LAND TRUST OF THE UPPER ARKANSAS **GRANT AMOUNT - $3,837**

PROJECT FINAL REPORT (12/1/13 to 8/1/15)

INITIAL MONITORING OF WATER QUALITY ON THE SOUTH ARKANSAS RIVER

INTRODUCTION

The purpose of this grant was to provide support for sampling water quality along the South Arkansas River in Chaffee County, Colorado. The South Arkansas River is a major tributary of the Upper Arkansas River that flows through Bighorn Sheep Canyon into the plains near Pueblo, Colorado. The South Arkansas River starts from the higher elevations of the Collegiate Peaks Range at Monarch Pass and flows through the Town of Poncha Springs and then the City of Salida before merging with the Upper Arkansas River. As of 2013, the South Arkansas River had not been the focus of water quality evaluation or any major protection or restoration work. The Land Trust of the Upper Arkansas (LTUA) has committed its resources and begun work to change this picture. In partnership with the Collegiate Peaks Anglers Chapter of Trout Unlimited, LTUA created the South Arkansas Watershed Coalition to help restore in-stream, riparian, and water quality characteristics important for people and wildlife.

The coalition found funding and contracted for a watershed assessment of the South Arkansas River, including preliminary measurements of water quality. The present grant helped the coalition continue water quality data gathering for 18 additional months. The data collected provide a baseline against which to evaluate changes in water quality over time as well as any changes resulting from river restoration projects. Overall, the data collection supported by this grant has helped the Land Trust prepare to evaluate the results of restoration projects; and, the data will be used as input on additional needs for work on the South Arkansas River and its environment. In sum, the water quality testing done with the support of this grant provides a solid baseline set of data along the elevational gradient of the river’s flow. These data are also available to identify potential problems in water quality needing further study, and to help to identify processes currently affecting water quality in the South Arkansas River.

Starting in winter 2012, samples were collected at five sites. These sites cover the South Arkansas River gradient from ~10,400 feet near the river's headwaters to the river's confluence with the Arkansas River at ~ 7,050 (Figure 1). Samples were taken twice a year – in winter (December/January) and in summer (July). To date, samples have been collected three times in summer and twice during the winter. No winter sample was collected during December 2014/ January 2015. Analyses included: chemical and physical characteristics, plus coliform bacterial counts. The chemical parameters were ion concentrations of: calcium (Ca), magnesium (Mg), sodium (Na), chloride (Cl), potassium (K), iron (Fe), manganese (Mn), sulfate (SO_3), nitrates (NO_3-N), and phosphorus (P), as well as carbonate, bi-carbonate, pH, alkalinity, and hardness. The physical parameters were pH, alkalinity, hardness, total dissolved solids and turbidity. Bacterial counts included total coliform bacteria and *E. coli* counts.

Five objectives were initially identified in this project. These objectives were to: (1) determine current water quality parameters along the South Arkansas River; (2) create a baseline of water quality data for future comparison; (3) compare water quality between normal flows and storm events; (4) develop a source of data to use for evaluating the success of restoration projects; and (5) initiate the creation of a volunteer group to continue water quality sampling on the South Arkansas River as our restoration efforts move forward.

To date, the coalition has met four of the five proposed objectives proposed (1, 2, 4, and 5). Achieving objective 3 – evaluation of the effects of storm events on water quality – has been problematic. Given the length of the watershed assessment corridor (15 miles / 24.6 km) and the extent of development at various points, we initially assumed that storm water runoff from local streets and highways would be directed into the river, and that such runoff would be quantifiable at drainage pipes installed at several locations along the South Arkansas River. To evaluate that assumption, we located all drainage pipes that daylight at the edge of the South Arkansas River in the river assessment, and documented any flows observed from those pipes at the time the pipes were located. Most of the pipes, however, did not evidence any flows; and, the pipes with water observed flowing had low, clear water inflowing. Further evaluation of road drainage networks suggests that, outside of U.S. Highway 50 through Salida, the predominant drainage into the South Arkansas River is intermittent, localize and informal, rather than via the drain pipes located.

Storm events outside of the winter and summer sampling periods were observed, but could not be sampled quantitatively. One impact to water quality observed during these storm events was a marked increase in turbidity. However, such events were short-lived and unpredictable in timing and location; these conditions made adequate sampling more difficult than anticipated. One alternative in the future would be to anticipate and sample when surface withdrawals for irrigation are discontinued in the fall. This change in water use has been observed to produce a notable increase in water level and turbidity in the South Arkansas River. The effect of such flows, however, may be significantly different, quantitatively or qualitatively, than those produced by storm water runoff. Quantification of storm water runoff effects in the future will likely require continuous sampling equipment located at permanent stations.

MATERIALS AND METHODS

First, we purchased the water quality meter, carrying case and sensors, as planned. The sensors record instantaneous pH, temperature, and dissolved oxygen concentrations. The meter purchased, *YSI Professional*, was chosen for its data capacity and its reputation for durability under field conditions, as well as its reliability in providing the required measurements under a range of conditions.

Second, water samples were collected five times (3 winters, 2 summers), as planned, from five sites along the South Arkansas River (see below; Figure 1 - map). Sampling times were December/January and July. Both represent times of sustained, low water flows, but the comparison allows evaluation of consistent seasonal variation in water quality.

Since no previous information on South Arkansas River water quality is available, the sampling sites were selected to integrate areas of common land use and to isolate potential impacts, for example, of Poncha Creek inflows and of the towns of Poncha Springs and Salida, Colorado (Figure 1). The sites were:

- Site 1: near the top of watershed, where Forest Road 231 crosses the South Arkansas River. Both Monarch Mountain Ski and Snowboard Area and Monarch Park Campground (U.S. Forest Service) are just upstream, allowing quantification of any potential impacts on water quality of these recreational areas. The ski area has a wastewater treatment facility, and the campground has several pit toilets.

- Site 2: located about 8.5 miles (23.5 km) downstream from Site 1, where Chaffee County Road 225 (CCR 225) crosses the South Arkansas River. Major land uses that could potentially affect water quality above this site include: gravel extraction and preparation operations at Monarch Mine, and wastewater from the Town of Monarch (formerly known as Garfield), Colorado.

- Site 3: located about 10.8 miles (17.4 km) downstream from Site 2, just upstream of where U.S. Highway 285 crosses the South Arkansas River. Land use between Sites 2 and 3 is largely agricultural, e.g., haying, cattle grazing, with some areas of rural residential.

- Site 4: about 0.5 mile (< 1.0 km) downstream from Site 3, but below the confluence of Poncha Creek with the South Arkansas River. Poncha Creek parallels U.S. Highway 285 for several miles, prior to its inflow into the South Arkansas River. Comparison of parameters from Site 4 with those from Site 3, just above the inflow of Poncha Creek, should help isolate any impact that inflows from Poncha Creek may have on South Arkansas River water quality.

- Site 5: about 6.0 miles (9.7 km) downstream from Site 4 at Chaffee County Road 105 (CCR 105). The South Arkansas River merges with the main stem of the Arkansas River at this point. The Town of Poncha Springs and the City of Salida are situated between Sites 4 and 5; so, water samples taken here should help isolate the effects of more intense development along this section of river.

Water samples were collected in 12-ounce plastic commercial drinking water bottles. Bottles were opened on site and the original water discarded in an area downstream of the sample site. Bottles were rinsed twice with the source water then filled, capped, and placed in a hard-sided cooler with ice packs for short-term storage. Samples were sent to Colorado State University for evaluation of chemical and physical characteristics, and also to Pueblo Department of Health for quantification of coliform bacterial loads.

RESULTS AND DISCUSSION

We asked two main questions about the previously unmeasured water quality in the South Arkansas River:

1. ***What are the characteristics of the water, and do any vary seasonally?***
2. ***Does water quality change significantly with location along the river?***

<u>Seasonal Patterns in Water Quality Parameters of the South Arkansas River</u>

Season, defined in this study as the sustained, low water of winter and summer, did not lead to significant seasonal differences in most of the key ion concentrations (non-overlap of 95% CIs). Calcium, magnesium, potassium and sodium were similar between winter and summer seasons (Table 1). However, chloride concentrations were significantly higher in summer than in winter (non-overlap 95 % CI), as were bicarbonate and sulfate concentrations (Table 1). Interestingly, the variability in calcium, magnesium, chloride, bicarbonate and sulfate concentrations along the South Arkansas River (Table 1) was greater on average in summer than in winter (~ 2-fold). Carbonates were below detection levels (Table 1). Bi-carbonates, however, were significantly higher in summer than in winter (non-overlap of 95% C.I.). Also, variability in bi-carbonate concentrations was greater in summer than in winter. Nitrates, nitrate-nitrogen and unionized nitrate also were below detectable levels at all sites (Table 1).

Metals, specifically iron, manganese, zinc, and copper, were relatively low; average values were typically below detectable levels in both winter and summer (Table 1).

Other critical water quality measures, the physical parameters such as pH, conductivity, alkalinity, hardness and total solids, also were similar between the winter and summer seasons (Table 1). However, turbidity, which was relatively low in both seasons, varied between seasons; it was significantly higher (non-overlap of 95% C.I.s) in summer than in winter. Turbidity levels also were more variable (compare C.I.s), in summer than in winter.

Finally, analyses for coliform bacteria showed that the average concentrations of the coliform bacterium *E. coli* were relatively low. However, the concentrations were higher (~7-fold) in summer than in winter (Table 1). In contrast, total coliform bacteria, from samples collected only in the summers, averaged relatively high colony counts (over 1,800 colonies/100 ml: Table 1). Since the EPA uses 200 total coliform colonies/100 ml water as the threshold for safe drinking water, these initial data suggest that average levels of coliform bacterial contamination in the summer are high and an issue to be addressed in restoration efforts on the South Arkansas River.

In summary, seasonal variation in water quality along the South Arkansas River, comparing winter and summer with sustained low flow rates, was primarily restricted to variation in turbidity and in coliform bacterial concentrations, rather than in mineral, ion or metals concentrations. Average mineral concentrations were generally similar between seasons. Carbonates and metals concentrations were so low as to be undetected on average. However, bi-carbonates were present, and increased dramatically in summer compared to winter. Most other important measures of water quality, e.g., conductance, alkalinity, hardness and total solids, were similar between winter and summer. The exception among physical parameters was turbidity, which was higher and more variable in summer. Average total coliform counts in summer exceeded the EPA criterion for drinking water. *E. coli* colony counts were not especially high, but higher in summer than in winter.

Water Quality in Relation to Position along the Length of the South Arkansas River

Examined by site, average concentrations of calcium, magnesium, potassium and sodium concentrations increased with position down the water course, from the highest elevation site (Site 1) to the lowest elevation site (Site 2) (Table 2); the patterns observed were generally consistent between winter and summer samples.

Mineral, Ion and Metal Concentrations

Calcium concentrations were significantly lower at Site 1 than at the other four sites lower along the South Arkansas River drainage (non-overlap 95% C.I.), and the differences occurred in both winter and summer (Table 2). Overall, calcium concentrations increased nearly linearly from low values at the highest (Site 1) to high values at the lowest site, below Salida (Site 5). Calcium concentrations in winter were significantly lower at Site 1 than at Site 5 (non-overlap 95% C.I.). The exception to a linear increase from Site 1 to Site 5 was evidence of a dip in calcium concentrations at Site 4, just below the inflow from Poncha Creek; this anomaly occurred in both winter and summer (Table 1), and it likely represents a dilution effect of inflow from Poncha Creek. Finally, variability in calcium concentrations was much higher (on average > 10-fold higher; C.I.s) in summer than in winter.

Magnesium followed the same spatial pattern as calcium (Table 2); it was significantly lower in the upper reaches than in the lower, more human-influenced reaches of the South Arkansas River (Table 2; non-overlap 95% C.I.). Variability in magnesium concentrations was higher in summer than in winter (> 2-fold).

Sodium concentrations were relatively low (Table 2); and, they showed a linear pattern of increase from Site 1 to Site 5; the sodium concentrations were lowest in the upper reaches and highest in sites lower on the gradient with increasing human influences. The increases observed were at least 2- to 4-fold (> 200 - 400%). The differences between Site 1, high on the gradient, and Site 5, lowest on the gradient, were highly significant statistically (non-overlap C.I.).Variation in sodium concentrations were similar among sites in both winter and summer.

Potassium concentrations were also quite low (Table 2); however, they showed a similar pattern to that for calcium, magnesium, and sodium, but without the dilution effect just below the town of Poncha Springs. Potassium concentrations increased linearly from Site 1 to Site 5, below the City of Salida. This increase was statistically significant (non-overlap 95% C.I.). The spatial change was correlated with increasing degrees of human influences. Variability in potassium concentrations was low, and it was similar in winter and summer.

Chloride concentrations were also low (Table 2). Interestingly, however, the spatial pattern in chloride concentrations was opposite of the pattern in the other minerals along the river course gradient. Highest concentrations of chloride were found at the highest site, in the National Forest, and lower concentrations occurred at the other four, lower sites (Sites 2 – 5); this pattern was consistent between seasons, but chloride concentrations were higher in the summer than in the winter (2-fold). Variation among sites along the gradient was relatively low, with only Sites 1 and 5 showing higher estimated variation in the summer samples (Table 2). The pattern suggest that dilution in chloride concentrations occurs as the South Arkansas River descends and approaches its confluence with the Arkansas River just below the City of Salida (Figure 1).

Carbonates were consistently below detection levels (Table 2). Bi-carbonates, however, showed a pattern similar to that of the minerals, calcium, magnesium, sodium and potassium (Table 2). Lower concentrations were recorded in the upper reaches, and the highest concentrations occurred at the lowest site (Site 5) in winter and in summer. Bi-carbonate concentrations tended to be higher in summer than in winter at the three lowest sites. Variability in concentrations tended to be higher in the summer than in winter (3- to 5-fold).

Sulfate concentrations (Table 2) were also significantly lower at the highest site, Site 1, than at the other four, more human-influenced sites, Sites 2 – 5 (non-overlap 95% C.I.). Also, sulfate concentrations were significantly higher at the lowest site (Site 5) than at the highest site (Site 1) in both winter and in summer (non-overlap 95% C.I.). Average concentrations were similar or trending lower in summer than in winter. Variability was higher (2-fold) in summer than in winter. Unionized sulfate concentrations were below detections levels (Table 2).

Phosphorus concentrations were low and relatively consistent along the gradient from Site 1 to Site 5 in both seasons, with only a small amount of variation within sites (Table 2). In winter, mean phosphate concentrations ranged from a low of 6.9 mg/L at Site 1 to 7.8 – 8.0 mg/L at Sites 2 – 5. No variation in these numbers was recorded within site in winter samples. In summer, however, mean phosphate concentrations did vary linearly, increasing from a low of 7.0 at Site 1, high on the gradient, to 7.2, 7.8, 7.8, and 8.0 at Sites 2, 3, 4 and 5, respectively, lower on the gradient. These differences between sites, however, were not statistically significant (overlap 95% C.I.).

Nitrate, nitrate-nitrogen and unionized nitrate were below detectable levels all along the gradient of the South Arkansas River in both seasons. These results suggest that organic input to the South Arkansas River is relatively low.

Concentrations of metals, i.e., iron, manganese, zinc and copper, also were consistently below detectable levels all along the gradient of the South Arkansas River at all sites and in both seasons (Table 2). These findings suggest that the influence of old mines in the area at this time is minimal for the South Arkansas River drainage.

Physical Parameters

The measurements of pH varied from 6.9 to 8.0 (Table 3), showing the neutral to alkaline nature expected given the ambient geological context of the granitic Rocky Mountains. The lowest pH levels were recorded at Site 1, high on the South Arkansas River drainage, in both winter and summer. The pH levels at Site 1 in winter were significantly lower than those at Site 5, near the South Arkansas River confluence with the Upper Arkansas River (non-overlap 95% CIs); these pH levels were similar and higher (7.8 – 8.0) at Sites 2 – 5 than at Site 1 (6.9). In summer, pH increased from 7.0 at Site 1 and 7.2 at Site 2 to 7.8 at Sites 3 and 4, and 8.0 at Site 5; however, the differences among sites though were not statistically significant (non-overlap 95% C.I.).

Conductivity, the ability of water electrolytes to transmit heat, increased approximately linearly from the highest site to lowest site along the South Arkansas River (Table 3). The exception observed was a dip at Site 4, just below the inflow of Poncha Creek into the South Arkansas River, similar to the pattern seen in some of the minerals (Table 2). The drop over the short distance from Site 3 to Site 4 suggests a dilution effect from Poncha Creek inflow into the South Arkansas River. In general, however, the data suggest that conductivity was generally higher in the lower reaches of the South Arkansas, with the highest levels consistently at the lowest site (Site 5: City of Salida area) and then at the middle site (Site 3: Town of Poncha Springs area). Thus, the pattern observed suggests there is an influence of human population density and activity, as well as a potential influence of Poncha Creek inflows, on conductivity. Overall, conductivity values observed were somewhat higher in the summer than in the winter, at least in the lower reaches of the South Arkansas River.

Alkalinity, the quantitative capacity of an aqueous solution to neutralize an acid, showed a strong linear trend, from lowest in the higher reaches (Site 1) to highest near the confluence of the South Arkansas River with the Arkansas River (Site 5). Alkalinity at Site 5 was significantly higher than at Site 1. The exception to the linear trend was again a dip at Site 4, just below the inflow of Poncha Creek (Table 3). Mean alkalinity at Site 4 tended to decrease relative to Sites 3 and 5 in both seasons. Again, the pattern suggests a small, local scale influence of Poncha Creek on water quality as it enters the South Arkansas River just above Site 4.

Hardness, a measure of the dissolved salts, paralleled the data on alkalinity (Table 3). So, the pattern observed was a trend toward increasing values of hardness from upper to lower portions of the South Arkansas River (Table 3). Again, the exception was a small dip in hardness at Site 4 relative to the hardness observed at Sites 3 and 5, reinforcing the suggestion of a small, local influence on the water chemistry by Poncha Creek inflow into the South Arkansas River.

Total dissolved solids also increased on average from the lowest values in the upper reaches (Site 1) to highest values at Site 5 at the confluence with the Upper Arkansas River (Table 3). Again, however, Site 4 just below the confluence of Poncha Creek had a dip in the magnitude of the increase observed. Comparing Site 4 to Site 3, below versus above input by

Poncha Creek, suggests again that input of Poncha Creek influences water quality in the South Arkansas River, in this case reducing total concentrations of total dissolved solids. The increase in total dissolved solids between Site 1, up high, and Site 5, at the confluence, was statistically significant in both winter and summer (non-overlap 95% C.I.). The inference is that increasing flow time and exposure to human input increased total dissolved solids.

Coliform Bacterial Loads

Bacterial content was determined as number of colonies per 100 ml of total coliform bacteria, and of *Escherichia coli* concentrations, specifically. Total coliform data were restricted to summer samples, and no sample was taken for Site 1, above the project corridor along the South Arkansas River. Additionally, *E. coli* counts were made on all samples, covering all five sites in both seasons.

Total coliform counts in summer appeared to be relatively high, but similar among the sites sampled – Sites 3, 4, 5 (1,986 to 2,400 colonies / 100 ml). These counts showed, as might be expected, the lowest value observed (770 colonies / 100 ml) was at Site 2 (Table 4); Site 2 is just below the National Forest, and farthest away from any concentrations of people, either high on the gradient (Monarch Mountain Ski and Snowboard Area) or low on the gradient (Town of Poncha Springs and City of Salida). Since the EPA uses 200 total coliform colonies / 100 ml water as the threshold for drinkable water, these initial data suggest that some contamination exists all along the gradient, at least in summer, with especially high readings in the lower reaches of the drainage near the Town of Poncha Springs and the City of Salida. Colorado.

Specific counts of *E. coli* (colonies/100 ml) showed a pattern correlated with human density and activity, rather than a consistent, linear pattern along the South Arkansas River drainage (Table 4). In winter, the counts averaged lowest at Site 3 (3.1 colonies/100 ml) and then at Site 2 (7.3 colonies/100 ml), both relatively isolated from consistent human exposure. Higher values (25 – 30 colonies/100 ml) occurred both upstream at Site 1, near Monarch Mountain Ski and Snowboard Area and Monarch Park Campground, and downstream at Sites 4 and 5, sites associated with higher density human activity and development.

SUMMARY

The grant provided support for purchase of a water quality testing meter and for initial water quality measurements over the full length of the South Arkansas River drainage, from Site 1 near Monarch Mountain Ski and Snowboard area, to Site 5, at the confluence of the South Arkansas River with the Arkansas River just southeast of the City of Salida, Colorado. Since no earlier water quality data were available for this stretch of river, the data gathered in this study provide fundamental baseline data, both for evaluation of the effects of planned restoration work along the South Arkansas River and for assessment of long-term changes in water quality.

The main results show a relatively consistent pattern on increasing mineral, ion and metal concentrations correlated with both decreasing elevation and increasing human influences on the South Arkansas River. An interesting finding was the inference that inflow from Poncha Creek into the South Arkansas River between Sites 3 and 4 had a measureable, local influence on multiple water parameters of the South Arkansas River. In general, parameter values dipped somewhat just below the inflow of Poncha Creek (Site 4) relative to the values just above (Site 3) and the confluence of the South Arkansas River into the Arkansas River (Site 5).

Further, the majority of the potentially problematic minerals, ions or metals were found to occur in relatively low concentrations in the South Arkansas River, both in winter and in summer low water flow seasons. The physical parameters measured generally showed the same pattern of increasing values downstream, with turbidity in particular increasing significantly as exposure to human influences increased. Finally, coliform bacteria concentrations, and specific counts of *E. coli*, also generally increased as the probability of exposure to human influences increased downstream. Concentrations total coliform bacteria in summer were higher than the EPA recommended concentration limit for clean drinking water, especially at the most downstream sites.

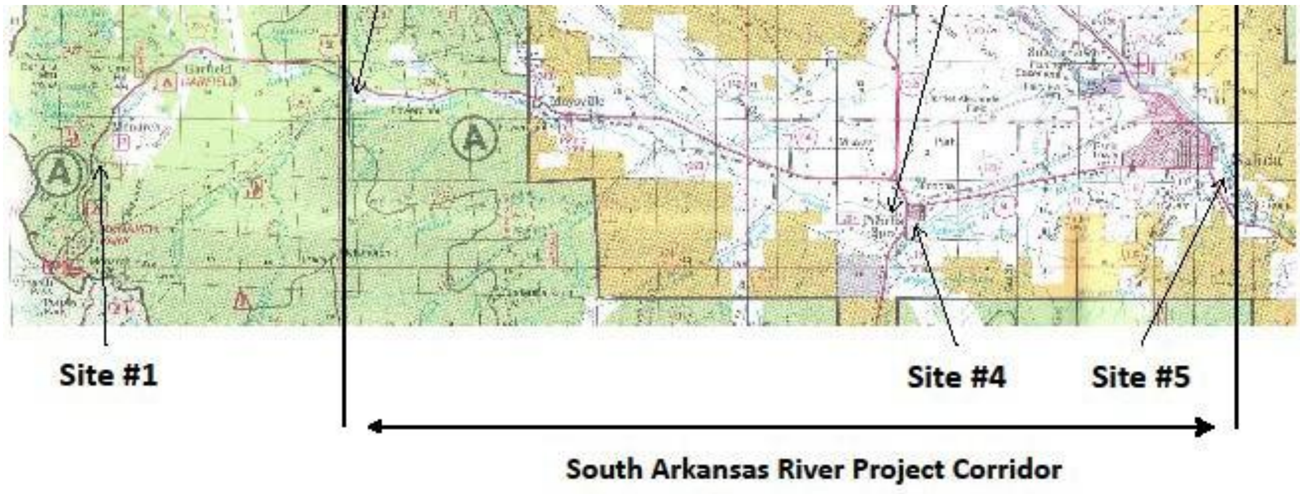
Thus, subsequent studies should examine potential causes of high summer total coliform bacterial loads in the lower reaches of the South Arkansas River. If further study confirms the consistency of excessive total coliform bacterial loads, then subsequent research needs to be

done to identify ways to decrease coliform bacterial contamination, especially at the downstream sites.

Future study of periods of high water flow, such after local storm events, may provide further insights into water quality in the South Arkansas River. Such data collection will require exploration of better ways to quantify locale, timing of input, and runoff influences on the water quality of the South Arkansas River.

In sum, this study successfully documented the sustained low water flow patterns of water quality, providing the first data on the measured parameters for this river; these data will be useful for both restoration work and studies of long-term environmental changes.

Figure 1. Map of water quality study sites along the South Arkansas River



Locations with GPS of the five study sites along the South Arkansas River:

Site 1, near Monarch Ski and Snowboard Area	-- N38° 31.129' W106° 02.303'
Site 2, at Chaffee County Road 225	-- N38° 32.618' W106° 14.657'
Site 3, upstream of Poncha Creek influx	-- N38° 30.624' W106° 04.622'
Site 4, just below of Poncha Creek influx	-- N38° 30.614' W106° 04.509'
Site 5, at confluence with the Arkansas River	-- N38° 31.263' W105° 58.671'

Table 1. Seasonal averages in concentrations of minerals, metals and ion concentrations across the five sites sampled along the South Arkansas River

	Calcium		***Magnesium***		***Sodium***		***Potassium***		***Chloride***	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Winter	24.82	3.81	7.54	0.78	5.22	1.19	0.64	0.14	1.66	0.44
Summer	27.04	5.58	7.26	1.76	5.72	0.94	0.98	0.10	4.64	1.08

	Carbonates		***Bicarbonates***		***Sulfates***		***Unionized Sulfates***		***Phosphorus***	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Winter	0	0	7.26	1.76	5.72	0.94	0	0	7.7	0.2
Summer	0	0	113.7	24.52	11.62	2.74	--	--	7.6	0.2

	Iron		***Manganese***		***Zinc***		***Copper***		***pH***	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Winter	0.04	0.02	0	0	0	0	0	0	7.7	0.2
Summer	0.02	0.02	0	0	0	0	0	0	7.6	0.19

	Conductivity		***Alkalinity***		***Hardness***		***Total Solids***		***Turbidity***	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Winter	161.9	19.41	89.3	12.74	88.06	13.92	162.6	23.10	0.1	0.10
Summer	161.4	33.51	94.9	25.52	99.6	21.88	174.1	41.92	2.72	1.04

	Total Coliform		***E. coli***	
	Mean	SE	Mean	SE
Winter	--	--	19.0	5.74
Summer	1898.9	389.88	131.3	42.70

Table 2: Mean concentrations for key minerals, ion and metals by site and season

Season	Site	*Calcium*		*Magnesium*		*Sodium*		*Potassium*		*Chloride*	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Winter	1	11.9	0.3	5.2	0.6	3.7	0.1	0.3	0.2	3.4	0.1
Winter	2	25.1	0.3	6.7	0.8	2.3	0.4	0.4	0.2	1.3	0.2
Winter	3	27.0	0.5	8.4	0.9	4.7	0.5	0.7	0.2	1.0	0.1
Winter	4	24.4	0.6	7.6	0.9	6.1	0.6	0.7	0.3	1.1	0.1
Winter	5	35.7	0.4	9.8	1.1	9.3	0.5	1.1	0.2	1.5	0.2
Summer	1	6.4	5.9	3.6	0.8	2.8	0.5	0.3	0.1	10.9	2.4
Summer	2	18.4	2.3	3.6	0.7	1.7	0.2	0.4	0	2.4	0.4
Summer	3	36.5	4.9	10.2	2.1	5.6	0.4	1.2	0	2.1	0.6
Summer	4	27.6	6.4	7.8	2.4	5.7	0.6	1.1	0.1	2.5	0.7
Summer	5	46.3	8.4	11.1	2.8	12.8	3.0	1.9	0.3	5.3	1.3

Season	Site	*Carbonates*		*Bicarbonates*		*Sulfates*		*Unionized Sulfates*		*Phosphorus*	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Winter	1	0	0	62.7	2.8	3.5	0.7	0	0	6.9	0
Winter	2	0	0	95.7	7.3	15.5	0.5	0	0	7.8	0
Winter	3	0	0	117.3	8.7	15	0.3	0	0	7.9	0
Winter	4	0	0	111.3	8.7	10.3	3.5	0	0	8.0	0
Winter	5	0	0	158.7	8.3	19	0.5	0	0	7.9	0
Summer	1	0	0	24.6	24.4	3.8	2.2	0	0	7.0	0.3
Summer	2	0	0	57.1	7.9	14.4	1.0	0	0	7.2	0.3
Summer	3	0	0	160	21.0	13.1	3.4	0	0	7.8	0.4
Summer	4	0	0	124.3	28.8	9.3	3.0	0	0	7.8	0.4
Summer	5	0	0	202.5	40.5	17.5	4.1	0	0	8.0	0.4

Season	Site	*Iron*		*Manganese*		*Zinc*		*Copper*	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE
Winter	1	0	0	0	0	0	0	0	0
Winter	2	0	0	0	0	0	0	0	0
Winter	3	0	0	0	0	0	0	0	0
Winter	4	0.1	0	0	0	0	0	0	0
Winter	5	0.1	0.1	0	0	0	0	0	0
Summer	1	0	0	0	0	0	0	0	0
Summer	2	0	0	0	0	0	0	0	0
Summer	3	0	0	0	0	0	0	0	0
Summer	4	0.1	0	0	0	0	0	0	0

Summer	5	0	0	0	0	0	0	0	0

Table 3. Site means (S.E.) by season for key physical parameters of water samples along the South Arkansas River drainage

Season	Site	***Conductivity***		***Alkalinity***		***Hardness***		***Total Solids***		***Turbidity***		***pH***	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Winter	1	100.7	15.3	51.7	2.3	51.0	3.0	91.7	3.3	0.5	0.5	6.9	0.0
Winter	2	153.0	23.0	78.0	6.0	65.3	28.7	147.3	7.7	0.0	--	7.8	0.0
Winter	3	173.3	24.7	96.0	7.0	101.7	5.3	173.7	10.3	0.0	--	7.9	0.0
Winter	4	161.0	25.0	91.0	7.0	92.0	5.0	165.0	11.0	0.0	--	8.0	0.0
Winter	5	221.7	30.3	130.0	7.0	130.3	5.7	235.3	10.7	0.0	--	7.9	0.0
Summer	1	79.0	3.0	29.5	10.5	42.5	6.5	68.5	9.5	1.6	--	7.0	0.3
Summer	2	99.5	2.5	46.5	6.5	61.0	9.0	98.0	12.0	0.5	--	7.2	0.3
Summer	3	201.5	8.5	131.0	17.0	133.0	21.0	228.5	32.5	2.0	--	7.8	0.4
Summer	4	164.5	27.5	101.5	23.5	101.0	26.0	178.0	42.0	2.9	--	7.8	0.4
Summer	5	262.5	27.5	166.0	33.0	160.5	32.5	297.5	60.5	6.6	--	8.0	0.4

Table 4. Site mean (SE) for coliform bacterial counts by season along South Arkansas River

Season	Site	***Total Coliform*** Mean	SE	***E. coli*** Mean	SE
Winter	1	--	--	29.3	14.2
Winter	2	--	--	7.3	3.6
Winter	3	--	--	3.1	1.1
Winter	4	--	--	30.1	21.6
Winter	5	--	--	25.4	2.3
Summer	1	--	--	95.0	90.9
Summer	2	770.1	--	15.6	11.5
Summer	3	2419.6	--	269.0	141.6
Summer	4	2419.6	--	101.7	0.3
Summer	5	1986.3	--	175.2	60.7