23.00	< 0.27	0.0120	1.800	< 0.017	0.560	< 0.45	17.0

Table A-2: Summary of Physical Data and Metals Concentrations in Fish Samples Collected during August 1997 at 2 Sites on the Cheyenne River

SITE		WEIGHT	SOLIDS	LENGTH	Al	As	Be
		(grams)	%	(cm)	[mg/Kg]	[mg/Kg]	[mg/Kg]
ORAL [n = 11]	Minimum	120.0	20.8	23.0	2.20	< 0.22	<0.0033
	25th Pctl	295.0	25.8	31.0	3.00	< 0.27	<0.0036
	Median	310.0	28.8	33.0	4.30	< 0.28	0.0110
	75th Pctl	350.0	32.6	35.0	29.50	< 0.28	0.0515
	Maximum	482.1	36.2	39.4	86.00	< 0.28	0.1500
RED SHIRT [n = 12]	Minimum	56.0	21.9	20.0	0.91	< 0.22	<0.0035
	25th Pctl	141.0	26.0	25.0	3.40	< 0.24	0.0035
	Median	245.0	27.5	31.5	6.75	< 0.26	0.0064
	75th Pctl	332.5	33.5	35.3	15.50	< 0.27	0.0228
	Maximum	460.0	42.3	37.0	38.00	0.47	0.3200
Summary	Minimum	56.0	20.8	20.0	0.9	< 0.22	<0.0033
	25th Pctl	225.0	26.0	29.0	3.0	< 0.25	<0.0037
	Median	310.0	27.6	33.0	5.7	< 0.27	0.0082
	75th Pctl	350.0	33.2	35.5	25.5	< 0.27	0.0082
	Maximum	482.1	42.3	39.4	86.0	0.47	0.0620
	%>Det. Limit	NA	NA	NA	100%	9%	74%
		Cu	Hg	Se	Tl	Zn	
ORAL [n = 11]	Minimum	0.710	< 0.014	0.690	< 0.37	18.3	
	25th Pctl	0.784	< 0.017	0.821	< 0.43	20.5	
	Median	1.084	< 0.019	1.100	< 0.45	24.0	
	75th Pctl	1.350	< 0.022	1.200	< 0.45	26.0	
	Maximum	2.200	0.062	1.600	< 0.46	32.0	
RED SHIRT [n = 12]	Minimum	0.530	< 0.017	0.330	< 0.36	15.0	
	25th Pctl	0.693	< 0.017	0.605	< 0.41	17.0	
	Median	0.905	< 0.019	0.655	< 0.43	19.0	
	75th Pctl	0.978	< 0.027	0.803	< 0.45	19.3	
	Maximum	2.300	0.055	0.950	< 0.46	24.0	
Summary	Minimum	0.530	< 0.014	0.330	< 0.36	8.8	
	25th Pctl	0.755	< 0.017	0.640	< 0.42	17.7	
	Median	0.970	< 0.019	0.800	< 0.43	20.0	
	75th Pctl	1.200	< 0.019	1.042	< 0.43	24.0	
	Maximum	2.300	0.320	1.600	< 0.46	32.0	
	%>Det. Limit	100%	13%	100%	0%	100%	

Table A-3: Statistical Comparison of Sites based on Physical Characteristics and Trace Elements in Fish (Data Summarized in Table A-2)

Variable	Mann-Whitney U	Probability
Weight	88.5	0.165
Length	82.5	0.309
Aluminum	66.0	1.000
Beryllium	67.5	0.926
Copper	85.0	0.242
Selenium	110.0	0.007
Zinc	108.0	0.009

Table A-4: Comparison of Fish Species based on Physical Characteristics and Trace Elements (Data Summarized in Table A-5)

Variable	Kruskal-Wallis X^2	Probability
Weight	5.293	0.071
Length	9.800	0.007
Aluminum	10.794	0.005
Beryllium	0.340	0.844
Copper	16.353	< 0.001
Selenium	6.385	0.041
Zinc	8.599	0.014

Table A-5: Summary of NIWQP & Reclamation Fish Trace Element Data on the Cheyenne River at Red Shirt

Source	Species		WEIGHT (grams)	SOLIDS %	LENGTH (cm)	Al [mg/Kg]	As [mg/Kg]
NIWQP - Oral 1986	Redhorse & carp	Minimum	---	--- ¹	---	4.50	< 0.20
		Median	---	---	---	15.00	< 0.20
		Maximum	---	---	---	29.25	< 0.20
		# of Obs.	0	0	0	5	5
RECLAMATION - ORAL 1997	Channel Cat, Goldeye, & White Sucker	Minimum	120	20.8	23.0	2.20	< 0.22
		Median	310	28.8	33.0	4.30	< 0.28
		Maximum	482	36.2	39.4	86.00	< 0.28
		# of Obs.	11	11	11	11	11
NIWQP - Bridge 1988	Channel Cat	Minimum	55	19.4	19.3	17.47	< 0.02
		Median	98	22.7	24.3	68.64	0.08
		Maximum	276	26.4	31.8	275.00	0.21
		# of Obs.	11	11	11	11	11
NIWQP - RED SHIRT 1988	Channel Cat	Minimum	25	18.8	15.1	15.78	< 0.02
		Median	49	23.7	20.0	54.51	0.02
		Maximum	139	25.9	28.5	112.21	0.10
		# of Obs.	7	7	7	7	7
RECLAMATION - RED SHIRT 1997	Channel Cat	Minimum	56	25.6	20.0	2.80	< 0.22
		Median	147	26.9	26.5	8.85	< 0.25
		Maximum	320	28.8	35.0	38.00	0.28
		# of Obs.	6	6	6	6	6
NIWQP - Bridge 1988	Goldeye	Minimum	270	27.9	32.2	2.46	< 0.03
		Median	336	29.8	35.0	3.14	0.06
		Maximum	456	30.9	36.8	5.36	0.12
		# of Obs.	7	7	7	7	7
NIWQP - RED SHIRT 1988	Goldeye	Minimum	198	23.0	32.4	2.52	< 0.02
		Median	279	29.3	35.3	5.98	0.05
		Maximum	344	32.3	35.7	31.06	0.06
		# of Obs.	7	7	7	7	7
RECLAMATION - RED SHIRT 1997	Goldeye	Minimum	280	33.3	33.0	0.91	< 0.25
		Median	400	37.4	36.5	3.15	< 0.26
		Maximum	460	42.3	37.0	6.80	0.47
		# of Obs.	4	4	4	4	4

¹ Conversion from dry weight based on an assumed moisture content of 75% (25% solids)

Table A-5 (continued)

Source	Species		Be [mg/Kg]	Cu [mg/Kg]	Hg [mg/Kg]	Se [mg/Kg]	Tl [mg/Kg]	Zn [mg/Kg]
NIWQP - Oral 1986	Redhorse & carp	Minimum	< 0.0175	0.600	0.025	1.000	< 1.25	11.5
		Median	< 0.0175	0.850	0.025	1.150	< 1.25	14.3
		Maximum	< 0.0175	1.375	0.050	1.850	< 1.25	60.5
		# of Obs.	5	5	5	5	5	5
RECLAMATION - ORAL 1997	Channel Cat,	Minimum	<0.0033	0.710	< 0.014	0.508	< 0.37	8.8
		Median	0.0110	1.084	< 0.019	1.100	< 0.45	24.0
	Goldeye & White Sucker	Maximum	0.1500	2.200	0.062	1.600	< 0.46	32.0
		# of Obs.	11	11	11	11	11	11
NIWQP - Bridge 1988	Channel Cat	Minimum	0.0025	0.369	0.037	0.588	< 0.10	15.7
		Median	0.0083	0.454	0.055	0.880	< 0.17	20.7
		Maximum	0.0264	0.872	0.075	1.475	< 1.54	27.9
		# of Obs.	11	11	11	11	11	11
NIWQP - RED SHIRT 1988	Channel Cat	Minimum	< 0.0022	0.466	0.029	0.569	< 0.11	23.5
		Median	0.0038	0.545	0.059	0.855	< 0.17	27.7
		Maximum	0.0255	3.945	0.083	1.519	< 1.28	49.2
		# of Obs.	7	7	7	7	7	7
RECLAMATION RED SHIRT 1997	Channel Cat	Minimum	0.0034	0.670	< 0.017	0.620	< 0.36	15.0
		Median	0.0042	0.950	< 0.018	0.700	< 0.43	18.0
		Maximum	0.0520	1.000	< 0.019	0.810	< 0.46	20.0
		# of Obs.	6	6	6	6	6	6
NIWQP - Bridge 1988	Goldeye	Minimum	< 0.0028	0.338	0.139	1.228	< 0.14	24.6
		Median	< 0.0031	0.558	0.189	1.474	< 0.25	26.6
		Maximum	< 0.0309	0.773	0.233	1.940	< 1.54	31.3
		# of Obs.	7	7	7	7	7	7
NIWQP - RED SHIRT 1988	Goldeye	Minimum	< 0.0023	0.287	0.084	0.674	< 0.14	26.9
		Median	< 0.0029	0.483	0.106	0.820	< 0.18	29.2
		Maximum	< 0.0032	0.870	0.218	0.932	< 0.26	36.9
		# of Obs.	7	7	7	7	7	7
RECLAMATION RED SHIRT 1997	Goldeye	Minimum	<0.0035	0.530	< 0.022	0.330	< 0.42	17.0
		Median	0.0141	0.635	< 0.024	0.540	< 0.43	19.5
		Maximum	0.3200	0.880	< 0.029	0.950	< 0.44	24.0
		# of Obs.	4	4	4	4	4	4

Table A-6: Statistical Comparison of 1988 and 1997 Samples from the Red Shirt Site based on Physical Characteristics and Trace Elements in Channel Catfish

Variable	Mann-Whitney U	Probability	X²	Median 1986-88	Median 1997
Weight (g.)	36.0	0.102	2.670	49.0	147.0
Length (cm)	34.5	0.084	2.979	20.0	26.5
Aluminum	122.0	0.000	12.751	54.51	8.85
Beryllium	70.0	0.672	0.179	0.004	0.004
Copper	10.0	0.001	10.293	0.545	0.950
Selenium	100.0	0.025	5.015	0.855	0.700
Zinc	117.0	0.001	10.690	27.71	18.0

Table A-7: Statistical Comparison of 1988 and 1997 Samples from the Red Shirt Site based on Physical Characteristics and Trace Elements in Goldeye

Variable	Mann-Whitney U	Probability	X²	Median 1986-88	Median 1997
Weight (g.)	3.0	0.037	4.341	49.0	310.0
Length (cm)	5.0	0.088	2.906	20.0	36.0
Aluminum	19.0	0.345	0.893	54.51	3.00
Beryllium	7.0	0.185	1.758	0.004	0.008
Copper	6.0	0.131	2.286	0.545	0.740
Selenium	21.0	0.186	1.750	0.855	0.732
Zinc	28.0	0.008	7.000	27.7	24.0

Table A-8: Summary of Organic Analyses and Detection Limits for the 1997 Fish Samples								
Herbicides	Observed	Detection Limit (ppb)	Insecticides	Observed	Detection Limit (ppb)	PCB's	Observed	Detection Limit (ppb)
ATRAZINE	NO	44	ALDRIN	YES	1.20	PCB-1016	NO	16
DESETHEYLATRAZINE	NO	65	α-BHC	YES	1.10	PCB-1221	NO	39
DESISOPROPYLATRAZINE	NO	70	β-BHC	NO	2.60	PCB-1232	NO	48
ALACHLOR	YES	120	γ-BHC	NO	3.00	PCB-1242	NO	28
BUTYLATE	NO	92	δ-BHC	YES	1.10	PCB-1248	NO	33
CYANAZINE	NO	38	CHLORDANE	NO	3.20	PCB-1254	NO	27
EPTC	NO	22	4,4-DDD	YES	1.20	PCB-1260	NO	12
METOLACHLOR	NO	45	4,4-DDE	YES	1.30			
METRIBUZINE	NO	120	4,4-DDT	NO	0.99			
PENDIMETHALIN	NO	36	DIELDRIN	YES	2.30			
PROMETON	NO	56	ENDOSUFAN I	NO	1.00			
PROPAZINE	NO	48	ENDOSULFAN II	NO	1.00			
SIMAZINE	NO	48	ENDOSULFAN SULFATE	NO	2.00			
TRIFLURALIN	NO	34	ENDRIN	NO	1.80			
			ENDRIN ALDEHYDE	NO	0.75			
			HEPTACHLOR	NO	1.60			
			HEPTACHLOR EPOXIDE	NO	1.40			
			MALATHION	NO	60			
			METHOXYCHLOR	YES	0.60			
			TOXAPHENE	NO	200			

Table A-9: Selected Pesticide Results (all in µg/Kg) - WET WEIGHTS (only those with results > L.O.D.)														
ORAL SITE	CCF	CCF	CCF	GOE	GOE	GOE	GOE	WHS	WHS	WHS	WHS			
	P1	P2	P3	P1	P2	P3	P4	P1	P2	P3	P4			
4,4'-DDD				2.5*										
4,4'-DDE	1.5*			16	7.7	5.3	2.3*	6.4		2.4*	3.8*			
Alachlor	530			420										
Aldrin					2.4*									
α-BHC			1.3*		1.4*		2.5*							
δ-BHC				1.2*										
Methoxychlor								0.64*		0.83*	0.68*			
RED SHIRT SITE	CCF	CCF	CCF	CCF	CCF	CCF	GOE	GOE	GOE	GOE	WHS	WHS	WHS	
	P1	P2	P3	P4	P5	P6	P1	P2	P3	P4	P1	P3	P4	
4,4'-DDD									1.3*					
4,4'-DDE			3.9*	1.8*			3.1*	5.9	5.8	2.4*				
Alachlor		220												
α-BHC					1.7*			1.4*	2.6*			1.8*	2.7	
Dieldrin									3.4*					
Methoxychlor									0.96*					
* indicates that the value shown is below the limit of quantitation; concentration is approximate. NOTE - CCF = channel catfish, GOE = goldeye, WHS = white sucker														

Table A-10: Geometric Mean and Maximum Organochlorine Residues (all in ppm) in Fish - NPMP 1976 - 81 (from Schmitt *et al.*, 1985)

Analyte	MEAN 1976-77	MAX. 1976-77	MEAN 1978-79	MAX. 1978-79	MEAN 1980-81	MAX. 1980-81
4,4-DDD	0.09	1.77	0.09	3.01	0.07	3.43
4,4-DDE	0.27	5.21	0.25	6.76	0.20	2.57
4,4-DDT	0.05	1.99	0.04	1.95	0.05	2.69
α-BHC	0.02	0.30	< 0.01	0.04	< 0.01	0.04
γ-BHC	0.01	0.28	< 0.01	0.02	< 0.01	0.03
CHLORDANE	---	---	---	---	---	---
DIELDRIN	0.05	5.01	0.05	3.72	0.04	0.72
ENDRIN	0.01	0.40	< 0.01	0.11	< 0.01	0.30
HEPTACHLOR	0.01	0.78	0.02	1.17	0.01	0.27
HEPTACHLOR EPOXIDE	---	---	---	---	---	---
METHOXYCHLOR	---	---	---	---	< 0.01	0.19
PCB-1260	---	5.60	---	7.60	---	2.63
TOXAPHENE	0.35	12.7	0.29	18.7	0.27	21.0

Table A-11: Organochlorine Residues (ppm) in Fish - NIWQP 1988 (from Greene *et al.*, 1990)

Analyte (all in ppm)	Co. Rd. <u>Bridge</u> Carp	<u>Fairburn</u> Carp	<u>Fairburn</u> Channel Catfish	<u>Fairburn</u> Carp	<u>Fairburn</u> Sauger	<u>Fairburn</u> Shorthead Redhorse
4,4-DDD	< 0.01	0.02	< 0.01	0.01	0.03	0.01
4,4-DDE	< 0.01	0.01	< 0.01	0.03	0.05	0.02
4,4-DDT	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
α-BHC	---	---	---	---	---	---
γ-BHC	---	---	---	---	---	---
CHLORDANE	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
DIELDRIN	< 0.01	< 0.01	< 0.01	0.01	< 0.01	< 0.01
ENDRIN	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
HEPTACHLOR	---	---	---	---	---	---
HEPTACHLOR EPOXIDE	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
PCB-1260	---	---	---	---	---	---
TOXAPHENE	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05

Addendum on 1998 fish samples -

Reclamation samples collected in 1998 were entered into a spreadsheet and combined with the samples collected in 1997 and with the NIWQP samples collected in 1985, 1986, and 1988. (The 1994 NIWQP data were not included because only 3 of the samples appeared to consist of common species with the Reclamation data.) The data (in Lotus format) were entered into the statistical analysis package SYSTAT, version 7, for statistical analysis. The complete SYSTAT output is included in the companion file, Fish-Stat.wpd.

As a group, the samples in 1998 include significantly larger fish than in 1997, both in terms of length and weight, based on both a nonparametric Mann-Whitney test or a parametric t-test. There is a significant difference in the concentration of Hg, Se, and Zn in the aggregated fish from the two years, but no significant difference in As or Cu (the probability level for As is 0.054, which is very near the significant α -level of 0.05). It was noted in the earlier data set that there was a relationship between fish size and the concentration of some contaminants. It was also noted that the Hg data from 1997 were probably artificially low as indicated by the poor recovery of spikes (< 50%). In comparison to the 1997 samples, the 1998 samples were significantly higher in Hg (expected) and significantly lower in Se and Zn. Because the fish were larger in 1998, all would be expected to be higher in contaminants that bioaccumulate, e.g. Hg and Se. However, the only such difference was in Hg, which can be explained on the basis of analytical difficulties in 1997 (poor analytical recovery), rather than the size of the fish.

The 1997 data also indicated that contaminant levels varied by species. To further evaluate this, the 3 common species in the two data sets were evaluated separately. There was a significant difference in Cu, Hg, and Zn among the 3 species. The species were then taken individually. The results of this analysis show that the channel catfish was the only species that showed a significant difference in size (both length and weight) between the two sets of samples; channel cat had significantly lower Se and Zn in 1998. Goldeye were significantly longer in 1998, but there was no significant difference in weight; in other words, the weight per unit length was different. Since it was lower, the fish were in poorer condition in 1998. Goldeye were significantly lower in Se and significantly higher in Cu in 1998. The white sucker showed no significant difference in either weight or length between years, but were significantly lower in both Se and Zn in 1998. Since there is such a mixed bag of results, *i.e.* there is no consistent pattern, the 1997 and 1998 data will be combined in comparing to the NIWQP data. The combination will simply expand the range of the Reclamation data in most cases.

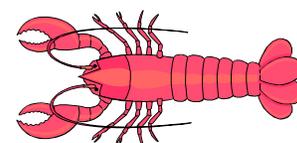
There are no size data available for the NIWQP data set. This eliminates any possibility of looking at the effect of size on the concentration of contaminants in that data set. It could affect the results of the comparison of the NIWQP and Reclamation data. Such a comparison assumes either that the two data sets consist of fish of comparable size classes or that size is not a factor in the level of contaminants in the fish. Either of these assumptions could be in error.

The comparison between the NIWQP and Reclamation data is based solely on the results of Mann-Whitney test performed on matching species. For channel catfish, the Reclamation data for As, Cu, Hg, Se, and Zn are all significantly greater than the NIWQP measures. For shorthead redhorse the NIWQP data for As, Cu, Hg, Se, and Zn are all significantly greater than the Reclamation data. The concentrations of As, Cu, Se, and Zn in Reclamation's white sucker samples are all significantly greater than those in the NIWQP samples, while there is no difference in Hg. It should be noted that NIWQP data only included 3 white suckers. For goldeye samples, Reclamation's samples were significantly higher in As and Cu, while the NIWQP samples were significantly higher in Hg, Se, and Zn. These results indicate that concentrations of the contaminants vary between species and over time. Because of the intermixing of results, the analytical results appear comparable.

An attempt was made to look at the possible effects of interactions of the independent variables. This was done using ANOVA (Analysis of Variance) techniques. A good example is provided by the Se results for the Reclamation and NIWQP data and the possible interaction with species effects. The results are summarized in Table 1 and illustrated graphically in Figure 1. Table 1 shows that all of the effects are very highly statistically significant. The species effect (Figure 1A) is based on the comparatively very high Se concentration in the white sucker; the shorthead redhorse are then higher in Se than the channel catfish and goldeye, which are approximately equal. Figure 1B shows that the NIWQP fish samples were much higher in Se than the Reclamation samples; this is the source effect (or possibly the time effect, *i.e.* 1980's vs. the 1990's). Figure 1C illustrates the interactions effect. The interaction is based on the fact that the species effect appears to be entirely due to the NIWQP results. The Reclamation samples show essentially no species effect whatsoever.

A statistical summary of the data from both sources for each of the 5 contaminants is presented in Table 2, which also shows ambient concentrations from the NCBP database. Complete results of the statistical analysis, including additional ANOVA results and plots, are presented in the companion output file referenced above. A comparison between the contaminants data and the ambient concentrations for fish in the U.S. is presented in Table 3. For a couple of the contaminants, *i.e.* Hg and Se, a large percentage of the NIWQP samples exceed the baseline. The Reclamation samples showed a much lower percentage of the Hg samples that exceeded the baseline and none of the Se samples above the baseline (Table 3).

Table 4 shows a comparison between the NIWQP and Reclamation results and a toxic threshold taken from DOI (1998). There is no comparison for Zn since the toxic threshold that is given is only $\frac{1}{10}$ of the ambient concentration from the NCBP. This means that the laboratory test fish used to develop the toxicity threshold would exhibit whatever effects were observed; these may be sublethal effects, *e.g.* reduced growth. Whether the fish from the river experience any effects is unknown. Because of the apparent contradiction, no comparison for zinc is made.



Most of the fish in the NIWQP data set, with the obvious exception of the goldeye, exceed the toxicity threshold. The toxicity of Se is based on the mortality of juveniles and reproductive failure in adults. Such effects would not affect the survival of individual adult fish, but would adversely affect fish population levels in the long term. No Reclamation samples exceeded any of the toxic thresholds.

Table 1. Analysis of Variance Results for Data Source (NIWQP or Reclamation) and Fish Species

Effects coding used for categorical variables in model.

Categorical values encountered during processing are:

TIME (3 levels)

Pre-1990, 1997, 1998

SPECIES\$ (4 levels)

Channel Cat, Goldeye, SH Redhorse, White Sucker

SOURCE\$ (2 levels)

NIWQP, USBR

Dep Var: SE N: 97 Multiple R: 0.818 Squared multiple R: 0.670

Analysis of Variance

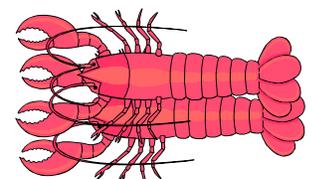
Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
SPECIES\$	85.892	3	28.631	9.177	0.000
SOURCE\$	467.381	1	467.381	149.815	0.000
SPECIES\$*SOURCE\$	83.332	3	27.777	8.904	0.000
Error	277.655	89	3.120		

*** WARNING ***

Case 10 is an outlier (Studentized Residual = 19.935)

Durbin-Watson D Statistic 1.559

First Order Autocorrelation 0.219



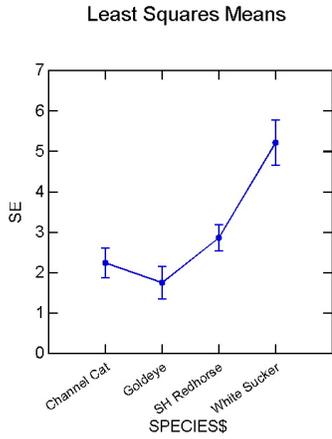


Figure 1A. Species Effect

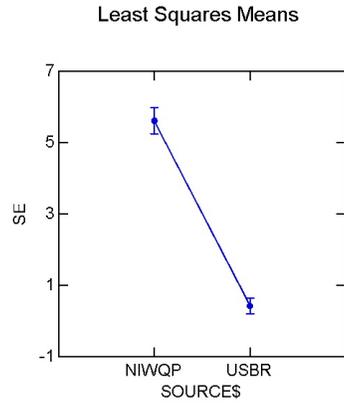


Figure 1B. Source Effect

Least Squares Means

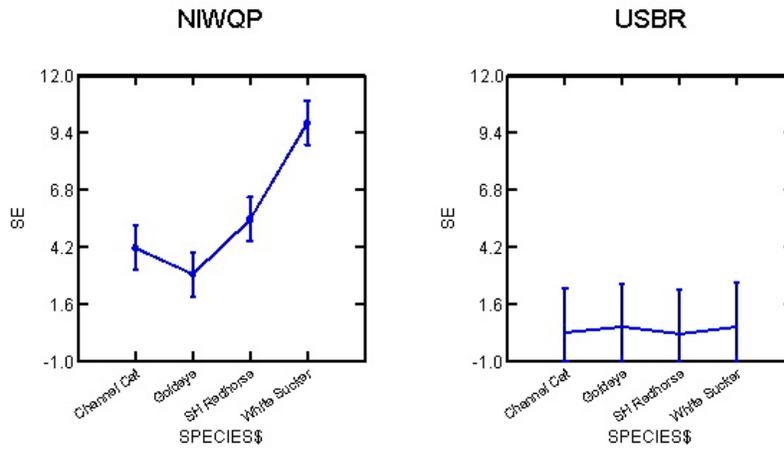


Figure 1C. Species and Source Interaction

Table 2: Summary Statistics - Comparison of NIWQP and Bureau of Reclamation Fish Contaminants Results for Four Common Species (All in mg/Kg dry weight)

Species	Source		As	Cu	Hg	Se	Zn
Channel Catfish	NIWQP	Minimum	< 0.1	1.8	0.12	2.4	87.0
		Median	0.1	2.8	0.25	4.1	107.5
		Maximum	0.4	16.0	0.35	6.2	201.0
		No. of Obs.	8	8	8	8	8
	BR	Minimum	< 0.1	0.5	0.12	< 0.03	5.0
		Median	< 0.1	0.8	0.12	< 0.03	7.8
		Maximum	0.28	2.1	0.53	0.8	20.0
		No. of Obs.	20	20	20	20	20
Goldeye	NIWQP	Minimum	< 0.1	1.2	0.26	2.1	89.0
		Median	0.1	1.7	0.46	3.0	100.0
		Maximum	0.2	3.3	0.74	3.9	146.0
		No. of Obs.	7	7	7	7	7
	BR	Minimum	< 0.1	0.5	0.03	< 0.03	16.0
		Median	< 0.1	0.8	0.12	0.5	22.0
		Maximum	0.47	5.6	0.12	1.2	28.0
		No. of Obs.	14	14	14	14	14
Shorthead Redhorse	NIWQP	Minimum	< 0.1	2.0	0.01	3.5	46.0
		Median	< 0.1	2.6	0.18	4.4	76.0
		Maximum	0.3	5.5	0.49	20.0	84.0
		No. of Obs.	14	14	14	14	14
	BR	Minimum	< 0.1	0.8	0.12	< 0.03	7.8
		Median	< 0.1	1.0	0.12	< 0.03	11.5
		Maximum	< 0.1	2.7	0.12	1.2	17.0
		No. of Obs.	16	16	16	16	16
White Sucker	NIWQP	Minimum	< 0.1	4.3	0.01	6.6	63.0
		Median	0.3	7.8	0.12	11.0	68.0
		Maximum	0.50	21.0	0.13	12.0	91.0
		No. of Obs.	3	3	3	3	3
	BR	Minimum	< 0.1	1.1	0.06	< 0.03	9.6
		Median	< 0.1	1.6	0.12	< 0.03	15.4
		Maximum	< 0.1	2.3	0.12	1.6	32.0
		No. of Obs.	15	15	15	15	15
Ambient Natural Concentrations	NCBP ¹	Percentile	0.96	9.8	0.44	3.0	160

¹ National Contaminants Monitoring Program 85th Percentile - Schmitt and Brumbaugh (1990); converted from wet weight concentration assuming a 75% moisture content.

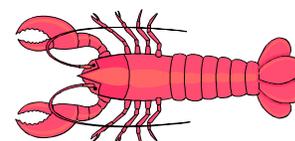


Table 3. Comparison to Ambient Concentrations - Number > NCBP 1990 85th Percentile Concentrations in Fish

Species	Source	As	Cu	Hg	Se	Zn
Channel Cat	NIWQP	0.0%	12.5%	0.0%	62.5%	12.5%
	BR	0.0%	0.0%	5.0%	0.0%	0.0%
Goldeye	NIWQP	0.0%	0.0%	57.1%	28.6%	0.0%
	BR	0.0%	0.0%	0.0%	0.0%	0.0%
Shorthead Redhorse	NIWQP	0.0%	0.0%	7.1%	100.0%	0.0%
	BR	0.0%	0.0%	0.0%	0.0%	0.0%
White Sucker	NIWQP	0.0%	33.3%	0.0%	100.0%	0.0%
	BR	0.0%	0.0%	0.0%	0.0%	0.0%
All fish	NIWQP	9.1%	3.0%	13.6%	86.4%	13.6%
	BR	0.0%	0.0%	1.5%	0.0%	0.0%

Table 4. Comparison to Ambient Concentrations - Percent > Toxic Thresholds

Species	Source	As	Cu	Hg	Se
Channel Cat	NIWQP	0.0%	0.0%	0.0%	50.0%
	BR	0.0%	0.0%	0.0%	0.0%
Goldeye	NIWQP	0.0%	0.0%	0.0%	0.0%
	BR	0.0%	0.0%	0.0%	0.0%
Shorthead Redhorse	NIWQP	0.0%	0.0%	0.0%	64.3%
	BR	0.0%	0.0%	0.0%	0.0%
White Sucker	NIWQP	0.0%	0.0%	0.0%	100.0%
	BR	0.0%	0.0%	0.0%	0.0%
All fish	NIWQP	0.0%	0.0%	0.0%	62.1%
	BR	0.0%	0.0%	0.0%	0.0%

