2.0 PROJECT STUDY AREAS

The Habitat Characterization Study was conducted on 10 effluent-dependent waters located in the arid West. The selected sites each serve as a case study of the physical, chemical, and biological characteristics of a created ecosystem or effluent-dependent water. To assist with the selection of study areas, the team relied on the information gathered from the Discharger's Survey of arid West streams (WQRP 2000). **Appendix C** includes the full description of each studied watershed, including all data used in the subsequent analyses and interpretation of the Habitat Characterization Study.

The Discharger's Survey used EPA's *STORET* database to identify existing NPDES permits within the 17 arid West states. This process identified 4,515 NPDES permits. Of this permit pool, 1,001 permits were issued to major municipal dischargers and of this pool, 251 permits had been issued to dischargers in arid and semi-arid lands. Through the use of questionnaires and telephone interviews it was determined that 71 of the 251 permit holders discharge to ephemeral, intermittent, or effluent-dependent streams. This set of dischargers represented the core of the survey and was used for additional analysis for the purposes of that survey.

Effluent-Dependent Water Study Areas

- Salt and Gila Rivers near Phoenix, Arizona
- Santa Cruz River near Nogales, Arizona
- Santa Cruz River near Tucson, Arizona
- Santa Ana River near San Bernardino, California
- Fountain Creek near Colorado Springs, Colorado
- South Platte River near Denver, Colorado
- Las Vegas Wash near Las Vegas, Nevada
- Santa Fe River near Santa Fe, New Mexico
- Carrizo Creek near Carrizo Springs, Texas
- Crow Creek near Cheyenne, Wyoming

With the set of 71 core dischargers identified, the project team identified a subset of effluent-dependent waters for inclusion in the Habitat Characterization Study. Study areas were not chosen randomly, but deliberatively so that a wide range of case study types would be evaluated to illustrate a range of conditions. Study areas were selected that (1) were widely distributed across the arid West; (2) had a variety of historical physical, chemical, and biological data; and (3) had dischargers that were willing to share their own historical data and assist with providing access to the study stream. Ultimately, 10 study areas were selected using this process (Table 2-1).

Of the 10 selected study areas, all but one, Carrizo Creek, had a variety of historical data; however, it was still included as a study area since it provided an example from the far eastern portion of the arid West.

2.1 HISTORIC DATA COLLECTION

The databases of federal (e.g., EPA) and state agencies (e.g., departments of environmental quality) served as the starting points for historical data research of the 10 selected study areas. These databases were easily accessible, either through the Internet or through publications. The next step was to contact local colleges and universities. Wastewater treatment plants (WWTPs)

within the 10 study areas were contacted for historical effluent sampling data and other relevant information. In addition to these local sources, the project team accessed an internal hydrologic information center with physical and chemical data from most of the 50 states.

Table 2-1
Habitat Characterization Study Areas

Study Area	Ecoregion	Watershed Area (mi^2)	Annual Precipitation (in.)	1.5-Year Bankfull Flow (cfs)	Wastewater Discharge (mgd)	Treatment Level
Salt and Gila Rivers Near Phoenix, Arizona	81 Sonoran Basin and Range	36,630	7.99	9,370	92.6	Secondary treatment; chlorination/dechlorination; nitrification/denitrification
Santa Cruz River Near Nogales, Arizona	79 Madrean Archipelago	541	16.30	1,780	10.9	Secondary treatment; chlorination/dechlorination; filtration
Santa Cruz River Near Tucson, Arizona	81 Sonoran Basin and Range	2,239	12.4	1,680	47	Secondary treatment; chlorination/dechlorination
Santa Ana River Near San Bernardino, California	6 Southern and Central California Plains and Hills	2,703	8.81	381	62.7	Secondary treatment; chlorination/dechlorination; nitrification/denitrification; filtration
Fountain Creek Near Colorado Springs, Colorado	26 Southwestern Tablelands	413	16.1	2,850	38.5	Secondary treatment; chlorination/dechlorination; nitrification/denitrification
South Platte River Near Denver, Colorado	25 Western High Plains	3,861	14.5	3,070	149	Secondary treatment; chlorination/dechlorination; partial nitrification/denitrification (north complex only)
Las Vegas Wash Near Las Vegas, Nevada	14 Mojave Basin and Range	1,834	4.4	106	134	Secondary treatment; chlorination/dechlorination; nitrification; phosphorus removal; filtration
Santa Fe River Near Santa Fe, New Mexico	22 Arizona/New Mexico Plateau	42	12.6	681	5.5	Secondary treatment; chlorination/dechlorination; nitrification/denitrification; filtration
Carrizo Creek Near Carrizo Springs, Texas	31 Southern Texas Plains	47	18.9	N/A	>0.9[1]	Secondary treatment; chlorination
Crow Creek Near Cheyenne, Wyoming	25 Western High Plains	297	15.4	40.0	9.97	Secondary treatment; chlorination

[1] Estimated

The majority of historical terrestrial ecology data were obtained by conducting a literature review and contacting local experts and personnel from the selected study areas. Literature sources included national and regional publications on the flora and fauna for each of the study areas, Internet data sources, scientific publications, and agency contacts. Data on threatened, endangered, or otherwise sensitive plant and animal species were obtained from U.S. Fish and

Wildlife Service (USFWS) web sites and from state agencies having jurisdiction over such information.

2.2 SITE RECONNAISSANCE DATA COLLECTION

Key Historic Data Sources

- Wastewater Dischargers
- Environmental Protection Agency
- State Environmental Agencies
- U.S. Geological Survey
- State/Local Universities
- Natural Resources Conservation Service
- The Nature Conservancy
- U.S. Fish and Wildlife Service
- Local Environmental Organizations
- National Oceanic and Atmospheric Administration
- Local Sources of Aerial Photography
- State Geological Surveys
- State Game and Fish Departments

During the spring of 2000 each of the study areas was visited to gather site reconnaissance-level data on the geomorphology, aquatic biology, and terrestrial biology currently present. This information was gathered primarily to provide an assessment of the extant physical and biological characteristics of each area and note important environmental stressors on the ecosystem created by the discharge of effluent. Wherever possible, site reconnaissance efforts were conducted at five locations, or reconnaissance sites, within each study area. The five sites included one site upstream of the effluent discharge, a location immediately below the effluent discharge, and three locations downstream of the discharge point. Generally, the downstream reconnaissance sites were spread out in such a way that 90 percent of the watered reach of the effluent stream was covered. However, covering 90 percent of the downstream watered reach was not possible at sites in Wyoming, California, and Colorado due to the extents of the flowing reaches at the time the sites were visited. A complete description of the methods used in this report is contained in **Appendix B**.

Geomorphology – Geomorphological observations and data were collected according to standard field procedures (for example, Leopold et al. 1964; Leopold 1994; Moody et al. 2000). The procedure consisted of a single site visit performed by a field geomorphologist. Morphometric data were collected at each site and combined with general observations to evaluate the relevant landform and fluvial processes active at each site.

Aquatic Biology, Habitat Assessment – Physical aquatic habitat characteristics can significantly influence the aquatic community that has the potential to colonize a given aquatic environment. Aquatic habitat characterization methods incorporate a range of factors that influence both the structure and function of the aquatic community. Methods can range from detailed quantitative field methods to qualitative scoring methods that rate habitat on the basis of best professional judgment. Regardless of the method used, the outcome or interpretation of data analysis should lead to an interpretation of whether or not habitat is a limiting factor.

A variety of aquatic habitat assessment methods are in use by federal and state water quality agencies. Similarities can be identified among methods, but there are significant dissimilarities as well. These differences are likely driven by the need to gather data for different purposes or agency missions. For the purposes of this study two methods were used: (1) the EPA Habitat Assessment Protocol for Low Gradient Streams (Barbour et al. 1999), and (2) a habitat method

developed specifically for this project. These methods incorporated two basic components: (1) qualitative information was recorded (e.g., aquatic vegetation density, water odor and clarity, substrate type and the relative proportion of run, riffle, and pool habitat), and (2) specific characteristics associated with in-stream habitat, channel morphology, and the riparian zone were scored. The alternative method, developed specifically for this project, was used at each site to provide an opportunity to evaluate the applicability of the EPA protocol in effluent-dependent waters. Although the EPA habitat assessment approach has gained general acceptance over the years, concerns exist that habitat assessment in streams of the arid West may not be accurately portrayed by direct application of the EPA habitat assessment procedures. This concern has been based on some of the habitat scoring factors in the EPA procedures that may naturally score "poorly" in arid West streams. For example, factors that rate the complexity of in-stream habitat may score poorly simply because of the natural lack of large woody debris or undercut banks.

Aquatic Biology, Macroinvertebrate Community – The project team conducted a screening-level field investigation of the macroinvertebrate community at each reconnaissance site within each study area. The primary purpose of this approach was to provide sufficient aquatic biological community data to identify macro-changes in the characteristics of the macroinvertebrate community along a longitudinal gradient from just upstream of the WWTP to some distance downstream of the WWTP discharge. In addition, sufficient data were gathered to allow a general comparison of macroinvertebrate community characteristics among the 10 study areas. It is recognized that the use and interpretation of site reconnaissance level data is limited. As such the data collected were not intended to make definitive statements regarding water or habitat quality at any particular site. Substantially more intensive sampling would have been necessary to accomplish such a purpose.

The macroinvertebrate community screening-level procedure consisted of the collection of three one-minute kicknet samples from each reconnaissance site within each study area. Kicknet samples were collected from the range of substrate types present at each site. Macroinvertebrates gathered in the kicknet were field-identified and a relative abundance of taxa was recorded.

Terrestrial Biology – A field data sheet was completed at each of the five reconnaissance sites visited within each study area. The three-page data sheet, tailored from a published EPA form (EPA 1998), allowed the field investigator to record information on vegetation, wildlife, and human influences noted at each site. Vegetation data included species composition, relative abundance, and estimates of cover for canopy, understory, and ground cover. Human influences recorded included stream channel features (e.g., riprap, dikes), pavement, pipes, mining activity, recreation use, and other influences.

Plant species that were not readily identifiable in the field were collected for later identification and verification. Plants were collected by taping samples into a spiral notebook and recording location and habitat information on the page to which the sample was affixed. Specimens were identified in the office using standard plant taxonomy keys and verified by personnel at the University of Arizona herbarium. In addition to plant samples and field data collected on standardized field data sheets, each site was also photographed and video-taped.

2.3 DATA ANALYSIS

Appendix D contains an extensive discussion of the data collected for each of the 10 sites and presents the results of data reduction and interpretation. Readers requiring a more detailed discussion are directed to that section of the report.

Hydrology and Geomorphology – Current understanding of stream ecology suggests stream communities are structured differently by biotic and abiotic controls along some type of biophysical gradient (Jensen et al. 2001; Osterkamp et al. 2001; Stanford et al. 1996; Vannote et al. 1980; Ward 1989). The magnitude, duration, and frequency of flood events are an important part of the biophysical environment. Fluvial channel organization (size, shape, substrate material and distribution of channels, banks, and interfluves) represents the complex interaction and feedback of hydrologic, geomorphic, and ecological processes.

The Habitat Characterization Study primarily used U.S. Geological Survey (USGS) stream gaging data, WWTP discharge data, and limited site reconnaissance data to assess the 10 arid West study areas. The study was designed to determine if these data were sufficient to develop a sense of the relationships between discharge (WWTP and in-stream), channel morphology, and condition of the habitat.

The project collected average daily stream flow from USGS records for all study areas except Carrizo Springs, Texas. For each study area, data were collected from one gage upstream and one gage downstream of the WWTP inputs to the stream. If available, the project obtained the average daily WWTP flows from the dischargers.

From the average daily stream flow and average daily WWTP flow, the project team performed the following analyses:

- hydrograph or average daily stream flow versus time for the period of record
- mean monthly flow to assess seasonal variation of stream flow
- Log Pearson Type III flood frequency analysis using annual series data
- Log Pearson Type III low flow frequency analysis using low flow duration of 7 days and 30 days (these low flow durations are typically used in establishing permit limits)
- flow duration curves to establish the percent of time that mean daily flows occur
- average annual yield at each gage (acre-feet)
- annual maximum flow versus annual mean flow to quantify "flashiness" of systems

In addition, the ratio of stream flow (inches) to rainfall (inches) through time was evaluated to assess if increase in urbanization has increased runoff amounts to stream systems.

Depth and velocity rating curves, where available, were also used. Power equations were used to classify the streams into four general categories of velocity and depth. The project team also used the rating curve data to estimate at what flow the streambed would begin to move. Morphometric data were used to compare the dimensions and discharge of the 10 streams to larger databases for arid West streams. Finally, the 1.5 recurrence interval for each of the 10 watersheds was determined from the upstream gage and this value was compared to the treated effluent discharge at each plant.

Chemistry – Characterization of the major cations (positively charged ions) and major anions (negatively charged ions) were primarily accomplished by using Piper diagrams (also known as trilinear diagrams). Piper diagrams are a simple fundamental method of examining and evaluating differences and similarities of major ion composition among samples or study sites. A Piper diagram consists of two triangles, one for the major cations and one for the major anions. The major cations shown on the cation triangle are calcium (Ca), magnesium (Mg), and sodium plus potassium (Na+K). The major anions shown on the anion triangle are sulfate (SO_4), chloride (Cl), and carbonate plus bicarbonate (CO_3+HCO_3). Ion concentrations are plotted on the triangles in units of percent milliequivalents per liter (% meq/L) for each of the cations and anions. The relative proportions of the cations and anions can be quickly determined on the triangular coordinate system. Points that plot near a particular corner of the triangle (e.g., Ca) indicate a higher proportion of that ion.

In addition to the use of Piper diagrams, box plots were developed to provide a simple but visual method of examining data distributions and comparing the distributions among different groups (e.g., sampling sites within and among study areas).

Biology – The aquatic biology dataset consisted of any historical fish and macroinvertebrate data as well as the data collected during the site reconnaissance conducted in the spring of 2000. Some study areas had substantial historical data (e.g., Fountain Creek and the South Platte River), while other study areas had few to no historical data. For example, the site reconnaissance data collected from Las Vegas Wash and Carrizo Creek constituted the only available aquatic biology information from these locations.

It was found that, for study areas with historical aquatic biological data, the data were often gathered by different organizations for different purposes, resulting in data collected by varying methods (e.g., level of effort, area of stream sampled and sample net mesh size). In addition, the level of taxonomic effort applied to the aquatic data also varied, especially for macroinvertebrates.

Variability in sampling methods coupled with variability in taxonomic effort limited the ability to analyze biological data. No correction is available to address variability in sampling methods. However, where an obvious artifact from sampling variability was observed, the artifact was identified as a footnote to apparent data trends.

Variability in taxonomic effort could be addressed by elevating, where necessary, taxonomic data to a common level of taxonomic effort. For example, the taxonomic identification effort applied to field samples collected during site reconnaissance was limited to the family, order, or

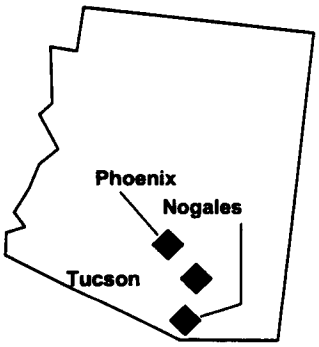
class level. To compare these data with historical data, which identified organisms to a lower taxonomic level (e.g., genus or species), it was necessary to elevate the historical data to the family, order, or class level, whichever level was appropriate. This type of data manipulation was only necessary where a biotic index required consistent levels of taxonomic effort (e.g., taxonomic richness or the Hilsenhoff Biotic Index [HBI]). To evaluate the impact of modifying taxonomic data, historical data were compared before and after the data manipulation to determine if there was any impact on data interpretation (e.g., spatial or temporal trends). Where an impact was identified, it was noted in the analysis; however, typically there was no impact on data interpretation.

To the extent possible, each dataset was analyzed to evaluate the following: (1) seasonal variability, (2) temporal trends, and (3) spatial or longitudinal trends. Site reconnaissance data were available from all sites to evaluate longitudinal trends. In addition, historical data were available to support the evaluation of longitudinal trends. Data for evaluating temporal trends were available from most sites, but only a few sites had sufficient data to evaluate seasonal variability.

Seasonal, temporal, and spatial trends were evaluated through the use of biotic indices. Because of data limitations, only a few key indices were used, indices commonly used in water quality studies to support bioassessments (Barbour et al. 1999): (1) taxonomic richness; (2) HBI; (3) Percent Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa; and (4) relative abundance of major taxonomic groups.

2.4 STUDY AREA DESCRIPTIONS

2.4.1 Gila and Salt Rivers, Phoenix, Arizona (Appendix C, Study Area 1)

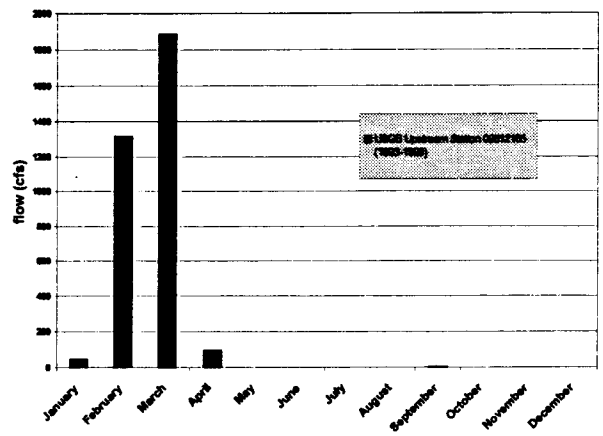


Ecoregion – Sonoran Basin and Range

The 91st Avenue WWTP, located in the Phoenix metropolitan area, discharges effluent to the Salt River. Within 3 miles downstream of the WWTP, the Salt River reaches its confluence with the Gila River. The 91st Avenue WWTP is operated by the cities of Phoenix, Glendale, Mesa, Tempe, and Scottsdale (a.k.a., the Sub-Regional Operating Group, or SROG).

During the early 1900s, dams were constructed on the Salt and Gila rivers for water diversion and flood control. By changing the way water flowed downstream, the dams completely changed the character of the two rivers. Before 1900, the Salt River was a perennial river with the heaviest flows in spring and early summer and lower flows in the fall and during droughts. The Salt River is now an ephemeral watercourse that experiences high flows only during wet cycles usually lasting two or more years (Thomson and Porcello 1991). Similarly, the Gila River is impounded primarily to provide water for agriculture, resulting in the loss of normal flow cycles (Huckleberry 1996). Today, the primary water source in the Salt and Gila rivers in Phoenix is wastewater effluent discharged from the 91st Avenue WWTP.

Wastewater Treatment Facility – The 91st Avenue WWTP consists of five treatment trains in three distinct plant complexes. Major upgrades to the plant in recent years have included the addition of dechlorination to all five trains within the past five years, and upgrades to each of the five trains to provide nitrification and denitrification in 1997. The plant is currently rated at 161.75 mgd. While a portion of the effluent from the 91st Avenue WWTP is conveyed to the Palo Verde Nuclear Generating Station for reuse, the majority of the treated effluent is discharged to the Salt River. In 1999, the total plant flow averaged 148 mgd, of which 92.6 mgd (63 percent) was discharged to the Salt River.



Mean monthly stream flow upstream of WWTP on Salt River

Hydrology – Mean monthly stream flow above the WWTP outfall ranges from 0 cubic feet per second (cfs) (January) to 1,889 cfs (May). The USGS gage downstream of the WWTP is located on the Gila River (09515410). The estimated average annual precipitation is 8.0 inches.

Average Monthly Precipitation – NCDC Station 6486 (1948-1998)			
Month	**Precipitation (Inches)**	**Month**	**Precipitation (Inches)**
January	0.9	July	0.8
February	0.8	August	1.1
March	1.0	September	0.7
April	0.3	October	0.7
May	0.1	November	0.6
June	0.1	December	0.9

Geomorphology – The drainage basin of the Salt and Gila rivers above Phoenix, with contributions downstream to north of Gila Bend, Arizona, is mostly in the Basin and Range physiographic province, which is characterized by fault-block mountains separated by valley-fill alluvium. Along the reach west of Phoenix, the river generally incises poorly cemented Quaternary valley-fill deposits. Alluvium is generally of Holocene age and reflects recent conditions of fluvial-sediment transport and deposition.

Chemistry – Chemical data were limited to two stations upstream and two stations downstream of the 91st Avenue WWTP. The cation data indicate a higher percentage of Na+K and Ca. The downstream samples had a higher percentage of Na+K compared to the upstream samples, which had a higher proportion of Ca. The anion data show a slight Cl enrichment relative to SO_4 and HCO_3+CO_3, with the exception of one upstream sample, which had a higher percentage of bicarbonate.

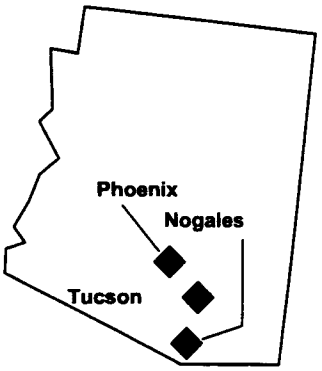
This study area is located within the same area addressed in the USGS Central Arizona Basins National Water Quality Assessment (NAWQA). Results from this study concluded that as the WWTP discharge increases, the ammonia concentration, turbidity, and conductivity increase, while the nitrate and dissolved oxygen concentrations decrease (Cordy et al. 1998). Water quality varies on a daily basis.

Site Reconnaissance Summary – Aquatic Biology – Macroinvertebrates were sampled only at four of the five reconnaissance sites (Sites 2, 3, 4, and 5) since upstream of the discharge the Salt River was dry. The number of taxa doubled from 5 to 10 between Sites 2 and 4 but declined at Site 5. EPT (mayflies, stoneflies, and caddisflies) taxa were limited to mayflies, which were relatively abundant only at Site 4. Habitat quality was best immediately below the discharge and declined with increased distance from the discharge. Much of the change in aquatic habitat quality appears to be the result of construction activities that have increased sediment loads and decay of salt cedar vegetation, which appears to contribute significant organic matter to the river. In addition to these factors, the channel is low-gradient with very sluggish flows, resulting in a fairly stagnant environment.

Terrestrial Biology – Riparian habitat data were collected from all five reconnaissance sites along the Salt/Gila River complex in Phoenix. The portion of the Salt River above the 91st Avenue WWTP outfall is ephemeral and contained no flow on the day of sampling. Vegetation at this site (Site 1) consisted of desert shrubs including saltbush (*Atriplex canescens*), rush bebbia (*Bebbia juncea*), and brittlebush (*Encelia arinose*). The riverbed itself is composed of coarse cobble with very little vegetation. Sites 2 through 5, all influenced by the presence of effluent, are generally dominated by exotic salt cedar (*Tamarix chinensis*). Patches of willow (*Salix gooddingii*) and cottonwood (*Populus fremontii*) may be locally present, but constitute less than 10 percent of the vegetation in the study area. Emergent vegetation in the form of cattail (*Typha domingensis*) and/or bulrush (*Scirpus* sp.) frequently occurs around the borders of ponds or in areas where water is particularly slow-flowing.

A variety of wildlife species or evidence thereof was encountered in the study area. Mammals included raccoon (*Procyon lotor*), coyote (*Canis latrans*), round-tailed ground squirrel (*Spermophilus tereticaudus*), and Harris antelope ground squirrel (*Ammospermophilus harrisii*). Birds encountered included several species of ducks and shorebirds as well as raptors, woodpeckers, and songbirds. Species of special concern to the State of Arizona that were observed included great egret (*Ardea alba*) and snowy egret (*Egretta thula*). The only amphibians observed were several bullfrogs (*Rana catesbiana*) present at Site 2, just below the outfall from the 91st Avenue WWTP. Reptiles encountered included one spiny softshell turtle (*Trionyx spiniferus*) at the outfall and several species of lizards encountered at several sites. Tilapia (*Tilapia* sp.), an introduced fish species, was noted in abundance at the WWTP outfall and for at least several hundred yards downstream.

2.4.2 Santa Cruz River, Nogales, Arizona (Appendix C, Study Area 2)



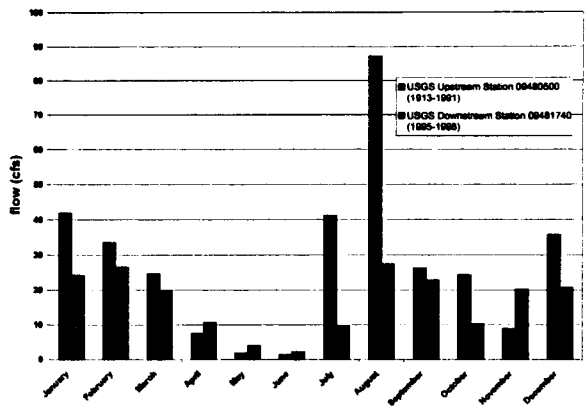
Ecoregion – Madrean Archipelago

The Santa Cruz River originates as a small southerly flow in the San Rafael Valley in southern Arizona, looping down into Mexico and then back up into the United States. The main sources of flow in the Santa Cruz watershed are precipitation, groundwater discharge, irrigation return flow, and treated sewage effluent. Flow from the headwaters into and out of Mexico is perennial. The stream just north of the border is essentially dry, except during the winter when it can be perennial up to the confluence with Nogales Wash, where it

receives effluent from the City of Nogales. Flow downstream of this point is mainly effluent. Groundwater inflow in this area is suspected (Arizona Department of Environmental Quality [ADEQ] 1995).

Wastewater Treatment Facility – The City of Nogales, Arizona, and the International Boundary and Water Commission (IBWC) are co-permittees for the Nogales International Wastewater Treatment Plant (NIWTP). The NIWTP treats wastewater from Nogales, Arizona and surrounding communities as well as wastewater originating in Nogales, Sonora, Mexico. Treated effluent is discharged to the Santa Cruz River adjacent to the NIWTP.

All effluent from the NIWTP historically has been discharged to the plant's single outfall on the Santa Cruz River. Originally constructed in 1972 with a rated capacity of 8.2 mgd, the NIWTP consisted of aerated lagoons, a stabilization lagoon, and disinfection with chlorine. Capacity and discharge water quality issues led to construction of major upgrades at the NIWTP, completed in 1992. Ultraviolet disinfection equipment was added as part of the 1992 upgrades, but presently is not used due to maintenance requirements and disinfection effectiveness issues. The liquid-train treatment processes now in use at the NIWTP have a rated capacity of 17.2 mgd, and the plant's discharge average is 10.9 mgd.



Mean monthly streamflow upstream and downstream of the NIWTP on the Santa Cruz River near Nogales

Hydrology – Mean monthly stream flow above the NIWTP outfall ranges from 1 cfs (June) to 87 cfs (August) and mean monthly streamflow below the NIWTP ranges from 2 cfs (June) to 27 cfs (August). The upstream USGS gage (09480500) is near the international border where the Santa Cruz is a perennial stream. The Santa Cruz River upstream of the NIWTP is ephemeral. The downstream analysis is based on three years of record. The estimated average annual precipitation is 16.3 inches.

Average Monthly Precipitation – NCDC Station 8865 (1948-1998)			
Month	**Precipitation (Inches)**	**Month**	**Precipitation (Inches)**
January	1.1	July	3.9
February	0.9	August	3.8
March	0.9	September	1.6
April	0.3	October	1.0
May	0.2	November	0.7
June	0.4	December	1.4

Geomorphology – The Santa Cruz River at the NIWTP drains an area of about 540 square miles, about 348 square miles of which are in Mexico. The Santa Cruz River drainage basin above Nogales and downstream to Chavez Siding Road is in the Basin and Range physiographic province, characterized by fault-block mountains separated by valley fill alluvium. Along the reach north of Nogales, the river and its tributaries incise moderately cemented fan deposits of Tertiary age. Alluvium is

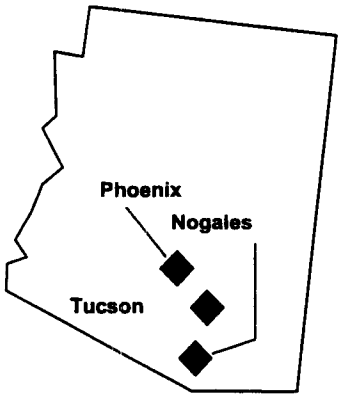
generally of Holocene age and reflects recent conditions of fluvial-sediment transport and deposition.

Chemistry – Two EPA storage and retrieval database (*STORET*) stations are within the vicinity of the NIWTP. The upstream station has a period of record of 1986 to 1992 with the dataset focusing on nutrients, metals, and temperature. The downstream station has a period of record of 1973 to 1984 with the dataset containing information on nutrients and temperature.

Site Reconnaissance Summary – Aquatic Biology – Macroinvertebrates were sampled only at Sites 2, 3, 4, and 5 since upstream of the discharge the Santa Cruz River was dry. The number of taxa declined between Sites 2 and 3 from 9 to 6, respectively. However, at Sites 4 and 5, the number of taxa was again similar to Site 2. Although the number of taxa recovered between Sites 3 and 4, the community shifted from a dominance of *Cladocera* to a dominance of *Oligochaete* worms. Aquatic habitat values increased downstream of the discharge, but no EPT taxa were collected at any site.

Terrestrial Biology – Riparian habitat data were collected at all five reconnaissance sites along the Santa Cruz River near Nogales. Site 1, upstream of the outfall of the NIWTP, is ephemeral. This site was completely dry on the day of sampling and showed no evidence of recent flow. Vegetation along the banks of Site 1 was dominated by mesquite (*Prosopis velutina*) with an understory of young mesquite and catclaw acacia (*Acacia greggii*) and other shrubby species. One large, mature cottonwood (*Populus fremontii*) was present on the north bank of Site 1. Virtually no vegetation was present in the stream channel and Bermuda grass (*Cynodon dactylon*) was a common ground cover species at Site 1. From Site 2 downstream to Site 5, the vegetation along the stream channel is clearly influenced by the presence of water. Cottonwood and willow (*Salix gooddingii*) are dominant species at all sites with some contribution from mesquite (*Prosopis velutina*), Mexican elder (*Sambucus mexicana*), and tree tobacco (*Nicotiana glauca*). Understory and ground cover species include the dominants along with a variety of other shrubs, forbs, and grasses.

A wide array of wildlife species or sign thereof was observed along the Nogales reach of the Santa Cruz River. Mammals included coyote (*Canis latrans*), mule deer (*Odocoileus hemionus*), raccoon (*Procyon lotor*), and skunk (*Mephitis* sp.). The visit to the Nogales study area occurred near the zenith of spring migration for birds. Consequently, a large number of species were observed, especially in the cottonwood forests. At Sites 2, 3, and 4, more than two dozen bird species were observed during the relatively short reconnaissance visit (45 to 90 minutes). Many of the species observed were migrating warblers, vireos, flycatchers, tanagers, and sparrows. Amphibians and reptiles observed at Nogales included several species of lizards, and at least one species of larval toad (tadpole), probably a red-spotted toad (*Bufo punctatus*).



Ecoregion – Sonoran Basin and Range

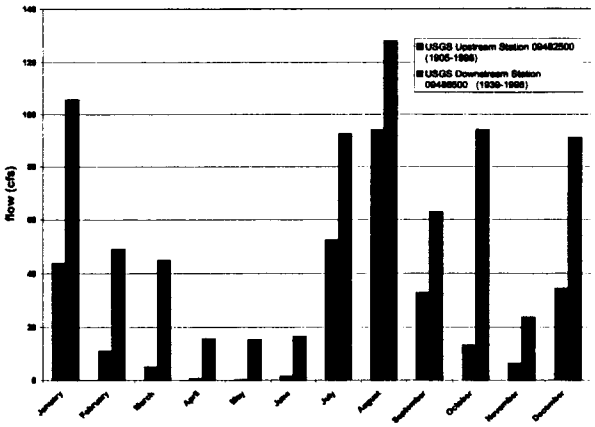
2.4.3 Santa Cruz River, Tucson, Arizona (Appendix C, Study Area 3)

The Pima County Roger Road WWTP and Ina Road Water Pollution Control Facility (WPCF) are both located in the Tucson metropolitan area. Tucson is centrally located within a 1,000-square-mile basin characterized by a northwest-sloping valley bordered by rugged mountain ranges. The surrounding mountains range in altitude from 4,000 to 9,000 feet above mean sea level (amsl). The land surface at the downstream end of the basin is at an altitude of 2,140 feet amsl.

Both the Roger Road WWTP and Ina Road WPCF discharge into the Santa Cruz River. The Santa Cruz River originates as a small southerly flow in the San Rafael Valley, flows down into Mexico, and then north into the United States. Historically, the Santa Cruz was a perennial stream until it reached Tubac, where it went subsurface. The main sources of flow in the Santa Cruz watershed are precipitation, groundwater discharge, irrigation return flow, and treated sewage effluent.

The majority of the river and tributary streams are intermittent or ephemeral. Flows in the Santa Cruz River below the Roger Road WWTP result from the discharge of effluent and any storm waters that are discharged to the riverbed. From the Rillito area downstream to the its confluence with the Gila River, the Santa Cruz River is ephemeral, and only once every 10 to 20 years does sufficient storm flow occur to allow the Santa Cruz River to flow to the Gila River.

Wastewater Treatment Facility – The Tucson metropolitan area is served by the Roger Road WWTP and Ina Road WPCF. Both treatment facilities are located in Pima County. The Roger Road WWTP has a capacity of 41 mgd and the Ina Road WWTP has a treatment capacity of 25 mgd.



Mean monthly streamflow upstream and downstream of WWTP on Santa Cruz River near Tucson

Average Monthly Precipitation – NCDC Station 8817 (1982-1998)			
Month	**Precipitation (Inches)**	**Month**	**Precipitation (Inches)**
January	1.1	July	1.6
February	1.3	August	2.6
March	1.0	September	1.3
April	0.3	October	0.9
May	0.2	November	0.8
June	0.1	December	1.4

Hydrology– Mean monthly stream flow above the Roger Road WWTP outfall ranges from 0 cfs (May) to 94 cfs (August) and mean monthly streamflow below the Ina Road WWTP ranges from 15 cfs (May) to 128 cfs (August). The estimated average annual precipitation is 12.4 inches.

Geomorphology – The Santa Cruz River at the Roger Road WWTP drains an area of about 2,240 square miles, about 348 square miles of which are in Mexico. The Santa Cruz River drainage basin above Tucson, with contributions downstream to Trico-Marana Road, is in the Basin and Range physiographic province, characterized by fault-block mountains separated by valley-fill alluvium. Along the reach northwest of Tucson, the river generally incises poorly cemented Quaternary valley-fill deposits, whereas the river and its tributaries upstream of the Roger Road WWTP in many places incise moderately cemented fan deposits of Tertiary age. Alluvium within 330 feet or more of the river between Roger Road and Trico-Marana Road is generally of Holocene age and reflects recent conditions of fluvial-sediment transport and deposition.

The Santa Cruz River underwent a period of pronounced arroyo entrenchment during the late 1800s. Human manipulation of the Santa Cruz River channel for irrigation is one of the primary reasons for the extensive erosion that occurred in the Tucson area. As the channel eroded southward, it cut deeper and deeper into the alluvium. Consequently, the water table dropped to the elevation of the channel bottom. This downcutting created a dependence on groundwater for irrigation, domestic uses, and industrial uses. After 1940, agricultural, mining, and urban water supply needs resulted in a groundwater overdraft, and the lowered water table resulted in the drying up of marshes and cienegas and their associated vegetation. The last naturally occurring, permanent water in the Santa Cruz River at Tucson occurred in 1941.

Since the 1950s, the Santa Cruz channel has undergone severe (several yards) sediment degradation in Tucson, while downstream reaches have experienced a period of aggradation. Gradual arroyo cutting over the past century has produced a channel that is now up to 33 feet below the historical floodplain. Effluent discharge has caused increased channel roughness due to vegetation and increased incision in the low-flow channel. Storm scouring can occur up to depths of 26 to 33 feet.

Chemistry – Two *STORET* stations are within the vicinity of the Roger Road WWTP and Ina Road WPCF. The upstream station has a period of record of 1975 to 1992 with the dataset focusing on nutrients, metals, and temperature. The downstream station has a period of the record of one month with the dataset containing information on nutrients and temperature.

Site Reconnaissance Summary – Aquatic Biology – Macroinvertebrates were sampled only at Sites 2, 3, 4, and 5, since upstream of the discharge the Santa Cruz River was dry. Only two or three taxa were collected at Sites 2, 3, and 4 but increased to seven at Site 5. EPT taxa (only mayflies) were collected only at Site 5, where they constituted 23 percent of the macroinvertebrates. Habitat values gradually increased with distance downstream of the discharge.

Terrestrial Biology - Riparian habitat data were collected at all five sites on the Santa Cruz River near Tucson. Site 1, upstream of the Roger Road WWTP outfall, is ephemeral and did not contain any flow on May 2, 2000, the date of the site visit. Perennial vegetation at Site 1 is dominated by riparian vegetation that is typical of large, ephemeral drainages in southern Arizona. The perennial, woody vegetation at Site 1 consists of burrowweed (*Hymonoclea salsola*), desert broom (*Baccharis sarothroides*), and scattered individuals of desert willow

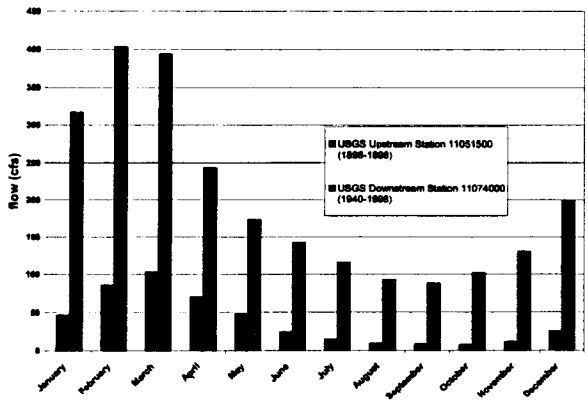
(*Chilopsis linearis*) and Mexican palo verde (*Parkinsonia aculeata*). Understory species are a mix of woody shrubs and herbaceous species including burroweed (*Haplopappus tenuisectus*) and cocklebur (*Xanthium stumarium*) and a variety of annual and perennial grasses and forbs. Conversely, riparian habitats at Sites 2 through 5, all of which were influenced by effluent flows, are variously dominated by willow (*Salix gooddingii*), mesquite (*Prosopis velutina*), and salt cedar (*Tamarix chinensis*) or combinations thereof. Individuals of blue palo verde (*Cercidium floridum*), cottonwood (*Populus fremontii*) and tree tobacco (*Nicotiana glauca*) are also present. Understory species include small individuals of the dominant species along with catclaw acacia (*Acacia greggii*), wolfberry (*Lycium* sp.), desert hackberry (*Celtus pallida*), and others. At Sites 3 and 4 (Ina and Cortaro Roads) emergent vegetation in the form of cattail (*Typha domininingensis*), Bulrush (*Scirpus* sp.), and smartweed (*Polygonum* sp.), and others form a very lush aspect of the vegetation.

Mammals, or sign thereof, observed along the Santa Cruz River at Tucson included raccoon (*Procyon lotor*), coyote (*Canis latrans*), pocket gopher (*Thomomys* sp.), and round-tailed ground squirrel (*Spermophilus tereticaudis*). Birds included four species of ducks, white-faced ibis (*Plegadis chihi*), black-necked stilt (*Himantopus mexicanus*), and several species of shorebirds, songbirds, and raptors. Observations of reptiles included individuals of western whiptail (*Cnemidophorus trigris*), side-blotched lizard (*Uta stansburiana*), and tree lizard (*Urosaurus ornatus*). No amphibians were observed along the Tucson reach of the Santa Cruz River.

Ecoregion – Southern and Central California Plains and Hills

2.4.4 Santa Ana River, San Bernardino, California (Appendix C, Study Area 4)

The Santa Ana River is the largest stream system in southern California, with a watershed covering an area of approximately 2,700 square miles (USGS 2000), reaching altitudes exceeding 10,000 feet, and flowing more than 100 miles to the Pacific Ocean near Huntington Beach. The San Jacinto River is a tributary of the Santa Ana River, but it normally terminates at Lake Elsinore. The Santa Ana Basin is substantially urbanized; about 32 percent of the land use is residential, commercial, or industrial, and the area is home to more than 4 million people. Agricultural land use accounts for about 10 percent of the watershed.



Mean monthly streamflow upstream and downstream of RIX facility on Santa Ana River

Wastewater Treatment Facility – The Colton/San Bernardino Regional Tertiary Treatment and Water Reclamation Authority's Rapid Infiltration and Extraction (RIX) Facility provides tertiary equivalent treatment for secondary effluents generated by the cities of

Colton and San Bernardino, including the separate outlying service areas located in San Bernardino County. This facility discharges into the Santa Ana River. The cities of Colton and San Bernardino each have secondary wastewater treatment facilities with the capacity of 6.4 and 33 mgd, respectively. In addition, the Riverside Regional Water Quality Control Plant discharges into the Santa Ana River. Discharge from the RIX facility is approximately 31 mgd.

Hydrology – Mean monthly stream flow above the RIX facility outfall ranges from 7 cfs (October) to 103 cfs (May) and mean monthly streamflow below the RIX facility ranges from 8 cfs (August though October) to 21 cfs (April). The estimated average annual precipitation is 8.8 inches.

Average Monthly Precipitation – NCDC Station 7123 (1948-1951)			
Month	**Precipitation (Inches)**	**Month**	**Precipitation (Inches)**
January	2.5	July	0.0
February	1.7	August	0.0
March	0.9	September	0.1
April	0.6	October	0.1
May	0.4	November	1.0
June	0.0	December	1.6

Geomorphology – The Santa Ana River collects tributaries and drains south from the San Gabriel, San Bernardino, and San Jacinto mountains of the Transverse Range. The higher elevations of this upper basin are in the Angeles National Forest and experience annual precipitation up to about 45 inches, mostly as rainfall. Annual rainfall at Riverside is about 10 inches. The river leaves the mountains at Mentone and flows southwest through the City of San Bernardino and across the interior alluvial valley for about 30 miles to the Prado Dam. The river then passes through a gap in the Chino Hills and Santa Ana Mountains and crosses the coastal plain south for about 30 miles, entering the Pacific Ocean near Costa Mesa.

The Santa Ana River is greatly affected by urbanization throughout the study area, more so than any other study area in this report. The bottomland of the Santa Ana River is dominated by easily eroded rocks and fine sediment typical of the geology and topography of near-coast California; therefore, the river has easily incised the predevelopment alluvium. Although wastewater inputs and urban encroachment into the Santa Ana River bottomland generally have had an apparent stabilizing effect on the channel, the typical tendency for channel cutting due to wastewater inputs is evident, and movement of sand as bed load continues at very high rates.

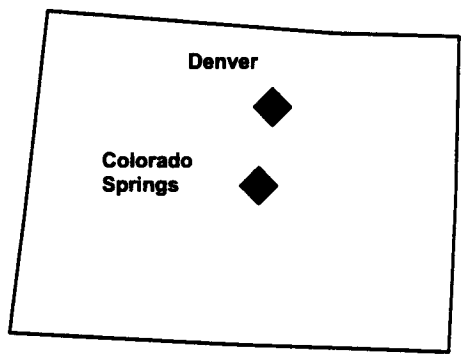
Chemistry – Three *STORET* stations are within the vicinity of the RIX facility outfall. Two stations are located upstream and one downstream. One upstream station has a period of record of 1976 to 1982 and contains data on temperature. The second upstream station has a period of record of 1989 to 1991 and contains information on temperature, dissolved oxygen, and nutrients. The downstream station has a period of record of 1966 to 1988 and contains information on temperature, dissolved oxygen, pH, nutrients, and metals.

Site Reconnaissance Summary – Aquatic Biology – Macroinvertebrates were sampled at three of the five reconnaissance sites. Access problems prevented sample collection at Sites 4 and 5. The number and types of taxa were similar above the discharge and at Site 3. Although the number of taxa declined substantially below the discharge (from nine to three) the dominant organisms were still baetid mayflies. Habitat quality was similar at Sites 1 and 2, immediately above and below the discharge, and declined somewhat at Sites 3 and 5.

Terrestrial Biology – Riparian habitat data were collected at four of the five reconnaissance sites along the Santa Ana River. The fifth site was not sampled due to an inability to access the river. On May 30, 2000, the day of the visit, there was some flow in the Santa Ana River upstream of the outfall at the RIX facility in San Bernardino and riparian vegetation extended upstream from the outfall. The dominant woody vegetation along the Santa Ana River at Sites 1, 2, and 3 was black cottonwood (*Populus trichocarpa*), black willow (*Salix nigra*), sandbar willow (*Salix interior*), and salt cedar (*Tamarix chinensis*). Understory and shrubby species consisted of juveniles of the above species along with seep willow (*Baccharis glutinosa*) and tree tobacco (*Nicotiana glauca*). The dominating perennial species throughout the reach was giant reed (*Arundo donax*). Giant reed often covered the entire river floodplain to the exclusion of all other species and occurred at such density that it was impossible to walk through it. Because of giant reed, it was impossible to access the fifth sample site.

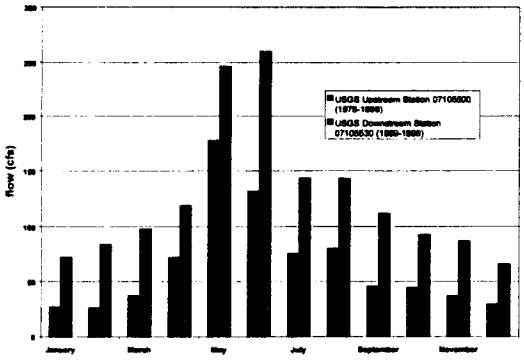
Mammals, or sign thereof, observed along the Santa Ana River included red fox (*Vulpes fulva*), cottontail rabbit (*Sylvilagus audubonii*), California ground squirrel (*Spermophilus beecheyi*), and pocket gopher (*Thomomys bottae*). A fairly large variety of birds were seen along the river including great egret (*Ardea alba*), great blue heron (*Ardea herodias*), green heron (*Butorides virescens*), and approximately 20 species of songbirds. The only amphibians observed were tadpoles believed to be those of the red-spotted toad (*Bufo punctatus*). Reptiles observed consisted of side-blotched lizard (*Uta stansburiana*) and Western fence lizard (*Sceloporus occidentalis*).

2.4.5 Fountain Creek, Colorado Springs, Colorado (Appendix C, Study Area 5)



Ecoregion – Southwestern Tablelands

The Fountain Creek basin is located in southeastern Colorado, originating in the Rampart Range. The Fountain Creek watershed is part of the Arkansas Basin. Fountain Creek passes through Colorado Springs and Pueblo, and parallels Interstate 25 for much of its length. The lower Fountain Creek has a stream length of approximately 52 miles, which extends from a point immediately upstream from the confluence with Monument Creek to the confluence with the Arkansas River at Pueblo. The northern part of lower Fountain Creek is perennial and receives from a variety of sources including Upper Fountain Creek, Monument Creek, tributaries that drain the Colorado Springs area, effluent from five WWTPs, and the alluvial aquifer. The stream traverses residential, commercial, industrial, and agricultural areas and consists primarily of sewage effluent.



Mean monthly streamflow upstream and downstream of WWTP on Fountain Creek.

Wastewater Treatment Facility – Colorado Springs Utilities (CSU) operates the Las Vegas Street WWTP, discharging effluent to Fountain Creek via the Fountain

Mutual Irrigation Canal. A variable portion of the effluent discharged to the creek is diverted into an irrigation ditch a few hundred feet downstream of the plant's outfall. The plant's NPDES permit limits flows to 65 mgd in January and February, and 75 mgd at all other times. In 1999, discharges from the WWTP to Fountain Creek averaged 44.5 mgd.

Hydrology – Mean monthly stream flow above the Las Vegas Street WWTP outfall ranges from 26 cfs (February) to 178 cfs (May) and mean monthly streamflow below the WWTP ranges from 66 cfs (December) to 260 cfs (June). The estimated average annual precipitation is 16.1 inches.

Average Monthly Precipitation – NCDC Station 1778 (1943-1998)			
Month	**Precipitation (Inches)**	**Month**	**Precipitation (Inches)**
January	0.3	July	2.9
February	0.3	August	2.9
March	0.9	September	1.3
April	1.3	October	0.8
May	2.3	November	0.5
June	2.3	December	0.3

Geomorphology – Fountain Creek at Janitell Road drains an area of about 413 square miles. The basin above Site 1 is largely in the Colorado Piedmont, an area of stream-dissected Mesozoic and Cenozoic-aged rocks east of the mountain front. The channel of Fountain Creek through the study area is mostly underlain by a veneer of stream alluvium on thick beds of marine shale of Cretaceous age. In many parts of the study area, the banks of Fountain Creek are composed of shale.

Channel incision is apparent along the entire study reach downstream from the Las Vegas Street WWTP. Although Fountain Creek is marginally alluvial in the Colorado Springs area, notable channel incision into soft marine shale was observed, possibly as much as 5 feet at Site 2. Intense channel disturbance at Site 3 made estimates difficult. At Site 4 the amount of incision is also indeterminate, but may be 2.3 to 2.6 feet. At Site 5 the estimated incision has been about 1.7 feet, also mostly into shale.

Fountain Creek is historically intermittent, but is now perennial. Ephemeral tributaries provide little base flow, but act as conduits for summer thunderstorms. Natural conditions, therefore, make Fountain Creek very "flashy" and it is highly susceptible to flash floods. Because only thin deposits of channel alluvium rest on shale throughout the Fountain Creek reach, transmission loss is inferred to be very low, and variation in flow rates appear mostly to be related to urban water use.

Chemistry – USGS has collected historical water quality data on Fountain Creek at 12 stations near the Las Vegas Street WWTP outfall. The period of record for this dataset is between 3 to 25 years. All regulated constituents are monitored.

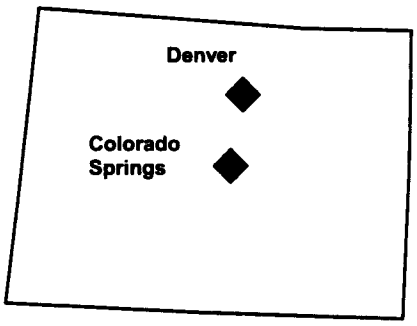
USGS, Colorado State University, and the City of Colorado Springs have completed several water quality investigations of Fountain Creek between 1980 and 1995. Additional work is ongoing.

Site Reconnaissance Summary – Aquatic Biology – Macroinvertebrates were sampled at all five reconnaissance sites; significant flow was present in Fountain Creek upstream of the effluent discharge. The number of taxa was greatest at Site 2, immediately below the effluent discharge; the number of taxa was similar above the effluent and at Sites 3, 4, and 5. The relative proportion of EPT taxa was greatest at Site 1 above the effluent discharge and declined at each site with the lowest proportion at Site 5. Diptera were dominant, especially those well-adapted to high sediment loads. Aquatic habitat in Fountain Creek was significantly impacted by an ongoing channel modification project that included the construction of erosion control structures (e.g., concrete aprons and riprap). Evidence of increased sediment loading caused by the construction project was evident on the day of sampling.

Terrestrial Biology – Riparian habitat data were collected at all five reconnaissance sites on Fountain Creek. Perennial woody vegetation at all sites on Fountain Creek is dominated by willow (*Salix* sp.) with eastern cottonwood (*Populus deltoides*) and Siberian elm (*Ulmus pumila*) playing subdominant roles. Sites 1 and 2 were rather strongly dominated by willow while Sites 3, 4, and 5 were characterized by cottonwood and willow acting as codominants. Siberian elm is present as a shrub or small tree species on all sites but is nowhere dominant. Box elder (*Acer negundo*) was present on Sites 1 and 2, but not recorded on other sites. The latter observation may, however, have been a function of phenology as most trees were in very early stages of leafing out and many had no identifiable leaves or flowers. Perennial understory vegetation at most sites consisted of willow saplings with snowberry (*Symphoricarpos* sp.) and currant (*Ribes* sp.) present at Site 2. Ground cover at all sites consisted of a variety of grass and forb species with large areas of open ground present.

Few wildlife species were observed at the Fountain Creek sites. Mammals, or sign thereof, observed included raccoon (*Procyon lotor*), mule deer (*Odocoileus hemionus*), eastern fox squirrel (*Sciurus niger*), and pocket gopher (*Thomomys* sp.). Many sapling willow trees at Sites 1 and 2 had been felled by beavers (*Castor canadensis*). Common birds included mallard (*Anas platyrhinchos*), magpie (*Pica pica*), and rough-winged swallow (*Stelgidoptyrx serripennis*). No reptiles were observed on any site. Frogs (*Rana catesbiana*) were observed at Site 5 on Fountain Creek, but positive species identification was not obtained.

2.4.6 South Platte River, Denver, Colorado (Appendix C, Study Area 6)

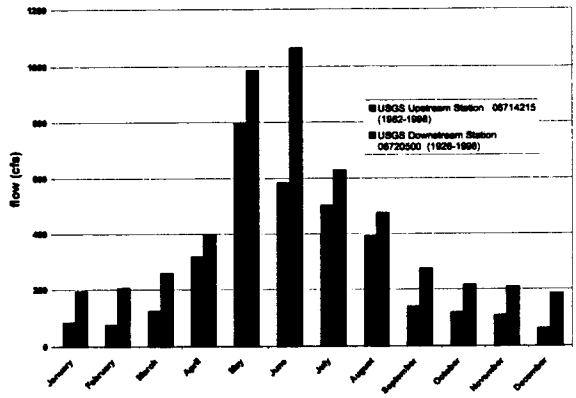


Ecoregion – Western High Plains

The South Platte River originates in the Rocky Mountains and flows east and northeast through forest and mountain rangeland to about 20 miles from Denver, Colorado where it enters the plains and flows into Chatfield Reservoir. The river then flows through mainly urban areas and into the City of Denver. Land use upstream of Denver is about 48 percent forest, 35 percent rangeland, 6 percent agriculture, 5 percent urban, and 6 percent other. However, most of the water from the forested headwaters is used as the municipal water supply for Denver and is removed upstream of Chatfield Reservoir. Urban land use predominates downstream of the reservoir.

Wastewater Treatment Facility – The Denver Metro Wastewater Reclamation District (MWRD) provides wastewater collection and treatment service to a portion of the Denver metropolitan area. MWRD provides service to 55 local cities and sanitation districts, for approximately 1.3 million people in a 380-square-mile service area. MWRD's central plant, located in Commerce City, discharges effluent to the South Platte River and the Burlington Ditch.

Effluent flows are limited in the plant's NPDES permit, varying monthly from 177.8 mgd in December to 227.0 mgd in May. In 1999, the combined total average of 148 mgd was discharged from the plant. The MWRD is authorized to discharge treated effluent to either the South Platte River or the Burlington Ditch, which serves agricultural irrigators and other users.



Mean monthly streamflow upstream and downstream of WWTP on South Platte River

Hydrology – Mean monthly stream flow above the MWRD plant outfall ranges from 63 cfs (December) to 798 cfs (May) and mean monthly streamflow below the plant ranges from 158 cfs (December) to 1,066 cfs (June). The estimated average annual precipitation is 14.5 inches. During the winter months, the river upstream of the MWRD plant is typically completely diverted for irrigation purposes.

Average Monthly Precipitation – NCDC Station 950 (1973-1998)			
Month	**Precipitation (Inches)**	**Month**	**Precipitation (Inches)**
January	0.5	July	1.6
February	0.4	August	1.5
March	1.3	September	1.0
April	1.6	October	0.9
May	2.4	November	0.9
June	1.8	December	0.5

Geomorphology – The South Platte River upstream from the MWRD central plant drains an area of about 3,860 square miles. Roughly the upper 70 percent of the South Platte River drainage basin above Commerce City, is in the southern section of the Rocky Mountains physiographic province. The remainder of the basin, plus additions to drainage-basin area between Site 1 and Site 5 (near Brighton, Colorado), lies in the western part of the Great Plains physiographic province. This province is characterized by stream-dissected plains underlain generally by a veneer of wind-deposited fine sand and silt resting on Cretaceous- and Tertiary-age rocks; Quaternary alluvium underlies most bottomland surfaces along stream channels.

The primary sources of water for this river are snowmelt in the mountains and rainfall. Groundwater also contributes substantially to the South Platte River in the plains. The South Platte River has its highest flows in the late spring and early summer because of snowmelt in the Rockies. Summer thunderstorms add to the flow, occasionally causing flooding.

Construction of reservoirs along the South Platte River began in 1879 to meet increased water demands. Water diversions have also contributed to the flow of the South Platte River. Hydrologic controls upstream of Denver include the Chatfield Reservoir; four headwater reservoirs (Antero, Spinney Mountain, Eleven Mile, and Cheeseman); and various agricultural, industrial, and municipal withdrawals and return flows. All of these human influences have changed the river's channel formation and sedimentation. The regulated flow has allowed riparian vegetation to stabilize the river channel, forcing it to become narrower and less sinuous. This, in turn, has restricted the river's lateral movement, prohibiting water dispersion during flooding. Irrigation return flows have contributed to the pollution of the river water.

Near Denver, the South Platte River has a mean velocity of approximately 1 foot per second and a mean gradient of 18.9 feet per mile. The stream is highly channelized in this region with a sinuosity of about 1.0 (low) and an average channel width of 122 feet. The river has been straightened and realigned in places and grade control and bank protection measures exist through much of the reach.

Chemistry – The MWRD plant has collected an intensive set of water quality data since 1988. Sampling has occurred bi-weekly and includes the following constituents: dissolved oxygen, temperature, ammonia, pH, mercury, cadmium, silver, lead, zinc, chromium, copper, and selenium.

In addition, this reach is within the USGS South Platte River Basin NAWQA program (Litke and Kimbrough 1998). The authors found that that this reach of the South Platte River was within the top 25th percentile of all NAWQA study units in the United States (1992-1995) for levels of nutrients and pesticides in the water column and for trace elements and semivolatile organic compounds in the sediment.

Three additional studies were conducted by USGS. These investigations concluded that a major source of pollutants to the South Platte River was from re-suspended bottom sediment, relative to tributary loadings. Nutrient loads increased slightly downstream from the city of Littleton, with organic nitrogen and ammonia the dominant nitrogen species. Investigations of groundwater sources suggested that subsurface contributions to streamflow may lower dissolved oxygen and pH and may contribute ammonia and phosphorus along upstream reaches and nitrate+nitrite, downstream.

MWRD has collected data to determine the relationship between low dissolved oxygen and fish species in Burlington Ditch (also referred to as O'Brien Canal). Additional monitoring for alkalinity, hardness, pH, conductivity, and ammonia was also conducted.

Site Reconnaissance Summary – Aquatic Biology – Macroinvertebrates were sampled at all five reconnaissance sites since flow was present in the river upstream of the MWRD discharge. The number of taxa was greatest at Site 1, above the effluent discharge, but only slightly greater than at Sites 4 and 5. EPT taxa constituted only a very small proportion of the aquatic community at Sites 1, 4, and 5. No EPT were found at Sites 2 and 3. Habitat was best above the effluent discharge and at Site 4. These two sites had the most similar aquatic communities. Habitat

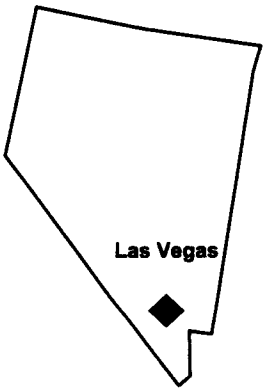
quality and the aquatic community changed somewhat between Sites 4 and 5, suggesting the presence of additional stressors on the aquatic community.

Terrestrial Biology – Riparian habitat data were collected at all five reconnaissance sites on the South Platte River. Perennial, woody vegetation on the South Platte River at all sites is dominated by eastern cottonwood (*Populus deltoides*) and willow (*Salix* sp.) with local dominance by Siberian elm (*Ulmus pumila*). Understory vegetation is composed mostly of willow and sapling or shrubby Siberian elm. Ground cover consists of a variety of annual and perennial forbs and grasses, many of which have been collected for later species identification.

Wildlife species observed at South Platte River reconnaissance sites consisted mostly of birds including great blue heron (*Ardea herodias*), mallard (*Anas platyrhinchos*), double-crested cormorant (*Phalacrocorax auritus*), spotted sandpiper (*Actitis macularius*), killdeer (*Charadrius vociferus*), magpie (*Pica pica*), rough-winged swallow (*Stelgidoptyrx serripennis*), and a variety of others including several other species of songbirds. Tracks of raccoon (*Procyon lotor*) and mule deer (*Odocoileus hemionus*) were noted in streamside muds and some evidence of beaver (*Castor canadensis*) in the form of sapling willow cutting was present at Sites 1, 4, and 5. No amphibians or reptiles were seen at any of the South Platte River reconnaissance sites, probably because of cool, windy weather.

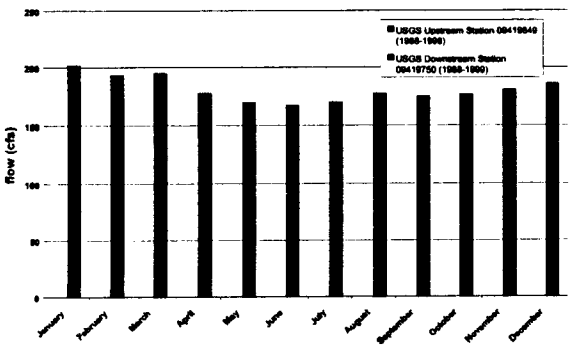
2.4.7 Las Vegas Wash, Las Vegas, Nevada (Appendix C, Study Area 7)

The Las Vegas Wash drains the Las Vegas Valley and flows into Lake Mead. Four tributaries merge in the valley to create the Las Vegas Wash: Las Vegas Creek, Flamingo Wash, Duck Creek, and Range Wash. Flow is sustained by urban drainage and discharge of treated sewage from the Las Vegas urban area. Flow in the underdeveloped headwater portions of the four contributing tributaries is ephemeral. A nearly 400 percent increase in streamflow was realized in the main stream from 1964 to 1995 as the rates of urban drainage and treated sewage discharge increased (Bevans et al. 1998).



Ecoregion – Mojave Basin and Range

Wastewater Treatment Facility – Three sewage treatment facilities discharge to Las Vegas Wash. The most upstream of these is the City of Las Vegas WPCF, which discharges to Las Vegas Wash just downstream of the confluence with Flamingo Wash. The Clark County Sanitation District Wastewater Treatment Facility (District WWTP) discharges to Las Vegas Wash approximately 1 mile downstream of the City of Las Vegas facility, and the City of Henderson Water Reclamation Facility (WRF) discharges to the wash approximately 3 miles farther downstream. Discharge flow limits are included in the



Mean monthly streamflow upstream and downstream of WWTP on Las Vegas Wash

NPDES permits for each plant, including 90 mgd for the District WWTP, 20 mgd for the City of Henderson WRF, and 66 mgd for the City of Las Vegas WPCF. Currently, the total combined flow from these facilities is approximately 150 mgd.

Average Monthly Precipitation – NCDC Station 5705 (1951-1998)			
Month	**Precipitation (Inches)**	**Month**	**Precipitation (Inches)**
January	0.6	July	0.3
February	0.6	August	0.3
March	0.6	September	0.4
April	0.2	October	0.2
May	0.1	November	0.5
June	0.1	December	0.4

Hydrology – Mean monthly stream flow above the WWTP outfall is 0 cfs (year-round) and mean monthly streamflow below the WWTP ranges from 160 cfs (June) to 202 cfs (January). The estimated average annual precipitation is 4.4 inches.

Geomorphology – Perennial flow in the Las Vegas Wash resulted in the development of wetlands. Between 1969 and 1975, the Las Vegas Wash supported approximately 1,800 acres of wetlands downstream from the discharge point of the City of Las Vegas WPCF. However, increased flows in the Las Vegas Wash were also causing erosion, which had become visually evident by 1969. Over the following four decades, increased wastewater discharge and flood events resulted in further erosion and dramatic headcutting and channel incision. As the headcut advanced upstream, the level of the creek bed dropped below the level of the wetlands, effectively draining the wetlands. By 1983, the area of wetlands had been reduced to its current level of about 175 acres.

Current efforts on the Las Vegas Wash are focused on controlling erosion. Construction on the first of 15 erosion control structures commenced in February 2000. These structures are intended to slow erosion and headcutting in the wash and to recreate wetland habitat. The Las Vegas Wash is a heavily managed and impacted system.

Chemistry – Two *STORET* stations are within the vicinity of the Las Vegas Wash. Both have a period of record of one year and have limited data. The Southern Nevada Water Authority (SNWA) maintains a water quality database that contains water quality data on the Las Vegas Wash from a variety of sources.

The Nevada Basin and Range NAWQA study unit included the Las Vegas Wash and USGS has completed several studies of water quality along the study reach (Bevans et al. 1998). The NAWQA study included fixed site water quality monitoring, fish tissue sampling and analysis, and a study of endocrine disruptors in wash waters. The authors concluded that the median nutrient load of the Las Vegas Wash had increased significantly, relative to the national median, during the years 1974 to 1988. Pesticides and volatile organic compounds appear to be originating in the urban waste stream and the bottom sediments of the wash contain detectable concentrations of trace elements and semi-volatile organic compounds. Evidence for the endocrine disruption of carp in the Wash and in Las Vegas Bay has been presented in the NAWQA investigation (Bevans et al. 1996).

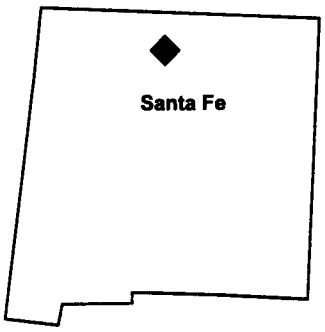
Other investigations have concluded that nutrients are being removed from the water column in the wetlands downstream of the WWTP. The data used in the Habitat Characterization Study primarily came from five stations maintained by SNWA.

Site Reconnaissance Summary – Aquatic Biology – Macroinvertebrates were sampled at all five reconnaissance sites. The number of taxa was greatest (10) at Site 1 above the discharge and declined to 5 to 7 at all other sites. The relative proportion of EPT taxa (only baetid mayflies) was similar (72 to 77 percent) at Sites 1, 3, and 5. The proportion of EPT taxa declined to 24 percent and 40 percent at Sites 2 and 4, respectively. The pattern of baetid mayfly dominance was closely coupled with habitat quality scores. The highest scores were tabulated for Sites 1, 3, and 5. Scores were considerably lower for Sites 2 and 4; the decline in baetid mayflies at Site 4 was likely the result of the dominance of fine, silty substrates.

Terrestrial Biology – Riparian habitat data were collected at all five reconnaissance sites along the Las Vegas Wash. There is flow in the Las Vegas Wash from above the City of Las Vegas WPCF all the way to Lake Mead. Site 1 on the Las Vegas Wash, above the outfall of the City of Las Vegas WPCF, is contained within a cement-lined channel. Perennial vegetation at this site consists of scrubby salt cedar (*Tamarix chinensis*) and saltbush (*Atriplex polycarpa*). None of the perennial vegetation is more than 10 feet tall. Most vegetation at Site 1 is weedy including cocklebur (*Xanthium stumarium*) and Bermuda grass (*Cynodon dactylon*). There are occasional, small patches of emergent cattail (*Typha domingensis*) in this area. Site 2 is regularly cleared of vegetation along the engineered, but not cement-lined, canal bank. Consequently vegetation is of low stature consisting of salt cedar, cocklebur, and saltbush. Site 2 does support good stands of emergent cattail. Sites 3 through 5 on the Las Vegas Wash are all located in an area of recent down-cutting and high stream velocities. Vegetation at all three of these sites is very strongly dominated by salt cedar and saltbush with occasional small patches of emergent cattail in backwaters and slack areas. Mesquite (*Prosopis glandulosa*) is present along the entire length of the Las Vegas Wash but it never assumes any stature as a dominant species.

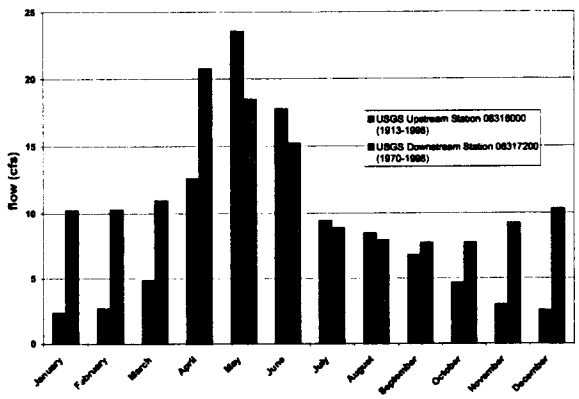
Wildlife and wildlife sign observed at sites along the Las Vegas Wash included evidence of raccoon (*Procyon lotor*), coyote (*Canis latrans*), and great blue heron (*Ardea herodius*). Species observed along the wash included white-tailed antelope squirrel (*Ammospermophilus leucurus*), desert cottontail (*Sylvilagus auduboni*), black-tailed jack rabbit (*Lepus californicus*), killdeer (*Charadrius vociferus*), phainopepla (*Phainopepla nitens*), blue grosbeak (*Guiraca caerula*), rough-winged swallow (*Stelgidoptyrx latipennis*), common raven (*Corvus corax*), side-blotched lizard (*Uta stansburiana*), and western whiptail lizard (*Cnemidophorus tigris*). Juvenile and larval red-spotted toads (*Bufo punctatus*) were also found at Site 1.

2.4.8 Santa Fe River, Santa Fe, New Mexico (Appendix C, Study Area 8)



Ecoregion – Arizona/ New Mexico Plateau

The Santa Fe River is located in the upper Rio Grande basin and drains the southernmost western slope of the Sangre de Cristo Mountains. The channel is usually dry in this reach and, consequently, the Santa Fe WWTP is the major source of water in the river between the WWTP and La Cienega. When flowing, the



Mean monthly streamflow upstream and downstream of WWTP on Santa Fe River

upper reaches of the Santa Fe River are accumulated in a series of reservoirs owned and operated by the City of Santa Fe.

Much reduced in discharge, the river exits the reservoirs and passes through the Santa Fe Metropolitan Area. Within the urban area, the Santa Fe River is an ephemeral stream. Upon reaching the urban outskirts along County Road 56 (Airport Road), it encounters the effluent outfall of the Santa Fe WWTP where the stream becomes perennial and effluent-dependent.

Wastewater Treatment Facility – The Santa Fe WWTP discharges the majority of its treated effluent to the Santa Fe River. A variable portion of treated effluent is also reused for irrigation and other non-potable purposes, with reuse demands peaking in summer and diminishing to much lower levels in winter. In 1998, the WWTP discharged an average of 5.5 mgd, or 86 percent of total plant flow.

Hydrology – Mean monthly stream flow above the WWTP outfall ranges from 2 cfs (January) to 24 cfs (May) and mean monthly streamflow below the WWTP ranges from 8 cfs (August though October) to 21 cfs (April). The upstream USGS gage (08316000) is upstream of two reservoirs east of the city of Santa Fe. The Santa Fe River above the WWTP outfall is ephemeral. The estimated average annual precipitation is 12.6 inches.

Average Monthly Precipitation – NCDC Station 1982 (1975-1998)			
Month	**Precipitation (Inches)**	**Month**	**Precipitation (Inches)**
January	0.6	July	1.8
February	0.5	August	2.1
March	0.6	September	1.5
April	0.7	October	1.1
May	1.1	November	0.9
June	1.0	December	0.7

Geomorphology – The Santa Fe River begins in the Southern Rocky Mountains physiographic province, including a region of Precambrian granite-gneiss and other metamorphic rocks overlain by Pennsylvanian to Permian limestones and sandstones.

After leaving the mountains, the river crosses into the Basin and Range physiographic province, specifically the tectonically active Rio Grande Rift, primarily underlain by Tertiary sediments and a thin veneer of Quaternary basaltic volcanic rocks. About 10 miles below the city, the river begins to cut a deep canyon below the resistant basaltic rocks. The drop in grade is due to the La Bajada escarpment, located about 19 miles downstream of the city.

The Santa Fe River below the WWTP is incised into a broad plateau. The wastewater effluent cuts a meandering channel below the existing and wider ephemeral streambed for about 0.5 mile, gradually becoming the active channel. About 10 miles below the WWTP, groundwater is added

to the discharge from springs of the La Cienega region. Further downstream, the channel banks are highly disturbed and cattle were grazing in the floodplain during both reconnaissance inspections.

Chemistry – Two *STORET* stations are located within the vicinity of the Santa Fe WWTP. The upstream station has a period of record of 1984 to 1988 with the dataset focusing on nutrients. The downstream station has a period of record of 1974 to 1999 with the dataset containing information on nutrients, metals, temperature, and pH. In addition, the New Mexico Environment Department (NMED) has collected data on the Santa Fe River since 1998 to support total maximum daily load (TMDL) development. This has included chemical sampling.

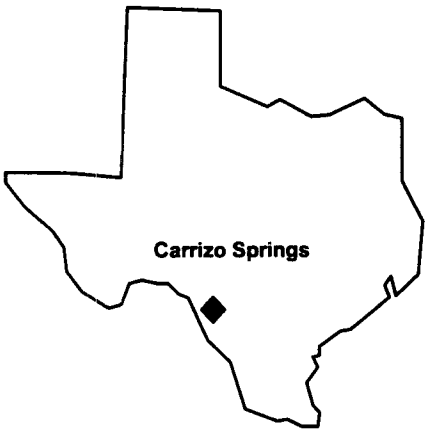
In 1994, the City of Santa Fe conducted a Use Attainability Analysis (UAA), under the federal Clean Water Act, for the Santa Fe River. Water quality data generated for the UAA included concentrations of nutrients, major ions, fecal coliform, and cyanide. The Santa Fe River is also included in the Rio Grande NAWQA study unit by USGS (Levings et al. 1998). Major findings are not specific to the Santa Fe River (only one fixed site was evaluated) but habitat degradation upstream of Cochiti Lake was attributed to stream modification, bank erosion, and loss of riparian vegetation; no significant correlation existed between fish community metrics and dissolved oxygen, water temperature, or specific conductance (Levings et al. 1998).

Site Reconnaissance Summary – Aquatic Biology – Macroinvertebrates were sampled only at Sites 2, 3, 4, and 5 since upstream of the discharge the Santa Fe River was dry. The number of taxa increased downstream of the discharge from 10 to 14 and 15 at Sites 4 and 5, respectively. The relative proportion of EPT taxa was greatest at Sites 3 and 5; EPT taxa (baetid mayflies) constituted almost 17 percent of the macroinvertebrates at Site 2 immediately below the discharge. Habitat quality increased downstream of the discharge; however, some decline in quality occurred at Sites 4 and 5 because of increased sediment loading.

Terrestrial Biology – Riparian habitat data were collected at all five reconnaissance sites along the Santa Fe River. Site 1, upstream of the WWTP outfall, is ephemeral and contained no water on May 22, 2000, the day of the sampling. Perennial woody vegetation at Site 1 is dominated by rabbitbrush (*Chrysothamnus nauseosus*), a shrub. Tree species in the vicinity include Russian olive (*Elaeagnus angustifolia*) and Siberian elm (*Ulmus pumila).* Sites 2 through 5, all influenced by effluent, all support riparian vegetation that is generally dominated by Russian olive with varying presence of willow (*Salix nigra*) and salt cedar (*Tamarix ramosissima*). There are occasional cottonwoods (*Populus fremontii*) along the river, but they are not a significant feature of the Santa Fe River flora. Site 3, the "Forest Guardians Site," has been planted with willow and cottonwood poles over at least the past two years. Some "saplings" are 10 to 12 feet high and others are much shorter. Site 5 on the Santa Fe River was characterized by fairly dense growth of salt cedar and willow right along the stream with Russian olive forming a fairly dense wall of vegetation upslope. Site 5 was highly degraded by livestock.

Mammals or sign thereof observed along the Santa Fe River included raccoon (*Procyon lotor*), coyote (*Canis latrans*), and mule deer (*Odocoileus hemionus*). Birdlife at the five reconnaissance sites was not highly diverse, probably as a result of the dominance of Russian olive. Species observed included red-tailed hawk (*Buteo jamaicensis*), common raven (*Corvus corax*), belted

kingfisher (*Ceryle alcyon*), spotted sandpiper (*Actitis macularius*), blue grosbeak (*Guiraca caerula*), lark sparrow (*Chondestes grammacus*), and an Empidonax flycatcher (*Empidonax* sp.). Amphibians and reptiles noted included eastern fence lizard (*Sceloporus undulatus*) and Woodhouse toad (*Bufo woodhousei*).



Ecoregion – Southern Texas Plains

2.4.9 Carrizo Creek, Carrizo Springs, Texas (Appendix C, Study Area 9)

The Carrizo Creek study area is located downstream of Carrizo Springs, the seat of Dimmit County, Texas. Population (according to 1990 Census data) is 5,745 and is served by the Carrizo Springs WWTP. Discharge from the plant flows through a small polishing wetlands and is conveyed to the creek in a small, unlined ditch. The site is located 123 miles southwest of San Antonio in the Gulf Coastal Plain physiographic province. Topography is flat and featureless, sloping gradually up to the north and northwest where it is bordered by the Balcones Fault Zone, a major structural boundary, separating the coastal plain from the Texas Hill Country.

Wastewater Treatment Facility – The Carrizo Springs WWTP is owned and operated by the City of Carrizo Springs, Texas. All effluent from the plant is discharged to Carrizo Creek, although golf course irrigation using plant effluent may be considered in the future. Originally designed for 2.5-mgd capacity, the Carrizo Springs WWTP is currently permitted at 0.995 mgd, making it a "minor" plant for permitting purposes. The average daily flow at the WWTP is approximately 0.6 mgd.

Average Monthly Precipitation – NCDC Station 1000 (1964-1997)			
Month	**Precipitation (Inches)**	**Month**	**Precipitation (Inches)**
January	0.5	July	2.8
February	0.3	August	3.7
March	0.8	September	2.1
April	1.1	October	1.3
May	2.3	November	0.7
June	2.8	December	0.5

Hydrology – There are no USGS stream gaging stations along Carrizo Creek. The Carrizo Springs WWTP Texas PDES permit allows the plant to discharge a daily average of no more than 0.95 mgd (1.5 cfs) or 2,062 gpm (4.6 cfs) for a two-hour peak flow. According to monitoring records, the plant normally discharges at about 0.47 cfs to Carrizo Creek. During the reconnaissance visit in May of 2001, the flow was estimated to be about 1 cfs.

The estimated average annual precipitation is 18.9 inches. Mean annual temperature is 71 degrees Fahrenheit.

Geomorphology – The Upper Nueces River includes northern headwater fed by spring discharges from the carbonate Edwards Aquifer, a groundwater source of regional extent.

However, Carrizo Creek drains the southern portion of the basin and is supplied with very limited base flow from the semi-consolidated sandstone of the Texas Coastal aquifer system.

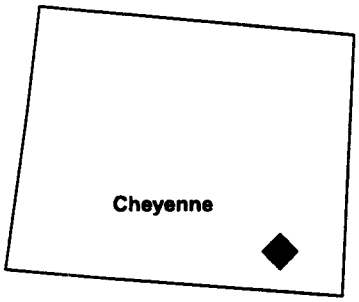
Chemistry – There are no historical chemical data for Carrizo Creek itself. One data point in the *STORET* database exists for a location in the town of Carrizo Springs.

Carrizo Creek is contained within the South-Central Texas NAWQA study unit (Bush et al. 2000). However, the focus of this investigation is on portions of the Nueces River watershed that might contribute to recharge of the Edwards Aquifer, far upstream of Carrizo Creek. Nevertheless, the study did conclude that nitrate levels in the streams of south-central Texas impacted by WWTPs were 5 times greater than similar agricultural lands and 20 times greater than rangeland.

Site Reconnaissance Summary – Aquatic Biology – Macroinvertebrates were sampled at all five reconnaissance sites. Significant flow was present upstream of the discharge, but the flow was no longer present less than a mile upstream of the discharge. The source of flow upstream of the discharge is unknown and could result from groundwater, springs, or backflow at the point of discharge to the main channel. Because of dense vegetation and private land, access to the creek was difficult and limited samples were collected. The number of taxa was greatest upstream of the discharge at Site 1 and lowest at Site 4, the most downstream site. The relative proportion of EPT taxa (all mayflies) was greatest at Site 1. Few or no EPT taxa were collected from other sites. Habitat quality was similar among all sites except Site 2 below the discharge where habitat quality was highest. The primary difference between Site 2 and all other sites was the presence of a variety of flow regimes, which increased habitat diversity. At all other sites, the stream was pond-like and somewhat stagnant. Large fish (e.g., gar) were present above and below the discharge.

Terrestrial Biology – Riparian habitat data were collected at four sites at Carrizo Springs. Sites 1 through 4 all contained water, although the water at Site 1 may have been backup water from the Carrizo Springs WWTP outfall. Perennial woody vegetation at all Carrizo Springs sampling locations was dominated by Goodding's willow (*Salix gooddingii*) with netleaf hackberry (*Celtis reticulata*) and sweet acacia (*Acacia farnesiana*). Several other large shrubs to mid-sized trees were present and collections of these species have yet to be identified in the laboratory. Understory vegetation was dense and consisted of several species of woody vines (still to be positively identified) and shrubs including whitethorn acacia (*Acacia constricta*).

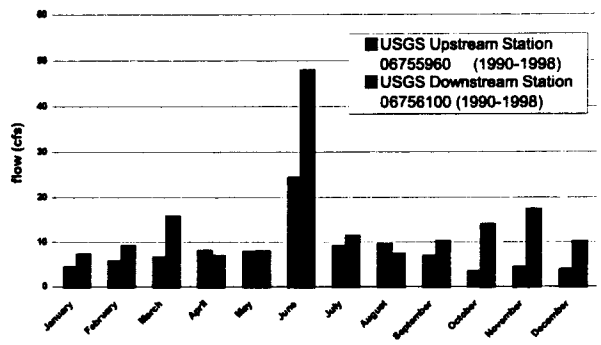
Wildlife observed at Carrizo Springs included sign of raccoon (*Procyon lotor*) and the subtropical and southeastern United States species; indigo snake (*Drymarchon corais*), diamondback watersnake (*Nerodia rhombifer*), great kiskadee (*Pitangus sulferatus*), and golden-fronted woodpecker (*Melanerpes aurifrons*). A number of other species were observed and have been recorded on field data sheets.



Ecoregion – Western High Plains

2.4.10 Crow Creek, Cheyenne, Wyoming (Appendix C, Study Area 10)

Crow Creek is a relatively large drainage basin in southeastern Wyoming and northeastern Colorado. About three-quarters of the basin lie in the High Plains region of Wyoming, while the remainder lies in the Laramie Range of the Rocky Mountains (the headwaters). From its headwaters, the Crow Creek watershed drains 297 square miles, rising in the gently sloping open lands and ponderosa pine west of Cheyenne in the Medicine Bow National Forest. The maximum elevation is about 8,300 feet near the crest of Interstate 30 roughly 10 miles southeast of Laramie or 35 miles west of Cheyenne. Collecting tributaries, Crow Creek flows east, enters Cheyenne, then flows south to join the South Platte River east of Greeley, Colorado. Most of the urban runoff from Cheyenne passes through Crow Creek.



Wastewater Treatment Facility – Two WWTPs discharge into Crow Creek: the Crow Creek WWTP and the Dry Creek WWTP. Both of these plants are operated by the Cheyenne Board of Public Utilities (BOPU). The Crow Creek WWTP currently has a rated capacity of 4.5 mgd. All flow treated at the plant is discharged to Crow Creek at the plant's outfall, except minor quantities used onsite for irrigation and non-potable plant water. The Dry Creek WWTP, which discharges downstream of the Crow Creek WWTP, has a capacity of 7.5 mgd. All flow treated at the plant is discharged to Crow Creek at the plant's outfall, except minor quantities used onsite for irrigation and non-potable plant water. The combined average daily flow of Crow Creek at the Dry Creek WWTP is approximately 9 mgd.

Average Monthly Precipitation – NCDC Station 1675 (1915-1998)			
Month	**Precipitation (Inches)**	**Month**	**Precipitation (Inches)**
January	0.5	July	2.0
February	0.5	August	1.7
March	1.1	September	1.3
April	1.7	October	0.9
May	2.5	November	0.6
June	2.1	December	0.5

Hydrology – Mean monthly streamflow above the WWTP outfall ranges from 3 cfs (October) to 24 cfs (June) and mean monthly streamflow below the WWTP ranges from 7 cfs to 48 cfs (June). The estimated average annual precipitation is 15.4 inches.

Geomorphology – Flows in the study area downstream from Cheyenne meander across an erosion surface on silt, sand, and gravel beds of the Miocene-age Ogallala Formation and eventually into the South Platte River near Greeley, Colorado. The current study area is a somewhat modified version of that setting.

In general, the current Crow Creek channel in the study area shows little or only muted entrenchment due to upstream effluent discharges and urban flood sources of recent decades. Natural adjustments, especially the tendency for channel incision, that have probably occurred may have been minimized by the channel modifications and controls that have been imposed on the system.

Transect measurements taken in a reach of Crow Creek from just upstream of the Crow Creek WWTP to about 5 miles downstream of the Dry Creek WWTP (at the Wyoming Hereford Ranch Reservoir #2) revealed the following estimates of stream morphology: mean depths were approximately 0.7 to 1.0 foot, mean velocities ranged between 1.2 to 1.3 feet per second, and mean widths fell between 14 to 20 feet.

The primary hydrologic control upstream of the Dry Creek WWTP appears to be the Hereford Reservoir #1. Hydrologic controls upstream of the Crow Creek WWTP appear to include diversions, return flows, and reservoir storage. There also appear to be a number of upstream dams in this region, as identified in the National Inventory of Dams (U.S. Army Corps of Engineers [USACE] Internet site).

Chemistry – Two *STORET* stations are within the vicinity of Crow Creek. The upstream station has a period of record of 1983 to 1993 with the dataset focusing on nutrients, temperature, pH, and metals. The downstream station has a period of record of 1990 to 1993 with the dataset containing information on nutrients, metals, temperature, and pH. In addition, the Cheyenne BOPU has conducted several hydrologic and water quality studies on Crow Creek and supplemented the USGS historical chemical data.

Site Reconnaissance Summary – Aquatic Biology – Macroinvertebrates were sampled at all five reconnaissance sites since flow was present in the creek upstream of the discharge from the Crow Creek WWTP. The number of taxa (16) was greatest at Site 1, above the effluent discharge, and declined significantly at Site 2 below the discharge where only 2 taxa were collected. The number of taxa increased at Sites 3 and 4 downstream of the Crow Creek WWTP but declined again below the point where effluent from the Dry Creek WWTP discharges to Crow Creek. Four EPT taxa were collected at Site 1; no EPT taxa were collected at any other sample sites. With the exception of Site 3, where a small storage reservoir affected channel structure, habitat quality was good at all sites.

Terrestrial Biology – Riparian habitat data were collected at the five reconnaissance sites along Crow Creek in Laramie County, Wyoming. Large, woody vegetation along Crow Creek consists primarily of Bebb willow (*Salix bebbiana*) with widely scattered eastern cottonwood (*Populus deltoides*). Shrubby understory vegetation, when present, is dominated by coyote willow (*Salix exigua*) and, possibly, sandbar willow (*Salix interior*). Other understory shrubs include snowberry (*Symphoricarpos* sp.) and wild rose (*Rosa* sp.). Emergent vegetation was the dominant feature observed at Site 3 and consisted of cattail (*Typha domingensis*) and bulrush (*Scirpus* sp.). Small patches of these two species also occurred at Sites 4 and 5.

Mammal species, or sign thereof, observed along the stream included red fox (*Vulpes fulva*), raccoon (*Procyon lotor*), mule deer (*Odocoileus hemionus*), and eastern cottontail (*Sylvilagus*

floridanus). A dead long-tailed weasel (*Mustela frenata*) was found at Site 3. A variety of birds were observed including mallard (*Anas platyrhynchos*), killdeer (*Charadrius vociferus*), red-tailed hawk (*Buteo jamaicensis*), great blue heron (*Ardea herodias*), and black-crowned night heron (*Nycticorax nycticorax*). Approximately 20 species of songbirds were observed including great crested flycatcher (*Myiarchus crinitus*), yellow warbler (*Dendroica petechia*), orchard oriole (*Icterus spurius*), common grackle (*Quiscalus quiscala*), and red-winged blackbird (*Agelaius phoenicius*). Perhaps due to the cool, windy weather on June 14, 2000, the day of sampling, no species of amphibians or reptiles were observed during the site reconnaissance.