Adopted February 7, 2007

Two Total Maximum Daily Loads for Chloride and Total Dissolved Solids in the Colorado River Below E. V. Spence Reservoir

For Segment Number 1426

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Prepared by the:
Chief Engineer's Office, Water Programs, TMDL Section

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

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EXECUTIVE SUMMARY

This document describes a project developed by the Texas Commission on Environmental Quality (TCEQ) to address water quality impairments related to excessive chloride and total dissolved solids (TDS) in the Colorado River Below E.V. Spence Reservoir (Segment 1426). Segment 1426 is a freshwater stream that flows southeasterly through Coke and Runnels Counties. It is approximately 66 miles long and has a watershed greater than 2,000 square miles. General water quality uses were first identified as impaired in the *Texas Water Quality Inventory and 303(d) List* for 2000.

The Colorado River Below E.V. Spence Reservoir is designated for contact recreation, public water supply, fish consumption, and high aquatic life uses under the Texas Administrative Code, Title 30 (30 TAC), Chapter 307: Texas Surface Water Quality Standards, Section 307.7: Site-Specific Uses.

The goal for this project is to determine the allowable loading that will still make it possible to meet water quality standards. Established numeric criteria to support general water quality uses are defined in the *Texas Surface Water Quality Standards* as annual average concentrations of 610 milligrams per liter (mg/L) of chloride and 2,000 mg/L of TDS.

The TCEQ conducted an investigation to identify possible point and nonpoint sources of chloride and TDS, and to quantify the appropriate reductions necessary to comply with established water quality standards. Field investigations identified that excessive chloride and TDS concentrations occur in E.V. Spence Reservoir and the Colorado River from below E.V. Spence Reservoir to below the city of Ballinger in Runnels County (EA, 2006).

Several load allocation scenarios were considered to determine the final load allocations. Before load allocation scenarios were developed, the loads for chloride and TDS at base conditions were estimated based on recent data and information provided by the Lower Colorado River Authority (LCRA). The minimum flow release requirements from E.V. Spence Reservoir to sustain habitat for the Concho Water Snake are 4 cubic feet per second (cfs) during the period from April to September and 1.5 cfs from October to March. As stipulated in the revised Biological Opinion issued by the United States Fish and Wildlife Service (USFWS) in December 2004, Colorado River Municipal Water District (CRMWD) will adhere to these release requirements. These requirements are applicable only when there is inflow to the reservoir and the water level remains at or above 1843.5 feet. Under these conditions, chloride concentrations in reservoir water ranged from 220 mg/L, to 480 mg/L from top to bottom, based on historical data.

Analysis of the load allocation scenarios indicates that releases from E.V. Spence Reservoir must be at or below 550 mg/L of chloride and 1,537 mg/L of TDS in order to meet the water quality standard.

INTRODUCTION

Section 303(d) of the federal Clean Water Act requires a state to identify waters that do not meet, or are not expected to meet, applicable water quality standards. For each listed water body that does not meet a standard, a state must develop a total maximum daily load (TMDL) for each pollutant that contributes to the impairment of water. The TCEQ is responsible for ensuring that TMDLs are developed for impaired surface waters in Texas.

In simple terms, a TMDL is like a budget that determines the amount of a particular pollutant that a water body can receive and still meet its applicable water quality standards. In other words, TMDLs are the best possible estimates of the assimilative capacity of the water body for a pollutant under consideration. A TMDL is commonly expressed as a load with units of mass per period of time, but may be expressed in other ways. TMDLs must also estimate how much the pollutant load must be reduced from current levels in order to achieve water quality standards.

The TMDL Program is a major component of Texas' effort to improve and manage surface water quality. The Program addresses impaired or threatened streams, reservoirs, lakes, bays, and estuaries (water bodies) in the state of Texas. The primary objective of the TMDL Program is to restore and maintain the beneficial uses—such as drinking water supply, recreation, support of aquatic life, or fishing—of impaired water bodies. This TMDL addresses impairments to general uses from chloride and TDS in the Colorado River Below E.V. Spence Reservoir, Segment 1426.

Section 303(d) of the Clean Water Act and the implementing regulations of the U.S. Environmental Protection Agency (EPA) (40 Code of Federal Regulations, Part 130) describe the statutory and regulatory requirements for acceptable TMDLs. Following these guidelines, this document describes the key elements of the TMDL as summarized in the following sections:

- Problem Definition
- Endpoint Identification
- Source Analysis
- Seasonal Variation
- Linkage between Sources and Receiving Waters
- Margin of Safety
- Pollutant Load Allocation
- Public Participation
- Implementation and Reasonable Assurance

This TMDL document was prepared based on the report titled "Colorado River below E.V. Spence Reservoir (Segment 1426): Total Maximum Daily Load for Chloride and Total Dissolved Solids" prepared by:

- EA Engineering, Science, and Technology, Inc., Lewisville, Texas
- The Louis Berger Group, Inc., Washington, D.C.
- The TMDL Section, Water Programs of the Chief Engineer's Office, TCEQ

This TMDL document was adopted by the TCEQ on February 7, 2007. Upon EPA approval, the TMDL will become an update to the state's Water Quality Management Plan.

PROBLEM DEFINITION

This document describes a project developed to address water quality impairments related to chloride and TDS in the Colorado River Below E.V. Spence Reservoir (Segment 1426). Segment 1426 is a freshwater stream approximately 66 miles long, with a watershed greater than 2000 square miles. The segment receives the majority of its flow from E.V. Spence Reservoir. It begins at Robert Lee Dam and flows southeasterly through Coke and Runnels Counties in Texas, ending 2.3 miles below the confluence of Mustang Creek in Runnels County (Figure 1). General water quality uses were first identified as impaired by TDS and chloride in the *Texas Water Quality Inventory and 303(d) List* for 2000.

Concentrations of chloride and TDS are among the numeric criteria used to evaluate the support of general uses. The criteria for chloride and TDS are average annual concentrations of 610 mg/L and 2,000 mg/L, respectively (Table 1). Figure 2 shows concentrations of TDS that were measured during 2004 at several sites in the watersheds of the E.V. Spence Reservoir (Segment 1411) and the Colorado River Below E.V. Spence Reservoir.

The goal of this TMDL project is to achieve the water quality standards. In the course of the project, the TCEQ identified possible point and nonpoint sources of chloride and TDS, and quantified the reductions necessary to comply with established water quality standards. Possible sources and/or causes include:

(1) release from the Spence Reservoir
(2) produced water
(3) abandoned brine pits
(4) phreatophytic brush
(5) point sources
(6) carbonate dissolution

DESIGNATED USES AND WATER QUALITY STANDARDS

The Colorado River Below E.V. Spence Reservoir, Segment 1426, is designated for contact recreation, public water supply, fish consumption, and high aquatic life uses in the *Texas*

Figure 1: Colorado River Below E.V. Spence Watershed

Table 1: Numeric Criteria for the Colorado River below E.V. Spence Reservoir

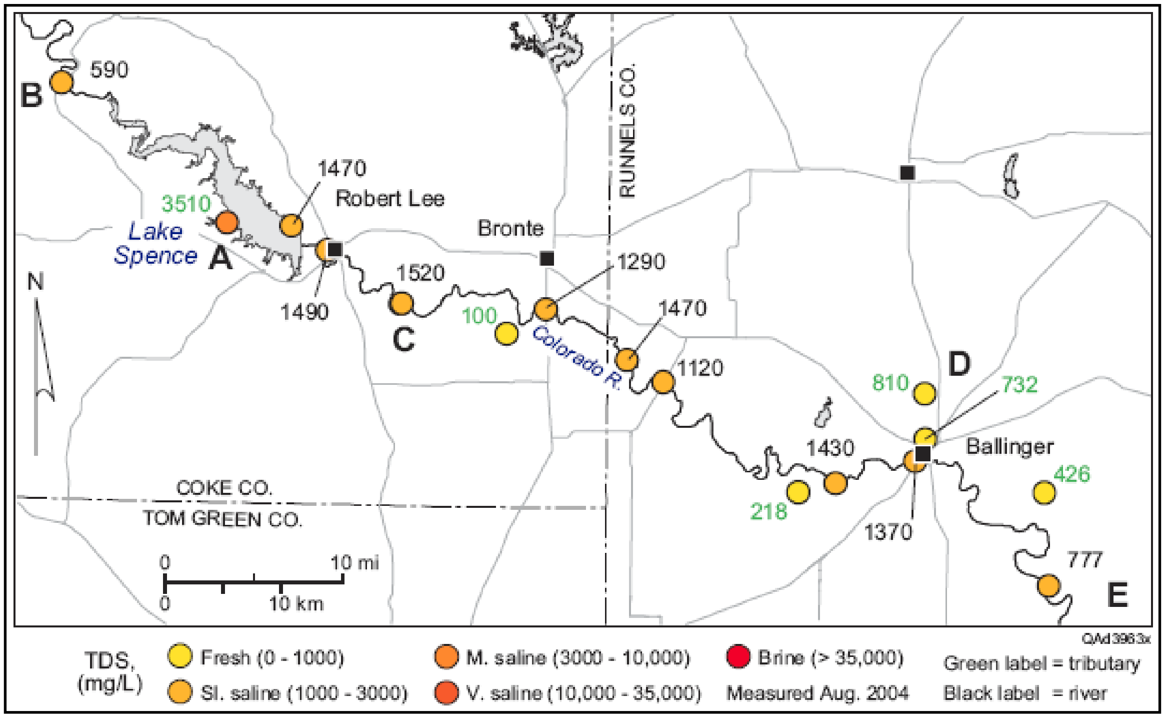
Segment	Criteria						
	Cl (mg/L)	SO4 (mg/L	TDS (mg/L)	Dissolved Oxygen (mg/L)	pH Range (Standard Units)	Indicator Bacteria #/100ml (E. coli)	Temperature (°F)
1426: the Colorado River Below E.V. Spence Reservoir	610*	980*	2,000*	5.0	6.5-9.0	126+/ 394++	91

* expressed as annual average values

+ expressed as a geometric mean

++ expressed as an instantaneous grab sample

Surface Water Quality Standards (30 TAC, Chapter 307, Section 307.7). The Upper Colorado River Authority (UCRA), the LCRA, CRMWD, the TCEQ, and the United States Geological Survey (USGS) all collect water quality samples in the Colorado River Basin. Assessment of their data found that elevated levels of chloride and TDS are affecting the general uses of the Colorado River Below E.V. Spence Reservoir. High chloride concentrations can cause bad-tasting water, harm plumbing, and increase the risk of hypertension in humans. Elevated concentrations of chloride and dissolved solids can be toxic to species that live in fresh water (Shipley, 1991).



Graduated circles, from yellow to red, represent increased concentrations of total dissolved solids. Circles with green labels represent tributaries off the main stem of the segment. Alphabetical letters in the map represent areas that do not correspond to information presented in this report.

Figure 2: Map of the segment study area (Segment 1426), depicting TDS concentrations measured in August 2004. (Paine et al, 2005)

DESCRIPTION OF THE WATERSHED

The Colorado River Below E.V. Spence Reservoir is a 66-mile-long freshwater stream located within the larger Colorado River Basin. Segment 1426 receives the majority of its flow from E.V. Spence Reservoir. It begins at Robert Lee Dam and flows southeasterly through Coke and Runnels Counties, ending 2.3 miles below its confluence with Mustang Creek in Runnels County.

The Edwards-Trinity aquifer is the principal source of groundwater in the Segment 1426 watershed. The aquifer is composed of sandstone and carbonate-rock aquifers and encompasses an area of 818 square miles.

Elevations in the watershed range from 1,650 to 2,350 feet above sea level. A majority of the land is well adapted to cultivation. Vegetation can be best described as mesquite savannah. Mineral resources include brick-making clay and oil and gas deposits.

Climatic, Economic, and Geographic Conditions

Conditions related to the climate, economy, and geography of the watershed directly affect water quality in a stream.

Climate

Temperature in this subtropical climate ranges annually from 34 degrees to 96 degrees Fahrenheit, with generally dry winters and humid summers. Average annual precipitation in the watershed is 22 to 23 inches. The months of September and October normally receive the most rainfall; December through July are the driest, normally receiving less than 1.5 inches per month.

Economy

Coke and Runnels Counties are agriculturally diverse in an area where the economy is dependent on the agriculture industry. Average annual cash receipts for agriculture are approximately $40 million. The counties are primarily farmland, producing cotton, grain sorghum, oats, and wheat. On range and pastureland, producers raise cattle, sheep, goats, hogs, and horses. Populations in both Coke and Runnels Counties have risen since 1990. Cities with a population of 1,000 or more are Bronte, Robert Lee, Ballinger, Winters, and Miles. Most of the land in both counties is privately owned, with a small percentage belonging to various governmental agencies in the area.

Stream Segment Geology and Hydrogeology

The geology of the West Texas region around Segment 1426 is composed of Permian-age carbonates, evaporates, shales, mudstones, sandstones, and conglomerates. The underlying geologic formations control topography, area drainage, and soil types. The geologic units that are exposed in the study area are, from west to east (oldest to youngest), the Talpa and Lueders Formations of the Wichita-Albany Group and the Clear Fork Group, both of the Permian Leonard Series. The San Angelo and Blaine formations of the Permian Guadalupe Series overlie these units.

The groundwater within the area are undifferentiated aquifers of the Edwards-Trinity system that provide fresh to slightly saline groundwater for agricultural, domestic, and municipal uses. Small and moderate amounts of water are recovered from Quaternary, Tertiary, Cretaceous, Permian, and Pennsylvanian age deposits. The Wichita Group, San Angelo Sandstone, and Whitehorse Group are some of the Permian units known to produce useable amounts of groundwater.

Soils

The soil characterization of Segment 1426 was based on the Soil Survey of Coke and Runnels County, Texas (USDA Soil Conservation Service Series 1970 and 1974). There are two soil associations within the project watershed: (1) the Spur-Colorado-Miles Association in Runnels County; and (2) the Miles-Colorado Association in Coke County. The Spur-Colorado-Miles Association consists of about 26 percent Spur soils, 24 percent Colorado soils, 19 percent Miles soils, and 31 percent other soils. Soils in this association are nearly level to gently sloping, deep and loamy, and mainly on flood plains, but also occur on out-wash plains and old stream terraces.

The Miles-Colorado Association consists of deep, noncalcareous, loamy soils on terraces and bottomlands. Colorado soils are reddish-brown calcareous loams, which make up 25 percent of this association, and are located on the flood plains. Miles soils are reddish-brown, noncalcareous, fine sandy loams that make up about 40 percent of this association and occupy adjoining terraces.

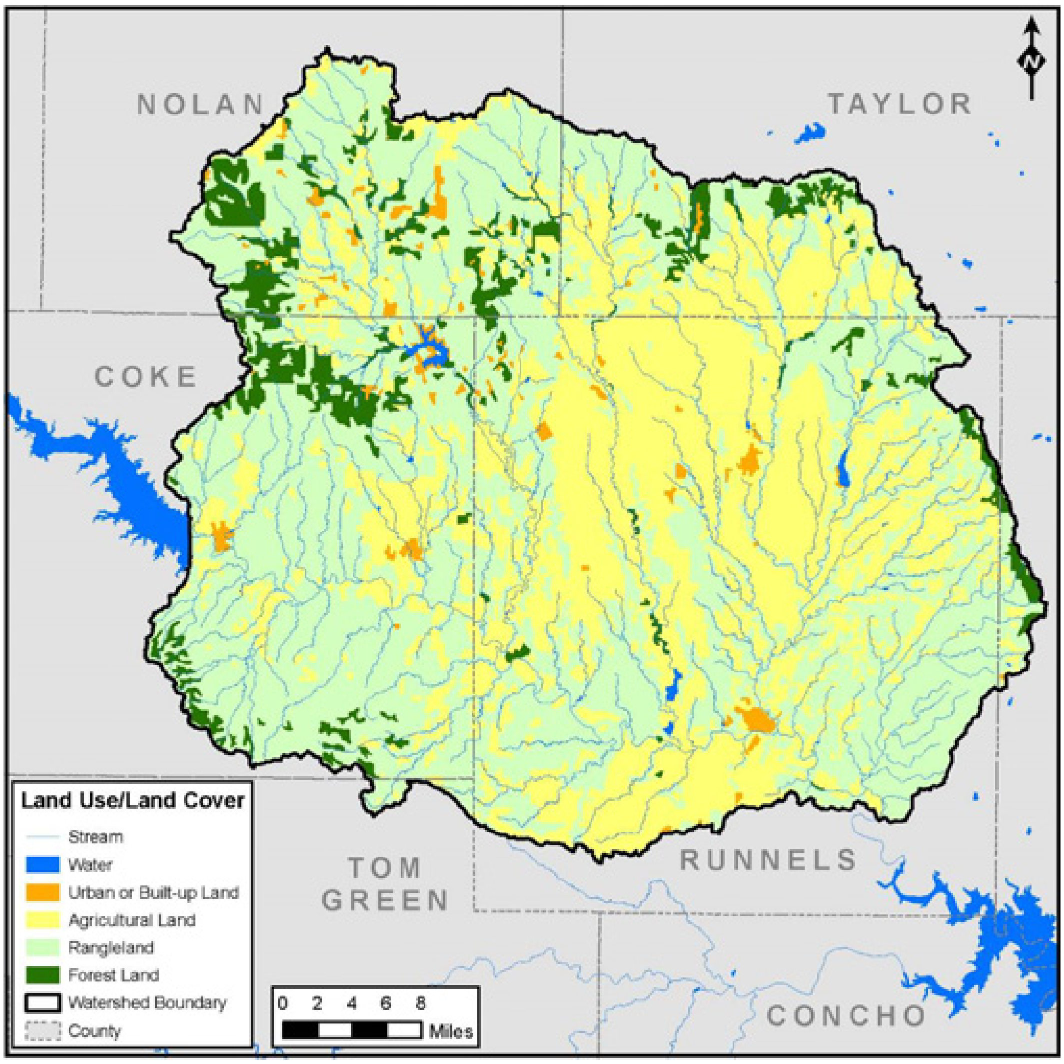


Figure 3: Land Use in the Watershed of the Colorado River Below E.V. Spence Reservoir

Land Use

Land use characterization was based on the most recent National Land Cover Data (NLCD), developed by the USGS in 2005. Dominant land uses for this area are agricultural (38.8%) and rangeland (53.6%), which account for a combined 92.4 percent of the land area in the watershed. The land use distribution in Colorado River below E.V. Spence Reservoir watershed is presented in Figure 3.

Oil and Gas Production

Oil and gas production and exploration are the dominant industrial activities in the watershed of the Colorado River below E.V. Spence Reservoir. As of September 2001, there were a total of 573 gas wells in Coke County, and 821 in Runnels County (RRC, 2001). Of the Coke County wells, 320 are regular producing wells, 195 are inactive, and 58 are injection wells used to inject water, air, and CO2 into productive formations. Of the 821 Runnels County wells, 501 are regular producing, 258 are inactive, and 62 are injection wells. Figure 4 shows the location of the non-compliant oil and gas and injection wells in the watershed. This information is based on data provided by the Railroad Commission of Texas (RRC). The TCEQ's Nonpoint Source (NPS) Program works with the RRC to eliminate potential sources of salinity in the watershed through the plugging of abandoned, non-compliant oil and gas wells and the re-plugging of improperly plugged wells.

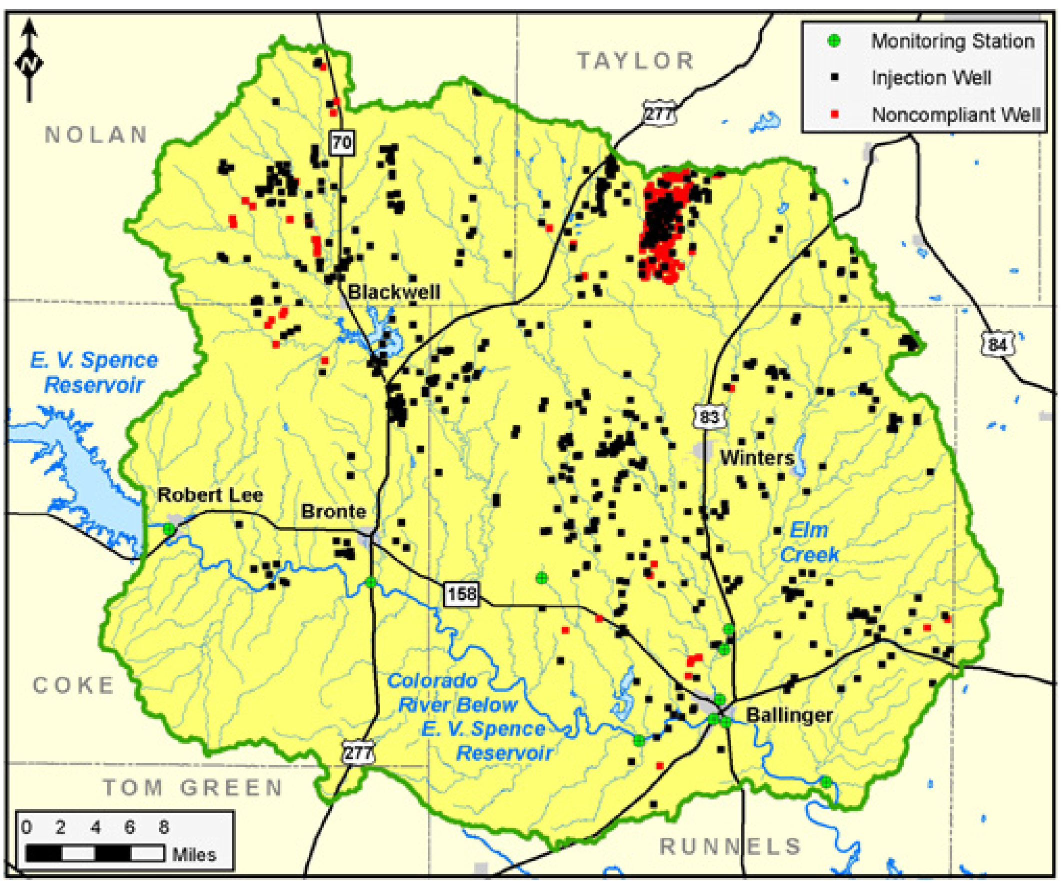


Figure 4: Non-Compliant Oil and Gas Wells and Injection Wells in the Watershed of the Colorado River Below E.V. Spence Reservoir

ASSESSMENT OF POLLUTANT SOURCES

The data used to assess sources affecting Colorado River Below E.V. Spence Reservoir are discussed in the following sections. The inventory of data and information is outlined, along with monitoring, water quality, streamflow, and meteorological weather data.

Data and Information Inventory

A wide range of data and information were used to develop the TMDLs for Colorado River Below E.V. Spence Reservoir. Categories of data used include the following:

- Hydrographic data that describe the physical conditions of the stream, such as the network and connectivity of the stream reach, and the depth width, slope, and elevation of the steam channel.
- Physiographic data that describe features such as topography, soils, and land use.
- Data and information related to watershed potential sources of chloride and TDS.
- Environmental monitoring data that describe streamflow and water quality.

Water Quality Monitoring

The LCRA is responsible for coordinating the monitoring activities of the Clean Rivers Program in the Colorado River Basin for inclusion in the TCEQ's Surface Water Quality Monitoring (SWQM) database. The UCRA and CRMWD collect data from nineteen fixed stations within the basin on a quarterly basis. Data collected at ten of those stations were used to develop these TMDLs (Table 2, Figure 5). Field and chemical parameters sampled included water temperature, pH, dissolved oxygen, specific conductivity, flow, chloride and TDS.

Table 2: Monitoring Stations on Segment 1426

Station I.D. Number	Period of Record	
	From	To
17244	2001	2004
12430	1968	2004
12431	1975	2004
13651	1981	2004
12432	1972	2004
15147	1996	2004
12169	1972	2004
12207	1988	2004
16899	2001	2004
15200	2003	2004

Water Quality Data

Review of the available water quality data reinforced early assessments that Segment 1426 contains moderate to high levels of chloride and TDS. Tables 3 and 4 summarize the available data collected on segment 1426, and present the number of samples collected, exceedances of the water quality standard, and the observed concentration ranges for chloride and TDS. Figures 6 and 7 display the data in charts depicting the high, low, and median values observed over the respective term of collection.

Figure 5: Water Quality Monitoring Stations Located on Segment 1426

Streamflow and Weather Data

Streamflow measurements are necessary to calibrate watershed and water quality models, calculate loadings of pollutants from point and nonpoint sources, characterize transport processes, and evaluate impacts of pollutant loadings. Rainfall data associated with steam flows were also collected. Current streamflow data were collected by the USGS at three stations in the watershed:

- Station 08124000 (Colorado River at Robert Lee)
- Station 08126380 (Colorado River near Ballinger)
- Station 08127000 (Elm Creek at Ballinger)

Table 3: Summary of Chloride Data for Colorado River below E.V. Spence Reservoir

Station I.D.	# of Samples	# of Exceedances	Data Range (mg/L)	Dates Collected
17244	12	8	110 - 1,370	1/16/2001 - 3/4/2004
12430	43	32	50 - 1,390	2/20/1996 - 3/4/2004
12431	24	10	110 - 1,280	2/23/1995 - 3/4/2004
13651	112	54	44 - 1,425	1/3/1995 - 3/4/2004
12432	55	52	90 - 2,190	2/20/1996 - 3/4/2004
15147	62	60	282 - 1,980	2/20/1996 - 3/4/2004
12169	17	0	65 - 439	1/6/1998 - 3/4/2004
12207	37	0	40 - 525	1/22/1996 - 3/4/2004
16899	9	0	170 - 290	1/30/2003 – 3/4/2004
15200	2	0	1.6 - 2	10/9/2003 – 3/4/2004

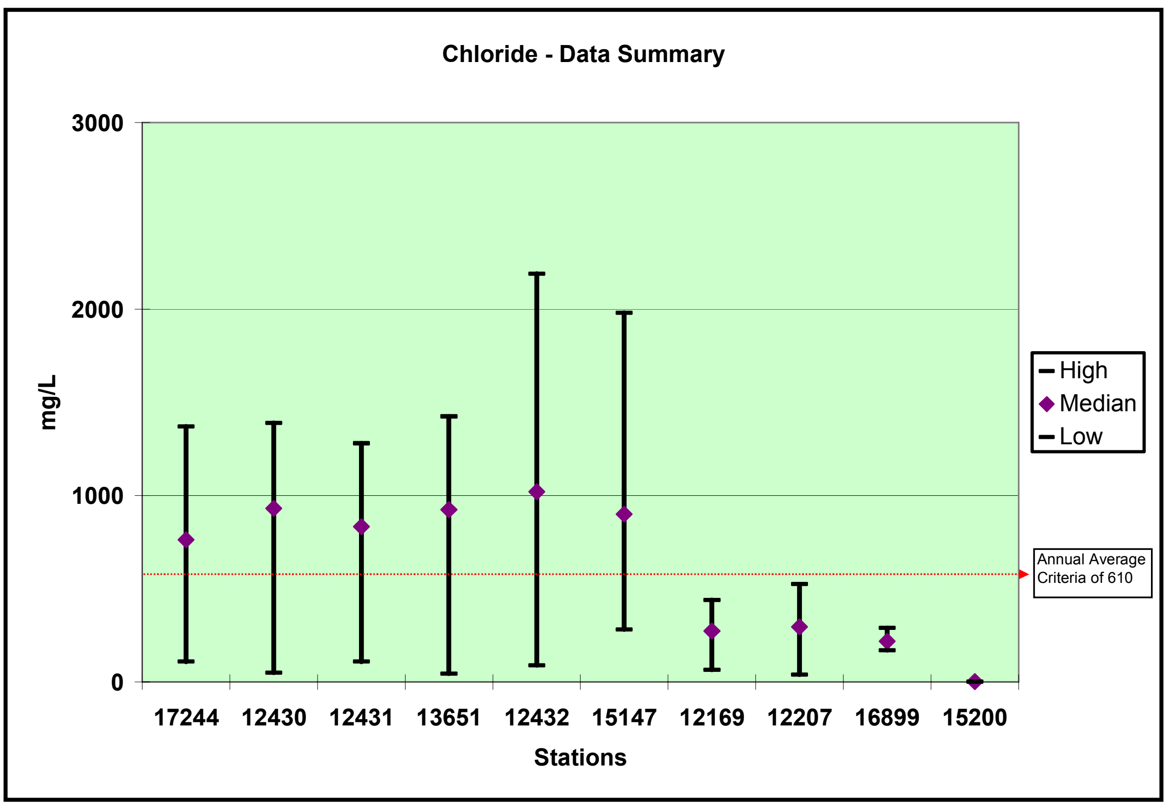


Figure 6: Summary of Chloride Data

Table 4: Summary of TDS Data for Colorado River below E.V. Spence Reservoir

Station I.D.	# of Samples	# of Exceedances	Data Range (mg/L)	Dates Collected
17244	58	30	301 - 5,450	2/26/1996 - 3/4/2004
12430	59	36	720 - 4,165	2/20/1996 - 3/4/2004
12431	20	12	460 - 4,430	6/14/1994 – 3/4/2004
13651	74	36	223 - 4,040	2/20/1996 - 3/4/2004
12432	52	48	340 - 5,432	12/20/1996 - 3/4/2004
15147	48	42	133 - 3,917	2/20/1996 - 3/4/2004
12169	25	0	351 - 1,639	1/6/1998 - 3/4/2004
12207	37	1	131 - 2,097	1/22/1996 - 3/4/2004
16899	41	3	254 - 2,333	1/22/1996 – 3/4/2004
15200	2	0	120 - 150	10/9/2003 – 3/4/2004

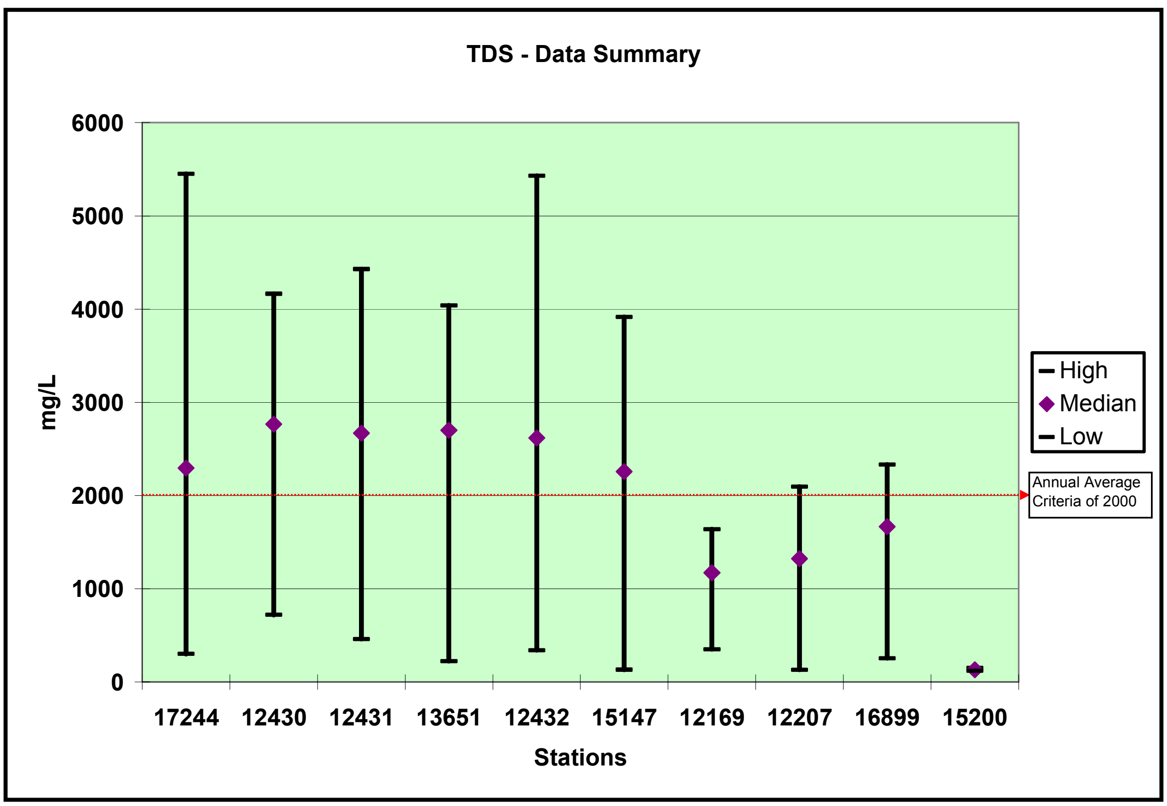


Figure 7: Summary of TDS Data

Hourly precipitation data were used to simulate the hydrologic cycle in modeling. Rainfall data were obtained from two weather stations in the vicinity of Segment 1426, the Abilene airport and the San Angelo airport. The National Climatic Data Center (NCDC) collects and distributes rainfall data from the airports.

The Critical Condition

Federal regulations in 40 CFR 130.7 (c) (1) require that TMDLs take into account the critical conditions for streamflow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality is protected during times when it is most vulnerable. The critical condition is considered the "worst case scenario" of environmental conditions in the watershed of Segment 1426. If the TMDL is developed so that the water quality targets are met under the critical condition, then the water quality targets are most likely to be met under all other conditions. Critical conditions are important because they describe the factors that combine to cause a violation of water quality standards and help in identifying the actions that may be necessary to meet water quality standards.

Chloride and TDS loadings result from sources that can contribute these pollutants during wet weather and dry weather. The critical conditions for Segment 1426 were determined from the available instream data collected by the TCEQ and from USGS streamflow data. Plotting chloride and TDS data along with streamflow data revealed that the exceedances of the geometric mean and annual average standard were occurring throughout Segment 1426, independent of the season and under both high flow and low flow conditions (Figures 8, 9, and 10). It is appropriate to consider chloride, TDS loadings on an annual basis since chloride and TDS loadings occur throughout the year, and their impacts are a function of cumulative loading rather than of particular events. Pollutant loadings and TMDL allocation scenarios were developed based on average annual loads determined from a 10-year model simulation period.

Consideration of Seasonal Variations

Streamflow and water quality vary by season because of hydrologic and climatic patterns. Seasonal variations were evaluated in the modeling approach for these TMDLs. This allowed the consideration of temporal variability in chloride and TDS loadings within Segment 1426. Exceedances occur throughout the segment independent of the season.

ENDPOINT IDENTIFICATION

TMDLs must identify a quantifiable water quality target for each constituent that causes a body of water to appear on the 303(d) list. For chloride and TDS, the primary water quality targets are established in the *Texas Surface Water Quality Standards*.

Chloride

The standards specify that annual average chloride concentrations in Segment 1426 should not exceed 610 mg/L.

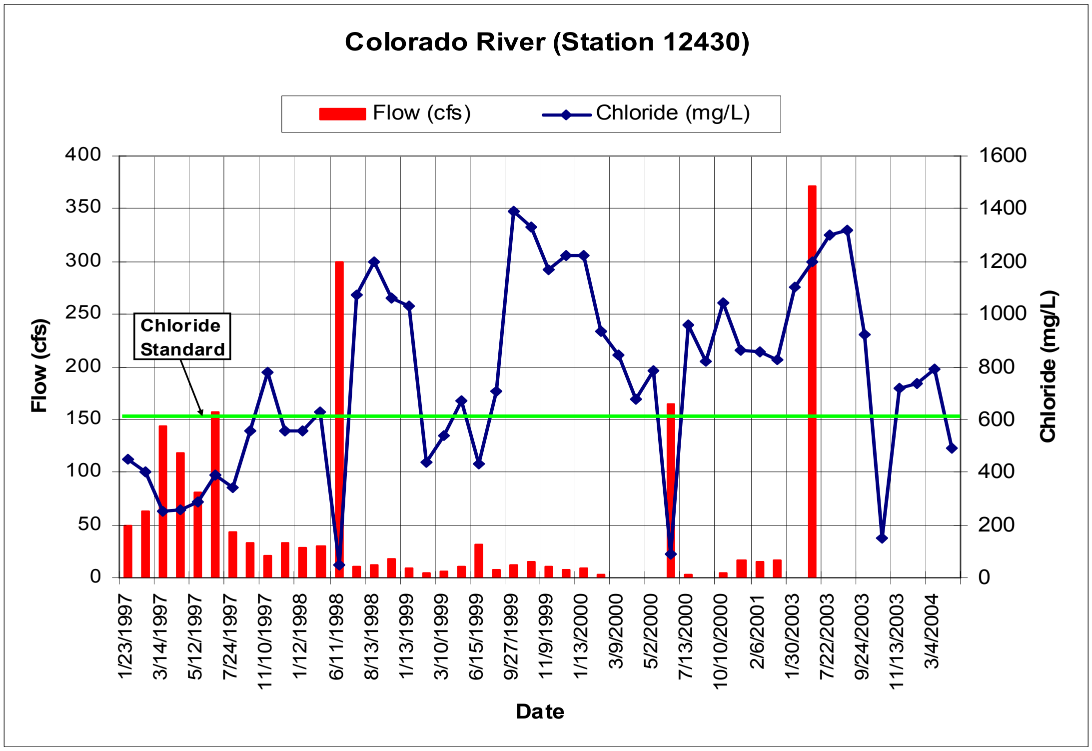


Figure 8: Flow and Chloride Concentrations at Station 12430

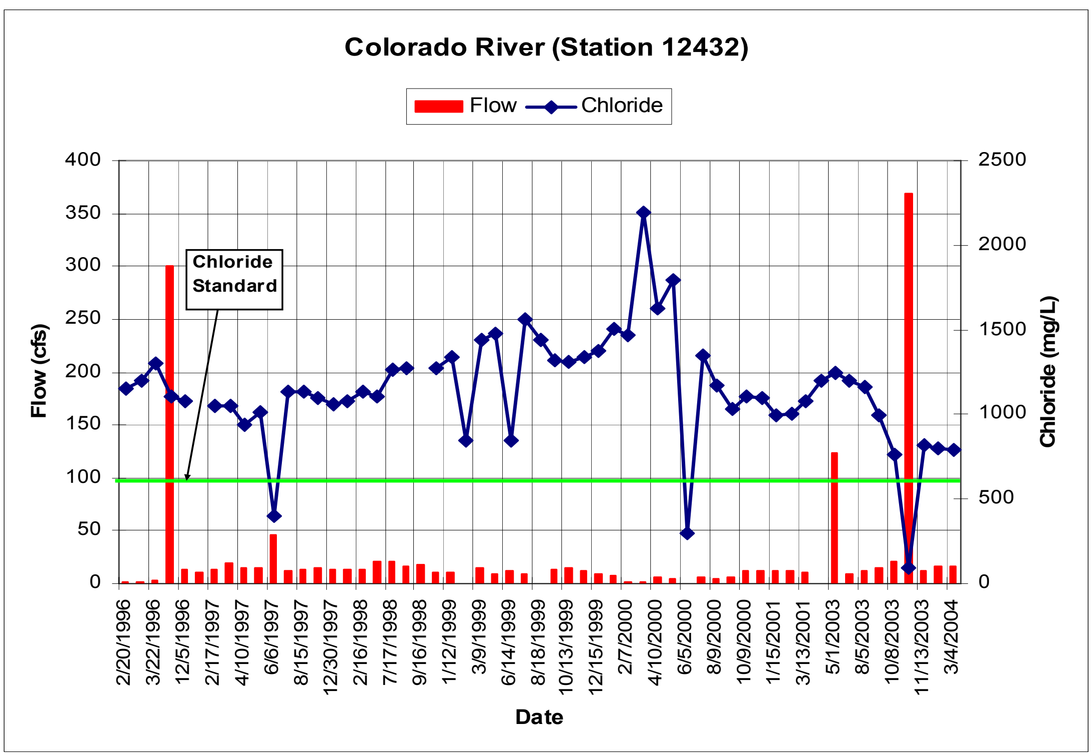


Figure 9: Flow and Chloride Concentrations at Station 12432

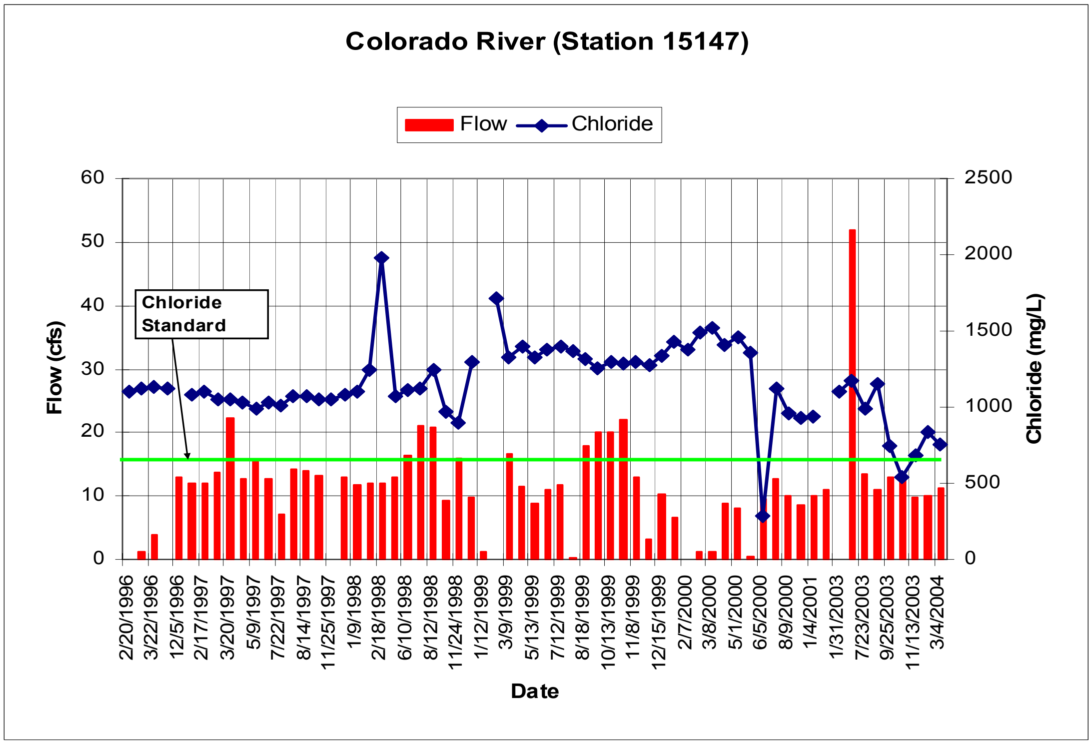


Figure 10: Flow and Chloride Concentrations at Station 15147

Total Dissolved Solids

The standards specify that annual average TDS concentrations in Segment 1426 should not exceed 2,000 mg/L.

SOURCE ANALYSIS

Pollutants may come from several sources, both point and nonpoint. The possible sources of chloride and TDS in Segment 1426 are discussed in this section.

Point Sources Dischargers

Point source pollutants come from a discernible, confined, and discrete conveyance, such as a pipe, ditch, channel, tunnel, conduit, well, or container; from concentrated animal feeding operations; or from vessels or floating crafts from which pollutants are discharged to surface water bodies. Point sources are regulated by permits under the Texas Pollutant Discharge Elimination System (TPDES); permits may include effluent limitations, monitoring, and reporting requirements. Storm water discharges from separate storm sewer systems of cities and those associated with industry and construction are considered point sources of pollution. There are five permitted facilities discharging to Segment 1426 (Table 6). AEP Texas North Company (Oak Creek Power Station) is authorized to draw water from Oak Creek Reservoir (Figure 5) to once-through cooling systems. Water drawn from the reservoir is non-contact and used only to cool miscellaneous equipment before being discharged back into the reservoir.

Table 6: Permitted Dischargers in Colorado River Below E.V. Spence Reservoir

Permit #	Name of Facility	Flow (MGD)
WQ0000997-000	AEP Texas North Company (Oak Creek Power Station)	60
WQ0010320-001	City of Winters	0.53
WQ0010325-003	Plant No. 2 City of Ballinger	0.375
WQ0010390-001	City of Bronte	0.15
WQ0013901-001	City of Robert Lee	0.121

Produced Water

There has been significant oil and gas exploration and production activity in the study area. The production of oil is always accompanied by the production of brine, which occurs in the same strata as the oil. During primary production of oil, the ratio of salt water to oil is usually less than 1:4, but as an oil well ages, the ratio of salt water to oil becomes closer to 1:1, and may be as high as 10:1. As the ratio increases, and a well becomes unprofitable to operate, it is abandoned and properly plugged, as required by the RRC. Unfortunately, many abandoned wells develop cracks and leaks that may eventually allow brine to reach the surface and contaminate ground water and surface water (Paine et al, 2005).

Abandoned Brine Pits

Historically, operators disposed of brine in large, shallow, unlined pits where water would be lost due to evaporation and seepage. When brine evaporates, dissolved solids are left behind as salt crusts that can cause infiltration to the shallow subsurface and local groundwater. Brine disposal pits were used extensively in areas of oil production until 1969, when the RRC placed a statewide ban on their use.

Brine Injection

The practice of injecting brine into subsurface strata is used for both disposal of excess brine and for recovering oil from under-pressurized formations. Many disposal wells inject brine into formations immediately below shallow aquifers. This relatively shallow disposal presents a higher risk of migration into groundwater and surface water bodies at the point where the formation outcrops. Surface and subsurface contamination associated with injection wells are often traced to cracked casings, leaking boreholes, or wells that are not operated properly.

Phreatophytic Brush

The proliferation of invasive species of brush (phreatophytic brush) into western portions of Texas is a recognized problem in water management. Salt cedar, juniper, and mesquite are the species of phreatophytic brush found in the Segment 1426 watershed. Phreatophytic brush species have a rate of high water consumption compared to most vegetation and easily out-compete most species in disturbed areas. Salt cedar is especially detrimental to water quality because of its ability to transport salts from groundwater to its leaves. Because salt cedar is a deciduous plant, salt stored in the leaves is transported to the ground when leaves drop in the fall, and from there can contaminate surface waters via runoff.

The average salt cedar density along stream banks of the Colorado River is estimated at 23,376 plants per acre (Hays 2003). It is assumed that one tree can consume over 75 gallons of water a day (Land and Water 2003) and can produce roughly 41,000 parts per million of salt annually (Wisenborn 1996). Salt cedar was estimated to be present within a 100-foot buffer on the main stem Colorado River and within a 50-foot buffer on its tributaries. Thus, there may be a correlation between decreased streamflows, higher ambient salinity, and increasing brush coverage.

Natural Salt Deposits

The surface geology of the Segment 1426 watershed includes significant areas of Permian gypsum. These salt deposits contribute to the total load via the transport action of runoff flowing through mineral beds, or by dissolution of natural underground mineral deposits into groundwater that discharges to the surface. The average groundwater concentrations reflecting the presence of these natural loads, such as gypsum, were estimated for chloride to be 156 mg/L. Geologic formations containing gypsum are present in the upper portion of the segment.

Field Monitoring Surveys

Field surveys of the watershed were conducted by EA from January 2003 through September 2004 to enhance our understanding of the nature and extent of salinity loading in the watershed. These surveys collected data on hydrology, water quality, and geology. Measurements of conductivity and salinity in surface water and shallow ground conductivity measurements were taken around E.V. Spence Reservoir, along the Colorado River from E.V. Spence Reservoir to below Ballinger, and along numerous Colorado River tributaries north and south of the river. Water samples verified the presence of saline water in E.V. Spence Reservoir and its Salt Creek tributary, as well as elevated salinities in the Colorado River from E.V. Spence Reservoir to Ballinger.

Concentrations in the Elm Creek and Quarry Creek tributaries of Segment 1426 were below the criteria of 610 mg/L for chloride and 2000 mg/L for TDS. At mainstream sampling stations (sites 12430, 12431, 12432, 13651, 15147, and 17244), minimum concentrations were found to be as low as 90 and 340 mg/L for chloride and TDS respectively in October 2003. These minimum concentrations occurred at sampling station 12431 located near Ballinger. Maximum concentrations in the main stream were found to be as high as 1,370 for chloride mg/L at sampling site 17244 in August 2003. TDS concentrations were found to be as high as 4,040 mg/L at sampling sites 12430 and 13651 in August 2003.

Electromagnetic Induction (EM) Surveys

In addition to surface-water sampling and analysis, geophysical instruments can be used to non-invasively identify saline soils that might contribute to the elevated salinity of Segment 1426. The electrical conductivity of the ground (McNeill, 1980a) is generally dominated by electrolytic flow of ions in pore water. Because the salinity of water is strongly correlated to its electrical conductivity (Robinove and others, 1958), the electrical conductivity of soil and sediment is also strongly influenced by the salinity of pore water. As pore-water salinity increases, so does the electrical conductivity of the ground.

In order to better define the sources of chloride and TDS in Segment 1426, the University of Texas' Bureau of Economic Geology (BEG) conducted TCEQ-sponsored ground-based and airborne geophysical surveys using electromagnetic induction (EM) instruments to delineate the extent and intensity of ground salinization and identify salinity sources.

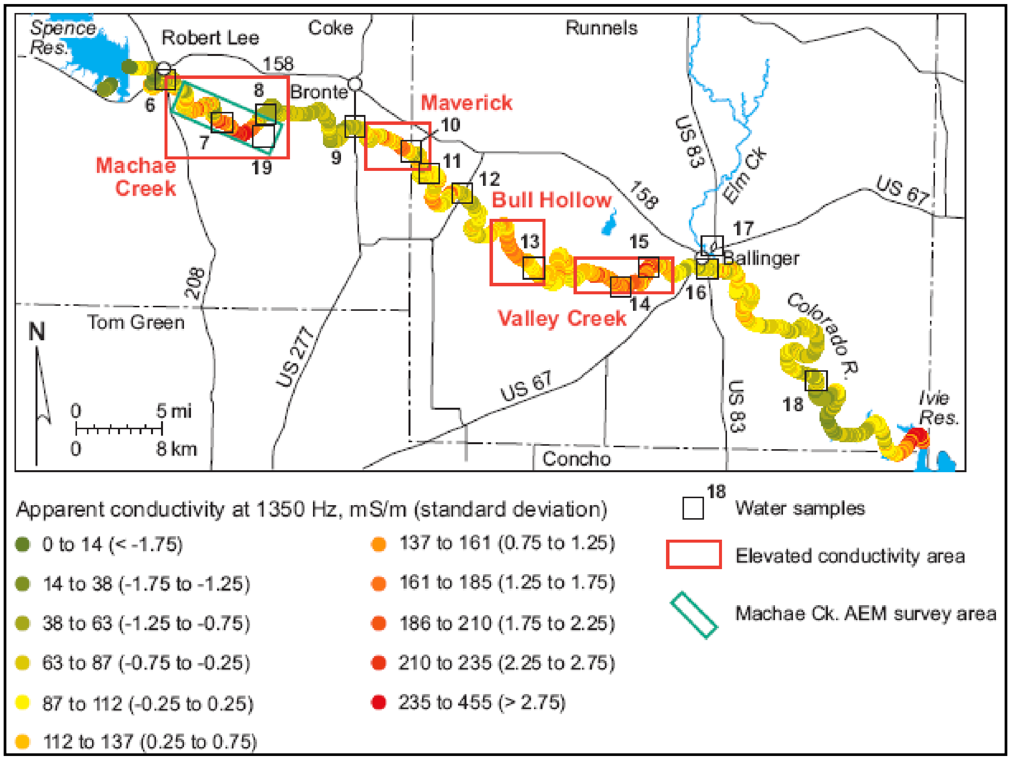
EM methods employ a changing primary magnetic field created around a transmitter coil to induce current to flow in the ground, which in turn creates a secondary magnetic field that is sensed by the receiver coil (Paransis, 1973; Frischknecht and others, 1991; West and Macnae, 1991). The strength of the secondary field is a complex function of EM frequency and ground conductivity (McNeill, 1980b), but generally increases with ground conductivity and constant frequency. This section summarizes results of the BEG's EM surveys (Paine et al, 2005).

Ground Surveys

The BEG used lateral and vertical conductivity trends to interpret the extent and intensity of salinization, and the presence of shallow or deep sources. By combining geophysical patterns with chemical surface water patterns, the likely source type can be identified. A Geonics EM31 ground conductivity meter was used to take conductivity measurements at 344 locations along Segment 1426. The instrument operates at a frequency of 9.8 kilohertz, measuring apparent conductivity to a depth of about 3 meters with a horizontal dipole [HD] orientation and 6 meters with a vertical diphole [VD] orientation. Measurements were taken in both the HD and VD orientation.

Aerial Surveys

Aerial conductivity measurements were acquired in early February 2005 along closely spaced flight lines within two blocks measuring 1.8 x 6.2 miles (mi), centered on the Colorado River near Robert Lee and Silver. The stream-axis airborne survey flew over 89 miles of the Colorado River downstream from E.V. Spence Reservoir (Figure 11). The survey subcontractor, Geophex, provided the technical survey crew and their GEM-2A airborne instrument (Figure 12). Airlift helicopters provided the flight crew and helicopter to tow the instrument.



Also shown are the Machae Creek, Maverick, Bull Hollow, and Valley Creek high-conductivity areas (red rectangles), and the names of Colorado River water measurement sites. (Paine et al, 2005)

Figure 11: Areas of Elevated Conductivity Measured at 1350 Hz along the axis of the Colorado River between Spence and Ivie Reservoirs.

Figure 12: Geophex GEM-2A in flight above the Colorado River near Robert Lee, Texas. (Paine et al, 2005)

The GEM-2A is an EM instrument that employs a single pair of transmitter and receiver induction coils in horizontal coplanar orientation that operate at multiple effective frequencies measured in hertz (Hz) and exploration depths simultaneously (Won and others, 2003). Five primary frequencies were selected: 450; 1,350; 4,170; 12,810; and 39,030 Hz that yield exploration depths ranging from a few meters at the highest frequency to several tens of meters at the lowest frequency, to survey salinity at different depths and to analyze sources of salinity from various water bearing strata. The BEG received final processed geophysical data from Geophex in April 2005 and converted the final processed data into images showing trends and variations in apparent conductivity laterally and with depth along and near the river.

Survey Results

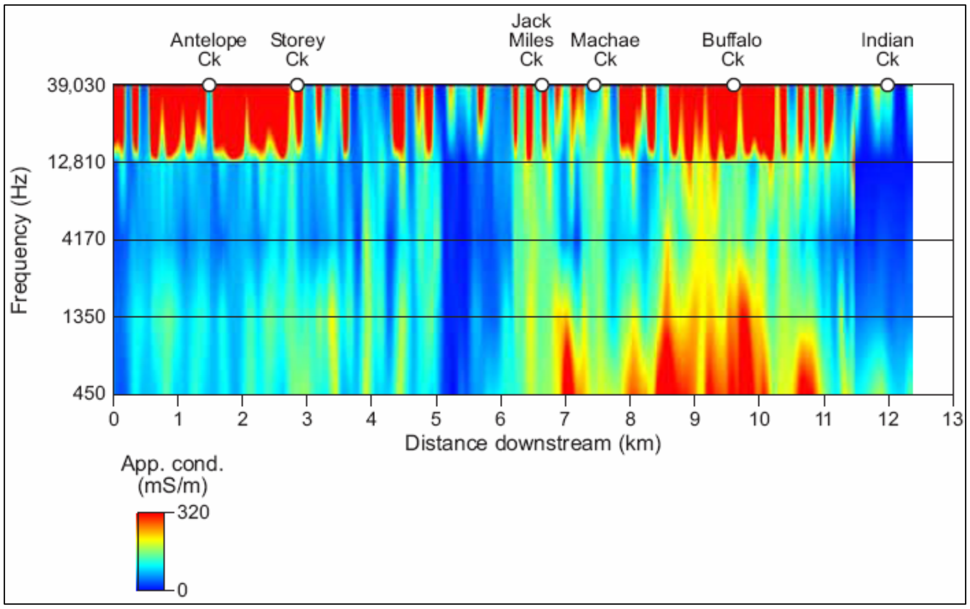
The exploration depth of the airborne EM instrument is governed by instrument frequency and ground conductivity. The BEG explored at five frequencies ranging from 450 Hz, which is the deepest-exploring frequency at an average exploration depth of about 28 meters, or 92 feet, for this area, to 39,030 Hz, the shallowest-exploring frequency at an average exploration depth of about 2 meters, or 7 feet. Apparent conductivity trends plotted from river-axis data allow delineation of four areas of where ground conductivity appears generally elevated along Segment 1426 (Figure 11). From upstream to downstream, these include the Machae Creek area near Robert Lee, the Maverick area near Bronte, the Bull Hollow area below FM 3115, and the Valley Creek area between FM 2111 and Ballinger. These areas represent the stream reaches most likely to be contributing highly saline water that degrades Colorado River water quality.

Machae Creek Area

The Machae Creek area is the most upstream conductive river reach within the impaired segment. It begins about 1.5 mi below the Texas 208 bridge at Robert Lee and extends downstream a total river length of about 7.7 mi (Figure 11). Several intermittent steams intersect the Colorado River along this segment, including Jack Miles, Machae, Buffalo, and Indian creeks. The river flows adjacent to the Wendkirk Oil Field for a distance of about 1.2 mi at the downstream end of the segment. Elevated conductivities in this area appear in both the shallowest exploring frequency (39,030Hz) and the two deepest-exploring frequencies (450 and 1,350 Hz) (Figure 13). At the highest frequencies, elevated conductivities were found between 0 and 1.8 mi at the upstream end of the segment and between 5 and 7.1 mi at the downstream end. These include areas where the BEG found evidence of near-surface salinization during ground-based studies, and probably represent near-surface accumulations of saline pore water from local sources. Elevated conductivities evident in deeper, low frequency data between about 3.7 and 7.5 mi downstream suggest that this is an area where saline groundwater may contribute to the degradation of surface water quality.

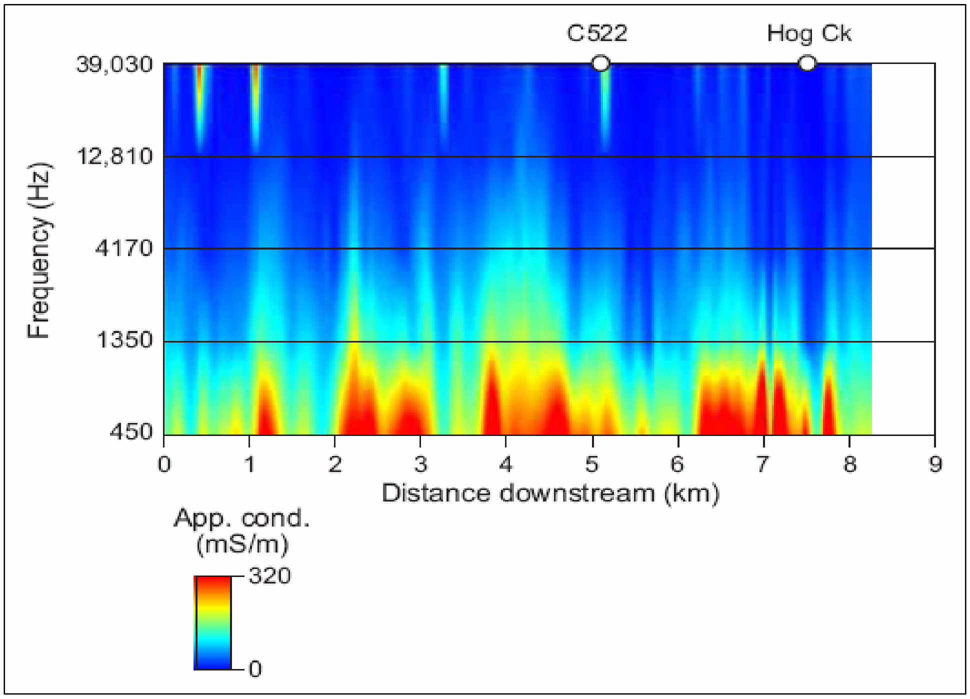
Maverick Area

The Maverick area of generally elevated ground conductivity begins about .6 mi below the U.S. 277 Bridge near Bronte and extends downstream a total length of about 5.1 mi (Figure 11). Hog Creek, a small intermittent drainage, intersects the Colorado River at the downstream end of the Maverick reach. Apparent conductivity measurements superimposed on



Conductivity using all frequencies acquired during the airborne stream-axis survey. The shallowest-exploring frequency is along the top of the image and the deepest-exploring frequency is along the bottom. (Paine et al, 2005)

Figure 13: Combined apparent conductivity pseudosection along the Machae Creek reach



Conductivity using all frequencies acquired during the airborne stream-axis survey. The shallowest-exploring frequency is along the top of the image and the deepest-exploring frequency is along the bottom. (Paine et al, 2005)

Figure 14: Combined apparent conductivity pseudosection along the Maverick reach

maps of the Maverick area show little evidence of elevated salinity at the highest and lowest exploring frequencies (12,810 and 39,030 Hz) (Figure14). Hog Creek is not associated with a high-frequency conductivity anomaly, suggesting there is no near surface salinization associated with this Colorado tributary. Higher apparent ground conductivities are evident on the maps and sections at lower frequencies and greater exploration depths (450, 1,350, and 4,170 Hz), particularly from 1.2 to 3.1 mi and from 3.7 to 5 mi downstream from the beginning of the segment (Figure 14). Increasing apparent conductivities with increasing exploration depth along these reaches, combined with little evidence of elevated conductivities associated with surface salinization, suggest that increases in salinity loading along this reach arise from base flow contributions.

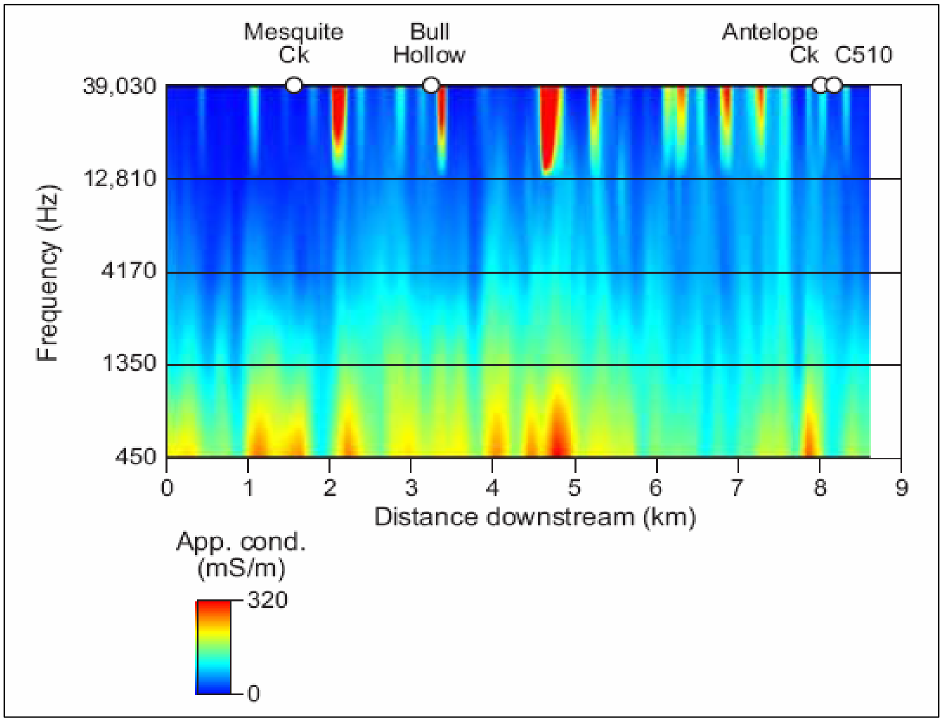
Bull Hollow Area

The Bull Hollow area encloses an 5.3 mi river reach that appears to have generally elevated ground conductivity that extends downstream from a point about 3.7 mi downstream from the FM 3115 bridge (Figure 11). Two small, intermittent streams, Mesquite Creek and Bull Hollow, intersect the Colorado River near the upstream end of this segment. Antelope Creek, another small intermittent stream, intersects the river at the downstream end of the segment. At high, shallow-exploring frequencies, elevated apparent conductivities were measured in several local areas between Mesquite and Antelope Creeks. This may indicate local shallow salinization (Figure 15). Elevated apparent conductivities are more extensive at lower frequencies and deeper exploration depths, particularly at 4,170 Hz and lower. At these frequencies, elevated conductivities are observed along most of the Bull Hollow stream. Increases in salinity loading within the Bull Hollow area are thus likely to be dominated by base-flow contributions of saline groundwater.

Valley Creek Area

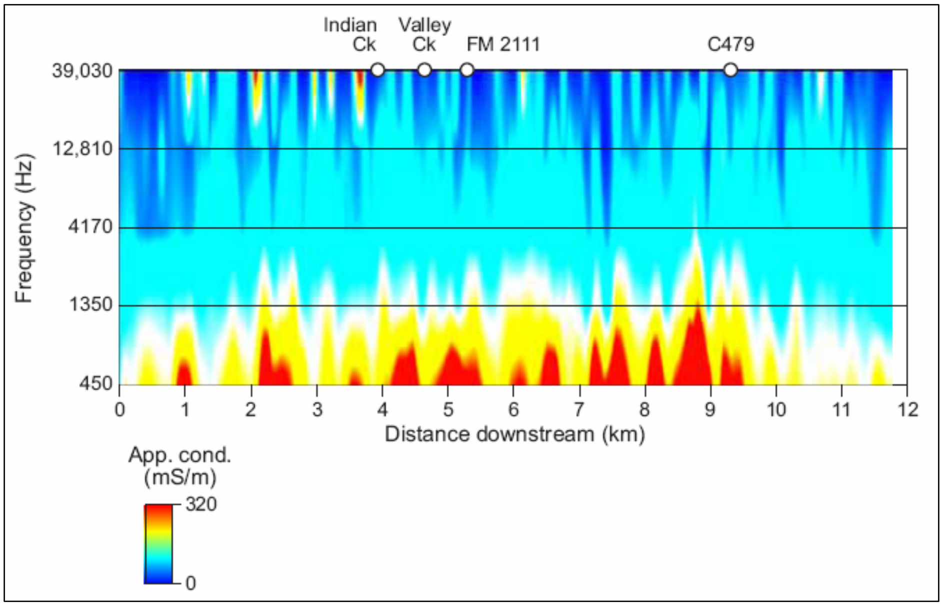
The Valley Creek area is the most downstream zone of generally elevated apparent conductivity along the Colorado River impaired segment (Figure 11). It is nearly 7.5 mi long, beginning about 3 mi upstream from the FM 2111 bridge and extending about 4.3 mi downstream from that bridge toward Ballinger. Minor drainages intersecting the river along this segment include Indian Creek and Valley Creek. Apparent conductivity measurements superimposed on Valley Creek maps show only minor, local areas of elevated ground conductivity at the shallowest-exploring frequencies (12,810 and 39,030 Hz), suggesting there is no pervasive shallow salinization along this segment (Figure 16). Apparent conductivities at lower, deeper-exploring frequencies (450, 1,350, and 4,170 Hz) are higher and more extensive, particularly between 1.2 and 6.2 mi downstream along this creek. The positions of the Indian Creek and Valley Creek confluences appear to have no geographic relationship to the elevated conductivity zones. The apparent increase in conductivity with exploration depth, the lack of elevated shallow or deep apparent conductivity associated with the minor tributaries, and the negligible flow contribution from the tributaries suggest that any increase in salinity loading along this segment is dominated by base-flow contributions.

Analysis suggests that relatively high sulfate concentrations, hydrochemical similarity with local shallow groundwater, the presence of local evaporite deposits, and the lack of signifi-



Conductivity using all frequencies acquired during the airborne stream-axis survey. The shallowest-exploring frequency is along the top of the image and the deepest-exploring frequency is along the bottom (Paine et al, 2005)

Figure 15: Combined apparent conductivity pseudosection along the Bull Hollow reach



Conductivity using all frequencies acquired during the airborne stream-axis survey. The shallowest-exploring frequency is along the top of the image and the deepest-exploring frequency is along the bottom (Paine et al, 2005).

Figure 16: Combined apparent conductivity pseudosection along the Valley Creek reach

cant nearby oilfield development implicate dissolved geological sources in the groundwater. Using April 2005 surface water data as an example, the Machae Creek, Maverick, Bull Hollow, and Valley Creek elevated conductivity segments account incrementally for a total dissolved solids loading of no more than 72,300 kg/day.

LINKAGE BETWEEN SOURCES AND RECEIVING WATERS

There have been many investigations of factors affecting relatively poor surface water and groundwater quality along this segment of the Colorado (including Mount and others, 1967; Leifeste and Lansford, 1968; Richter and others, 1990; Slade and Buszka, 1994; Paine and others, 1999). Most previous studies attribute degraded quality of both surface water and groundwater in the upper Colorado River area to a combination of causes, including:

- natural dissolution of evaporite deposits and subsequent migration of saline water to the surface.
- introduction of highly saline formation water into the surface and near-surface environment through the discharge of surface water, produced water into pits, and unplugged or leaking oil and gas wells in oil fields.

Recent water sampling and analysis by the CRMWD and others has repeatedly documented elevated concentrations of chloride and TDS in the Colorado River along and upstream from Segment 1426. Chemical analyses of surface water flowing in the river conducted in support of the airborne survey allow the following general observations.

- Specific conductivity concentrations, and therefore TDS concentrations, vary along the stream course even while total loading continuously increases. These variations do not generally reflect direction of flow, suggesting that there are local sources of highly saline water and that dilution lowers salinity downstream from locations where elevated salinity occurs.
- Groundwater salinity varies in similar patterns to stream salinity. Areas characterized by higher and lower groundwater salinities are configured as northeast-southwest elongate bands that probably reflect Permian and Triassic stratigraphic and structural strike. Areas of locally elevated river salinity appear to lie within northeast-southwest elongate zones that are characterized by locally elevated groundwater salinity. This strongly suggests a connection between groundwater and surface water systems.
- Stream salinities are higher during lower-flow conditions than during higher-flow conditions. This suggests that groundwater base flow is the primary source of elevated salinity rather than contaminants entrained in precipitation runoff. Sampling was conducted during January and April 2005 during relatively low-flow conditions that are typical of the river except when it is briefly interrupted by storm events.
- The Colorado River has been generally a gaining stream during recent low-flow conditions. Events during which salinity between the groundwater and the stream was elevated probably reflect contamination of the river by groundwater rather than contamination of groundwater by the river (Paine et al, 2005).

MARGIN OF SAFETY

The margin of safety (MOS) accounts for any lack of knowledge concerning the relationship between effluent limitations and water quality. According to EPA guidance (*Guidance for Water Quality-Based Decisions: The TMDL Process, 1991*), the MOS can be incorporated into the TMDL using two methods:

- Implicitly incorporating the MOS using conservative model assumptions to develop allocations; or
- Explicitly specifying a portion of the TMDL as the MOS and using the remainder for allocations.

The MOS is explicitly incorporated into this TMDL. An explicit margin of safety is more appropriate when there is some degree of uncertainty in input data and model results. Though there was good agreement in hydrologic and water quality calibration, natural sources of salinity, such as ground water dissolution of geologic formations, salt secreted and deposited from salt cedar, and abandoned brine pits were difficult to quantify with certainty. Consequently, a five percent explicit margin of safety was used to account for this uncertainty. Incorporating an MOS of five percent will require that allocation scenarios be designed to meet annual average chloride and TDS criteria of 580, and 1,900 mg/L, respectively (as compared to the segment-specific standards of 610 and 2,000 mg/L).

POLLUTANT LOAD ALLOCATION

For Segment 1426, the TMDL allocation analysis for chloride and TDS is the third stage in the overall process of developing the TMDL. The TMDL represents the maximum amount of pollutant that the stream can receive without exceeding the water quality standard. The load allocations for the selected scenarios are calculated using the following equation:

$$TMDL = \sum WLA + \sum LA + MOS$$

Where

WLA = wasteload allocation (point source pollutant contributions)
LA = load allocation (nonpoint source pollutant contributions)
MOS = margin of safety
$\sum$ = sum

Several potential allocation strategies would achieve the TMDL endpoint and water quality standards. Available control options depend on the number, location, and character of pollutant sources.

Allocation Scenario Development

Allocation scenarios that would reduce the existing chloride and TDS loads to meet the corresponding water quality standards were simulated using the Hydrological Simulation Program–FORTRAN (HSPF) model. (Bicknell et al., 1993)

Wasteload Allocation

There are four permitted point source dischargers in the watershed, excluding the Oak Creek SES facility. However, none of these facilities has permit limits for chloride and TDS, and no discharge monitoring report (DMR) data were available for chloride or TDS concentrations. The point source loads for existing condition were calculated using the design flows and typical chloride and TDS concentrations ordinarily present in domestic wastewater effluent. Based on this literature, an average concentration in discharge effluent was used to determine the average loads (50 mg/L and 105 mg/L, respectively) (Metcalf and Eddy, 1995). Then, allocated loads or percent reductions were calculated using the design flows and the water quality criteria for chloride and TDS with five percent reserved for MOS. For this TMDL, the wasteload allocations for the dischargers were set equal to the water quality criteria minus the MOS. The wasteload allocations are provided in Table 7. All four facilities are not exceeding their allocated loads; therefore, no reduction of point source loads is necessary. Table 7 shows the waste load allocations.

Table 7: Wasteload Allocations

Name of Facility	Existing Condition Loads Based on Avg Flow (lbs/day)		Allocated Loads Based on Design Flow (lbs/day)		Percent Reductions	
	Cl	TDS	Cl	TDS	Cl	TDS
City of Winters	221	464	2,562	8,398	0	0
Plant No. 2 City of Ballinger	156	328	1,812	5,942	0	0
City of Bronte	63	131	725	2,377	0	0
City of Robert Lee	50	106	585	1,917	0	0

Load Allocation

The reductions of loading from nonpoint sources, including abandoned brine pits, produced water, groundwater, and the upstream boundaries (E.V. Spence Reservoir) are incorporated into the load allocation. A number of scenarios were considered to identify the final TMDL load allocations. Prior to the implementation of a scenario, the loads for chlorides and TDS at base conditions are estimated. The base-condition loads for the TMDL take into account data and information provided by the LCRA.

The minimum flow release requirements from E.V. Spence Reservoir to sustain habitat for the Concho Water Snake are 4 cfs during the period from April to September and 1.5 cfs from October to March. As stipulated in the revised Biological Opinion issued by the USFWS in December 2004, CRMWD will adhere to these release requirements. These requirements are applicable only when there is inflow to the reservoir and the water level remains at or above 1843.5 ft. Under these conditions based on historical data, chloride concentrations in reservoir water ranged from 220 mg/L, to 480 mg/L from top to bottom.

Base-condition loads were computed using the maximum observed concentration in E.V. Spence Reservoir (480 mg/L) and the observed flow. Table 8 shows the loads under base-conditions that serve as the basis for developing the load allocations. The approach used for the development of base-condition loads takes into account the fact that chlorides are the dominant species in the TDS composition (Figure 17). Due to its multi-constituent nature, TDS is adequately simulated using a surrogate constituent. Therefore, it is preferable to derive simulated values for TDS using another constituent that is highly correlated to TDS. In order to identify the constituent that can be best used as a surrogate for TDS, it was necessary to first derive an overall composition of TDS in the Colorado River.

Table 8: Chloride and TDS Load Distributions by Source under Base Conditions

Source	**Annual Average Loads**			
	Chloride (Lbs/Year)	**Percent of Total (%)**	**TDS (Lbs/Year)**	**Percent of Total (%)**
Spence Reservoir	4.89E+05	3.90%	1.37E+06	3.90%
Produced Water	1.27E+06	10.20%	3.55E+06	10.20%
Abandoned Brine Pits	3.61E+05	2.90%	1.01E+06	2.90%
Groundwater	8.26E+06	66.10%	2.31E+07	66.10%
Salt Cedar	4.29E+04	0.30%	1.20E+05	0.30%
Point Sources	2.08E+06	16.60%	5.80E+06	16.60%
Total	**1.25E+07**	**100%**	**3.49E+07**	**100%**

Using all chemical water quality data collected in the Colorado River, an average existing TDS distribution was derived and is presented in Figure 17. Figure 17 indicates that chlorides are the dominant species, comprising an average of 34% of the TDS load. Consequently, all the observed chloride and TDS data was correlated, which is presented in Figure 18. Figure 19 shows that the correlation between all the observed sulfate and TDS data was not as closely correlated (r^2=0.2248) as the correlation shown in Figure 18 between TDS and all observed chloride data (r^2=0.8154). Since Figure 18 indicates a strong correlation between TDS and chlorides, the relationship, TDS=2.7954 chlorides was used to derive TDS simulated concentrations using the chloride values simulated by the HSPF model.

The transport action of runoff flowing through mineral beds and the dissolution of local natural geologic formations containing carbonates, such as gypsum, explains that under base conditions the majority of the loads are originating from groundwater.

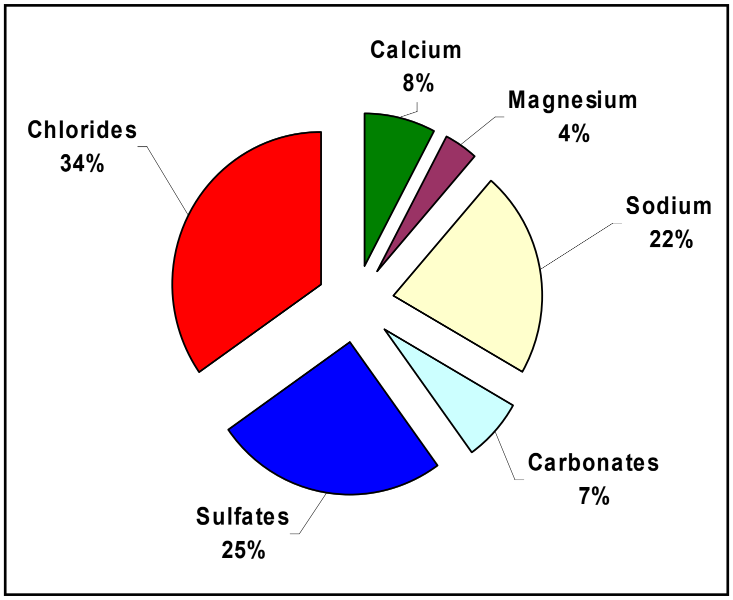


Figure 17: Existing TDS Composition in the Colorado River

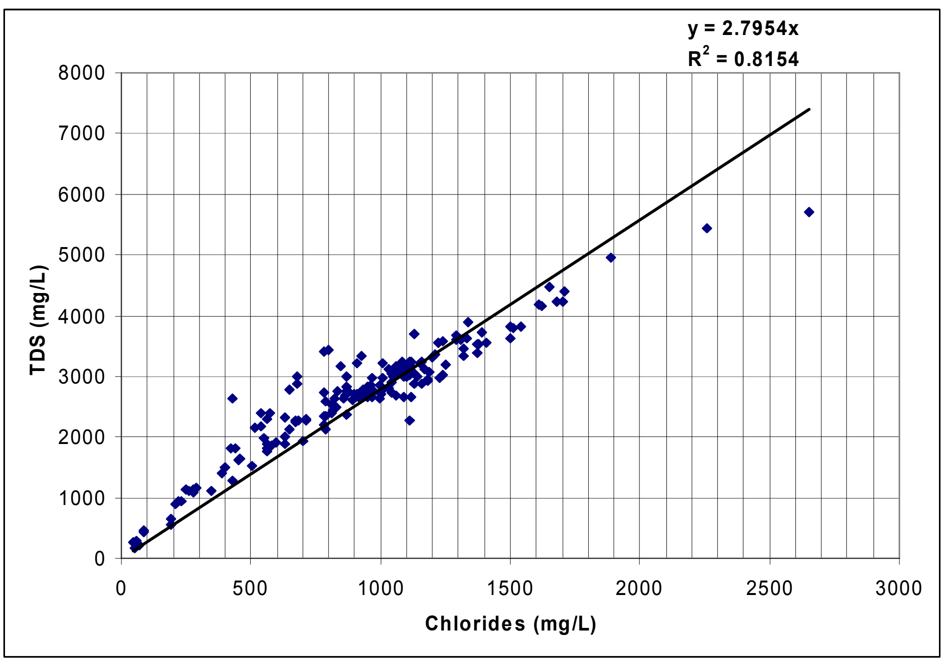


Figure 18: Correlation between Chloride and TDS

Table 9 shows the scenarios considered for each of the load allocation calculations and shows the percent load reduction from each source. Scenarios 1 through 5 assume a chloride concentration of 480 mg/L from Spence Reservoir. Additional scenarios are possible and will be investigated during implementation planning. Table 9 is added to the TMDL document only to show that the water quality standards are achievable. No regulatory actions are implied by inclusion of Tables 9 and 10.

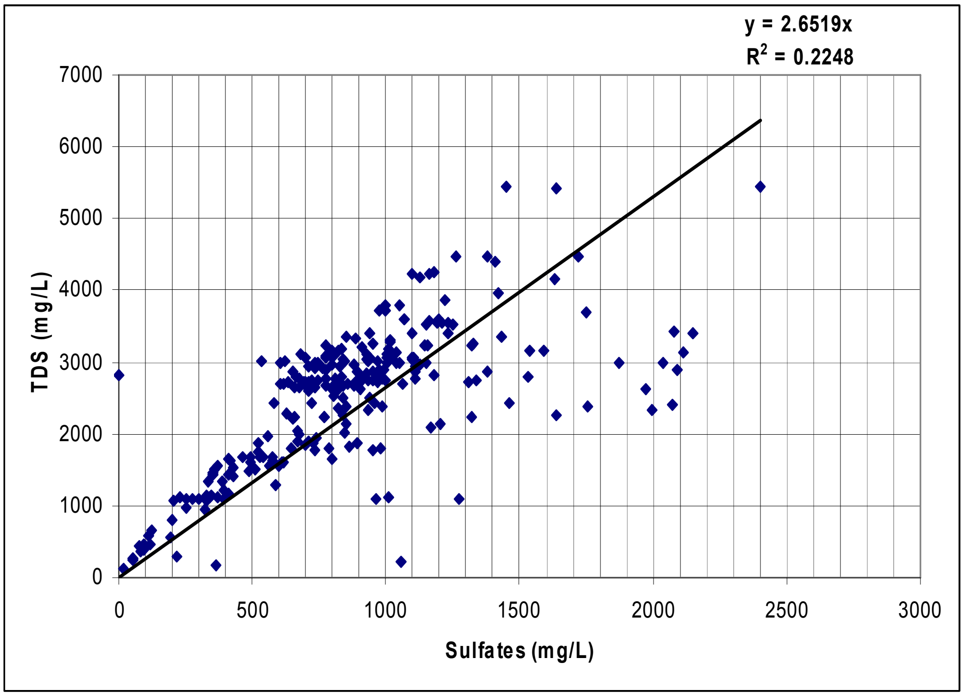


Figure 19: Correlation between TDS and Sulfates

Table 9: Load Allocation Scenarios – TDS and Chloride

Scenario	Percent Reductions				
	Upstream Boundary	**Abandoned Brine Pits**	**Produced Water**	**Ground-water**	**Salt Cedar**
0 (Existing Conditions)	0	0	0	0	0
1 (Base Conditions)	Maximum observed concentration at Spence	0	0	0	0
2	Maximum observed concentration at Spence	100	0	0	0
3	Maximum observed concentration at Spence	0	100	0	0
4	Maximum observed concentration at Spence	0	0	0	100
5	Maximum observed concentration at Spence	100	100	0	100
6	Spence at WQ Standard MOS	0	0	0	0
7	Different concentrations until the TMDL was established	0	0	0	0

Scenario 0 represents the existing loading, which uses observed Spence Reservoir discharge and concentrations.

Scenario 1 assumes that the Spence Reservoir is releasing at observed flow, and chloride and TDS concentrations in the Spence Reservoir release are at 480 mg/L and 1342 mg/L, respectively. These concentrations are the maximum observed values based on data and information provided by the LCRA. This scenario represents the Base Conditions that's served as a basis for the computations of the load allocations.

Scenario 2 assumes 100% reduction of chloride and TDS loads from abandoned brine pits and no reduction of the Base Conditions chloride load in the release from the reservoir. Rules and regulations enforced by the RRC specifically address water protection (Texas Administrative Code, Title 16, Part 1, Chapter 3, Rule 3.8, Water Protection), therefore 100% surface water pollution reductions from abandoned brine pits are assumed.

Scenario 3 assumes 100% reductions of chloride and TDS loads from produced water and no reduction of the Base Conditions chloride load in the release from the reservoir. Rules and regulations enforced by the RRC specifically address produced water (Texas Administrative Code, Title 16, Part 1, Chapter 3, Rule 3.8, Water Protection), therefore 100% surface water pollution reductions from produced water are assumed.

Scenario 4 assumes 100% reduction of chloride and TDS loads from Salt Cedar in addition to reduction of the Base Conditions chloride load in the release from the reservoir.

Scenario 5 assumes 100% reduction of chloride and TDS loads from abandoned brine pits, produced water, and Salt Cedar, and no reduction of the Base Conditions chloride load in the release from the reservoir. Rules and regulations enforced by the RRC specifically address water protection (Texas Administrative Code, Title 16, Part 1, Chapter 3, Rule 3.8, Water Protection), therefore 100% surface water pollution reductions from abandoned brine pits are assumed.

Scenario 6 assumes that the Spence Reservoir releases at observed discharge rate, and chloride and TDS concentrations in the Spence Reservoir release are at 95% of the water quality standards (i.e. 580 mg/L and 1900 mg/L). It should be noted that these assumed concentrations are higher that the one used in the Base Conditions (Scenario 1 using the most recent data).

Scenario 7 assumes that the Spence Reservoir releases at observed discharge rate. The maximum chloride and TDS concentrations in the reservoir release water were varied using the model. A maximum chloride concentration of 550 mg/L and a TDS concentration of 1537 mg/L in the release water would attain the water quality standard. These concentrations are higher than the one used in the Base-Conditions scenario (Scenario 1 using the most recent data).

For the hydrologic period spanning from January 2000 to December 2004, the simulated chloride and TDS concentrations were compared against the corresponding standards to estimate the number and frequency of exceedances. Running averages of chloride and TDS concentrations over consecutive 365 days were calculated for direct comparison with the water quality standards. Water quality exceedances occur when the 365-day running average exceeds the standard.

Table 10 summarizes the results of the comparison for all the scenarios. Simulated chloride and TDS concentrations under the existing conditions show 100% and 70.1% exceedances of the water quality standards, respectively. The base condition and all pollutant load reductions (Scenarios 2 through 5) show no exceedance of the annual average in the water quality standards. Scenario 6 shows 16.0% and 20.5% annual average exceedance of the chloride and TDS criteria, respectively. Scenario 7 shows no exceedance of the annual average chloride and TDS criteria. Therefore, Scenario 7 was selected as the TMDL.

Table 10: Load Reduction Analyses for Chloride and TDS

Scenario	Percent Reduction in Loadings from Existing Conditions (%)					Percent of Time the Annual Average Standard is Violated (%)	
	Upstream Boundary	Abandoned Brine Pits	Produced water	Ground water	Salt Cedar	Chloride	TDS
0	0	0	0	0	0	100	70
1	Set to 480 mg/L	0	0	0	0	0	0
2	Set to 480 mg/L	100	0	0	0	0	0
3	Set to 480 mg/L	0	100	0	0	0	0
4	Set to 480 mg/L	0	0	0	100	0	0
5	Set to 480 mg/L	100	100	0	100	0	0
6	580 mg/L	0	0	0	0	16	21
7	550 mg/L	0	0	0	0	0	0

TMDL Summary

Based on analysis of the load allocation scenario, a TMDL allocation plan to meet the respective water quality standard goals requires the Spence Reservoir to release chloride and TDS at or below 550 mg/L and 1537 mg/L, respectively. Figure 20 shows the modeled chloride concentrations and 365-day running average concentrations at station 12430 with the applicable water quality standards. Figure 21 shows the modeled TDS concentrations and 365-day running average concentrations at station 12430 with the applicable water quality standards. Station 12430, Colorado River bridge at US 83 in Ballinger, is located at the downstream end of the watershed, and is therefore used to develop the TMDLs. These plots display that the water quality standards are not violated under TMDL allocation Scenario 7.

A summary of the chloride and TDS TMDL allocation loads for the Colorado River is presented in Table 11.

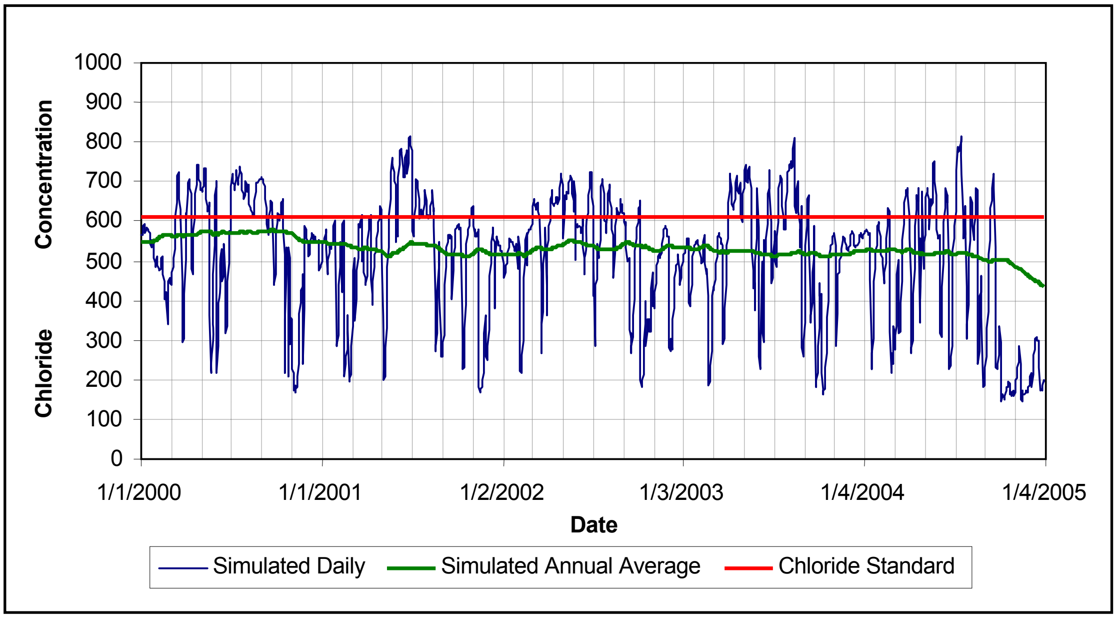


Figure 20: Simulated Chloride Concentrations at Station 12430 under TMDL Allocation

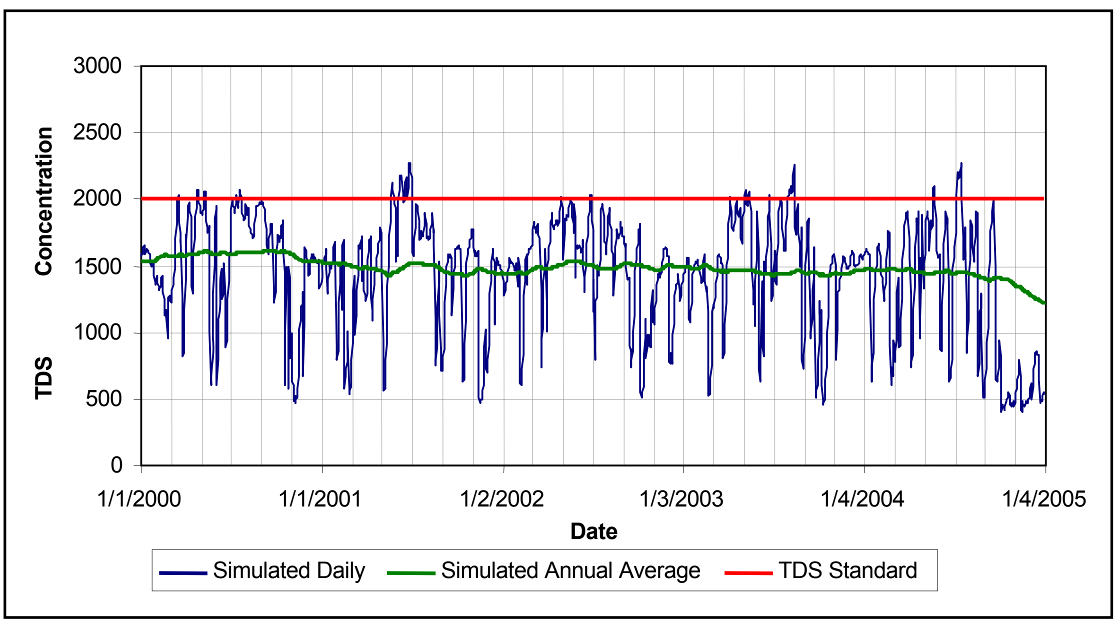


Figure 21: Simulated TDS Concentrations at Station 12430 under TMDL Allocation

TMDL Expressions

The total load allocations, wasteload allocations, and margins of safety for chloride and TDS are summarized in Tables 12 and 13. The natural loads from chloride and TDS are included in groundwater contributions and explicitly considered in the LA. The sum of WLA and LA is divided by 0.95 to obtain the TMDL. The margin of safety (MOS) is calculated by subtracting WLA and LA from the TMDL.

Table 11: TDS and Chloride TMDL Allocation Load Distributions by Source

Source	Annual Average Loads (lbs/Year)			
	Chlorides	**% Total**	**TDS**	**% Total**
Spence Reservoir	5.60E+05	4.5%	1.57E+06	4.5%
Produced Water	1.27E+06	10.1%	3.55E+06	10.1%
Abandoned Brine Pits	3.61E+05	2.9%	1.01E+06	2.9%
Groundwater	8.26E+06	65.7%	2.31E+07	65.7%
Salt Cedar	4.29E+04	0.3%	1.20E+05	0.3%
Point Sources	2.08E+06	16.5%	5.80E+06	16.5%
Total	**1.26E+07**	**100%**	**3.51E+07**	**100%**

Table 12: Chloride TMDL

TMDL (lbs/year)	WLA (lbs/year)	LA (lbs/year)	MOS (lbs/year)
1.32E+07	2.08E+06	1.05E+07	6.62E+05

Table 13: TDS TMDL

TMDL (lbs/year)	WLA (lbs/year)	LA (lbs/year)	MOS (lbs/year)
3.70E+07	5.80E+06	2.93E+07	1.85E+06

PUBLIC PARTICIPATION

The TCEQ maintains an inclusive public participation process. From the inception of the investigation, the project team sought to ensure that stakeholders were informed and involved. The project team also recognized that communication and comments from stakeholders in the watershed would strengthen the project and its implementation plan.

In accordance with requirements under Texas House Bill 2912 (2001), an official stakeholder committee was established and notices of meetings were posted on the TCEQ's calendar and in the *Texas Register*. Two weeks prior to scheduled meetings, notices were released to the media and stakeholder committee members were formally invited to attend. To ensure that absent stakeholders and the public were informed of meetings and other pertinent material, a project web page was established to provide meeting summaries, presentations, ground rules, and a list of stakeholder committee members.

Throughout the term of the project (2002 to 2006), seven meetings were held in Ballinger, in Runnels County. Based on interest and attendance, meetings were held in both the afternoon and evening. The objectives of the first stakeholders meeting were to:

- Introduce the project team and summarize the public participation process
- Define what the project was intended to accomplish
- Provide historical monitoring data, information, issues, and potential sources

During the first meeting in September 2002, the project team received and responded to a number of questions and comments which were taken into account when developing the sampling plan. The objectives of the second stakeholders meeting were to:

- Inform the stakeholders on the status of work being performed on the project
- Provide information about the TMDL stakeholder process and about how interested parties could participate and influence the development of the TMDL.
- Provide information on the monitoring plan and monitoring schedule
- Provide information on of the project's phases; specifically, historical data review, data collection, modeling, approval, and implementation.

During the second meeting in December 2003, the project team received a number of comments and suggestions. The objectives of the third stakeholders meeting were to:

- Inform the stakeholders on the status of work being performed on the project
- Provide a survey questionnaire to assist in evaluating how effective the information about the project is being understood by the stakeholders and the public
- Provide information and data to summarize results
- Inform stakeholders about a prospective study through the BEG to conduct electromagnetic surveys on the Upper Colorado River
- Provide information on the selected model, HSPF, and its process.

During the third meeting in April 2004, the project team received a number of comments and suggestions. The objectives of the fourth stakeholders meeting were to:

- Inform the stakeholders on the status of work being performed on the project
- Provide information about Phase I of the BEG electromagnetic conductivity survey study
- Provide an update on the status of the modeling phase of the project

During the fourth meeting in November 2004, the project team received a number of questions and comments concerning the project and the BEG study. The objectives of the fifth stakeholders meeting were to:

- Provide information on the stakeholder goals and the public participation process
- Provide a re-cap of the TMDL process
- Present results of the airborne geological survey

During the fifth meeting in June 2005, the project team received a great deal of comment and questions. The BEG electromagnetic conductivity survey results were posted on the project web page. The objectives of the sixth stakeholders meeting were to:

- Summarize the last three years of progress on the TMDL project
- Present a re-cap of data including the most recent sample collection
- Present an abbreviated version of results from the airborne geophysical survey performed in January 2005 and make interpretations about the mechanisms of the contamination
- Present a re-cap of the TMDL process, model, and draft TMDL
- Speak about a Texas Railroad Commission project to address salinity; specifically abatement practices and remediation associated with oil field exploration in the watershed

During the sixth meeting in October 2005, the project team received a great deal of comment concerning the project. The objectives of the seventh stakeholders meeting were to:

- Provide information on the draft TMDL and load allocation

IMPLEMENTATION AND REASONABLE ASSURANCES

The TMDL development process involves the preparation of two documents (1) a TMDL, which determines the amount of pollutant a water body can receive and continue to meet applicable water quality standards, and (2) an implementation plan, which is a detailed description and schedule of regulatory and voluntary management measures necessary to achieve the pollutant reductions identified in the TMDL. It is the policy of the TCEQ to develop implementation plans for all TMDLs adopted by the Commission, and to assure the plans are implemented. Implementation plans are not subject to EPA approval.

During TMDL implementation, the TCEQ works with stakeholders to develop the management strategies needed to restore water quality to an impaired water body. This information is summarized in the TMDL Implementation Plan (IP), which is separate from the TMDL document. Preparation of an implementation plan is critical to ensure water quality standards are restored and maintained.

Several implementation activities have already been initiated during the TMDL project to achieve pollutant reductions.

(1) The EPA has awarded a nonpoint source grant through the TCEQ to the RRC to investigate the nature and extent of known salinity contamination associated with oil and gas production, the development of remediation/abatement alternatives or BMPs, and the implementation of the BMPs to specifically reduce water pollution.

(2) The Texas State Soil and Water Conservation Board (TSSWCB) is in the process of funding a multi-year project to control salt cedar.

(3) Because it has been confirmed that the area upstream is generally more conductive than the area downstream from E.V. Spence Reservoir, and contributes a significant saline load to E.V. Spence Reservoir and therefore segment 1426, the TCEQ and the CRMWD have deployed two continuous monitoring stations to measure specific conductivity. These continuous monitors will guide the district in management of flow, and therefore salinity, from the upper watershed into E.V. Spence Reservoir, which discharges to segment 1426. To date management of flow has improved water quality and reduced the level of salinity in E.V Spence Reservoir, a source of drinking water.

(4) The RRC is working cooperatively with the TCEQ to eliminate pollution caused by unplugged or improperly plugged wells and reduce the chloride content of the Upper Colorado River basin through a project called Runnels County/Upper Colorado River Saltwater Discharge Minimization Project. Activity associated with oil and gas operations, such as abandoned, improperly plugged, or unplugged oil and gas wells, and salt-water injection and/or disposal wells have been identified as possible sources of salinity. As of June 2006, 167 of the 189 wells identified, recommended, and approved for plugging, have been plugged since the project began in 2003.

Preparation of the implementation plan for Segment 1426 will begin upon Commission approval of the TMDL. The IP will detail any activities such as mitigation measures, permit actions, best management practices, and additional sampling and monitoring determined to be necessary to restore water quality. Additional sampling at appropriate locations and frequencies will allow tracking and evaluation of progress toward the targeted and primary endpoints. These steps will provide reasonable assurances that the regulatory and voluntary activities necessary to achieve the pollutant reductions will be implemented.

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