DEPARTMENT OF THE ARMY
SOUTHWESTERN DIVISION, CORPS OF ENGINEERS
1100 COMMERCE STREET, Suite 831
DALLAS, TEXAS 75242-1317

Reply to
Attention of:

CESWD- PD

02 MAY 2013

MEMORANDUM FOR Commander, Tulsa District, ATTN: CESWT-PP-C, 1645 South 101st East Avenue, Tulsa, Oklahoma 74128-4609

SUBJECT: Area VI Feature Reevaluation, Feasibility Scoping Meeting Document, Red River Chloride Control Project, Texas and Oklahoma

1. References:

a. CECW-CP memorandum, 8 Feb 12, subject: U.S. Army Corps of Engineers Civil Works Feasibility Study Program Execution and Delivery.

b. CESWT-PP-C memorandum, 25 Apr 13, subject: Area VI Feature Reevaluation, Feasibility Scoping Meeting Document, Red River Chloride Control project, Texas and Oklahoma (Encl).

c. EC 11-2-204, 31 Mar 13, Corps of Engineers Civil Works Direct Program Budget Development Guidance, Fiscal Year 2015.

2. The Feasibility Scoping Meeting (FSM) documentation is being returned without action since study funds have been exhausted, and the study has been placed in the inactive status in accordance with reference 1.a. The district may furnish to interested non-Federal stakeholders, agencies, and the public all findings including data, information, and studies completed to date.

3. A request from a non-Federal entity to reinitiate the study is required to place the study into the active category prior to the district recommending the study for potential future budgets. While project authority allows for the study to be conducted at full federal expense, reference 1.c. requires the feasibility phase of the study be cost shared 50 – 50 with a non-Federal entity to be in accord with policy. Once funds are appropriated, the first action to reinitiate the study will be to scope the study based on SMART Planning principles defined in reference 1.a.

4. If you have any questions, please contact Ms. Noel Clay at 469-487-7065.

ROBERT SLOCKBOWER
Director
Programs Directorate

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

DEPARTMENT OF THE ARMY
U.S. ARMY, CORPS OF ENGINEERS, TULSA DISTRICT
1645 SOUTH 101ST EAST AVENUE
TULSA, OKLAHOMA 74128-4609

CESWT-PP-C

25 APR 2013

MEMORANDUM THRU Ms. Margaret Johanning, CESWD-PDP

FOR Commander, Southwestern Division

SUBJECT: Area VI Feature Reevaluation, Feasibility Scoping Meeting Document, Red River Chloride Control Project, Texas and Oklahoma

1. Enclosed is the Feasibility Scoping Meeting (FSM) documentation for the subject project feature. Budget issues will likely result in stopping the study and changing the status to inactive.

2. Tulsa District is requesting vertical team review of the FSM for two purposes:

a. Vertical team review is required prior to study release to stakeholders. Our corporate policy for draft products and with respect to Freedom of Information Act, do not allow the dissemination of products prior to approval by the vertical team. Therefore, without vertical team review the efforts to date may not be released to stakeholders. Red River Chloride Control Stakeholders include Senator James Inhofe, Congressman Frank Lucas, Lugert-Altus Irrigation District, Oklahoma Water Resources Board, Oklahoma Department of Wildlife Conservation, Oklahoma Department of Environmental Quality, Texas Parks and Wildlife Department, U.S. Fish and Wildlife Services and the Bureau of Reclamation, as well as multiple universities Oklahoma University, Oklahoma State University and University of North Texas), and the Red River Valley Association.

b. Vertical team review of the FSM documentation of existing conditions and proposed evaluation criteria of alternatives as documented in the guidance memorandum will provide the most cost effective and informed milestone from which the study may proceed in the future. The current project delivery team has a thorough understanding of the studies to date. However, project delivery team attrition and the general loss of institutional memory for this project would pose a significant disadvantage for the study restart without the benefit of a FSM review and guidance memorandum.

3. Tulsa District retains Red River Chloride funds in the amount of $20K which will allow for a brief response to the guidance memorandum.

4. The District suggests these next steps:

a. Conduct a FSM briefing with Corps staff.

b. Vertical team prepare a memorandum documenting the FSM process including agreement on key planning and project evaluation considerations typically associated with the feasibility scoping meeting milestone.

c. In that memorandum or another formal correspondence, identify the status of the Area VI project as either an active or inactive project, and the implications of such in terms of:

(1) The procedural stage in the planning process to be used to reinitiate the evaluation once funds are available.

(2) Any cost-share requirements in the reinitiated evaluation effort, along with explanation.

(3) The status of releasing portions of the evaluation effort to date to interested stakeholders, agencies and the public. Without the vertical team's endorsement/review of the existing product, those components would be draft, raising the issue of those being pre-decisional and non-releasable.

5. Suggest the Feasibility Scoping Meeting be held via a teleconference using the information below:

Telephone Number: 877-336-1839
Access Code: 6157965
Security Code: 1111

6. Please select from the following date/times for the teleconference FSM to occur:

12 June 2013 at 1300 hours
17 June 2013 at 1300 hours
18 June 2013 at 1000 hours

7. The Chloride Control Area VI P2 Project Number is 329787.

8. The Tulsa District point of contact is Ms. Dawn Rice, Red River Chloride Control Project Manager. She can be reached at 918-669-7249 or Dawn.Rice@usace.army.mil if you have questions or comments.

MICHAEL J. TEAGUE
Colonel, EN
Commanding

5 Encls
1. Area VI FSM Report
2. Legal Sufficiency
3. Review Plan Approval Memo
4. Agency Technical Review Documentation
5. P2 Schedule

U.S. ARMY CORPS OF ENGINEERS

AREA VI FEATURE REEVALUATION Feasibility Scoping Meeting Documentation Red River Chloride Control Project

Arkansas, Texas, Louisiana, and Oklahoma

September 2012

TULSA DISTRICT 1645 S 101 EAST AVE, TULSA, OK 74128-4609

AREA VI FEATURE REEVALUATION
Feasibility Scoping Meeting Documentation
RED RIVER CHLORIDE CONTROL PROJECT
Arkansas, Texas, Louisiana, and Oklahoma

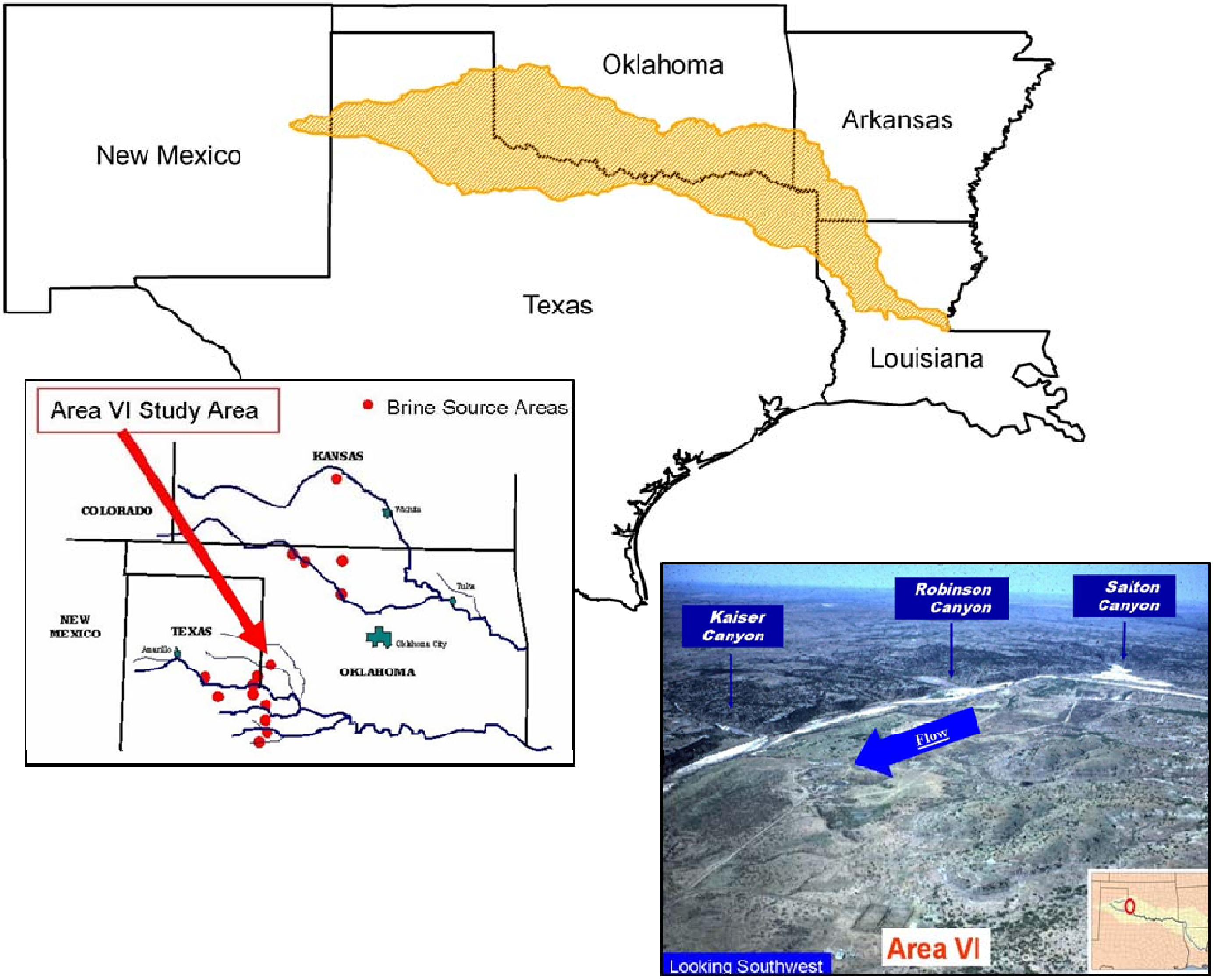
Table of Contents

TABLE INDEX

FIGURE INDEX

REEVALUATION
OF
AREA VI CHLORIDE CONTROL FEATURE
RED RIVER CHLORIDE CONTROL PROJECT
Arkansas, Texas, Louisiana, and Oklahoma

September 2012



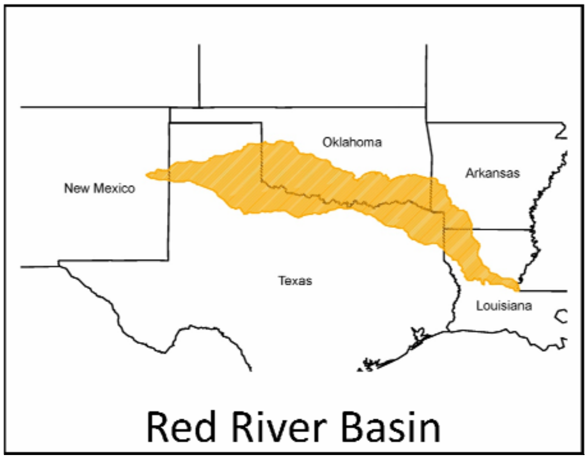
INTRODUCTION

This report is a reevaluation of the Area VI chloride control feature of the authorized Red River Chloride Control Project. The history of chloride control began in 1957. At that time the Public Health Service initiated studies to determine the causes of natural pollution in the Red River Basin (and the Arkansas River Basin). They concluded that chlorides and sulfates are the principal natural pollutants. (Since that time, the term “pollutants” has fallen out of favor when referring to natural brine emissions.) In 1959, Congress authorized the Corps of Engineers to enter the study. The Public Health Service was to identify the natural brine sources and the Corps of Engineers was to develop plans to control the brine emissions that contain the chlorides and sulfates.

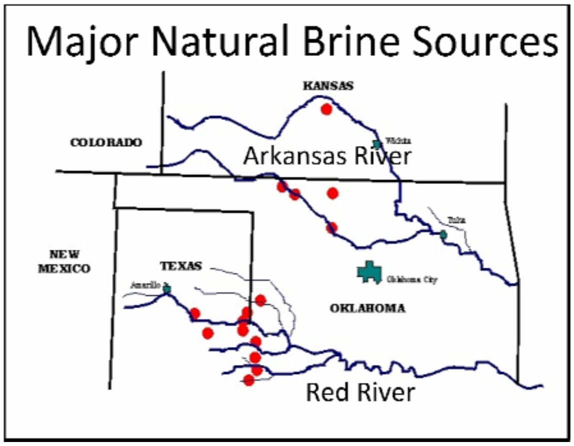
Over the last 53 years the Corps has pursued the investigation of methods to reduce the natural brine emissions and has construction features of the project that Congress authorized for implementation in the Red River Basin. The long study and implementation period to date involves a complicated series of issues related to the large geographic area of benefits and potential impacts, budgets, administration policy changes, misinformation, and disinformation related to potential economic and social impacts of reduced brine emissions – the purpose of the chloride control project.

The Red River originates in New Mexico, crosses the high plains of Texas, gathers flows from Oklahoma, Texas, and Arkansas and passes through Louisiana on its way to the Mississippi River. It drains about 93,500 square miles.

About 90 percent of the basin drainage area is downstream of the major salt source areas. Therefore, the natural brine emissions are carried along most of the length of the Red River.



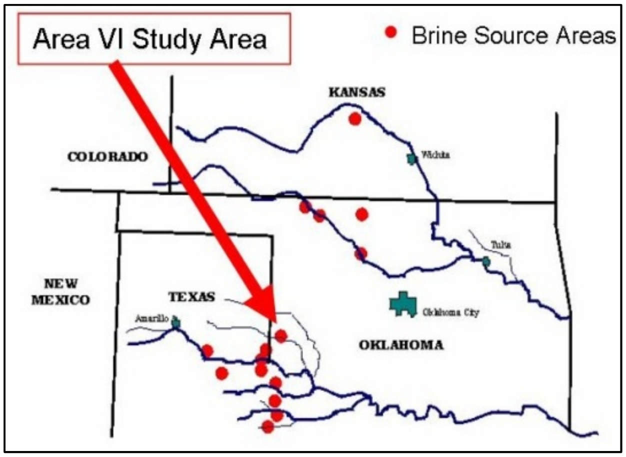
Red River Basin


Major Natural Brine Sources

At Lake Texoma, roughly halfway across the southern border of Oklahoma, the amount of chlorides and other dissolved solids from the brine source areas has generally reached its maximum load – and the load, expressed in tons per day, strains our comprehension. The chloride load is about 4,400 tons per day. The value of total dissolved solids (chlorides, sulfates, and other “salts”) is about 12,000 tons per day. Those values represent the dry weight of the dissolved solids if they were extracted from the Red River each day as it flowed out of Lake Texoma.

STUDY AUTHORITY

The Area VI brine area is located on the Elm Fork of the North Fork of the Red River in Harmon County, Oklahoma. There are three chloride sources at Area VI - Salton, Robinson, and Kaiser Canyons along the south bank of the Elm Fork. These narrow canyons emit brine in high concentrations from low average flows that originate from emission points confined to relatively small areas. The canyons are located from about one mile west of Oklahoma State Highway 30 to 3 miles east of the Texas-Oklahoma State line.



The Chief of Engineers recommended Part I of the Arkansas-Red River Basin Water Quality Control Study for Areas VII, VIII, and X, Wichita River, Red River Basin, in Senate Document No. 110, 89th Congress, 2nd Session. The Flood Control Act of 1966 (Public Law [PL] 89-789, dated November 7, 1966) incorporated Senate Document No. 110 by reference and authorized Part I.

> *"Arkansas and Red Rivers*
> *The project for water quality control in the Arkansas and Red River Basin,Texas, Oklahoma, and Kansas, designated as Part I is hereby authorized substantially in accordance with the recommendation of the Chief of Engineers in Senate Document Numbered 110, Eighty-ninth Congress, at an estimated cost of $46,400,000. Actual construction of the part I works shall not be initiated until the related and 'supporting works of part II have been authorized by Congress."*

The Flood Control Act of 1970 (PL 91-611, dated December 31, 1970) amended the 1966 Act and authorized Part II of the study for Areas VI, IX, XIII, XIV, and XV in the Red River Basin, and Areas I through IV in the Arkansas River Basin. The Chief of Engineers in his report dated May 6, 1970, recommended Part II of the study.

"Arkansas-Red River Basin
The project for water quality control in the Arkansas-Red River Basin, Texas, Oklahoma, and Kansas, designated as Part I, authorized by the Flood Control Act of 1966, is hereby modified to include Part II of such project, substantially in accordance with the recommendations of the Chief of Engineers in his report dated May 6, 1970, except that the amount authorized for Part I shall be utilized for initiation and partial accomplishment of Parts I and II. Construction shall not be initiated until approved by the Secretary of the Army and the President."

Other significant authorizing legislation is contained in:

a. Section 74, Water Resources Development Act of 1974, PL 93-251, dated March 7, 1974.

The project for water quality control in the Arkansas-Red River Basin, Texas, Oklahoma, and Kansas, authorized by the Flood Control Acts of 1966 and 1970, is hereby modified to authorize the Secretary of the Army, acting through the Chief of Engineers to initiate construction of the area VIII feature of the project, consisting of a low-flow dam, pumping station and pipeline, and a brine dam, prior to the approval required by section 201 of the Flood Control Act of 1970.

b. Section 153, Water Resources Development Act of 1976, PL 94-587, dated October 11, 1976.

"The last sentence under the center heading "ARKANSAS-RED RIVER BASIN" in section 201 of the Flood Control Act of 1970 (84 Stat. 1825) is amended to read as follows: "Construction shall not be initiated on any element of such project until such element has been approved by the Secretary of the Army."."

c. Section 1107, Water Resources Development Act of 1986, PL 99-662, dated November 17, 1986. This law amended the above authorization to separate the overall project into the Arkansas River Basin and the Red River Basin and authorized the Red River Basin for construction subject to a favorable report by a review panel (Red River Chloride Control Project Evaluation Panel) established to evaluate the effectiveness of operation of Area VIII of the Red River Chloride Control Project, and a finding of it being consistent with the project benefits projected in Memorandum No. 25, completed in November 1980..

"RED RIVER CHLORIDE CONTROL.
(a) The first sentence of the paragraph under the center heading "Arkansas and red rivers" in section 203 of the Flood Control Act of 1966 is amended by striking out "$46,400,000" and inserting in lieu thereof "$177,600,000".
(b) Section 201 of the Flood Control Act of 1970, as amended by section 153 of the Water Resources Development Act of 1976, is amended by striking out the last sentence under

the heading "arkansas-red river basin" and inserting in lieu thereof the following: "Construction shall not be initiated on any element of such project involving the Arkansas River Basin until such element has been approved by the Secretary of the Army. The chloride control projects for the Red River Basin and the Arkansas River Basin shall be considered to be authorized as separate projects with separate authority under section 203 of the Flood Control Act of 1966.
(c) Construction of remaining elements of the project involving the Red River Basin shall be initiated in accordance with the recommendations regarding general design memorandum numbered 25 by the director of civil works on behalf of the Chief of Engineers, dated August 8, 1977. Such construction shall commence upon transmittal of a report to the Secretary and to the Committee on Environment and Public Works of the Senate and the Committee on Public Works and Transportation of the House of Representatives of a favorable finding of the effectiveness of the operation of area VIII, to be made by a panel consisting of representatives of the United States Geological Survey and the Texas Water Commission, a person selected by the National Academy of Sciences, and two other qualified persons to be appointed by the Secretary with the concurrence of the governors of Texas and Oklahoma. The panel shall assess the improvement in water quality downstream of area VIII to determine its consistency with the water quality assumed in the development of project benefits in the economic reanalysis of the project completed in November 1980. Such report shall be submitted to the Secretary and to such committees no later than three years after the date area VIII commences operation. Cost sharing for construction on the Red River Basin project initiated under this section shall be the same as the cost sharing for area VIII of the project."

d. Section 3136, Water Resource Development Act 2007, PL 110-114, dated November 8, 2007. This law modified Sec 203 of the Flood Control Act of 1966 and Sec 1107(a) of WRDA 1986 to direct the Secretary of the Army to provide operation and maintenance for the Red River Chloride Control project, Oklahoma and Texas, at full Federal expense.

"RED RIVER CHLORIDE CONTROL, OKLAHOMA AND TEXAS.
The project for water quality control in the Arkansas and Red River Basin, Texas, Oklahoma, and Kansas, authorized by section 203 of the Flood Control Act of 1966 (80 Stat. 1420) and modified by section 1107(a) of the Water Resources Development A of 1986 (100 Stat. 4229) is further modified to direct the Secretary to provide operation and maintenance for the Red River Chloride Control project, Oklahoma and Texas, at Federal expense."

The Red River Chloride Control Project Evaluation Panel submitted the August 1988 *Report on the Evaluation of the Effectiveness of Operation of Area VIII Red River Chloride Control Project.* In the report, the panel concluded that operation of the completed works in Area VIII were consistent with the project benefits projected by the economic reanalysis in the U.S. Army Corps of Engineer Design Memorandum No. 25 of 1980. Chloride removal during the test year actually exceeded projections and the expected level of control over the anticipated life of the project was estimated to be at least 87%, which also exceeded projections. Based on those findings, the Evaluation Panel felt that proceeding with construction of the remaining elements of the project were justified in accordance with the intent of Section 1107 of Public Law 99-662.

The Wichita River Basin Project Reevaluation, Red River Chloride Control Project, April 2003, was conducted by the Corps to reexamine all data, assumptions, methodologies, and conclusions and was not constrained to the previously recommended or authorized chloride control plan. All potential chloride control issues and environmental effects were reassessed as related to the Wichita River Basin chloride control features, including related issues downstream in the Red River and Lake Texoma. From 1994, when construction was stopped, until 2010, additional data were gathered and new monitoring activities were conducted as specified by an Environmental Operational Plan (EOP) for the Wichita River Basin features. By completing these data gathering efforts, the Corps was responding to specific areas of concern expressed by the U.S. Fish and Wildlife Service (USFWS), the Texas Parks and Wildlife Department (TPWD), and the Oklahoma Department of Wildlife Conservation (ODWC). By following the EOP, the Corps obtained data under the criteria requested by those agencies. These collected data reflect, in part, the operations of completed features of the Red River Chloride Control Project. Having actual data for completed features significantly benefits the evaluations of the Wichita River Basin control measures. The Corps determined that by pumping Area VII brine emissions to the Truscott Brine Lake, in addition to brine collections from Areas VIII and X, and by making modifications to existing features, that implementation would be environmentally acceptable. The plan recommended would control about 83% of the natural chloride load discharged from the three primary brine sources on the North, Middle, and South Forks of the upper Wichita River Basin. The recommended plan would produce the greatest net economic development benefits and would be technically sound, economically justified, environmentally sustainable, and would best meet the objectives of chloride control authorized by Congress. The supporting National Environmental Policy Act document, the Final Supplement to the Final Environmental Statement for the Authorized Red River Chloride Control Project; Wichita River Only Portion, 2003, was finalized in 2004.

FSM Notes

The purpose of this interim document is to provide the feasibility report component of the read ahead package for the feasibility scoping meeting (FSM).

"The purpose of the FSM is to bring the USACE vertical team, the non-Federal sponsor, and resource agencies together to reach agreement on the problems and solutions to be investigated during the feasibility study and the scope of analysis required. ER 1105-2-100

STUDY PURPOSE AND SCOPE

The overall Red River Chloride Control Project study area includes north-central and northeastern Texas, including the Dallas-Fort Worth region and the Oklahoma and Texas region along the Red River; and the Red River Basin as far downstream as Shreveport, Louisiana. The reason the study area is greater than the Area VI vicinity is because the chloride load from Area VI is a significant percentage of the chloride load in the upper Red River Basin and comprises about 10 percent of the measurable load at Lake Texoma, over 380 miles downstream of Area VI (Carl Gage to Denison gage). Therefore, chloride load changes from Area VI could reasonably affect the economic, social, or environmental conditions in the basin and in the areas outside the basin where water from the Red River would be used. Whether the change to conditions would be positive or negative depends on which specific issue is being examined. In some cases the change of conditions is considered positive by some stake holders and negative by others

The legislated goal of chloride control studies is to reduce naturally occurring chlorides in the Red River so water could be used more economically for agricultural, municipal, and industrial uses. The reduction of chlorides was envisioned by Congress to have a number of primary benefits for those uses. The benefits were the object of the Congressional direction to the Corps of Engineers to study and recommend a plan for chloride control. The Corps responded by conducting extensive studies and then recommended a plan to Congress to reduce chlorides in the Red River. Congress, in turn, authorized the implementation of that plan and the Corps began construction.

From Congress' direction to study the reduction of chlorides and their subsequent authorization of the Corps' recommended plan for implementation, the purpose of the chloride control project was (and is) to reduce chlorides in the Red River to allow more economical use of this water source. However, benefits are not the only measure of a project. The Corps is an agency of the Federal government that is tasked with management of natural resources. Therefore, the Corps complied with the National Environmental Policy Act (NEPA) and all other relevant environmental law when formulating the chloride control plan. Similarly, the Corps continues to comply with Federal law when reevaluating the chloride control features. The Corps knows it is important to clearly present the rationale and thought processes for arriving at a final selection, so that, while reasonable people may disagree with the conclusion, they can see how the various decision factors were considered. Therefore we attempt to identify, consider, and present all aspects of potential project implementation and operation.

The Area VI Feature Reevaluation (Reevaluation) purpose is twofold: (1) to reassess the authorized project at Area VI based on current conditions, and (2) to reexamine the feasibility of other chloride control alternatives to verify if the authorized feature remains the best plan of action for chloride control at Area VI. The overall scope of the Reevaluation is the scientific assessment of all economic, social, and environmental benefits and impacts of implementing chloride control at Area VI. The study area varies in geographic extent among evaluations (scientific disciplines) and therefore the relevant study area for each evaluation will vary. For example, the study area for the hydrology evaluation includes the entire Red River watershed while the study area for the environment evaluation is more narrowly focused on the water courses and lakes (and adjoining riparian and irrigation areas) where reductions in chloride loads could affect the environment. Terrestrial impacts are primarily focused on the footprint of potential feature components.

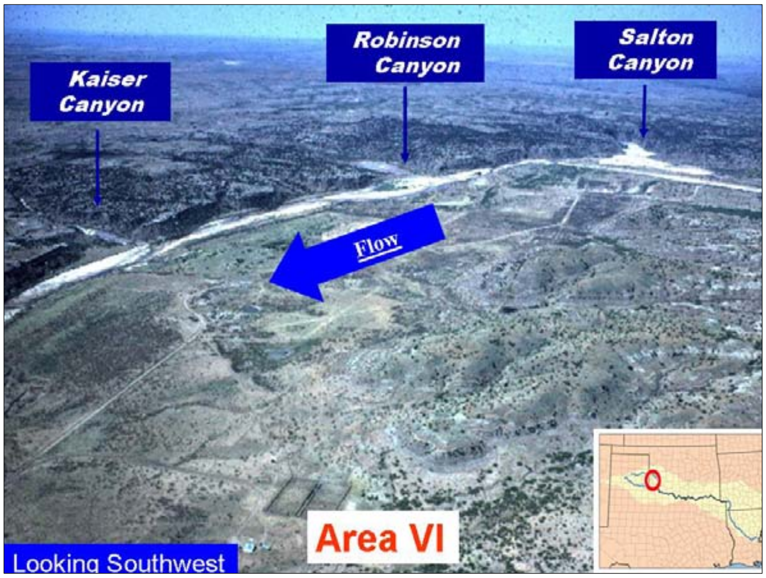
The evaluation of current conditions is the starting point for forecasting the conditions that would exist during the period of operation of the chloride control feature at Area VI and the already completed chloride control features and features of the chloride control project that may be completed before or during the operation of Area VI. The different potential scenarios of forecast conditions with various combinations of chloride control features makes this reevaluation effort somewhat more complicated than a single forecast condition, but by having the different scenarios the Corps is prepared to answer a number of what-if questions that may be posed by various stakeholders.

Alternatives that would reduce chlorides in the Red River would meet the intent of Congress. These included previously studied alternatives and variations or new concepts to meet current conditions. Two of those new concepts were suggested by the U.S. Fish and Wildlife Service (USFWS).

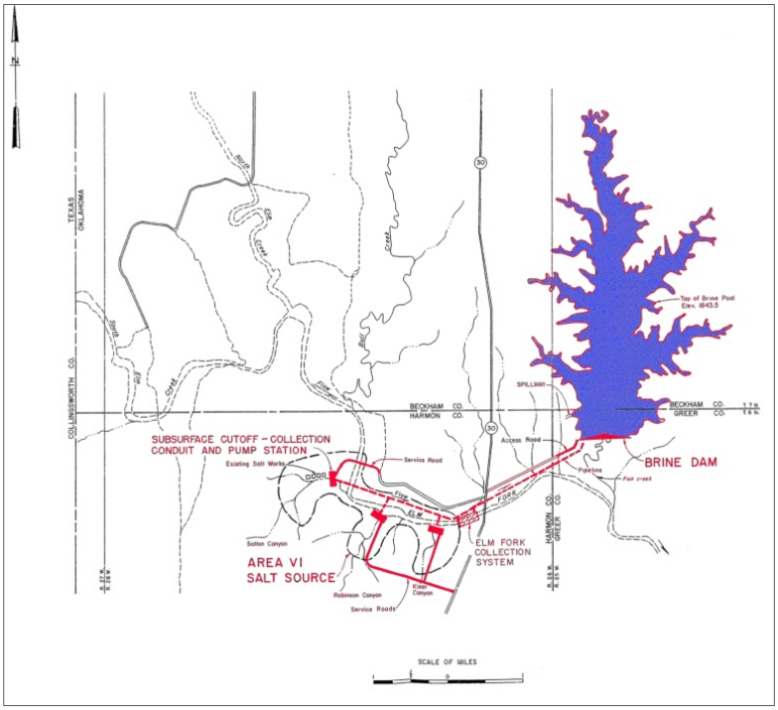
The Oklahoma Ecological Services Field Office of the USFWS has recommended ideas for rerouting the brine emissions or not controlling the brine emission. Neither of these ideas would reduce chlorides in the Red River and would, therefore, not meet the intent of Congress. These ideas were recommended by the Oklahoma Ecological Services Field Office in a short one page draft discussion paper on April 19, 2011. The ideas are supported by the Oklahoma Department of Wildlife Conservation and the Texas Parks and Wildlife Department. The two ideas include (1) collecting brine from the Area VI source and pumping it overland, via pipeline, to the state line where it would be discharged into the Red River, and (2) not collecting any brine from Area VI, but instead, creating new freshwater storage reservoirs in the region that would have “a long lifespan” and “relatively little natural inflow or sediment load” yet have sufficient capacity to store excess water pumped from existing reservoirs or pumped from rivers when at high flows. These ideas were evaluated and are discussed in this Reevaluation.

The Corps held public scoping meetings at the start of the Area VI Reevaluation in 2006 to obtain public and agency input on the scope of the study, including the different methods of controlling the brine emissions that were to be considered in the Reevaluation. Because the

Oklahoma Ecological Services Field Office didn't provide their input until 2011, those ideas were not coordinated with the public or other stakeholders to access their views.



The Area VI brine source is located on the Elm Fork of the North Fork of the Red River in Harmon County, Oklahoma. There are three major chloride sources at Area VI - Salton, Robinson, and Kaiser Canyons along the south bank of the Elm Fork. These narrow canyons emit brine in high concentrations from low average flows that originate from emission points confined to relatively small areas. The canyons are located from about one mile west of Oklahoma State Highway 30 to 3 miles east of the Texas-Oklahoma State line. The drainage area of the three canyons combined is about seven square miles. The drainage area of the Elm Fork at the Carl gaging station, just below Area VI, is about 416 square miles. The total Area VI chloride load is about 510 tons per day (T/D).



The authorized chloride control feature for Area VI would utilize subsurface cutoff walls and collection conduits at the mouths of the three canyons for the collection of brine with attended pumping facilities and pipelines for disposal in Fish Creek Brine Lake. The pumped brine would be prevented from flowing into the Red River and would be stored and evaporated in the brine lake. Annual evaporation in the area is about 65 inches compared to about 25 inches of rainfall (or less) per year Projected trends in climate change would tend to increase the net evaporation rate, thereby aiding the effectiveness of the evaporation reservoir. An increase in average annual temperatures would tend to increase the value of water, thereby supporting the purpose of the chloride control.

Concrete subsurface walls would extend about seven feet from the streambed down to bedrock to stop brine flow in the alluvium. Brine would enter perforated conduits on the upstream (brine) side of the cutoff wall. Collected brine would flow by gravity to a sump on one side of the stream. From a central pump, an average flow of five cubic feet per second (cfs) of brine could be pumped to the evaporation lake about five miles downstream. The pump rate of five cfs is larger than the average of the three brine canyon emissions that average less than two cfs total brine flow. The chloride control plan would remove about 420 tons per day of chlorides from the Elm Fork (and the Red River). That would be an 82 percent level of control. Other dissolved solids (such as sulfates) and elements (such as selenium) would also be removed in similar proportion to the level of chloride control. Other dissolved solids account for a similar load as the chlorides, but slightly less. Therefore, the total of dissolved solids removed from the Red River would be about 740 tons per day.

While Fish Creek Brine Lake would not be expected to release brine flows, it would have an emergency spillway to ensure that a very large flood event could be safely discharged with minimal risk of damaging the brine lake's dam. The lake would be designed to store a 100-year flood event on top of a 100-year accumulation of brine and sediment. When the brine pool filled after about 100-years of operation, the surface area of the lake would be large enough so that average annual evaporation from the lake would keep pace with continued brine inflow and rainfall runoff from the watershed. Average annual evaporation is about 62 inches. Therefore, brine pumping and lake operation would not be limited to a specific operating period. With proper maintenance the project could store dissolved solids for a period of time well in excess of 100 years. By storing the brine in the vicinity of Area VI, the natural resources (salt and other dissolved solids) within the brine would be preserved near the source of the emission and within the state of origin, thereby allowing future mining of this resource. If an economical use for the dissolved solids is identified they could be recovered. If, on the other hand, technological advances rendered the project unnecessary, the brine lake could be decommissioned and any stored dissolved solids would be available for mining. The brine pool was designed to store about 74,320 acre-feet with an additional 2,410 acre-feet of storage for sediment. The dam would be about 3,000 feet long and the lake would have a maximum surface area of about 2,200 acres. No specific evaluations to account for climate change were conducted because there are currently no specific evaluation methodologies in place. But if average annual temperatures would rise during the evaluation period of the project, as is generally expected by the scientific community, then the function of the brine reservoir would be enhanced through increased evaporation.

The authorized chloride control project is shown on Figure 1. Modifications to the authorized project were identified during the reevaluation of the Wichita River Basin chloride control features concluded in August 2003. Those modifications are noted on Figure 1. Because the level of chloride control in the Wichita River Basin was not significantly altered, those modifications to the authorized project do not impact the reevaluation of Area VI. The proposed Wichita Basin feature modifications were included in appropriate forecast scenarios for the Area VI Reevaluation.

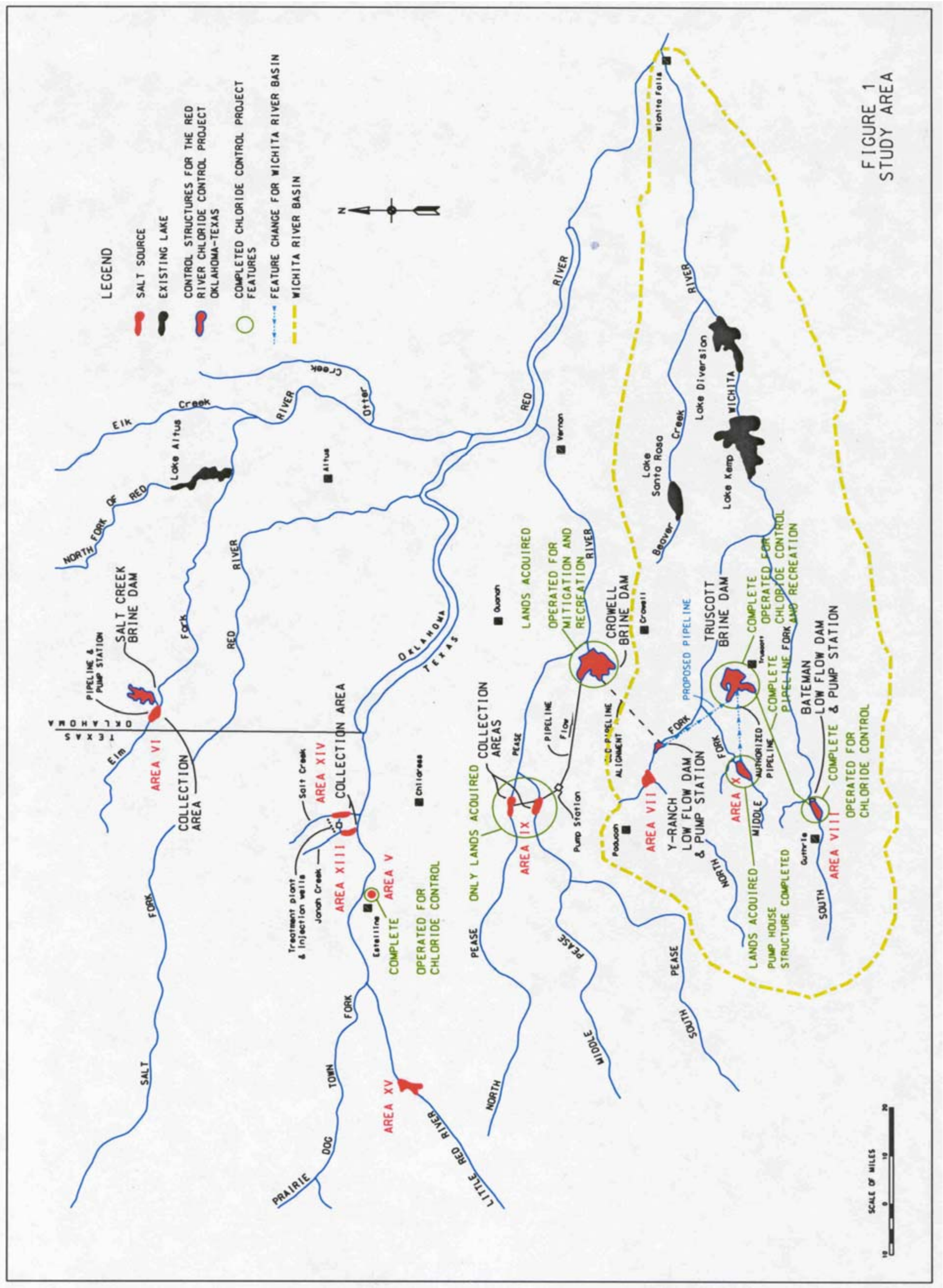


Figure 1 – Study Area

The following terms are used in this report and the definitions may be helpful.

Concentration is the amount of something within something else. An example would be a spoonful of salt in a glass of water. Most dissolved solids (like sugar or salt) are described in this report as milligrams per liter {mg/l} (about the same as parts per million {ppm}; therefore, 1 mg/l equals about 1 ppm). When there is very little of something in water, the units are changed to allow for easier discussion of numbers. This is the case for selenium where the units are micrograms per liter {µg/l} (approximately the same as parts per billion{ppb}).

Load is the term used to describe the amount of dissolved solids (including chlorides, sulfates, or the total of all dissolved solids) that are emitted from a spring or passing a stream location in a certain period of time. Due to the large amounts of dissolved solids in Red River Basin streams, the load in this report is discussed in terms of tons of dissolved solids that pass a location in one day (tons per day). Because the load fluctuates from day to day, all the daily loads are averaged and this average is used to describe the load. *The average total chloride load passing through Lake Texoma is 4,400 tons per day. The total dissolved solids passing through Lake Texoma contributed by all natural brine emissions is about 12,000 tons per day.*

Flow is the volume of water that passes a location in a specified period of time. *Load and concentration are related by the "flow".* The units of describing stream flow in this report are cubic feet per second (cfs). *Think of 1 cfs as about 7-1/2 gallons moving past a point every second.*

Storage is discussed as lake storage. It is measured in acre-feet. *Visualize an acre-foot of storage as 1 acre of flat land with water covering it 1 foot deep.*

Chloride is a portion (the Cl portion) of sodium chloride (NaCl) that is released to the streams from natural brine emissions. *Chlorides that pollute the streams as a result of oil and gas exploration or production or other human contributions are referred to as man-made chloride pollution.* Water collected below the natural brine springs contains more than just sodium chloride. It also contains large amounts of sulfates and other dissolved solids, and may contain small amounts of elements such as selenium and other metals.

Control describes the change from conditions with natural chlorides to conditions with chloride reduction efforts in place in the future. Both conditions attempt to look into the future. Control is represented as changes in load and/or concentration and can be shown as a percentage reduction.

Salinity is a measure of the ionic composition of water. It is routinely measured with an electrical meter in units of parts per thousand (ppt). Salinity in fresh waters is usually low enough that accurate measurements are difficult; therefore salinity is more often measured using the surrogate parameter of specific conductance. It is routinely measured with an electrical meter in units of micro Siemens per centimeter (uS/cm). Chloride is only one of a number of ions that contribute to salinity. Ions are simply charged atoms or molecules. Where concentration deals with the amount of materials by weight or volume, salinity is a measure of the total electrical charge. **More information about ions**: *Negatively charged ions are called "anions" and include Chloride, Sulfate, and Phosphate. Positively charged ions are called "cations" and include Sodium, Potassium, Calcium, and Iron. These are fairly common items in our households, drinking water, and food.*

Benefits are the social, economic, and environmental measurement of plans evaluated and recommended for implementation. Plans are derived from a systematic planning process that reflects reason, common sense, and sound judgment. Through planning, design, and implementation of measures, every effort is made to ensure that social, economic, and environmental values are added to water resource projects. The process is grounded in the economic and environmental principles set forth in law that apply to the Corps of Engineers, the Bureau of Reclamation, the Tennessee Valley Authority, and the Natural Resources Conservation Service. For these agencies, the Federal objective of water and related land resources planning is to contribute to national economic development consistent with protecting the Nation's environment pursuant to national environmental statutes, applicable executive orders, and other Federal planning requirements.

Selenium is a naturally occurring element present in many water sources. It is a nutritionally essential element that, in low concentrations, is beneficial to all living organisms. If present at high enough concentrations in aquatic environments, selenium can be toxic to certain aquatic organisms and waterfowl.

While concentration, load, flow, and other data may be referred to by their average values or percentages, the evaluations in this report discuss the results of computer models that dealt with the most appropriate detailed values available, whether daily, monthly, or other units of measure. Averages or percentages are used to simplify presentation of these detailed models and results.

STUDIES, REPORTS, AND EXISTING WATER PROJECTS

Studies and Reports

a. *Survey Report on Lake Kemp, Wichita River, Texas, Tulsa District, Corps of Engineers, dated November 15, 1961.*

b. *Interim Survey Report on Water Quality Study, Arkansas-Red River Basins, Tulsa District, Corps of Engineers, dated January 15, 1962, and revised February 2, 1962.*

c. *Survey Report on Arkansas-Red River Basins Water Quality Control Study, Texas, Oklahoma, Kansas [Part I], Volume 5, Appendix IX, "Arkansas-Red River Basins, Water Quality Conservation, U.S. Department of Health, Education, and Welfare, Public Health Service, dated June 1964.*

d. *Arkansas-Red River Basins Water Quality Control Study, Texas, Oklahoma, and Kansas – Survey Report (Part 1), Tulsa District, Corps of Engineers, dated April 28, 1965.*

e. *Arkansas-Red River Basins Water Quality Control Study, Texas, Oklahoma, and Kansas – Survey Report (Part I1), Tulsa District, Corps of Engineers, dated May 13, 1966.*

f. *Lake Kemp Dam and Reservoir, Wichita River, TX, Design Memorandum No. 2, General Design, Tulsa District, Corps of Engineers, dated March 1968.*

g. *Survey Report on Arkansas-Red River Basin Water Quality Control Study, Texas, Oklahoma, and Kansas (Part II), Tulsa District, Corps of Engineers, March 1968.*

h. *Final Environmental Statement, Arkansas-Red River Basin Chloride Control, Texas, Oklahoma, and Kansas (Red River Basin), Tulsa District, Corps of Engineers, dated July 1976.*

i. *Arkansas-Red River Basin Chloride Control, Texas, Oklahoma, and Kansas (Red River Basin), Design Memorandum No. 25, General Design, Phase I – Plan Formulation, Volumes I and II, Tulsa District, Corps of Engineers, dated July 1976.*

j. *Supplemental Data to Arkansas-Red River Basin Chloride Control, Red River Basin, Design Memorandum No. 25, General Design, Phase I – Plan Formulation, Volumes I and II, Tulsa District, Corps of Engineers, dated November 1980.*

k. *An Interagency Reconnaissance Report, Red River Basin, Arkansas, Texas, Louisiana, and Oklahoma Comprehensive Study and the Arkansas River and Tributaries South-Central and Southeast Oklahoma Comprehensive Study, Tulsa District, Corps of Engineers, dated March 1985.*

l. *Report on the Evaluation of the Effectiveness of Operation of Area VIII Red River Chloride Control Project, Red River Chloride Control Project Evaluation Panel, dated August 1988.*

m. *Red River Basin, Arkansas, Texas, Louisiana, and Oklahoma, Interagency Comprehensive Technical Report, Volume I, Main Report, Tulsa District, Corps of Engineers, dated March 1989.*

n. *Limited Reevaluation Report, Red River Chloride Control Project, Tulsa District, Corps of Engineers, Revised June 1993.*
o. *Red River Chloride Control Project, Supplemental Assessment Report (to the Environmental Impact Statement), Tulsa District, Corps of Engineers, dated February 1997.*

p. *Red River Basin Chloride Control Project, Evaluation of Wichita River Basin Completion, Tulsa District, Corps of Engineers, dated October 1997.*

q. . *Red River Basin Chloride Control Project, Evaluation of Wichita River Basin Completion, Tulsa District, Corps of Engineers, dated August 2003*

r. *Wichita River Basin Project Reevaluation, Red River Chloride Control Project, April 2003*

s. *Final Supplement to the Final Environmental Statement for the Authorized Red River Chloride Control Project, Wichita River Only Portion, April 2003*

Existing Water Projects

Included in existing water projects are these Red River Chloride Control Project features:

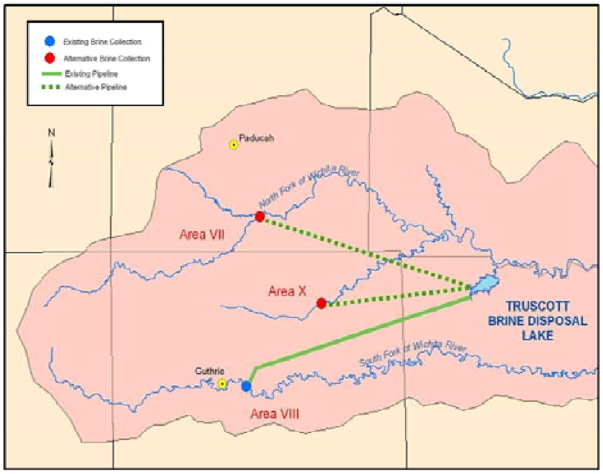


Figure 2 - Features

Area V – Estelline Springs

The first chloride control feature was authorized in 1962 as an experimental project. This site was called Area V from the original U.S. Public Health Service study. Area V is simply a ring dike around the brine spring. It is located on the Prairie Dog Town Fork of the Red River in Hall County, less than 1 mile east of Estelline, Texas. The collection area is at river mile 1074.5. The structure is a ring+ dike 9 feet high and 340 feet in diameter. The weight of the water contained by the dike stops the spring from flowing. Construction started in 1963 and the ring dike was completed and placed in operation in January 1964. The dike has stopped about 240 tons of chlorides (out of 300) from entering the Red River each day since it was completed. This feature is upstream of Lake Texoma; therefore, Lake Texoma no longer receives an average daily chloride load of 240 tons per day from Estelline Springs. This represents a 7% reduction of the long-term chloride load into Lake Texoma (previously 3,300 tons per day). See Figure 1.

Area VIII

In 1974, Congress authorized construction of Area VIII on the South Fork of the Wichita River. Area VIII was constructed in May 1987. It is located about 5 miles east of Guthrie near the center of King County, Texas, and about 4 miles north of U.S. Highway 82. The collection area is at river mile 299.6. The low-flow collection dam was constructed to collect brine for pumpage to Truscott Brine Lake.

The structure is a deflatable, fabric-type weir 5 feet high and 49 feet long that extends across the existing stream channel impounding a pool to facilitate pumping. The pump station has three vertical turbine pumps with discharge capacities of 2,244 gallons per minute. Area VIII has been in full operation pumping brine through the 22-mile-long pipeline to Truscott Brine Lake and has stopped about 165 tons per day (out of 189) of chloride from entering the Wichita River and the Red River downstream since 1987. This represents about a 5% reduction of the long-term chloride load into Lake Texoma. See Figures 1 and 2.

Truscott Brine Lake

Truscott Brine Lake was designed as a brine disposal site, receiving brine pumped from the collection sites. This lake was completed in December 1982. The dam is located at river mile 3.6 on Bluff Creek, a south bank tributary of the North Fork of the Wichita River in Knox County, Texas. The drainage area of the basin is 26.2 square miles and begins approximately 2 miles west and 2.5 miles south of Truscott, Texas. The drainage area extends approximately 6 miles northeastward to the dam site and ranges in width from 7 miles at the upper end of the basin to approximately 3 miles at the dam site. The project has been collecting brine since 1987.

The economic evaluation period is 50 years. The economic evaluation time period does not imply an operational or design life for the chloride control features. The physical life of the facility is not limited, and the chloride control areas could operate well beyond 100-years with proper maintenance. Given that maintenance is a Federal responsibility for the chloride control project, operation beyond 100-years is a likelihood. The brine lake was designed so that as the area of the brine pool becomes large enough, evaporation from the lake would match the amount of rainfall and brine going into the lake. In the event of changing climate, adjustments to increase or decrease evaporation measures or pumping rates can be made to prolong chloride control operations and optimize its effectiveness.

Recreation activities available at Truscott are continuing to expand. They currently include swimming, jet skiing, wind surfing, camping, hiking and equestrian trails, bird and hog hunting, nature walks, star watching, photography, and project tours. An estimated 30,000 to 40,000 geese winter at the brine reservoir and freshwater ponds. No current or projected recreational benefits related to the Truscott Brine Lake are included in the economic evaluations within the Wichita River Basin Reevaluation.

Crowell Mitigation Area

The Red River Chloride Control Project mitigation area is located in Foard County about 8 miles northwest of the city of Crowell, Texas. The area includes Canal Creek, a south bank tributary of the Pease River. See Figure 1.

About 11,954 acres are currently owned by the Federal Government and held by the U.S. Army Corps of Engineers. These lands have been determined sufficient to offset all terrestrial impacts of chloride control features, constructed and proposed which comprise about 4,417 acres of lost habitat. The habitat impacted by construction was primarily composed of mesquite/juniper and small amounts of cropland and range habitat.

The primary purpose of the mitigation land is to offset or replace terrestrial habitat losses due to construction of project features, such as construction of the brine pipelines and the Truscott Brine Lake. The greatest value for the Crowell mitigation land can be realized through management of fish and wildlife resources to provide the public with fishing and hunting opportunities. Native species include white-tailed deer, mule deer, scaled quail, bobwhite quail, Rio Grande turkey, cottontail, mourning dove, and migratory waterfowl. Hunting opportunities for these species and feral pigs are currently available.

Fishing is available at several constructed ponds located within the mitigation area and constitutes the major aquatic resource that has management potential for warm water aquatic species. Characteristic species found in ponds of this region include green sunfish, bluegill, orange spotted sunfish, largemouth bass, crappie, common carp, black bullhead, and channel catfish. Vegetation generally consists of woodland, mixed shrub savannah, upland grassland, and bottomland grassland. A small amount of riparian vegetation and marsh communities are present.

Recreation activities are currently available at Crowell and include camping; hiking; equestrian trails; turkey, deer, and hog hunting; nature walks; star watching; and photography. There are also historical sites located in the area in close proximity to the mitigation area.

While hunting and fishing opportunities currently exist, these opportunities will be improved with future management. No current or projected recreation benefits related to the Crowell mitigation area are included in the economic evaluations within the Reevaluation.

Authorized Unconstructed Brine Collection Facilities

Area VII

The authorized Area VII brine collection area is at river mile 209.6, which is about 8 miles southeast of Paducah in the southeastern quarter of Cottle County, Texas. The authorized collection site includes a 1-mile reach of the North Fork of the Wichita River and a 3-mile reach of Salt Creek, a tributary to the North Fork. The North Fork of the Wichita River above the Salt Creek confluence contributes about 10% of the chloride load of the area. Flows from springs and seeps in Salt Creek average about 3.5 cfs during normal periods at the stream confluence. The average chloride load from Area VII is 244 tons per day, which is more than 40% of the chlorides entering Lake Kemp, a major reservoir on the main stem of the Wichita River. The drainage area above the dam site is 492 square miles. The low-flow collection structure is designed as a deflatable, fabric-type weir 5 feet high with a base width of 80 feet. The weir would extend across the existing stream channel impounding a pool to facilitate pumping. The top of the deflatable weir is designed to be at elevation 1539.0, have a 14-acre area, and a capacity of 22 acre-feet. The concrete supporting slab is designed to be 12 feet wide and stabilized with end-bearing piling with concrete approach walls to retain fill and direct flows through the pumping facilities. Collected brine would be pumped to Truscott Brine Lake. The pump station would have three vertical turbine pumps providing a maximum flow rate of 9,200 gallons per minute. The pipeline will be a 20- to 24-inch-diameter steel pipeline approximately 15 miles long. A total of 195 tons per day would be controlled or about 84% of the site emissions.

Area X

The watershed above the brine collection site covers 61 square miles. The Area X brine source and collection features are located about 13 miles northeast of Guthrie in King County, Texas, on the Middle Fork of the Wichita River. The collection area is at river mile 19.7. The low-flow dam is at river mile 20.5.

The structure is a deflatable, fabric-type weir 5 feet high with a base width of 30 feet. The weir extends across the existing stream channel impounding a pool to facilitate pumping. The top of the deflatable weir is at elevation 1561.8, contains an area of 5 acres, and has a capacity of 10 acre-feet. The low-flow dam and pump house were completed before construction was interrupted in 1997; however, the brine pumps were not purchased, and the pipeline was not constructed. The inflatable weir is functional.

Brine would be pumped to Truscott Brine Lake. The pump station would have three vertical turbine pumps from 150 to 200 horsepower providing a total pump station flow of 1,800 to 4,500 gallons per minutes. The pipeline would be 18-inch-diameter steel/PVC pipe.

The salt springs and seep area extend about 6 river miles. The Middle Fork becomes a perennial stream where the first brine seeps appear. Seeps appear along both sides of the stream, emerging from gypsiferous shale at the base of vertical cliffs that partially define the margin of the alluvial plain. During dry seasons, a salt crust forms on the seeps. One spring found in the area has a flow of 0.7 cfs.

The Middle Fork contributes about 58 tons per day of chlorides, or about 12% of the total Wichita River Basin salt load. The plan is to control 49 tons per day of chlorides. The Area X pipeline to Truscott Brine Lake would be about 10 miles in length and will impact about 146 acres of mesquite/juniper habitat. The collection area impacts about 42 acres of mesquite/juniper habitat.

The Wichita River Basin Project Reevaluation, Red River Chloride Control Project, April 2003, was conducted by the Corps. The Wichita River Basin Reevaluation was supported by the *Final Supplement to the Final Environmental Statement for the Authorized Red River Chloride Control Project, Wichita River Only Portion, April 2003*.

The District Commander determined that resumption of construction of chloride control features in the Wichita River Basin could be accomplished with modifications that are within the discretion of the Commander, Headquarters U.S. Army Corps of Engineers (HQUSACE). The plan would consists of three low-flow dams (Areas VII, VIII, and X) for collection of brine, five evaporation spray fields for volume reduction before and after pumping, three pumping plants, and three pipelines to transport brine from the low-flow dams to the one disposal reservoir for holding and evaporating concentrated brine. Also included were conditional measures for terrestrial and aquatic mitigation that could be implemented if monitoring indicated that the low risk of potential impacts was, in fact, occurring.

The features already completed at the time of the Reevaluation consisted of:

- ☑ Area VIII low-flow brine dam - operating,
- ☑ Area X low-flow brine dam – completed,
- ☑ Area X pump house - completed,
- ☑ Area VIII experimental evaporation field - operating,
- ☑ Area VIII pumping plant and Area X pump house - operating,
- ☑ Area VIII pipeline - operating,
- ☑ Truscott Brine Lake - operating,
- ☑ Area V experimental project - operating (assumed future conditions), and
- ☑ Crowell Mitigation Area - operating (for wildlife and recreation).

The unconstructed features consisted of:

☐ Area VII low-flow brine dam,
☐ Areas VII, VIII, and X evaporation fields,
☐ Area X pumps and Area VII pumping plant,
☐ Areas VII and X pipelines, and
☐ Aquatic mitigation at Lake Kemp.

Completion of the Wichita River Basin features is dependent on funding to complete plans and specifications and to award construction contracts.

What is important here is:

Construction of two additional brine collection and conveyance facilities would complete the ***Wichita River Basin*** *chloride control features (VII, VIII, & X) and would reduce chlorides in the Red River by about 669 tons per day (includes 240 tons per day controlled by* ***Area V*** *since 1964).*

In the current state of construction, the Area VIII brine collection facility is reducing chlorides in the Red River by 165 tons per day and Area V is reducing 240 tons per day.

Other Area Water Resources Projects

Tom Steed Reservoir (Mountain Park Project)

Tom Steed Reservoir is located on West Otter Creek, a tributary of the North Fork of the Red River, approximately 6 miles north of Snyder in Kiowa County, Oklahoma. Tom Steed Reservoir was authorized by Public Law 90-503, September 21, 1968 (82 Stat. 853). This authorization included aqueducts to serve the cities of Altus and Snyder and a diversion structure on Elk Creek and associated canal. The authorization was amended to include an aqueduct to the city of Fredrick by Public Law 93-493 (88 Stat. 1492). Public Law 103-434 dated October 31, 1994 added environmental quality as an authorized project purpose.

Construction on Mountain Park Project began in 1971. Mountain Park Dam was completed on June 20, 1975. The dam is a thin double curvature concrete arch flanked by thrust blocks which rises 60 feet above the streambed. The spillway consists of an ungated overflow section 320 feet long located near the center of the dam. The flood outlet works consist of one 84-inch concrete lined conduit and slide gate.

Construction of the Bretch Diversion Dam and Canal began in September 1975 and was completed in October 1977. The Bretch Diversion Dam and Canal divert high flows on Elk Creek for conveyance to Tom Steed Reservoir by way of Noname Creek and West Otter Creek. Construction of the aqueduct system began in April 1974 and was completed in December 1979.

Tom Steed Reservoir is operated by the Mountain Park Master Conservancy District. The reservoir is one of the principal suppliers of drinking water to southwest Oklahoma. The reservoir supplies drinking water to the cities of Altus, Mountain Park, Snyder, Manitou, and Fredrick. The conservancy district also delivers water to the Oklahoma Department of Wildlife Conservation's Hackberry Flat Wildlife Management Area.

An inventory of land and water resources needs and problems of the Red River Basin was initiated by the Bureau of Reclamation in1948. While these studies were underway, the Arkansas-White-Red Basin Interagency Committee was authorized by the Flood Control Act of 1950 to formulate a comprehensive long-range plan for development of the land, water, and other resources in those basins. Following establishment of the interagency committee, the investigation of the potential Mountain Park Project by the Bureau of Reclamation was carried out as a part of the overall basin study. The cooperative investigations undertaken by the various agencies resulted in a tentative plan which included the Mountain Park Reservoir, a diversion dam on Elk Creek, a diversion canal between Elk and Otter Creeks, and distribution works to irrigate suitable lands near Tipton. The evaluated plan was found to be economically unjustified for inclusion in the overall basin plan.

In 1958, the cities of Altus, Frederick, Snyder, and Roosevelt expressed interest in a plan to obtain water from the Mountain Park Project. Detailed investigations of the project were initiated early in 1959. In 1962, a feasibility report was submitted. The Secretary`s report on the project was transmitted to the President on May 12, 1964, and authorized on May 11, 1966.

The Mountain Park Project was authorized by Public Law 90-503, September 21, 1968 (82 Stat. 853). This authorization included aqueducts to serve the cities of Altus and Snyder, Oklahoma. The authorization was amended to include an aqueduct to the city of Frederick, Oklahoma, by Public Law 93-493 (88 Stat. 1492), dated October 27, 1974.Public Law 103-434 dated October 31, 1994 added environmental quality as an authorized purpose to the project.

Construction began on Mountain Park Project in 1971 with the award of contracts for exploratory drilling, breaching Snyder Dam, warehouse and shop buildings, and minor contracts. Relocation contracts for power lines, highways, county roads, and railroads were initiated in 1972. Construction of Mountain Park Dam began with award of contract July 26, 1973, and was completed on June 20, 1975. Construction of Bretch Diversion Dam and Canal started with award of contract on September 12, 1975, and the work was essentially complete October 28, 1977.

Construction of the aqueduct system began with the award of contract for Altus Aquaduct and Pumping Plant on April 25, 1974; the contract was substantially completed on May 26, 1976. The contract for the Frederick Aqueduct and Pumping Plant was awarded August 5, 1976, and the contract was substantially completed at the end of calendar year 1979.

Altus Reservoir (also known as Lake Altus-Lugert and the W.C. Austin Project)

Altus Reservoir is located at river mile 73.5 on the North Fork of the Red River in Greer and Kiowa counties, Oklahoma. Altus Reservoir was constructed by the Bureau of Reclamation to fulfill flood control, irrigation, and water supply requirements on the North Fork of the Red River. Altus Reservoir was authorized by the Flood Control Act approved June 28, 1938 (52 Stat. 1215 and 1219), Public Law 761, 75th Congress, 3rd Session; and specifically by the President on February 13, 1941.

Construction of Altus Reservoir began in April 1941 and was completed in December 1948. The structure consists of a 1,104-foot concrete dam with masonry facing which rises 90 feet above the streambed with an associated 348.5 ft spillway. The spillway consists of nine 15- by 21-foot radial gates and 110.5 feet of uncontrolled spillway. Irrigation releases are made through three 72-inch conduits controlled by three 5-foot by 5-foot slide gates. Four earth-filled dikes having a combined length of 17,701 feet are located along the rim of the reservoir.

Altus Reservoir is operated by the Lugert-Altus Irrigation District which supplies irrigation to more than 330 land owners located in southwestern Oklahoma and provide approximately 48,000 acres of municipal/industrial water to the city of Altus. Other benefits include fish and wildlife benefits, and numerous public recreation benefits.

Photograph looking across Lake Altus-Lugert at Quartz Mountain taken by Sue Hokanson

Lake Altus-Lugert is the primary storage facility for the W.C. Austin Project of the U.S. Bureau of Reclamation.

Lake Altus had its beginnings in 1927 when the city of Altus, Oklahoma built Altus Dam as a source of municipal water for the city. Interest in providing irrigation water to farmers in the region prompted the U.S. Government to authorize construction of a larger reservoir in the Rivers and Harbors Act of 1938. The dam was raised 50 feet to impound more water. The lake surface measures 6,260 acres and 49 miles of shoreline at its conservation pool elevation of 1,559 feet. Lake Altus-Lugert has a storage capacity of 134,495 acre-feet at conservation elevation.
The dam, as it stands today, was completed in 1947.

There is an extensive system of canals leaving Lake Altus in order to deliver the irrigation water to farmland. Most of these canals and distribution laterals were completed by 1953.

Annually Lake Altus-Lugert supplies 70,000 acre-feet to irrigation and 10,000 acre-feet to the City of Altus. It serves as the secondary supply to Altus Municipal and Altus Air Force Base. The ever increasing demand of the water is exacerbated by the shrinking storage. At the time of construction, Lake Altus was estimated to silt in approximately 640 acre-feet per year. There is no other water source in southwestern Oklahoma available for this area. All reservoirs and ground water sources are under contract or contain high chloride levels. This severely limits regional economic growth and during drought events places the economy of southwestern Oklahoma in highly stressed condition. The irrigation district recognized an opportunity to supplement the regions need for water by supporting the Federal chloride control feature at Area VI.

According to the Altus Times interview with Tom Buchanan (Irrigation District Manager), last year (2010) the irrigation district produced in excess of 100,000 bales of cotton -- about half of the total production of the state. And that, he said, translates into some $45 million in income to landowners and producers, which in turn is circulated numerous times in the local economy, rendering an estimated impact of $330 million.

Municipal and industrial water use from Lake Altus has been minimal. The average delivery from storage for municipal and industrial needs since 1951 has been 837 acre-feet annually, but distribution of this demand is concentrated from the middle 1960's to the late

1970's. Since the early 1980s, water deliveries for municipal consumption have been negligible The reduced municipal and industrial water usage from Lake Altus reflects the use of an alternate water supply made available to Altus by the completion of Tom Steed Reservoir. Beginning in 1979, Tom Steed Reservoir has been the primary source of municipal and industrial water supply for Altus, Snyder, and Frederick, Oklahoma. Source: US Bureau of Reclamation Appraisal Report Water Supply Augmentation W. C. Austin Project (Altus) Oklahoma- http://www.usbr.gov/gp/otao/wcaustin2005.pdf

References:
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Discussions with Mr. Tom Buchanan
Altus Times article from Tuesday July 26, 2011 at
http://altustimes.com/pages/full_story/push?article-Lake+Lugert-Altus+turned+Southwest+Oklahoma+into+a+field+of+streams%20&id=1309944
http://www.outdoorsok.com/Oklahoma/AltusLugert

Altus Lugert Irrigation District

The irrigation District was founded in the 1940s to meet the irrigation and municipal and water supply needs of southwest Oklahoma. In 1942 the District signed a contract with the United States Department of Interior for the construction of the dam and lake. By the end of 1946, the irrigation system and Altus dam was 95 percent complete.

The District serves farms in 46,000 acres with more than 300 miles of canals and laterals. The source of irrigation water is Lake Altus, with an overall capacity of 134,495 acre-feet. The District maintains and operates the Altus Lake dam as well as the irrigation canals that serve members of the district.

Billington 1952. *The Chronicles of Oklahoma 30* (Summer 1952)
http://digital.library.okstate.edu/Chronicles/v030/v030p207.pdf

Other Related Water Resources Projects

Lake Texoma

Lake Texoma is a man-made lake formed by the Denison Dam and is located at river mile 725.9 on the Red River between Oklahoma and Texas. It is 5 miles northwest of Denison in Grayson County, Texas. The project was constructed for flood control, water supply, hydroelectric power, regulation of Red River flows, improvement of navigation, and recreation by the Corps of Engineers. The lake is an 89,000 surface-acre impoundment.

The U.S. Army Corps of Engineers manages 4,250 recreation sites at 422 lakes and reservoirs. Online reservations may be made by visiting www.reserveusa.com, the official website of the National Recreation Reservation Service (NRRS) or by calling toll free, 1-877-444-6777. The National Recreation Reservation Service web site is a non-government commercial site maintained in partnership with the U.S. Army Corps of Engineers and the USDA Forest Service.

The Corps began construction in August 1939 and the project was completed in February 1944. The project was first available to operate for full flood control without any restrictions in January 1944. The first hydroelectric turbine was placed on line in March 1945 and the second in September 1949. Construction of a highway bridge across Lake Texoma at the Willis Ferry site started April 24, 1958, and was completed October 30, 1960. The 5,426-foot-long bridge replaced a former crossing south of Woodville, Oklahoma, on Oklahoma State Highway 99 and Texas State Highway 91. At normal pool elevation, 617.0 feet, maximum depth is 112 feet, and mean depth is approximately 30 feet. The lake drains an area of approximately 39,719 square miles, with 5,936 square miles, most of which is pasture and cropland, not contributing to basin runoff.

From a 1985 sediment resurvey, the conservation pool is projected to contain about 1,115,000 acre-feet of storage in 2044. Section 838(a) of the Water Resources Development Act of 1986 (Public Law 99-662) authorizes the Secretary of the Army to reallocate an additional 300,000 acre-feet of hydropower storage to water supply, allowing up to 158,060 acre-feet each for Oklahoma and Texas municipal, industrial, and agricultural water users.

The estimated peak discharge for the May through June 1908 flood was 470,000 cfs. The volume was 8,517,000 acre-feet, which is equivalent to 4.73 inches of runoff over the basin. The peak inflow for the May 1990 flood was 300,000 cfs with a volume of 5,087,000 acre-feet.

The powerhouse contains two 35,000-kilowatt generators, with provisions for three additional 43,000-kilowatt units. One 20-foot-diameter steel-lined conduit provides water for each power unit.

Lake Texoma is a major resource for many recreational activities and for potable water to residents in the surrounding areas of Texas and Oklahoma. Lake Texoma is about 120 miles from Wichita Falls. Western Wichita Basin communities are about 200 miles from Lake Texoma. In fiscal year 2010, there were 6,205,187 visitors. Public access is supported through about 110 Federal and non-Federal public boat ramps, roughly 540 privately owned boat docks, and about 6,000 slips in 26 commercial marinas. General access to Corps lakes is free, but use of developed facilities (boat ramps, beaches, camping) may include fees. Annual passes costing $30 may be purchased which permit vehicle and accompanying passengers to use all boat launching ramps and swimming beaches at all Corps operated lakes without further charges. Camping fees vary based on location and facilities offered.

Lake Texoma is recognized as a top fishing lake, primarily for striped bass, and is one of the most popular recreational destinations in the southwestern United States. Recreational opportunities include camping, fishing, hunting, water-skiing, swimming, jet skiing, hiking, horseback riding, and wildlife watching.

Sport fish occupying the lake include largemouth, spotted, and smallmouth bass; white, and striped bass; walleye; white and black crappie; channel; flathead and blue catfish; bullhead; and sunfish. Approximately 450-700 fishing guide services are available on the lake offering a variety of guided trips. Of these sport fish populations, striped bass have developed into one of the dominant fisheries of the lake. Striped bass were initially stocked in Lake Texoma by the ODWC in 1965. Since the initial stocking of striped bass, the striped bass fishery in Lake Texoma has developed into an extremely popular fishery. The abundance and size of the striped bass has varied between specific years in response to strength of year classes and availability of forage species.

Angler expenditures for all sport fishing at Lake Texoma generates about 0.8% (eight-tenths of 1%) of the income of the seven-county lake region. Striped bass fishing accounts for about 60% of angler expenditures or less than one half of one percent of the seven county lake region income.

The Corps manages 54 parks on the lake including 40 miles of equestrian/hiking trails, 15 campgrounds (a total of 2,176 campsites) and other water-related activities. Two State parks, two National Wildlife Refuges, and several local parks are also located on the lake and provide additional recreational activities.

The marinas and resorts located near the lake offer a variety of recreational activities, including recreational vehicle and tent camping, fishing and fishing supplies, motor boat, sailboat, and watercraft rentals, canoe rentals, swimming beaches, tennis courts, horseback riding, restaurants, and hiking trails.

Lake Texoma is a major water supply storage reservoir. The lake supplies water to north Texas and potentially to south-central Oklahoma. The total water supply storage available is about 158,060 acre-feet. Water supply storage in Lake Texoma is under contract to:

Water Storage Customer	Storage (acre-feet)
City of Denison	21,300 acre-feet
Texas Power & Light	16,400 acre-feet
Red River Valley	2,736 acre-feet
North Texas Municipal Water District	95,023 acre-feet
Buncombe Creek	1 acre-feet
Greater Texoma Utility Authority/Sherman	11,000 acre-feet
Not Under Contract	11,600 acre-feet
Total	158,060 acre-feet

Chloride concentrations generally range from 165 mg/l to 469 mg/l with concentrations below 345 mg/l 50 percent of the time. As a result, water from Lake Texoma has to be either treated for chloride removal or blended with waters from other sources which have lower chloride concentrations. The customers identified above utilized both treatment and blending practices for delivery of water to their retail customers.

Lake Texoma is currently experiencing a loss of volume due to the transport of sediment into the reservoir. The most recent sediment survey of Lake Texoma, conducted in 2002, resulted in an estimated average rate of sedimentation to be 10,099 acre-feet per year with approximately 6,000 acre-feet of sediment deposited in the conservation pool per year. The conservation pool, since impoundment has suffered a permanent loss of volume in the conservation pool (elevation 590 – 617 feet) of 22 percent. The forecast effects will be a general aging of the reservoir and changes in deep water temperatures that will alter the remaining, and decreasing volume of, aquatic habitat. Ongoing sediment transport from the watershed into Lake Texoma provides the opportunity to work with other local, state, and federal stakeholders to evaluate the watershed of Lake Texoma for the purposes of identifying the primary sediment contributing sub-basins and identify best management practices for implementation within the watershed. Additional opportunities exist in Lake Texoma for updating shoreline management plans to incorporate sediment management applications as well as ecological management of recently created ecological zones in areas currently impacted by substantial sediment accumulations.

PLAN FORMULATION

Evaluation of chloride control, or any water resources problem, involves a watershed approach to seek a balance between environmental sustainability and water resource development so that projects are compatible with and contribute to a regional plan. Planning activities to achieve this goal include looking at a study area as it was, as it is, and estimating how it will be in the future. The Corps looks at future conditions with two options: one **without** the Federal assistance being considered to solve water resources problems, and the other condition **with** the Federal assistance being considered.

Assessing the current condition is usually the easiest part of the process. Looking back in time may be limited to a number of decades for some recorded information, but may extend thousands of years in the case of archaeological information, or millions of years for geologic information. The Corps is directed to begin an investigation because of current problems, but the planning process needs to forecasts the conditions expected to occur in the future so that the project to be implemented will be appropriate for many years of forecast operation. An initial part of the forecast operation is called the economic evaluation period. For this project the evaluation period is 50 years. The starting point for the evaluation period is the first year that a potential project might be implemented. Through this approach the Corps is anticipating the problems that are expected to exist in the study area and is formulating a potential project that would best address those future problems.

The No Action Alternative

The without-project condition is what will result if no action is taken.

When formulating plans, NEPA regulations *(40 CFR 1502.14(d))* require that the No Action alternative always be considered. In essence, this requires any action that is taken to be more in the public interest than doing nothing.

Alternative plans require that we take some action to meet the planning objectives. Therefore, while "no action" is an alternative future, it is not strictly speaking an alternative plan.

Independent of the NEPA regulation, the Corps' planning process is, in a sense, built on the default assumption that the Federal agency should do nothing unless doing something is better for society than doing nothing. Hence, the planning process must convincingly establish that Federal involvement in some project is preferred over no action.

Forecasting the problems and basin conditions is more difficult than examining current conditions, but for many areas of interest the forecasts are straightforward progressions of how conditions have changed in recent history. For example, the following conditions are current conditions and are very likely future conditions:

- Demand for water in North Texas region will continue to expand as supply sources diminish and the population increases in the region (Dallas/Ft Worth).
- Lake Texoma's aquatic ecosystem will continue to age as sediment deposition reduces lake volume and the amount of thermal refugia for fish declines; and nutrient loads will further, negatively, alter the ecosystem.

- Agricultural production in southwest Oklahoma is an important component of the economy. Demand for irrigation water to support agriculture will continue to expand.
- Brine sources at Area VI will discharge chlorides and sulfates.
- Invasive plant species will continue to be serious problems for farming, ranching, and the environment.

From very basic observations like these, the foundation is laid for determining more specific existing conditions related to aspects of the problem and potential solutions. The description of existing conditions is then used to forecast future conditions. Some forecasts are based on trends, like population. Others are based on governmental or industry plans, or on economic forecasts, such as the detailed evaluation of the relationship of water quality and agricultural production. Other evaluations are more complex still, such as assessing the interlinked function of ecological systems. Because the Corps is as concerned about the environment as we are about the engineering quality of our water resources projects, much effort goes into evaluation of all aspects of existing and forecast conditions. Whether data are plentiful or limited, the Corps makes conservative and reasonable interpretations based on data, experience, scientific processes, and professional judgment.

The Corps has accumulated technical expertise from chloride control studies over the past 58 years, and through the design, construction, and operation of brine control facilities since 1964. However, the Corp recognizes and relies on the specialized knowledge and professional abilities of others.

While the Area VI Feature Reevaluation was not to be constrained by existing Congressional authorization of features of the Red River Chloride Control Project, the existence of completed (and operating) chloride control features in the Red River Basin were recognized. The Reevaluation involves detailed formulation, economic, environmental, social, and cost analyses of constructed or authorized chloride control features and other chloride control measures. The method used to gauge the effectiveness of measures was to compare the future condition without further chloride control measures to a forecast future condition assuming the chloride control measures were implemented. The first forecast is called the **future without-project condition (**the without Federal assistance option mentioned at the start of this section). The second is called the **future with-project condition** (the with Federal assistance option above). These evaluations consider all reasonable economic, social, and environmental effects associated with the area problems and the potential solutions being evaluated. The future without-project condition is the most likely condition to exist in the future in the absence of a proposed Federal water resource project. Proper definition and forecast of the future without-project condition are critical to the success of the planning process. The future without-project condition constitutes the benchmark against which plans are evaluated.

Typically a water resources evaluation by the Corps will consider only one without-project condition and as many with-project conditions as are necessary to evaluate the various alternatives proposed for potential implementation. Because the Chloride Control Project has been partially implemented and there are recommendations to complete Wichita River Basin features, the definition of conditions in the Area VI Reevaluation was expanded to anticipate "what-if" questions about the future without- and with-project conditions. The Reevaluation presents three without project conditions and four with-project conditions.

The without-project conditions consist of one necessary baseline scenario that assumes no chloride control features would ever be (or had ever been) constructed, and two optional conditions based on (1) completed chloride control features and (2) completed features plus features expected to be completed in the near future.

FSM Notes

Without-project conditions are described in this FSM version of the Area VI Reevaluation. Those conditions include historic, current, and forecast conditions.

With-project conditions and evaluations will be added in a future Alternative Formulation Briefing (AFB) version of the Reevaluation.

The four with-project conditions will include the construction of Area VI, and also include combinations of completed chloride control features or features expected to be completed in the near future. Two of the with-project conditions include a potential fresh water reservoir on the North Fork of the Elm Fork of the Red River. The reservoir was identified by the Bureau of Reclamation as a potential regional resource for water supply, if the natural chlorides were not present in such high concentrations. The natural chlorides are largely contributed by Area VI. This reservoir, Cable Mountain Reservoir, would not be feasible as a fresh water resource due to the existing chloride loads in the North Fork. Therefore, the Bureau would not consider constructing the dam and reservoir project until the chloride load was reduced. If the Area VI chloride control feature was implemented, the chloride load would be reduced by about 80%, making the reservoir feasible as a fresh water resource. The with-project conditions considered in this Area VI Reevaluation that include the reservoir would incorporate estimates of both the benefits and impacts of constructing the reservoir within the overall economic, social, and environmental evaluations. Another way of saying that is that this Reevaluation would consider the estimated costs and benefits of the reservoir, even though it would potentially be constructed by the Bureau, and constructed only after the Bureau was satisfied that the Area VI chloride control feature was functioning as expected.

Many factors define with- and without-project conditions. Regional water supply sources, agriculture irrigation practices, farm budgets, population projections, municipal and industrial water use, regional recreation, and environmental changes are just some of the general categories. The following descriptions of different aspects of existing conditions were identified as relevant to the problems and evaluations of potential water resources projects.

Problems and Opportunities

The following description of existing conditions provides the foundation for the identification of problems and opportunities. Forecast conditions described later in the Reevaluation will complete the information necessary for the appropriate identification of problems and opportunities expected during the period of analysis. The future without-project condition provides the basis from which alternative plans are formulated and impacts are assessed.

Existing Conditions

The previous discussion of existing water projects generally describes the existing physical man-made features in the study area. The following section describes events leading to the current study (the Area VI Feature Reevaluation) to provide an understanding of why the chloride control project came to exist and why it hasn't been completed. A great deal of data gathering and scientific investigation was conducted for the evaluation and design of the authorized chloride control project and in preparation of the environmental document discussed below.

National Environmental Policy Act Documentation.

A Final Environmental Statement (FES) for the Red River Chloride Control Project, dated July 1976, was prepared, distributed for agency and public review, and filed with the Environmental Protection Agency (EPA) on May 18, 1977.

In 1994, due to the length of time between filing the 1976 FES for the Red River Chloride Control Project, initiation of construction of the project, and changes in study area conditions as well as in project design, a Supplement to the 1976 FES was required to comply with the intent of the National Environmental Policy Act (NEPA).

Subsequently, a Notice of Intent to prepare a supplement to the FES was published in the Federal Register on April 12, 1994. A Draft Supplement to the FES (DSFES) was prepared and released for public review on April 27, 1995. However, due to geographic shifts in water demand projections, potential impacts upon environmentally sensitive areas along the Red and Pease Rivers, and potential impacts to fish and wildlife species habitat, the Final SFES was never coordinated or filed with the EPA. The District elected to tie the June 2002 DSFES to the 1976 FES.

A Notice of Intent to prepare the Wichita River supplement to the FES was published in the Federal Register on July 22, 1998. Two public information scoping workshops were held by the

In 1976, the terminology in use was Environmental Statement. A final environmental statement was abbreviated as an FES – not the current terminology of environmental impact statement (EIS) or FEIS.

That is why the NEPA document prepared for the Wichita River Basin Reevaluation was a Supplement to the FES for the Red River Chloride Control Project FES.

Similarly, the NEPA document that will be prepared for the Area VI Reevaluation will be a Supplement to the Red River Chloride Control Project FES.

Corps on December 9 and 16, 1998 in Wichita Falls, Texas and Durant, Oklahoma, respectively. The Corps published a Draft SFES in June 2002 which was open for public comment for 90 days (initial 45 days plus two extensions). Approximately one-quarter way through the comment period, two public workshops were advertised and held to solicit additional input with regard to the draft document and proposed plan. The final SFES was published in April 2003. Following public and agency input and comment, the Record of Decision (ROD) was signed by the Director of Civil Works on March 5, 2004.

Issue Resolution Efforts.

In 1994, the Corps suspended construction of the Red River Chloride Control Project due to concerns expressed by the USFWS, the ODWC, and the TPWD and what they thought would result from construction of the chloride control project. The Corps had completed three of the authorized chloride control features - Area V (Estelline Springs) in 1964, Truscott Brine Lake in 1982, and Area VIII in 1986. Brine collection site Area X was under construction at the time. The Corps evaluated each concern by conducting detailed studies. The concerns were not based on studies conducted by those agencies or any relevant investigation; and the Corps found no scientific evidence to support the concerns. However, the resource agencies continued to reiterate the same concerns.

The Corps elected to resolve the issues through an environmental issue resolution process (EIRP). The Corps initiated the EIRP discussions in December 1995 to resolve differences of opinions of the resource agencies concerns versus the evaluation of data and system models that had been prepared by the Corps in the evaluation of the Red River Chloride Control Project.

The EIRP discussions included several working sessions and spanned from December 1995 to July 1996. The initial purpose of the EIRP was not successful. None of the issues were resolved. However, a process was defined by the three resource agencies whereby environmental monitoring by the Corps would occur for those Red River Chloride Control Project features that had been constructed or would be constructed in the future. The purpose of monitoring was to determine the actual effects of existing and future operating chloride control components on the environment. Many of the monitoring components included continuation of data gathering

Achieving environmentally sustainable solutions requires collaboration among Federal, State, and local government agencies, and non-governmental organizations. Above all, Corps efforts focus on identification of reasonable and innovative alternatives and objective evaluation to achieve sustainable solutions.

Collaboration with other agencies, stakeholders, and citizen groups is essential to ensure that Federal decisions consider the full range of consequences of actions.

The Corps works to foster cooperation and build teams with other agencies; to confront and resolve both technical and social conflicts between those agencies; and, finally, to develop information in support of decisions. Individuals and organizations may have different mental models of the environmental issues the Nation faces. Such individuals and organizations often have significant insights to contribute to the potential environmental solutions the Corps evaluates. The Corps encourages this type of dialogue and listens to what citizens and organizations have to say.

already being conducted by the Corps. Other components would require collections of new data sources and would involve intensive initial data gathering (to establish a baseline) and then later periodic updates (to identify trends of change).

The monitoring was specified in an environmental operational plan (EOP) to be funded and conducted by the Corps for the entire Red River Chloride Control Project. (The Corps has continued to honor the agreements of the EIRP and has conducted monitoring when funding has been available.) The purpose of the data collection was to demonstrate through empirical evidence of existing conditions (without chloride control) to compare to forecast conditions (with chloride control) in the Wichita River Basin. The Wichita River Basin was viewed as a test case to gauge the merits and potential impacts of chloride control. The potential impacts related to the environment for aquatic species in the Wichita Basin tributaries below the three brine collection areas and the economy for sport fishing (general non-native striped bass) at Lake Texoma. The data collection was also seen as an opportunity to provide for chloride control operational adjustments, if required, to minimize or avoid unforeseen impacts. The Corps assisted in development of the EOP for the Red River Chloride Control Project with the expectation that the USFWS, TPWD, and ODWC would support completion of construction. The concept of completing construction within the Wichita Basin as a test case was generally understood in the 1996-1997 time frame and was documented in at least one case.

While the concerns of the agencies were not revised during the EIRP in light of scientific evidence, model forecasts, or the professional assessment of the Corps' engineers and other scientists, the transformation of the EIRP into an initiative to define long-term monitoring provided valuable information for later chloride control evaluations – initially the Wichita River Basin Reevaluation completed in 2003 and the Area VI feature Reevaluation (this report).

The Corps followed the EOP with the expectation that the three agencies that helped to prepare it would support completion of construction within the Wichita Basin to allow for the collection of with-project empirical data. In a 1997 letter, the TPWD indicated that they would have no objection to the Corps completing construction of the chloride control features within the Wichita River Basin as a test case, provided that adequate monitoring was included. That expectation was not realized. The Corps has been operating under the applicable components of the EOP since it was developed. However, contrary to the TPWD position in 1997, when the Wichita River Basin Reevaluation was underway from 1997 to 2003, the agency raised (re-raised) numerous objections to the project. The Corps addressed each objection of the TPWD (and the USFWS and ODWC) with the benefit of additional data and modeling. The Corps ultimately concluded that implementation of the Wichita Basin chloride control features or the overall Red River Chloride Control Project would have no significant social, economic, or environmental impacts.

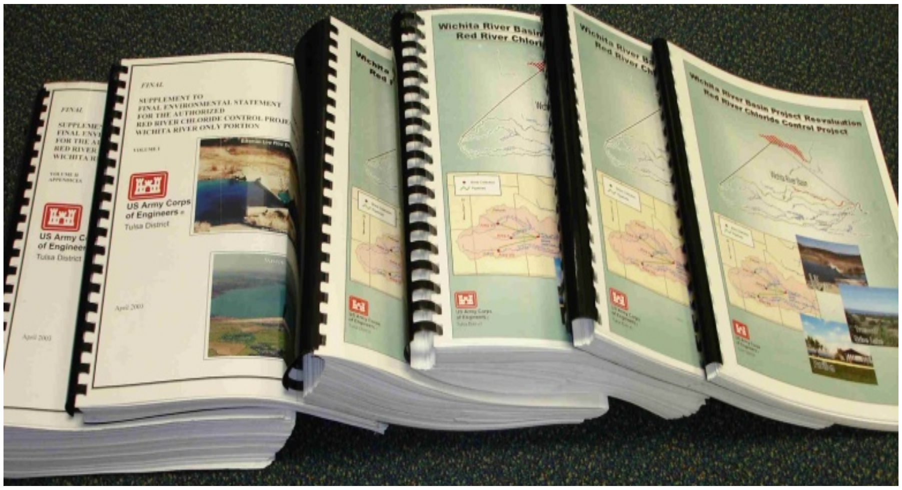
The Assistant Secretary of the Army for Civil Works, ASA (CW), approved of the approach to complete the Wichita Basin features. But the economic viability needed to be confirmed for controlling the remaining two Wichita Basin areas independent of the overall Red River Chloride Control Project consisting of seven brine control areas. To address that concern, the ASA (CW) directed an initial review, then a thorough reevaluation of chloride control for those features within the Wichita River Basin. The reevaluation was to reexamine all data, assumptions, methodologies, and conclusions and was not to be constrained to the previously recommended or authorized chloride control plan. The agencies position was not swayed by the technical and scientific body of data and information.

From 1994 when construction was stopped until 2002, additional data were gathered and new monitoring activities and studies (recommended by the EIRP work groups) were conducted as specified by the EOP for the Wichita River Basin features. All the additional data were used in the Wichita River Basin Reevaluation study. This significantly expanded and confirmed the Corps' understanding of the environmental effects of chloride control. Some earlier preliminary study findings were replaced by the later more thorough investigations. The Wichita River Basin Reevaluation did not address the overall Red River Chloride Control Project economic issues but did evaluate cumulative environmental impacts of operating chloride control features of the Red River Chloride Control Project. As directed by the ASA (CW), the Reevaluation addressed the chloride control features within the Wichita River Basin. The recommendations contained in the Wichita River Basin Reevaluation did not change the general scope of the Red River Chloride Control Project authorized by Congress. The recommended change was to pump brine from Area VII to the Truscott Brine Lake and to add evaporation fields at the intake and discharge points of Areas VII, VIII, and X to offset the additional volume in the brine lake.

All potential chloride control issues and environmental effects were reassessed that related to the chloride control features in the Wichita River Basin Reevaluation and NEPA studies. These issues included potential related issues downstream along the Red River and at Lake Texoma. The Corps' earlier conclusions of potential, but minor, adverse effects were generally verified. However, during the Wichita River Basin Reevaluation the Corps found that some of the effects previously identified and reported had been overstated – in other words, the previous estimates of potential minor effects were reassessed using state of the art evaluation techniques and were found to have less risk of occurring. The proposed plan for the Wichita River Basin was found to be economically viable and would minimize environmental impacts. By completing the Wichita River Basin features authorized for construction by Congress, the project would provide environmental, agricultural, municipal, and industrial water use benefits. The plan for implementation of the Wichita River Basin features, when evaluated with existing Red River Basin Chloride Control Project mitigation, would fully mitigate the construction impacts to terrestrial habitat – generally noxious mesquite and juniper. The only other mitigation measure would be to provide fish habitat in Lake Kemp as it partially transitions from an interim State sport fishing resource to its constructed purpose of a State water supply resource. Environmentally sensitive design of chloride control features would otherwise (a) avoid environmental impacts or (b) minimize potential environmental impacts to such a low level that measurement of effects would be realistically impossible.

However, in 2002, following coordination of the scientific evaluations presented in the Corps' Wichita River Basin Reevaluation and NEPA studies (shown below), the USFWS (with the concurrence of the ODWC) concluded that in their opinion the Wichita Basin features would result in significant impacts and that the Wichita Basin features should not be implemented due to unmitigable impacts to important fish and wildlife resources; and that other alternatives should be incorporated into a limited project.

The agencies' positions were summarized in 15 recommendations applicable to the Wichita River Basin Reevaluation. The USFWS and ODWC opinions were again discussed and readdressed in the Corps' *Supplement to the Final Environmental Statement for the Authorized Red River Chloride Control Project Wichita River Only Portion)*. While the resource agencies continued to voice their concerns, those concerns were not based on scientifically supported data, models, or conclusions.



What is important here is:

The only scientifically supported data, models, and conclusions relevant to the Wichita River Basin Reevaluation were funded and prepared by the Corps.

That information was provided to the resources agencies and their concerns were addressed numerous times throughout the Reevaluation study process.

The resource agencies continued to expresses their concerns, in spite of the thorough investigations and the body of information developed by the Corps.

FSM Notes

"The purpose of the FSM is to bring the vertical team, the non-Federal sponsor, and resource agencies together to agree on the problems and solutions to be investigated and the scope of analyses required. An FSM will address the problems, opportunities, and needs; refine study constraints; identify the key alternatives; and further define the scope, depth, and methods of analyses required." ER 1105-2-100

Because the feasibility scoping meeting (FSM) is focused on Step 1 - Identifying Problems and Opportunities and Step 2 – Inventory and Forecast, the documentation of those two steps has not been summarized. A summary of the efforts to fulfill those planning steps, immediately followed by detailed discussion in appendices, would not have added value to the FSM documentation – only bulk.

"The purpose of the AFB is to ensure that plans have been properly formulated, legal and policy issues have been identified and a consensus on resolution has been reached, and the MSC concurs with the plan that will likely proceed into the design and implementation phase." ER 1105-2-100

When the AFB documentation is prepared, the following discussions of conditions will be summarized within the main report and the detailed information will be organized in appendices.

Inventory of Existing and Forecast Conditions.

The following sections present the socioeconomic, municipal and industrial water supply, Lake Texoma recreation, environmental, and hydrologic conditions that have been identified to be necessary for a scientific evaluation of the potential impacts and impacts of Area VI chloride control.

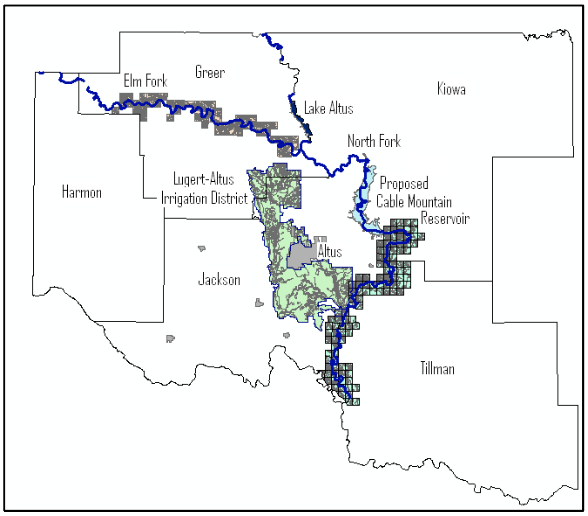
Socioeconomic Conditions.

The waters of the upper Red River tributaries are an important resource for Texas and Oklahoma. They provide an important water supply resource for the Dallas-Fort Worth Metropolitan area, the fourth largest Metropolitan area in the United States. These waters could potentially provide water supply for smaller municipalities in Oklahoma. Agriculture in southwest Oklahoma is to a large degree dependent on the tributaries of the Red River in Oklahoma and the associated alluvial ground water. The economies of the state and nearby communities have close ties to production associated with irrigated agriculture. The waters of the Red River also provide a major recreational resource for the region and the nation. Lake Texoma, on the main stem of the River, provides water based recreation for over six million visitors each year, supporting a sports fishery that generates income for the region's economy. The future conditions of the waters of the Red River will remain an important resource.

The following sections address the existing and future without-project conditions for agriculture, municipal and industrial water supply, and recreation as related to the Red River. The section on agricultural conditions describes irrigation practices in southwest Oklahoma and how such practices are related to production. The section on municipal and industrial water supply will focus on uses of Lake Texoma and use of the waters of the Elm Fork of the Red River. Lastly the section on recreation will focus on one component the striped bass fishery in Lake Texoma, as it has been a concern of local stakeholders and natural resource managers. The sections provide a background on the potential value of the Red River resource to irrigation, water supply, and recreation.

Background.

Southwest Oklahoma is an important agricultural production center and contributes to the national economy. The area produces wheat, cotton, alfalfa, and other crops that are consumed throughout the United States and the globe. According to the US Department of Agriculture counties in southwest Oklahoma produce over 85% of the cotton produced in Oklahoma and account for about 2 percent of the total production of cotton in the United States. Source: http://www.nass.usda.gov/Statistics_by_State/Oklahoma/Publications/Oklahoma_Crop_Reports/2011/ok_cotton_review_2011.pdf. Much of cotton grown in southwest Oklahoma uses the Elm Fork of the North Fork of the Red River for irrigation. The key element to the area reaching its potential to become an even more important player in the production of agriculture is the availability of quality water. While both alluvial and stream waters in the area provide irrigation for crop production, its use is limited because of the high salt content, especially on the Elm Fork of the Red River and associated alluvial aquifers. Tributaries of the Elm Fork have high chloride levels, limiting the use of Elm Fork for irrigation. The alluvial aquifer along the Elm Fork is recharged from stream flows which are high in chloride content, which limits irrigation from the aquifer and suppresses crop yields. Crop yields from land irrigated with alluvial and stream waters of the Elm Fork are limited because of high salt content. Irrigation from these sources results in chlorides accumulating in the soils on irrigated lands. Farmers manage flushing of soils of salt by temporarily ceasing irrigation and allowing rainfall to percolate through the soils carrying chlorides



below the crops root zone. Essentially, this practice leaves thousands of acres idle each year.

As a result of the presence of chlorides in the Elm Fork and the effect it has on crop production in the state of Oklahoma, the Oklahoma State University Department of Agricultural Economics and the Altus Experiment Station have evaluated the effects of salts and chlorides on farm practices in the area. The evaluation was performed in three phases. The first phase was to take soil samples in potentially irrigable land areas and determine their soil characteristics. This helped in indentifying which crops would grow in the area. The second phase was to gather the existing conditions and conduct a literature review. GIS layers were made for soil types, land use and land cover, elevation, and study location. Soil types were used in the first phase to classify agriculture land that could be farmed. Land use was evaluated to find and identify the changes in land use in the study area. Elevation was considered to identify agricultural areas suitable for pumping irrigation water. A literature review was performed to identify the best approach to modeling the impacts of salinity on crop yields. Historical crop and agricultural data was collected to find the historical and current farm practices in the area. Crop budgets have been developed for the main crops and show the different costs associated with each crop. These budgets provide the basis for updating cost and return information. Machinery cost estimates will be adjusted to the average farm size. The Soil and Water Assessment Tool model (SWAT), has been calibrated with existing information from phase one of the study. The SWAT model is a river basin model developed to quantify the impacts of land management practices in watersheds. These crop budgets will then be used in the benefit evaluation part of the agriculture evaluation of this analysis. The General Algebraic Modeling System (GAMS) will be used to help determine the net agricultural benefits. The effects of agricultural production will be differentiated by soil type, dryland or irrigated production, method of irrigation, and crop type and crop response to salinity. Different alternatives will be compared and net benefits for each alternative will be calculated.

The agricultural analysis includes five counties in southwest Oklahoma. The agricultural study area is shown in the figure.

MODEL REVIEW

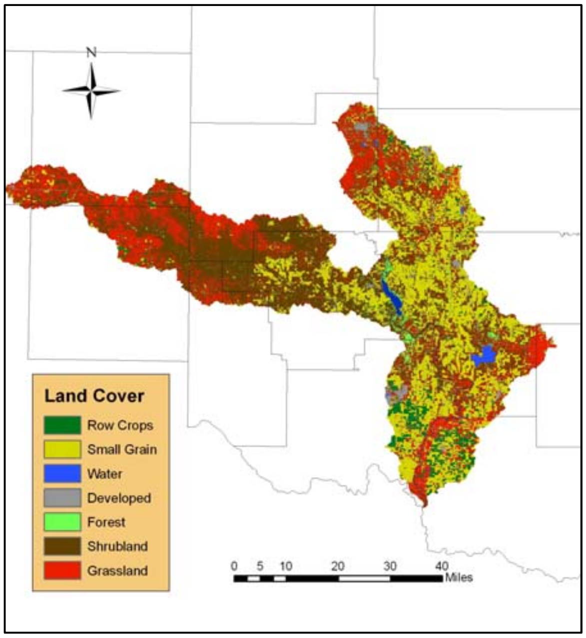
The use of certified or approved models for all planning activities is required by EC 1105-2-407. The goal of certification/approval is to establish that planning products are theroetically sound, compliant with USACE policy, computationally accurate, and based on reasonable assumptions. The following models will be used in the agiculture evaluation of Area VI: Soil and Water Assessment Tool (SWAT), Environmental Policy Integrated Climate Model (EPIC) and Agricultural Policy Extender (APEX); and the General Algebraic Model System (GAMS).

SWAT: This model was developed by the USDA and is widely applied. This model will be used to determine which areas are are effected down stream of the chloride soucres for with project conditions.

EPIC/ APEX: EPIC was developed by USDA and Texas A&M. It will be used to assess the effects of soil eroison on productivity and water quality. APEX is an extension of EPIC developed by Blacklands Research Center at Texas A&M. APEX is a tool that is capable of simulationg a wide array of managemnt practices, cropping systems, and other land use across a broad range of aricultural landscapes.

GAMS: This model is used for determining the maximum net agricultural benefits and costs assoicated with aricultural use of waters from the study area.

Land Cover

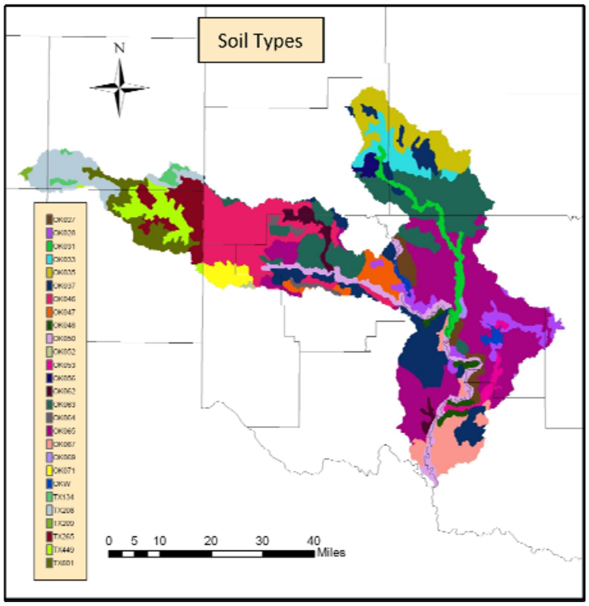


Land cover data were collected from http://datagateway.nrcs.usda.gov. The 30-meter USDA/NRCS NASS (National Agricultural Statistics Survey) cropland data were chosen over NLCD (National Land Cover Dataset) data because the NLCD data combines all crops into one category. Row crops and small grain crops were needed in two categories for an effective evaluation. Canola, other small grains, rye, oats, and alfalfa had a total percentage of 1.02 and were combined with wheat in the small grain category. Soybeans, corn, sorghum, peanuts, peas, and herbs had a total percentage of 1.06 and were combined with cotton in the row crops category. Barren land and fallow/idle crops (0.60 percent) were consolidated with shrubland. Developed low, medium, and high intensity (0.70 percent) were consolidated with developed-open space. Other tree nuts, deciduous forest, evergreen forest, and woody wetlands (0.47 percent) were consolidated with mixed forests. Pasture/hay and seed/sod grass (0.02 percent) were consolidated with grassland herbaceous for the final category. Row crops were then divided into irrigated and non-irrigated lands. Fifty-three percent of the row crops were calculated as non-irrigated and 47 percent as irrigated.

- Row Crops (3.8%)
    - Non-Irrigated (2.0%)
    - Irrigated (1.8%)
- Small Grain Crops (27.1%)
- Shrubland (37.4%)
- Developed Land (4.5%)
- Forest (2.1%)
- Grassland (24.4%)
- Water (0.7%)

Soil Types

State Soil Geographic Database (STATSGO) was used to determine the soil layers in the study area. Soil data was downloaded from http://soildatamart.nrcs.usda.gov/ and used for identifying the different types of soils.



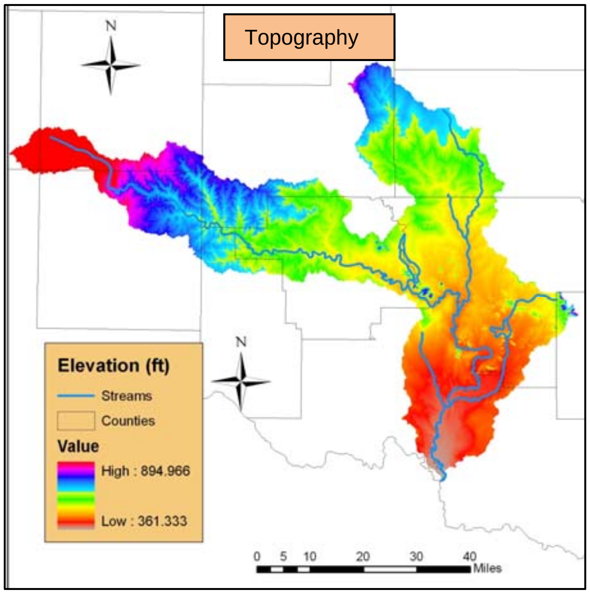


Figure 3 – Digital Elevation Grids

Topography

Topography was defined by a digital elevation grid (Figure 3). Seamless elevation grids were downloaded from the USGS Seamless Data Distribution System (http://seamless.usgs.gov/). A 10-meter digital elevation model (DEM) was used in this study, which was a higher resolution than the common 30-meter DEM. The high resolution DEM was used to calculate slope, length, and to define the stream network. The resulting stream network was used to define the layout of the subbasins.

Irrigation Water Demand

Water Demand information related to agriculture was taken from the Oklahoma Comprehensive Water Plan. The Water Plan divided the agriculture study area into two regions: Southwest Region and Beaver-Cache Region. Existing demand in the Southwest Region is 158,760 acre-feet per year for crop irrigation and 3,660 acre-feet per year for livestock. Existing demand in the Beaver-Cache Region for crop irrigation is 12,390 acre feet per year and 3,910 acre feet per year for livestock.

Historical Acres

Historical planting conditions provided a projection of crop type and location in the study area by county. It also provided a guideline of future cropping practices in the study area. Table 1 shows the study area had on average 1.2 million acres of planted crop land from 1966-2005. The major crop in terms of planted acres in all counties is wheat followed by cotton, other hay, with smaller acreages of alfalfa and sorghum.

Table 1- Average Acres Planted by Crop by County

	Crop Acres Planted					
County	Alfalfa	Cotton	Other Hay	Sorghum	Wheat	Total
Harmon	3,528	30,050	8,892	8,440	95,440	146,350
Greer	7,873	19,451	14,632	3,980	102,993	148,929
Jackson	5,605	46,833	15,027	10,340	228,668	306,473
Kiowa	7,408	39,899	18,294	6,413	259,320	331,334
Tillman	11,880	86,896	21,121	8,803	196,100	324,800
Total	36,294	223,129	77,966	37,976	882,521	1,257,886

NASS (National Agricultural Statistics Service) county level statistics on irrigated and dryland crops were not available before 1972. Separate data for irrigated and dryland production were not available by county for hay crops. In the sections below the trends are examined crop by crop. For each crop, the five-year means of total planted acres, total harvested acres, and total production are presented.

Wheat Area Harvested and Yields.

Figure 4 shows the mean five-year yields per harvested acre of all wheat have been increasing over the period from 1960 through 2005. The lower yields tend to be in Greer and Harmon counties while the higher yields are in Jackson, Kiowa, and Tillman counties.

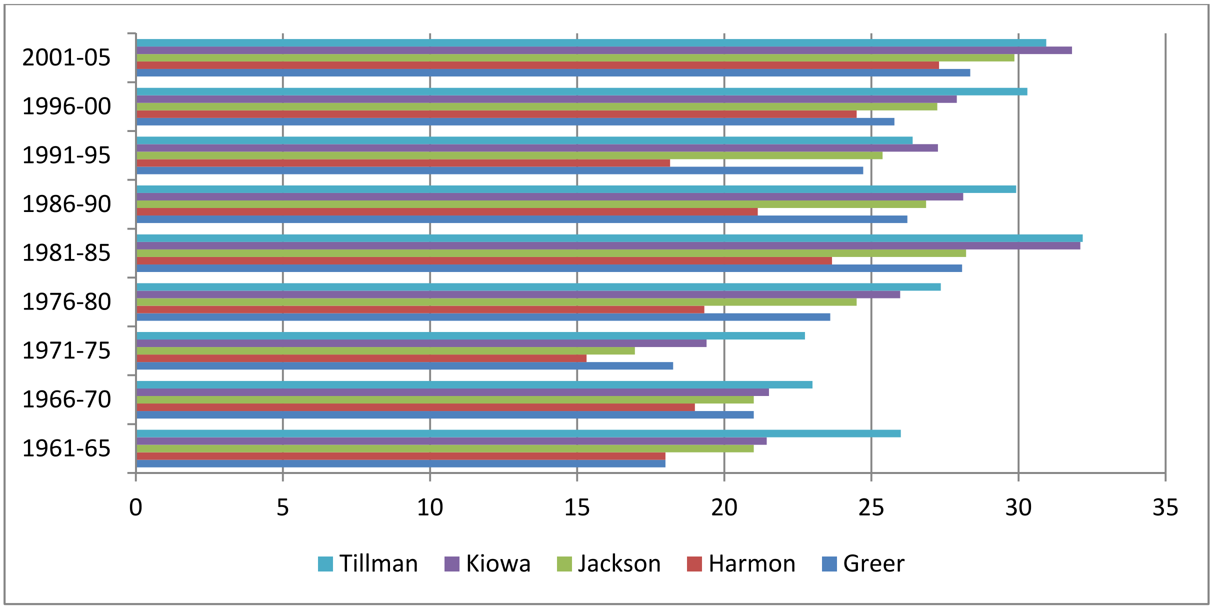


Figure 4 – Average Yields (bushels/acre) of Wheat for every 5-yr period

The five-year means for total acres planted and harvested are shown in Table 2. Kiowa County has the largest area planted to wheat of the five counties followed by Jackson and Tillman. With the exception of Kiowa County, the number of harvested acres of wheat increased from 1960 through 1985 and then declined from 1986-2005. In Kiowa County, the increase in harvested acres remained fairly steady through the 1986-2005. Kiowa County currently leads the other four counties in total acres harvested acres of wheat.

Table 2 – Average Harvested Acres and Yields (bushels/acre) of Wheat for Every 5-yr Period

Average Harvested Acres							Average yield (bus/ac)				
Years	Greer	Harmon	Jackson	Kiowa	Tillman	Total	Greer	Harmon	Jackson	Kiowa	Tillman
1960-65	53,200	48,380	116,680	7,460	152,900	378,620	18	18	21	21	26
1966-70	66,360	49,540	138,440	8,240	172,060	434,640	21	19	21	22	23
1971-75	67,140	62,600	147,520	197,680	178,280	653,220	18	15	17	19	23
1976-80	91,000	88,320	221,800	243,600	202,400	847,120	24	19	25	26	27
1981-85	99,000	83,800	207,200	211,600	152,600	754,200	28	24	28	32	32
1986-90	77,000	60,000	180,000	201,000	128,000	646,000	26	21	27	28	30
1991-95	77,380	67,100	190,400	214,800	133,400	683,080	25	18	25	27	26
1996-00	76,000	41,600	151,000	215,000	156,000	639,600	26	25	27	28	30
2001-05	67,000	37,600	149,000	208,000	125,000	586,600	28	27	30	32	31

Source: National Agricultural Statistics Service (NASS), USDA.

Dryland Wheat Yields and Area Harvested by County

Yields of dryland (non-irrigated) wheat are shown in Figure 5 along with acres harvested in Table 3. The dryland wheat yields in all counties are generally increasing over the 1971-2005.

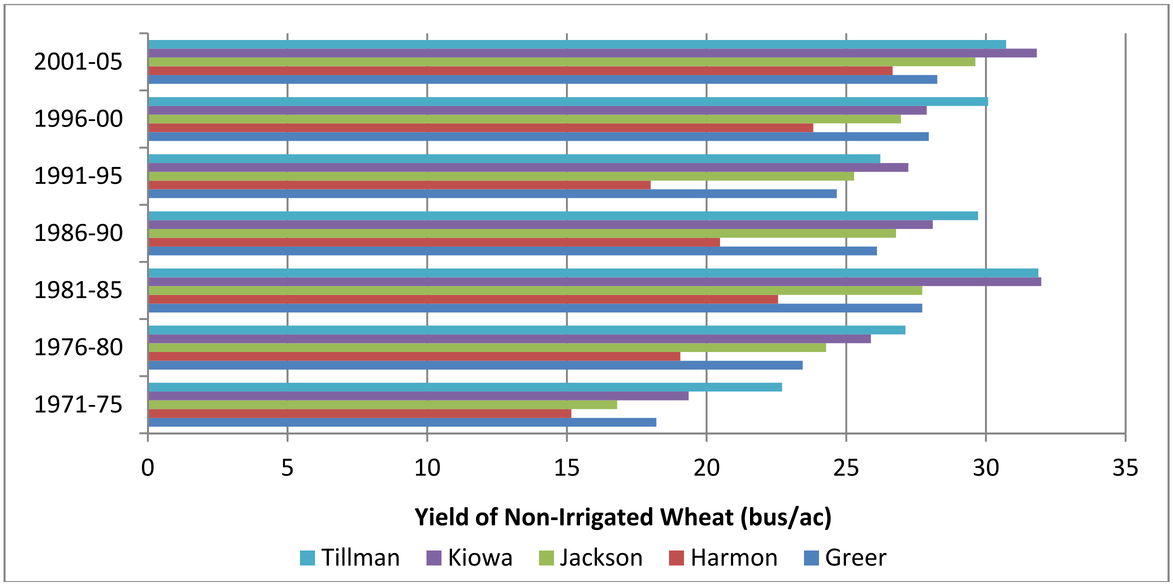


Figure 5 – Yields of Non-Irrigated Wheat by County by Five-Year Periods from 1971 to 2005

Table 3 – Average Harvested Acres and Yields of Non-Irrigated Wheat by County by 5-Year period from 1971 to 2005

Average Harvested Acres of Wheat (non-irrigated)							Average dryland wheat yield (bus/ac)				
Year	Greer	Harmon	Jackson	Kiowa	Tillman	Total	Greer	Harmon	Jackson	Kiowa	Tillman
1971-75	66,648	61,888	144,162	196,680	175,640	645,018	18	15	17	19	23
1976-80	89,880	87,100	217,020	241,820	198,340	834,160	23	19	24	26	27
1981-85	96,980	79,400	201,700	210,220	150,120	738,420	28	23	28	32	32
1986-90	75,760	57,180	177,120	199,860	126,080	636,000	26	20	27	28	30
1991-95	77,200	66,600	189,340	214,630	131,760	679,530	25	18	25	27	26
1996-00	74,620	39,660	147,740	214,890	153,640	630,550	28	24	27	28	30
2001-05	66,660	36,120	146,360	208,000	123,080	580,220	28	27	30	32	31

Source: National Agricultural Statistics Service (NASS), USDA.

Irrigated Wheat Yields and Acres Harvested by County

The peak in acres harvested was reached in the 1976-1980 period. While the number of harvested acres has declined since 1980, the average yields have continued to increase. The mean yield of irrigated wheat by five-year periods from 1973 through 2005 are shown in Figure

6 and Table 4 below. As shown in Figure 6, irrigated wheat yields increased in all counties from 1970-1990. The yield increase continued from 1991 through 2005 in Tillman and Jackson counties but declined in Greer and Kiowa counties. The harvested acreage of irrigated wheat also declined in these same counties and no irrigated wheat production was reported in Kiowa county after the year 2000. Tillman County has shown the highest average irrigated yield over the time followed by Jackson County. .

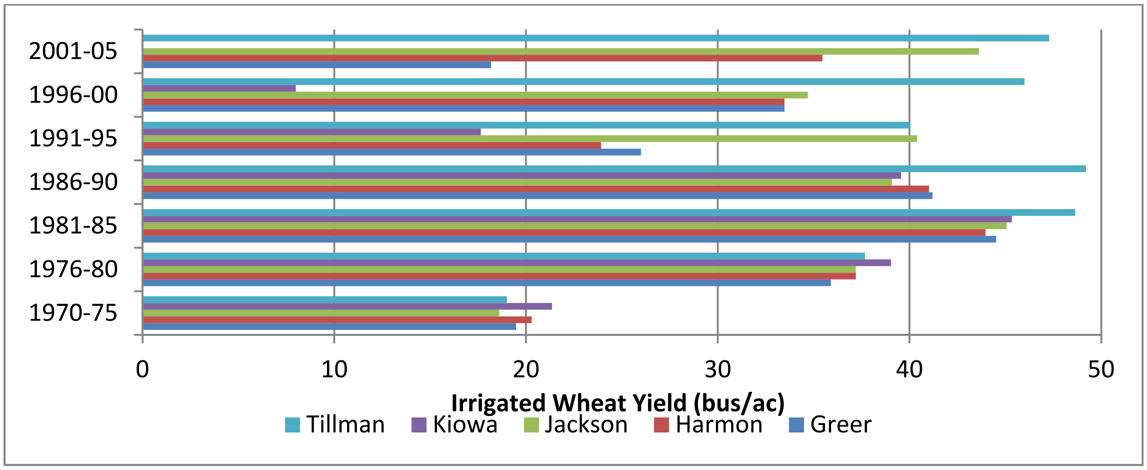


Figure 6 – Average Yields (bushel/acre) for Irrigated Wheat by Five year periods by county

Table 4 indicates the area planted to irrigated wheat for all five counties never exceeded 16,000 acres and declined to as few as 3,500 acres in the five year periods between 1971 through 2005. Jackson County had the largest area planted to irrigated wheat of any of the five counties. The harvested acres of irrigated wheat peaked during the 1985 period and have decreased since that period.

Table 4 – Harvested Acres and Yields of Irrigated Wheat for Each 5-year Period by County

Average harvested acres of Wheat (Irrigated)							Irrigated Wheat: Ave. Yield (bus/ac)				
Years	Greer	Harmon	Jackson	Kiowa	Tillman	Total	Greer	Harmon	Jackson	Kiowa	Tillman
1971-75	492	712	3,358	1,000	2,640	8,202	19	20	19	21	19
1976-80	1,120	1,220	4,780	1,780	4,060	12,960	36	37	37	39	38
1981-85	2,020	4,400	5,500	1,380	2,480	15,780	45	44	45	45	49
1986-90	1,240	2,820	2,880	1,140	1,920	10,000	41	41	39	40	49
1991-95	180	500	1,060	170	1,640	3,550	26	24	40	18	40
1996-00	1,380	1,940	3,260	110	2,360	9,050	33	33	35	8	46
2001-05	340	1,480	2,640	-	1,920	6,380	18	35	44	0	47

Source: National Agricultural Statistics Service (NASS), USDA

Total Cotton Area Harvested and Yields.

Figure 7 shows average yields of cotton by five-year intervals from 1960 through 2005.

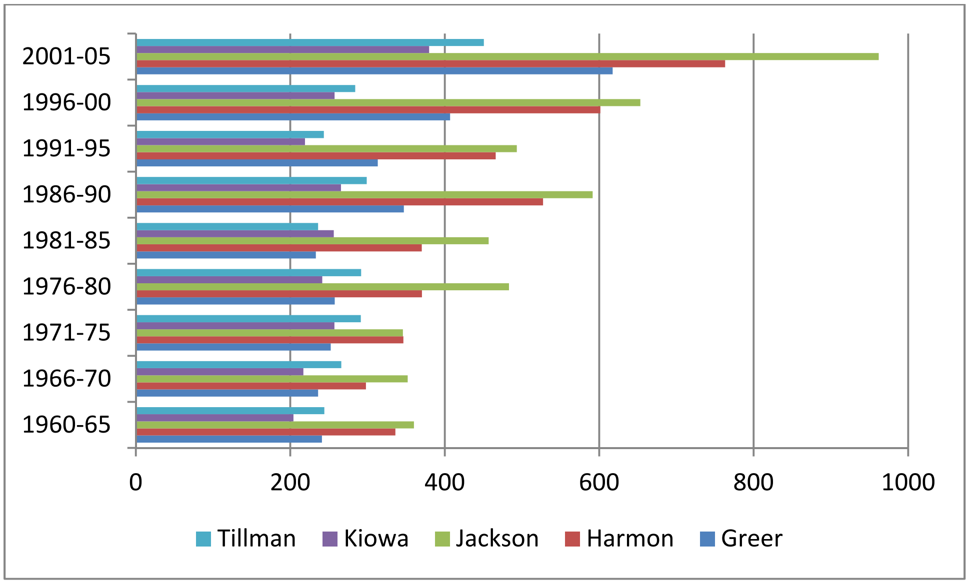


Figure 7 – Average Yields in Five-Year periods of All Cotton by County from 1960-2005

Table 5 presents average acres and yields of cotton by county and period. Total harvested acres of cotton peaked between 1971 to 1975 at nearly 282 thousand acres and declined to 143 thousand acres in the 2001 to 2005 period. Irrigated acres harvested have remained in the 50 thousand acre range. Irrigated acres in Tillman County have varied between 25,000 to 110,000 acres. Kiowa, Greer and Harmon counties have seen average number of acres decrease in last 20 years.

Table 5 – Average County Acres and Yields of Cotton for each Period by County

Average harvested acres of Cotton							Cotton: Ave. Yields (lbs/acre)				
Years	Greer	Harmon	Jackson	Kiowa	Tillman	Total	Greer	Harmon	Jackson	Kiowa	Tillman
1960-65	34,320	39,980	52,800	47,120	67,320	241,540	241	336	360	204	244
1966-70	22,142	25,970	34,794	32,946	49,922	165,774	236	298	352	217	266
1971-75	29,474	30,350	46,830	50,074	58,840	215,568	252	346	346	257	291
1976-80	28,480	35,100	54,280	56,000	108,020	281,880	258	370	483	241	292
1981-85	21,420	28,840	51,520	48,220	115,350	265,350	233	370	457	256	236
1986-90	16,350	24,560	50,680	43,350	107,220	242,160	347	527	592	266	299
1991-95	13,940	23,720	57,240	38,,960	94,120	227,980	313	466	493	219	243
1996-00	5,000	19,500	52,800	13740	25,300	116,340	407	601	653	257	284
2001-05	5,120	20,240	55,800	7,240	54,900	143,300	617	763	962	380	451

Source: National Agricultural Statistics Service (NASS), USDA.

Dryland Cotton Yields and Area Harvested by County

The county data for different counties vary vastly. The figures and tables below show the differences among the mean five-year county yields for the cotton for every five years.

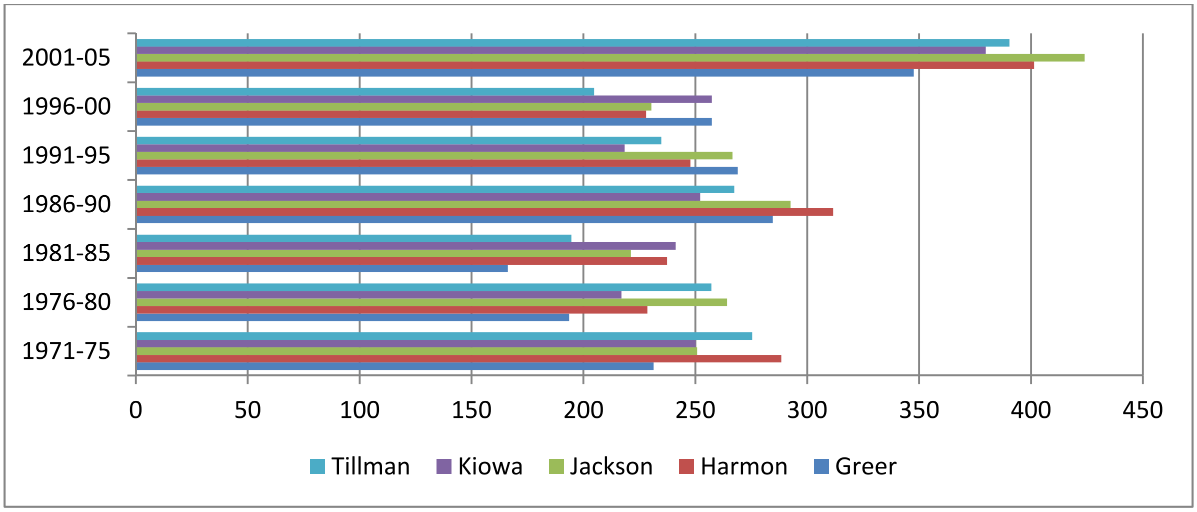


Figure 8 – Average County yields for Non-Irrigated Cotton for each 5 years.

Figure 8 shows that Jackson County has the highest average dryland yields for most periods followed by Harmon County. There has been a large increase in dryland cotton yields in the period from 2001 -2005. However, Table 6 indicates there is general downward trend in the dryland cotton acreage planted during the last 10 years.

Table 6 - Average County Level Acres Harvested and Yields of Dryland Cotton from 1971 to 2005 by 5-year period by County

Average Annual Harvested Acres of Dryland Cotton							Average Yield/ Harvested Dryland Acre (lbs)				
Period	Greer	Harmon	Jackson	Kiowa	Tillman	Total	Greer	Harmon	Jackson	Kiowa	Tillman
1971-75	26,930	23,280	30,268	48,226	53,850	182,554	231	288	251	250	275
1976-80	22,380	19,180	20,060	50,780	87,990	200,390	194	229	264	217	257
1981-85	16,260	14,380	10,840	45,140	97,210	183,830	166	237	221	241	195
1986-90	12,164	7,340	5,960	40,806	91,250	157,520	285	312	293	252	267
1991-95	11,160	7,120	16,620	38,860	89,960	163,720	269	248	267	218	235
1996-00	3,220	5,500	11,180	13,740	21,080	54,720	257	228	230	257	205
2001-05	2,100	7,300	11,440	7,240	46,600	74,680	348	401	424	380	390

*Source: USDA, National Agricultural Statistics Service

Irrigated Cotton Yields and Area Harvested by County

Figure 9 shows yields of irrigated cotton have been increasing since the 1970's but show a greater increase in the 2001 to 2005 period as compared to the 1973 to 1995 period. Interviews with local farmers attributed the increase in cotton yields to eradication of the boll weevil and the adoption of genetically modified cotton varieties.

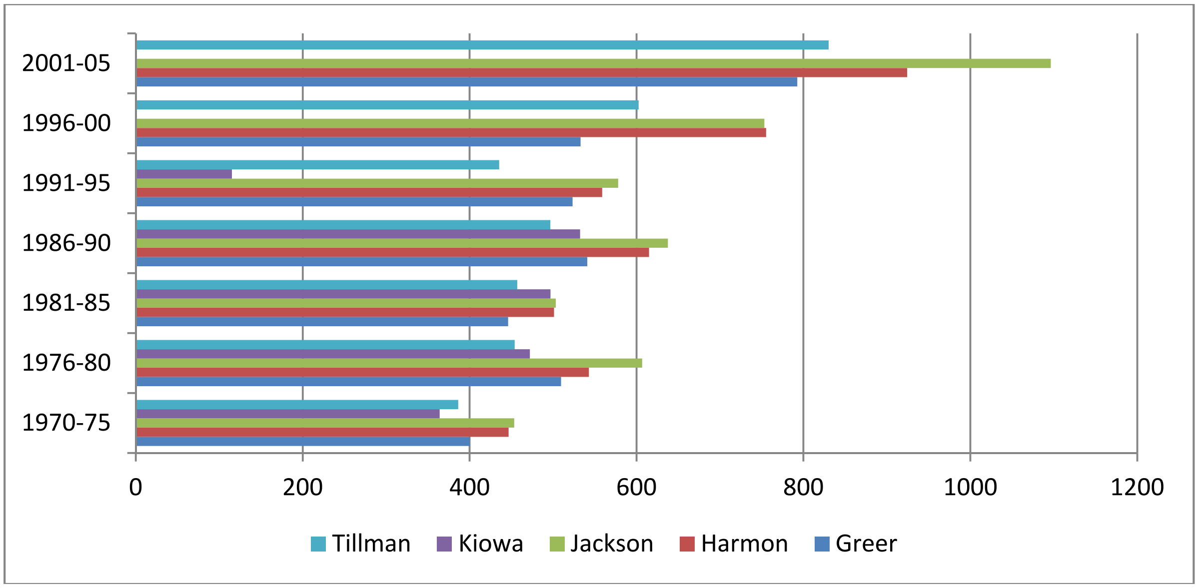


Figure 9 - Average Yields of Irrigated Cotton for every 5-yr period.

Table 7 indicates the greatest area of irrigated cotton is in Jackson County. The harvested acres of irrigated cotton have declined in Greer, Kiowa, and Tillman Counties while increasing slightly in Jackson County. Irrigated cotton was no longer reported in Kiowa County after 1996.

Table 7 - Average Harvested acres and Yields of Irrigated Cotton by County for each 5-year Period

Average harvested acres of Irrigated Cotton							Average Yields (Pounds) of Irrigated Cotton				
Period	Greer	Harmon	Jackson	Kiowa	Tillman	Total	Greer	Harmon	Jackson	Kiowa	Tillman
1971-75	2,544	7,070	16,562	1,848	4,990	33,014	400	447	453	364	386
1976-80	6,100	15,920	34,220	5,220	20,030	81,490	510	543	607	472	454
1981-85	5,160	14,460	40,680	3,080	18,140	81,520	446	501	503	497	457
1986-90	4,186	17,220	44,720	2,544	15,970	84,640	541	615	638	532	497
1991-95	2,780	16,600	40,620	100	4,160	64,260	523	559	578	115	435
1996-00	1,780	14,000	41,620	0	4,220	61,620	533	755	753	0	603
2001-05	3,020	12,940	44,360	0	8,300	68,620	793	924	1096	0	830

Source: National Agricultural Statistics Service (NASS), USDA.

A comparison between Tables 6 and 7 indicates that dry land cotton yields are about half those of the irrigated cotton.

Total Grain Sorghum Area Harvested and Yields

Average yields of all sorghum by county by five-year periods from 1971 to 2005 are shown in Figure 10 and acres harvested are presented in Table 8. There is a general upward trend in yields for all sorghum over the 1960 to 2006 period.

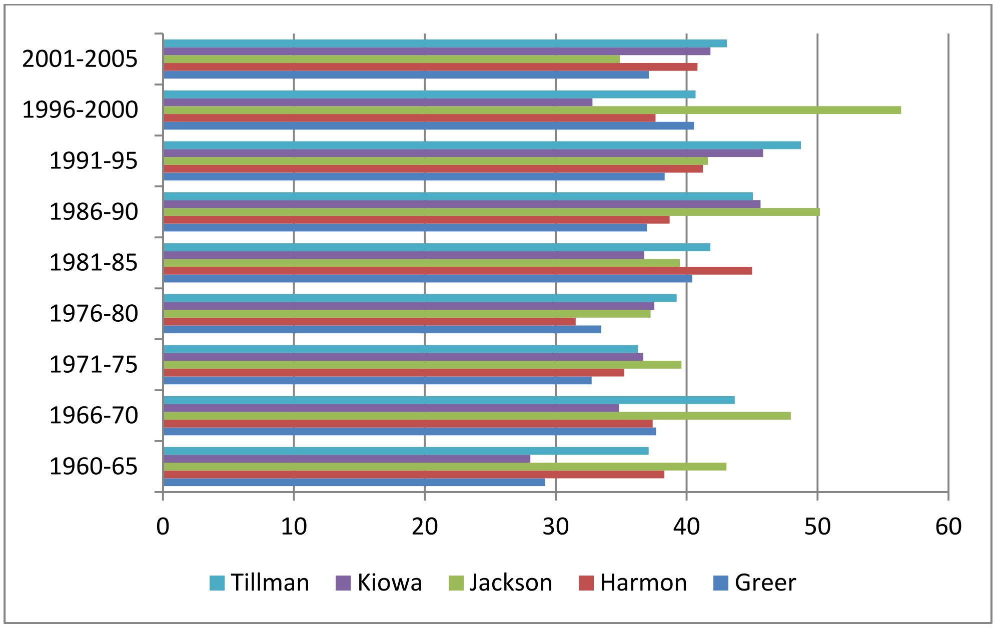


Figure 10 – Average Yields (bushel/acre) of all Sorghum by five-year period by County.

Greer County has harvested the fewest acres of grain sorghum over the last four decades. No single county dominates in terms of harvested acres. The average number of acres harvested varies from decade to decade. Although the harvested acres dropped during the 1980's and 1990's, the overall yields per acre have improved during these decades.

Table 8 - Average Harvested acres and Yields of Sorghum from 1960-2005 by 5-year Period

Average Annual Harvested Acres of Sorghum							Average Yield Per Harvested Acre (bus)				
Period	Greer	Harmon	Jackson	Kiowa	Tillman	Total	Greer	Harmon	Jackson	Kiowa	Tillman
1960-65	3,600	5,080	13,380	7,060	17,060	46,180	29	38	43	28	37
1966-70	2,380	5,160	11,120	2,240	10,580	31,480	38	37	48	35	44
1971-75	4,340	6,520	6,580	5,140	6,920	29,500	33	35	40	37	36
1976-80	1,880	3,980	4,060	4,520	4,940	19,380	33	32	37	38	39
1981-85	1,680	1,980	5,280	4,180	6,980	20,100	40	45	39	37	42
1986-90	1,340	1,560	5,260	4,500	7,180	19,840	37	39	50	46	45
1991-95	1,100	1,120	2,580	2,640	5,560	13,000	38	41	42	46	49
1996-00	1,040	8,100	12,800	5,560	6,020	33,520	41	38	56	33	41
2001-05	520	4,880	5,340	4,560	5,220	20,520	29	41	38	42	43

Source: National Agricultural Statistics Service (NASS), USDA.

Dryland Grain Sorghum Yields and Area Harvested by County

Figure 11 indicates that while dryland grain sorghum yields peaked during the 1986-90 period that there is a steady upward trend in yields over the entire 1973 to 2005 period.

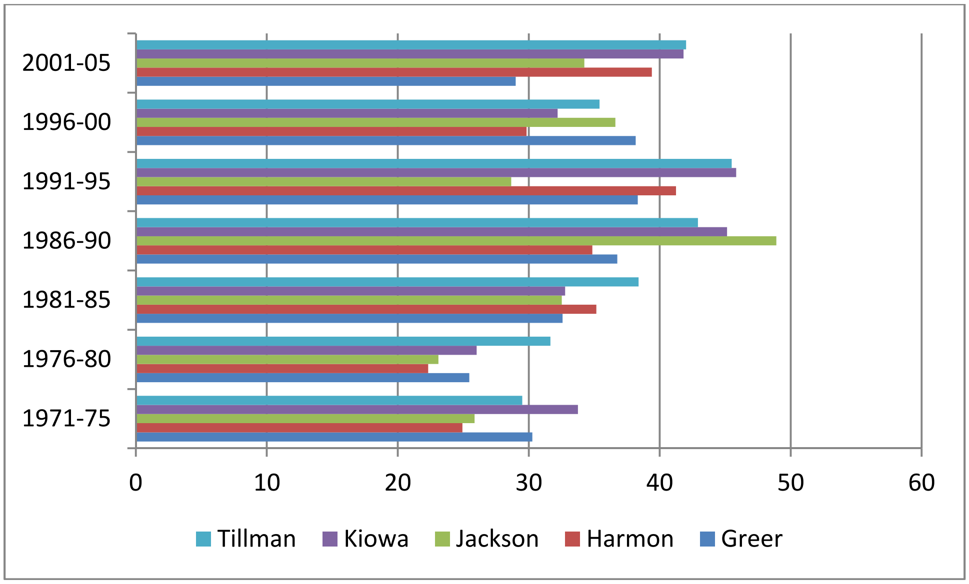


Figure 11 - Average County yields (bushel/acre) for Non-Irrigated Sorghum for each 5-year period.

Table 9 indicates that total acres of dryland grain sorghum in the five county area have varied from 11,000 to 24,000 acres over the 1972-2005 period. However, dryland grain sorghum acreage does not exhibit any significant increasing or decreasing trend.

Table 9 - Average Harvested Acres and Yields of Non-Irrigated Sorghum from 1972-2005

Average Annual Harvested Acres of Sorghum							Average Yield Per Harvested Acre (bus)				
Period	Greer	Harmon	Jackson	Kiowa	Tillman	Total	Greer	Harmon	Jackson	Kiowa	Tillman
1972-75	4,000	4,640	3,980	4,680	5,360	22,660	30	25	26	34	30
1976-80	1,220	3,260	1,860	3,040	3,300	12,680	25	22	23	26	32
1981-85	1,450	1,580	4,630	3,970	6,370	18,000	33	35	33	33	38
1986-90	1,320	1,414	5,042	4,420	6,770	18,966	37	35	49	45	43
1991-95	1,100	1,120	1,580	2,640	4,680	11,120	38	41	29	46	46
1996-00	940	7,280	5,800	5,380	4,760	24,160	38	30	37	32	35
2001-05	520	4,700	4,460	4,560	4,680	18,920	29	39	34	42	42

Irrigated Grain Sorghum Yields and Area Harvested by County

Figure 12 shows that in contrast to the previous dryland and irrigated crops discussed, the yields of irrigated sorghum have declined since 1985.

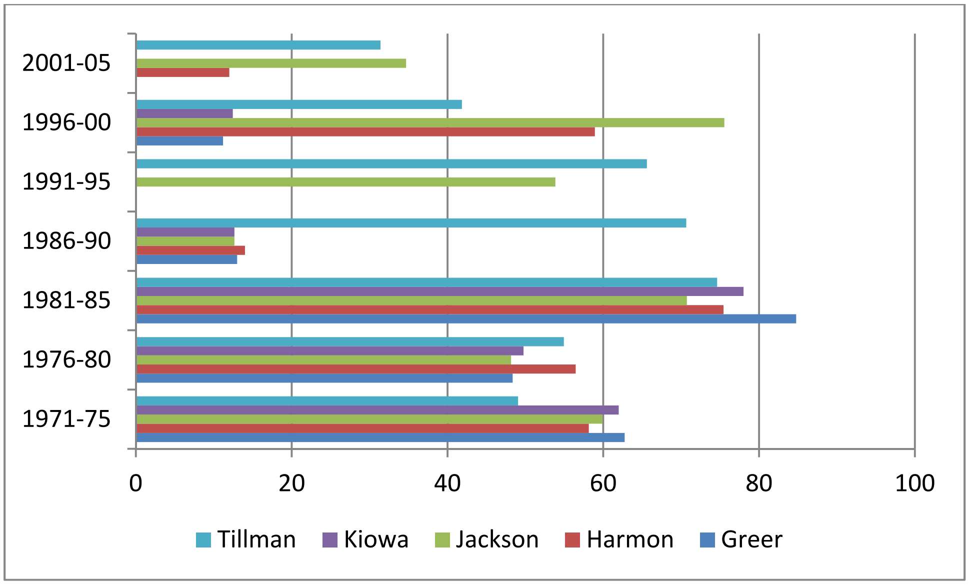


Figure 12 - Average County yields (bushel/acre) for Irrigated Sorghum for each 5-year period

Table 10 indicates that grain sorghum occupies only a small part of the irrigated acreage in the five county area. No irrigated acreage of grain sorghum was reported in Greer, Harmon, and Kiowa counties during one or more of the five year periods. General trends in acres harvested are trending downward during the 1973 to 2005 period.

Table 10 - Average Harvested acres and Yields of Irrigated Sorghum for Each 5-year Period

Average Annual Harvested Acres of Irrigated Sorghum							Avg. Yield Per Harvested Acre (bus)				
Period	Greer	Harmon	Jackson	Kiowa	Tillman	Total	Greer	Harmon	Jackson	Kiowa	Tillman
1971-75	340	1,880	2,600	460	1,560	6,840	63	58	60	62	49
1976-80	660	720	2,200	1,480	1,640	6,700	48	56	48	50	55
1981-85	230	400	650	210	610	2,100	85	75	71	78	75
1986-90	20	146	218	80	410	874	13	14	13	13	71
1991-95	-	-	1,000	-	880	1,880	0	0	54	0	66
1996-00	100	820	7,000	180	1,260	9,360	11	59	76	12	42
2001-05	-	180	880	-	540	1,600	0	12	35	0	31

Source: National Agricultural Statistics Service (NASS), USDA.

Total Area Harvested and Yields of All Hay and Alfalfa

Figure 13 shows the yields per harvested acre of all hay have steadily increased over the 1961 to 2005 period. The highest yields are in Harmon and Greer Counties.

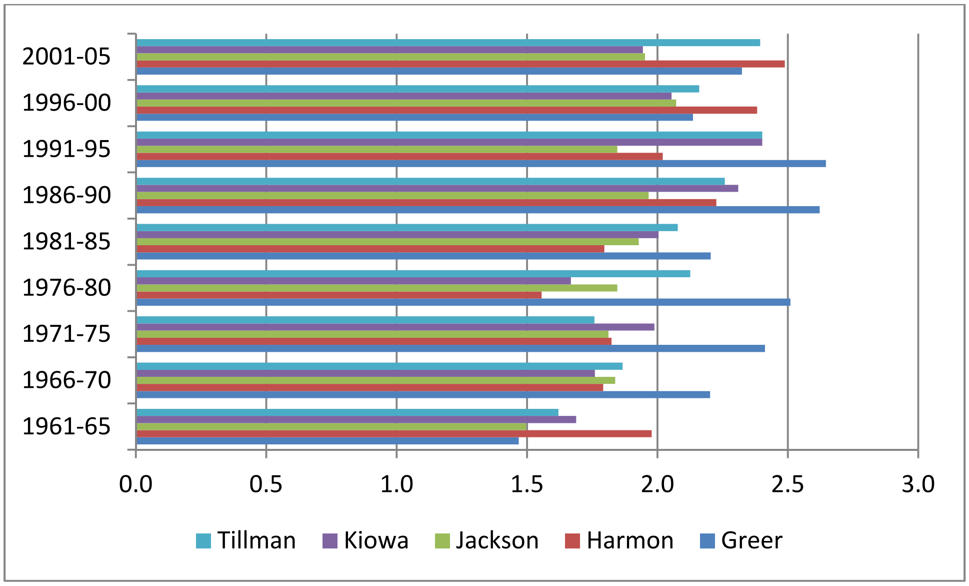


Figure 13 – Average Yields (tons/acre) of all Hay by county for every 5-yr period.

Table 11 indicates the acreage of all hay has been increasing over the 1961 to 2005 period with large increases in Harmon, Jackson, Kiowa, and Tillman counties during the 2000 to 2005 period.

Table 11 - Average County Level Harvested acres and Yields(tons) of All Hay by County by 5-year Period

Average Annual Harvested Acres of All Hay							Average Yield Per Harvested Acre (tons)				
Year	Greer	Harmon	Jackson	Kiowa	Tillman	Total	Greer	Harmon	Jackson	Kiowa	Tillman
1961-65	9,582	4,268	13,318	16,116	19,376	62,660	1.5	2	1.5	1.7	1.6
1966-70	13,172	6,008	14,162	15,972	21,600	70,914	2.2	1.8	1.8	1.8	1.9
1971-75	16,222	5,886	13,410	18,340	19,990	73,848	2.4	1.8	1.8	2	1.8
1976-80	18,480	6,300	12,680	17,560	17,780	72,800	2.5	1.6	1.8	1.7	2.1
1981-85	13,100	12,200	13,600	16,100	21,200	76,200	2.2	1.8	1.9	2	2.1
1986-90	15,700	9,600	15,300	19,200	17,000	76,800	2.6	2.2	2	2.3	2.3
1991-95	12,880	7,760	14,100	18,580	20,820	74,140	2.6	2	1.8	2.4	2.4
1996-00	13,400	8,600	16,400	16,300	21,700	76,400	2.1	2.4	2.1	2.1	2.2
2001-05	14,100	14,780	20,560	24,300	28,880	102,620	2.3	2.5	2	1.9	2.4

Source: National Agricultural Statistics Service (NASS), USDA.

Figure 14 indicates that county level yields of alfalfa have steadily increased over the 1961 to 2005 period. The highest alfalfa yields are generally found in Harmon County.

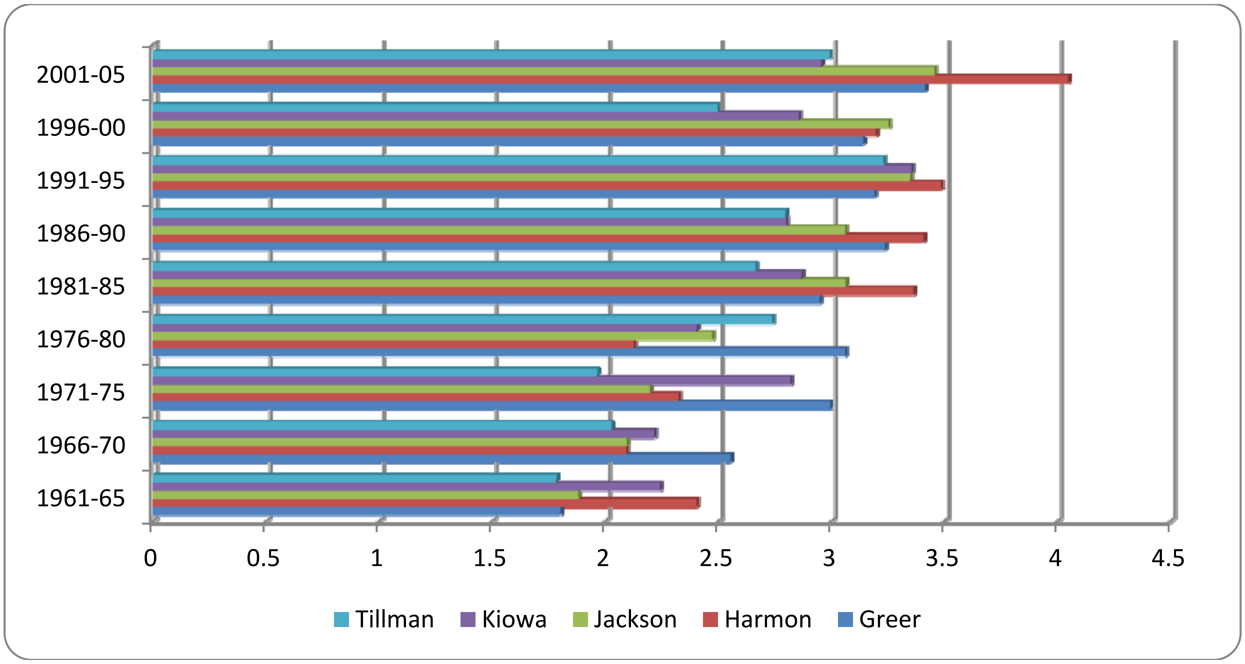


Figure 14 - Average Yields (tons/acre) of Alfalfa for every 5-yr period from 1961 to 2005

Table 12 shows that in terms of area harvested, Tillman County has the larger number of acres followed by Kiowa and Jackson Counties.

The U.S. Census of Agriculture provides estimates of total and irrigated acres of all hay (including alfalfa) and of alfalfa only. These data are available every five years but do not include estimates of production or per acres yields of either all hay or alfalfa. Census estimates are also subject to disclosure rules which results in a “d” for the acreage in some counties. Table 19 contains the available Census of Agriculture estimates from 1974 through 2007. The data in the upper half of Table 19 indicates that only 10 to 20 percent of the total hay acreage is irrigated.

Table 12 - Average County Level Harvested acres and Yields (tons) Alfalfa for each 5-yr Period

Average Annual Harvested Acres of Alfalfa							Ave. Yield Per Harvested Acre (tons)				
Period	Greer	Harmon	Jackson	Kiowa	Tillman	Total	Greer	Harmon	Jackson	Kiowa	Tillman
1961-65	5,860	3,117	8,883	7,133	13,383	38,376	1.8	2.4	1.9	2.2	1.8
1966-70	9,340	3,880	9,500	8,240	16,980	47,940	2.6	2.1	2.1	2.2	2
1971-75	10,420	2,720	7,400	8,180	13,880	42,600	3	2.3	2.2	2.8	2
1976-80	11,240	2,120	6,180	5,980	10,200	35,720	3.1	2.1	2.5	2.4	2.7
1981-85	5,900	3,380	4,260	5,580	9,380	28,500	3	3.4	3.1	2.9	2.7
1986-90	9,400	3,600	5,400	8,900	9,300	36,600	3.2	3.4	3.1	2.8	2.8
1991-95	8,080	2,560	4,000	9,080	10,020	33,740	3.2	3.5	3.4	3.4	3.2
1996-00	4,300	3,580	4,740	6,000	11,800	30,420	3.1	3.2	3.3	2.9	2.5
2001-05	4,300	6,380	3,360	7,300	13,480	34,820	3.4	4.1	3.5	3	3

Source: National Agricultural Statistics Service (NASS), USDA.

Crop Budgets

Crop Budgets will be developed by Oklahoma State University Department of Agriculture Economics.

Future Without-Project Conditions

Water Demand

Projected water demand was obtained from the 2011 Oklahoma Comprehensive Water Plan. The data is shown for two reaches in Tables 13 and 14, below. Reach 1, Table 13, has the highest demand for agriculture water due to the fact that the Altus-Irrigation District is located in the reach.

Table 13 – Projected Water Demand Reach 1

Use	Projected Water Demand (Acre-Feet per Year)				
	2020	2030	2040	2050	2060
Crop Irrigation	164,000	169,250	174,490	178,520	184,980
Livestock	3,760	3,860	3,960	4,060	4,160
Total	167,760	173,110	178,450	182,580	189,140

Source: Oklahoma Comprehensive Water Plan

Table 14 – Project Water Demand Reach 2

Use	Projected Water Demand (Acre-Feet per Year)				
	2020	2030	2040	2050	2060
Crop Irrigation	13,090	13,780	14,480	15,010	15,860
Livestock	3,950	4,000	4,040	4,090	4,140
Total	17,040	17,780	18,520	19,100	20,000

Source: Oklahoma Comprehensive Water Plan

Projected Acres

Table 15, below, presents an aggregate summary of the area in the one-half mile, the one-mile and the section buffers along the Elm Fork and North Fork of the Red River. The total area encompassed varies from nearly 83,300 to nearly 211,000 acres for the half-mile and section buffers respectively. After the total area, the rest of Table 15 deals with areas after the removal of slopes eight percent and greater. The prime agricultural soils are summarized by total and then by slopes of 1-3%. The data indicate there are approximately 28, 59, and 88 thousand acres of prime agricultural soils with slopes of 3% or less located within one-half mile, one-mile and in the section buffers, respectively. The lower part of Table 15 indicates there are approximately 15,500, 33,000, and 50,000 of prime agricultural soils with irrigation class I-III with slopes of <3% in the respective buffers. The distribution of these soils by counties is examined in the following section.

Table 15 – Summary of Farm Land (acres)

Category	Specified Distance		
	One-half Mile	One Mile	Sections[a]
Total Acres in Buffer	83,294	158,073	210,810
Total Acres, Slopes <8%			
Total Acres	73,788	133,218	186,621
Not Prime	41,918	67,050	88,370
Prime Agricultural (PA)	31,870	66,167	98,252
PA, slopes 0-0.99%	18,446	37,602	54,767
PA, slopes 1-1.99%	6,770	14,769	23,499
PA, slopes 2-2.99%	2,931	6,400	9,776
Total Acres, slopes < 3%	28,147	58,771	88,042
Prime Soils with Irrigation Capability (IrrCap)			
Prime, IrrCap	25,137	49,087	71,865
IrrCap I, slopes <3%	3,587	10,011	16,489
IrrCap II, slopes <3%	11,230	21,668	32,569
IrrCap III, slopes <3%	7,143	11,206	14,583
Subtotal, IrrCap I-III, slopes <3%	21,960	42,885	63,641
IrrCap I, slopes <3%	3,587	10,011	16,489
IrrCap II, ‘e’, slopes <3%	11,945	22,995	34,016
Subtotal, Irrigable Area No Limitations	15,532	33,006	50,505
Prime Soils with Irrigation Capability but with Wetness and Salinity Limitations			
IrrCap II, 'w'	6,402	8,278	9,015
IrrCap II, 's'	26	1,602	4,121

[a] Sections traversed by or adjacent to sections traversed by the Elm Fork and North Fork of the Red River.

Projected Crop Budgets

Projected crop budgets are currently being developed by Oklahoma State University.

Municipal and Industrial Water Supply Conditions.

Introduction.

Use of saline water from the Red River limits municipal and industrial water supply (M&I) uses in a multiregional area in Oklahoma, Texas, and Louisiana. If implemented, the Area VI Feature would reduce chlorides in waters of the Red River and some of its Oklahoma tributaries. With reduced chlorides, waters in these waterways become a more economically desirable water supply source to meet multiregional demands. Previous Corps studies have identified how chloride control measures in tributaries in Texas provide benefits to water supply users in Oklahoma, Texas, and Louisiana. Proposed chloride control features in Texas would benefit downstream users by making the associate waters a more economical source for meeting existing and future demands. The Area VI feature in Oklahoma would increase the benefits achieved by the chloride control features in Texas. The Area VI project features would also benefit users in southwest Oklahoma. The analysis needs to assess existing and future water demands for all regions using waters of the Red River and its tributaries. Demand and supply information was obtained from the state water plans of Oklahoma and Texas. Previous studies were used for Arkansas and Louisiana because these states do not have water plans with detailed information.

This section identifies municipal and industrial water supply demands for five economic reaches. Those reaches are:

- Southwest Region - a region identified in the State of Oklahoma Comprehensive Water Plan as “Southwest Region” in southwest Oklahoma which is above Lake Texoma on the Red River;
- Beaver-Cache Region - a region identified in the State of Oklahoma Comprehensive Water Plan as “Beaver-Cache Region” just east of the Southwest Region.
- Region C - a region identified in the State of Texas Comprehensive Water Plan as “Region C” including the Dallas-Fort Worth Texas metropolitan area.
- Region B - a region identified in the State of Texas Comprehensive Water Plan as “Region B” in north central region of Texas
- a region along the Red River that includes areas in Southeast Oklahoma, Northeast Texas, Southwest Arkansas and Northeast Louisiana.

Table 16 provides a reference for hydrologic study reaches and how they relate to the economic analysis. The hydrologic reaches relate to hydrologic and biological issues. The economic reaches relate to municipal and industrial water supply.

Table 16 - Reach Conversions

Economic Reaches	Hydrologic Reaches	River/Lake	State/County/Parish
(5) Below Texoma			
	1-LA	Red River	Bossier, LA
			Natchitoches
			Avoyelles
			Caddo
			Grant
			Rapides
			Red River
	2-AR	Red River	Hempstead, AR
			Lafayette
			Miller
	3-AR	Red River	Little River, AR
	3-OK	Red River	McCurtain, OK
	3-TX	Red River	Bowie, TX
			Red River, TX
	4-OK	Red River	Bryan, OK
	4-TX	Red River	Fanin, TX
			Lamar
(4) Region B			
	6-OK	Red River	Jefferson, OK
			Love, OK
	6-TX	Red River	Cooke, TX
			Montague, TX
	7-TX	Red River	Clay, TX
			Wichita, TX
			Wilbarger, TX
	8	Wichita River	Archer, TX
			Clay, TX
			Montague, TX
			Wichita, TX
	9	Lake Kemp	Baylor, TX
			Wilbarger, TX
	10	North Fork Wichita River	Foard, TX (50%)
	11	South Fork Wichita River	Knox, TX
	13	Pease River	Foard, TX (50%)
			Hardeman, TX (50%)
			Wilbarger, TX
	15-T	Prairie Dog Town Fork	Hardeman, TX (50%)

Table 16 (Continued)

Economic Reaches	Hydrologic Reaches	River/Lake	State/County/Parish
(3) Region C			
	5-OK	Lake Texoma	Marshall, OK
	5-GTUA	Lake Texoma	Grayson, TX
	5-Gray.Den	Lake Texoma	Grayson, TX
	5-NTMWD	Lake Texoma	Collin, TX
			Dallas,TX
			Kaufman, TX
			Rockwall, TX
	5-DAL	Lake Texoma	Collin, TX
			Dallas,TX
			Denton, TX
			Kaufman, TX
			Rockwall, TX
	5-TRWD	Lake Texoma	Tarrant, TX
			Ellis, TX
(2) Beaver-Cache			
	12	Red River	Tillman, OK
(1) Southwest			
	7-OK	Red River	Cotton, OK
	14-A	North Fork Red River	Jackson, OK
			Kiowa, OK
	14-B	Elm Fork Red River	Greer, OK
	15-O	Prairie Dog Town Fork	Harmon, OK

Reaches

Reach 1 Southwest Region – Oklahoma

The Southwest Watershed Region is located in Southwest Oklahoma and has 12 basins as defined in the Oklahoma Comprehensive Water plan. The region is approximately 4,045 square miles containing all of Harmon, Jackson, and Greer Counties, and portions of Tillman, Kiowa, Beckham, Roger Mills, Comanche, and Washita Counties. The largest cities in the area are Altus, Elk City, and Hobart. The region consists primarily of farming areas and the Quartz Mountains in southeastern Kiowa and Greer Counties. The region has dry and hot summers with mild winters with average temperatures between 59°F and 64°F. Average annual precipitation is between 22 inches in the west to 28 inches in the east. Figure 15 shows the location of Reach 1.

Figure 15 – Reach 1 Southwest Region Oklahoma

Source: Oklahoma Comprehensive Water Plan

Reach 2 Beaver-Cache Region Oklahoma

The Beaver-Cache Watershed Region includes basins 24 through 31 in southwest Oklahoma and has a total area of 3,288 square miles. The region contains all or portions of Tillman, Comanche, Cotton, Grady, Stephens, and Jefferson Counties. The largest cities in the region include Lawton, Duncan, Frederick, and Marlow. The area typically has a mild climate with the average monthly temperatures ranging from 38 degrees Fahrenheit in January to 84 degrees Fahrenheit in July, and average annual precipitation ranging from 28 inches in the west to 34 inches in the east. Figure 16 shows the location of Reach 2.

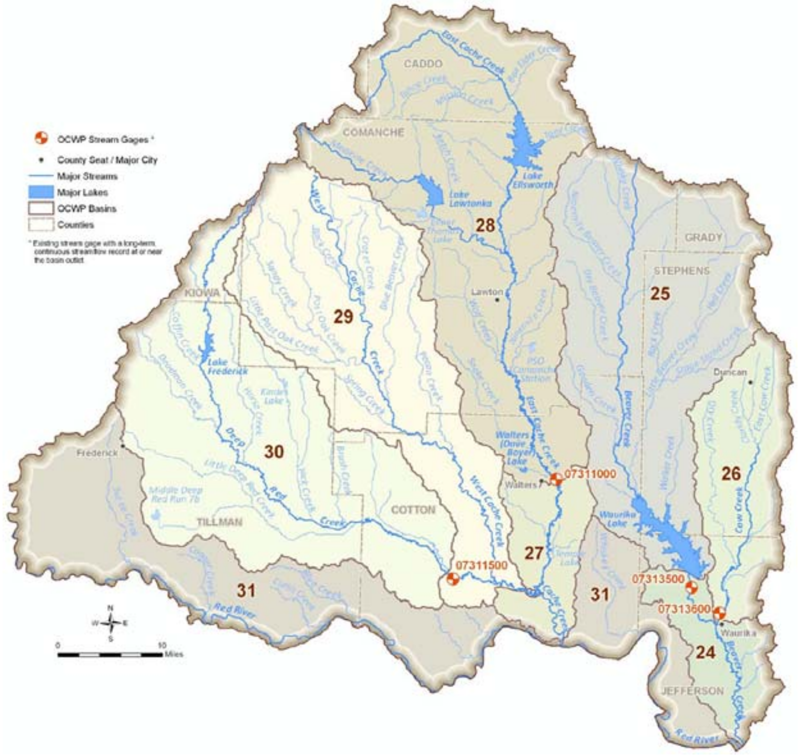
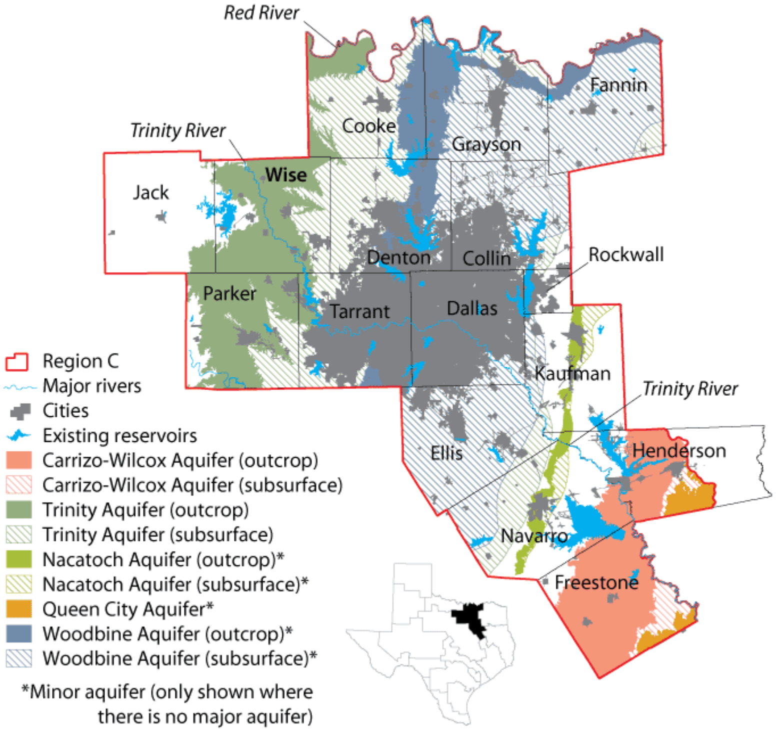


Figure 16 – Reach 2 Beaver-Cache Region Oklahoma

Source: Oklahoma Comprehensive Water Plan

Reach 3 Region C

Region C is made up of 16 counties in North Central Texas, which include Cooke, Grayson, Fannin, Jack, Wise, Denton, Collin, Parker, Tarrant, Dallas, Rockwall, Kaufman, Ellis, Navarro, Freestone, and part of Henderson County. The largest metropolitan area in the region is the Dallas-Fort Worth area. The average annual precipitation increases from west to east and ranges from 30 inches to 44 inches per year, and has a typically mild climate with an average daily temperature of 65.4 degrees Fahrenheit for the Dallas area. The area lies in the upper Trinity River Basin and part of the Red River Basin around Lake Texoma. Location of Reach 3 is shown in Figure 17.



Source: Texas Water Development Board.

Figure 17 – Reach 3 Region C Texas

Reach 4 Region B

Region B is comprised of 10 counties and one partial county (Young) in the north-central region of Texas. The counties of Region B are Archer, Baylor, Clay, Cottle, Foard, Hardeman, King, Montague, Wichita, and Wilbarger; also included is the city of Olney in Young County. The largest cities are Wichita Falls and Vernon. The climate of the region can be extremely volatile. The average annual rainfall for the region is 27.4 inches but can greatly vary from year to year, and the average daily temperature for the Wichita Falls area is 63.0 degrees Fahrenheit. Region B is located in the Red River Basin, Trinity River Basin, and Brazos River Basin, with most of the area lying in the Red River Basin as shown in Figure 18.

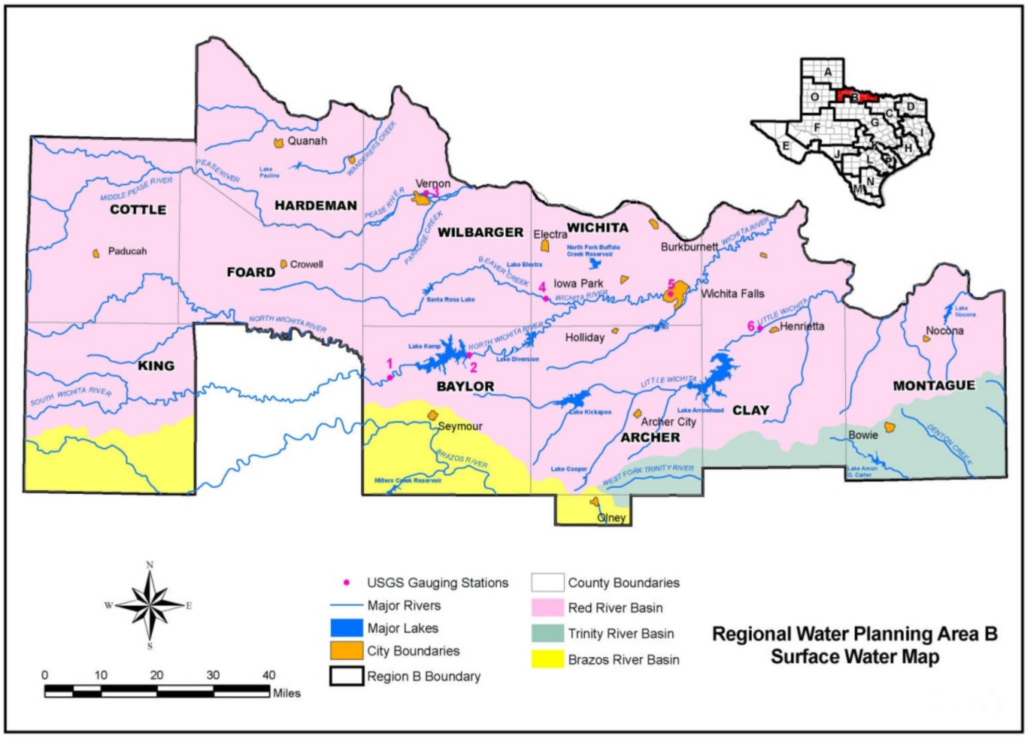
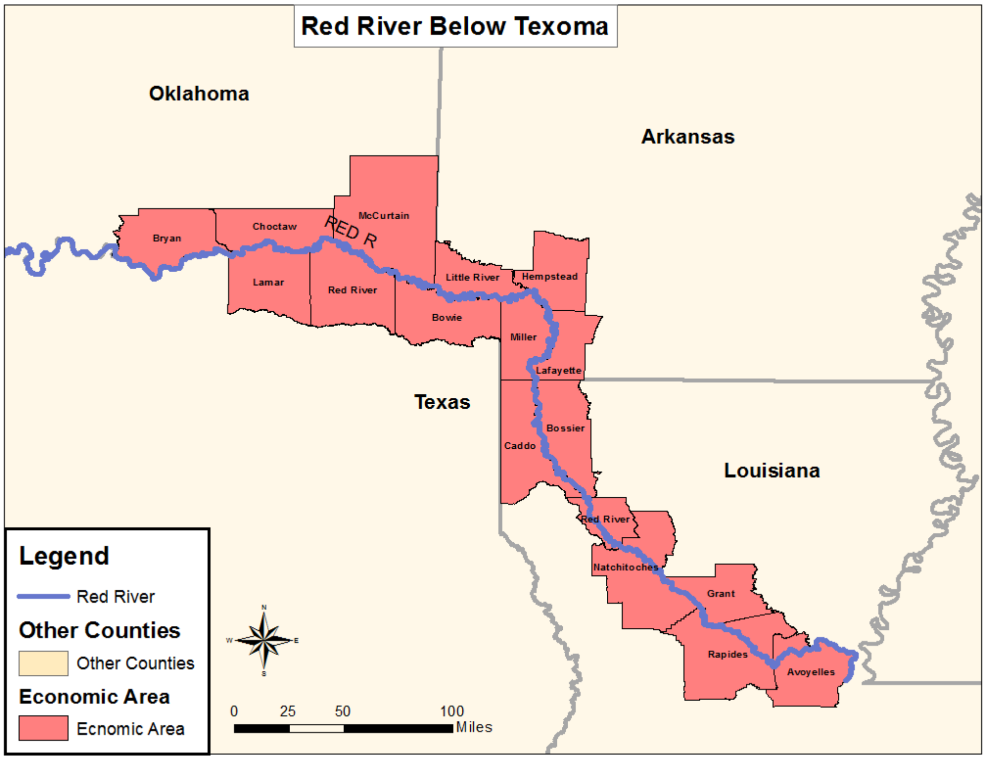


Figure 18 – Reach 4 Region B Texas

Source: Texas Water Development Board

<u>Reach 5 Below Texoma</u>

Reach 5 comprises the counties located along the Red River below Lake Texoma. The reach contains southeast Oklahoma, northeast Texas, far southwest Arkansas, and Louisiana, and includes the counties of Bryan, Choctaw, and McCurtain in Oklahoma; Lamar, Red River, and Bowie in Texas; Little River, Hempstead, Miller, and Lafayette in Arkansas; and Caddo, Bossier, Red River, Natchitoches, Grant, Rapides, and Avoyelles Parishes in Louisiana. The climate for Reach 5 is very diverse due to the large expanse included. The average annual rainfall ranges from 47.35 inches in the west to 61.78 inches in the east, and the average daily temperature ranges from 61.7 degrees Fahrenheit in the west to 66.7 degrees Fahrenheit in the east. The location of Reach 5 is shown in Figure 19 below.



Source: Tulsa District

Figure 19 – Reach 5 Below Lake Texoma

Existing Demand

Reach 1

The population for Reach 1 is 87,802 with the majority of the population living in Jackson and Beckham Counties as shown in Table 17.

Table 17 - Existing Population Reach 1

Population for Reach 1 Oklahoma Southwest Region in 2010		
State	County	Population
Oklahoma	Beckham	20,212
	Greer	5,810
	Harmon	2,890
	Jackson	26,249
	Washita	11,786
	Kiowa	9,399
	Tillman	8,148
	Roger Mills	3,308
Total		87,802

Source: Oklahoma Comprehensive Water Plan

The Southwest Region currently has 9 percent of the total statewide water demand. Crop Irrigation has the largest demand, making up approximately 90 percent, followed by M&I and livestock, as shown in Table 18.

Table 18 - Existing Demand Reach 1

Existing Demand	
Use	Acre Feet per Year
Crop Irrigation	158,760
Livestock	3,660
M&I	12,350
Oil & Gas	1,110
Industrial	610
Self Supplied	500
Electric	0
Total	176,990

Source: Oklahoma Comprehensive Water Plan

Reach 2

The population for Reach 2 is 273,935 with most people residing in Comanche County, which includes the city of Lawton, as shown in Table 19.

Table 19 - Existing Population Reach 2

Population for Reach 2 Oklahoma Beaver-Cache Region in 2010		
State	County	Population
Oklahoma	Caddo	29,584
	Comanche	128,490
	Tillman	8,148
	Cotton	6,357
	Jefferson	6,273
	Grady	51,761
	Stephens	43,322
Total		273,935

Source: Oklahoma Comprehensive Water Plan

The Beaver-Cache Regions water needs currently account for 2 percent of the total demand in the state. Currently, municipal and industrial water supply makes up over half of the demand in the region followed by crop irrigation and livestock, as shown in Table 20.

Table 20 - Existing Demand Reach 2

Existing Demand	
Use	Acre Feet per Year
Crop Irrigation	12,390
Livestock	3,910
M&I	24,600
Oil & Gas	550
Industrial	200
Self Supplied	370
Electric	2,570
Total	44,590

+Source: Oklahoma Comprehensive Water Plan

Reach 3

The population for Reach 3 is 6,670,493, where most reside primarily in Dallas and Tarrant Counties, which include the Dallas-Ft. Worth metropolitan area, as shown in Table 21.

Table 21 - Existing Population Reach 3

Population for Reach 3 Texas Region C in 2010		
State	County	Population
Texas	Collin	790,648
	Cooke	40,674
	Dallas	2,512,352
	Denton	674,322
	Ellis	169,514
	Fannin	38,129
	Freestone	19,701
	Grayson	126,099
	Henderson	56,254
	Jack	9,567
	Kaufman	103,249
	Navarro	52,752
	Parker	121,653
	Rockwall	89,144
	Tarrant	1,800,069
	Wise	66,366
TOTAL		6,670,493

Source: Texas Water Plan

Even though over 26 percent of the population of Texas lives in the region, it consumed just over 7 percent of the state's water in 1997 because the bulk of demand is for municipal use and only limited water is used for irrigation in the area. Table 22 shows the demand by use.

Table 22 - Existing Demand by Use Reach 3

Use	Existing Demand 2010 (Acre-Feet per year)
Municipal	1,512,231
Manufacturing	72,026
Steam Electric Power	40,813
Irrigation	40,776
Mining	41,520
County Other	34,738
Livestock	19,248
Total	1,761,352

Source: Texas Water Plan

Reach 4

The total population for Reach 4 is 210,642 with the majority of the population living at Wichita Falls in Wichita County, as shown in Table 23.

Table 23 - Existing Population Reach 4

Population for Reach 4 Texas Region B in 2010		
State	County	Population
Texas	Archer	4,885
	Baylor	2,692
	Clay	4,716
	Cottle	1,458
	Foard	1,137
	Hardeman	3,777
	King	152
	Montague	9,994
	Wichita	131,012
	Wilbarger	12,139
	Young	3,429
	Other Rural	35,251
TOTAL		210,642

Source: Texas Water Plan

Irrigation makes up the largest portion of water use in the area with many irrigated crops such as cotton, wheat, peanuts, vegetables, orchards, and other such agricultural goods, but the total demand for the region makes up less than 1 percent of the state's total water use. Table 24 shows the demand by use.

Table 24 - Existing Demand Reach 4

Use	Acre-Feet per year
Manufacturing	3,547
Power	13,360
Mining	909
Irrigation	99,895
Livestock Watering	12,489
Municipal	36,695
County Other	4,269
TOTAL	171,164

Source: Texas Water Plan

Reach 5

The total population for Reach 5 is 942,145 with the largest portion of the population living in Caddo, Bossier, and Rapides Parishes, as shown in Table 25.

Table 25 - Existing Population Reach 5

Population for Reach 5 Below Texoma in 2010		
State	County/ Parish	Population
Oklahoma	Bryan	40,827
	Choctaw	15,127
	McCurtain	33,939
Texas	Lamar	52,525
	Red River	14,251
	Bowie	96,953
Arkansas	Little River	13,260
	Hempstead	23,469
	Miller	44,746
	Lafayette	7,688
Louisiana	Caddo	247,970
	Bossier	112,470
	Red River	9,330
	Natchitoches	37,350
	Grant	20,460
	Rapides	129,520
	Avoyelles	42,260
TOTAL		942,145

Sources: Oklahoma Comprehensive Water Plan, Texas Water Plan, UALR IEA, Louisiana.gov

Reach 5 has demand for Red River water from two users. Bossier City has a demand of 10,977 acre-feet per year, of which 10,641 acre-feet per year for municipal and 336 acre-feet per year for industrial, and Willamette Industries, a paper manufacturing facility, has a demand of 11,201 acre-feet per year, as shown in Table 26.

Table 26 - Existing Use Reach 5

Use	Acre-Feet per year
Municipal	10,641
Industrial	336
Manufacturing	11,201
Total	22,179

Source: Wichita River Basin Reevaluation Report

Future Demand

Reach 1

The population for Reach 1 is expected to reach 106,456 by 2060 with most of the growth coming in Jackson and Beckham Counties, as shown in Table 27.

Table 27 - Future Population Reach 1

Population for Reach 1 Oklahoma Southwest Region (2020-2060)						
State	County	Year				
		2020	2030	2040	2050	2060
Oklahoma						
	Beckham	22,015	23,913	25,811	27,709	29,797
	Greer	5,810	5,810	5,908	6,007	6,105
	Harmon	2,890	2,977	3,065	3,152	3,240
	Jackson	27,819	29,127	30,173	31,045	31,743
	Washita	12,182	12,479	12,677	12,974	13,172
	Kiowa	9,399	9,494	9,589	9,779	9,969
	Tillman	8,325	8,502	8,679	8,857	9,122
	Roger Mills	3,308	3,308	3,308	3,308	3,308
Total		91,748	95,610	99,210	102,831	106,456

Source: Oklahoma Comprehensive Water Plan

The water demand will increase 20 percent over the next 50 years in Reach 1. The largest increase will be in the crop irrigation sector followed by Municipal and Industrial water supply. Crop irrigation is projected to be 87 percent of the total regional demand by 2060. Table 28 shows the total water demand by sector for the Southwest Region between 2020-2060.

Table 28 - Future Demand Reach 1

	Projected Water Demand (Acre-Feet per Year)				
Use	2020	2030	2040	2050	2060
Crop Irrigation	164,000	169,250	174,490	178,520	184,980
Livestock	3,760	3,860	3,960	4,060	4,160
M&I	13,060	13,760	14,440	15,100	15,770
Oil & Gas	1,850	2,800	3,940	5,290	6,840
Industrial	610	610	640	650	670
Residential	540	580	610	650	690
Thermo Electric	0	0	0	0	0
Total	183,820	190,860	198,090	204,270	213,110

Source: Oklahoma Comprehensive Water Plan

Reach 2

The population for Reach 2 is expected to Reach 328,271 with large amounts of growth in Comanche and Grady Counties, as shown in Table 29.

Table 29 - Future Population Reach 2

Population for Reach 2 Oklahoma Beaver-Cache Region (2020-2060)						
State	County	Year				
		2020	2030	2040	2050	2060
Oklahoma						
	Caddo	30,833	31,793	32,754	33,714	34,579
	Comanche	137,442	144,210	149,473	153,609	156,993
	Tillman	8,325	8,502	8,679	8,857	9,122
	Cotton	6,453	6,549	6,646	6,838	6,935
	Jefferson	6,368	6,463	6,558	6,748	6,938
	Grady	55,473	58,655	61,519	64,382	67,352
	Stephens	43,827	44,231	44,736	45,443	46,352
Total		288,721	300,403	310,365	319,591	328,271

Source: Oklahoma Comprehensive Water Plan

Demand is expected to grow 27 percent from 2010 to 2060 with the largest increases in municipal and industrial, and crop irrigation. By 2060 municipal and industrial is expected to account for 51 percent and crop irrigation will account for 28 percent of total demand for the region. Table 30 below shows the breakdown of total demand by sector.

Table 30 - Future Demand Reach 2

	Projected Water Demand (Acre-Feet per Year)				
Use	2020	2030	2040	2050	2060
Crop Irrigation	13,090	13,780	14,480	15,010	15,860
Livestock	3,950	4,000	4,040	4,090	4,140
M&I	25,980	26,970	27,780	28,480	29,110
Oil & Gas	810	1,120	1,470	1,890	2,350
Industrial	200	200	210	210	220
Residential	400	410	430	440	450
Thermoelectric Power	2,860	3,190	3,560	3,980	4,440
Total	47,290	49,670	51,970	54,090	56,560

Source: Oklahoma Comprehensive Water Plan

Reach 3

The population for Reach 3 is expected to reach 13,045,592 by the year 2060 primarily due to growth in the Dallas-Ft.Worth metropolitan area and the surrounding counties, as shown in Table 31.

Table 31 - Future Population Reach 3

Population Texas Region C (2020-2060)						
State	County	Year				
		2020	2030	2040	2050	2060
Texas	Collin	1,046,601	1,265,373	1,526,407	1,761,082	1,938,067
	Cooke	46,141	51,749	56,973	65,099	71,328
	Dallas	2,756,079	2,950,635	3,128,628	3,365,780	3,695,125
	Denton	889,705	1,118,010	1,347,185	1,573,994	1,839,507
	Ellis	233,654	293,665	351,919	411,721	471,317
	Fannin	42,648	49,775	60,659	74,490	86,970
	Freestone	21,826	23,704	25,504	27,148	28,593
	Grayson	152,028	179,725	203,822	227,563	253,568
	Henderson	65,009	75,232	85,112	96,835	111,026
	Jack	10,275	10,915	11,415	11,915	12,415
	Kaufman	162,664	208,009	254,609	297,391	349,385
	Navarro	58,919	65,331	72,374	80,168	89,638
	Parker	193,559	262,053	301,760	324,546	342,887
	Rockwall	141,386	171,373	199,044	215,312	232,186
	Tarrant	2,061,887	2,337,390	2,646,559	2,964,622	3,353,509
	Wise	89,347	108,711	127,068	148,020	170,071
TOTAL		7,971,728	9,171,650	10,399,038	11,645,686	13,045,592

Source: Texas Water Plan

With the exception of livestock, all sectors will see a large increase in water use over the next 50 years in Reach 3 with increases of approximately 38,500 acre-feet in manufacturing, 85,600 acre-feet in steam electric power, 8,700acre-feet in mining, and 1,000 acre-feet in irrigation, but the biggest strain to water supplies will be the almost 1.37 million acre-feet increase in municipal water use by the year 2060 as shown in Table 32.

Table 32 - Future Demand by Use Reach 3

Use	**Projected Water Demand (Acre Feet per Year)**				
	2020	2030	2040	2050	2060
Municipal	1,796,086	2,048,664	2,304,240	2,571,450	2,882,356
County Other	37,584	38,932	39,874	40,725	41,800
Manufacturing	81,273	90,010	98,486	105,808	110,597
Mining	38,961	41,630	44,486	47,435	50,200
Irrigation	40,966	41,165	41,373	41,596	41,831
Steam Electric Power	64,625	98,088	107,394	116,058	126,428
Livestock	19,248	19,248	19,248	19,248	19,248
Total	**2,078,743**	**2,377,737**	**2,655,101**	**2,942,320**	**3,272,460**

Source: Texas Water Plan

Reach 4

The population for Reach 4 is expected to grow to 221,734 by 2060 with most of the growth coming in Wichita County, as shown in Table 33.

Table 33 - Future Population Reach 4

Population for Reach 4 Texas Region B (2020-2060)						
State	**County**	**Planning Horizon (Year)**				
		2020	**2030**	**2040**	**2050**	**2060**
Texas	Archer	5,315	5,665	5,772	5,573	5,369
	Baylor	2,569	2,378	2,206	2,089	1,933
	Clay	4,851	4,820	4,622	4,337	4,054
	Cottle	1,455	1,384	1,304	1,233	1,193
	Foard	1,145	1,121	1,081	1,055	1,017
	Hardeman	3,749	3,654	3,532	3,397	3,140
	King	144	124	98	77	75
	Montague	10,189	10,252	10,265	10,254	10,270
	Wichita	136,665	140,404	142,360	143,724	144,826
	Wilbarger	12,655	12,706	12,451	11,844	11,144
	Young	3,504	3,509	3,469	3,418	3,386
	Other Rural	36,677	37,234	37,005	36,214	35,327
TOTAL		**218,918**	**223,251**	**224,165**	**223,215**	**221,734**

Source: Texas Water Plan

Water use in Reach 4 is projected to decrease by approximately 1 percent by 2060 with the only increases coming in Manufacturing and Steam-electric. Table 34 shows the projected future demand for water in Region B.

Table 34 - Future Demand by use Reach 4

Use	Projected Water Demand (Acre Feet per Year)				
	2020	2030	2040	2050	2060
Municipal	35,394	35,964	35,532	35,107	34,964
County Other	4,261	4,232	4,132	3,855	3,732
Manufacturing	3,755	3,968	4,260	4,524	4,524
Mining	845	811	785	792	792
Irrigation	97,702	95,537	93,400	91,292	91,292
Steam-electric	17,360	21,360	21,360	21,360	21,360
Livestock	12,489	12,489	12,489	12,489	12,489
Total	171,806	174,361	171,958	169,419	169,153

Source: Texas Water Plan

Reach 5

Although population projections were not available past 2030 for Arkansas and Louisiana, the population of Reach 5 is expected to reach 993,076 by 2030. Most of the growth is seen in Bossier Parish, and Miller, Bryan, and Bowie Counties. The future population for Reach 5 is shown in Table 35.

Table 35 - Future Population Reach 5

Population Projections for Region 5 Below Texoma						
State	County/ Parish	Year				
		2020	2030	2040	2050	2060
Oklahoma	Bryan	45,040	49,353	53,667	57,980	62,394
	Choctaw	15,515	15,806	16,194	16,582	16,970
	McCurtain	35,465	36,704	37,753	38,897	39,946
Texas	Lamar	56,536	60,286	64,036	64,036	64,036
	Red River	14,251	14,251	14,251	14,251	14,251
	Bowie	103,397	108,397	113,397	113,397	113,397
Arkansas	Little River	13,260	13,260	-	-	-
	Hempstead	23,469	23,469	-	-	-
	Miller	48,542	52,239	-	-	-
	Lafayette	6,790	5,891	-	-	-
Louisiana	Caddo	240,880	231,790	-	-	-
	Bossier	126,780	141,350	-	-	-
	Red River	9,170	8,890	-	-	-
	Natchitoches	35,610	34,170	-	-	-
	Grant	22,440	24,110	-	-	-
	Rapides	131,090	130,730	-	-	-
	Avoyelles	42,630	42,380	-	-	-
TOTAL		970,865	993,076	299,298	305,143	310,994

Sources: Oklahoma Comprehensive Water Plan, Texas Water Plan, UALR IEA, Louisiana.gov

Bossier City and Willamette Industries will continue to use Red River at their current usage. Due to the abundance of water options there is not a high demand for Red River Water. There may be new potential users if water quality is increased. Future demand is shown in Table 36.

Table 36 - Future Demand Reach 5

Use	Projected Water Demand (Acre-Feet per Year)				
	2020	2030	2040	2050	2060
Municipal	10,641	10,641	10,641	10,641	10,641
Industrial	336	336	336	336	336
Manufacturing	11,201	11,201	11,201	11,201	11,201
Total	22,179	22,179	22,179	22,179	22,179

Source: Wichita River Basin Reevaluation Report

Existing Supply

Reach 1

Stream flow in Reach 1 has high variability. Low stream flows can happen in all basins in the reach. Reservoirs in the region increase the dependability of water supply for the water users. According to the Oklahoma Comprehensive Plan, surface water historically has been about a third of the supply that has been used to meet demand. Existing supply is shown in Table 37.

Table 37 - Existing Supply Reach 1

Reach 1 Existing Supply	
Category	Existing Supply (Acre-Feet per Year)
Groundwater	89,404
Reservoir	4,320
Stream flows	1,372,330
Total	1,466,054

Source: Oklahoma Comprehensive Water Plan

Reach 2

The Oklahoma Comprehensive Water Plan reported that surface water has historically been the primary source of water in the region, with 64 percent of current water use coming from surface water. The region's main streams include the Red River, Cache Creek, and Beaver Creek. Many streams in the region experience a large variation in flows ranging from no-flow conditions to periodic flooding events making some streams an unreliable source of supply for most purposes.

Table 38 - Existing Supply Reach 2

Reach 2 Existing Supply	
Category	Existing Supply (Acre-Feet per Year)
Groundwater	16,452
Reservoir	44,231
Stream flows	1,374,553
Total	1,435,236

Source: Oklahoma Comprehensive Water Plan

Reservoirs help to provide the area with a dependable supply source, and a large portion of the available water supply yield is not being used.

The Arbuckle-Timbered Hills and Rush Springs are the two major bedrock aquifers in the area and are located in part of the Beaver-Cache Region, and the two major alluvial aquifers are Tillman Terrace and Red River and are located in the southern portion of the region. There are also many minor bedrock and alluvial aquifers in the region that provide an important source of domestic and stock water for rural users that are not served by rural water districts.

Reach 3

Most of Region C lies in the upper portion of the Trinity Basin, with smaller parts in the Red, Brazos, Sulphur, and Sabine basins. The Red River flows west to east and forms the northern border of the region. Other major water features include the Brazos and Trinity Rivers, and several major lakes including Lake Texoma. The existing supply for Reach 3 is shown in Table 39.

Table 39 - Existing Supply Reach 3

Category	Existing Supply (Acre-Feet Per Year)
Ground Water	125,939
Reuse	182,686
Surface Water	1,481,272
TOTAL	1,789,897

Source: Texas Water Plan

Most of the groundwater supplies come out of the Trinity aquifer, but there are other aquifers in the region, which include the Carrizo-Wilcox, the Woodbine, the Nacatoch, and the Queen City. The Nacatoch and Queen City aquifers make up the other category.

Reach 4

Region B contains numerous lakes, rivers, streams, and groundwater resources that help to provide people with safe drinking water, irrigation for farmers, and the water industrial firms need to obtain economic growth. However, due to the high salinity of local water, not all water supplies can be fully utilized because much of the water is undrinkable and can hinder crop yields. The regions three main aquifers are Blain, Trinity, and Seymour. There are large amounts of water supply available in these three aquifers. However, water quality is an issue in the Blaine Aquifer and Seymour Aquifer. Due to high total dissolved solids (TDS) in the Blaine Aquifer it is unusable for municipal use without additional treatment, and high levels of nitrates and TDS in the Seymour Aquifer also limit its usefulness. There is currently no infrastructure in place to treat and make full use of these water supplies. Existing firm supplies for Reach 4 are shown in Table 40.

Table 40 - Existing Firm Supplies Reach 4

Category	Existing Supply (Acre-Feet Per Year)
Ground Water	58,456
Surface Water	115,509
TOTAL	173,965

Source: Texas Water Plan

Reach 5

The table below shows the existing supply of surface in the area closest to the Red River. There are other lakes in the region that would help supply water but are located too far from the locations that could use the water. Table 41 shows the surface water that is currently being supplied in Louisiana. Arkansas currently uses some Red River Water when Millwood Reservoir releases water for Irrigation purposes but does not have a need for Red River Water for M&I purposes. Southeast Oklahoma has an enough water to meet their demands.

Table 41 - Surface Water Reach 5

Source	Yield (Acre Feet per Year)	Location (County)	Usage (Acre Feet per Year)	Category
Georgetown Reservoir		Georgetown (Grant)	NA	Municipal
Sibley Lake	8,961	City of Natchitoches (Natchitoches)	5	Municipal
Black Lake	78,410	Natchitoches Parish	NA	Industrial
Caddo Lake	111,454**	Mooringsport (Caddo)	48,760	Steam-Electric
Cross Lake	36,965**	Shreveport (Caddo)	36,965	Municipal

** Use can exceed dependable yield since yield is a conservative measure of water supply that will, in fact, be greater than the given figure most of the time. Also, once-through cooling for steam-electric usage returns most of the water to the source

NA = Not Available

Source: Gulf South Research Institute, 1979 Water Use Survey; and Gulf Engineers Consultants, 1992 Water Use Survey.

Stream water is not used as extensively as stored surface water. The largest stream in the area is the Atchafalaya River, with a dependable yield of 25,000 mgd. It is not used and is located well away from any major water use centers. The only other stream in the area with a large dependable yield is the Red River, which has water quality issues. Stream water for Reach 5 is shown in Table 42

Table 42 - Stream Water Reach 5

Source	Yield (Acre-Feet per Year)	Location (County)	Usage (Acre-Feet per Year)
Twelve-Mile Bayou	11,201	Shreveport (Caddo)	11,201
Little River	11,201	Pollock (Grant)	NA
Bayou Boeuf	336	Avoyelles Parish	NA
Red River	963,325	Bossier City (Bossier)	8,401
Red River	963,325	Campti (Natchitoches)	NA
Cane River	5,377	Natchitoches Parish	NA
Big Creek	4,481	Tioga (Rapides)	2,834

Source: Gulf South Research Institute, 1979 Water Use Survey; and Gulf Engineers Consultants, 1992 Water Use Survey.

Groundwater is widely used by the smaller communities and industries in the study area. The only large groundwater development is in the vicinity of Alexandria in Rapides Parish where 25,200 acre-feet per year of good quality groundwater is withdrawn, about half of which is supplied to one industry near the city. In general, groundwater is not available in very high well yields except in the Alluvial aquifer of the Red River. Some use of this alluvial groundwater is currently being made in Avoyelles Parish (24,643 acre-feet per year) for irrigation. However, this water is very hard and is not currently used for municipal purposes when other sources are available. The groundwater supply for Reach 5 is shown in Table 43.

Table 43 - Groundwater Supply Reach 5

Source	Yield (Acre Feet per Year)	Location (County)	Usage (Acre Feet per Year)
Carrizo Sand	5,746	1 town (Caddo)	NA
Alluvium	461,500	8 towns	NA
Alluvium	461,500	2 industries (Avoyelles)	NA
Alluvium	461,500	Avoyelles	24,643
Wilcox	132,177	16 towns	NA
Wilcox	132,177	1 industry (Bossier)	NA
Miocene	23,523	23 towns	NA
Miocene	23,523	5 industries (Avoyelles & Rapides)	NA
Terrace	173,622	12 towns	NA
Terrace	173,622	2 industries (Rapides)	13,498
Terrace	173,622	1 industry (Bossier)	952

Sources: Gulf South Research Institute, 1979 Water Use Survey; and Gulf Engineers Consultants, 1992 Water Use Survey.

Existing Supply Costs

Approximately 3,300 tons of chlorides (Cl) are introduced into the Red River and its tributaries daily from natural sources. The large chloride concentration along with high sulfates (SO4) and total dissolved solids (TDS) make the water unsuitable for most municipal, industrial, and agricultural uses without treatment. The drinking water standard limits currently in place by the U.S. Environmental Protection Agency (EPA) require drinking water to contain no more than 500mg/l of TDS, 250 mg/l of Cl, and 250 mg/l of SO4. However, the State of Texas has established its own water quality limits of 1,000 mg/l of TDS, 300 mg/l of Cl, and 300 mg/l of SO4. Most communities in the study area are within the Texas limits, but do not currently meet the limits required by the EPA. Water is currently treated through the use of reverse osmosis, electrodialysis reversal units, and various mixing (blending) techniques to maintain water quality standards. Although these processes are effective they can be expensive, and most small communities cannot afford the capital investment necessary to build such facilities. Based on a 1992 study of U.S. desalination plants the median selling price of water coming from plants with a capacity of 3 mgd or more is $2.00/1,000 gals. Tables 44-46 below summarize the cost of current blending operations and the treatment costs for municipal and industrial water currently utilized in the study area.

Table 44 - Blending Cost of Red River Water (2011 Price Level)

Reach	Red River Blended w/	Quantity Acre-Feet per Year	Source Costs	Transport Costs	Untreated Damages	Untreated Cost w/ Damages
3	Lake Lewisville	36,181	$0.09	$0.91	$1.80	$2.79
3	Ray Roberts & Lewisville	67,433	$0.09	$0.84	$1.80	$2.72
3	Eagle Mountain Lake	20,723	$0.09	$2.88	$1.80	$4.76
4	Kickapoo & Arrowhead	1,344	$0.09	$1.14	$8.07	$9.30
4	Kickapoo & Arrowhead	2,016	$0.09	$3.40	$6.88	$10.37
5	Lake Lavon	28,676	$0.09	$0.12	$1.80	$2.00
5	Lake Lavon & L. Cooper	48,390	$0.09	$0.12	$1.80	$2.00
5	Lake Ray Roberts	31,252	$0.09	$1.01	$1.80	$2.90

Source Wichita Reevaluation Report

Table 45 - Municipal Cost of Red River Water (2011 Price Level)

Reach	Demand Center	Qty. (Acre feet per Year)	Alt. Source Threshold mg/l	Source Costs	Treatment Costs	Transport Costs	Treated Damages	Untreated Damages	Treated Cost w/ Damages	Untreated Cost w/ Damages
3	Sherman, TX (GTUA)	11,201	500	$0.09	$2.64	$0.10	$ -	$1.10	$2.82	$1.28
3	Denison, TX	5,601	500	$0.09	$2.71	$0.32	$ -	$1.10	$3.12	$1.50
3	DWU	72,809	200	$0.09	$2.48	$0.81	$0.70	$1.80	$4.07	$2.69
3	TRWD	72,809	200	$0.09	$2.48	$1.83	$0.70	$1.80	$5.10	$3.71
4	NTMWD	72,809	200	$0.09	$2.48	$0.12	$0.70	$1.80	$3.38	$2.00
4	Wichita Falls	11,201	315	$0.09	$3.97	$0.30	$0.43	$8.07	$4.79	$8.46
4	Wichita Falls	11,201	315	$0.09	$3.19	$1.08	$0.43	$6.88	$4.79	$8.05
5	Bossier City, LA	11,201	200	$0.09	$2.37	$0.59	$0.39	$0.60	$3.44	$1.27
5	Shreveport, LA	28,004	200	$0.09	$2.27	$0.40	$0.39	$0.60	$3.15	$1.09

Source: Wichita Reevaluation Report

Table 46 - Industrial Cost of Red River Water

Industrial Treatment Cost of Red River Water 2011 Price Level								
Reach	Range for SIC Threshold mg/l	Source Costs	Range of Treatment Costs	Treated Damages	Range of Untreated Damages	Range of Treated Cost w/ Damages	Range of Untreated Cost w/ Damages
3	200-900	$ 0.09	$ 2.50-5.51	$ 0.21	$ 0.10-0.49	$ 2.67-5.60	$ 0.18-0.58
4(*)	200-900	$ 0.09	$ 2.50-5.51	$ 0.21	$ 0.10-0.49	$ 2.67-5.60	$ 0.18-0.58
4(**)	200-900	$ 0.09	$ 2.88-5.43	$ 0.20	$ 0.31-0.77	$ 2.96-5.52	$ 0.40-0.85
4(***)	200-900	$ 0.09	$ 2.67-5.56	$ 0.21	$ 0.15-0.63	$ 2.76-5.57	$ 0.24-0.71
5	200-900	$ 0.09	$ 2.22-5.27	$ 0.11	$ 0.00-0.16	$2.39-5.36	$ 0.09-0.25

(*) Hydrologic Reaches 6, 7, 10, 11, 13, 15 (Table 16)
(**) Hydrologic Reach 8 (Table 16)
(***) Hydrologic Reach 9 (Table 16)
Source: Wichita Reevaluation Report

Future Supply

Reach 1

Water supply yields and aquifer recharge rates were assumed to be the same for all the horizons in the Oklahoma Water Plan. Many streams in the region experience a large variation in flows ranging from no-flow conditions to periodic flooding events making some streams an unreliable source of supply for most purposes. Future supply for Reach 1 is shown in Table 47.

Table 47 - Future Supply Reach 1 (Acre-Feet per Year)

Category	2020	2030	2040	2050	2060
Groundwater	89,404	89,404	89,404	89,404	89,404
Reservoir	4,320	4,320	4,320	4,320	4,320
Stream flows	1,018,879	1,010,386	1,001,973	994,654	985,548
Total	1,112,603	1,104,110	1,095,697	1,088,378	1,079,272

Source: Oklahoma Comprehensive Water Plan

Reach 2

Just like the Southwest Region water supply yields and aquifer recharge rates were assumed to be the same for all the horizons in the Oklahoma Water Plan. Many streams in the region experience a large variation in flows ranging from no-flow conditions to periodic flooding events making some streams an unreliable source of supply for most purposes. The future stream-flow supply for Reach 2 is shown in Table 48.

Table 48 - Future Stream flow Supply Reach 2 (Acre-Feet per Year)

Category	2020	2030	2040	2050	2060
Groundwater	16,452	16,452	16,452	16,452	16,452
Reservoir	44,231	44,231	44,231	44,231	44,231
Stream flows	1,371,431	1,368,525	1,365,794	1,363,243	1,360,548
Total	1,432,114	1,429,208	1,426,477	1,423,926	1,421,231

Source: Oklahoma Comprehensive Water Plan

Reach 3

Future water supply is expected to remain fairly constant with minor losses from increased sedimentation in reservoirs. With Region C depending heavily on surface water, reuse water will be an important supply source in the future. Currently, only a fraction of treated wastewater from municipal use is reused in the region, and could provide a significant source of supply in future water planning. Future supply for Reach 3 is shown in Table 49.

Table 49 - Future Supply Reach 3 (Acre-Feet per Year)

Category	2020	2030	2040	2050	2060
Ground Water	121,827	121,916	122,074	122,117	122,106
Reuse	231,816	273,003	293,292	300,143	307,129
Surface Water	1,406,598	1,359,808	1,343,319	1,328,097	1,305,588
Total	1,760,241	1,754,727	1,758,685	1,750,357	1,734,823

Source: Texas Water Plan

Reach 4

Due to the high levels of TDS and chlorides in the water in Region B, the full amount of water is kept from being utilized due to infrastructure and treatment capacities. Table 50 shows the future water supply.

Table 50 - Future Supply Reach 4

Category	2020	2030	2040	2050	2060
Ground Water	58,439	58,431	58,410	58,403	58,403
Surface Water	111,239	106,991	102,724	98,477	94,179
Total	169,678	165,422	161,134	156,880	152,582

Source: Texas Water Plan

Reach 5

Since there is currently no use and abundant supplies in Oklahoma, Texas, and Arkansas no information is included for water supplies in these areas. No data is available for future supplies for Reach 5 in the Louisiana area, and existing supplies data should be assumed to be constant for the future planning horizon (years 2020-2060).

Demand/Supply Depletions and Gaps

Gaps refer to surface waters when demands exceed supply. Depletions refer to groundwater when demands exceed the recharge rate of an aquifer. A surface water gap occurs in any month where demand on surface water supply exceeds the basin's physically available surface water supply. The maximum annual surface water gap for the period of record is defined as the maximum of the sum of the monthly gaps for a given year. An alluvial groundwater or bedrock groundwater depletion occurs when the demand exceeds the aquifer recharge rate, at which point the demand draws supplies from aquifer storage and reduces the amount of water in storage.

The Oklahoma depletion ground water Comprehensive Water Plan used the model "Oklahoma H2O" to determine gaps in water supply. Oklahoma H2O is a model that has the ability to analyze different scenarios and potential future conditions. For Reaches 1 and 2 the designated gaps were surface water, alluvial, and bedrock groundwater

The Oklahoma Comprehensive Water Plan determined the probability of a gap occurring at least one month in a year. The plan looked at each basin within the watershed and determined the likelihood of a gap or depletion occurring. However, the Oklahoma Water Plan did not analyze the probability of a gap occurring at a watershed region.

The Texas Water Plan used the drought of record to determine surface water supply availability. Using this approach produced a conservative number for gaps and probability. The Texas Water Plan has not published any information on the intensity or probability of gaps occurring.

The Texas and Oklahoma water plans looked at conversation measures in their gap analysis. The Oklahoma Comprehensive Water Plan looked at two different types of conservation plans. They evaluated moderate conversation measures and substantial levels of conservation in M&I used and crop irrigation. Conservation measures looked at include: wider implementation of plumbing codes or more aggressive building code requirements, water use metering, tiered water rate structures, regional irrigation practices, improvements in water conveyance systems, acreages and types of irrigated crops, types of irrigation systems, seasonal rainfall variations, water availability, fuel and commodity prices, trends in irrigation efficiency, improvements in field application efficiency, increased use of micro irrigation technology, and shifting to less water demanding crops. Gaps values were determined for 2060 using moderate conservation measures. The values are located in Tables 51 and 52.

Conservation measures are included in the Texas Water Plan numbers for Reaches three and four. Some of the conservation strategies include flushing a low flow toilet or showering with a low flow showerhead. Educational programs have been developed to help conserve water. Region B conservation measures include canal lining for irrigation conservation. Basic conservation strategies in Region C include: education, pricing structure, water waste prohibitions, water system audits, and plumbing code changes. Expanded measures include landscape irrigation restrictions and residential water audits.

Reach 1

Gaps in Reach 1 will result from an increase in crop irrigation in the region. Local gaps are calculated from probabilities of draught and other low flow events as determined in the Oklahoma Comprehensive Water Plan. The annual probability is based on the number of years that a gap or depletion occurs in one or more months in a year. Gaps may vary from supply and demand projections due to the inconsistency of stream flows in the region, especially during low flow conditions (refer to Table 51). With moderate conservation measures for irrigation and M&I, gaps in 2060 are reduced significantly compared to no conservation measures in place.

Table 51 - Gaps in Reach 1

Maximum Gaps (Acre-Feet per Year)			
Year	Surface Water	Alluvial Groundwater	Bedrock Groundwater
2020	740	1,630	1,420
2030	2,140	3,790	2,860
2040	3,680	5,940	4,320
2050	5,360	8,030	5,450
2060	7,490	10,850	7,200
2060*	2,200	5,650	1,090

Source: Oklahoma Comprehensive Water Plan

Reach 2

Gaps in Reach 2 will come primarily from increased municipal use. Local gaps are calculated from probabilities of draught and other low flow events as determined in the Oklahoma Comprehensive Water Plan. The annual probability is based on the number of years that a gap or depletion occurs in one or more months in a year. Gaps may vary from supply and demand projections due to the inconsistency of stream flows in the region, especially during low flow conditions (refer to Table 52). With moderate conservation measures for irrigation and M&I, gaps in 2060 are reduced significantly compared to no conservation measures in place.

Table 52 - Gaps in Reach 2

Maximum Gaps (Acre Feet Per Year)			
Year	Surface Water	Alluvial Groundwater	Bedrock Groundwater
2020	130	90	260
2030	270	280	480
2040	450	410	740
2050	550	530	990
2060	730	770	1,320
2060*	70	160	990

Source: Oklahoma Comprehensive Water Plan

Reach 3

With the continued increase of population in the Dallas-Ft. Worth metropolitan area, demand will continue to increase. Demand will increase approximately 1,500,000 Acre-Feet between 2010-2060. Reach 3 will exceed its current supplies starting in 2020 (refer to Table 53).

Table 53 - Gaps in Reach 3 (Acre-Feet per Year)

Summary	2020	2030	2040	2050	2060
Supply	1,760,241	1,754,727	1,758,685	1,750,357	1,734,823
Demand	2,078,743	2,377,737	2,655,101	2,942,320	3,272,460
Need	-318,502	-623,010	-896,416	-1,191,963	-1,537,637

Source: Texas Water Plan

Reach 4

Population increase isn't the main problem in Reach 4. Water quality, water treatment and infrastructure costs will be the main drivers behind needs in this region. Reach 4 is projected to exceed its current supplies by 2050.

Table 54 - Gaps in Reach 4

Gaps (Acre feet per Year)					
Summary	2020	2030	2040	2050	2060
Supply	169,678	165,422	161,134	156,880	152,582
Demand	171,806	174,361	171,958	169,419	169,153
Need	-2,128	-8,939	-10,824	-12,539	-16,571

Source: Texas Water Plan

Reach 5

Reach 5 has adequate supply of water for the region. SE Oklahoma has enough water while Arkansas has very little need for the water and Louisiana has plenty of potential water supply sources to meet future demand.

Future Supply Costs

Due to the high concentrations of chlorides, sulfates, and total dissolved solids, the Red River and its tributaries are not currently considered a viable future supply source because of the high treatment costs. Without chloride control, areas along the Red River will be confronted with future supply gaps and will face the costs of finding alternative supply sources. The Army Corps of Engineers Wichita River Basin Project Reevaluation Report outlined various alternative source options and costs and these are summarized in Table 55 below.

Table 55 - Alternative Source Costs (2011 Price Level Cost per 1,000 Gallons)

Reach	Source	Demand Center	Quantity Acre Feet per Year	Source Cost ($)	Transport Cost ($)	Total Cost ($)
3	Lake Fork	DWU	119,855	$0.00	$1.51	$1.51
	Lake Palestine	DWU	113,919	$0.00	$1.92	$1.92
	Cooper Reservoir	DWU	75,722	$0.09	$1.90	$1.99
	*Little Cypress Reservoir	DWU	131,729	$0.37	$2.19	$2.56
	*George Parkhouse II	DWU	112,014	$0.63	$2.01	$2.64
	*Marvin Nichols Reservoir I	DWU	201,626	$0.31	$1.29	$1.60
3	Richland Chambers Reservoir	TRWD	42,005	$0.00	$0.33	$0.33
	*Tehuacana Reservoir (Post-2035)	TRWD	68,329	$0.93	$2.19	$3.12
	Trinity River Diversion	TRWD	73,482	$0.12	$1.83	$1.95
	*Marvin Nichols Reservoir I	TRWD	134,417	$0.31	$1.82	$2.13
4	*Ringgold Reservoir	Wichita Falls	27,556	$1.59	$0.93	$2.52
5	Toledo Bend Reservoir	Shreveport	56,007	$0.09	$1.61	$1.70
	Cypress Black Bayou No. 1	Bossier City	15,458	$0.09	$0.57	$0.66
5	*New Bonham Reservoir	NTMWD	93,756	$0.41	$0.69	$1.10
	*George Parkhouse II	NTMWD	134,417	$0.63	$0.31	$0.95
	*Marvin Nichols Reservoir I	NTMWD	134,417	$0.31	$1.82	$2.13
* Proposed New Impoundment						

Source: Wichita Reevaluation Report

Although Oklahoma was not evaluated in the report, information on potential reservoirs was available from the Oklahoma Comprehensive Water Plan. Costs have been estimated for construction of the new reservoirs, but not for transportation cost. Tables 56-60 provide information on potential reservoirs and future infrastructure needs in the Southwest and Beaver-Cache Regions of Oklahoma.

Table 56 - Potential Reservoirs in the Beaver-Cache Region (2011 Price Levels)

Name	Basin	Purposes	Total Storage	Conservation Pool			Primary Study		Updated Cost Estimate
				Surface Area AF	Storage AF	Dependable Yield AF/Y	Date	Agency	
Cookietown	30	WS, FC, F&W, R	400,000	13,100	208,190	34,700	1979	Bureau of Reclamation	$304,914,000
Snyder	30	F&W, WS, R	110,000	3,668	90,000	10,600	1974	Bureau of Reclamation, Plans and Estimates Branch, Amarillo, TX	$105,386,000

Source: Oklahoma Comprehensive Water Plan

Table 57 - Beaver Cache Infrastructure Cost Summary

Provider System Category	Infrastructure Need (millions of 2011 dollars)			
	Present - 2020	2021 - 2040	2041 - 2060	Total Period
Small	$542	$158	$328	$1,028
Medium	$45	$282	$11	$339
Large	$181	$90	$79	$350
Reservoir	$68	$0	$0	$68

Source: Oklahoma Comprehensive Water Plan

Table 58 - Potential Reservoirs in the Southwest Region (2011 Price Levels)

			Conservation Pool			Primary Study		
			Surface Area	Storage	Dependable Yield			
Name	Purposes	Total Storage	Acres	Acre Feet	Acre Feet per Year	Date	Agency	Updated Cost Estimate
Mangum Reservoir (Lower Mangum Damsite)		47,043	2,604	0	18,494	2005	U.S. Army Corps of Engineers	N/A
Port Lake	FC, WS, F&W, R	115,700	4,480	42,000	9,000	1973	Bureau of Reclamation, Oklahoma City Planning Office	$114,603,000

Source: Oklahoma Comprehensive Water Plan

Table 59 - Southwest Infrastructure Cost Summary (2011 Price Levels)

	Infrastructure Need ($ Millions)			
Provider System Category	Present - 2020	2021 - 2040	2041 - 2060	Total Period
Small	$307	$546	$155	$1,008
Medium	$147	$73	$49	$269
Large	$0	$0	$0	$0
Reservoir	$0	$8	$150	$158

Source: Oklahoma Comprehensive Water Plan

Table 60, below, lists the potential reservoirs in the central part of Louisiana for water. The Louisiana office of Public Works (OPW), which is the chief sponsor of water developments in Louisiana, has no plans for the creation of reservoirs in the study area. The OPW has developed one reservoir in the study area since the 1980 study - Grand Bayou Reservoir in Red River Parish, with a dependable yield of 13.1 mgd.

Table 60 - Future Potential Reservoirs Reach 5

Parish	Name	Drainage (Square Miles)	Elevation (Feet)	Area (Acres)	Volume (Acre-Feet)	Yield (Acre Feet per Year)
Red River	Boggy Lake	10.9	143	600	47,000	1,792
Grant	Big Creek	99	141	3,800	43,000	32,820
Bossier	Black Bayou	22	187	680	5,400	3,921
Caddo	Black Bayou*	231	199	11,000	137,000	73,145
Red River	Black Lake No. 3	535	140	8,250	4,900	100,029
Natchitoches	Black Lake*	630	137.5	19,780	272,000	112,014
Rapides	Brown Creek	13	109.2	725	9,000	10,921
Red River	Bull Lake	4.7	143	220	1,700	NA
Rapides	Castor Creek	35	102	3,000	37,500	28,004
LaSalle	Catahoula*	2,672	34	28,000	132,000	NA
Rapides	Cedar Lake	22	75	1,000	4,850	9,969
Evangeline Rapides	Cocodrie*	240	75	19,500	285,000	246,432
Bossier	Cypress Bayou	149.1	177	2,690	17,000	8,401
Bossier	Cypress Bayou	149	197	7,330	116,500	57,127
Caddo	Cypress Bayou	65	210.1	4,300	61,000	38,085
Natchitoches	Goldonna	280	140.5	12,500	160,000	112,014
Natchitoches	Halls and Berry Brake	49	135	4,075	49,500	34,724
Grant	Iatt Lake*	242	93	12,500	125,000	78,410
Rapides	Indian Creek*	23	90	2,650	33,000	22,291
Natchitoches	Kisatchie	278	120	5,800	65,000	67,209
Bossier-Bienville	Lake Bistineau*	1,410	164.5	46,000	870,000	472,253
Rapides	Longleaf	499	156.5	12,300	199,000	240,831
Rapides	Longleaf	499	164.5	16,100	300,000	301,319
Red River	Pine Tumbly Creek	5.2	143	190	1,540	NA
Red River-Winn	Saline	232	140	1,730	12,000	24,643
Red River-Winn	Saline	232	150	3,950	40,000	58,808
Natchitoches	Sibley*	40	120	2,775	29,200	14,562
Rapides	Spring Creek	67	116.7	2,240	40,000	65,865
Rapides	Valentine	36	92	2,100	26,000	33,044

* Enlargements
NA = Not Available.

Source: Louisiana Office of Public Works, Biennial Report.

Lake Texoma Recreation Conditions

Study Background

The recreation study component of the Area VI Feature Reevaluation assesses the potential effects on the Red River and Lake Texoma if Area VI was implemented. Lake Texoma stakeholders consist of Federal and state resource agencies and a broad array of local interests. The resource agencies have expressed concerns that if chloride control is implemented that the resulting reduction in salinity in Lake Texoma would reduce the ability of striped bass to reproduce naturally. There is a history of striped bass successfully reproducing in Lake Texoma. From this initial concern, there has been a significant amount of further stakeholder speculation about the potential social and economic impact of chloride control at Lake Texoma –particularly impacts related to recreational fishing and striped bass guide services. While the project area reaches into western Oklahoma and Texas, the area of concern for the fishing resource is immediately around Lake Texoma. Other minor effects may be present which encompass the entire Red River Chloride Control area, however the recreation study focuses on the recreation economic region located directly around the lake which has been the focus of stakeholder concerns.

Introduction

Lake Texoma is an 86,910 acre lake located on the Red River border between Texas and Oklahoma. Lake Texoma was created with the construction of Denison Dam in 1944. Few lakes in the U.S. are as large. In addition to its size, Lake Texoma is one of the few U.S. lakes where striped bass can spawn naturally. The lake is within a two hour drive north of the Dallas-Fort Worth metroplex, and can be accessed by two major roads (Interstate 35 and Highway 75). Lake Texoma experienced 6,205,187 total visitors in 2010. A lake breakdown of its activities can be found at http://www.corpsresults.us/recreation/fastfacts/lake.cfml?lakeID=404.
Pool size, recreation infrastructure development, recreation accessibility and the highly desired game fish all contribute to Lake Texoma's importance as a recreation resource not only to the region but to the Nation. Pool size, recreation infrastructure development and recreation accessibility have not been expressed to be impacted by Red River Chloride Control. Pool size, pool level, infrastructure, aesthetics, water quality etc are all functions of demand, these functions of overall recreation demand at Lake Texoma is thought to be unchanged by Red River Chloride Control Project Area VI. The expressed concern is that of the unique striped bass population. This characteristic as it relates to fish catch will be evaluated through the specific activity of striped bass fishing.

Demographic Characteristics

Table 61 provides basic demographic information on the seven counties adjacent to Lake Texoma. Information is provided on the employment categories that are believed to have the most direct impact from recreational opportunities at the lake.

Table 61 - Demographic Information by County

			Employed in Industries of Interest (%)		
County by State	Population (2006*)	Median Household Income ($)	Fishing & Hunting**	Retail Trade	Recreation etc.***
Texas	*23,507,783*	*41,645*	*2.7*	*12.0*	*7.3*
Cooke	38,946	41,200	5.4	13.6	5.3
Grayson	118,478	38,752	1.9	12.5	6.1
Oklahoma	*3,579,212*	*37,109*	*4.1*	*12.0*	*7.5*
Bryan	38,395	29,055	3.8	12.9	7.3
Carter	47,503	32,046	7.9	15.4	7.8
Johnston	10,436	28,306	7.3	11.4	5.4
Love	9,162	34,431	7.3	10.2	8.4
Marshall	14,558	29,344	3.9	13.4	9.4

Source: U.S. Census Population and Housing, 2000
* estimate
** this category also includes the agriculture, forestry, and mining industries
*** this category also includes the arts, entertainment, accommodation, and food services industries

Recreation Existing Condition

Anglers pursue striped bass, catfish, crappie, sand bass, and largemouth bass, with striped bass being the most sought after game fish. Competitive fishing events, commonly for striped bass, are held annually on Lake Texoma. It is estimated that there are between 450 and 700 fishing guides who provide services on the lake. Other water-based recreation activities include boating, waterskiing, jetskiing, and swimming. Other lakes in the region provide substitutes for most of Lake Texoma recreation activities (discussed in substitutes section). Lake Texoma facilities are also popular for family reunions, camping, hiking, and golfing. The vibrant bass fishery is not adequately substitutable by lakes in the region. Of the total annual visitors, 101,000 were estimated to participate in this fishery taking seven trips a year. Visitation estimates were based on Oklahoma and Texas' fish and wildlife licenses sales. A significant amount of license sales reached as far as Colorado and Kansas. The expanse of license sales highlights the significance of Lake Texoma as a fishing destination.

National Economic Development

Phase I of the recreation study included other recreation opportunities, description of the study area, sample design, survey questionnaire and identified the economic valuation method (USACE 2007). The Phase I report was provided to the TPWD, U.S. Fish and Wildlife Service (USFWS), and Oklahoma Department of Wildlife Conservation (ODWC) in the fall of 2008. Phase I concluded that a Willingness-to-Pay (WTP) survey with Contingent Value Method

(CVM) and Travel Cost Method (TCM) components is the appropriate method for valuing the Nation Economic Development (NED) provided by the striped bass recreational resource (USACE 2007). Phase I identified a larger study area to encompass users from Oklahoma City, Tulsa, Houston, Dallas-Fort Worth and Colorado. The user area was identified using data provided by Texas Parks and Wildlife Department (TPWD). This larger NED user area better identifies travel costs structure needed in the TCM component of the survey. In Phase II administration of the survey and an econometric analyses were performed to develop lower-bound, upper-bound, and most likely (WTP) estimates for the striped bass fishery. The range of estimates calculated was reasonable compared with previous similar research and ranged from $9 to $21 per year, with a most likely value of $17 per year for the Texas (surveyed) side of the lake. Due to average incomes being lower in Oklahoma, the WTP for that side of the lake is estimated to be $16 per year. The Texas user population is approximately 39,000 anglers and the Oklahoma user population is an estimated 62,000 anglers per year. Based on the calculated WTP values and user population, the aggregate WTP for Lake Texoma's striped bass fishery ranges from $909,000 to $2,121,000, with a most likely value of $1,655,000 (USACE 2009).

Regional Economic Development

Phase II included preliminary Regional Economic Development (RED) components. Phase II provided some incite to the expenditures in the region tied to the use of the resource. The economic impact region is different than the NED user study area. The economic impact region includes Bryan, Carter, Johnson, Love, Marshall, in Oklahoma and Cooke and Grayson Counties, in Texas. The striped bass regional recreation expenses are estimated to be $2,180 annually per visitor, totaling $220,180,000 annually within the region (USACE 2009). It's important to note that these expenses are for the striped bass fishery alone. Phase III (ongoing) will provide a regional economic impact assessment for possible outcomes. Regional economic impact assessments will document the multiplicative effects of these lost recreation expenditures in the regional economy. Regional impact account typically consists of; jobs, income, business revenue, local tax revenue and gross regional product lost.

Other Social Effects

Local municipalities depend on sales tax revenue collected from expenditures. Recreation expenditures can be a sbstantial portion of those revenues, particularly striped bass fisherman. These revenues help fund local schools, fire departments, police departments and other local municipal services. As well as the services provided by municipalities the accumulation of jobs in the region support worship facilities, and other socially cohesive groups.

Agency Revenues

There are 10 USACE parks located around the perimeter of Lake Texoma. USACE collects approximately $700,000 in user fees each year at Lake Texoma. Approximately 101,000 licenses were sold by Texas Parks and Wildlife Department (TPWD) and Oklahoma Parks and

Wildlife Department (OPWD) in 2006. Licenses sell for $12 equating to $1,212,000 annually in license revenues for both groups.

Regional Substitutes

The regional substitutes provide certain recreation activities without the existence of Lake Texoma. Listed are a few of the available substitutes within a 100 mile radius: Lake Ray Roberts, and Pat Mayse Texas, Lake Murray, Arbuckle Reservoir, Waurika Lake, Lake McGee Creek, and Atoka Lake Oklahoma. These lakes provide water-based recreation activities include boating, waterskiing, jetskiing, camping and swimming. Not only is there sufficient substitutes for these activities, the changes in salinity will have no effect on these activities. The value of these activities to the nation will not be lost or affected in any way.

Inventory of Existing Recreation Conditions: Oklahoma

There are many outdoor recreation opportunities in Oklahoma, with the central and eastern portions of the State having the largest number of opportunities. Oklahoma Tourism divides the State in to six regions: Red Carpet Country, Great Plains Country, Frontier Country, Lake and Trail Country, Green Country, and Kiamichi Country. Primary alternative recreation sites to Lake Texoma in the State of Oklahoma are located in Green Country

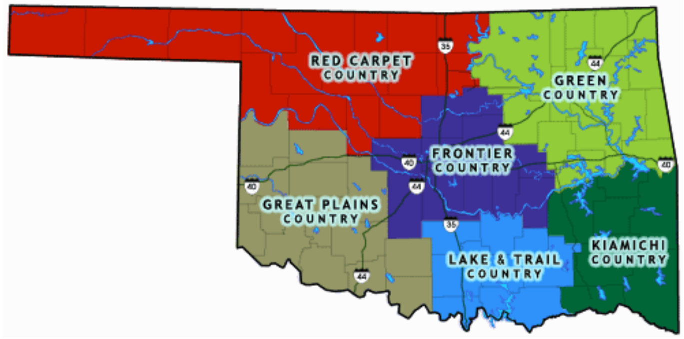


Figure 20 – Oklahoma Tourism Regions

Green Country, which includes Tulsa, provides 39 lakes with 21 State parks with various recreation facilities. Not all of these State parks are located on or near lakes. However, Keystone Lake State Park is located on Keystone Lake, between Sand Springs and Mannford, just outside of Tulsa. Lake Keystone is home to various recreational fish, including largemouth, smallmouth, white, and striped bass; channel catfish; crappie; sunfish; walleye; and saugeye. This variety closely resembles what is available on Lake Texoma. Twenty-seven lakes and four State parks are located in Great Plains Country, however fishing and boat access is limited. Quartz Mountain State Park, which surrounds Lake Altus-Lugert, provides a variety of recreation opportunities, including hunting, fishing, camping, and golfing. (Map from Travel Oklahoma. http://www.travelok.com/ada-rec/)

Inventory of Existing Recreation Conditions: Texas

Figure 21 - Texas Travel Regions

Texas Parks and Wildlife Department.
http://www.tpwd.state.tx.us/spdest/findadest/

Texas is divided into seven travel regions: Panhandle Plains (1) Prairies and Lakes (2), Pineywoods (3), Gulf Coast (4), South Texas Plains (5), Hill Country (6), and Big Bend Country (7). Three areas—Prairies and Lakes, the eastern portion of Hill Country, and Pineywoods—provide similar recreation opportunities to Lake Texoma.

Lake Texoma is located on the north edge of Prairies and Lakes. There are 60 lakes in the Prairies and Lakes region of Texas, four of which Texas Parks and Wildlife Department stocks with striped bass. Eighteen State parks offer access to fishing and other outdoor recreation facilities and two parks offer river shore fishing.

Hill Country, located southwest of the Dallas/Fort Worth metroplex, and includes the City of Austin. The eastern portion of the region offers 13 freshwater lakes, four of which Texas Parks and Wildlife department stocks with striped bass. Other recreation opportunities, including hiking, fishing, boating, camping, and golfing, are available throughout the region. The Pineywoods region is located to the east and southeast of the Dallas/Fort Worth metroplex. There are 31 freshwater lakes with 41 state parks located in this region. Pineywoods offers a variety of recreation activities similar to those found at Lake Texoma, including striped bass fishing at Livingston Lake.

Future Without Project Conditions

Lakes and reservoirs fill with sediment over time. Lake Texoma is no exception. From the bathometric survey conducted in 2002, the volume of the reservoir at the conservation pool of 617 feet is estimated to be 2,516,232 acre-feet. By comparing that survey of the reservoir volume to previous surveys, the average rate of sedimentation is estimated to be 10,099 acre-feet per year. The loss of reservoir storage is a loss of aquatic habitat. More discussion on this biological change can be found in the environmental setting. This natural degradation will affect the overall fishery much earlier than other recreation activities taking place at the lake. It is this natural degradation that will be used when evaluating the future with-out project conditions and the project alternatives. For economic purposes the natural degradation will correlate with a loss to the desired fishery. However with Texoma's large size, recreation infrastructure and easy accessibility the resource will continue to play an important role in the region's economy. Opportunities may be realized to replace losses in fishing recreation and its economic component in the region's economy. Both Texas and Oklahoma have developed a Statewide Comprehensive Outdoor Recreation Plans (SCORP) which lay out several different activity options. Its size and increasing demand for outdoor recreation will likely allow Lake Texoma to maintain much of its regional economic activity. To achieve this, management of the resource will need to explore other recreation activities. Also, a $350 million project to include a new resort, conference center and cottages, and modification of the existing Chickasaw Pointe Golf Course could contribute an initial regional economic impact. Recreation infrastructure improvements such as this will further increase the value and demand for Lake Texoma as an outdoor recreation resource.

Environmental Conditions

The Red River above Lake Texoma drains about 39,719 square miles and flows generally in a southeasterly direction. Streams and tributaries are not deeply entrenched except where located adjacent to the High Plains escarpment to the west. During extended droughts, only major streams maintain continuous flows. Major tributaries of the Red River in this segment of the basin are the Pease and Wichita rivers in Texas and the Prairie Dog Town Fork, Salt Fork, and North Fork of the Elm Fork in Oklahoma and Texas. The Wichita River is the major tributary to the Red River in the study area.

Chloride Sources.

Assessment of chloride source areas since 1957 has identified two major types of chloride contributions to the Red River: oil field brines and natural chloride seeps or springs.

Oil Field Brines.

The principal man-made sources of chloride in the study area have been identified as originating from oil field brine disposal operations and storm water runoff. The production of oil and/or gas commonly includes chlorides, often referred to as oil field brine, as a byproduct which requires proper disposal. Previous brine disposal practices from the early 1900's through the 1960's were by discharge into open earthen evaporation pits or the nearest watercourse. This method continued as an acceptable practice by many independent oil operators until regulations prohibited the disposal of brine in open pits. The chloride concentration of disposed brines typically ranged from 3,000 mg/l to as high as 35,000 mg/l.

Reduction of these sources is not included as a goal of the Red River Chloride Control authorization. However, recognizing the impact to the environment and both surface and groundwater supplies, the State of Texas, acting through the Texas Railroad Commission, promulgated regulations that resulted in the emptying and backfilling of brine disposal pits, and required that the brine be injected into authorized zones as the only accepted means of disposal.

Other man-made sources of chlorides enter the river system from municipal and industrial waste discharges. Since the 1970's, in response to the Federal Clean Water Act, the States of Texas and Oklahoma have continued to work with municipal and industrial waste dischargers to meet higher water quality standards with each new permit. Although chlorides are not normally a regulated parameter in waste discharge permits, advanced treatment techniques used to meet permitted parameters in conjunction with requirements to meet higher water quality stream standards have had, and will continue to have, a declining effect on chloride loads into the river system.

Manmade brine now appear to contribute less than 5% of the 4,400 tons per day of chlorides entering Lake Texoma.

Natural Chloride Sources.

Natural chloride areas occurring as seeps, springs, and salt flats are located in the basin study area. The North Fork of the Elm Fork of the Red River is representative of several river basins in the southwestern United States in regard to natural salt concentrations. Geologic formations underlying portions of Texas, Oklahoma, New Mexico, Kansas, and Colorado are sources of salt emissions to the rivers. In the past, this region was covered by a shallow inland sea. Salts precipitated from evaporating seawater formed the salt-bearing geologic formations. Salt springs and seeps and salt flats in upstream areas of the basins now contribute large salt loads to the rivers.

Springs are natural groundwater seeps or flows, formed where underground water intercepts a low permeability material, such as rock or clay. Instead of filtering down, water moves horizontally, much like rain running off the roof of a house. This horizontal pooling of water forms the water table. The water table typically follows surface topography. Springs, ponds, lakes, and streams mark places where the surface intercepts the water table. Salt seeps and springs are formed as the water table dissolves salt present in geologic formations as it flows. The chloride loads by source areas are shown below.

Affected Environment

The purpose of this section is to describe areas potentially affected by the proposed project. The beginning of this section addresses general area-wide attributes while later portions describe geographically specific conditions.

Study Area.

The study area encompasses the Elm Fork Red River beginning at the brine source areas west of Highway 30 in Harmon County, Oklahoma, downstream to the Elm Fork's confluence with the North Fork Red River, the North Fork Red River to its confluence with the Red River, and the Red River downstream to Lake Texoma (Denison Dam). Hydrologic study reaches include Reach 15 (Salt Fork Red River to confluence with the North Fork Red River), Reach 14 (Elm Fork of the North Fork Red River to confluence with North Fork Red River downstream to North Fork Red River confluence with the Red River), Reach 12 (Red River downstream from confluence with North Fork Red River to Tillman/Cotton county line), Reach 7 (Red River from Tillman/Cotton county line to Cotton/Jefferson county line), and Reach 5 (Lake Texoma). The hydrologic study reaches are presented in USACE (2011).

The study area encompasses lands within 50 elevation feet of rivers and reservoirs within the study area as well as agricultural lands within each hydrologic region affected by potential changes in irrigation. Oklahoma counties within the study area include: Greer, Harmon, Jackson, Kiowa, Tillman Cotton, Jefferson, Love, Marshall, Johnston, Bryan. Texas counties within the study area include: Collingsworth, Childress, Hardeman, Wilbarger, Wichita, Clay, Montague, Cooke, Grayson, The project area and scope constitutes major change over the Red River Chloride Control Project authorized in the Water Resources and Development Act of 1986. Reaches previously evaluated within the Wichita River basin have not been included in this study and would not be affected with implementation of the currently proposed project. The evaluation and impacts of chloride control activities in the Wichita River basin (Areas VII, VIII, and X) are presented in the Final Supplement to the Final Environmental Statement for the Authorized Red River Chloride Control Project; Wichita River Only Portion (USACE 2003, Federal Register 2004).

Physiographic and Climate Setting.

The study area extends from Denison Dam, Denison, TX upstream to the western extremes of the Elm Fork of the North Fork Red River in Greer County, Oklahoma. Chloride source areas are located approximately 140 miles west southwest of Oklahoma City, Oklahoma County, Oklahoma and approximately 45 miles northwest of Altus, Jackson County, Oklahoma. The upper basin study area lies within the Central Great Plains ecoregion (Level III) (Omernik 1987). Level IV ecoregions within the upper reaches of the study area include Caprock Canyons, Badlands, and Breaks, Red Prairie, Wichita Mountains, Red River Tablelands, and Broken Red Plains (Woods *et al*. 2005). Chloride source areas are located within the Caprock Canyons ecoregion and the remainder of the upper basin study area is comprised primarily by Red Prairie, Red River Tablelands, and Broken Red Plains ecoregions. Elevation of the upper basin areas level to rolling plains, scattered ledges and escarpments, low mountains, and hills range from 850 to 2550 feet above sea level. The lower basin study area comprising the Lake Texoma area lies within the Cross Timbers level III ecoregion (Omernik 1987). Level IV ecoregions surrounding Lake Texoma and the lower basin study area include Eastern Cross Timbers and Western Cross Timbers (Woods *et al*. 2005). Elevation of the lower basin areas rolling hills, cuestas, and ridges range from 640 to 1200 feet above sea level.

The climate is humid-subtropical with hot summers, it is also continental, characterized by a wide annual temperature range. Annual precipitation also varies considerably, ranging from 26 to 34 inches within the upper portions of the study area and from 26 to 46 inches within the lower portions of the study area. Usually, periods of rainy weather last for only a day or two and are followed by several days with fair skies. A large part of the annual precipitation results from thunderstorm activity, with occasional heavy rainfall over brief periods of time. Thunderstorms occur throughout the year, but are most frequent from March through June. Precipitation between March and June comprises approximately 40% to 45% of average annual rainfall amounts. Average snowfall amounts range from 3 inches in the eastern portions of the study area to 3.2 inches in the western portions. Throughout the study area, on average, approximately 1 day per year has at least 1 inch of snow on the ground. However the number of days varies from year to year. Average relative humidity in mid-afternoon ranges from 55 percent in the eastern portions of the study to 40 percent in the western portions.

The highest temperatures of summer are associated with fair skies, westerly winds, and low humidity. Characteristically, hot spells in summer are broken into three-to-five day periods by thunderstorm activity except during El-Nino years. There are only a few nights each summer when the low temperature exceeds 80 degrees F. Summer daytime temperatures frequently exceed 100 degrees F. Average low and high temperatures, in the eastern portion of the study area, range from 28.9 degrees F in January to 95.2 degrees F in August. Average low and high temperatures, in the western portion of the study area, range from 25.2 degrees F in January to 96.6 degrees F in August.

The average length of the warm season (freeze-free period) is approximate 229 days. The average last occurrence of 30 degrees F or below is mid-April, and the average first occurrence of 32 degrees F or below is in early November.

Vegetation.

Vegetative communities occurring within the study area are predominately a function of human influence. Existing vegetative communities throughout the entire basin include a number of different types composed of various sub-climax stages. True climax communities are largely absent throughout this area having been modified by cultivation, fire control, and grazing. Agriculture is the principal land use throughout the study area. Native floodplain vegetation largely has been cleared or fragmented into small, isolated patches and replaced with tame pasture, hay, vegetables, cotton, and small grains. Although highly impacted by human activity, remnant habitats still provide essential life requisites for aquatic and terrestrial life. The upper Red River basin is dominated by rangeland used primarily for pasture and cropland. Most of the study area watershed is a mixture of juniper and mesquite shrubs and grasslands, with some areas of cropland. The riparian community is relatively narrow in most of the watershed and consists largely of saltcedar (*Tamarix chinensis*), willow (*Salix spp.*) and some cottonwood (*Populus deltoides*).

Soils.

The proposed plan features would be located in southwest Oklahoma in a region dominated by Permian Age sedimentary rocks. The project lies near the southwestern edge of the Osage Plains section of the Central Lowlands Physiographic Province and adjacent to the High Plains Physiographic Province to the west. The project sites are underlain by the relatively flat lying Permian age Flowerpot Shale and Blaine Formations. Flowerpot Shale is a thick unit of impervious red-bed shales, interbedded with thin green-gray shales and, in the upper part of the formation, with bed of gypsum and dolomite. The overlying Blaine formation consists of interbedded gypsum, dolomite, and shale. With the exception of low-lying drainage areas, bedrock consisting of the above-described units is exposed or is anticipated to be present at shallow depths across most of the upland surfaces.

Soils in the proposed project area consist primarily of colluvial deposits on the upland areas and sidehill slopes. These deposits consist primarily of silt and clay with varying amounts of bedrock float fragments and are interpreted to be the product of weathering of the underlying bedrock. These deposits range in depth from zero feet, where bedrock is exposed on the surface, to a depth of several feet, generally near the base of slopes. Alluvial deposits are present in the drainage areas. The deposits are generally in the form of flat surfaced terraces. In some of the larger drainage areas, two levels of terraces are present – low narrow terrace adjacent to the active stream channel and a higher level terrace beyond. The thickness of the deposits are thinnest near the margins of the drainage and adjacent to the steeper slopes and range from 10 to 20 feet in thickness near the drainage. These deposits generally consist of an upper portion of sandy, silty clay underlain by coarse grain sediments consisting of silt, sand and gravel with occasional cobbles.

Air Quality.

A non-attainment area is an area which does not meet one or more of the National Ambient Air quality Standards (NAAQS). The EPA Office of Air Quality Planning and Standards has set NAAQS for the six criteria pollutants listed in Table 62. Information reported in 40 CRF Part 81 (2009) by the Texas Commission on Environmental Quality (TCEQ) and the Oklahoma Department of Environmental Quality indicates that the project is not located in a non-attainment area.

Table 62 – National Ambient Air Quality Standards for criteria pollutants (carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), lead (Pb), particulate matter less than 2.5 micrometers ($PM_{2.5}$), particulate matter less than 10 micrometers (PM_{10}), and sulfur dioxide (SO_2)) and attainment status of Air Quality Control Regions (AQCR) 188, 189, 210, and 211.

Pollutant	Type of Average	Primary Standard	Secondary Standard	Designation (2010)	
				OK[1]	TX[2]
CO	8-hour	9 ppm	None	Unclassifiable/Attainment	Unclassifiable/Attainment
	1-hour	35 ppm			
NO_2	Annual Arithmetic Average	53 ppb	Same as Primary	Cannot be classified or better than national standards	Cannot be classified or better than national standards
	1-hour	100 ppb	None		
O_3	8-hour	0.075 ppm	Same as Primary	Unclassifiable/Attainment	Unclassifiable/Attainment
	1-hour	0.12 ppm	Same as Primary	Unclassifiable/Attainment	Unclassifiable/Attainment
Pb	Rolling 3-Month Average	0.15 ug/m^3	Same as Primary	Not reported	Not designated
$PM_{2.5}$	Annual Arithmetic Average	15.0 ug/m^3	Same as Primary	Unclassifiable/Attainment	Unclassifiable/Attainment
PM_{10}	24-hour	150 ug/m_3	Same as Primary	Not reported	Unclassifiable
SO_2	Annual Arithmetic Average	0.03 ppm	0.5 ppm/3-hour	Better than national standards	Better than national standards
	24-hour	0.14 ppm			
	1-hour	75 ppb	None		

1. AQCR 188 and 189 (40 CFR § 81.337)
2. AQCR 210 and 211 (40 CRF § 81.344)

Wild and Scenic Rivers.

The Federal Wild and Scenic Rivers Act, Public Law 90-542, established that a wild, scenic or recreational river must possess one or more of the following three traits to be designated a Wild and Scenic River: 1) Wild river areas, characterized as being unpolluted, free from impoundments, generally inaccessible except by trail, with primitive watershed or shorelines; 2) Scenic river areas, characterized as being free from impoundments, generally accessible in places by road, and having shorelines or watershed still largely undeveloped; and 3) Recreational river areas, which may include some development along their shoreline, readily accessible by road or railroad, and may have undergone some impoundment or diversion in the past. Currently there are no streams or rivers within the proposed project area that are classified as wild and scenic pursuant to the Federal Wild and Scenic Rivers Act.

Environmental Justice.

Executive Order 12989 requires each Federal agency to make environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations.

Under NEPA, the identification of a disproportionately high and adverse human health or environmental effect on a low-income population, minority population, or Indian tribe does not preclude a proposed agency action from going forward, nor does it necessarily compel a conclusion that a proposed action is environmentally unsatisfactory. Rather, the identification of such an effect serves to heighten agency attention to alternatives (including alternative sites), mitigation strategies, monitoring needs, and preferences expressed by the affected community or population.

Low-income populations in an affected area are identified with the annual statistical poverty thresholds from the Bureau of the Census Reports on Income and Poverty. In identifying low-income populations, agencies my consider as a community either a group of individuals living in geographic proximity to one another, or a set of individuals (such as migrant workers or Native Americans), where either type of group experiences common conditions of environmental exposure or effect.

Minorities are comprised of individual(s) who are members of the following population groups: American Indian or Alaskan Native; Asian or Pacific Islander; Black, not of Hispanic origin; or Hispanic.

Minority populations are identified where either: (a) the minority populations of the affected area exceeds 50 percent or (b) the minority population percentage of the affected area is meaningfully greater than the minority population percentage in the general population or other appropriate unit of geographic analysis. In identifying minority communities, agencies may consider as a community either a group of individuals living in geographic proximity to one another, or a geographically dispersed/transient set of individuals (such as migrant workers or Native American), where either type of group experiences common conditions of environmental exposure or effect. The selection of the appropriate unit of geographic analysis may be a governing body's jurisdiction, a neighborhood, census tract, or other similar unit that is to be chosen so as to not artificially dilute or inflate the affected minority percentage, as calculated by aggregating all minority persons, meets one of the above-stated thresholds.

Disproportionately high and adverse human health effects: When determining whether human health effects are disproportionately high and adverse, agencies are to consider the following three factors to the extent practicable: (a) Whether the health effects, which may be measured in risks and rates, are significant or above generally accepted norms. Adverse health effects may include bodily impairment, infirmity, illness, or death; and (b) Whether the risk or rate of hazard exposure by a minority population, low-income population, or Indian tribe to an environmental hazard is significant and appreciably exceeds or is likely to appreciably exceed the risk or rate to the general population or other appropriate comparison group; and (c) Whether health effects occur in a minority population, low-income population, or Indian tribe affected by cumulative or multiple adverse exposures from environmental hazards.

Disproportionately high and adverse environmental effects: When determining whether environmental effects are disproportionately high and adverse, agencies are to consider the following three factors to the extent practicable: (a) Whether there is or will be an impact on the natural or physical environment that significantly and adversely affects a minority population, low-income population, or Indian tribe. Such effects may include ecological, cultural, human health, economic, or social impacts on minority communities, low-income communities, or Indian tribes when those impacts are interrelated to impacts on the natural or physical environment; and (b) Whether environmental effects are significant and are or may be having an adverse impact on minority populations, low-income populations, or Indian tribes that appreciably exceeds or is likely to appreciably exceed those on the general population or other appropriate comparison group; and (c) Whether the environmental effects occur or would occur in a minority population, low-income population, or Indian tribe affected by cumulative or multiple adverse exposure from environmental hazards.

Threatened and/or Endangered Species.

The most recently updated list of Oklahoma Federally-Listed Endangered Threatened, Proposed, Candidate, Recovered, Extirpated and Extinct Species, dated January 14, 2010 has been provided by the U.S. Fish and Wildlife Service (USFWS) by letter dated November 22, 2010. Endangered and threatened species that exist in the proposed project area include the black-capped vireo (V*ireo atricapilla*), interior least tern (*Sterna antillarum*), whooping crane (*Grus americana*), piping plover (*Charadrius melodus*), and American burying beetle (*Nicrophorus americanus*). Candidate species that exist in the proposed project area include the lesser prairie-chicken (*Tympanuchus pallidicinctus*). Additionally, the USFWS has been petitioned to list the prairie chub (*Machrybopsis australis*). Currently, the petition for the listing of the prairie chub is under review by the USFWS.

The State of Oklahoma and the State of Texas maintain lists of State Endangered, Threatened and Candidate Species. State listed species have no legal protection under the Endangered Species Act, as amended, and have been provided here for planning purposes only. Federal and state listed species and their status are provided in Table 63. Coordination and Section 7 consultation with the USFWS in Arlington, TX for counties in Texas within the project area is ongoing.

Table 63 - Federally- and State-listed endangered threatened, candidate, recovered, and proposed species that exist in the proposed project area

Scientific Name	Common Name	Federal Status	Oklahoma State Status	Texas State Status
<u>Mammals</u>				
Dipodomys elator	Texas kangaroo rate		SS2	T
Oryzomys palustris	Marsh rice rat		SS2	
Notiosorex crawfordi	Desert shrew		SS2	
Tadarida brasiliensis	Brazilian free-tailed bat		SS2	
Bassariscus astutus	Ringtail		SS2	
Corynorhinus townsendii pallescens	Pale lump-nosed bat		SS2	
Cynomys ludovicianus	Black-tailed prairie dog	C		
Anthus spragueii	Sprague's Pipit	C		
Canis lupus	Gray Wolf	E		E
Canis rufus	Red Wolf	E		E
<u>Birds</u>				
Sterna antillarum	Interior least tern	E	E	E
Haliaeetus leucocephalus	Bald eagle	R/D, M	E	T
Athene cunicularia	Burrowing owl		SS2	
Buteo swainsoni	Swainson's hawk		SS2	
Buteo regalis	Ferruginous hawk		SS1	
Tyto alba	Barn owl		SS2	
Aquila chrysaetos	Golden eagle		SS1	
Falco mexicanus	Prairie falcon		SS1	
Falco peregrine	Peregrine falcon			T
Falco peregrine anatum	American Peregrine falcon			T
Grus Americana	Whooping crane	E, CH	E	E
Tympanuchus pallidicinctus	Lesser prairie-chicken	Cw		
Vireo atricapilla	Black-capped vireo	E	E	E
Mycteria Americana	Wood stork			T
Numenius borealis	Eskimo curlew	E		E
Charadrius melodus	Piping plover	T		T
<u>Reptiles</u>				
Macrochelys temminckii	Alligator snapping turtle		CS, SS2	T
Phrynosoma cornutum	Texas horned lizard		CS, SS2	T
Crotalus horridus	Timber/Canebrake rattlesnake			T

Scientific Name	Common Name	Federal Status	Oklahoma State Status	Texas State Status
Fish				
Scaphirhynchus platorynchus	Shovelnose sturgeon		SS2	T
Percina maculate	Blackside darter		T	
Micropterus punctulatus	Spotted bass		SS2	
Notropis girardi	Arkansas River shiner	T,CH	T	
Machrybopsis australis	Prairie chub	SC, C		
Cycleptus elongates	Blue sucker			T
Erimyzon oblongus	Creek chubsucker			T
Polyodon spathula	Paddlefish			T
Invertebrates				
Nicrophorus americanus	American burying beetle	E	E	
Quadrula cylindrical	Rabbits foot mussel		SS2	
Potamilus amphichaenus	Texas heelsplitter			T

Federal Status: E – Endangered; T – Threatened; C – Candidate Taxa; SC – Species of Concern (those species with insufficient data to make a decision regarding status); CH – Critical Habitat Designated; Cw – Candidate, warranted but precluded

Oklahoma State Status: E – Endangered; T – Threatened; SS1 – Species of Special Concern that current evidence indicates especially vulnerable; SS2 – Species of Special Concern that have been identified by experts as possible threatened or extirpated; CS – Statewide Closed Season

Texas State Status: E – Endangered; T – Threatened

Cultural Historic Setting

General.

The following background review is excerpted from Peter et al (1995), "Research Design for Cultural Resources Investigations at Crowell Reservoir, Foard County, Texas," a document incorporated here by reference. Peter et al. (1995) serves as a general model guiding cultural resource investigations within the RRCCP and as a contextual description of the affected environment. The document edited by D.G. Wyckoff and R.L. Brooks (1983), "Oklahoma Archeology: A 1981 Perspective of the State's Archeological Resources, Their Significance, Their Problems and Some Solutions," serves as a model characterizing those areas affected by the RRCCP located in the state of Oklahoma. Wyckoff and Brooks (1983) is incorporated here by reference.

The portion of northern Texas and southwestern Oklahoma where the Red River Chloride project area is located generally falls within the Southern Great Plains culture area (Brooks and Hofman 1989; Wyckoff and Brooks 1983), although within the state of Texas the project area has been placed within several different regions. Wyckoff and Brooks (1983:23ff) designated extreme southwestern Oklahoma where part of the RRCCP is located as Region 1: Short Grass Plains. The 1954 overview of Texas archeology by Suhm, Krieger, and Jelks placed the project area on the western edge of their North Central Texas regions (Suhm et al. 1954: Figure 1). In

1981, Lynott placed this area in what he called Northern Texas, which included everything between the High Plains and East Texas and everything north of the Edwards plateau (Lynott 1981: Figure 1). In its designation of the archeological regions in Texas for purposes of comprehensive planning, the Texas Historical Commission (THC) placed the project area near the center of the Lower Plains regions, falling between the High Plains, Central Texas, and North Central Texas (Biesaart et al 1985; Figure 15.) In this review, Tulsa District will follow the THC's designation of the pojrect area as laying within the Lower Plains as a separate area, while recognizing the strong similarities described in Wyckoff and Brooks (1983), both cultural and natural, between this region and the surrounding territories.

Cultural History.

The general understanding of prehistoric chronology for the Lower Plains of Texas has not advanced much beyond Ray and Sayles' standardization of terminology in 1941. Since then, advances have been made in surrounding archeologically defined provinces. As a result, models of cultural chronology for the project area have depended heavily on making correlations between the project area and the surrounding provinces (see Wyckoff and Brooks [1983] and Etchieson, Speer, and Hughes [1979], "Archeological Investigations in the Crowell Reservoir Area, Cottle, Foard, King and Knox Counties, Texas"). Currently, six major eras are recognized as characterizing the cultural history of the project area: Paleo-Indian, Archaic, Plains Woodland, Plains Village, Protohistoric, and Historic (Table 64.) A brief discussion of this cultural historic sequence is presented below.

Paleo-Indian Period.

The Paleo-Indian era is the earliest substantiated cultural period documented in the Southern Great Plains (Gettys 1984). Unequivocal evidence of human occupation and use of the Southern Great Plains dates to about 12,000 years before present (B.P.) and is characterized by the Clovis complex (11,800 to 10,900 B.P., see Table X). Prior to the Clovis complex, indefinite or less than positive evidence of human occupation of the area has been used to support or otherwise characterize a Pre-Clovis horizon. The Clovis complex is followed by the Folsum complex (ca. 10,800 to 10,200 B.P.). Folsum is followed by a generalized series of regionally variable Late Paleo-Indian complexes (10,100 to 8,500 B.P.). These Paleo-Indian complexes are characterized by distinctive forms of fluted and later lanceolate projectile points, including the Clovis, Folsum, and Plainview points (see Hofman 1989b: Figure 8).

Table 64 - General Cultural Chronology

Paleo-Indian		
	Pre-Clovis	Prior to 11,800 B.P.*
	Clovis	11,800 to 10,900 B.P.
	Folsum	10,800 to 10,200 B.P.
	Late Paleo-Indian	10,100 to 8,500 B.P.
Archaic		
	Early	8,000 to 5,000 B.P.
	Middle	5,000 to 3,000 B.P.
	Late	3,000 to 2,000 B.P.
Plains Woodland		
	Transition from Terminal Archaic to Late Prehistoric	2,000 to 1,200 B.P.
Plains Village		
	Late Prehistoric I	1,200 to 750 B.P.
	Late Prehistoric II	750 to 500 B.P.
Protohistoric/Early Historic	450 to 200 B.P.	
Historic/Pan-American Culture	200 B.P. to Present	

*B.P. denotes Before Present

Archaic Period.

The subsequent period in the Southern Great Plains is generally referred to as the Archaic, which is characterized by diverse use of a wide array of modern plant and animal species in what is generally thought to have been a diffuse foraging economy (Hofman 1989b:44-47; D. Hughes 1984). Even with this diversification of resources used, the single most important resource within the region, when it was available, was the bison. There is evidence, however, that suggests that bison were not abundant in the Southern Great Plains between 7,000 and 3,500 years ago. Cultural material associated with the Archaic in the Southern Plains includes grinding tools thought to be used for processing plant foods, roasting ovens, rock-lined hearths, and a large variety of notched and stemmed projectile points. This cultural material appears to set the Archaic period apart from the earlier Paleo-Indian sites. In addition, it is thought that the Archaic people were more restricted than their forbearers in their movements across the landscape. This idea is based on evidence for more frequent and intensive reoccupation of many sites and more intensive use of local resources during this period. The Archaic is also characterized by the absence of ceramics and the bow and arrow, technologies which help to characterize the later Plains Woodland period. The evidence for increasingly restrictive movements, more frequent reoccupation of sites, more intensive use of local resources, and simply an increase in the number of sites, has been taken by many to indicate steady population growth.

The beginning dates of the Archaic are approximate and vary with changes in geographic location, while ending dates, although usually more precise, show a similar degree of spatial (horizontal and/or vertical) variation. In southwestern Oklahoma, the most recent estimate has it beginning around 8,000 B.P. and ending around 2,000 B.P. (Hofman 1989b). On the Lower Plains of Texas, the Archaic may have begun as late as 7,000 B.P. and continued up to 1,500 B.P. (Etchieson et al. 1978, 1979). For purposes of presentation, the Archaic has traditionally been divided into three parts: early, middle, and late (Table 64.).

Plains Woodland Period.

By about 2,000 B.P., a number of technologies had been added to the basic Archaic lifeway on the Southern Great Plains. These technological innovations distinguish the Plains Woodland period from its predecessors in the Archaic. The most visible change in the archaeological record involves the shift from the use of darts and dart points to the use of the bow and arrow, with associated small stone arrow points. A second important shift which generally dates between 2,000 and 1,500 B.P., was the introduction of ceramic technology in the form of cordmarked grit or bone tempered vessels. The period of time when these innovations first appear and are widely adopted has been generally referred to as the Woodland or Plains Woodland period in southwestern Oklahoma (ca. 2,000 to 1,200 B.P., see Table X.). Immediately to the south, this period overlaps with the Terminal Archaic period (ca. 2,000 B.P. to 1,500 B.P.; Etchieson et al. 1978) and is equivalent to the beginning of the Late Prehistoric I period (ca. 1,500 to 800 B.P.). On the High Plains immediately to the west, Hughes (1991) has recently termed the same period as the Early Neo-Indian, which he places roughly between 1,800 and 900 B.P.

Plains Village Period.

After about 1,200 B.P., a large portion of the Southern Great Plains was occupied by sedentary or semi-sedentary agricultural people who have been characterized archaeologically as the Plains Village tradition (Brooks 1989). Because of the large number of sites that date to this period and the extensive research efforts of sites that date to this period and the extensive research efforts that they have attracted, a large and broad-based nomenclature has been developed to characterize this time period throughout the Southern Plains (Brooks 1989).

The sites making up the Plains Village period are generally small, principally located along major river or stream systems and are closely linked to fertile floodplain soils that are well suited for an agricultural lifeway. The Plains Village lifeway was organized around both clustered village communities and more isolated, or scattered, farmsteads. These communities and farmsteads exhibit houses, numerous cache or storage pits, midden accumulation, and cemeteries. Current data indicate that in addition to an agricultural or horticultural lifeway, Plains Village people also relied heavily on bison and deer, fish, shellfish, and wild plants. Agricultural crops included corn, beans, squash, sunflowers, tobacco, and probably other plant species. On the Lower Plains of Texas, the Plains Village period is roughly contemporary with the later part of the Late Prehistoric I era (ca. 1,200 to 750 B.P.) and all of the Late Prehistoric II era (ca. 750 to 500 B.P.).

Protohistoric Period.

On the Southern Plains, the Protohistoric/Early Historic period is generally considered to have begun with the initial Spanish *entrada* of Francisco Vásquez de Coronado in 1541 and to encompass that period of time when there were limited European contacts and only brief records of journeys into or through the Southern Plains (see Hofman 1989c:91). Although the distinction between the Protohistoric and Historic periods is arbitrary, for purposes here, this transition period on the Lower Plains of Texas and on the Southern Plains in general is bracketed in time from ca. 450 to 200 B.P. While European occupation had started having strong effects on Native American societies before 200 years ago, the most profound effects of European occupation generally took place after this time, which is here referred to as the Historic period. The inhabitants of the south central Great Plains, including the project area, were dominated by a large confederation of tribes who today are the Wichita and Affiliated Tribes. The Lower Plains of Texas were also used at different times by the Kiowa, Comanche, and Apache tribes.

Currently, archeological evidence from the Lower Plains of Texas that dates to this period is rare compared with earlier occupations of this area, although during the Protohistoric period, the surrounding territory was heavily occupied by Southern Great Plains tribes. A large series of sites in western and southwestern Oklahoma, referred to as the Edwards and Wheeler complexes, and those that were occupied between about 500 and 250 years ago exhibit small triangular arrow points; large end and side scrapers; expanding based drills; dark sand-tempered ceramics; shell and bone beads; bison scapula hoes; and abundant remins of bison. These sites also contain exotic materials, including obsidian turquoise, and glaze painted ceramics from the southwest and other ceramics originating downstream on the Red River, as well as Euro-American trade materials, including gun flints and glass beads. These sites are closely tied to the modern day Wichita and Affiliated Tribes.

Sites believed to be of Apache origin that date to this period have been identified along the border of the High Plains to the northwest along the Prairie Dog Town Fork of the Red River in Randall, Armstrong, and Brisco counties, Texas (south-central Texas Panhandle) (Hughes 1978; Katz and Katz 1976). These sites contain small, triangular arrow points and thin, dark, plain, often micaceous, ceramics of local manufacture. The late date of these sites is based on the presence of late Puebloan painted wares from New Mexico. To the west of these sites, in Deaf Smith County, Texas, Hughes (1991:35) has defined a Tierra Blance complex at a site of the same name. This site is no older than 600 years old and had a tipi ring, a semi-subterranean slab-lined circular structure, and a windbreak or small arbor (Hofman 1989:c:99). Similar cultural characteristics are found to the south of the project area.

The cultural remains of the Comanche, Kiowa, and Kiowa-Apache have been the most difficult to identify of all the Southern Plains tribes. Hays (1989:Table I-5) lists 41 Comanche, Kiowa, and Kiowa-Apache sites located on the Southern Plains. At least 25 of these are historic cemeteries.

Historic Period.

The Historic period in western Oklahoma and northwestern Texas (A.D. 1800 – present) is characterized primarily by Euroamerican settlement, intermittent conflict between

Euroamericans and Plains tribes, and finally by agricultural and oil production development of the area. Fencing of the open range and deep-well irrigation fostered an increase in the number of small farms in the region. The effects of the Great Depression and its passing with the advent of World War II and more recent economic changes and growths have left the project area as an agricultural region.

Archaeological Investigations of Area VI.

Area VI was initially examined for archaeological resources and reported on by Pollyanna B. Hughes (1973:pp.2-46ff) and J.T. Hughes (1973:pp.2-67ff) in a report by West Texas State University, titled "Environmental Inventory and Assessment: Areas VI, IX, XIII, XIV, and XV, Red River Chloride Control Project, Oklahoma and Texas." This document is incorporated here by reference. Hughs (ibid) reported that seven prehistoric sites were identified in the vicinity of Area VI during a preliminary cultural resources reconnaissance. These sites were identified as being in the Kiser, Robinson, and Salton canyons and along Fish Creek.

Subsequent to this initial assessment, the Area VI collection area, pipeline, and Fish Creek Brine Lake were inventoried and reported on by J. Northcutt (1979), "An Archaeological Survey in the Gypsum Breaks on the Elm Fork of the Red River." Northcutt identified three previously unrecorded archaeological sites, including 34GR196, 34HR40, and 34HR41. In addition, Northcutt reinvestigated previously recorded sites 34HR10, 34HR58, 34HR59, 34GR40, and 34GR41. Two additional archaeological sites, 34GR39 and 34GR94, were recommended for further investigation. None of the other archaeological sites addressed in Northcutt's report were recommended for National Register evaluation. Section 106 (National Historic Preservation Act) consultation with the Oklahoma State Historic Preservation Office (SHPO) resulted in concurrence between Tulsa District and SHPO that sites 34GR39 and 34GR94 should be evaluated for NRHP eligibility should they be affected by the proposed Area VI project. Subsequent to these archaeological investigations, the proposed location of the brine disposal reservoir changed from Fish Creek to Root Creek. The area affected by the project at Root Creek has not been inventoried for cultural resources.

In summary, any of the proposed Area VI alternatives/alignments has the potential to impact cultural resources. Sections 106 and 110 of the National Historic Preservation Act (NHPA) of 1966 (as amended) require agencies to evaluate the impacts of federal undertakings on historic properties, which include prehistoric and historic archaeological sites, and historic standing structures. Section 106 requires the identification of all historic properties, which emphasizes an evaluation of eligibility for listing on the National Register of Historic Places (NRHP). Agencies must then determine which historic properties (those eligible for listing on the NRHP) will be adversely impacted. Sections 106 and 110 require that agencies resolve adverse effects to these properties. Plans for resolving adverse effects will be determined through consultation with the Texas Historical Commission, potentially the Advisory Council on Historic Preservation (ACHP), and appropriate and interested Native American tribes and other interested parties.

To fulfill the requirements outlined in Sections 106 and 110 of the NHPA, several tasks will require funding and execution within the feasibility phase of this project. In order to accomplish these tasks, the project area should be expanded to its fullest extent possible, so that design considerations can incorporate multiple variables, including cultural resources. Archaeological reconnaissance investigations, to include archival research, will be necessary to identify archaeological sites and standing structures that exist within the proposed project area. Each site and structure will require National Register evaluation; some will require sub-surface evaluation, detailed archival research or architectural documentation. NRHP-eligible sites and structures that will be adversely impacted by the undertaking will require mitigation, which will be determined through formal consultation with the THC, and potentially the ACHP. Mitigation requirements will be established in a Memorandum of Agreement (MOA).

Land Use.

Land use will be evaluated for the brine collection area, the brine disposal site and the general project area once a final plan has been recommended. Generally, land use within the project area is plowed agriculture (irrigated and dry-land), rangeland, and pasture.

Environmental End Use by Reach.

This section will include an evaluation of agricultural land use within the economic study reaches specific to this project. Study reaches will include reaches 6, 7, 12, and 14. A cumulative evaluation associated with all study reaches upstream of Denison Dam will also be included.

Socioeconomic Setting.

FSM Notes

Socioeconomic information can be found earlier in this Reevaluation. The environmental conditions, this section, will be moved to a NEPA document for the AFB documentation. The socioeconomic information in the Reevaluation will be duplicated in the NEPA document.

Hazardous, Toxic, and Radiological Waste (HTRW).

The Corps has not formalized an initial assessment of the potential for encountering HTRW on lands in the study area in preparation for the feasibility scoping meeting. Land use has historically been ranching and cattle grazing. The potential for HTRW to be present within the potential project area is remote. Land access is available to limited portions of the potential project area via farm and ranch roads. An initial assessment will be conducted when the potential project area is better defined.

When conducted, an initial assessment will include review of aerial photographic time series, interviews with local authorities, interviews with contract personnel working in the area, and interviews with regulatory agency personnel combined with a review of files maintained by those agencies. Visual site surveys will include a search for any visual evidence of past HTRW storage or release (e.g., abnormal soil staining, drums or chemical containers, aboveground tanks, lagoons, landfills). Agency files and databases will be searched for reported spills or potential problem areas.

Lake Texoma.

With its dam located at river mile 725.9 on the Red River between Oklahoma and Texas, Lake Texoma is an 89,000 surface-acre impoundment. Completed in 1944 by the USACE, the lake occupies portions of both south-central Oklahoma and north-central Texas. At normal pool elevation, 617.0 feet, maximum depth is 112 feet and mean depth is approximately 30 feet. Lake Texoma drains an area of approximately 39,719 square miles, with 5,936 square miles non-contributing, most of which is pasture and cropland.

The lake was constructed for flood control, regulation of Red River flows, improvement of navigation and hydroelectric power. Water supply and recreation were added later as project purposes. Based on 2002 sediment resurvey, the conservation pool (590 – 617 feet NGVD) is projected to contain 986,730 acre-feet of usable storage in 2044 (USACE 2010) based on a 2002 sedimentation resurvey of Lake Texoma (TWDB 2003). The conservation pool, since impoundment has suffered a permanent loss of storage in the conservation pool (590 – 617) of 22%.

Lake Texoma is a major resource for recreational activities and potable water to residents in the surrounding areas of Texas and Oklahoma. Because of its resource importance, Lake Texoma, more than any of the water bodies in this study, has been thoroughly investigated by many parties over many years. This section summarizes research that has been completed for the lake.

Water Quality.

General water quality is characterized by moderate to high levels of salinity with a predominance of sodium and calcium salts of chloride and sulfate (Leifeste *et al.* 1971). Chloride and sodium are the most abundant ions in Lake Texoma. From historical data the lake has been classified as mesotrophic based on chlorophyll *a* concentrations (Ground and Groeger 1994). Based on chlorophyll *a* concentrations for the Main Lake Zone (near dam) from Atkinson *et al.* (1999) during the summer months trophic status ranged from mesotrophic to hypereutrophic with a mean trophic classification of slightly eutrophic.

In a report by Atkinson *et al.* (1996), selected water quality data from Lake Texoma were reviewed to provide background information in developing a water quality monitoring program for Lake Texoma. Historical data relating to chloride and sulfate concentrations throughout the lake defined four zones: the Upper Red River Arm (lotic zone), the Red River Transition Zone, the Main Body (lacustrine zone), and the Washita River Arm (lotic zone). It was hypothesized that a Washita River Transition zone existed, however, monthly data from Stanford and Zimmerman (1978), Stanford *et al*. (1977), Perry *et al*. (1979), and Atkinson *et al*. (1999) all indicate that chloride and sulfate concentrations are highest in the Upper Red River Zone and are more variable than in other zones. The Red River Transition Zone shows decreasing concentrations from west to east and is influenced by loadings from Big Mineral Creek. The Main Lake Zone is relatively homogenous in surface layers in terms of chlorides and sulfates and shows much less variability than the other zones. The Washita River Arm is lowest in its concentration of chlorides and sulfates but shows considerable variability attributable to fluctuating loadings from the Washita River. Sampling locations and reservoir zones are shown in Figure 22. TDS differences between the reservoir zones is illustrated in Figure 23.

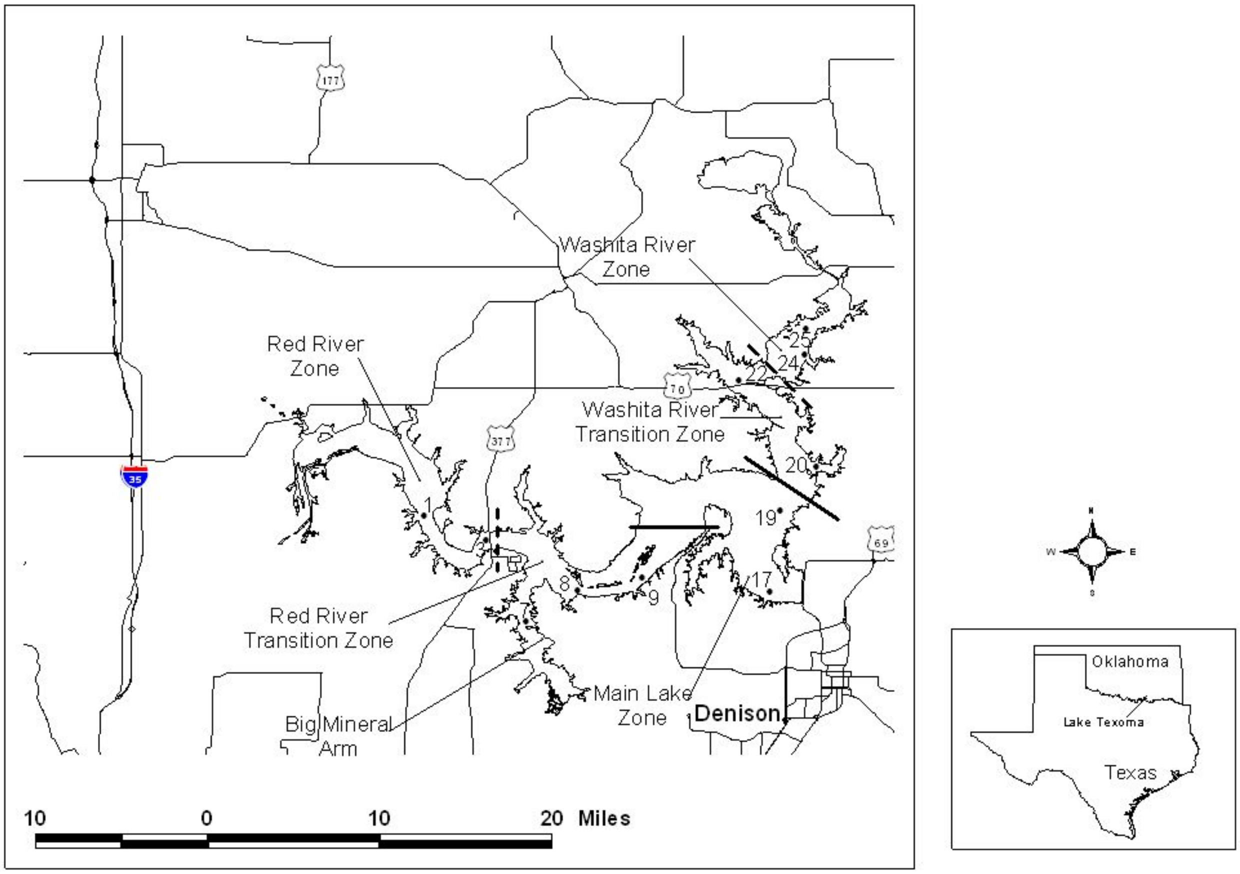


Figure 22 – Fixed sampling locations and reservoir zones in Lake Texoma (from Atkinson et al. 1999)

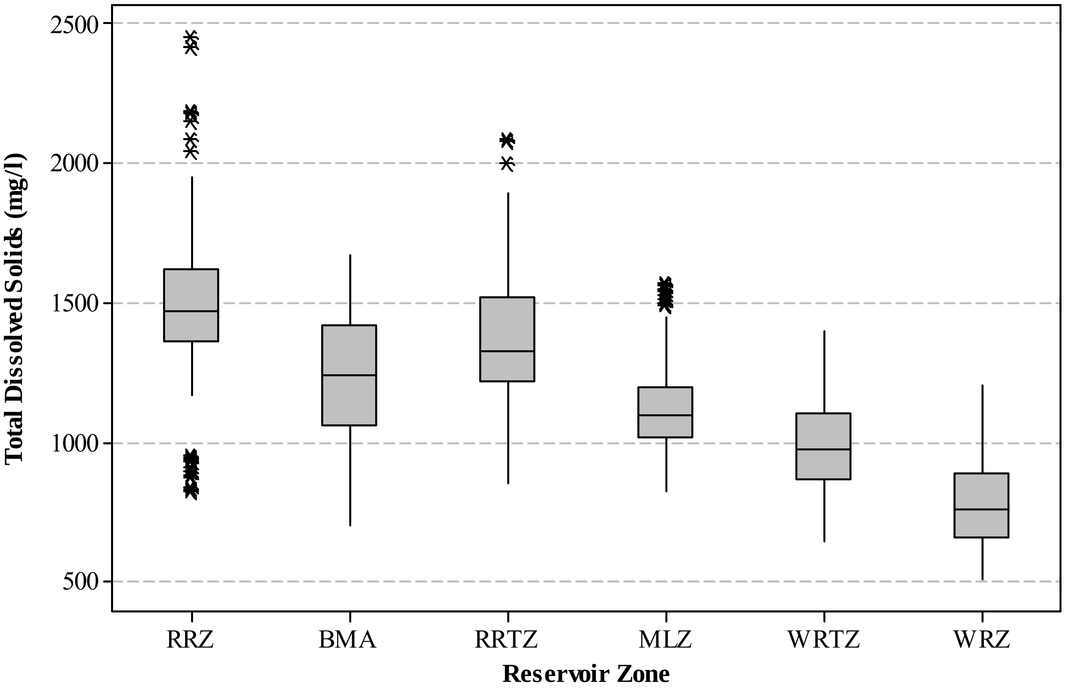


Figure 23 – Example of water quality differences
between reservoir zones, using total dissolved solids (mg/l) (modified from Atkinson *et al.* 1999). RRZ = Red River Zone, BMA = Big Mineral Arm, RRTZ = Red River Transition Zone, MLZ = Main Lake Zone, WRTZ = Washita River Transition Zone, WWZ = Washita River Zone.

Temporal (seasonal) variability of chlorides and sulfates in the four zones appears to be a direct function of discharge from the Red River and the Washita River. Maximum chloride concentrations in the Upper Red River Zone are typically observed during seasons of low discharge (winter and late summer) and minimum chloride concentrations are generally observed following late spring/early fall periods of high discharge. By contrast, chloride loadings were maximal during high discharge periods and lower during low discharge periods. Atkinson *et al.* (1996) determined that the influence of river discharge was most apparent in the zones proximate to each river and less apparent in the Main Lake Body Zone based on historical water quality studies. Stanford and Zimmerman (1978), Stanford *et al.* (1977) and Perry *et al.* (1979) found that late spring/early summer periods of high river discharge only occurred in the latter 2 years of their 3-year monitoring period, indicating a considerable degree of inter-annual variability. The degree to which inter-annual variability and river discharge can influence all zones of the lake was observed in the Main Lake Zone in August 1996 when chloride concentrations there were comparable to chloride concentrations in the Red River Zone (423 mg/l and 535 mg/l, respectively) (Atkinson *et al.*, 1999) following a period of increased discharge from the Red River.

Additional studies addressing the spatial and temporal (horizontal and/or vertical differences) variability (seasonal and/or inter-annual differences) of Lake Texoma water quality parameters were examined by contrasting the results of Stanford and Zimmerman (1978), Stanford *et al.* (1977), and Perry *et al.* (1979) to three other studies: Pettitt (1976), USACE

(1989), and Matthews and Hill (1988). A comparison of chloride and sulfate data from Pettitt's study conducted December 2-3, 1975, with results of the Stanford *et al.* December 18-20, 1975 study showed similar zonational trends in the lake but consistently higher chloride and sulfate concentrations in early December (Pettitt) versus late December (Stanford *et al.*). This comparison demonstrates the variability that can exist between two sets of data collected in the same month at similar locations.

Comparing the water quality results from the USACE study conducted in 1987 and 1989 in the Rock Creek tributary to results from a similar station gathered from Stanford and Zimmerman (1978), Stanford *et al.* (1977), and Perry *et al.* (1979) showed considerably lower chloride and sulfate concentrations in Rock Creek during the 1987-1989 study versus the 1975-1978 study. However comparisons between the USACE (1989) study and the Atkinson *et al.* (1999) study indicates that chloride concentrations in Rock Creek have increased slightly in the 1990s, and that sulfate concentrations have increased to levels comparable to those present in the 1970s.

A third study by Matthews and Hill (1988) in the summer of 1982 and 1983 provided insight into the behavior of vertical stratification in Lake Texoma. Comparing results from their study to the 1975-1978 study demonstrated that the deep sample sites showed similar patterns of stratification during early summer months (May-June) of 1976-1978. Thermal stratification did not exhibit a sharp thermocline in the traditional sense but apparently was stable enough to isolate the hypolimnion long enough to develop anoxic conditions. During summer conditions, establishment of a "traditional" thermocline does not appear to occur in the transition zones of either the Red River or the Washita River arms. Instead, a gradual decrease of temperature with depth occurs with surface temperatures of approximately 32º Celsius (C) and bottom temperatures around 20º C.

A "chemocline" based on dissolved oxygen and pH appears to gradually develop around a depth of 10 meters. Below the "chemocline", dissolved oxygen is low (< 2.0 mg/l) indicating that much of the hypolimnion is relatively anoxic. Vertical stratification of inorganic salts is not as distinctive as that of oxygen and pH. There appeared to be a general increase in specific conductance in the hypolimnion but no distinct zone of demarcation in the Red River arm (Matthews and Hill 1988). Data from the 1975-1978 study (Stanford and Zimmerman 1978; Stanford *et al*. 1977; and Perry *et al.* 1979) indicated that during that period the lake exhibited similar vertical gradients in temperature, dissolved oxygen, and pH, but that vertical gradients of specific conductance were more sporadic with higher values in the epilimnion and lower values in the hypolimnion.

Several factors have been reported to influence the vertical stratification of Lake Texoma. Hubbs *et al*. (1976) reported the presence of a "halocline" in the Red River arm of the lake below which total dissolved solids were found to substantially increase. During periods of stratification, "halocline" development would begin in the old river channel of the Red River in early summer and then move out into the old floodplain during extended periods of "warm, quiet weather" (Hubbs *et al.* 1976). Mathews and Hill (1988) concluded that although chemical gradients are present in the lake during periods of stratification, these chemical gradients (e.g., salinity) do not contribute to stratification stability to the degree that water temperature does. In contrast, using techniques described by Matthews and Hill (1988), Clyde (2004) evaluated stratification intensity and stability data from August 1996 – September 1997. Analysis of thermal and salinity density differences across the epilimnion-hypolimnion boundary in the summer of 1997 indicated that both thermal and salinity densities contributed equally to stratification stability. Although there was no clear spatial trend in thermal versus salinity stratification stability, a temporal trend was evident and appeared to be correlated with hydraulic residence time. Clyde (2004) concluded even moderate decreases in hydraulic residence time (i.e., increases in inflow) can influence stratification stability.

Aquatic Invertebrates.

Atkinson *et al.* (1999) analyzed lacustrine zooplankton samples collected between August 1996 and September 1997. The lacustrine zooplankton community in Lake Texoma during this study consisted of 72 species within 39 genera. The Rotifera exhibited the largest number of species (44) and the Harpacticoida the smallest number of species (1). Of the remaining crustacean species, the Cladocera exhibited the largest number of species (18) followed by the Cyclopoids (6) and the Calanoids (3). Historically, 28 zooplankton species had been reported from the lake (Crist, 1980). A comparison of the Atkinson *et al.* (1999) study with the Crist (1980) study revealed that the most dramatic change in the zooplankton community was due to the addition of new Cladoceran species. Within the Cladoceran group three new genera were identified (i.e., *Alona, Chydorus*¸ and *Leydigia*), as well as new species identifications within the genera *Ceriodaphnia* and *Moina*. Within the genus *Daphnia*, four new species were identified in samples taken from Lake Texoma (i.e., *D. lumholtzi, D. longiremis, D. pulex, D. cawtaba*).

J. Franks (2000) addressed the relationship between zooplankton populations and physical/chemical water characteristics from August 1996 to September 1997. The results of the study indicated that a strong chloride gradient exists within the lake as well as a weaker turbidity gradient. This conclusion has been confirmed by other studies as well (Atkinson *et. al.* 1996). Physical-chemical factors alone were found to explain on average 90% more of the variation in the zooplankton community than seasonal factors. The Red River arm of the lake was found to exhibit the greatest zooplankton density as well as the greatest diversity. This same pattern was reported by Crist (1980). However, the two contributing river systems, including the Red River and Washita River, though varying by an order of magnitude in chloride concentrations, each harbor significant populations of zooplankton which contribute to lake conditions.

Temporal variability in zooplankton abundance followed the typical seasonal pattern represented by a major pulse in the spring (May and June) and a second smaller pulse in the fall (September) as zooplankton populations recovered from the summer die-off. Zooplankton densities, as well as species diversity (i.e., Shannon diversity index), were greatest in the Red River and Washita River arms and generally tended to decrease through the transitional zones and Main Lake Zone. Analysis of community similarity (i.e., Bray-Curtis Similarity Index) between the reservoir zones revealed that within each arm of the lake (i.e., Red River and Washita River), species composition was similar between the river zone and transition zone, and the species composition in the Main Lake Zone was similar to the Red River Transition Zone twice as often as it was similar to the Washita River Zone.

Schnell *et al*. (2002) analyzed littoral zooplankton samples collected between April and October 2001. The littoral zooplankton community in Lake Texoma during this study consisted of 17 species within 12 genera collected from 41 sites. The Rotifer exhibited the largest number of species (7) the Copepoda the fewest number of species (3). The Cladocera comprised the remaining 7 species. The litoral zooplankton community exhibited temporal trends similar to those reported by Franks (2000), Atkinson *et al.* (1999), and Waller *et al*. (2002) with total abundance increasing monthly from April and May with peak abundances occurring in September and October and no clearly defined spatial distinction was observed between the riverine and main lake body portions of the lake.

Schnell *et al*. (2002) also analyzed the littoral aquatic invertebrate community in June and July of 1999, 2000, 2001. The aquatic invertebrate community in Lake Texoma during this study consisted of 57 taxa. All taxa present were common to silt-sand bottomed reservoirs and common to the Red River region of Oklahoma and Texas. Abundances in Lake Texoma averaged 22 ± SE of 9.6 organisms per dredge and where considered low when compared with southern reservoirs in general. The majority of substrate (habitat) available for benthic macroinvertebrates were primarily comprised of sand and fine gravel along windswept and wave disturbed shorelines, however areas protected from wind and wave action (e.g., creek embayments, coves) usually exhibited abundances greater than areas located within the lack proper (> 100 organisms/dredge) (Schnell *et al*. 2002). The most abundant group of benthic aquatic invertebrates during this study was comprised of chironomid dipterans and oligochaete worms (45 of 57 taxa). Seven chironomids (*Cladotanytarsus, Cryptochironomus, Dicrotendipes, Glyptotendipes, Polypedilu, Pseudochironomus,* and *Tanypus*) and three oligochaetes (*Aulodrilus, Branchiura,* and *Limnodrilus*) comprised 82% of all organisms collected. Benthic aquatic invertebrates did exhibit spatial distribution with differing dominant taxa present in Washita River arm (*Psudochironomus*), Red River arm (*Limnodrilus*), and Main Body (*Polypedilum*). Taxa richness and abundance were greater in the riverine portions of the reservoir and multiple regression suggested invertebrate richness was inversely related to turbidity and wind and wave action, and directly related to reservoir alkalinity. Overall, conclusions of Schnell *et al*. (2002) suggest that the benthic aquatic invertebrate community during this study primarily influenced by turbidity, nutrients (total Kjeldahl nitrogen), specific conductivity, and secondarily influenced by inter-annual variability in species richness and abundance related to fluctuations of water elevation in the conservation pool.

While only one individual mussel was reported by Schnell *et al*. (2002), the zebra mussel (*Dreissena polymorpha*) was reported to be present in Lake Texoma in 2008 via polymerase chain reaction (PCR) analyses (Sager *et al*. 2011). The first live adult zebra mussel was reported to be attached to a communication line beneath a boathouse in Lake Texoma (Hysmith and Mozygemma 2008; Sager *et al*. 2011) near Eisenhower State Park, Texas. Since 2009, the zebra mussel population has become well established throughout the reservoir and it appears that large concentrations of adult zebra mussels provide preferable habitat for the invasive Harris mud crab (*Rhithropanopeus harrisii*) (Boeckman and Bidwell 2010).

Fish Resources of Lake Texoma.

A description of fishery resources in Lake Texoma was prepared Wilde, *et al.*, (1996). Lake Texoma provides habitat for at least 73 species of fish (University of Tulsa 1971). Species popular for recreation and fishing include channel, blue, and flathead catfish; white and black crappie; temperate basses such as largemouth, smallmouth, and spotted bass; and true basses including white and striped bass (Sager *et al.* 2011). Gizzard shad, threadfin shad, and inland silversides are important forage species in the lake. Drum, carp, gar, buffalo, and river carpsucker make up the bulk of the non-game fish in the lake. An important tailwater fishery also exists for striped bass and channel, blue, and flathead catfish. The striped bass and smallmouth bass fisheries were developed in Lake Texoma after the initial FES (1976) was prepared for the RRCCP.

Reservoir strain smallmouth bass were stocked in Lake Texoma in 1981, 1982, and 1983. Natural reproduction was confirmed in 1985 (Hysmith 1988). Since that time, populations have been expanding and growth rates have equaled or exceeded most of those reported in the literature (Gilliland and Horton 1989). Additional reservoir strain smallmouth bass stockings occurred in 1987, 1991, 1996, 1998, and 1999. Largemouth bass is predominant *Micropterus* species in Lake Texoma and has been intensively managed by ODWC and TPWD to increase the abundance of trophy-sized bass (Sager *et al.* 2011). A important management strategy of largemouth bass management has relied on stocking Florida-strain bass in Lake Texoma in 1986, 1995, 1996, 1997, 1998, 1999, 2002, 2004, and 2010 however, while growth rates are comparable to other large reservoirs within the region, recruitment of young-of-year largemouth bass is occasionally below target recruitment rates (Sager *et al.* 2011).

Striped bass were initially stocked in Lake Texoma by the ODWC from 1965 until 1974 (Harper and Namminga 1986) and have successfully spawned annually since 1973 (Mauck 1991). Since the initial stocking, the striped bass fishery in Lake Texoma has developed into an extremely popular fishery and is considered one of the most successful striped bass fisheries in the nation (U.S. Fish and Wildlife Service 1989). Mauck (1991) estimated that from 1987 through 1990, the annual harvest of striped bass ranged from 630,000 to 930,000. The abundance and size of the striped bass has varied between specific years in response to strength of year classes and availability of forage species.

Striped bass are known to spawn in both the Washita and Red rivers and in the Red River striped bass have been caught near Spanish Fort, Texas which is greater than 30 miles upstream from the I-35 bridge upstream from Lake Texoma. Viable striped bass eggs floating down the Red River have been collected at the I-35 bridge. As discussed previously, under existing conditions, the salinity of the Red River flowing into Lake Texoma exceeds 500 mg/l, 95% of the time and 250 mg/l, 99% of the time. These high salinity concentrations may affect striped bass usage of the Red River.

An economic study and analysis of the value of the Lake Texoma sport fishery indicated that the indirect and direct effect of angler expenditures is $28.1 million, with striped bass fishing accounting for over 60% of the expenditures (Schreiner 1995). This reported maximum value of the fishery represents 0.8% of the income of the seven-county region and indicates that angler expenditures associated with the Lake Texoma sport fishery have an insignificant effect on the region's overall economy.

Vertical stratification in Lake Texoma is well documented (Schorr *et al.* 1993, Matthews and Hill 1988, and Hubbs *et al.* 1976). Stratification has a negative impact on freshwater species, especially striped bass. Striped bass have narrow tolerance ranges for dissolved oxygen and temperature. During periods of stratification, striped bass concentrate near the themocline where dissolved oxygen levels are low and this can result in summer die-offs (especially larger fish) due to stress induced by stratification. The ODWC has reported that smaller stripers are not as readily subjected to thermal stress and this tolerance allows them to occupy the shallow upper reaches of the reservoir during the summertime.

Golden Algae (*Prymnesium parvum*).

Golden algae was first reported in Lake Texoma in January 2004 and was identified as the factor responsible for a winter fish kill in the Lebanon pool in the upper Red River arm of the reservoir (Hysmith and Moczygemba 2005 and 2008). Since 2004, minor fish kills associated with the presence of golden algae toxin have been documented in 2006, 2007, and 2009. The cause of fish kills was due to exposure to the toxin produced by golden algae. To date, all fish kills associated with golden algae blooms have been isolated to the Red River arm of the reservoir (Sager *et al.* 2011). The ODWC (2008) reported golden algae blooms typically occur during the winter months with peak cell densities present during the February to March period in any given year with previous major blooms (>100,000 cells/ml) located in the Lebanon pool and minor blooms (up to 50,000 cells/ml) reported within the Red River arm at Briar, Keeton, and Buncombe Creeks with only trace densities (<5,000 cells/ml) present within the Red River transitional zone and main lake body.

The toxicity of golden algae blooms appears to be related to N:P ratios during bloom periods with toxicity increasing as N:P decreases (ODWC 2007). Additionally, the general pattern of blooms occurring in winter months coincides with periods when the N:P is less than 15 (Clyde 2004, ODWC 2008) and nitrogen is more likely to be limiting. While fish have been reported to be most susceptible to the golden algae toxin, experiments with *Daphnia pulicaria* and *Dapnia pulex* indicate that juvenile daphniid growth rates and survivorship can be adversely impacted by chronic exposure to the golden algae toxin (ODWC 2007).

Recreation.

FSM Notes

Additional recreation information can be found earlier in this Reevaluation. The environmental conditions, this section, will be moved to a NEPA document for the AFB documentation. To limit duplication of recreation information, only the brief summary below is included at this time.

Many different characteristics of a recreation resource add value to the resource. Size, water quality, fish quality or catch rate, recreation infrastructure, travel distance and other management practices all add value to those using the resource. Those changes in these recreation characteristics can change recreation users' behavior. It has been expressed that there may be a change in the resource as related to water quality and catch rate. Lake Texoma experienced 6,205,187 visitors in 2010 with approximately 909,000 of those visitors with the main purpose of fishing for striped bass. Fisherman with the main purpose of fishing for striped bass spent approximately $220,180,000 annually to go striped bass fishing most of which was captured in the region. This user group also expressed the willingness to pay $17 to forgo any negative impacts on catch rate up to a 30% decrease.

Water Supply.

As a water supply, Lake Texoma serves north Texas and south-central Oklahoma. The total water supply storage available is about 158,060 acre-feet, with a dependable yield of 150 million gallons per day (mgd). Water supply storage in Lake Texoma is under contract to specified users as shown in Table 65.

Table 65 - Lake Texoma Water Supply Allocations

User	Allocated Storage (acre-feet)	Yield (mgd)
City of Denison	21,300	295.0
Texas Power & Light	16,400	16.127
Red River Authority of Texas	2,504	2.462
North Texas Municipal Water District	185,406	182.316
Greater Texoma Utility Authority for Sherman, TX	72,600	71.39
Greater Texoma Utility Authority for Pottsboro, TX	1514.7	1.49
Buncombe Creek View	0.3	0
OTRD	275	0.270

In 2010, 150,000 acre-feet of hydropower storage was reallocated to water supply storage (100,000 acre-feet for NTMWD and 50,000 acre-feet for GTUA) under Section 838 of Public Law 99-662. Section 838 of Public Law 99-662 gives the USACE the authority to reallocate an additional 150,000 acre-feet of hydropower storage to water supply storage for the State of Oklahoma. In 1990, the Lake Texoma Advisory Committee was established by Public Law 100-71.

Denison Dam Hydropower.

The powerhouse contains two 35,000-kilowatt generators, with provisions for three additional 43,000-kilowatt units. One 20-foot-diameter, steel-lined conduit provides water for each power unit. Each of the power conduits is equipped with two 9- by 19-foot vertical lift gates located in the intake structure. The powerhouse and power conduits are located adjacent to the outlet works near the right abutment of Denison Dam.

At full power pool, Lake Texoma has 103.2 feet of water depth available for power production. Section 838(a) of the Water Resources Development Act of 1986 (Public Law 99-622) authorizes the Secretary of the Army to reallocate an additional 150,000 acre-feet of hydropower storage to water supply which could affect the pool volume available for long-term power supply.

Upper Red River Basin from the North Fork of the Red River to Lake Texoma.

Description.

The study area for this reach of the upper Red River includes the basin from its confluence with the North Fork of the Red River at river mile 987 downstream to Lake Texoma. Overall, the Red River is an interstate stream, which originates in Curry County, New Mexico, as Tierra Blanca Creek, then enters the Prairie Dog Town Fork of the Red River through the eastern portions of the Texas panhandle, then flows along the Texas/Oklahoma border into southwestern

Arkansas and then turns south into Louisiana, where it discharges into the Mississippi River near Simmesport, Louisiana. The main stem of the Red River has a total length of 1,217 river miles. The topography of the basin ranges from flat prairie in the western reach at an elevation of approximately 4,835 feet NGVD to rolling hills in eastern Texas at an elevation of approximately 495 feet NGVD.

Reach 14 of the upper Red River includes the North Fork Red River from its confluence with the Red River, at river mile 987, upstream to the Area VI chloride source canyons. Overall, the Elm Fork of the North Fork of the Red River originates in the rolling hills country of Gray County, Texas. The stream follows a meandering easterly and southeasterly course into southwestern Oklahoma and enters the North Fork of the Red River approximately 2 miles below Altus-Lugart Reservoir in Greer and Kiowa Counties, Oklahoma. The watershed has a drainage area of approximately 416 miles above the chloride source canyons.

Area VI, the only major chloride source area of the upper Red River basin located in Oklahoma is located along the Elm Fork in Harmon County. The primary sources of chloride are seeps and springs emitting from Kiser, Robinson, and Salton Canyons located west of Highway 30 approximately 6 miles south of Erick, Oklahoma. An abandoned commercial salt works composed of several small evaporation ponds is located on the north bank of the stream at the mouth of Kiser Canyon. Additionally, numerous small seeps and springs are found in middle and lower reaches of the Elm Fork. Emissions from chloride sources move downstream primarily as surface flows in the streambed. The chloride load contributed from the Elm Fork is estimated to be 510 tons/day of which 420 tons/day are contributed directly from the three canyon source areas (USACE 2011).

Water Quality.

Water quality in the upper Red River is influenced by both natural and anthropogenic discharges. Natural (no chloride control) chloride, sulfate, and TDS data for Hydrologic/Economic Reaches 6, 7, 12 and 14 are shown in Table 66.

Water quality data for the Elm Fork are available from the USGS gaging station (07303400) located in Harmon County on State Highway 30 about 4.5 miles northeast of Carl, OK. This station is about 7.5 miles downstream from the Area VI source canyons. The watershed at this location drains an area of 416 square miles. Water quality data for the North Fork of the Red River are available from the USGS gaging station (07305000) located in Kiowa County on U.S. Highway 62 about 2 miles east of Hedrick, Oklahoma. The watershed at this location drains an area of 4,244 square miles. Water quality data for the Red River near Burkburnett, Texas, are available from the USGS gaging station (07308500) located in Cotton County, Oklahoma, on Interstate Highway 44 about 1 mile northeast of Burkburnett, Texas. The watershed at this location drains an area of 20,570 square miles. Water quality data for the Red River near Terral, Oklahoma, are available from the USGS gaging station (07315500) located in Jefferson County, Oklahoma, on U.S. Highway 81 about 1 mile south of Terral, Oklahoma. The watershed at this location drains 22,787 square miles. Water quality data for the Red River near Gainesville, Texas, area available from the USGS gaging station (07316000) located in Love

County, Oklahoma, about 4.5 miles north of Gainesville, Texas. The watershed at this location drains 24,846 square miles.

Table 66 - Water quality in the upper Red River Hydrologic/Economic Reaches

Reach	Gage	Chloride (mg/l)	Sulfate (mg/l)	TDS (mg/l)
6	Gainesville	990	536	2541
7	Terral	1266	719	3265
12	Burkburnett	1999	176	5224
14a	Hedrick	1807	860	4529
14b	Carl	9900	1806	19483

Source: USACE 2011 (Draft)
*50% exceedence level

Anthropogenic Influences.

Human populations living in north-central Texas and south-central Oklahoma extensively use rivers in the study area. Uses include municipal and industrial water supply, recreation, flood risk reduction, wastewater disposal, agricultural activities, and petroleum exploration and production. Table 67 shows the number of NPDES permits, by county, within the proposed project area reported by the USEPA as of July 13, 2011 (USEPA 2011).

Table 67 - Wastewater discharges* and water impoundments within the upper Red River basin

County	No. of Wastewater Permits	Major Impoundments
TEXAS		
Grayson	32	Texoma
Cooke	16	Texoma
Montague	6	
Clay	7	Arrowhead
Collingsworth	1	
Childress	3	
Hardeman	6	
Wilbarger	8	
Wichita	22	Wichita
OKLAHOMA		
Marshall	4	Texoma
Johnston	15	Texoma
Love	3	
Jefferson	3	Waurika
Cotton	4	
Tillman	5	
Jackson	6	
Kiowa	5	Tom Steed
Greer	3	Altus
Harmon	2	
Total	151	

* Maximum Permitted Wastewater Flow (mgd) not available

Selenium (Se).

Elevated concentrations of Se occur naturally in surface waters of the general area. While natural background concentrations of Se in freshwater environments are typically less than 0.2 µg/l (Skorupa *et al*. 1996), concentrations appear to be much higher in the upper Red River Basin. For example, data from USGS gaging stations on the Elm Fork of the North Fork Red River near Carl, Oklahoma, and on the North Fork Red River near Hedrick, Oklahoma, indicate that total Se concentrations range from < 3 to 11 and < 1 to 5 µg/l, respectively. The upper end of this naturally-occurring range exceeds concentrations of Se reported as hazardous to health and long-term survival of fish and wildlife populations (Lemly 1993, 1995). The recommended selenium aquatic life criterion continuous concentration (CCC), published by the USEPA in 1995, is 5.0 ug/l in freshwater.

Water Quantity.

The upper Red River Basin watershed receives an average annual precipitation varying from 34 inches near its confluence with the North Fork Red River to 38 inches at Lake Texoma. Stream flow in Hydrologic Reach 14a has a flow rate of 74 cfs, 50% of the time. Stream flow in

Hydrologic Reach 14b has a flow of 16.7 cfs, 50% of the time. Stream flow in Hydrologic Reach 12 has a flow rate of 290 cfs, 50% of the time. Downstream Hydrologic Reaches 7 and 6 have flow rates of 613 and 915 cfs, 50% of the time (USACE 2011).

Aquatic Invertebrates.

Information about aquatic invertebrates in the Red River upstream from Lake Texoma is scarce as long reaches of the river cross private lands and few roads exist. These reaches are basically inaccessible without permission from landowners. Stream margins throughout the basin provide breeding habitat for horseflies and deerflies, which become abundant at certain times of the year.

Other than the survey conducted in the early 1970's by West Texas State University (now West Texas A&M University) under contract to the USACE for baseline information on streams that could be affected by the RRCCP, no other written information could be found about the structure of aquatic invertebrate communities upstream from Lake Texoma. The USACE reported that verbal communications with faculty members at the University of Oklahoma at Norman, Texas Tech University at Lubbock, and the University of North Texas at Denton produced no additional information. Neither the Oklahoma Biological Survey at Norman nor the TPWD had any aquatic invertebrate information for the project area.

Fish Resources in the Upper Red River Basin.

Fish communities in the upper Red River basin, above Lake Texoma, have been described by Lewis and Dalquest (1955, 1956, 1957), Dalquest (1958), Dalquest and Peters (1966), Echelle *et al*. (1972), Taylor *et al.* (1991), Taylor *et al.* (1996), and Gelwick *et al*. (2000). Fish Communities in the basin are often subjected to a high degree of variability in flow, temperature, turbidity, and salinity. Consequently, species composition and relative abundance can be highly variable among locations and season (Matthews 1991; Taylor *et al.* 1996) and may fluctuate widely over long periods of time (Wilde *et al*. 1996). Because of this, specific fish sampling events have been heavily influenced by the environmental conditions in the river that preceded the sampling events. Therefore, the results of fish collections must be interpreted with some level of caution regarding relative abundance (% of total catch) of various species.

Fishery resources in the upper Red River basin, including North Fork Red River and the Elm Fork of the North Fork Red River, where described in detail by Wilde, *et al*. (1996). Information contained in the 1976 FES was used to identify fish species that have been collected in the three reaches of the Red River (Reaches 6, 7, and 12). These reaches are described in Table 16 and fish species that have been collected in the three reaches are shown in Table 68. Overall within the Red River reaches, a total of 60 fish species were collected. Of these 30 species were collected in all three reaches. Although collected within one or more of the identified reaches within the upper Red River, only 15% (9 of 60) of the fish species collected had a high abundance (i.e., greater than 1% of the fish collected in all stream reaches). Species occurring in a greater than 1% abundance are identified in Table 68 with a superscript "1". Species occurring in a greater than 5% abundance are identified with a superscript "2". Five species (red shiner, Red River pupfish, plains minnow, emerald shiner, and Red River shiner) exhibit relative abundance greater than 5% in the Red River reaches (Wilde *et al.* 1996). In the lower reaches of the Red River (reaches 6 and 7) the red shiner, plains minnow, and emerald shiner comprised over 85 and 65% of the fish that have been collected from Reaches 6 and 7, respectively. General trends within Reaches 6, 7, and 12 exhibit increases in the relative abundance of red shiner, emerald shiner and Red River shiner and decreases in the relative abundance of Red River pupfish and plains minnow. Four fish species collected in Reaches 6, 7, and 12 (Red River pupfish, Red River shiner, speckled chub, and prairie chub) have been identified by resource agencies as being of special concern because of their limited distribution.

Table 68 - Common and Scientific Names of Fish Species collected from fish reaches of the upper Red River from Lake Texoma to the mouth of the North Fork Red River (a superscript “1” denotes fish species with a greater than 1% abundance and a superscript “2” denotes fish species with a greater than 5% abundance in all four reaches.).

Scientific Name	Common Name	Reach 6	Reach 7	Reach 12	Reach 14
Ameiurus melas	Black bullhead	X	X	X	X
Ameiurus natalis	Yellow bullhead	X	X		X
Aplodinotus grunniens	Freshwater drum	X	X	X	
Campostoma anomalum	Stoneroller	X	X		X
Carpiodes carpio	River carpsucker	X	X	X	X
Cyprinella lutrensis$^{1, 2}$	Red shiner	X	X	X	X
Cyprinella venustus^{1}	Blacktail shiner	X	X		
Cyprinodon rubrofluviatilis$^{1, 2}$	Red River pupfish	X	X	X	X
Cyprinus carpio	Common carp	X	X	X	X
Dorosoma cepedianum^{1}	Gizzard shad	X	X	X	X
Dorosoma petenense	Threadfin shad	X			X
Etheostoma sp	Darter	X			
Etheostoma spectabile	Orange throated darter	X	X		
Fundulus zebrinus	Plains killifish	X	X	X	X
Gambusia affinis^{1}	Mosquitofish	X	X	X	X
Hiodon alosides	Goldeye	X	X		X
Hybognathus nuchalis^{1}	Silvery minnow	X			
Hybognathus placitus$^{1, 2}$	Plains minnow	X	X	X	X
Ictalurus furcatus	Blue catfish	X			
Ictalurus punctatus	Channel catfish	X	X	X	X
Ictiobus bubalus	Smallmouth buffalo	X	X	X	X
Ictiobus cyprinellus	Bigmouth buffalo	X	X		
Ictiobus sp	Buffalo	X	X		
Labidesthes sicculus	Brook silverside	X	X		X
Lepisosteus osseus	Longnose gar	X	X		X
Lepisosteus platostomus	Shortnose gar	X	X		
Lepisosteus sp	Gar	X			
Lepomis cyanellus	Green sunfish	X	X	X	X
Lepomis cyanellus x *macrochirus*	Green-Bluegill sunfish hybrid	X	X		
Lepomis cyanellus x *megalotis*	Green-longear sunfish hybrid	X			
Lepomis gulosus	Warmouth	X	X		X
Lepomis humilis	Orangespotted sunfish	X	X	X	X
Lepomis macrochirus	Bluegill sunfish	X	X	X	X
Lepomis macrochirus x *meglotis*	Bluegill-longear sunfish hybrid	X			X
Lepomis megalotis	Longear sunfish	X	X	X	
Lepomis microlophus	Redear sunfish	X	X		X
Lepomis sp	Sunfish	X	X		

Macrhybobsis aestivalis[1]	Speckled chub	X	X	X	X
Macrhybopsis storeriana	Silver chub	X	X	X	
Menidia beryllina	Inland silverside	X	X	X	
Micropterus punctulatus	Spotted bass	X	X		
Micropterus salmoides	Largemouth bass	X	X	X	X
Morone chrysops	White bass	X			X
Morone chrysops x *saxatilis*	White-Striped bass hybrid	X			
Morone saxatilis	Striped bass	X			
Morone sp	Bass	X			
Moxostoma erythrurum	Golden redhorse	X	X		X
Moxostoma sp	Redhorse		X		
Notemigonus crysoleucas	Golden shiner	X	X	X	
Notropis atherinoides[1, 2]	Emerald shiner	X	X	X	X
Notropis bairdi[1, 2]	Red River shiner	X	X	X	X
Notropis bairdi x *potteri*	Red River-ghost shiner hybrid	X			
Notropis buchanani	Ghost shiner	X	X	X	X
Notropis girardi		X			
Notropis potteri	Chub shiner	X	X	X	X
Notropis sp	Shiner	X	X		
Notropis stramineus	Sand shiner	X			X
Notropis stramineus x *Cyprinella lutrensis*	Sand-Red shiner hybrid	X			
Noturus gyrinus	Tadpole madtom	X	X		X
Noturus nocturnes	Freckled madtom	X			
Noturus sp	Madtom	X			
Percina caprodes	Logperch	X	X	X	X
Percina macrolepida	Bigscale perch	X			
Percina sp	Perch	X			
Phenacobius mirabilis	Suckermouth minnow	X	X	X	X
Phoxinus erythrogaster			X		
Pimephales notatus			X		
Pimephales promelas	Fathead minnow	X	X	X	X
Pimephales sp	Bullhead minnow	X			
Pimiphales vigilax		X	X	X	X
Pomoxis annularis	White crappie	X	X	X	X
Pomoxis nigromaculatus	Black crappie	X			
Pylodictis olivaris	Flathead catfish	X	X	X	
Scaphirhynchus platorhynchus	Shovelnose sturgeon	X			
Stizostedion canadense	Sauger	X		X	
Stizostedion vitreum	Walleye	X			

Source: Modified from Wilde *et al*. 1996

Of the species that have been reported to have been collected from these reaches of the Red River, Wilde, *et al.* (1996), identified three species (sharpnose shiner, freckled madtom, and shovelnose sturgeon) that are possibly extirpated from the basin. All three of these species have not been collected from the basin since the 1960's (Wilde, *et al.* 1996).

The upper Red River supports a commercial bait minnow fishery that appears to be highly variable. The ODWC (Wallace and Driscoll 1994) reported the commercial bait minnows consisting primarily of "River shiners" were harvested from the North Fork of the Red River (18,500 lbs), the Red River (7,850 lbs), and the Salt Fork of the Red River (1,000 lbs). No data are available regarding the impacts of commercial minnow harvest on fish communities, but it could be a factor in the general decline of some minnow species throughout the upper basin. Bait minnow harvest data reported to the ODWC between 1995 and 2009 are presented in Table 69.

Table 69 - Pounds of bait fish harvested by commercial minnow dealers in the upper Red River basin.

Year	Red River (lbs)	North Fork of Red River (lbs)	Salt Fork Red River (lbs)
1995	26,368	9,200	1,650
1996	24,350	41,200	9,800
1997	20,900	6,800	800
1998	16,500	1,800	3,200
1999	19,500	8,200	6,400
2000	26,300	5,400	4,400
2001	28,100	1,750	10,080
2002	N/A	N/A	N/A
2003	N/A	N/A	N/A
2004	17,620	11,400	5,416
2005	14,000	12,000	1,840
2006	26,000	24,000	280
2007	21,200	10,000	---
2008	33,000	2,400	---
2009	41,400	---	---

N/A = data not available from ODWC for 2002 and 2003.

FUTURE WITHOUT PROJECT CONDITIONS

The purpose of this section is to describe the future conditions of the proposed project area if there is no federal action taken with respect to the control of total dissolved solids (TDS) loadings into the upper Red River basin from chloride source Area VI. The without-project condition is the same as the “No Action” alternative required by USACE regulations governing the implementation of the National Environmental Policy Act (NEPA) of 1969. The planning horizon for this analysis is the 50-year horizon typical of water resources project with a base-year of 2020.

Physiographic and Climate Setting.

Under the various scenarios of global climate change temperatures within the contiguous United States are predicted to rise anywhere from 3 to 6 degrees F between 2040-2059 and anywhere from 4 to 11 degrees F between 2080-2099 (Global Climate Change Impacts in the United States 2009). In the Great Plains, temperatures are predicted to increase by as much 3 degrees F by 2020, 1.5 to 6 degrees F by 2050, and 2 to 13 degrees F by 2090 depending upon the level of atmospheric carbon emissions (Global Climate Change Impacts in the United States 2009). In addition to projected average annual temperature increases, precipitation projections indicate the southern Great Plains could experience a decrease in precipitation. Global Climate Change Impacts in the United States (2009), reported decreases in projected spring precipitation ranging from 10% in the eastern portions of the study area (Lake Texoma) to 30% in the western portions of the study area within the upper reaches of the Elm Fork of the North Fork Red River by 2090.

Under these projected climate change scenarios, the general climate characteristics are expected to shift away from a humid-subtropical climate with hot summers to an arid climate with precipitation still varying considerably with precipitation amounts ranging from 18.2 to 23.8 inches in the upper portions of the study area and from 23.4 to 41.4 inches in the lower portions of the study area. Additionally, precipitation patters could be altered considerably relative to those currently experienced throughout the study area along with an increase in the average length of the warm season (freeze-free period) beyond the 220 days currently observed.

Air Quality.

The air quality of the study area is not expected to change in the future in the upper reaches of the study area. Air quality in the lower reaches of the study area, especially those areas in close proximity to Lake Texoma, could be expected to experience deteriorating air quality conditions if land use changes and urban development pressures in north-central Texas continue at their current levels. Future without-project air quality deterioration could be attributable to multiple pollutants including ground level ozone, carbon monoxide, particulate and particulate matter could exceed the National Ambient Air Quality Standards for criteria pollutants.

Threatened and/or Endangered Species.

No change to threatened and/or endangered species is forecast to occur. This forecast, as with others, will be reassessed as the study progresses.

Land Use.

Land use within the upper reaches of the study area would not be substantially altered over existing land uses of irrigated and dry-land agriculture, rangeland, and pasture. In the lower reaches of the study area the current trend of land use change away from agriculture, pasture, and range land use to semi-rural residential land use would continue.

Lake Texoma.

Lake Texoma will continue to be a major resource for recreational activities, hydropower, and water supply providing potable water to residents in the surrounding areas of Texas and Oklahoma, however the reservoir would not be able to fully meet all authorized purposes in the future.

Water Quality.

The loadings of total dissolved solids from the upper Red River basin would continue, however sediment accumulates in Lake Texoma at a rate of approximately 10,000 acre-feet per year with 6000 acre-feet deposited in the conservation pool and 4000 acre-feet deposited in the flood control pool. General water quality relative to total dissolved solids (TDS) would not be impacted by the current sedimentation rate of the reservoir and TDS concentrations within the reservoir would continue to exhibit strong zonal patterns described by Dickson *et al*. (1996) and Atkinson *et al*. (1999). These zonal patterns within the reservoir could intensify as TDS concentrations within the reservoir would be likely to increase as precipitation declines and evaporative losses from the reservoir increase as a result of global climate change impacts.

The "chemocline" based on dissolved oxygen and pH would also be impacted by global climate change and loss of storage due to sedimentation. Chemocline stability is hydrologically driven (Clyde 2004) and, under low inflow conditions, would become much more entrenched for longer periods of time. The ramifications of longer periods of stratification could be significant. Longer and more entrenched periods of stratification would result in increased nutrient (nitrogen, phosphorus, and iron) loading from lake sediments, increased volume of anoxic water, and decrease the amount of thermal refugia available for large fish (e.g. striped bass, largemouth bass, blue catfish).

Aquatic Invertebrates.

The future conditions relative to aquatic invertebrates, absent any federal action, are not fully understood. Presently, Lake Texoma has a zooplankton typical of reservoirs of the southern Great Plains. Temporal variability could be altered due to global climate change, however the impacts to zooplankton populations under the various global climate change scenarios is not well documented. The most likely scenario could be multiple pulses of throughout the warm (frost-free) season and a transition from lacustrine dominated species to a zooplankton population dominated by lentic species.

Taxa richness and abundance of benthic invertebrates would increase in the future as the current rate of sedimentation within Lake Texoma continues to create shallow water lentic habitat within the upper reaches of the Red River and Washita River arms of the reservoir. Additionally, projected decreases in precipitation further differentiating the community composition within the respective arms of the reservoir. This coupled with the strong likelihood of increased nutrient loading from the lake sediments suggests that the abundance of benthic macroinvertebrates within the reservoir could increase as this community appears to be primarily influenced by turbidity, nutrients, and specific conductivity (Schnell *et al*. 2002).

The zebra mussel population present in Lake Texoma has only been recently established (Hysmith an Mozygemma 2008; Sager *et al*. 2011). The zebra mussel population has become well established since 2009 throughout the reservoir, however at present, the dynamics of the population present in Lake Texoma is not well documented. However it is evident that the population present in Lake Texoma is able to withstand water temperatures that exceed the established thermal tolerance documented for other populations within the northern United States (Everett Laney personal communication 2011).

Fish Resources of Lake Texoma.

Fisheries resources would decline into the future due to habitat and thermal refugia losses critical for species popular for recreation and fishing. Habitat losses are occurring and will continue to occur due to sediment accumulation within the conservation pool (6000 acre-feet per year). As sedimentation continues to decrease the volume of the conservation pool, oxygenated water with a temperature less than 26 degrees C will become increasingly limited. The loss of thermal refugia from sedimentation is only expected to be accelerated by projected temperature increases and precipitation decreases associated with global climate change.

An example of how the loss of thermal refugia can impact sport fish populations is Keystone Lake, Oklahoma. Keystone Lake supported a popular striped bass fishery throughout the 1970' and early 1980's (ODWC 2008), however beginning in the mid-1980's significant declines in the striped bass population occurred. Prior to 1984 total striped bass gill net catch rates (C/f) ranged from 0.13 to 0.43 and while these catch rates are not indicative of a quality fishery, the fishery was popular with anglers within the Tulsa, OK region. Beginning in 1984, the striped bass fishery experienced a precipitous decline following large floods in the mid-1980's. Associated with a flood event in 1986, a large amount of sediment was deposited in Keystone Lake. Following the floods, and loss of reservoir storage due to sediment deposited in during the 1986 flood, large mortalities of striped bass where began to be reported to the USACE and the ODWC. The largest striped bass mortalities occurred in the summers of 1989, 1990, and 1991. Between 1990 and 1992, the ODWC investigated the cause of the striped bass mortalities (ODWC 1990, 1991, 1992) and concluded that mortalities were primarily due to a loss of thermal refugia within the reservoir. The ODWC concluded that adult striped bass can tolerate water temperatures of 27-28 degrees C for no longer than one month and then die when exposed to increased water temperatures for an equal amount of time (one month). Additionally, ODWC concluded that mortality can increase following exposures to water temperatures of 27-28 degrees C for prolonged periods (greater than one month). Since 1984, the gill net catch rate (C/f) for striped bass in Keystone Lake has ranged from 0.092 to 0.13 with an average gill net catch rate of 0.07. The final conclusions of the ODWC (1990, 1991, 1992) where that mortalities were the result of temperature-oxygen "squeeze" where the only the only portions of the reservoir with water temperatures < 28 degrees C were present below the thermocline in the anoxic waters of the hypolimnion.

Lake Texoma could experience declines in gill net catch rate (C/f) of striped bass similar to those observed in Keystone Lake as sediment accumulation in the conservation pool continues to decrease fisheries habitat (water volume) and thermal refugia is lost. The impact on other sport fish (e.g. largemouth bass, white bass) would not be expected to be as severe as the impact to striped bass as largemouth bass, white crappie, and white bass have not been impacted at Keystone Lake to the degree exhibited by striped bass (ODWC 2008).

Upper Red River Basin from the North Fork of the Red River to Lake Texoma.

The upper reaches of the Red River basin, including the North Fork tributary, are projected to experience the greatest increase in temperature and greatest decrease in precipitation, due to global climate change, within the study area. Stream flows within this area could be expected to decrease from the current 16.7 cfs at the Carl, Oklahoma, USGS gage and 74 cfs at the Hedrick, Oklahoma, UGSG gage (50% equaled or exceeded rate of flow) to a range between 0.3 to 8.7 cfs at the Carl, Oklahoma, gage and 0.0 to 30 cfs at the Headrick, Oklahoma, gage (99-80% equaled or exceeded rate of flow) (USACE 2011). Chloride source loadings from the source canyons comprising Area VI could continue unabated at a rate of 510 tons/day from the Elm Fork of the North Fork Red River. Conversely, the projected decreases in precipitation associated with global climate change could decrease loadings to less than 510 tons/day as stream baseflows are impacted. However, as loadings continue and flows decrease under global climate change projections, TDS concentrations within the North Fork Red River basin could increase substantially, limiting the fish species to only those with a tolerance for high salinity waters (e.g. Plains killifish, Red River pupfish).

Fish Resources in the upper Red River Basin.

Fish communities in the upper Red River basin would continue to exhibit highly variable species composition and relative abundance among sampling locations and season. The longer-term understanding of impacts to the regional stream fishery owing to global climate change is not currently well documented or well understood. In general, fishes of the southern Great Plains within the study area are present in streams and rivers with environmental conditions at or very near the extreme limits of thermal tolerance (Matthews and Zimmerman 1990).

In portions of the Elm Fork and the North Fork, the impact of projected increased temperature coupled with an increase in the number of zero and low-flow (<2 cfs) days from global climate change could force species requiring high-flow habitat for spawning to drop out of the fish assemblage. Additionally, for native fishes to successfully migrate from stream reaches impacted by global climate change, whole populations would be required to first migrate longitudinally from west to east, enter the mainstem of the Mississippi River and/or Arkansas River, then migrate latitudinally from south to north in search of appropriate physical and thermal habitat (Matthews and Zimmerman 1990). Any population making a migration of this magnitude would suffer substantially from predation and extreme environmental conditions and would have to occur over multiple spawning cycles, if adequate spawning habitat was available. Additional pressures would continue to be placed upon remaining populations due to commercial minnow harvest in the upper Red River basin. While commercial minnow harvesters are required to report harvest amounts to the Oklahoma Department of Wildlife Conservation, no in-depth analysis has been conducted to determine the long-term impacts of commercial minnow harvest on native stream fishes of the upper Red River basin.

SUMMARY OF OTHER FUTURE WITHOUT-PROJECT CONDITIONS

Chloride Control Features.

One likely without-project condition for the operating features of the Red River Chloride Control Project is a continuation of operation and maintenance of Area VIII, X, and the Truscott Brine Lake. The cost of operation and maintenance for the existing features is the same for with- and without-project conditions. Similarly, for the features listed below, the EOP monitoring measures that would be required with continued operation of existing facilities are therefore the same for with- and without-project conditions. The potential addition of one or two more brine collection facilities [Areas VII and X as found to be feasible from the Reevaluation of the Wichita River Basin chloride control features] would increase monitoring efforts and costs. Baseline monitoring has been ongoing since the EIRP process. All baseline monitoring would be completed in 2015, before completion of additional chloride control features.) Without-project conditions include these completed Red River Chloride Control Project features:

- Area V – Estelline Springs (currently operated)
- Area VIII – Low-flow Brine Collection Area (currently operated)
- Area VIII - Experimental evaporation field (currently operated)
- Area VIII - Pumping plant (currently operated)
- Area VIII – Pipeline to Truscott Brine Lake (currently operated)
- Area X – Low-flow Brine Collection Area (currently owned lands, completed low-flow dam, and completed pump house building)
- Truscott Brine Lake (currently operated)
- Crowell Mitigation Area (currently operated)

Other likely without-project conditions were considered and are described later. The different potential scenarios of forecast conditions with various combinations of chloride control features makes this reevaluation effort somewhat more complicated than a single forecast condition, but by having the different scenarios the Corps is prepared to answer a number of what-if questions that may be posed by various stakeholders.

Brush Management.

Removal of brush, generally composed of mesquite and juniper, would tend to restore uplands to near pre-settlement conditions of grass prairies. The results of brush management could alter (restore) the watershed characteristics which would tend to increase stream flows, increase reservoir yield, and cause different economic and environmental results. Brush removal is occurring through landowner efforts within the Red River Basin.

In Texas, a State cost-shared program is proposed by the Red River Authority to expand brush removal in the basin below the brine collection areas and above Lake Kemp. Implementation of the State program is dependent on State funding, local landowner funding, and voluntary participation. Whether the program is initiated, when it might start within the basin, or how extensive the watershed changes might be is somewhat speculative. However, the potential water resources changes (more flow and therefore lower concentrations of chlorides and other dissolved solids) were significant enough to warrant an evaluation of brush management within the Wichita Basin Reevaluation study.

The Corps chose to conservatively approach the Red River Authority's plan by assuming with- and without-project conditions would result in implementation at only a 50% level of the state plan. That is, only one half of the brush removal proposed in the Red River Authority's feasibility report was assumed for future conditions.

Flow additions that could result from brush management were found to offset flow reductions estimated to result from brine removal. The Corps' economic and environmental evaluations did not rely on the implementation of brush management, but an evaluation of the potential influences of brush management was conducted for purposes of impact evaluation. One concern was that the combined effect of reduced chloride load and increased flow might have detrimental effects on the salt tolerant species in the upper Wichita Basin. *The findings were that no persistent, long term, or significant impacts to salt tolerant species would be anticipated.*

No changes in brush management are forecast over the economic evaluation period from 2020 to 2070 that would have a significant impact on the social, economic, or environmental conditions in the basin or the reevaluation of Area VI.

While mesquite and juniper are native brush species, salt-cedar is an invasive species that is found primarily along watercourses and which reduces stream flow and causes other environmental damages.

Salt-Cedar.

In the 1800's, Tamarix (salt-cedar) was imported to both U.S. coasts. It may have been intended for various purposes: an ornamental shrub; windbreaks; and to protect stream banks from erosion. By 1950, it had spread to streams in several western states and is now causing problems in 13 western states. It grows well in arid climates and survives by sending roots deep into the soil. It primarily reproduces by flowering (small pink to white, 4- or 5-petalled blooms in the spring and summer), and the wind and water spreads the seeds. The seeds have little protein value to wildlife and are too small for most animals, compared in size to fine ground pepper or pollen. The seeds may even germinate while floating on water. Damaged or cut salt-cedar can spread by re-sprouting from the roots. Under the right conditions, it can grow 9 to 12 feet in a year, with most plants ranging from 5 to 20 feet tall. When the plant matures, it can produce up to one half million seeds a year and can transpire about 200 gallons of water per day.

Unfortunately, this shrub spread from its intended uses and now dominates many streams. Salt-cedar changes the soil chemistry around it by secreting salt from stems and leaves, which eventually fall to the ground forming a salt crust that inhibits the growth of native plants. To make matters worse, the wildlife that benefit from native plants tend to not utilize salt-cedar. If not removed, salt-cedar can negatively alter the plant and animal communities in riparian areas along streams, clog streams impacting fish and other aquatic species, and consume a large percentage of the stream water. Honeybees do benefit from the source of pollen and nectar.

Many State and Federal agencies are actively involved in salt-cedar control or eradication programs. The Corps' environmental mission is applicable for the control of salt-cedar and is available to local sponsors. The Corps and the Red River Authority have discussed opportunities to work together under the Corps' Environmental Program to help control salt-cedar.

Salt-cedar in area streams will continue to out-compete native plants unless landowners intervene. Without intervention, the salt-cedar will continue to expand and damage the aquatic and riparian environments in the Red River Basin. Farmers and ranchers are encouraged to eliminate salt-cedar in favor of willows, grasses, and other native riparian plants.

(From http://oklahomainvasivespecies.okstate.edu/saltcedar.html) "Saltcedar has been designated as one of the 10 worst noxious weeds in the U.S. Some research has suggested that salt cedar uses more groundwater than the native plants it displaces. Such high levels of water uptake cause the total water flow along drainages that are heavily infested with saltcedar to be reduced or possibly eliminated. High densities of saltcedar can increase flood potential for the area. Decreased water velocity and increased sediment deposit caused by saltcedar infestations can reduce stream width. Research has indicated areas of saltcedar infestation show decreases in density and diversity of native species. Several species of trees, as well as many species of shrubs, grasses and forbs are displaced by saltcedar. Once established, saltcedar is able to prevent native species from reestablishing. The population and diversity of many animals, such as birds, rodents, and insects, also decline in areas of infestation. Saltcedar also reduces forage material thus altering livestock and wildlife habitat. Saltcedars do provide shelter for doves, however they produce less food than do the displaced native species (Grubb). Saltcedar provides little value to wildlife as a food source. Wildlife habitat is degraded, stream flow is altered, and soil salinity is increased. Saltcedar also increases wildfire hazards, uses extensive amounts of water, and increases flooding. Estimates have the economic losses from saltcedar around millions of dollars per year (USDA)."

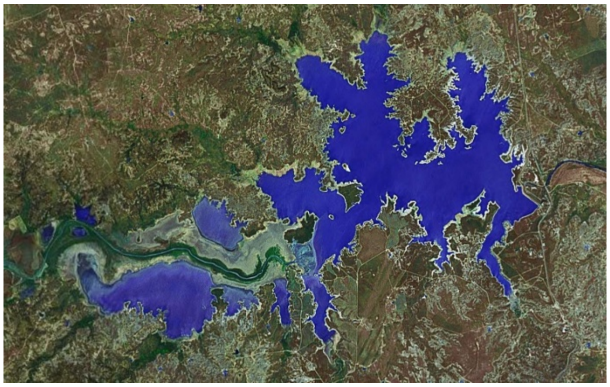
No changes in salt cedar management are forecast over the economic evaluation period from 2020 to 2070 that would have a significant impact on the social, economic, or environmental conditions in the basin or the reevaluation of Area VI.

Water Supply and Needs.

The data used in the Area VI Reevaluation regarding water supply sources and projection of future water supply needs are from detailed projections presented in the Texas and Oklahoma Comprehensive Water Plans. These data fully meet the Corps' requirements for the reevaluation. While there are other approaches and variations of water use projection, the State water plans are very thorough and have been evaluated in-depth by State agencies and approved by the State legislature. The study data and methodologies were examined by the Corps and were found to be appropriate.

The Area VI brine emissions are located in Oklahoma near the Altus Irrigation District, but the study area includes much of the Red River Basin, including the water supply stakeholders associated with Lake Texoma, because the Red River Chloride Control Project is a multi-state project with potential multi-state impacts and benefits. Therefore, the following description of water supply resources includes resources in Texas and Lake Texoma on the Oklahoma-Texas border.

Lake Kemp Storage.



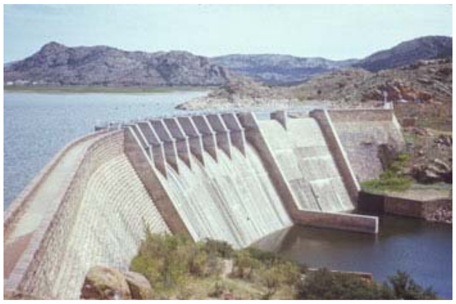
The city of Wichita Falls and Wichita County Water Improvement District No. 1 originally constructed Lake Kemp in 1923. Lake Kemp was redesigned, with Corps of Engineers involvement, in the 1960's. The goal of the redesign and reconstruction was to add additional flood control storage. Loss of storage to sedimentation was taken into account during the design effort. Lake Kemp was designed with additional flood storage so the conservation pool could be raised at regular intervals throughout the life of the project to regain water supply storage lost to sedimentation. Pool rises were planned for 2008, 2028, 2048, and 2068 with the maximum conservation pool at elevation 1150. The conservation pool is currently elevation 1144.

The original design projected sediment loss equally throughout the conservation and flood pool. Subsequent sedimentation surveys indicate that the majority of sediment has been deposited in the conservation pool with limited loss of storage in the flood pool. Recent partial sedimentation surveys, using improved technology and methods, indicate that storage loss at Lake Kemp is not as great as originally estimated.

Using recent partial sedimentation data and projected storage loss estimates, Lake Kemp capacity was estimated for 50 and 100 years into project life starting in 2005. An annual storage loss of 1,451 acre-feet was used. Conservation storage at 50 years at elevation 1148 was estimated to be 261,000 acre-feet. Conservation storage at elevation 1150 at 100 years was estimated to be 223,000 acre-feet. Current conservation storage at elevation 1144 is estimated to be 263,000 acre-feet.

Altus Lake Storage.

Lake Altus had its beginnings in 1927 when the city of Altus, Oklahoma built Altus Dam as a source of municipal water for the city. Interest in providing irrigation water to farmers in the region prompted the U.S. Government to authorize construction of a larger reservoir in the Rivers and Harbors Act of 1938. The dam was to be raised 50 feet (15 m) to impound more water. Construction started in 1941, and was interrupted by World War II. Construction resumed in 1944. The dam, as it stands today, was completed in 1947.



Lake Altus-Lugert, also known as Lake Altus and Lake Lugert is located 17 miles north of Altus, Oklahoma, on the former site of the town of Lugert, Oklahoma. The lake is used for fishing, boating, swimming, and irrigation. Incorporated within the dam section are both controlled and uncontrolled overflow-type spillways and an irrigation outlet works which delivers water into the project canal system. Lake Altus has a total capacity of 154,092 acre feet (190,000,000 m³), of which 1,663 acre feet (2,000,000 m³) are dead storage, 19,597 acre feet (24,000,000 m³) are flood control storage, and 132,832 acre feet (164,000,000 m³) are conservation storage. The last 10,000 acre feet (12,000,000 m³) of conservation storage is reserved for municipal water for Altus, Oklahoma. Appurtenant reservoir structures are Lugert, East, North, and South Dikes, located at low places on the reservoir rim. Lugert Dike, the largest, is 4,245 feet (1,294 m) long and has a maximum height of 45 feet (14 m).

Lake Altus-Lugert is the primary storage facility for the W.C. Austin Project of the U.S. Bureau of Reclamation. This project provides irrigation water to some 48,000 acres (190 km²) of land located in southwestern Oklahoma.

There is also an extensive system of canals leaving Lake Altus in order to deliver the irrigation water to farmland. Most of these canals and distribution laterals were completed by 1953. (Edited extracts from http://en.wikipedia.org/wiki/Lake_Altus-Lugert.)

In March of 2005 the Bureau of Reclamation, Oklahoma-Texas Area Office, published an Appraisal Report titled "Water Supply Augmentation, W.C. Austin Project, Oklahoma. The report stated, "The primary problem now confronting the District is a decreasing storage capacity due to sediment accumulation in Lake Altus. Sedimentation is a natural occurrence in surface water reservoirs that continually reduces available volume. At present, the sediment in Lake Altus is estimated to have replaced about 37 percent of the original conservation storage capacity. By 2050, sediment is projected to account for over 60 percent of this volume.

Since its construction in 1946, Lake Altus has continued to capture inflowing sediments from the North Fork Red River. In 1940, when the original contour survey for this project was conducted, it was calculated that there would be 192,842 acre-feet of storage capacity below the maximum water elevation of 1,564.0 ft msl (Seavy 1949). After its completion, contour and range surveys of Lake Altus were conducted by Reclamation in 1948, 1953 and in 1967. The most recent (1967) survey revealed that the total reservoir capacity had been reduced by about 13 percent due to sediment accumulation during the 26.4 year period since the original survey (Lara 1971). This loss translated into an average sedimentation rate of about 937 acre-feet per year. Since 1967, sediments have continued to accumulate in Lake Altus, but the exact amount or rate is unknown.

Implications

The displacement of available reservoir capacity by sediment reduces the ability of the project to provide the designed benefits. For example, sedimentation in the surcharge and flood control pools lessens the volume of water that can be retained during a flood event and thereby reduces the ability of Altus Dam to protect downstream interests. Similarly, sedimentation in the conservation pool reduces the amount of water that can be stored in Lake Altus for irrigation and other purposes, rendering these purposes more vulnerable to dry climatic periods.

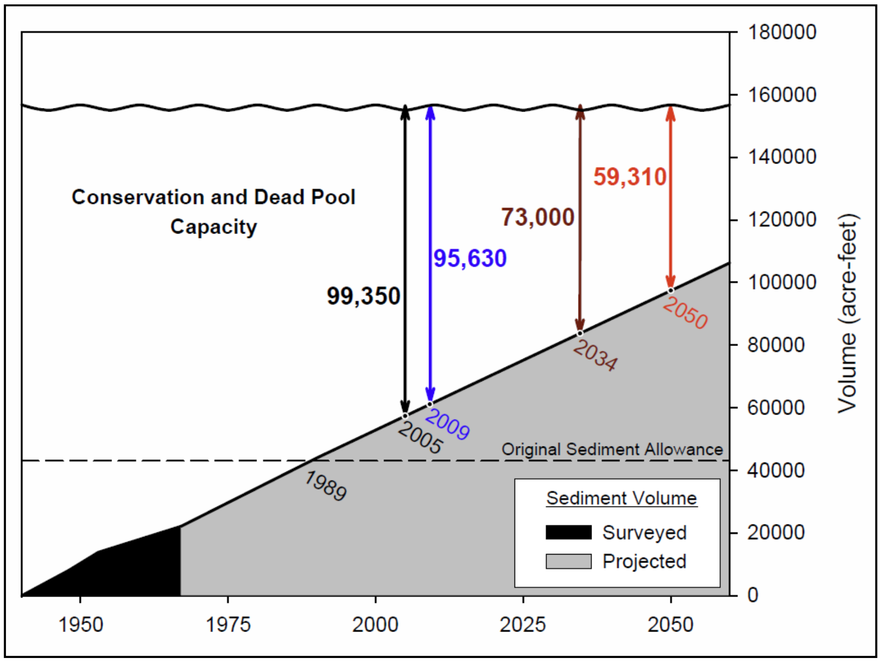


Illustration of surveyed and projected sediment volume in Lake Altus. All values reported in acre-feet using the estimated sedimentation rate and distribution classification reported by Ferarri (1991).

Because the effects of sedimentation are realized over time, predicting future impacts to project benefits from sedimentation requires extrapolation of observed rates. Not having more recent survey data available, Reclamation has estimated future sedimentation impacts to Lake Altus based on the results of this 1967 survey. Assuming that sediment had continued to accumulate in Lake Altus at a rate of 937 acre-feet per year, this analysis estimates the present (2005) conservation pool capacity to be approximately 99,350 acre-feet (Ferrari 1991) [8] . If accurate, this estimate would represent a reduction of over 57,000 acre-feet (37 percent) from the original conservation volume. This analysis also indicates that the 43,000 acre-foot sedimentation allowance was filled by about 1989.

Continuing the extrapolation of projected sedimentation into the future, several operational conditions may be defined in terms of their occurrence in time. For example, beginning about the year 2009, the storage capacity of the conservation pool is projected to be insufficient to contain the full irrigation water right held by the District (85,630 acre-feet) and the agreed storage allocation for municipal and industrial water (10,000 acre-feet). Similarly, beginning about the year 2034, the storage capacity of the conservation pool is projected to be insufficient to contain the average annual irrigation use of the District (63,000 acre-feet) and the agreed municipal and industrial storage allocation. Finally, by the year 2050, the conservation storage capacity of Lake Altus is projected to be only about 59,300 acre-feet. “

FUTURE WITH-PROJECT CONDITIONS

For the evaluation of each potential new chloride control measure, a common future condition was projected. In several cases, that future with-project condition also assumed continued existence and operation of the chloride control features listed above. But, in some cases, the alternatives being evaluated called for elimination or closure of one or more of the existing features.

Existing Conditions

Condition 1 – No chloride control in the Red River Basin.
Condition 2 - Chloride control at Areas V and VIII
Condition 3 - Chloride control at Areas V, VII, VIII, and X

With Project Conditions

Condition 4a - Chloride control at Areas V, VIII, and VI
Condition 4b - Chloride control at Areas V, VIII, and VI with Cable Mtn Dam
Condition 5a - Chloride control at Areas V, VII, VIII, X, and VI
Condition 5b - Chloride control at Areas V, VII, VIII, X, and VI with Cable Mtn Dam

HYDROLOGIC EVALUATIONS

Introduction

Background

Natural brine sources have historically limited the municipal and industrial use of water resources within the upper reaches of the Red River basin. Efforts to study and control natural brine emissions in the Red River Basin began in 1957 when Congress directed the U.S. Public

Health Service (PHS) to investigate the sources of salt pollution on the Arkansas and Red River Basins. This effort culminated in the PHS report "Water Quality Conservation, Arkansas-Red River Basins, June 1964." The PHS study identified 10 major brine sources in the Red River Basin. The Corps of Engineers became involved in 1959 when directed by the Committee on Public Works to investigate "methods and means of improving and managing water quality in the Arkansas and Red River Basins." This effort culminated in 1966 in a two part survey report. Part I of the survey report recommended a control condition for Areas VII, VIII, and X on the Wichita River. Part II of the survey report recommended control conditions for Areas VI, IX, XIII, XIV, and XV on the Red River. The Chief of Engineers recommended Part I of the Arkansas-Red River Basin Water Quality Control Study for Areas VII, VIII, and X, Wichita River, Red River Basin, in Senate Document 110, 89th Congress, 2nd Session. The Flood Control Act of 1966 incorporated Senate Document 110 by reference and authorized Part I. The Chief of Engineers in his report dated 6 May, 1970, recommended Part II of the study. The Flood Control Act of 1970 amended the 1966 Act and authorized Part II of the study for Areas VI, IX, XIII, and XV in the Red River Basin. Preconstruction planning was initiated in 1968. Detailed studies for the three areas in the Wichita River Basin were completed in 1972 culminating in General Design Memorandum No. 3 (GDM No. 3), Chloride Control, Part 1. In 1974, the Water Resources Development Act provided special authorization to construct control measures on the Wichita River. In 1976, GDM No. 25 recommended control measures for the Wichita and Red River areas.

To date, two chloride control projects are operational in the upper Red River Basin, Areas V and VIII. Control measure for Area V, located on the Prairie Dog Town Fork of the Red River, consists of a ring dike which prevents discharges from the brine source. Area V was completed as an operational test for chloride control on the Prairie Dog Town Fork of the Red River. Control measures at Area V were completed in January of 1964 and are estimated to control 240 of the 300 tons/day chlorides emitted by the source. Area VIII, located on the South Fork of the Wichita River, became fully operational in May 1987. Construction of the remaining portions of Part I, Areas X and VII, were delayed due to growing concerns about the economic benefits and environmental consequences of the project. At the request of the Secretary of the Army, an effort was initiated in 1997 to reevaluate the Wichita River portion of the project. The result of that study was a report entitled "Wichita River Basin Project Reevaluation Red River Chloride Control Project," April 2003. Areas VII and X on the Wichita River are authorized for construction. Area X pump facility and low flow dam are constructed and efforts are underway to complete construction by 2013. Area VII construction is planned to be completed by 2016.

Proposed chloride control at Areas VII and X are identical to existing chloride control at Area VIII. Chloride control at Area VIII consists of an inflatable low flow dam and pumping facility located downstream of the source area. The project is designed to capture and pump concentrated brine from the source area and pump those brines to Truscott Lake for storage and evaporation. During rain events where local freshwater runoff dilutes the brines, the inflatable low flow dam is designed to deflate when the river stage rise 0.5 ft above the top of dam elevation, allowing the diluted flows to pass downstream. All pumping stops when the low flow dam deflates.

Chloride control on the Wichita River at Areas VII, VIII, and X are expected to have impacts to flow and solute concentrations downstream of each project. These projects are located in the upper reaches of the South Fork, Middle Fork, and North Fork of the Wichita River. Each project is designed to capture the total discharge of the source areas plus additional flow during runoff events. Impacts to flow are expected to be most apparent in the reaches immediately downstream of the low flow dams with the greatest impacts during extended dry periods. During extended dry periods, source area flows may be the only flow in the upper reaches of the river. Impacts to high flows are expected to be minimal. Areas VII, VIII, and X are expected to remove approximately 420 tons/day of chlorides from the upper Wichita River Basin.

Area VI, Elm Fork of the Red River, Reevaluation Effort

Due to increasing demand for water in Southwestern Oklahoma, state and local stakeholders expressed interest in reevaluating chloride control options for Area VI located on the Elm Fork of the Red River in Harmon County, Oklahoma. Brine sources at Area VI are located in three box canyons located within a three mile reach upstream of the Carl, Oklahoma, stream gage (USGS Gage 07303400) (Figure 1). The sources located in Kiser, Robinson, and Salton Canyons contribute approximately 420 tons/day of the 510 tons/day of chlorides measured at the Carl, Oklahoma, stream gage. Previous studies have been completed assessing the consequences of existing and proposed chloride control operations on the Wichita River and the main stem of the Red River downstream of the confluence with the Wichita River. This study will reevaluate changes to flow and solute concentrations on the Elm Fork, North Fork, and entire main stem of the Red River and include consequences from the Wichita River and Prairie Dog Town Fork projects.

Conditions Evaluated

Five conditions were identified for evaluation in this study (Table 70). These conditions include natural conditions which represents no chloride control in the Red River Basin. Condition 2 represents existing conditions with Areas V and VIII in operation. Conditions 3, 4, and 5 represent possible future expansions of chloride control within the upper Red River basin. The USFWS also submitted two additional alternatives for consideration.. These are discussed in Appendix C.

Table 70 - Conditions Investigated

Condition	Chloride Control Areas in Operation
1	Natural Conditions
2	Areas V & VIII
3	Areas V, VII, VIII & X
4	Areas V, VI & VIII
5	Areas V, VI, VII, VIII & X

Study Methodology

To assess implications of chloride control activities to natural solute concentrations on the Red River, daily loads in tons/day of chlorides, sulfates, and total dissolved solids, were calculated from average daily flows and average daily conductivity data. The average daily load and flow removed by each existing or future condition were then subtracted from natural daily loads to generate modified average daily loads from chloride control reductions for each condition and each reach. Modified daily loads and flows from chloride control actions were further reduced as a result of future increased water usage. Natural and modified daily loads were calculated for the entire period of record, October 1961 – September 2006, for all reaches included in the study (Exhibit B). Natural and modified daily loads were then converted to natural and modified daily concentrations. From this effort, concentration duration data for each reach and each condition were compared to natural concentration data.

This study evaluated the range of flows found in gage data but concentrated on effects to low flows which relate to critical environmental conditions. The United States Army Corps of Engineers (USACE) has expressed concerns that flow reductions from chloride control efforts and future water demands would adversely impact the environment. The USACE recognizes that flow reductions would extend periods of naturally occurring low flow in the basin. To estimate the consequences, the number of low flow days under natural conditions was determined. A low flow routing program was developed to modify natural flows based on flow reductions for each condition. Modified low flows for each condition, at each reach, were compared to natural low flows to estimate changes.

This study also investigated two other Federal actions in the Red River Basin: the recent reallocation of 300,000 acre feet of conservation storage at Lake Texoma from the hydropower purpose to water supply, and a potential future Bureau of Reclamation (BOR) water supply reservoir on the North Fork of the Red River. The combined changes from chloride control, increased future irrigation water usage and the proposed impoundment of flows on the North Fork were assessed. This study focused on cumulative changes to Lake Texoma.

Economic Reaches

In previous reports, economic reaches were often referred to as hydrologic reaches. In reality, these reaches were determined based on economic considerations and are defined by stream gage locations. Table 71 presents the economic reaches used in this study, their defining stream gage, and a description of each reach. Figure 1 presents a map of the study area. Drawing 1 in Exhibit A presents a map of the study area. Drawing 2 in Exhibit A presents a map of the economic reaches.

Table 71 - Economic Reach Definitions

Economic Reach	Defining Gage	River	Description
1	Hosston	Red	
5	Denison	Red	Denison Gage upstream to Cooke county line
6	Gainesville	Red	East Cooke county line to West Cooke county line
7	Terral	Red	Cooke/Montague county line to mouth of Wichita River
8	Wichita Falls	Wichita	Mouth of Wichita River to Lake Diversion
9	Mabelle	Wichita	Lake Diversion upstream to the confluence of the
			North and South Wichita Rivers
10	Truscott	Wichita	North and Middle Wichita Rivers upstream from the
			confluence of the North and South Wichita Rivers
11	Benjamin	Wichita	South Wichita River upstream from the confluence of
			the North and South Wichita Rivers
12	Burkburnett	Red	Mouth of the Wichita River to the Mouth of the Pease River
13	Vernon	Pease	Mouth of Pease River to headwaters of Pease River
14a	Headrick	N. Fork	Mouth of the N. Fork of the Red River to mouth of Elm Fork
14b	Carl	Elm Fork	Mouth of the Elm Fork to Carl gage

WATER QUALITY AND FLOW DATA AVAILABLE

The period of record (POR) for this study was October 1961 - September 2006. Data was available from USGS published records and archived PHS records. The period of record used in the previous "Wichita River Basin Project Reevaluation" was October 1961 through September 1998. This data set was expanded to include the additional data from 1998 through 2006. Drawing 3 in Exhibit A presents the flow and water quality data available for the period of record.

Synthesized Data

Flow and water quality data available included daily average flows and daily average conductivity. Many of the gage sites involved in the study had daily average flow data for each day of period of record. Additional flow data for the Denison gage, below Lake Texoma, for the period of October 1989 - January 1997, was obtained from USACE sources as hourly flow. This data was converted to daily average flow to bridge USGS data gaps at the site. Flow data was not available at the Carl gage on the Elm Fork of the Red River for WY 80 – 94. Daily average conductivity data was not readily available at all sites during the period of record. To bridge data gaps for flow and conductivity, the following methods were used:

- Missing flow data was usually generated using flow data available at either an upstream or downstream gage. Drainage area ratios or flow correlations were applied to the available data to generate flow data to populate data gaps. Additional methods such as rainfall/runoff relationships were investigated, however, drainage area ratios or flow correlations generally provided the most consistent results. A complete description of the methods used at each reach to bridge data gaps is included in Appendix A.

- Flow/specific conductivity or flow/chloride (Cl), sulfate (SO_4), total dissolved solids (TDS) correlations were used to populate water quality data gaps. Discrete water sampling data throughout the period of record was usually available for all sites. Water quality data was plotted against flow data and linear regression analysis was used to develop a correlation between the water quality data and flow. The correlations were used to generate water quality data to bridge data gaps.

- TDS data was generated to populate data gaps from available or calculated chloride and sulfate concentrations. A ratio was calculated using existing data from available chloride and sulfate concentrations. The ratio was used in the following equation: TDS conc. = (1.6*Cl concentration +1.4*sulfate concentration)/Factor (ratio). By rearranging the equation, the ratio can be computed from known Cl, SO_4 and TDS concentrations. This ratio generally runs from 0.85 to 0.95.

Water Quality Data Conversions

Daily average concentration data for chlorides, sulfates, and TDS were generated from average daily conductivity data using regression coefficients developed by the PHS/USGS or coefficients developed during this study. Monthly load totals were checked against USGS published monthly load totals, when available, to validate this methodology.

MAN-MADE CHLORIDE LOADS

Man-made chloride pollution was a problem during earlier portions of the period of record. Oil field drilling operations, surface storage of oil production brines, and discharge of oil production brines into receiving streams increased the chloride load in the basin. Man made chloride pollution was eliminated when environmental regulations stopped surface disposal of oilfield brines. Some residual oil production brine may still exist in the basin due to occasional discharges and leaching of residual brines from former surface disposal/storage sites.

The method used to estimate the percent contribution of man-made chloride is based on the assumption that magnesium chloride is a product of oil field drilling and oil production. Using available USGS data at a site, the amount of Cl required to combine with the available Na is calculated. Excess Cl atoms, not associated Na, can then be calculated. This value is then used to calculate the amount of Mg required to combine with excess Cl. Using a flow-weighted average of all samples, the maximum percent of total Cl of man-made origin can be estimated. An estimate of man-made chloride of 5% was calculated during the Wichita Basin Project based on the available data at the Seymour gage (UGSG Gage 0731190) (Drawing 1). An evaluation of 2005 Seymour gage data indicates the previous estimate is still valid. Calculations for the 2005 estimate are presented in Table 72.

Table 72 -Man-Made Chloride Estimates

		Atomic Weights			Cl Required For Na	Excess Cl	Mg Required For Excess Cl	% Total Cl. In MgCl	Flow x Cl	Flow x Cl x %Cl
		Mg	Na	Cl						
		24.31	22.99	35.45						
		USGS Analysis								
	Flow	Mg	Na	Cl						
Date	cfs	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	%l		
5/9/2005	23.00	236.0	2860.0	4750.0	4411	339	232	7.1	109250	7790.3
6/7/2005	48.00	104.0	849.0	1410.0	1310	100	69	7.1	67680	4823.7
7/11/2005	70.00	63.3	713.0	2420.0	1100	1320	905	3.8	169400	6460.7
8/2/2005	5.00	119.0	1540.0	2420.0	2375	45	31	1.8	12100	223.4
9/13/2005	24.00	78.0	788.0	1410.0	1215	195	133	8.1	33840	2729.5
11/1/2005	44.00	160.0	2000.0	3310.0	3085	225	154	6.8	145640	9907.9
11/21/2005	33.00	204.0	2540.0	4160.0	3918	242	166	5.8	137280	7995.2
2/28/2006	13.00	214.0	3170.0	4160.0	330	2840	1948	7.5	54080	4056.3
4/6/2006	16.00	181.0	2530.0	4190.0	3902	288	197	6.3	67040	4222.5
5/31/2006	31.00	46.0	460.0	747.0	710	37	26	5.0	23157	1162.2
7/10/2006	0.23	115.0	1430.0	2270.0	2206	64	44	2.8	522.1	14.8
8/25/2006	28.00	279.0	560.0	928.0	864	64	44	6.9	25984	1799.0
										11111
			Flow* Cl Weighted Average					6.1	845973	51186111

ALLUVIAL STORAGE AND CLEANUP

Brine sources discharge on a continuous basis. Under normal conditions a portion of the brine load does not travel very far downstream. Due to evaporation, transpiration, and recharge of alluvial aquifers part of the brine loads are stored in the streambed alluvium. It is a common sight in the upper reaches of the Red River Basin to see river beds that are white with dried brine loads during late summer and extended drought periods. As a result, these alluvial deposits can be flushed out during higher flow events and the quantity of the load can depend directly on the magnitude and duration of the flow.

It was noted in previous Wichita Basin studies that prior to May 1987, there were 64.5 tons/day more chloride load going by the Truscott (USGS Gage 07311700) and Benjamin (USGS Gage 07311800) gages than appeared to be recorded at the Mabelle gage (USGS Gage 07312100) below Lake Kemp on the Wichita River. There are two possible explanations for this phenomenon. One explanation could be the buffering effect of storage in Lake Kemp. Another explanation could be the alluvial storage of brine loads which were flushed out by higher flows. The assumption in this report was the difference in loads was due to alluvial storage. The Mabelle gage record was adjusted to reflect an increase of 64.5 tons/day of chlorides prior to May 1987. Load estimates for the Wichita River indicate that after May 1987, the chloride load was 89.5 tons/day higher at the Truscott and Benjamin gages. It is assumed the chloride load stored in the alluvium prior to operation of Area VIII is being flushed out. The Mabelle gage record was adjusted to reflect an increase of 89.5 tons/day from May 1987 through WY 2006.

SOURCE AREAS AND DISTANCES TO DOWNSTREAM GAGING SITES

Distances between Point A and Point B on a river or stream are measured in river miles and are presented as the number of miles upstream from the mouth of the river with the mouth of the river being zero. Comparing the distance between two points on a river in river miles and the straight line distance can yield answers that differ widely.

Tables 73 and 74 presents the distances between source areas in the upper reaches of the Red River Basin to the Gainesville. In this discussion, the river mile presented as the source area river mile is the river mile of the stream gage located at the low flow dam or collection area. The downstream point in this discussion was chosen as the Gainesville gage.

Table 73 presents the locations, by river mile, of source areas VII, VIII, and X located within the upper Wichita River basin, river mile location of the confluence of the Wichita River with the Red River, river mile location of the Gainesville gage (USGS Gage 07316000) on the Red River, and distance of travel from the source areas to the Gainesville gage.

Table 73 - Wichita River Basin
River miles

	Wichita River River Mile	Mouth of Wichita River Red River River Mile	Gainesville Red River River Mile	Distance: Source Area to Gainesville gage
Area VII	211.3	907	732	386.3
Area VIII	218.1	907	732	393.1
Area X	213.3	907	732	388.3

Area V is located on the Prairie Dog Town Fork of the Red River at river mile 1068 near Estelline, Texas. The Red River west of the Texas/Oklahoma border is referred to as the Prairie Dog Town Fork. The nearest stream gage downstream from Area V is located on the Red River at Burkburnett, Texas, at river mile 933, 135 miles downstream. Distance in river miles from Area V to the Gainesville gage is 336 river miles.

Area VI is located on the Elm Fork of the Red River, 54 river miles upstream from the mouth (Drawing 1, Exhibit A). The mouth of the Elm Fork is located at river mile 70.5 on the North Fork of the Red River. Table 5 presents the locations, by river mile, of source areas V and VI located on the Red River, river mile location of the confluence of the North Fork Red River with the Red River, river mile location of the Gainesville gage (USGS Gage 07316000) on the Red River, and distance of travel from the source areas to the Gainesville gage.

TABLE 73

Table 74 - Red River and North Fork Basins River Miles

	Red River River Mile	N. F. Red River River Mile	Mouth of N.F. Red River River Mile	Burkburnett Red River River Mile	Gainesville Red River River Mile	Distance Source Area to Gainesville
Area V	**1068**			**933**	**732**	**336**
Area VI		**124.3**	**987**	**933**	**732**	**379.3**

This discussion illustrates the distances in river miles that reductions in flow and load must travel to downstream points within the basin. Flow reductions at source areas are generally detectable in the reaches immediately downstream but as they travel the distances presented above, flow reductions may not be noticeable at points farther downstream. In-stream withdrawals for irrigation are usually much larger than flow reductions from chloride control alone and are usually withdrawn during the growing season (May-Sep). Irrigation withdrawals would tend to a much larger impact to flows due to the volume of daily withdrawal and timing during the driest low flow months of summer.

The movement of solute loads from source areas downstream generally does not occur in a steady, step by step progression downstream. Due to temporary/partial alluvial storage of solute loads, distances between gaging sites, and current river conditions, much of the load may not reach downstream gaging sites for months or longer. These loads are stored in the alluvium for months or years and flushed out during periods of higher flows. As a rule of thumb, higher flows on the Red River have lower solute concentrations (mg/l) but higher loads (tons/day) due to higher flow volumes (cfs or dsf).

LOW FLOW ANALYSIS

The USACE has expressed concerns that chloride control and irrigation reductions to flow have the potential to cause adverse environmental impacts in the Red River Basin due to potential increased frequency of low flow events. A routing program was developed to simulate chloride control and irrigation reductions to flow under natural/existing conditions and modified conditions. The routing program and assumption is explained in the following paragraphs.

Overview of the Method

The routing method developed for this study is based on the assumption that the whole alluvial flood-plain/aquifer is involved in the mechanics of flow modifications. Previous investigations in the basin have documented the extent of the alluvial aquifer associated with the Red River and its tributaries. The assumption used in this study is that surface flows and alluvial aquifer storage are interconnected. Reductions in surface flows are actually a reduction in total aquifer storage. Increases in surface flow increase total aquifer storage. This approach was chosen because it is deemed more realistic when compared to other approaches. Other approaches subtracted 100% of flow reductions directly from surface flows and routed the resulting modified flow downstream to the next reach. These approaches assumed the river was in effect a continuous, uniform pipeline with no interaction from the associated alluvial aquifer.

A routing program was developed to simulate the storage in the alluvial aquifer system. Reductions in flow were routed through the aquifer system for each reach and result in changes to total aquifer storage and resulting stage. Flows less than daily flow reductions would result in a decrease in aquifer storage and a cumulative drawdown in storage and stage. Flows in excess of daily flow reductions would result in an increase in aquifer storage and a recharge of the aquifer and resulting stage. The steps, assumptions, and data available are discussed in the following paragraphs.

Low Flow Program Steps

The reduction in flow each day is computed as the sum of daily reduction and cumulative reduction. The daily flow reduction is a constant reduction applied each day and is computed as a reduction in stage. For extended drawdown periods, the drawdown has the cumulative effect of reducing stage based on the previous days' reduction. The low flow program uses a cumulative reduction in flow, in addition to the daily reduction, to determine day-by-day modifications in flow. The following steps are used to compute the reduction in flow:

- Compute the Stage from the daily gage flow and rating table.
- Compute Today's Shortage/Recharge = flow – flow reduction.
- Recharge of the Aquifer. Recharge of the aquifer is relatively simple and straightforward. If flow for any day or consecutive days is greater than the total drawdown amount minus the daily flow reduction, the aquifer has been recharged. The total drawdown is the sum of the deficit of daily flows. A deficit of daily flow is a condition when flow reductions or pumped flows are greater than daily flow. For example, if the total drawdown is 100 day-second- feet (DSF) and flow is 100 cfs with the pumped flow at 10 cfs, the new computed total drawdown would be 100 cfs (100 cfs-10 cfs) = 10 dsf. The 100 cfs-10 cfs represents an excess above the required 10 cfs pumped that is available to recharge the aquifer. If the next day's flow is 20 cfs or more (10 cfs needed for pumping and 10 DSF required to fill the remaining drawdown deficit), the aquifer will be completely recharged.
- Total Flow Shortage = Previous Summation + Today's Shortage/Recharge (when this value exceeds zero, it is set to 0).
- Compute Today's Stage Reduction using the Total Flow Shortage and the Stage Reduction.
- Compute New Modified Stage = Original Stage (first step, above) minus Today's Stage Reduction computed in No. 4, above, minus the Normal Stage Reduction.
- Compute Final Modified Flow using the New Modified Stage and rating table.

Assumptions

- The water level in the alluvium would be equal to the water level in the river
- The stream and alluvial volumes were computed using the same method, i.e., the porosity values are the same (rather than 100% for the stream). The error would be minor when the volume of the alluvium is compared to the volume in the river.
- The cross section of the alluvium was considered rectangular. Cross sectional area was calculated using reach river miles and alluvial acreage per reach.
- Daily low flow dam reductions in flow and load were average daily reductions for the period of record (WY1962 - 2006).
- The alluvial stage reduction was based on alluvial volume. The alluvial volume and flow reductions were constant; therefore, a constant daily stage reduction was computed.
- Since the flow reductions due to project implementation were negligible, the assumption was made that movement of loads through the basin would result in the same distribution at points downstream reduced by a factor of the flow reduction. This assumption was made to simplify duplicating alluvial storage of Cl loads during periods of low flow when flushed out during high flow periods.

Data Used in the Analysis

The data used by the model ranged from constant or non-changing data, such as flood plain areas and porosities, to variables, such as annual irrigation requirements. The following paragraphs and tables define the types and values of data used.

1. Flows pumped from the low flow dams are shown in Table 79.
2. Properties of the alluvial aquifer were obtained from USACE investigations of the Red River Basin. The Reach 14 Area was reduced by 50% due to the portion of the Red River above the mouth of the North Fork of the Red River that was not used for this study. Porosity and area of the alluvial aquifer by reach are listed in Table 75.
3. Daily flows used as a foundation in this analysis were considered the existing conditions data set. This data set includes periods where Areas V and VIII were in operation. The Area V reductions were considered minor based on the distance from the source area to the next downstream gage. In the previous Wichita Basin Project Reevaluation (USACE 2003), an identical low flow analysis was performed. The previous study showed no changes to low flows on the Lower Red River Basin
4. Irrigation withdrawal data used in the concentration duration analysis was used in the low flow analysis. Daily irrigation withdrawals in cfs by reach are presented in Table 18. An irrigation return flow of 26.5% was assumed. Condition 5, which represents the maximum reduction in flow, was analyzed.

Table 75 - Alluvial Aquifer Porosity and Surface Area by Reach

Reach	Porosity	Area (acres)
6	0.425	56,236
7	0.425	44,250
8	0.425	33,088
9	0.430	18,490
10	0.430	24,531
11	0.430	21,792
12	0.430	73,721
14	0.423	19,900

Low Flow Analysis Results

The low flow routing program generated a period of record data set for Condition 5 with future irrigation. Condition 5 represents the condition with greatest chloride control and future irrigation reduction. A separate data set was not generated for Condition 5 with chloride control reductions only because the reductions in chloride control are minor compared to predicted irrigation reductions. Condition 2 & 3 low flow implications were evaluated during the Wichita Basin Project Reevaluation study and showed no increases to low flow days on the lower Red River Basin on Reaches 6 and 7. As mentioned previously, due to the distance of Area V to the next downstream gage, reduction in flows were considered insignificant. Table 75 presents the results of the low flow study.

The greatest increase in low flow days would be in the Upper Red River Basin in Reaches 12, 14a, and 14b. Reaches 14a and 14b show increases of 3.6% in the number of days with flows ≤ 0 cfs when existing conditions and Condition 5 are compared. The increases at Reach 14b were expected since the Carl gage is less than three miles downstream from the source areas. Reach 12 also shows an increase of 2.04% in days with flows ≤ 0 cfs.

Reaches 6 & 7, located in the Lower Red River Basin, would be impacted by Areas V, VI, VII, VIII, and X. The low flow analysis showed no days with flows ≤ 0 cfs or ≤ 1 cfs under natural conditions or with Condition 5. Generally, flows increase as you travel down a basin as the drainage areas increase. The results of this low flow analysis correspond with the results of the low flow analysis produced during the Wichita Basin Project Reevaluation study for the lower Red River reaches.

Even under existing or natural conditions, zero flows days for each reach are based on flows measured at the representative gage. A day of zero flow at a representative gage does not necessarily mean that there is absolutely no flow or water in the entire reach or at that location. Water is still available and flowing through the alluvium and may appear in low areas and pools throughout the reach. Measuring low flows in sandy, wide, braided channels such as the Red River and many of its tributaries present the greatest challenge to hydrologists and hydraulic engineers. With each flow event, the dynamics of flow at representative gaging sites are changed. Rating curves, the flow/stage correlations for each site, may change from one flow event to the next, with low flows presenting the greatest challenge.

Table 76 - Low Flow Analysis Results

LOCATION		NUMBER OF LOW FLOW DAYS*				PERCENT OF TIME*			
	REACH	EXISTING COND.		Condition 5 w/ Future Irrigation		EXISTING COND.		Condition 5 w/ Future Irrigation	
	NUMBER	≤0 cfs	≤1 cfs	≤0 cfs	≤1 cfs	≤0 cfs	≤1 cfs	≤0 cfs	≤1 cfs
CARL	14b	26	397	616	947	0.16%	2.42%	3.75%	5.76%
HEADRICK	14a	188	357	779	1122	1.14%	2.17%	4.74%	6.83%
BURKBURNETT	12	182	244	517	545	1.11%	1.48%	3.15%	3.32%
TERRAL	7	0	0	0	0	0	0	0	0
GAINESVILLE	6	0	0	0	0	0	0	0	0

* Total Number of Days = 16436

CONCENTRATION DURATION ANALYSIS

Natural Conditions

Two chloride control areas were in operation during the period of record chosen for this study. Area V at Estelline Springs on the Prairie Dog Town Fork of the Red River went into operation in January 1964. A starting date of Oct 1964 was used in this study so that the start date would correspond with the starting date of a new water year. Area VIII on the South Fork of the Wichita River also went into operation in May 1987. Only three years of natural conditions data exist in the period of record chosen for the study. To obtain a natural condition data set, the existing conditions flow and concentration data were modified to represent natural conditions. Modifications were applied for the time periods listed in Table 76.

Existing conditions concentration duration data was modified for each reach and representative gage by applying a ratio of the average daily load divided by the modified average daily load. Ratios were developed for chlorides, sulfate, and TDS for each reach. Ratios used to generate natural conditions are included in Appendix A. Existing conditions flow data was modified by adding the average daily flow reductions to daily flow data.

Chloride control at Area V consists of a ring dike surrounding the source area. A constant daily reduction in solutes was assumed. Area V is located on the Prairie Dog Town Fork of the Red River near Estelline Springs, Texas approximately 135 river miles upstream from the next downstream gage at Burkburnett, Texas. It was assumed that any reduction in flow due to the operation of Area V was not detected at the Burkburnett gage. As a result, no modifications to flow at downstream gages were made to account for the operation of Area V.

Recorded pumped flow and concentration data for Area VIII on the Wichita River were used to modify existing conditions data to represent natural conditions. Table 78 presents the flows and loads added back into the data set to obtain a natural conditions data set.

Table 77 - Upstream Conditions for Natural Water Quality

Condition	Application Period
Natural=Gaged	1962-1964 WY
Area V in operation	1965 WY-Apr 1987
Area V, VIII in operation	May 1987-2006 WY

Table 78 - Natural Conditions
Calculated Average Daily Flow and Loads Reductions

	1964 WY-Apr 1987 (cfs and tons/day)				May 1987-WY06 (cfs and tons/day)			
Location	Flow cfs	Cl tons/ day	SO_4 tons/ day	TDS tons/ day	Flow cfs	Cl tons/ day	SO_4 tons/ day	TDS tons/ day
Area V		240.0	220.0	790.0		240.0	220.0	790.0
Area VIII					*5.9*	*179.0*	*44.0*	*356.0*
Total Reduction		*240*	*220*	*790*		*419*	*264*	*1146*
Average Daily Flow and Load								
Burkburnett	1207	3000	1902	7983				
Terral	2039	3319	1792	8627	2854	3951	2545	10895
Gainesville	2769	3770	1845	9517	3908	4952	3001	13154
Denison	4556	3655	2345	10629	6661	5025	3123	14375

LOW FLOW DAM ROUTING PROGRAM

A low flow dam routing program was developed during the Wichita River Reevaluation study and used in this study. The program is a reservoir routing program which simulates the low flow dams/collection areas and is used to route flow and water quality data. The program determines the pumped or captured flow and load, and the flow and load that passes downstream. The low flow dam routing program is used to generate modified flows and loads and route them downstream.

AREAS VII, VIII, AND X LOW FLOW DAM ROUTINGS

Chloride control at Areas VII, VIII, and X is accomplished by low flow dams which capture concentrated low flows that are pumped to Truscott Brine Storage Reservoir. The dams are designed to deflate when the flow increases and reaches a stage of one-half foot above the top of the dam allowing the diluted, higher flows to pass downstream. Pumping stops when the low flow dam deflates. Table 79 presents the pumped flows and loads for the different time periods in the period of record. The low flow routing programs used for Areas VII, VIII, and X were developed using the following assumptions:

- Flows up to the maximum design pump rate for each area were pumped.
- Maximum Pump rates: Area VII=20 cfs, Area VIII=15 cfs, Area X= 10 cfs
- The low flow dam is assumed to deflate and all flow allowed to pass downstream if daily average flows are greater than the maximum pump rate.

Table 79 - Wichita River Source Areas
Pumped Flows and Loads

Area	Condition	Max Pump Rate	WY62-06 (cfs or tons/day)				WY62-64 (cfs or tons.day)			
		Flow cfs	Flow cfs	Cl tons/day	SO_4 tons/day	TDS tons/day	Flow cfs	Cl tons/day	SO_4 tons/day	TDS tons/day
VII	Natural		24.93	237.3	84.7	522.3	9.99	158.5	49.9	347.8
	Modified	20	11.38	201	67	433	7.53	150	47	327
VIII	Natural		10.18	188.6	48.7	379.7	9.83	152.9	33.6	299.7
	Modified	15	6.23	179	43	358	4.76	133	29	261
X	Natural		7.77	55.2	41.0	154.0	5.67	45.0	33.8	135.1
	Modified	10	5.09	49	38	135	4.13	41	31	122
AREA	CONDITION	Max Pump Rate	WY65 - Apr 1987 (cfs or tons/day)				May 1987 - WY06 (cfs or tons/day)			
		FLOW Cfs	FLOW Cfs	Cl tons/day	SO_4 tons/day	TDS tons/day	FLOW cfs	Cl tons/day	SO_4 tons/day	TDS tons/day
VII	Natural		25.20	226.6	75.6	490.7	26.93	261.9	100.7	586.0
	Modified	20	10.92	194	90	413	12.51	217	77	474
VIII	Natural		10.37	164.2	41.2	328.2	8.87	237.5	57.3	476.0
	Modified	15	5.44	151	38	301	5.98	178	44	355
X	Natural		7.84	57.8	39.8	157.2	8.01	53.9	43.5	153.2
	Modified	10	5.07	52	35	140	5.31	47	38	132

AREA VI LOW FLOW DAM ROUTINGS

Water quality and flow data were collected for the three source areas at Area VI during the early stages of chloride control investigations in the Red River Basin. Data was available for WY 1963-1970 at Kiser, Robinson, and Salton Canyons and also for a site immediately upstream of the source areas, Salton Crossing. Table 79 presents the average flow and load data for this time period. This data was used to develop the assumptions used in the low flow dam routing program for Area VI.

Table 80 - Area VI Source Area Summary

Location	Flow	Chloride	Sulfate	TDS
	Avg (cfs)	Avg Load (tons/day)	Avg Load (tons/day)	Avg Load (tons/day)
Carl Gage	38.37	482	144.20	1063
Kiser Canyon	0.10	34	0.60	61
Robinson Canyon	0.78	113	1.97	203
Salton Canyon	0.56	246	4.30	444
Salton Crossing	11.85	153	21.40	305
Sum above Carl	13.29	546	28.27	1013
% of Carl	34.64%	113.28%	19.60%	95.30%
Sum of Canyons	1.44	393	6.87	708
% of Carl	3.75%	81.54%	4.76%	66.60%

Chloride control at Area VI would capture flow from the three source areas (canyons). The captured brine would then be pumped offsite for either surface storage and evaporation or subsurface disposal. Since data for source areas was limited, the low flow dam routing program for Area VI uses data at the Carl gage. Table 81 presents the average pumped flow and loads for Area VI. The routing program for Area VI was based on the following assumptions:

- If the flow at the Carl gage was ≤ 2 cfs, all flow and load would be captured.
- If the flow at the Carl gage was ≥ 2 cfs, the following load would be captured:
  1. 82% of the chloride load at the Carl gage (representing loads from source areas)
  2. 2.8% of chloride load from 2 cfs at the Carl gage(representing runoff from canyons)
  3. 5% of the sulfate load at the Carl gage (representing loads from source areas)
  4. 5% of the sulfate load from 2 cfs at the Carl gage (representing runoff from canyons)
- Maximum flow captured at the Carl gage is 2 cfs

Table 81 -Area VI
Average Natural and Pumped Flows/Loads

	PARAMETER (cfs or T/D)			
	FLOW Cfs	Cl tons/day	SO_4 tons/day	TDS tons/day
Natural	38.1	501.0	144.0	1066.0
Pumped	1.96	423.0	16.6	744.0
% Captured	5%	84%	12%	70%

AREA V REDUCTIONS TO FLOW AND LOAD

Reductions in load were already present in the period of record data set for Area V for WY 1964 through WY 2006. Reductions in load for areas downstream of Area V were adjusted to represent the operation of Area V for WY 1962 through WY 1963.

MODIFIED CONDITIONS DUE TO CHLORIDE CONTROL

Modified conditions flow and concentration data were determined using methods similar to the methods used to generate natural conditions data. Natural conditions concentration duration data was modified by applying a ratio of average daily modified loads divided by average daily natural loads for each reach to generate modified concentration duration data. Ratios used to generate modified concentration data are presented in Appendix A. Modified flows for each reach were generated by subtracting the cumulative reduction in flow from upstream reduction from daily natural conditions flow data. Table 82 presents the total flow/load reductions at each source area. Due to limited data for Reach 1, represented by the Hosston gage, natural and modified conditions were calculated using a different method. A complete explanation of the method is included in Appendix A.

Table 82 - Daily Average Flow/Load Reductions by Project

	1962-2006 WY			
Area	Flow Cfs	Cl tons/day	SO_4 tons/day	TDS tons/day
V		240	220	790
VI	1.96	423	17	744
VII	11.38	201	67	433
VIII	6.23	179	43	358
X	5.09	49	38	135
5% alluvial clean up		25		

To aid in the explanation of cumulative reductions to flow and load, the Red River Basin was divided into the upper and lower Red River Basins. The upper Red River basin includes all portions upstream of the confluence of the Wichita River with the Red River. The lower Red

River basin includes all portions of the basin downstream of the confluence with the Wichita River.

The upper Red River basin is comprised of Reaches 12, 14a, and 14b and is represented by the Burkburnett, Headrick, and Carl gages. The Headrick gage is located on the North Fork of the Red River and is affected only from reductions in flow/load from Area VI. The Burkburnett gage is located on the main stem of the Red River downstream of the confluence with the Prairie Dog Town Fork and North Fork of the Red River. The Burkburnett gage is affected by reductions in flow/load from both Areas V and VI. Table 14 presents the daily load reductions for the Upper Red River Basin. Note that the combined changes to flow/loads of Conditions 2&3 and Conditions 4&5 are presented for the Headrick and Burkburnett gages. Conditions 2 & 3 include only Area V at the Burkburnett gage. Conditions 4 & 5 include both Areas V & VI at Burkburnett.

Table 83 -Upper Red River Basin
Total Daily Load Reductions

	Burkburnett					Headrick		
Condition	Flow Cfs	Cl tons/ day	SO_4 tons/ day	TDS tons/ day	Flow cfs	Cl tons/ day	SO4 tons/ day	TDS tons/ day
2 & 3		240	220	790				
4 & 5	1.96	663	237	1534	1.96	423	17	744

The lower Red River basin is comprised of Reaches 5, 6, and 7 and are represented by the Denison, Gainesville, and Terral gages. The lower Red River basin is affected by reductions to load/flow from Areas V, VI, VII, VIII, and X. Cumulative reductions to load/flow are presented in Table 83. Changes to flow/load in reaches 8, 9, 10, and 11 on the Wichita River were presented in the Wichita Basin Project Reevaluation and will not be discussed in this study. Reductions in flow and load from the Wichita River Basin projects are included in the reductions on the main stem of the Red River downstream of the confluence with the Wichita River in Reaches 5, 6, and 7.

Table 84 -Lower Red River Basin
Total Daily Flow/Load Reductions by Condition

		Lower Red River			
Condition	Areas	Total Reductions			
	In Operation	Flow Cfs	Cl tons/day	SO_4 tons/day	TDS tons/day
2	V, VIII	6.23	419	263	1148
3	V, VII, VIII, X	22.70	669	368	1716
4	V, VI, VIII	8.19	842	280	1892
5	V, VI, VII, VIII, X	24.66	1092	385	2460

MODIFIED CONDITIONS WITH FUTURE IRRIGATION

As successive portions of the Red River Chloride Projects are completed, water quality would improve throughout the basin. One of the implications of improved water quality in the basin would be increased irrigation water usage. Future in-stream water withdrawals, in combination with reductions from chloride control, have the potential to change flows and solute concentrations in the Red River Basin.

To evaluate the combined effects of chloride control and future irrigation to solute concentrations in the Red River, a program was developed to simulate reductions in flow/load from irrigation requirements and the resulting flow/load for each reach and each condition. A complete explanation of the steps in the process is explained in the following paragraphs.

During the previous Wichita Basin Project Reevaluation, the Texas Agricultural Experiment Station evaluated the future agricultural and economic consequences of Areas VII, VIII, and X on the Wichita River and Red River basins. The final report, “Analysis of the Wichita River Portion of the Red River Chloride Control Study,” dated September 2000, included future irrigation water use for Reaches 5-11 on the Wichita and Red River. The report detailed future irrigation water use in the basin starting in 2005 through 2035 for the conditions investigated in the Wichita River Basin Project Reevaluation effort. The 2035 irrigation water requirements for Condition 2 (as designated in the Wichita Basin Reevaluation, Area VIII in operation) and Condition 5 (Areas VII, VIII, & X in operation) were chosen for use in this study. The Texas A&M study used different irrigation return flow rates for different conditions. In this study, an irrigation return flow of 26.5% was used across all conditions. The irrigation requirements used in this study for Reaches 5-8 are presented in Table 84.

Table 85 -Texas A&M Irrigation Data

	Downstream Gage		Irrigation (acre feet/yr)	
Reach	Affected	River	w/VIII only	w/ VII, VIII & X
5	Denison	Red	0	0
6	Gainesville	Red	58806	60131
7	Terral	Red	0	419
8	Terral	Wichita	75025	172420

In 2006, Oklahoma initiated a program to develop a comprehensive state water plan, similar to the comprehensive state water plan developed by the state of Texas in 2001. As a part of this effort, the Oklahoma Water Resources Board completed the report “Oklahoma Comprehensive Water Plan, Water Demand Forecast Report” in October 2009. The report included future irrigation water demands by county. Of interest to this study were the irrigation requirements for Greer, Jackson, Kiowa, and Tillman counties which include the upper Red River basin. Since future irrigation requirements in the OWRB report were developed by county, not by river basin and were not tailored for this study, assumptions were made on the percentage of each counties irrigation demand to use in this study. In Reach 12, 58,806 acres are available for irrigation in 2040 forecast for Jackson County. It was assumed that 48, 000 acres would be supplied from Lake Altus on the North Fork of the Red River. The remaining 10,806 acres were equally divided between Reach 12 and Reach 14a. In Reach 12, no irrigated acreage data were available for Wilbarger and Wichita Counties in Texas. As a result, 200% of the forecast acreage was used for Tillman County to represent total irrigated acreage in Texas and Oklahoma for Reach 12. Annual irrigation requirements were calculated by multiplying the forecast acreage by a factor of 1.2, a factor presented in the OWRB report, to generate annual irrigation requirements in acre feet. Annual irrigation requirements in acre feet for the Upper Red River Basin are presented in Table 85. Daily irrigation requirements for each reach were determined assuming a 150 day irrigation season (May – September). Table 86 presents total daily irrigation withdrawals in cfs by reach and condition.

A program was developed to rout future irrigation requirements or holdout downstream. The period of record data set representing modified flows from chloride control (modified Cl) was used as a foundation. The routing program performed the following steps for each day of the period of record, each reach and each condition:

1. The program first calculated the total irrigation reduction or holdout in flow. An irrigation return flow percentage of 26.5% was used for all conditions in this study. Daily irrigation withdrawals were assumed to be taken during a 150 day irrigation season from May through September. The total irrigation reduction for each reach was calculated using the following equation: total reach irrigation reduction=irrigation reduction* (100%-% return flow).

2. The program assumed 75% of the total upstream reach reduction were routed downstream to the next reach. Downstream reach irrigation reductions were calculated using the following equation: Total Reach holdout= Reach Holdout + 75% of upstream reduction.

3. The program assumed that irrigation resulted in no reduction in load. In effect, the irrigation withdrawals resulted in a reduction in flow but no reduction to load. The loads in the irrigation withdrawals were assumed to return to the river with the return flow.

4. Modified solute concentration data reflecting the combined changes of chloride control and future irrigation were calculated using the following equation:

Total modified concentration=modified Cl conc.*modified Cl flow /total modified flow

Modified concentration/flow data were generated using the method described above for all reaches except Reach 5. For Reach 5, Lake Texoma was assumed to buffer or smooth out any change in flow. A ratio of the change in average inflows was computed and an inverse proportional ratio was used to compute the concentration data. The following equation was used to calculate a ratio that was applied to loads at Reach 5 flow: Reach 5 Ratio = Denison Natural avg. flow/(Denison Natural avg. flow - reduction in flow at Gainesville.

TABLE 85
Table 86 - Annual Upper Red River Irrigation Requirements

	County	OWRB Forecast Acreage	Forecast Acreage Used	Annual Irrigation Acre feet
Reach 12	Greer	8,043	0	0
	Jackson	58,806*	5,403	6484
	Kiowa	2,854	0	0
	Tillman	13,563	27,126	32551
		Total	32,529	39,035
Reach 14a	Greer	8,043	0	0
	Jackson	58,806*	5,403	6484
	Kiowa	2,854	1,427	1712
	Tillman	13,563	0	0
		Total	6,830	8,196
Reach 14b	Greer	8,043	8,043	9,652
	Jackson	58,806*	0	
	Kiowa	2,854	0	
	Tillman	13,563	0	
		Total		

*48,000 acres assumed to be irrigated from Lake Altus storage

TABLE 86
Daily Irrigation Withdrawal by Reach

		Daily Irrigation Withdrawals (cfs)			
Representative	Reach	Condition			
Gage	No.	2	3	4	5
Carl	14b	0	0	32	32
Headrick	14a	0	0	28	28
Burkburnett	12	0	0	131	131
Wichita Falls	8	252	580	252	580
Terrel	7	0	419	0	419
Gainesville	6	198	202	198	202

CONCENTRATION DURATION STUDY RESULTS

Concentration duration data for chloride, sulfates, and TDS were generated for each reach for the following conditions:

- Natural conditions
- Modified by chloride control
- Modified by chloride control and future Irrigation

Concentration duration data for all conditions are presented as the percent of time a concentration is equaled or exceeded. Duration results for all reaches and conditions are available in Exhibits A and B. The discussion of concentration duration results in this report will focus on the Reach 14a (Headrick) and Reach 5 (Denison). Concentration duration results for Reaches 14a and 5 are presented in Tables 87 through 92 below. Flow durations for natural condition and condition 5 are presented in Table 93.

Reach 14a is located on the North Fork of the Red River near Headrick, Oklahoma, below the confluence with the Elm Fork of the Red River and Elk Creek. Reach 14a is affected only by chloride control at Area VI (conditions 4&5). Concentration duration results indicate that chloride control on the Elm Fork of the Red River at Area VI (conditions 4&5) has the potential to reduce chloride concentrations by 80% and TDS concentrations by 47% downstream at Reach 14a when the 50% duration results are compared to natural conditions. Sulfate concentrations are reduced by a modest 5%. This lower reduction in sulfate is due to the low sulfate concentration from the sources areas. Chloride concentrations at Reach 14a are expected to meet the U.S. Environmental Protection Agency’s secondary drinking water standard of 250 mg/l approximately 35% of the time. A review of concentration duration data for chloride control with future irrigation at Reach 14a indicates that chloride concentrations actually increase with future irrigation when compared to concentration durations from chloride control only. Chloride concentrations increase 4% at the 80% duration, 13% at the 50% duration, and 22% at the 20% duration with future irrigation in Reach 14a.

Table 87 -Reach 14a Concentration Duration Results Chloride Concentrations

Condition	Percent of Time Equaled or Exceeded								
	1	5	10	20	50	80	90	95	99
Natural	5709	4298	3718	1940	1807	797	457	263	0
Conditions 4 & 5	1125	847	732	579	356	157	90	52	0
Conditions 4 & 5 w/ Future Irrigation	2780	1182	962	739	407	166	94	54	0

Table 88 -Reach 14a Concentration Duration Results

Condition	Percent of Time Equaled or Exceeded								
	1	5	10	20	50	80	90	95	99
Natural	1621	1343	1246	1112	860	552	401	215	0
Conditions 4 & 5	1533	1270	1179	1052	814	522	379	203	0
Conditions 4 & 5 w/ Future Irrigation	2780	2084	1784	1271	905	554	396	212	0

Table 89 - Reach 14a Concentration Duration Results TDS Concentrations

Condition	Percent of Time Equaled or Exceeded								
	1	5	10	20	50	80	90	95	99
Natural	11821	9150	8222	6825	4529	2263	1427	814	0
Conditions 4 & 5	5532	4282	3949	3194	2120	1059	668	381	0
Conditions 4 & 5 w/ Future Irrigation	9660	6364	5182	3985	2415	1121	695	400	0

Reach 5 is located on the main stem of the Red River and is represented by the Denison gage. A review of concentration duration results for Reach 5 indicate that Condition 5, which includes Areas V, VI, VII, VIII, and X in operation, has the potential to reduce chloride concentrations by 25%, sulfate concentrations by 14%, and TDS concentrations by 19% from natural conditions based on 50% duration results. Reach 5 can be expected to meet the USEPA secondary drinking water standard of 250 mg/l for chlorides approximately 45% of the time. A review of concentration duration data for chloride control with future irrigation indicates that chloride concentrations increase 3% at the 80% duration, 5% at the 50% duration, and 3% at the 20% duration above chloride control only durations.

Table 90 -Reach 5 Concentration Duration Results Chloride Concentrations

Condition	Percent of Time Equaled or Exceeded								
	1	5	10	20	50	80	90	95	99
Natural	581	461	441	417	343	273	245	223	174
Conditions 4 & 5	437	347	332	314	258	205	184	168	131
Conditions 4 & 5 w/ Future Irrigation	450	357	342	323	266	211	190	173	135

Table 91 -Reach 5 Concentration Duration Results Sulfate Concentrations

Condition	Percent of Time Equaled or Exceeded								
	1	5	10	20	50	80	90	95	99
Natural	430	394	325	292	238	167	117	104	81
Conditions 4 & 5	373	342	282	253	206	145	101	90	70
Conditions 4 & 5 w/ Future Irrigation	384	352	290	261	213	149	104	93	72

Table 92 -Reach 5 Concentration Duration Results TDS Concentrations

Condition	Percent of Time Equaled or Exceeded								
	1	5	10	20	50	80	90	95	99
Natural	1788	1342	1286	1220	1009	785	683	606	505
Conditions 4 & 5	1450	1088	1043	989	818	637	554	491	410
Conditions 4 & 5 w/ Future Irrigation	1494	1121	1074	1019	843	656	571	506	422

As noted above, concentration duration results show an increase for chloride control with future irrigation concentrations above chloride control for Condition 5. This increase was noted in all conditions evaluated. When data was reviewed beginning at Reach 5 and progressing upstream, the percent increase between chloride control and chloride control with future irrigation appeared to increase. This is a function of drainage area. Drainage area increases as one progresses downstream in a basin along with a corresponding increase in average daily flow. Reductions in flow in the upper reaches of the basin have a greater effect on concentrations due to lower average daily flows. The increase in concentrations for chloride control with future irrigation above chloride control only is explained as a result of assumptions in the routing program. The routing program developed for this study assumed all chloride load in irrigation withdrawals were returned to the river with irrigation return flow. This assumption was used to represent long term irrigation and may not be representative of short term irrigation. This was considered a reasonable assumption meant to represent maximum effects of future irrigation.

The concentration duration results presented in this study are intended to be used a tool to gauge potential changes and not to predict future outcomes. The routing program assumes that chloride control and future irrigation reductions begin on Day 1 of the period of record and continue uninterrupted through the period of record. In reality, chloride control reductions are curtailed for extended periods of time due to mechanical breakdowns, routine maintenance, and electrical outages. Irrigation withdrawals are dependent on meteorological trends and may not occur every day of the irrigation season.

Table 93 -Flow Durations
Natural Conditions and Condition 5 with Future Irrigation

	Percent of Time Flow (cfs) Equaled or Exceeded								
	1	5	10	20	50	80	90	95	99
Carl mg/l									
Natural	386.0	101.0	61.0	35.0	16.7	8.7	5.2	2.7	0.3
Condition 5 w/ Future Irrigation	384.0	99.0	59.0	33.0	14.7	6.7	3.2	0.7	0.0
Headrick mg/l									
Natural	5070	1150	585	249	74	30	15	6.5	0.0
Condition 5 w/ Future Irrigation	5070	1120	569	235	68	22	10	3.8	0.0
Burkburnett mg/l									
Natural	15700	4340	2320	1040	290	100	50	21	0
Condition 5 w/ Future Irrigation	15700	4255	2250	991	259	74	35	14	0
Terral mg/l									
Natural	28742	9140	5260	2420	613	286	196	155	100
Condition 5 w/ Future Irrigation	28279	8820	5019	2180	498	210	141	104	62
Gainesville mg/l									
Natural	39900	12800	7130	3310	915	372	242	191	126
Condition 5 w/ Future Irrigation	39362	12300	6940	3059	759	277	185	133	82

OTHER RED RIVER BASIN FEDERAL ACTIONS

Future local/state/Federal actions with potential impacts in the Red River Basin were investigated. Two separate Federal actions in the Red River Basin were deemed to have the greatest potential impact. The two Federal actions are the reallocation of 300,000 acre feet of conservation storage in Lake Texoma from the hydropower purpose to water supply and the proposed future construction of a water supply reservoir on the North Fork of the Red River near Headrick, Oklahoma, referred to in this report as Cable Mountain Reservoir.

Each Federal action has implications within the basin. The Lake Texoma reallocation results in changes to Lake Texoma storage and elevations and possibly flows in reaches downstream. Downstream flows are not evaluated in this study. The construction of Cable Mountain Reservoir has consequences to flows in the Upper and Lower Red River Basin. The impoundment of water in Cable Mountain has consequences to Lake Texoma by decreasing inflows. The focus of this study will be the evaluation of the combined consequences of chloride control, future irrigation, reallocation of storage in Lake Texoma, and construction of Cable Mountain Reservoir on storage and pool elevations in Lake Texoma. Each Federal action is evaluated separately then the combined implications discussed.

Cable Mountain Reservoir Background

The W.C. Austin Project, also known as Lake Altus, is a Bureau of Reclamation (BOR) reservoir located on the North Fork of the Red River north of Altus, Oklahoma in Greer County. Lake Altus was constructed in 1946 and is operated by the Lugert-Altus Irrigation District for irrigation water supply. Due to concerns about loss of storage due to sedimentation and the future water supply yield, the Lugert-Altus Irrigation District requested the BOR perform an investigation on options to augment the water supply at Lake Altus and offer recommendations on water conservation within the irrigation district, increasing the yield of Lake Altus, and potential future sources of water supply in the region.

The BOR report, "Water Augmentation, W.C. Austin Project, March 2005," found that by the year 2034, Lake Altus would have insufficient storage to hold the average annual irrigation requirement (63,000 acre feet) and the municipal and industrial allocation (10,000 acre feet). The report investigated options to augment the water supply. These options included wastewater reuse, improvements to the irrigation delivery system to improve efficiency, improvements to Altus Lake to allow full use of available storage, and new impoundment options in the basin.

The option considered by the BOR that would provide the highest water supply yield/storage was the construction of a new reservoir on the North Fork of the Red River downstream of Lake Altus, referred to in the report as Cable Mountain Reservoir. Cable Mountain Reservoir would be located near Headrick, Oklahoma, on the North Fork and would impound water from the Elm Fork of the Red River, Elk Creek, and flood releases from Lake Altus on the North Fork of the Red River. The BOR report stated that before construction of the reservoir would be considered, water quality in the basin required improvement. To improve water quality in the basin, the BOR recommended the USACE chloride control project completion on the Elm Fork of the Red River, Area VI, before the Cable Mountain project would be considered a viable option.

Cable Mountain Investigation

The construction of Cable Mountain Reservoir has the potential to impact flows and water quality in the Red River Basin. The impoundment of Cable Mountain has the potential to reduce flows on the North Fork of the Red River and main stem of the Red River. Cable Mountain also has the potential to impact water quality in the basin when evaluated in combination with chloride control and future irrigation.

Pertinent data on Cable Mountain was limited. The BOR report offered the approximate dam location, estimated top of conservation pool elevation, storage, and area, and the estimated water supply yield. A feasibility level study is not available.

A routing routine was developed to simulate the operation of Cable Mountain Reservoir on the North Fork of the Red River. The routing routine captures inflows on the North Fork at

Headrick up to the assumed conservation storage in Cable Mountain. All inflow above conservation storage was assumed to be a flood release. The routing method accounts for irrigation withdrawals, losses to evaporation, and for precipitation on the pool.

Data Required for the Investigation

- *Elevation-Area-Capacity Data for Cable Mountain*. The only capacity data available for Cable Mountain was the proposed top conservation pool elevation and total conservation storage, a process was devised to develop an estimated elevation-area-capacity table for the proposed reservoir. ArcGIS, ArcMAP and USGS Digital Elevation Model (DEM) data were used to generate the required EAC data. The elevation-area-capacity data table generated for Cable Mountain is included in Appendix B.
- *Monthly Inflow Data*. The Headrick stream gage site was a just a few miles downstream of the dam site. Monthly flows for the period of record were used as inflow input and are presented in Appendix B
- *Monthly Evaporation Data*. Evaporation data was collected from several sources and sites in the area. Altus Lake monthly data was the most complete source of information. When data was not available from Lake Altus monthly charts, data from the Tipton Oklahoma Mesonet site was used. If data was not available from these sources, National Climatic Data Center data was used. Evaporation data used in the study is presented in Appendix B.
- *Monthly Precipitation*. Lake Altus monthly precipitation data was available. When Lake Altus data was not available, data from other nearby sites was used. These sites included Lake Tom Steed and the Roosevelt gage on Elk Creek.
- *Sedimentation Rate*. The sedimentation rate at Lake Altus was used to estimate the sedimentation rate of Cable Mountain. The sedimentation rate at Lake Altus was determined by taking the original conservation storage (1940) and subtracting the current storage (2007 data) and dividing by the number of years of data available. An annual sedimentation loss of 417 acre feet/year was calculated for Lake Altus. A ratio of the contributing drainage areas for Lake Altus and Cable Mountain (1729 sq. miles/2117 sq. miles=0.817) was then applied to the Lake Altus sedimentation rate to estimate the sedimentation rate for Cable Mountain. An estimated sedimentation rate of 341 acre feet/yr loss was calculated for Cable Mountain.

Reservoir Routing Assumptions

- Top of inactive pool for 100 years of sediment was estimated to be elevation 1378. All storage below this elevation was not available in the routing.
- Inflows above top of conservation pool storage were considered flood releases and were not stored and were released downstream.
- Irrigation withdrawals from Cable Mountain were based on average monthly irrigation withdrawals for Lake Altus, 2001-2008 for the months of June - September.

- Water quality releases were based on 7 day volume 2 year frequency (7Q2) data for the Headrick gage presented in the USGS publication “Statistical Summaries of Streamflow in Oklahoma Through 1999” by Robert Tortorelli, 2002. The daily water quality release from Cable Mountain was assumed to be 7 cfs, the 7Q2 daily flow for Headrick in the above referenced USGS report.
- Releases for downstream water rights were assumed to be 3 cfs, June – October. Data for water quality, irrigation withdrawals, and downstream water rights releases are presented in Appendix B.

Routing Method

The focus of the routing method was to generate flow data downstream of Cable Mountain to illustrate the combined effects of chloride control, future irrigation, and Cable Mountain impoundment. Period of record modified flows representing chloride control and future irrigation were routed through Cable Mountain. Using the modified flows, downstream concentrations were recalculated. Modified concentrations at the Headrick gage were not altered by the construction of Cable Mountain. Flow and concentration data downstream of Cable Mountain were altered due to the reduced flows from the North Fork of the Red River. Conditions 4 & 5 were the only conditions investigated in this study.

Results of Cable Mountain Investigation

Concentration duration data were generated for each reach and each condition investigated. Concentration duration data for each reach affected by the construction of Cable Mountain Reservoir are presented in Tables 26, 27, 28, and 29. A review of the data reveals the construction of Cable Mountain would result in dramatic changes to the solute concentrations achieved by chloride control on the Red River Basin.

Reach 12 is the reach immediately downstream of Cable Mountain and is represented by the Burkburnett gage on the main stem of the Red River below the confluence of the North Fork and the main stem of the Red River. Reach 12 is impacted by chloride sources on the Elm Fork of the Red River, Pease River, and Prairie Dog Town Fork of the Red River. As a result of Cable Mountain construction and impoundment, 98% of the flows coming from the North Fork of the Red River were captured in this study. The reductions in flow from the North Fork of the Red River eliminate the improved water quality on the main stem of the Red River achieved by chloride control at Area VI. Chloride concentrations at Reach 12 increase with the construction of Cable Mountain to chloride concentrations 39% higher than natural concentrations at the 50% duration. As duration data is reviewed sequentially downstream, the same increase in chloride concentrations to levels above natural conditions concentrations are noted. The percent increase above natural concentrations decreases at each downstream reach. At Reach 5, with project chloride concentrations drop below natural concentrations at the 50% duration. The same condition applies to sulfate and TDS concentrations.

Review of concentration data generated in this study indicates that construction of Cable Mountain Reservoir would eliminate chloride concentration reductions in the Red River Basin above Reach 5. Table 94 presents a comparison of average daily flows generated under natural conditions and with project conditions including Cable Mountain. Condition 5 with future irrigation has the potential to reduce average annual flows at Reach 6 (Gainesville) by as much as 4.5%. Condition 5 with future irrigation and the construction of Cable Mountain has the potential to increase these reductions in flow at Reach 6 to 8.3%. The most dramatic reduction in flows are seen at Reach 14a (Headrick) on the North Fork of the Red River. The average annual flow at Headrick, downstream of the proposed Cable Mountain dam site, was 8.26 cfs. This represents a 98% reduction in average annual flows when compared to average annual flows under natural conditions of 355 cfs. The construction of Cable Mountain Reservoir, in combination with Lake Altus and Tom Steed Reservoir, will effectively capture all flows on the North Fork of the Red River. The only flows in this study in the North Fork downstream of Cable Mountain would be low flow and water right releases made from Cable Mountain Reservoir.

Table 94 -Reach 5- Denison Modified Concentration Duration Results
Combined Effects of Chloride Control, Future Irrigation, and Cable Mountain

	Percent of Time Concentration Equaled or Exceeded								
Parameter	1	5	10	20	50	80	90	95	99
	mg/l								
Natural Cl	581	461	441	417	343	273	245	223	174
Modified Cl. - Condition 4	512	406	388	367	302	240	216	196	153
Modified Cl. - Condition 5	476	378	361	342	281	224	201	183	143
Natural SO_4	430	394	325	292	238	167	117	104	81
Modified SO_4 - Condition 4	423	388	320	287	234	164	115	102	80
Modified SO_4 - Condition 5	416	381	314	282	230	161	113	101	78
Natural TDS	1788	1342	1286	1220	1009	785	683	606	505
Modified TDS - Condition 4	1666	1250	1198	1137	940	731	636	565	470
Modified TDS - Condition 5	1580	1186	1136	1078	892	694	604	536	446

Table 95 -Reach 6-Gainesville Modified Concentration Duration Results
Combined Effects of Chloride Control, Future Irrigation, and Cable Mtn.

	Percent of Time Concentration Equaled or Exceeded								
Parameter	1	5	10	20	50	80	90	95	99
	mg/l								
Natural Cl	2006	1713	1599	1393	990	576	396	282	155
Modified Cl. - Condition 4	3076	2696	2468	2116	1209	537	355	244	131
Modified Cl. - Condition 5	2932	2542	2340	2039	1276	547	352	241	125
Natural Sul	1253	954	855	733	536	307	205	149	84
Modified SO_4 - Condition 4	1874	1572	1403	1187	750	324	202	142	79
Modified SO_4 - Condition 5	1894	1540	1383	1176	798	339	205	144	78
Natural TDS	4980	4255	3924	3500	2541	1487	1040	759	410
Modified TDS - Condition 4	8391	7304	6752	5924	3513	1557	1028	728	388
Modified TDS - Condition 5	7171	6398	5972	5284	3442	1459	920	633	244

Table 96 -Reach 7-Terral Modified Concentration Duration Results
Combined Effects of Chloride Control, Future Irrigation, and Cable Mtn.

	Percent of Time Concentration Equaled or Exceeded								
	1	5	10	20	50	80	90	95	99
	mg/l								
Natural Cl	2209	1929	1782	1593	1266	748	497	359	190
Modified Cl. - Condition 4	3392	2964	2741	2446	1934	855	483	324	166
Modified Cl. - Condition 5	3107	2714	2510	2240	1772	783	443	297	150
Natural Sul	1136	1014	945	876	719	455	317	232	126
Modified SO_4 - Condition 4	1989	1772	1652	1536	1246	581	353	238	123
Modified SO_4 - Condition 5	1888	1682	1568	1458	1183	552	335	226	114
Natural TDS	5318	4679	4368	3957	3265	2048	1409	1032	573
Modified TDS - Condition 4	8684	7610	7118	6448	5254	2442	1441	983	522
Modified TDS - Condition 5	8099	7098	6638	6014	4902	2277	1345	917	480

Table 97 -Reach 12-Burkburnett Modified Concentration Duration Results Combined Effects of Chloride Control, Future Irrigation, and Cable Mtn.

	Percent of Time Concentration Equaled or Exceeded								
Parameter	1	5	10	20	50	80	90	95	99
	mg/l								
Natural Cl	4014	3393	3033	2675	1999	1199	825	555	194
Modified Cl. - Conditions 4- 5	6112	5186	4576	4094	2787	1429	884	578	186
Natural SO_4	1931	1664	1562	1451	1176	785	571	415	166
Modified SO_4 - Conditions 4-5	3300	2883	2701	2505	1881	1034	688	472	174
Natural TDS	9399	8048	7438	6754	5224	3286	2347	1638	657
Modified TDS - Conditions 4-5	14848	12845	11914	10710	7583	4044	2597	1749	617

Table 98 -Average Daily Flow Comparison

	Condition	Flow (cfs)
Gainesville	Natural Avg. Gaged	3364
Gainesville	Avg. Modified w/Condition 5 w/ future irrigation	3211
Gainesville	Avg. Modified w/Condition5 w/ future irrigation plus Cable Mtn.	3087
Denison	Reduction in Inflows w/Condition 5 w/ future irrigation	153
Denison	Reduction in Inflows w/Condition 5, future irrigation plus Cable Mtn.	277
Cable Mountain	Outflows	8.26
Headrick	Natural Gaged	354.75

CUMULATIVE EFFECTS OF FEDERAL ACTIONS ON LAKE TEXOMA

Background

Due to future water supply demand projections in North Texas, stakeholders petitioned Congress during the 1980's to allocate additional water supply storage in Lake Texoma. The 1986 Water Resources Development Act (WRDA) authorized the reallocated 300,000 acre-feet of conservation storage from the hydropower purpose to water supply. The original allocation of storage to water supply at Lake Texoma was 150,000 acre feet. The 1986 WRDA allocated 150,000 acre feet to interests in the State of Texas and 150,000 acre feet to interests in the State of Oklahoma.

Efforts to implement the reallocation were begun in 2001. The final reallocation report was completed in March 2010. Water supply storage contracts for the 150,000 acre feet of storage allocated to the State of Texas were signed in March 2010. The State of Oklahoma has not expressed a need for water from Lake Texoma.

The Lake Texoma Reallocation Study, completed in March 2010, investigated the implications of the reallocation of storage from the hydropower purpose to water supply. The program SUPER, a period of record basin simulation model, was used to evaluate consequences. The SUPER runs evaluated the implications from the following conditions:

- 150,000 acre feet of water supply storage use, considered existing conditions or the original allocation to water supply,
- 300,000 acre feet of water supply storage use, considered to be the original allocation plus the 150,000 acre feet of storage allocated to the state of Texas
- 450,000 acre feet of water supply storage use, considered the original allocation plus the 150,000 acre feet allocated to the state of Texas, and the 150,000 acre feet of storage allocated to the state of Oklahoma.

A reservoir routing program was developed to assess the combined effects on Lake Texoma from chloride control, future irrigation, construction of Cable Mountain Reservoir, and the reallocation of storage at Lake Texoma. The routing program used input and output data from the SUPER runs completed for the Lake Texoma Reallocation study. The routing program evaluated the following future conditions:

1. Condition 5 with future irrigation using 150,000 water supply allocation at Lake Texoma.
2. Condition 5 with future irrigation, Cable Mountain completion, with 150,000 acre-feet water supply at Lake Texoma.
3. Condition 5 with future irrigation using 300,000 water supply allocation at Lake Texoma.
4. Condition 5 with future irrigation, Cable Mountain completion, with 300,000 acre-feet water supply at Lake Texoma.
5. Condition 5 with future irrigation using 450,000 water supply allocation at Lake Texoma.
6. Condition 5 with future irrigation, Cable Mountain completion, with 450,000 acre-feet water supply at Lake Texoma.

The routing program used the following input or output data from the SUPER runs:

- Daily Lake Texoma pool elevation data.
- Daily Lake Texoma capacity data.
- Daily Lake Texoma total inflow data.
- Daily Lake Texoma total release data.
- Daily Lake Texoma net evaporation losses in day second feet.
- Daily Lake Texoma leakage in day second feet.
- 2002 elevation area capacity data for Lake Texoma.
- The SUPER runs used the period of record January 1940 – Dec 2000 for the reallocation study. The period of record used in this study was October 1962 – December 2000.

Period of record flows for Gainesville during the study were used to show modified flow reductions. The existing conditions data set (Condition 2) was used as a foundation since this data set closely mirrored the existing conditions inflow data used by SUPER. Daily modified flows for Gainesville for Condition 5 with future irrigation and modified flows with future irrigation and Cable Mountain were subtracted from the existing conditions data set to generate reduction in inflow at Gainesville for both modified conditions. The modified conditions reductions were then subtracted from the daily SUPER inflow data to generate modified inflow data sets for the SUPER runs.

The routing program was calibrated by routing the original SUPER existing conditions input data for the Lake Texoma Reallocation Study. The routing program was adjusted to match the original SUPER existing conditions daily pool elevations. The routing program was then used to generate daily Lake Texoma pool elevations and storages for the modified conditions presented above. Lake Texoma pool elevation durations were then generated from the daily modified pool elevation data sets for each condition.

Results of Cumulative Effects of Federal Actions on Lake Texoma Study

Lake Texoma pool elevation duration data generated by the study are presented below in Tables 31, 32, and 33. An initial review of all duration data was performed to identify general trends in the data. Significant reductions in pool elevation were not experienced until the 50% duration interval in all conditions. The lower duration intervals can generally be associated with higher pool elevations and higher inflow events so differences in pool elevation durations between the different conditions are not as pronounced. At pool elevations durations greater than 50%, differences between conditions do become more evident. The higher pool elevation durations are associated with lower pool elevations and usually lower inflows so the consequences between conditions become more apparent.

The SUPER run representing 150,000 acre feet of water supply was considered existing conditions during the Lake Texoma Reallocation Study and represents the original water supply allocation in Lake Texoma. When the 50% duration from this run is compared to the 50% duration from the SUPER run representing 450,000 acre feet reallocation, a maximum pool reduction of 0.4 foot is indicated. This 0.4 foot reduction in pool duration could be considered the total impact of the reallocation of the maximum storage legislated by 1986 WRDA. Differences between the SUPER runs for 150,000 acre feet condition and the 450,000 acre feet condition at the 90% duration shows a maximum pool duration reduction of 1.5 feet.

As mentioned in the background information, contracts for the 150,000 acre feet of storage allocated to Texas were signed in March 2010. As a result, the 300,000 acre feet reallocation SUPER runs should now be considered existing condition from March 2010 forward. Minor changes to pool duration are noted between the 150,000 acre feet original allocation and the additional 300,000 allocation authorized by 1986 WRDA (represented by the 450,000 acre-feet SUPER runs).

Significant changes to Lake Texoma pool elevation durations are a result of upstream reductions in flow representing chloride control, future irrigation, and the construction of Cable Mountain. As mentioned above, the changes to Lake Texoma pool elevation durations for Condition 5 with future irrigation condition and the Condition 5 with future irrigation and construction of Cable Mountain Reservoir condition are pronounced once the 50% duration is reached. At the 50% duration and above effects become evident. A comparison of the existing conditions SUPER durations at 80% to the existing conditions durations for Condition 5 with future irrigation shows a maximum reduction of 2.2 ft in pool durations. With the addition of Cable Mountain to these upstream changes results in a total reduction of 3.0 ft in pool duration. When the existing conditions SUPER at the 80% duration are compared to the 80% duration representing 450,000 water supply allocation, Condition 5 with future irrigation, and construction of Cable Mountain, differences in pool duration are estimated at 4.5 feet.

Table 99 -Lake Texoma Pool Elevation Durations SUPER 150,000 acre feet

	Percent of Time Equaled or Exceeded								
Condition	1	5	10	20	50	80	90	95	99
	Elevation (msl)								
SUPER 150,000	628.4	620.3	619.1	617.7	616.4	614.5	612.4	611.1	607.7
Condition 5*	628.4	620.2	619.0	617.5	615.3	612.3	610.3	608.7	605.5
Condition 5 w/ Cable Mtn*	628.4	620.2	618.9	617	615	611.5	609.2	607.7	604.5

*Condition 5 represents Condition 5 with future irrigation

Table 100 -Lake Texoma Pool Elevation Durations SUPER 300,000 acre feet

	Percent of Time Equaled or Exceeded								
Condition	1	5	10	20	50	80	90	95	99
	Elevation (msl)								
SUPER 300,000	628.4	620.2	619.1	618.2	616.2	613.9	611.7	610.4	607.5
Condition 5*	628.4	620.2	618.9	617.6	615.0	611.6	609.5	607.8	605.1
Condition 5 w/ Cable Mtn*	628.3	620.1	618.8	617.4	614.8	610.8	608.3	606.7	603.6

*Condition 5 represents Condition 5 with future irrigation

Table 101 -Lake Texoma Pool Elevation Durations SUPER 450,000 acre feet

	Percent of Time Equaled or Exceeded								
Condition	1	5	10	20	50	80	90	95	99
	Elevation (msl)								
SUPER 450,000	628.2	620.2	619.0	618.1	616.0	613.2	610.9	609.7	607.1
Condition 5*	628.2	620.1	618.8	617.5	614.9	610.8	608.4	606.6	604.0
Condition 5 w/ Cable Mtn.*	628.2	620.0	618.7	617.2	614.6	610.0	607.3	605.2	602.2

*Condition 5 represents Condition 5 with future irrigation

CONCLUSIONS

Chloride control on the Red River Basin has the potential to control approximately 25% of the natural chloride emissions within the basin. Conditions 4 and 5, which include Area VI in operation on the Elm Fork of the Red River, have the potential to significantly reduce chloride concentrations in the Upper Red River Basin. With Area VI in operation, chloride concentrations would be expected to decrease by 83% in Reach 14b and 80% in Reach 14a in the Upper Red River Basin. Reach 14a would be expected to reach the USEPA secondary drinking water standard for chloride of 250 mg/l approximately 35% of the time. Corresponding chloride reductions would be seen in the lower Red River basin with chloride concentrations at Reach 5 decreasing as much as 25%.

Along with the reductions in chloride concentrations there would be corresponding reductions in flow. Reductions in flow from chloride control would be expected to have greater effects in the reaches immediately downstream of the source areas. The greatest effects would be to low flows and higher duration flows. Low flow analysis results indicate increases as high as 3.6% in the number days with zero flow in Reaches 12, 14a, and 14b downstream from Area VI. No increase to the number of low flow days would be seen in the Lower Red River Basin.

Future in-stream withdrawals for irrigation would be expected to increase as chloride control is achieved on the Red River Basin. Future reductions to flow resulting from future irrigation would be expected to have a much greater effect than reductions resulting from chloride control alone. Cumulative effects of future irrigation and reductions from chloride control would be expected to reduce flows in the lower Red River Basin as much 17% at the 50% duration. Future irrigation withdrawals, as modeled in this study, may also increase chloride concentrations as much as 13% above concentrations representing chloride control only at the 50% duration.

The forecast condition for construction of Cable Mountain Reservoir on the North Fork of the Red River would tend to have the greatest effect on flow and chloride concentrations on the Red River. Cable Mountain, as modeled in this study, would capture all flows at the Headrick gage on the North Fork of the Red River and would release minimum low flows for water quality (7Q2 data) and to maintain water rights (an assumed flow of 3 cfs). Cable Mountain, in combination with Lake Altus and Tom Steed Reservoir on Otter Creek, would effectively capture all flows on the North Fork. The combined reductions in flow on the Red

River result in an increase in chloride concentrations at Reach 12 to approximately 39% above natural chloride concentrations at the 50% duration. Increases in chloride concentrations above natural conditions concentrations would be experienced at all downstream reaches except Reach 5. Chloride concentrations at Reach 5 would remain slightly below natural concentrations.

The cumulative effects of Federal actions in the upper Red River basin and the reallocation of storage in Lake Texoma would result in changes to pool elevation durations at Lake Texoma. The cumulative reductions in flow due to chloride control and the resulting increases in irrigation would reduce inflows into Lake Texoma. These effects would be expected to be more evident during periods of naturally occurring low flows. The forecast construction of Cable Mountain Reservoir, in combination with Lake Altus and Tom Steed Reservoir, would be expected to capture all flows on the North Fork of the Red River except for water quality and water right releases. The water quality and water right releases are expected to decrease the number of low flow days immediately below Cable Mountain (a positive change) and would result in significant improvements to water quality on the North Fork of the Red River. Cable Mountain impoundment would result in further reductions to inflow into Lake Texoma. The construction of Cable Mountain is also forecast to increase chloride concentrations on the main stem of the Red River to concentrations above natural conditions concentrations, thereby eliminating the chloride reductions achieved by Red River chloride control projects constructed or included in the forecast conditions. Reductions in chloride concentrations would not be affected on the North Fork of the Red River upstream of Headrick and the Wichita River by the impoundment of Cable Mountain. Chloride concentrations at Lake Texoma would remain slightly below natural conditions concentrations with the construction of Cable Mountain.

EXHIBITS (Precede the Appendices)

A. Drawings
    1 Study Area Map
    2 Economic Reach Map
    3 Period-of-Record for Recorded Gages
B. Chloride Control Concentration Duration Tables
C. Chloride Control with Future Irritation Concentration Duration Tables
D. Lake Texoma Pool Elevation Duration Plots

Problems and Opportunity Statements

These statements are the foundation for scoping the planning process. They reflect the priorities and preferences of the Congress and stakeholders. (Not all water resources problems identified may be within the authority specified by Congress for resolution by the Corps of Engineers.)

This Area VI Reevaluation is not a comprehensive reevaluation of the Red River Chloride Control Project, but it will address the potential for cumulative impacts of the operating and recommended completion of chloride control features. The evaluation of potential impacts is accomplished through the evaluation of different what-if scenarios (forecast conditions) that consider the completion of Wichita River Basin features as part of additional without-project condition scenarios or as part of with-project scenarios.

The problem statements reflect issues related to the natural brine emissions for the Altus, Oklahoma, vicinity and the Red River Basin related to the authorized chloride control feature being reevaluated at Area VI. The problem statements are based on the without project forecast conditions for the evaluation period 2020 through 2070. All of the statements, except number 2, were focused on the Altus, Oklahoma, vicinity and the North Fork and Elm Fork watersheds. If this was a general reevaluation of the Red River Chloride Control Project, all of the statements would tend to apply to the Red River Basin. There is emphasis on the Altus vicinity, because of the proximity of Area VI. However, all potential economic, social, and environmental benefits and impacts of chloride control described in the with-project conditions (not just Area VI) are assessed throughout the Red River Basin.

1) **Problem:** Poor water quality in the Elm Fork of the North Fork of the Red River due to high concentrations of dissolved solids contributed by brine emissions of Area VI.
Opportunity: Reduce dissolved solids in the Elm Fork of the North Fork of the Red River contributed by brine emissions of Area VI**.**

2) **Problem:** Poor water quality in the Red River due to high concentrations of dissolved solids contributed by natural brine sources.
Opportunity: Reduce dissolved solids in the Red River contributed by natural brine sources.

3) **Problem**: Limited and declining water supply for agricultural irrigation in the Altus, Oklahoma, vicinity.
Opportunity: Increase water supply for agricultural irrigation in the Altus, Oklahoma, vicinity.

4) **Problem**: Limited and declining water supply for municipal use in the Altus, Oklahoma, vicinity.
Opportunity: Increase water supply for municipal use in the Altus, Oklahoma, vicinity.

5) **Problem**: Reduced watershed runoff due to noxious mesquite and juniper brush into prairie grasslands.
Opportunity: Restore watershed runoff associated with prairie grasslands

6) **Problem**: Stream water losses due to transpiration by invasion of non-native saltcedar in riparian areas.
Opportunity: Reduce stream water transpiration losses due to invasive saltcedar.

7) **Problem**: Riparian habitat value and diversity losses due to invasion of non-native saltcedar out competing native species.

Opportunity: Restore native riparian habitat overtaken by invasive saltcedar.

8) **Problem**: Limited public resources for water related recreation in the Altus, Oklahoma, vicinity.
   Opportunity: Provide water related recreation resources in the Altus, Oklahoma, vicinity.
9) **Problem:** Declining aquatic habitat (volume and quality) in Lake Texoma due to sedimentation.
   Opportunity: Assist local, state, and federal stakeholders to evaluate the watershed of Lake Texoma for the purposes of identifying the primary sediment contributing sub-basins and the best management practices for implementation within the watershed to reduce the rate of sedimentation and impacts to aquatic habitat in Lake Texoma.

Reevaluation Objectives

Once the problems and opportunities are identified, the next task is to define the study planning objectives. The objectives provide metrics that allow measures (simple components) or alternatives (more complex combinations of measures) to be evaluated in terms of their capacity to addressing the problems and meeting the objectives. Water resources projects may have several possible viable solutions. Identifying the "best" solution requires consideration of the overall economic, social, and environmental issues; and also the completeness, effectiveness, efficiency, and acceptability. (The economic, social, and environmental criteria for selecting a plan are generally defined by law and should be considered as universal constraints – discussed later.) The objectives are consequently necessary to aid in the evaluation of the completeness, effectiveness, efficiency, and acceptability of solutions. These evaluation criteria are defined by the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G)*. Definition excerpts from the P&G are shown below. The associated discussion is from the Institute of Water Resources Report IWR 96-R-21, The Planning Manual.

"Completeness is the extent to which a given alternative plan provides and accounts for all necessary investments or other actions to ensure the realization of the planned effects. This may require relating the plan to other types of public or private plans if the other plans are crucial to realization of the contributions to the objective." (P&G Section VI.1.6.2(c)(1)) A complete alternative is one that is well thought out. All the necessary implementation actions have been accounted for in the planning process.

"Effectiveness is the extent to which an alternative plan alleviates the specified problems and achieves the specified opportunities." (P&G Section VI.1.6.2(c)(2)) An effective plan is responsive to the wants and needs of people. An effective plan makes a significant contribution to the solution of some problems and achieves some opportunities. In other words, it contributes to the attainment of the planning objectives. The most effective alternatives make significant contributions to all the planning objectives.

"Efficiency is the extent to which an alternative plan is the most cost effective means of alleviating the specified problems and realizing the specified opportunities, consistent with protecting the Nation's environment." (P&G Section VI.1.6.2(c)(3)) When you think about cost-effectiveness, don't think only about dollar costs. Efficiency refers to the allocation of resources. Are resources, not just dollars, used efficiently in the construction of a project or the implementation of a plan? Are the outputs produced by the plan produced in an efficient manner? Are the resources that are going to be significantly affected by the plan still going to be available for efficient use by society?

"Acceptability is the workability and viability of the alternative plan with respect to acceptance by State and local entities and the public and compatibility with existing laws, regulations, and public policies." (P&G Section VI.1.6.2(c)(4) There are two primary dimensions to acceptability. One we call implementability, meaning is it feasible in the technical, environmental, economic, social, and similar senses? The other is the satisfaction it brings. A common error that must be avoided with this criterion is the tendency to equate acceptability with the non-Federal partner's willingness to sign a Project Cooperation Agreement for the plan. It's often thought if they would sign, the plan is acceptable; if they wouldn't, it is not. This is not what acceptability means. If it were, there would be no need for a partnership or a planning process at all. The local partner would need only say, "this is what we want," and it would become the only acceptable plan. To be acceptable to state and local entities as well as the public, a plan has to be doable (feasible). There are many factors that can render a plan infeasible. These factors can generally be categorized as technical (engineering or natural world limitations), economic, financial, environmental, social, political, legal, and institutional. If a plan cannot be done for legitimate reasons, it is not feasible. If a plan has opposition or is not the favored plan of the non-Federal partner that does not make it infeasible or unacceptable. That simply makes it unpopular. If a plan requires changes in laws or authorities, that alone doesn't make it unacceptable. That only makes it difficult.

The objectives may state qualitative or quantitative metrics. The Objective statements are directly related to the Problem and Opportunity statements. So, for clarity, the Problem and Opportunity statements are restated below, with the addition of the Objective statement.

1) **Problem**: Poor water quality in the Elm Fork of the North Fork of the Red River due to high concentrations of dissolved solids contributed by brine emissions of Area VI.
   Opportunity: Reduce dissolved solids in the Elm Fork of the North Fork of the Red River contributed by brine emissions of Area VI.
   Objective: Reduce Area VI chloride loads in the Elm Fork of the North Fork of the Red River by about 80 percent.

2) **Problem:** Poor water quality in the Red River due to high concentrations of dissolved solids contributed by natural brine sources limits or precludes the feasibility of agricultural, municipal, and industrial use.
   Opportunity: Reduce dissolved solids in the Red River contributed by natural brine sources to allow for agricultural, municipal, and industrial use.
   Objective: Reduce Area VI chloride loads in the Red River by about 80 percent to

improve water quality for agricultural, municipal, and industrial use.

3) **Problem**: Limited and declining water supply for agricultural irrigation in the Altus, Oklahoma, vicinity; primarily due to sedimentation of Altus Lake.
   Opportunity: Increase water supply for agricultural irrigation in the Altus, Oklahoma, vicinity.
   Objective: Increase water supply for agriculture irrigation in the Altus, Oklahoma, vicinity to offset water supply storage losses due to sedimentation in Altus Lake; or to increases water supply storage in excess of sedimentation losses in Altus Lake.

4) **Problem**: Limited and declining water supply for municipal use in the Altus, Oklahoma, vicinity.
   Opportunity: Increase water supply for municipal use in the Altus, Oklahoma, vicinity.
   Objective:

5) **Problem**: Reduced watershed runoff due to noxious mesquite and juniper brush into prairie grasslands.
   Opportunity: Restore watershed runoff associated with prairie grasslands
   Objective: Restore prairie grasslands in the North Fork of the Red River watershed – including the Elm Fork of the North Fork.

6) **Problem**: Stream water losses due to transpiration by invasion of non-native saltcedar in riparian areas.
   Opportunity: Reduce stream water transpiration losses due to invasive saltcedar.
   Objective: Reduce stream water transpiration losses due to invasive saltcedar in the North Fork of the Red River watershed – including the Elm Fork of the North Fork

7) **Problem**: Riparian habitat value and diversity losses due to invasion of non-native saltcedar out competing native species.
   Opportunity: Restore native riparian habitat overtaken by invasive saltcedar.
   Objective: Restore native riparian habitat in the North Fork of the Red River watershed – including the Elm Fork of the North Fork.

8) **Problem**: Limited public resources for water related recreation in the Altus, Oklahoma, vicinity.
   Opportunity: Provide water related recreation resources in the Altus, Oklahoma, vicinity.
   Objective: Provide an additional reservoir resource in the vicinity of Altus, Oklahoma, to provide fishing, bird watching, picnicking, swimming, boating, camping, and hiking.

9) **Problem**: Declining aquatic habitat (volume and quality) in Lake Texoma due to sedimentation.
   Opportunity: Assist local, state, and federal stakeholders to evaluate the watershed of Lake Texoma for the purposes of identifying the primary sediment contributing sub-

basins and the best management practices for implementation within the watershed to reduce the rate of sedimentation and impacts to aquatic habitat in Lake Texoma.
Objective: Update the Corps shoreline management plan for Lake Texoma to incorporate sediment management applications as well as ecological management of recently created ecological zones in areas currently impacted by substantial sediment accumulations. This first step will provide a foundation of lake sedimentation forecasts and related ecological consequences and opportunities from which stakeholders can assess the need and priority of efforts to identify and reduce watershed sediment transport.

Reevaluation Constraints

Constraints are restrictions that help define the limits of the planning process. These include resource, legal, and policy constraints.

The planning constraints of the Reevaluation are:

1) Comply with Federal law and consider state laws and local regulations.
2) Comply with current Administration policy.
3) Follow Corps planning and policy guidance.
4) Follow study specific guidance from higher headquarters.

Measures Available to Address Problems and Opportunities

The U.S. Public Health Service study, started in 1957, found that water in the Red River was generally unusable for municipal and industrial purposes. The Congressional direction to the Corps was to improve the water in the Red River. There are two basic ways to improve in-stream water quality problems caused by naturally occurring dissolved solids, in this case chlorides: 1) **reduce the inflow** of those chlorides, and 2) **dilute saline water** with relatively chloride free water.

Many methods to **reduce the inflow** were examined. These included a <u>pipeline to the Gulf of Mexico</u>, <u>deep well injection</u>, an <u>underground cavity</u> within which brine would be stored, and <u>surface storage and evaporation</u>. Of these measures, deep well injection and surface storage and evaporation will be evaluated among potential solutions in the Area VI Reevaluation.

Mixing is a measure that the North Texas Municipal Water District has considered. In that case the Water District would be blending higher quality water from reservoirs in Texas with salty water withdrawn from Lake Texoma. The implementation of chloride control would reduce the concentration of chlorides in the Lake Texoma storage and therefore the Water District would use less of the higher quality water to blend with the Red River water source. The result would be an overall greater supply of water for municipal and industrial uses.

Methods to **dilute saline water** in the Red River Basin were also examined in earlier studies in the 1970's.. Because groundwater sources are limited in the region, new surface water sources (lakes) were the default alternative. The lakes might be in the western portion of the basin (Texas, Oklahoma, or New Mexico) or in more eastern locations (Oklahoma, Texas nearer to Arkansas, or Louisiana) where rainfall is more plentiful. After consideration, all surface reservoirs conceived for dilution of chlorides were dropped from evaluation because too little rainfall occurs in the far western portion of the basin and because of legal, social, economic, and political issues related to mixing good quality water sources with the salty Red River flow. Dilution of the Red River was not considered in the Area VI Reevaluation as a viable measure.

The Oklahoma Ecological Services Field Office of the U.S. Fish and Wildlife Service has recommended ideas for rerouting the brine emissions or not controlling the brine emission at all. Neither of these ideas would reduce chlorides in the Red River and would, therefore, not meet the intent of Congress. These ideas were recommended by the Oklahoma Ecological Services Field Office in a short one page draft discussion paper on 19 April 2011. The ideas are supported by the Oklahoma Department of Wildlife Conservation and the Texas Parks and Wildlife Department. The two ideas include (1) collecting brine from the Area VI source and pumping it overland, via pipeline, to the state line where it would be discharged into the Red River, and (2) not collecting any brine from Area VI, but instead, creating new freshwater storage reservoirs in the region that would have "a long lifespan" and "relatively little natural inflow or sediment load" yet have sufficient capacity to store excess water pumped from existing reservoirs or pumped from rivers when at high flows.

The USFWS does not indicate the intended benefit of Idea 1 but the USFWS does indicate the idea would maintain the high concentrations of dissolved solids in the Red River and, thereby, Lake Texoma. Diverting the chloride load from Area VI would reduce the chloride load along about 30 miles of the North Fork of the Red River and would provide a source of water usable for irrigation – although the stream flow would only be a few cubic feet per second. Without a reservoir to store the resulting relatively low chloride flows of the North Fork, there would be negligible (or negative) benefits of pumping brine to the Red River because the North Fork is relative "dry" throughout the summer when irrigation water is needed. To have sufficient water from the North Fork when needed for summer irrigation, the only feasible measure would be a storage reservoir, and the most likely site would be the Cable Mountain site identified by the Bureau of Reclamation on the North Fork of the Red River. It is unclear if the USFWS is therefore indirectly supporting the construction of the Cable Mountain Dam or if the need for a storage reservoir was considered as a necessary part of Idea 1. In contrast, the pumping costs to divert the brine to the Red River would be higher than for other measures considered because of the 30 mile pipeline distance.

For Idea 2, the USFWS proposes to construct one or more new freshwater storage reservoirs in areas that would have good deep storage and relatively low natural inflow and sediment load. The USFWS did not suggest the sites of the reservoirs. The USFWS proposes to pump water from Lake Altus and other existing reservoirs when these lakes have flood storage available. The USFWS also proposes to pump water into the proposed lakes from rivers in the area when they are at high flows.

Lake Altus and Tom Steed Reservoir are the only two reservoirs that exist in southwestern Oklahoma from which stored flood water could be pumped to the USFWS hypothetical reservoirs. Lake Altus was constructed by the BOR and is managed by the Lugert-Altus Irrigation District to supply local irrigation and industrial demand. Lake Altus has a high demand during summer months and is typically drawn down from 15 to 35 feet into the conservation pool at the end of the irrigation season. Tom Steed Reservoir supplies regional municipal demand to southwestern Oklahoma and is typically drawn down 3-7 feet into the conservation pool at the end of their high demand season. A hypothetical reservoir, based on the Cable Mountain Reservoir's area and capacity, was modeled and found to yield 10 million gallons per day, assuming no inflow except rainfall, historic flood release flows from Lake Altus and Tom Steed Reservoir, per the USFWS conditions. Pumping from rivers during high flows was not evaluated due to the low sediment load requirement stated in the USFWS idea – river flood flows tend to contain the highest sediment loads. Even if a reservoir site existed that met the USFWS conditions, the yield would be significantly less than the future water needs in the region and would have the associated economic penalty of pumping costs. In addition, there are technical concerns related to the ability to control flood flows at the two existing reservoirs so that they could be pumped to the hypothetical reservoir location.

Both USFWS ideas were found to be ineffective in reducing chlorides and were screened from further consideration. The evaluation of the ideas is presented in Appendix C.

Formulation of Alternative Plans

In the formulation process, potential solutions are composed to address problems, and evaluations of all positive and negative effects are conducted to gauge the merit of each alternative.

PROJECT MEASURES/ALTERNATIVES

Various, previously investigated, measures to control the Red River chloride pollution were reviewed during preparation of this report. These include a pipeline to the Gulf of Mexico, , importation of water for dilution, desalination, and collection and disposal systems in the vicinity of the brine source. As a result this Reevaluaton is based on the conclusion that the most practical and economic method of controlling the chloride pollution is to capture and contain the brine as near the emission source as possible.

Following is a summary of the measure screening described in the Red River Basin, General Design Memorandum No. 25, General Design, Phase I – Plan Formulation, Volume I, Main Report & Appendix I, July 1976, of the Arkansas-Red River Basin Chloride Control, , Texas, Oklahoma, and Kansas, Project. The measures studied were summarized as general or specific alternatives. The general alternatives of a pipeline to the Gulf of Mexico, importation of water (e.g. from eastern Oklahoma), and desalination were eliminated from further study. The pipeline to the Gulf would have high initial and operating costs. Environmental and social concerns about the discharge point in the Gulf were also noted. The importation of water to blend with the brine flows would have high initial and operating costs. (Environmental, social, and political concerns for inter-basin water transfer were also identified by the Area VI Reevaluation study team in 2012.) The desalination measure was eliminated because the first costs and operating costs were not competitive with other alternatives. (The desalination process has an associated waste discharge that would either be returned to the Red River (thereby eliminating downstream benefits of desalination) or would require disposal (thereby adding initial and operating costs to a desalination alternative.). The waste stream would consist of virtually all the dissolved solids from the treated water, but now contained in only about 30 percent of the amount of treated water. Returning the higher concentrated waste stream to the Red River would have environmental issues.)

The remaining measure after screening was brine collection and disposal in the vicinity of the brine source. That measure had lower initial and operating costs and would provide benefits from the point of collection all the way to the mouth of the Red River.

Various alternative **collection** measures at Area VI were considered in this Reevaluation, however, investigation of the **disposal** system was constrained by sites suitable for brine disposal (storage and evaporation or deep well injection).

ALTERNATIVE PLANS FOR AREA VI

The total Area VI chloride load at Carl gage is 510 tons per day (T/D). The authorized plan for collection and disposal would provide an average control of 400 T/D.

Plan A - Subsurface Collection and Brine Impoundment. (Figure 24)

Collection. Brine would be collected by subsurface cutoff walls located in the canyons. The collected brine would be transferred by a feeder line to the sump, then pumped to the brine dam. In addition to the cutoff wall collection in the canyons, the plan would have a surface flow collection facility augmented by wellpoints in the Elm Fork River which would collect brines originating above the three source area canyons and along the canyon walls of the Elm Fork.

Disposal. The brine would be pumped approximately 3 miles from the collection site for disposal in an evaporation pool formed by Fish Creek Dam.

Synopsis. Identification of additional chloride emitting sources, especially in the streambed and floodplain areas, cast doubt on the control effectiveness of this plan, since, it was predicated on the premise that all chloride load between Salton Canyon and Highway 30 was emitted from the three canyons - Salton, Robinson and Kiser. Given the streambed emissions, an optimum control plan would have to control both canyon and adjacent streambed and floodplain emission sources. The low flow dam control feature in this plan would only control emissions in the baseflow, however, emissions during high water periods and from any sources in the floodplain north of the channel would not be controlled and would be washed downstream. These conditions indicate that the multiple collection system originally proposed to control specific emission sources will not be as effective as predicted, and the corollary conclusion that an effective collection system should control the general emission zone area. Evaluation of storage volumes allocated in Fish Creek reservoir indicate other potential reservoir sites have an advantage over this site in that a lesser volume of storage would be required just to contain runoff from the reservoir tributary area. The relative size of the Fish Creek tributary area would require a disproportionately large dam and reservoir by comparison with other potential reservoir sites. Further, subsurface investigations of the Fish Creek damsite have revealed potential geologic problems that make this a marginal damsite.

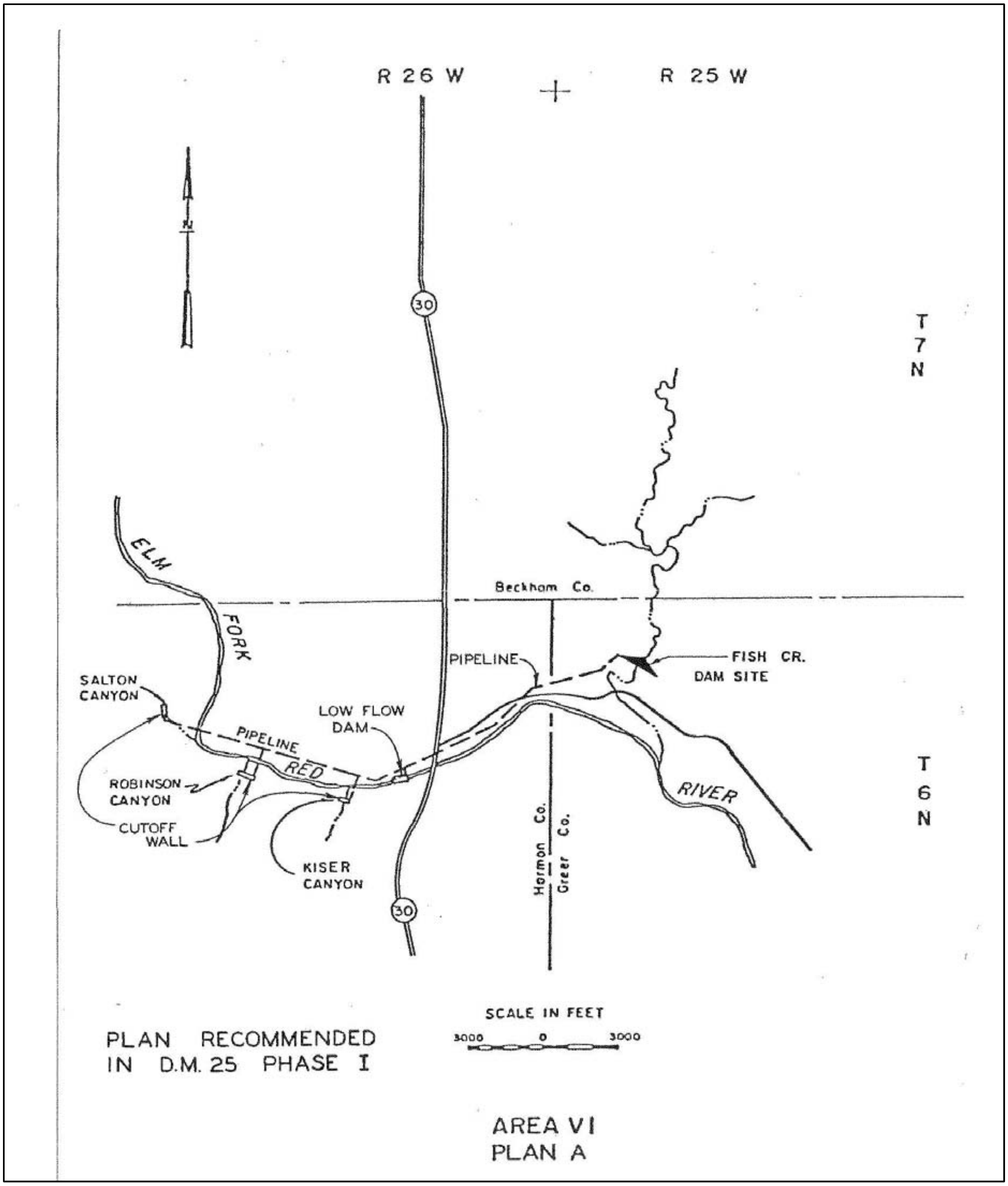


Figure 24 – Area VI Plan A

Plan B - Elm Fork Diversion and Brine Impoundment. (Figure 25)

Collection. A channel would be excavated to divert water in the Elm Fork around the emission area. A brine, collection/detention reservoir would be formed in the existing Elm Fork Channel and South Bank Floodplain by closure dams constructed across the existing channel at the upstream and downstream limits of the emission zone and connected by an earthfill dike.

Disposal. The brine would be pumped approximately 4.0 miles from the collection site for disposal in an evaporation pool formed by Salt Creek Dam. This disposal reservoir has a 5.1 square mile drainage tributary area.

Synopsis. This plan provides for effective brine collection over the entire emission zone, limits the gross volume of brine handled, requires a minimum of mechanical devices subject to malfunction and maintenance, includes protection of the structural facilities for a one-hundred-year return period flood, and requires the least storage volume and concurrent real estate for the disposal reservoir.

Plan C - Elm Fork Diversion, Brine Impoundment and Evaporation Ponds (Figure 26)

This plan would be similar to Plan B except for disposal. All collection and disposal facilities would be located in the South Bank Floodplain of the Elm Fork River.

Collection. A dike approximately 60 feet high along the south side of the existing Elm Fork streambed would direct surface brine flows to the pump station. A channel would be excavated to divert the unpolluted waters in Elm Fork past the source areas. Collected brine would be pumped into the evaporation ponds. Dike heights were predicated on storage requirements.

Disposal. Multiple ponds would be constructed in the valley area between the existing Elm Fork streambed and the excavated diversion channel. Brine collected from the canyons would be pumped into these ponds and chlorides concentrated by evaporation.

Synopsis. A positive cutoff either by impervious soils or construction of an impervious key trench along the full length of the diversion channel would be required to control brine seepage from the evaporation ponds to the Elm Fork. Because the hydrostatic head produced by the brine evaporation ponds could conceivably develop new direct flow paths through rock formations below the overburden zone, the cutoff may be only partially effective in limiting brine outflow. Limitations in the available storage capacity of the collection-evaporation area would require periodic overflow of floodwater into the Elm Fork from the area tributary to the collection-storage facilities with probable concurrent release of concentrated brine solutions and a resulting reduced level of control by comparison with Plan B.

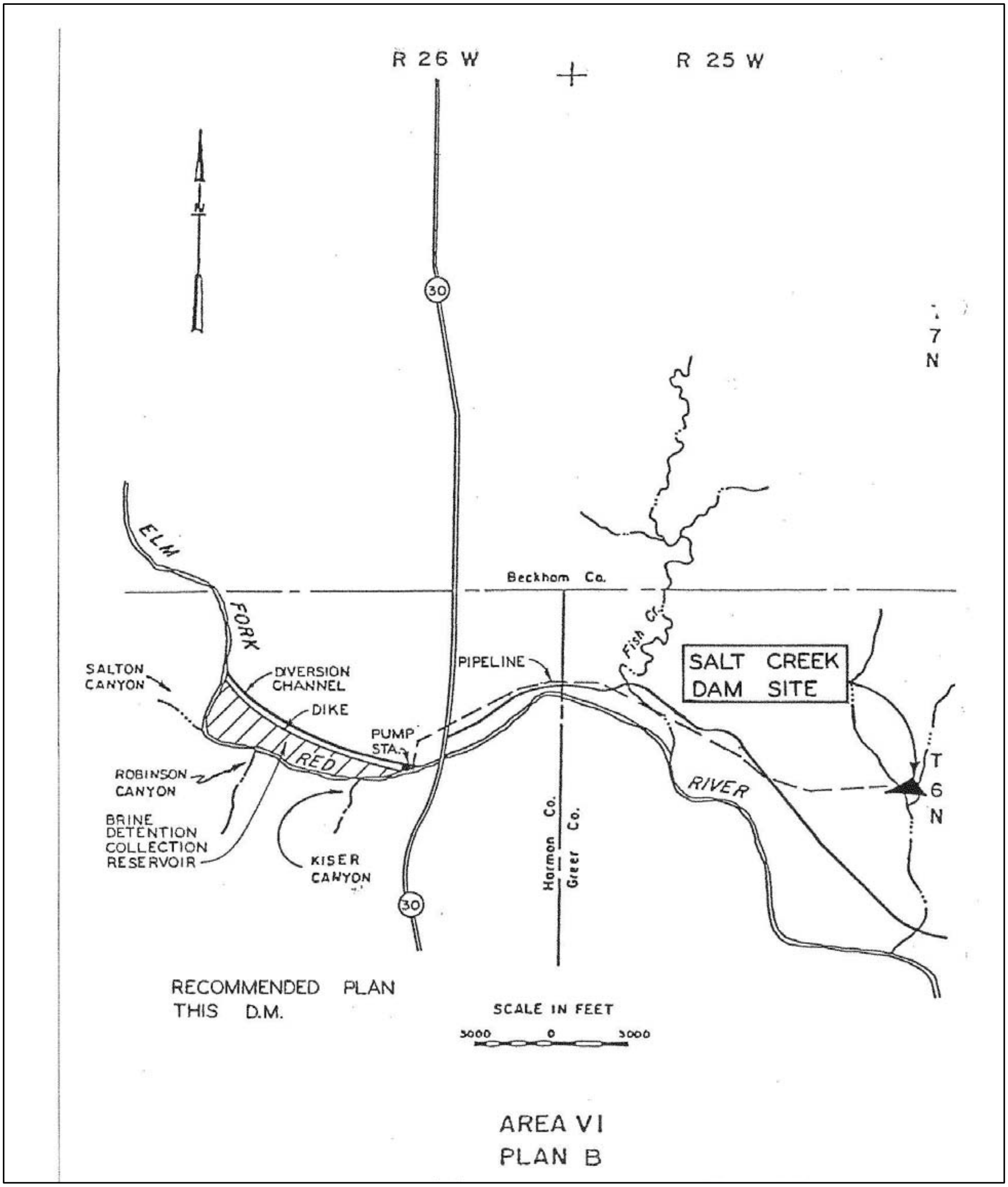


Figure 25 – Area VI Plan B

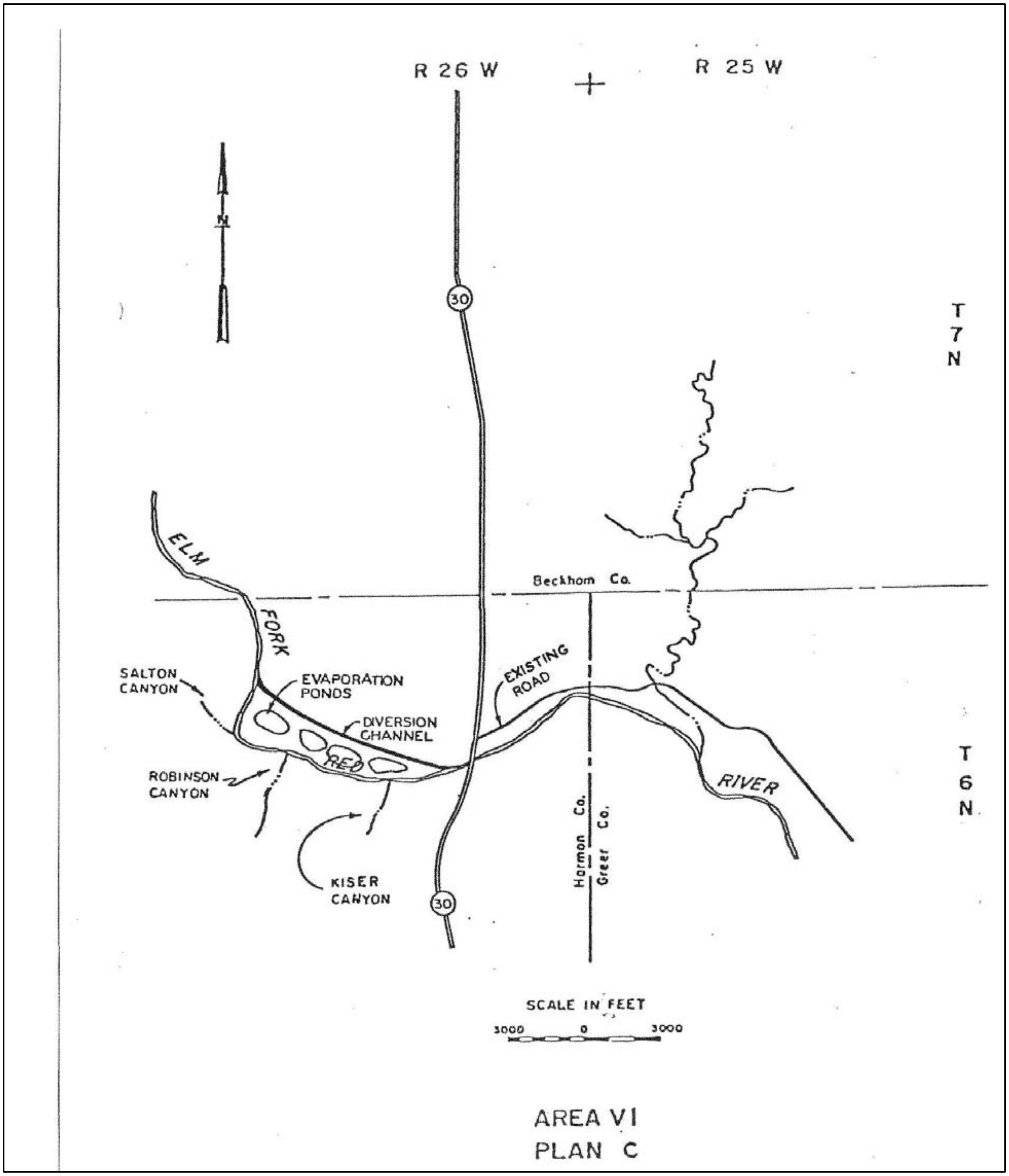


Figure 26 - Area VI Plan C

Plan D - Elm Fork Diversion and Brine Impoundment (Figure 28)

This plan would be similar to Plan B except for a smaller scale diversion storage and dike, plus no diversion channel.

Collection. A 17-foot high dike would be constructed along the north bank of the Elm Fork adjacent to the emission areas, creating a diversion storage area in the existing natural channel. No diversion channel would be constructed under this scheme--the dike becoming the new south bank of the Elm Fork. Height of dike was established by 10-year floods on the Elm Fork and 100-year floods from the three canyons, pumping aspects same as Plan B.

Disposal. Very similar to Plan B.

Synopsis. Along with possible direct flows through rock formations which could nullify the effectiveness of any cutoff wall ability to limit brine outflow, and a much reduced level of control, this plan was not further analyzed.

Plan E – Subsurface Collection and Deep Well Injection (Figure 29)

Collection. This plan would have a collection system similar to Plan A. The brine from the collection systems would be piped 15 to 20 miles to the disposal site.

Disposal. Deep well injection would be used to dispose of the brine. The brine would be treated as necessary and injected in the well. There are no existing oil-producing wells in the vicinity of the Area VI injection well which might be affected by deep well injection of the brines.

Synopsis. The subsurface formation suitable for deep well injection is not present in the area around these three brine producing tributaries. Further research will have to be performed to determine if a suitable disposal location can be found close to the collection point.

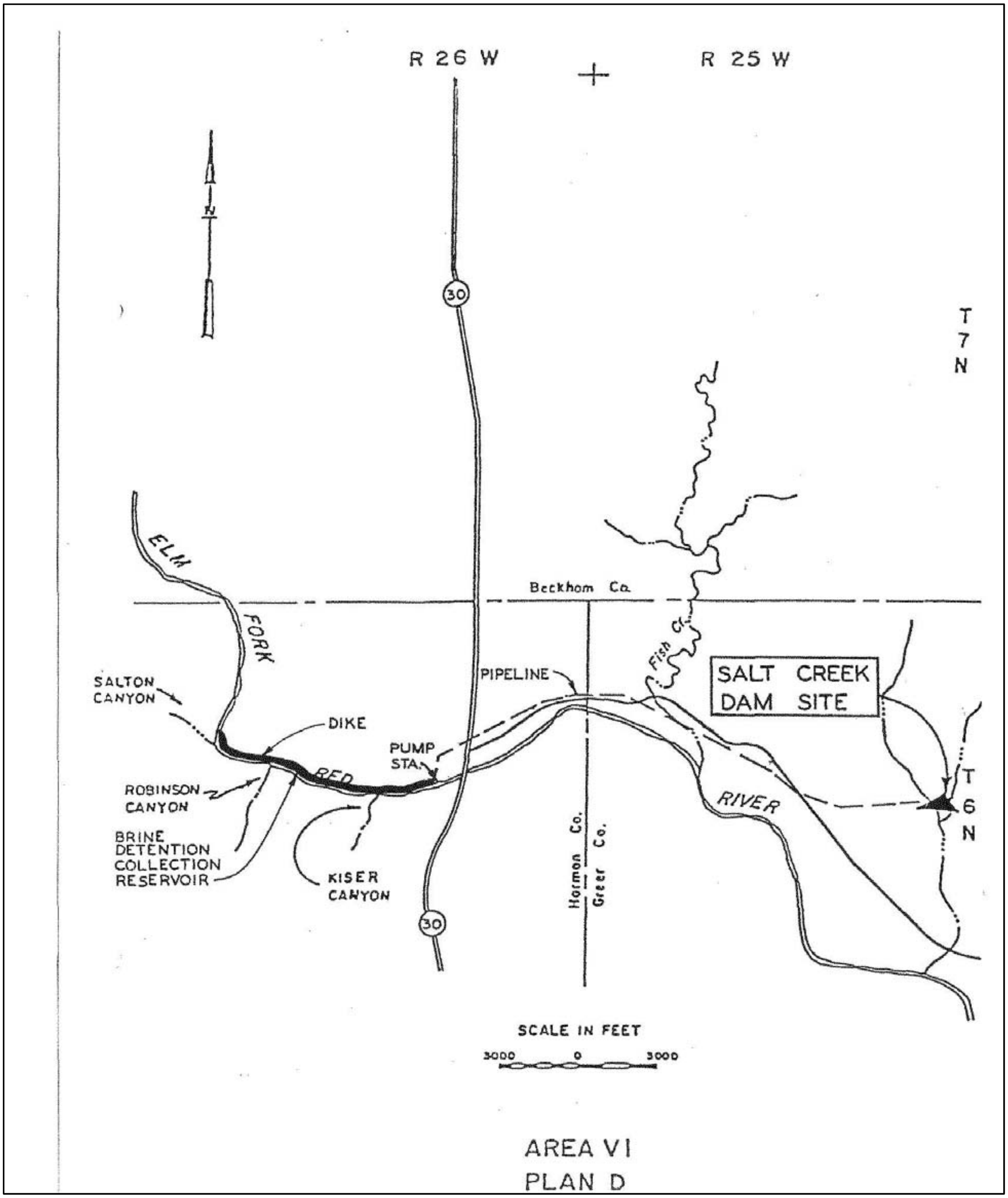


Figure 27 - Area VI Plan D

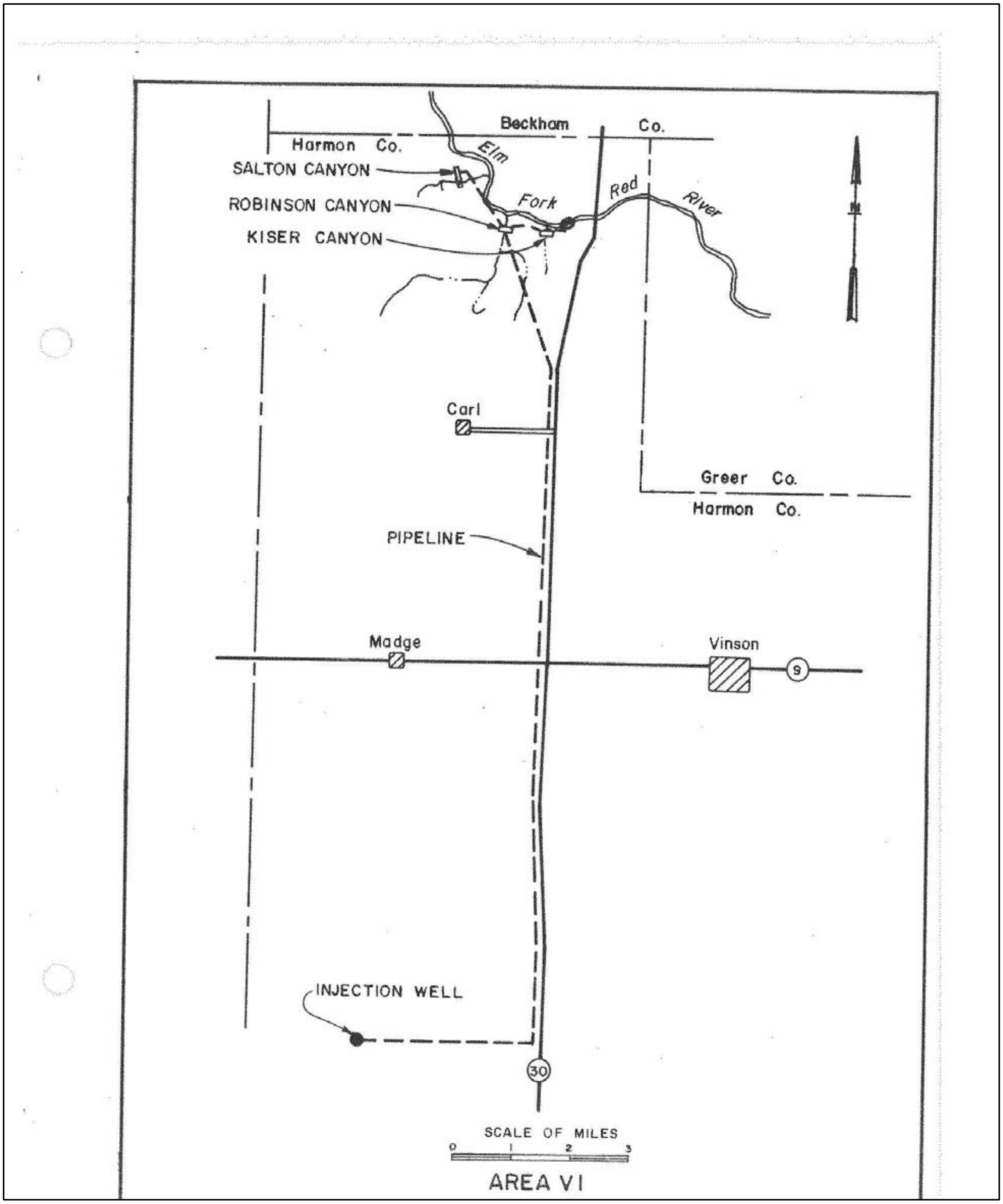


Figure 28 - Area VI Plan E

Other alternatives or variations may be evaluated.

FSM Notes

The following outline of the reevaluation content is provide as an example of the Reevaluation report content for the Alternative Formulation Briefing.

Alternative Evaluation Summary.

Potential Stream Flow Impacts.

Potential Turbidity Impacts.

Low-Flow Analysis.

Construction and Terrestrial Habitat Losses.

Brine Control Levels and Flow Analysis.

Chloride Control Effectiveness.

DESCRIPTION OF SELECTED PLAN

DESIGN AND CONSTRUCTION CONSIDERATIONS

OPERATION AND MAINTENANCE CONSIDERATIONS

PLAN ACCOMPLISHMENTS

ENVIRONMENTAL SUMMARY

PLAN IMPLEMENTATION

DIVISION OF PLAN RESPONSIBILITIES, COST SHARING, AND OTHER NON-FEDERAL RESPONSIBILITIES

VIEW OF NON-FEDERAL SPONSOR AND OTHERS

SUMMARY OF COORDINATION, PUBLIC VIEWS, AND COMMENTS

ENVIRONMENTAL COORDINATION

National Environmental Policy Act Documentation

Endangered Special Act Coordination

U.S. Fish and Wildlife Service Coordination

Corps of Engineers Position

District Engineer's Findings and Conclusions

The recommendations contained herein reflect the information available at this time and current Departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of a national Civil Works construction program nor the perspective of higher review levels within the Executive Branch. Consequently, the recommendations may be modified before they are transmitted to the Congress as proposals for authorization and implementation funding. However, prior to transmittal to the Congress, the sponsor, the States, interested Federal agencies, and other parties will be advised of any modifications and will be afforded an opportunity to comment further.

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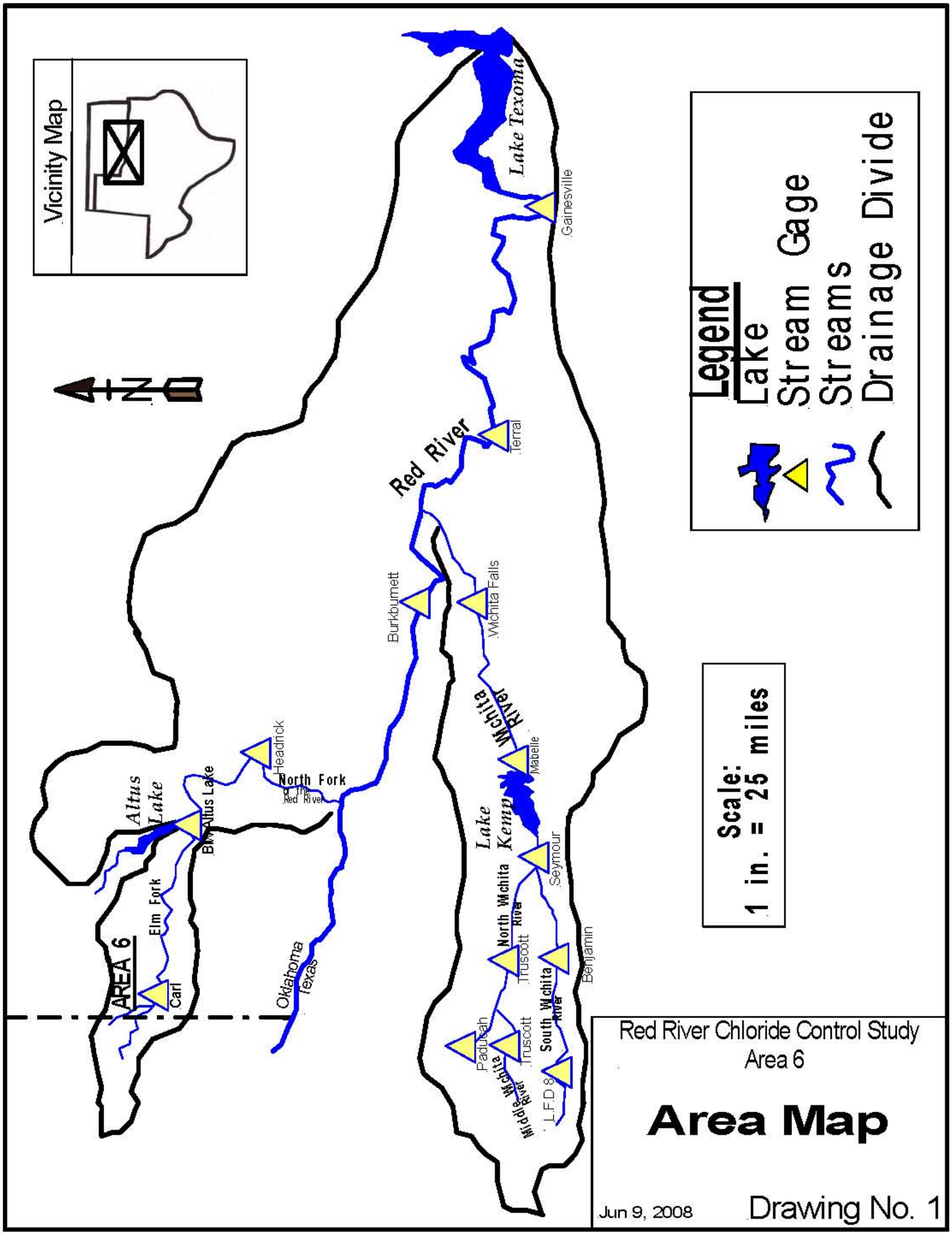
EXHIBIT A

DRAWINGS

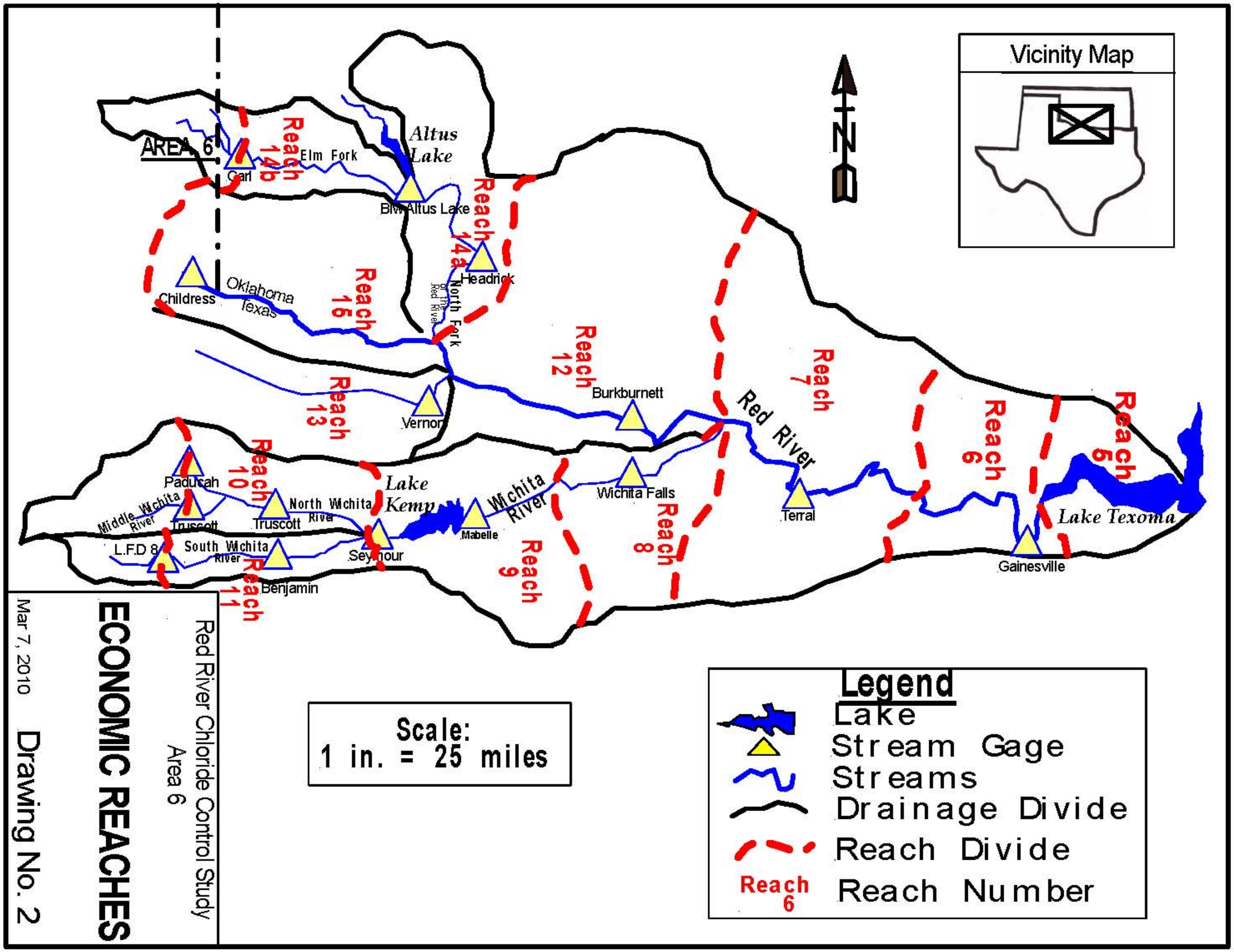


Red River Chloride Control Study
Area 6

Area Map

Jun 9, 2008

Drawing No. 1



Red River Chloride Control Study
Area 6

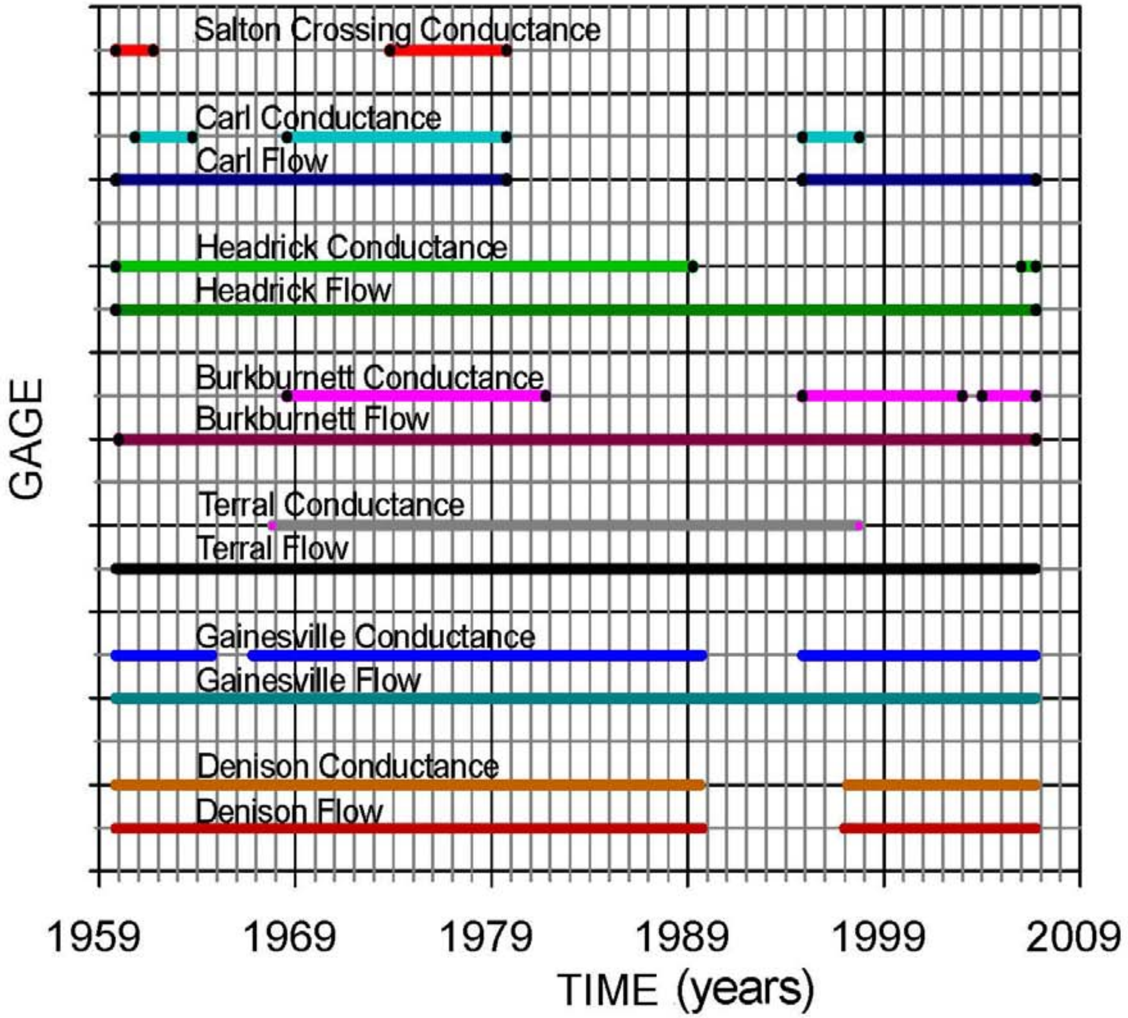
ECONOMIC REACHES

Mar 7, 2010

Drawing No. 2

PERIOD-of-RECORD

Recorded Daily Flows and Specific Conductances



Tulsa District Corps of Engineers
Chloride Control Study
Area VI

RECORDED FLOWS AND SPECIFIC CONDUCTANCES

Computed by: E.D.
Reviewed by: D.T.
May 2010

Drawing 3

EXHIBIT B

DURATION TABLES

NATURAL CONDITIONS
(CONDITION 1)

AND

CONDITIONS 2 – 5

EXHIBIT B

TABLE OF CONTENTS

Table 1
ECONOMIC REACH 1
HOSSTON, RED RIVER

CHLORIDE CONCENTRATION DURATION									
	Percent of time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	424	308	263	209	96	40	24	17	12
Condition 2 Areas V & III	386	280	240	190	87	37	22	15	10
Condition 3 Areas V,VII,VIII,X	360	268	230	182	84	36	22	14	9
Condition 4 Areas V,VI,VIII	346	251	215	171	78	33	20	13	9
Condition 5 Areas V,VI,VII,VIII,X	322	233	200	158	73	31	19	12	8
SULFATE CONCENTRATION DURATION									
	Percent of Time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	322	249	190	148	76	35	18	14	9
Condition 2 Areas V & III	294	228	173	135	69	32	17	13	8
Condition 3 Areas V,VII,VIII,X	282	219	166	130	66	31	16	12	7
Condition 4 Areas V,VI,VIII	292	226	172	134	68	32	17	13	8
Condition 5 Areas V,VI,VII,VIII,X	281	217	165	129	66	31	16	12	7
TDS CONCENTRATION DURATION									
	Percent of Time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	1457	988	896	712	404	196	145	109	87
Condition 2 Areas V & III	1355	918	833	662	375	182	134	102	80
Condition 3 Areas V,VII,VIII,X	1290	874	793	629	358	174	12	97	77
Condition 4 Areas V,VI,VIII	1270	861	781	621	352	171	126	96	75
Condition 5 Areas	1205	816	741	588	334	162	12	90	72

TABLE 2
ECONOMIC REACH 5
DENISON, RED RIVER

CHLORIDE CONCENTRATION DURATION									
	Percent of time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	581	461	441	417	343	273	245	223	174
Condition 2 Areas V & III	524	416	398	376	309	246	221	201	157
Condition 3 Areas V,VII,VIII,X	489	399	382	361	297	236	212	193	151
Condition 4 Areas V,VI,VIII	469	372	356	337	277	221	198	180	141
Condition 5 Areas V,VI,VII,VIII,X	437	347	332	314	258	205	184	168	131

SULFATE CONCENTRATION DURATION									
	Percent of Time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	430	394	325	292	238	167	117	104	81
Condition 2 Areas V & III	391	358	295	265	216	152	106	95	74
Condition 3 Areas V,VII,VIII,X	375	344	283	255	208	146	102	91	71
Condition 4 Areas V,VI,VIII	388	356	293	264	215	151	106	94	73
Condition 5 Areas V,VI,VII,VIII,X	373	342	282	253	206	145	101	90	70

TDS CONCENTRATION DURATION									
	Percent of Time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	1788	1342	1286	1220	1009	785	683	606	505
Condition 2 Areas V & III	1631	1224	1173	1113	920	716	623	553	461
Condition 3 Areas V,VII,VIII,X	1552	1165	1116	1059	876	681	593	526	438
Condition 4 Areas V,VI,VIII	1529	1147	1100	1043	863	671	584	518	432
Condition 5 Areas V,VI,VII,VIII,X	1450	1088	1043	989	818	637	554	491	410

TABLE 3
ECONOMIC REACH 6
GAINESVILLE, RED RIVER

CHLORIDE CONCENTRATION DURATION

	Percent of time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	2006	1713	1599	1393	990	576	396	282	155
Condition 2 Areas V & III	1807	1543	1441	1255	892	519	357	254	140
Condition 3 Areas V,VII,VIII,X	1685	1439	1343	1170	832	484	333	237	130
Condition 4 Areas V,VI,VIII	1619	1382	1290	1124	799	465	320	228	125
Condition 5 Areas V,VI,VII,VIII,X	1508	1288	1202	1047	744	433	298	212	117

SULFATE CONCENTRATION DURATION

	Percent of Time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	1253	954	855	733	536	307	205	149	84
Condition 2 Areas V & III	1121	854	765	656	480	275	183	133	75
Condition 3 Areas V,VII,VIII,X	1069	814	729	625	457	262	175	127	72
Condition 4 Areas V,VI,VIII	1113	847	759	651	476	273	182	132	75
Condition 5 Areas V,VI,VII,VIII,X	1060	807	723	620	453	260	173	126	71

TDS CONCENTRATION DURATION

	Percent of Time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	4980	4255	3924	3500	2541	1487	1040	759	410
Condition 2 Areas V & III	4487	3834	3536	3154	2289	1340	937	684	369
Condition 3 Areas V,VII,VIII,X	4243	3625	3343	2982	2165	1267	886	647	349
Condition 4 Areas V,VI,VIII	4168	3561	3284	2930	2127	1245	870	635	343
Condition 5 Areas V,VI,VII,VIII,X	3929	3357	3096	2761	2005	1173	821	599	323

TABLE 4
ECONOMIC REACH 7
TERRAL, RED RIVER

CHLORIDE CONCENTRATION DURATION									
	Percent of time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	2209	1929	1782	1593	1266	748	497	359	190
Condition 2 Areas V & III	1953	1705	1575	1408	1119	661	439	317	168
Condition 3 Areas V,VII,VIII,X	1794	1566	1447	1294	1028	607	404	292	154
Condition 4 Areas V,VI,VIII	1708	1491	1377	1231	979	578	384	278	147
Condition 5 Areas V,VI,VII,VIII,X	1564	1366	1262	1127	896	530	352	254	135

SULFATE CONCENTRATION DURATION									
	Percent of Time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	1136	1014	945	876	719	455	317	232	126
Condition 2 Areas V & III	1006	898	837	776	637	403	281	206	112
Condition 3 Areas V,VII,VIII,X	955	853	795	737	605	383	267	195	106
Condition 4 Areas V,VI,VIII	999	891	831	770	632	400	279	204	111
Condition 5 Areas V,VI,VII,VIII,X	847	747	710	657	533	338	238	171	92

TDS CONCENTRATION DURATION									
	Percent of Time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	5318	4679	4368	3957	3265	2048	1409	1032	573
Condition 2 Areas V & III	4728	4160	3883	3518	2903	1821	1253	917	509
Condition 3 Areas V,VII,VIII,X	4435	3902	3643	3300	2723	1708	1175	861	478
Condition 4 Areas V,VI,VIII	4345	3823	3569	3233	2668	1673	1151	843	468
Condition 5 Areas V,VI,VII,VIII,X	3648	3229	2987	2815	2299	1432	990	721	391

TABLE 5
ECONOMIC REACH 12
BURKBURNETT, RED RIVER

CHLORIDE CONCENTRATION DURATION									
	Percent of time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	4014	3393	3033	2675	1999	1199	825	555	194
Conditions 2 & 3	3705	3132	2799	2469	1845	1107	761	512	179
Conditions 4 & 5	3167	2677	2393	2111	1577	946	651	438	153

SULFATE CONCENTRATION DURATION									
	Percent of Time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	1931	1664	1562	1451	1176	785	571	415	166
Conditions 2 & 3	1724	1486	1395	1296	1050	701	510	371	148
Conditions 4 & 5	1707	1471	1381	1283	1040	694	505	367	147

TDS CONCENTRATION DURATION									
	Percent of Time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	9399	8048	7438	6754	5224	3286	2347	1638	657
Conditions 2 & 3	8525	7300	6746	6126	4738	2980	2129	1486	596
Conditions 4 & 5	13362	6591	6092	5532	4278	2691	1922	1342	538

TABLE 6
ECONOMIC REACH 14a
HEADRICK, NORTH FORK OF RED RIVER

CHLORIDE CONCENTRATION DURATION									
	Percent of time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	5709	4298	3718	1940	1807	797	457	263	0
Conditions 4 & 5	1125	847	732	579	356	157	90	52	0

SULFATE CONCENTRATION DURATION									
	Percent of Time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	1621	1343	1246	1112	860	552	401	215	0
Conditions 4 & 5	1533	1270	1179	1052	814	522	379	203	0

TDS CONCENTRATION DURATION									
	Percent of Time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	11821	9150	8222	6825	4529	2263	1427	814	0
Conditions 4 & 5	5532	4282	3949	3194	2120	1059	668	381	0

TABLE 7
ECONOMIC REACH 14b
CARL, ELM FORK OF THE NORTH FORK OF RED RIVER

CHLORIDE CONCENTRATION DURATION									
	Percent of time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	117300	44124	25998	17217	9900	5351	3778	2502	818
Conditions 4 & 5	9060	5372	3847	2866	1670	871	532	186	0

SULFATE CONCENTRATION DURATION									
	Percent of Time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	3687	2906	2449	2112	1806	1580	1425	1299	1000
Conditions 4 & 5	2970	2431	2185	1956	1699	1465	1273	998	0

TDS CONCENTRATION DURATION									
	Percent of Time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	212600	78971.	47816	32106	19483	11616	8571	6263	2900
Conditions 4 & 5	19181	12588	9569	7759	5417	3764	2858	1845	0

EXHIBIT C

DURATION TABLES

CONDITIONS 2 - 5
WITH FUTURE IRRIGATION

EXHIBIT C

TABLE OF CONTENTS

TABLE 1
ECONOMIC REACH 1
HOSSTON, RED RIVER

CHLORIDE CONCENTRATION DURATION									
	Percent of time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	424	308	263	209	96	40	24	17	12
Condition 2 Areas V & III	397	261	224	177	81	35	21	14	9
Condition 3 Areas V,VII,VIII,X	371	261	224	177	81	35	21	14	9
Condition 4 Areas V,VI,VIII	356	258	221	176	80	34	20	14	9
Condition 5 Areas V,VI,VII,VIII,X	331	240	206	163	75	32	19	13	8
SULFATE CONCENTRATION DURATION									
	Percent of Time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	322	249	190	148	76	35	18	14	9
Condition 2 Areas V & III	303	235	178	139	71	33	17	13	8
Condition 3 Areas V,VII,VIII,X	291	225	171	134	68	32	17	12	8
Condition 4 Areas V,VI,VIII	301	233	177	138	71	33	17	13	8
Condition 5 Areas V,VI,VII,VIII,X	289	224	170	133	68	32	17	12	7
TDS CONCENTRATION DURATION									
	Percent of Time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	1457	988	896	712	404	196	145	109	87
Condition 2 Areas V & III	1396	946	858	682	387	188	138	105	83
Condition 3 Areas V,VII,VIII,X	1329	900	817	648	368	179	13	100	79
Condition 4 Areas V,VI,VIII	1308	887	804	639	362	176	130	98	78
Condition 5 Areas V,VI,VII,VIII,X	1241	841	763	606	344	167	12	93	74

TABLE 2
ECONOMIC REACH 5
DENISON, RED RIVER

CHLORIDE CONCENTRATION DURATION									
	Percent of time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	581	461	441	417	343	273	245	223	174
Condition 2 Areas V & III	540	428	410	387	319	254	228	207	162
Condition 3 Areas V,VII,VIII,X	503	388	371	351	288	230	206	188	146
Condition 4 Areas V,VI,VIII	484	384	367	347	285	227	204	186	145
Condition 5 Areas V,VI,VII,VIII,X	450	357	342	323	266	211	190	173	135

SULFATE CONCENTRATION DURATION									
	Percent of Time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	430	394	325	292	238	167	117	104	81
Condition 2 Areas V & III	403	369	304	273	223	156	110	97	76
Condition 3 Areas V,VII,VIII,X	386	354	292	262	214	150	105	93	73
Condition 4 Areas V,VI,VIII	400	366	302	272	221	155	109	97	75
Condition 5 Areas V,VI,VII,VIII,X	384	352	290	261	213	149	104	93	72

TDS CONCENTRATION DURATION									
	Percent of Time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	1788	1342	1286	1220	1009	785	683	606	505
Condition 2 Areas V & III	1680	1261	1208	1146	948	737	642	569	474
Condition 3 Areas V,VII,VIII,X	1599	1200	1150	1091	902	702	611	542	451
Condition 4 Areas V,VI,VIII	1575	1182	1133	1074	889	691	601	534	440
Condition 5 Areas V,VI,VII,VIII,X	1494	1121	1074	1019	843	656	571	506	422

TABLE 3
ECONOMIC REACH
GAINESVILLE, RED RIVER

CHLORIDE CONCENTRATION DURATION									
	Percent of time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	2006	1713	1599	1393	990	576	396	282	155
Condition 2 Areas V & III	3266	2560	2156	1572	1037	554	378	269	141
Condition 3 Areas V,VII,VIII,X	3044	2387	2010	1466	967	516	353	251	132
Condition 4 Areas V,VI,VIII	2924	2294	1932	1408	929	496	339	241	127
Condition 5 Areas V,VI,VII,VIII,X	2726	2137	1799	1312	866	462	315	225	118

SULFATE CONCENTRATION DURATION									
	Percent of Time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	1253	954	855	733	536	307	205	149	84
Condition 2 Areas V & III	1841	1384	1134	868	546	297	195	138	77
Condition 3 Areas V,VII,VIII,X	1756	1318	1080	828	521	283	186	131	73
Condition 4 Areas V,VI,VIII	1827	1373	1124	862	542	295	194	137	76
Condition 5 Areas V,VI,VII,VIII,X	1741	1308	1072	821	516	281	184	130	73

TDS CONCENTRATION DURATION									
	Percent of Time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	4980	4255	3924	3500	2541	1487	1040	759	410
Condition 2 Areas V & III	7960	6424	5418	4006	2641	1440	988	717	376
Condition 3 Areas V,VII,VIII,X	7527	6074	5124	3788	2498	1361	934	678	356
Condition 4 Areas V,VI,VIII	7400	5968	5034	3721	2454	1337	917	666	348
Condition 5 Areas V,VI,VII,VIII,X	6971	5626	4746	3508	2313	1260	864	628	330

TABLE 4
ECONOMIC REACH 7
TERRAL, RED RIVER

CHLORIDE CONCENTRATION DURATION									
	Percent of time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	2209	1929	1782	1593	1266	748	497	359	190
Condition 2 Areas V & III	3584	2926	2532	2093	1255	733	473	335	174
Condition 3 Areas V,VII,VIII,X	3292	2688	2326	1922	1153	672	435	308	160
Condition 4 Areas V,VI,VIII	3134	2558	2214	1830	1098	641	414	293	152
Condition 5 Areas V,VI,VII,VIII,X	2870	2344	2028	1676	1005	587	379	268	139
SULFATE CONCENTRATION DURATION									
	Percent of Time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	1136	1014	945	876	719	455	317	232	126
Condition 2 Areas V & III	1862	1590	1454	1179	717	441	301	217	114
Condition 3 Areas V,VII,VIII,X	1768	1508	1380	1119	680	419	286	206	108
Condition 4 Areas V,VI,VIII	1848	1576	1442	1170	710	438	299	215	113
Condition 5 Areas V,VI,VII,VIII,X	1754	1496	1368	1110	675	415	284	204	107
TDS CONCENTRATION DURATION									
	Percent of Time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	5318	4679	4368	3957	3265	2048	1409	1032	573
Condition 2 Areas V & III	8642	7266	6615	5462	3301	1994	1343	967	518
Condition 3 Areas V,VII,VIII,X	8106	6815	6205	5125	3097	1867	1259	907	485
Condition 4 Areas V,VI,VIII	7941	6676	6079	5021	3034	1833	1234	889	475
Condition 5 Areas V,VI,VII,VIII,X	7407	6227	5670	4682	2829	1709	1151	828	442

TABLE 5
ECONOMIC REACH 12
BURKBURNETT, RED RIVER

CHLORIDE CONCENTRATION DURATION									
	Percent of time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	4014	3393	3033	2675	1999	1199	825	555	194
Conditions 2 & 3	6323	4574	3659	2926	2103	1250	824	538	180
Conditions 4 & 5	5403	3909	3128	2501	1797	1070	705	460	159
SULFATE CONCENTRATION DURATION									
	Percent of Time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	1931	1664	1562	1451	1176	785	571	415	166
Conditions 2 & 3	2970	2448	2010	1518	1176	787	547	395	151
Conditions 4 & 5	2930	2424	1989	1503	1164	780	542	391	151
TDS CONCENTRATION DURATION									
	Percent of Time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	9399	8048	7438	6754	5224	3286	2347	1638	657
Conditions 2 & 3	14676	11354	9065	6162	5356	3356	2292	1565	600
Conditions 4 & 5	13182	10252	8185	6466	4836	3031	2071	1414	545

TABLE 6
ECONOMIC REACH 14a
HEADRICK, NORTH FORK OF RED RIVER

CHLORIDE CONCENTRATION DURATION									
	Percent of time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	5709	4298	3718	1940	1807	797	457	263	0
Conditions 4 & 5	1816	1182	962	739	407	166	94	54	0
SULFATE CONCENTRATION DURATION									
	Percent of Time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	1621	1343	1246	1112	860	552	401	215	0
Conditions 4 & 5	2780	2084	1784	1271	905	554	396	212	0
TDS CONCENTRATION DURATION									
	Percent of Time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	11821	9150	8222	6825	4529	2263	1427	814	0
Conditions 4 & 5	9660	6364	5182	3985	2415	1121	695	400	0

TABLE 7
ECONOMIC REACH 14b
CARL, ELM FORK OF THE NORTH FORK OF RED RIVER

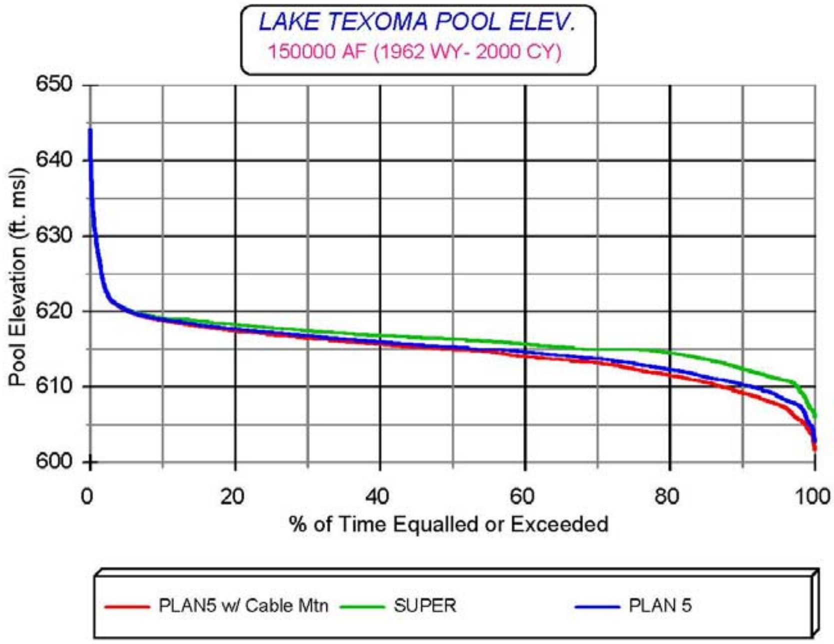
CHLORIDE CONCENTRATION DURATION									
	Percent of time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	117300	44124	25998	17217	9900	5351	3778	2502	818
Conditions 4 & 5	19110	8940	6276	3944	1970	980	610	212	0

SULFATE CONCENTRATION DURATION									
	Percent of Time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	3687	2906	2449	2112	1806	1580	1425	1299	1000
Conditions 4 & 5	5580	4474	3926	3400	1835	1541	1354	1072	0

TDS CONCENTRATION DURATION									
	Percent of Time Equaled or Exceeded, mg/l								
	1	5	10	20	50	80	90	95	99
Condition 1 Natural	212600	78971 .	47816	32106	19483	11616	8571	6263	2900
Conditions 4 & 5	38362	21362	16258	11554	6273	4135	3140	2025	0

EXHIBIT D

LAKE TEXOMA POOL ELEVATION DURATION PLOTS



Condition	Percent of Time Equalled or Exceeded								
	1	5	10	20	50	80	90	95	99
SUPER	628.4	620.3	619.1	617.7	616.4	614.5	612.4	611.1	607.7
Plan 5	628.4	620.2	619.0	617.5	615.3	612.3	610.3	608.7	605.5
Plan 5 w/ Cable Mtn	628.4	620.2	618.9	618.0	615.0	611.5	609.2	607.7	604.5

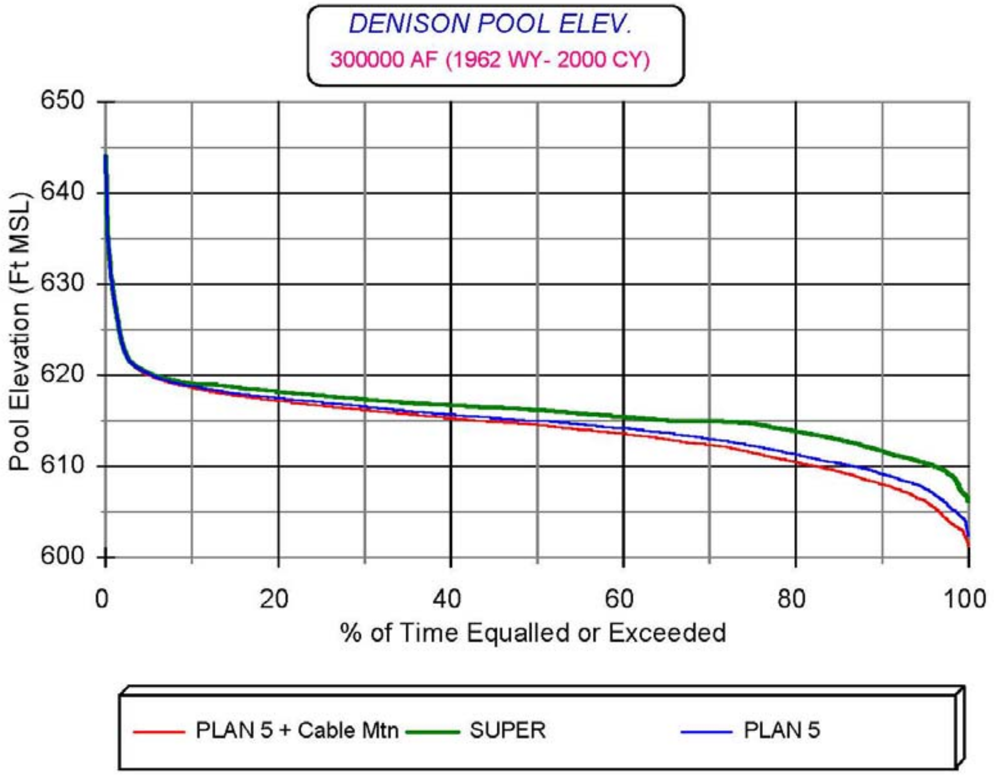
Tulsa District Corps of Engineers
Chloride Control Study
Area VI

Pool Elev. Duration

Lake Texoma

w/150,000 A.F. Cons. Stg.

Computed by: E.D.
Reviewed by: D.T.
Oct 2010
Drawing No. 1



Condition	Percent of Time Equalled or Exceeded								
	1	5	10	20	50	80	90	95	99
SUPER	628.4	620.2	619.1	618.2	616.2	613.9	611.7	610.4	607.5
Plan 5	628.4	620.2	618.9	617.6	615.0	611.6	609.5	607.8	605.1
P5 w/Cable Mtn	628.3	620.1	618.8	617.4	614.8	610.8	608.3	606.7	603.6

Tulsa District Corps of Engineers
Chloride Control Study
Area VI

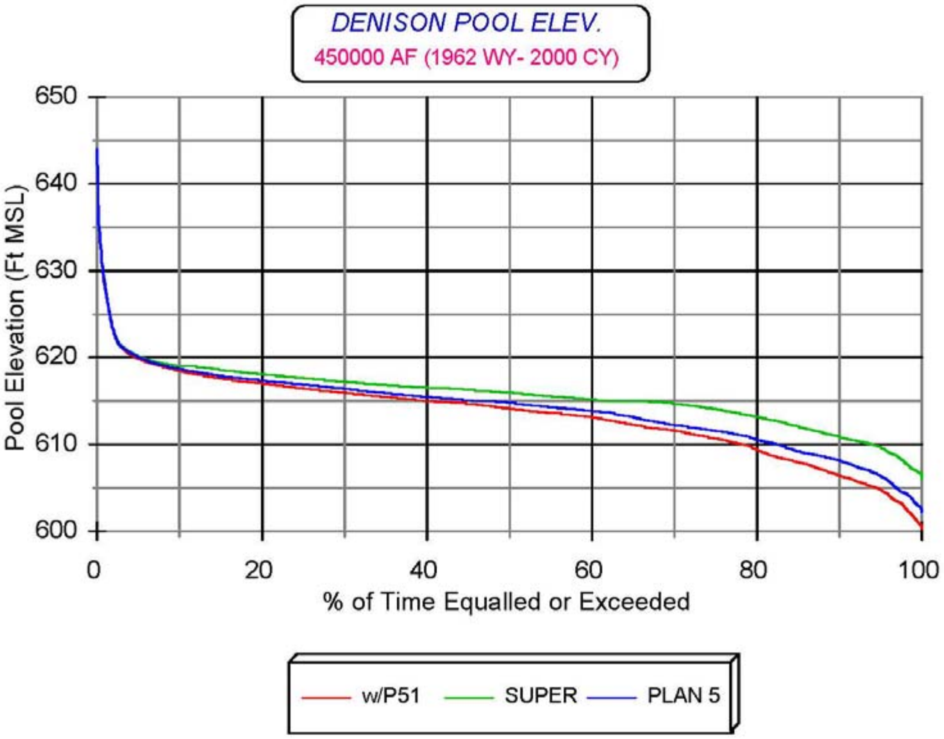
Pool Elev. Duration

Lake Texoma

w/300,000 A.F. Cons. Stg.

Computed by: E.D.
Reviewed by: D.T.
Oct 2010

Drawing No. 2



Condition	Percent of Time Equalled or Exceeded								
	1	5	10	20	50	80	90	95	99
SUPER	628.2	620.2	619.0	618.1	616.0	613.2	610.9	609.7	607.1
PLAN 5	628.2	620.1	618.8	617.5	614.9	610.8	608.4	606.6	604.0
P5 w/Cable Mtn	628.2	620.0	618.7	617.2	614.6	610.0	607.3	605.2	602.2

Tulsa District Corps of Engineers
Chloride Control Study
Area VI

Pool Elev. Duration

Lake Texoma

w/450,000 A.F. Cons. Stg.

Computed by: E.D.
Reviewed by: D.T.
Oct 2010
Drawing No. 3

APPENDICES

APPENDIX A

SYNTHESIZED FLOWS AND WATER QUALITY DATA

SYNTHESIZED FLOWS AND WATER QUALITY DATA

TABLE OF CONTENTS

TABLE INDEX

DRAWING INDEX

SYNTHESIZED FLOW/WATER QUALITY DATA

Introduction

This appendix is intended to provide insight into the methods used to fill data gaps and generate water quality data for the gages used in this study. If flow and water sampling data for the period of record were available for a site, the flow data was plotted against specific conductivity data and a correlation between flow and conductivity was developed. A linear regression analysis produced a relationship of flow to conductivity. Missing conductivity data for periods in the record could then be estimated using the correlation. Using water sampling data for the period of record at a site, similar correlations could be established between specific conductivity and chlorides, sulfates, and TDS. Linear regression analyses produced correlations which could be used to generate daily chloride, sulfate, and TDS data.

Flow and water quality data (chloride, sulfate, and TDS daily concentrations) were calculated for the previous Wichita River Project Reevaluation study using the period of record WY 62 - 98. This data was available for use in this study. The water quality data were calculated for WY 99 - 06 to complete the period of record data set used in this study. The period of record data was reviewed and corrected as necessary.

Carl Gage, Elm Fork of the Red River

Data Available

Water quality data available: WY 60-73.
Flows: WY 60-79, WY 95 - Present.
Specific Conductivity: 7/60-9/67 (PHS), 7/68-9/79, WY 95-97, 7/06 to present.

Daily flow data was for the Carl gage was not available for WY 80 – 94. Two options were considered to generate the required flow data: rainfall/flow correlations and flow correlations using the Headrick gage.

Limited rainfall data was available for the area. Many of the rainfall data sites were either outside the basin or the distance to the Carl gage were considered too great. Attempts were made to develop rainfall/flow correlations using the rainfall data available but no clear correlations could be established. Drawings 1 and 2 present rainfall site above Carl and Headrick.

Several flow correlations were investigated using various combinations of flow data at Hobart, Altus, and Headrick. None of the approaches resulted in a well defined correlation. As a result, a correlation was developed using available flow data at the Carl and Headrick gages. This correlation was used to fill data gaps in flow data at the Carl gage. A plot of the Carl-Headrick flow correlations for different time periods is presented in Drawings No. 3 and 4.

Specific conductivity data was not available for WY80-94 and WY98- Jul 11, 2006. A flow versus specific conductivity correlation was developed using water quality sampling data available. Enough data was available to develop a correlation for low and high flows. Drawing 5 presents the correlation for the Carl gage.

Missing specific conductivity data or errors in the data were found during WY 74 – 79 and WY95 – 97. A flow versus specific conductivity correlation developed from discrete sampling data was used to generate data to fill in the data gaps. There were also data in WY 95 – 97 that was off by a factor of 10. This data was also corrected. The generated conductivity data was compared to discrete sampling data within the time period and further adjusted to better match sampling data. Hourly data was available for 7/1//2006 - 9/2006 and converted to average daily conductivity. There were some periods of missing conductivity data due to equipment failure but these estimated by straight line interpolations or flow correlations.

Specific conductivity versus chloride/sulfate/TDS correlations were developed to generate daily chloride, sulfate, and TDS concentration data. Drawings 6 and 7 present the correlations as log-log plot along with the best fit line used in this study. Drawing 8 presents the plot of the TDS concentrations versus (1.6*Cl+1.4*Sul)/TDS from which the TDS factor was determined. TDS concentrations were calculated using a factor of 0.95. Table 1 shows the values taken from these plots which describe the best-fit line.

TABLE 1
Values Describing the Best-Fit Line for Correlation Plots at Carl

Correlation Type		High Low Curve	Cross Over Value	Values				Period Used
Independant Parameter	Dependant Parameter			Indep Value 1	Depend Value 1	Indep Value 2	Depend Value 2	
Flow	Conductivity			2	40000	40000	300	4/89-7/11/06
Conductivity	Chloride			210	20	27100	10000	10/73-9/06
Conductivity	Sulfate	Low	400	200	10	4000	1000	
		High		300	100	40000	3000	
Flow	Chloride			0.1	500000	6000	100	60-73 WY
Flow	Sulfate			0.1	5000	1000	800	

A mass plot was developed for the period of record at Carl and an average chloride load calculated. Correlation curves used to compute flows and chloride concentrations were further calibrated using the mass plot. The average daily load after calibration was 504 tons/day. Drawing 11 presents the Carl mass plot.

Headrick Gage, North Fork of the Red River

Data Available.
Water quality data available: 1960-1973 W.Y.
Flows: 1960-present
Specific Conductivity: 7/60-9/62 (PHS); 11/59-3/89; 7/11/2006-Present

Daily specific conductivity data were not available for 4/89 – 7/10/2006. A flow versus specific conductivity correlation was developed to generate the missing conductivity data. In the course of plotting the correlation, discrepancies in the data were discovered. The conductivity data for the 9th month of each year for the period 10/01/73 – 3/31/89 were off by a factor of 10. This data was corrected. Generated conductivity data was calibrated and adjusted by comparing generated data to sampling data.

Daily chloride, sulfate, and TDS data were generated from specific conductivity versus chloride, sulfate, and TDS correlations developed in this study. Specific conductivity correlations are presented in Drawings 12, 13, 14, and 15. Table 2 shows the values that describe the best-fit line from the above correlation plots.

TABLE 2
Values Describing the Best-Fit Line
For Correlation Plots at Headrick

Correlation Type		High/ Low Curve	Cross Over Value	Values				Period Used
Independent Parameter	Dependent Parameter			Indep. Value 1	Depend. Value1	Indep. Value 2	Depend. Value 2	
Flow	Conductivity			2	40000	40000	300	4/89-7/11/06
Conductivity	Chloride			210	20	27100	10000	10/73-9/06
Conductivity	Sulfate	Low	400	200	10	4000	1000	
		High		300	100	40000	3000	
Conductivity	TDS			160	100	30000	20000	

Flow and specific conductivity data were available for approximately 30 years at Headrick. The average chloride load for the 30-year period was 557 tons/day. This load was used as a guide when synthesizing the missing data. A final mass plot of chloride loads for Headrick revealed a period of record load of 558 T/D. The mass plot of chloride load is presented in Drawing 16.

Burkburnett gage - Red River

Data Available:
Existing water quality data available: Oct 1959 - Sep 1973
Flows: Jan 1920 - Present
Specific conductivity: 6/60 – 9/67 (PHS), 7/68 -9/81, 10/94 - present

Specific conductivity data were not available for WY 82-94. A flow versus chloride correlation for WY60-81 was developed. A review of the plot indicated data problems during WY71 – 72. A review of the data indicated that flow and conductivity data were off by a factor of 10 for this period. The erroneous data were corrected and mass plots of corrected and uncorrected data for WY60 - 81 were compared to validate the method. Conductivity data was also generated for data gaps in WY 2003 – 2005. A flow versus conductivity correlation was developed for WY 95 - 06 to generate this missing data. This correlation is presented as Drawing 21. Points representing the best-fit line for the correlation are presented in Table 4. Generated conductivity data was calibrated and adjusted by comparing generated data to sampling data.

Daily water quality data were generated by developing conductivity versus chloride, sulfate, and TDS correlation. Using a best-fit line from a log-log plot for each of the above plots, water quality data were generated. Table 3 shows the points taken from the above plots that represent a best-fit line for chloride, sulfate and TDS.

TABLE 3
Burkburnett
Specific Conductivity vs Cl-Sul-TDS Conc.
Best-Fit Points

Correlation	Low Point		High Point	
	Conductivity	Cl-SO_4-TDS	Conductivity	Cl-SO_4-TDS
Cl-Conductivity	1000	180	20000	6100
SO_4-Conductivity	1000	140	20000	2800
TDS-Conductivity	1000	580	20000	13000

TABLE 4
Burkburnett
Flow vs Specific Conductivity
Best-Fit line Points
(1995-2006 WY)

Correlation	Low Point		High Point	
	Flow	Conductivity	Flow	Conductivity
Low Flow	1	10000	10000	9000
High Flow	10	40000	100000	1000
Cross-over flow	400			

A mass plot of the period of record loads for the Burkburnett gage was generated and the average daily load calculated. Average daily load calculated for the Burkburnett gage was 3121 tons/day. Drawing 22 presents the mass plot of chloride loads. Average daily loads at Burkburnett were compared to the Terral average daily loads downstream. The average daily load at Terrel was 3784 tons/day with 501 tons/day of this total coming from the Wichita River. Wichita River loads were calculated for the Mabelle gage. Mabelle loads added to Burkburnett average daily loads produced an average load at Terral of 3622 tons/day which was within 5% of the Terral average daily loads generated.

Terral Gage - Red River

Data available

Existing water quality sampling data available: Oct 1959 - Sep 1997
Flows: Apr 1938 - Sep 2006
Specific conductivity: Oct 1961 - Sep 1997

Water quality data were needed for Oct 1997 - Sep 2006. Daily flows were available for the entire period, but daily specific conductivity data and discrete sampling data were not available. A flow versus specific conductivity correlation was developed using sampling data to generate missing conductivity data; a best fit line drawn to represent the correlation. A log-log plot was made using the daily data for 1979-1997 WY. A flow versus conductivity correlation was also developed for WY88-97 to see if there was a discernable difference with Area VIII in operation. Best fit lines were chosen for low and high flows on this correlation plot. The pair of best fit lines were drawn on the 79-97 correlation plot and then transposed onto the WY88-97 plot. The WY88-97 correlation is presented as Drawing 23. The values representing the best fit correlations are presented in Table 5. A plot of the period of record conductivity data indicated the generated data did not transition into the recorded data very well. A program was written to smooth the data in a three month transition period at either end of the missing data. Mass plots were made for the entire period-of-record using the original data and the new synthesized data but no significant difference was noted.

TABLE 5
Terral
Flow-Specific Conductivity Correlation
Best-Fit Points

	Flow 1 cfs	**Cond. 1 mg/l**	**Flow 2 cfs**	**Cond. 2 mg/l**
Low Flows	10	10000	100000	2000
Higher Flows	100	12000	300000	500

Break point flow: 1500 cfs

Daily concentration data for chlorides, sulfates, and TDS were generated using specific conductivity versus chloride, sulfate, and TDS correlations. These correlations are presented as Drawings 24-26. Table 6 presents the Best-Fit points for these correlations.

TABLE 6
Terral
Cl, Sul,TDS vs Conductivity Correlation
Best-Fit Points

Correlation	High/Low	Low Point		High Point	
	Cond. mg/l	Cond.	Cl-SO_4-TDS	Cond.	Cl-SO_4-TDS
Cl-Conductivity	Low	200	33	20000	5000
	High	400	48	20000	7000
SO_4-Conductivity		100	27	20000	2800
TDS-Conductivity		300	150	10000	6400

Mass plots of the period of record chloride load were developed and a period of record chloride load computed. Drawing 27 presents the final mass plot. Average daily loads for WY 59 - 97 and WY 59 – 06 were calculated. Table 7 presents the average daily loads for the two time periods. No significant differences in average daily loads were noted.

TABLE 7
Terral Average Daily Chloride Loads

Period of Record	Long Term Loads
	(tons/day)
Oct 1959-Sep 1997	3758
Oct 1959-Sep 2006	3784

Gainesville gage – Red River

Data available

Water quality data available: Oct 1959 - Sep 1998
Flow Data: Oct 1923 - Sep 2006
Specific conductivity: Oct 1952-Sep 1964; Oct 1966-Sep 1989;
Oct 1994-Sep 2006

Specific conductivity data were available for 1994-06. There was an estimated 3 months of data missing scattered thru the WY 2003, 2005, and 2006. These data gaps were filled in using a flow-specific conductivity correlation developed for Gainesville gage. The flow versus conductivity correlation is presented as Drawing 28. Table 8 lists the points representing the best-fit line for these plots.

TABLE 8
Gainesville
Flow-Specific Conductivity Correlation
Best-Fit Points

Correlation	Low Point		High Point	
	Conductivity	Flow	Conductivity	Flow
Flow-Conductivity	300	1,000,000	10000	100

Period of record specific conductivity data were plotted against sampling data to generate conductivity correlations between conductivity and chlorides, sulfates, and TDS. Daily chloride, sulfate, and TDS data were then generated using these correlations. Drawings 29-31 present the correlation plots. Table 9 presents the values used to represent the best-fit lines used for each plot.

TABLE 9
Gainesville
Cl, SO_4, TDS vs Specific Conductivity Correlation
Best-Fit Points

Plot	Low Point		High Point	
	Conductivity	Cl-SO_4-TDS	Conductivity	Cl-SO_4-TDS
Cl-conductivity	1000	180	20000	6300
SO_4-Cconductivity	500	50	20000	3000
TDS-Conductivity	400	190	10000	6500

A mass Plot of Cl Loads was made to determine the long term load. The long term chloride load at Gainesville was 4474 t/d. The mass plot for Gainesville is presented in Drawing 32.

Denison gage – Red River

Data Available

Water Quality data available: Oct 1959 - Sep 1989, Feb 1997 - Sep 1998
Flows Data Available: Oct 1923 -Sep 2006
Specific Conductivity Data Available: Oct 1944 - Sep 1989; Feb 1997-Sep 2006

The Denison gage is located approximately 1 mile downstream of Denison dam and Lake Texoma. The water quality data at the Denison gage represents water quality in Lake Texoma. Conductivity data was not available for 10/89 - 2/97. To generate the missing conductivity data, a flow/conductivity correlation using available data or a reservoir routing were the options available. A reservoir routing was chosen to generate the missing conductivity data. The following data for 10/89 - 2/97 would be required for the routing:

- Lake Texoma releases
- Lake Texoma inflows

- Evaporation data
- Rainfall
- Gainesville W.Q. Data (used to estimate inflow Cl and Sul Loads)
- Lake Texoma end of month storage-acre feet
- Lake Texoma Elevation/Area/Capacity data
- Estimate of Washita water quality contributions

Two elevation-area-capacity tables were available for Lake Texoma, 1985 and 2002. The area data and capacity data in the two tables were averaged at each one foot increment to generate an elevation/area/capacity table used in the routing.

To estimate the water quality contributions from the Washita River, discrete water sampling data at the Dickson gage for WY70-06 period were used. Chloride and sulfate loads were calculated for each sample and averaged to get an estimate of the loads contributed by the Washita River. The Red River and Washita River contributions were compared and the percent contribution of the Washita River and Red River were calculated. The percent contributions were used as a ratio to increase the chloride and sulfate loads at Gainesville to account for the Washita loads. Table 10 presents the ratios used at the Gainesville gage.

Daily TDS loads for the Washita River were estimated using the daily chloride and sulfate loads listed in Table 13. An estimated daily TDS contribution of 1612 tons/day was calculated using the following formula: TDS Conc= (1.6*Cl Conc + 1.4* Sul Conc)/TDS Ratio). A TDS ratio of 0.85 was used. The calculated contribution was rounded up to 1700 tons/day for this study.

Table 10
Lake Texoma
Average Water Quality Inflow Loads and Ratios

		Loads tons/day		
Gage	**River**	**Chloride**	**SO_4**	**TDS**
Dickson	**Washita**	200	750	1700
Gainesville	**Red**	3800	2500	11100
Ratio		1.053	1.13	1.15

The estimated loads were routed through Lake Texoma for the missing period of record. The beginning chloride load was calculated using the following formula: Beginning Cl Load = Outflow Cl Conc* lake contents on 9/30/89. Daily lake storage volumes were available from USACE daily reservoir reports. Daily estimated loads were routed beginning with the daily load calculated for 9/30/89. Final routed loads were compared to calculated loads on 2/1/97. Daily estimated loads were adjusted to closely match the 2/1/97 loads at the Denison gage. TDS daily loads were calculated using a TDS ration of 0.87.

Flow and Specific conductivity data were available for Oct 1998 - Sep 2006. Daily conductivity data was plotted against discrete sampling data for chlorides and sulfates to develop correlations.

A review of the data indicated that the chloride and sulfate data needed to be divided into two groups and develop separate correlations for each time period. The data was divided into the time periods listed in Table 14 and separate correlations developed. The correlation plots are presented in Drawings 34-37. Table 11 presents the plotting positions of the best fit lines for each log-log plot.

TABLE 11
Denison Gage Specific Conductivity Best Fit Points

							Cond.
Parameter	Period	Curve	Conc1	Cond1	Conc2	Cond2	Break Point
Chloride	1999 WY - 2001 WY	Lower Cond.	160	1000	1000	6000	1800
		Higher Cond.	110	1000	1000	3800	
	2002 WY - 2006 WY	Lower Cond.	145	1000	820	3000	1750
		Higher Cond.	195	1000	580	3000	
Sulfate	1999 WY - Jul 2002	Lower Cond.	135	1000	710	3000	1950
		Higher Cond.	295	1400	534	2800	
	Aug 2002 - 2006 WY	Lower Cond.	170	1200	320	2800	
		Higher Cond.	only	one	curve		

A mass plot of the period of record chloride load was generated. The chloride mass plots at Denison and Gainesville were compared. It appeared that there was 16% more chloride load at Gainesville than at Denison during WY 89-97. Denison loads were increased by 16%. The period of record daily average chloride at the Denison gage was calculated to be 4515 ton/day. Drawing 38 shows the final plot of mass loads at Denison.

Area VII

The N. Wichita @ Paducah gage was used to define the Area VII data
Period of available data
Water Quality data available: Oct 1961 - Sep 1998 (gaged and synthesized)
Flows: Jul 1961 - Sep 1982; Oct 1994 - Sep 2006
Specific conductivity: Oct 1994 - Sep 2006

Water quality data was needed for Oct 1998-Sep 2006. Flow and specific conductivity data were available for the period. USGS regression coefficients were applied to the specific conductivity data to generate chloride, sulfate, and TDS data. Table 17 shows the USGS Regression Constants for Paducah Gage which is the location of the Area VII Low Flow Dam.

Area VIII

Area VIII data was derived from several gages over the period of record. Since Oct 1985, there were two gages at the Area VIII low flow dam; one to record upstream flow and pumped flow and the other to record any downstream releases.

Period of available data
    Existing Water quality data available: Oct 1961 - Sep 1998 (gaged and synthesized)
    Flows: S. Wichita near Guthrie: Oct 1970 - Sep 1976
        Low flow dam near Guthrie: Oct 1984 - Sep 2005; May 2006 - Sep 2006
        Below low flow dam near Guthrie: Oct 1985 - Sep 2006
    Specific conductivity
        S. Wichita near Guthrie: Oct 1973 - Sep 1976\
        Low flow dam near Guthrie: Oct 1984 - Sep 2006
        Below low flow dam near Guthrie: May 1987 - Sep 1989

Flow data was missing for 8/30/02-10/22/02. The annual period of record flow for September – October ranged from 355-395 day second feet. The Sep-Oct 2001 flows were used for the missing data in 2002.

Daily specific conductivity data was available for Oct 1998-Sep 2006. USGS regression coefficients were applied to the specific conductivity data to generate chloride, sulfate, and TDS data. USGS regression coefficients are presented in Table 12.

TABLE 12
Area VIII USGS Regression Constants

Parameter	CON1	CON2
Cl	3483	2.779E-07
SO_4	1066	-8.891E-07
TDS	7272	-8.955E-07

Where Conc. = SC*CON1 + SC*CON2*2

A mass plot of period of record chloride loads was generated. The mass plot indicated a increase in load beginning in 1986, about the time operations began at Area VIII. It was suspected that the increased loads were due to stratification of the pool at Area VIII and placement of the conductivity probe. Monthly average flow, specific conductivity, Cl loads, and Cl concentrations were generated. A closer review of the data indicated that the WY99-06 needed to be corrected.

There were just a few years of conductivity data prior to 1985 that was recorded in the standard daily water quality formatted data files. Chloride concentration data were used since there was a good correlation between chloride concentration and conductivity. A comparison of chloride concentrations was made for various time periods. It appeared that chloride concentrations were higher during the 98-06 time period. The flows were approximately 22% lower during the 98-06 time period when compared to the 61-85 time period. Table 13 presents the comparison of monthly data. The decision was made to modify the specific conductivity data by a factor of 0.75 for WY99-06.

TABLE 13
Area VIII Data Comparisons

Type of Data	Period	Value	label	Comments
Avg. Cl Conc.	10/61-12/85	11636	mg/l/mon	
	1/86-9/06	12642		
	1/86-12/97	10476		
	1/98-9/06	15615		to reduce this to 11636, use .75
Avg. flow	10/61-12/85	936	Cfs	
	1/86-9/06	938		
	1/86-12/97	1136		
	1/98-9/06	734		
Median flow	10/61-12/85	4375	Cfs	
	1/86-9/06	7.05		
	1/86-12/97	7.25		
	1/98-9/06	6.8		
Avg. Cl Load	10/61-12/85	157	t/d	
	1/86-9/06	239		
	1/86-12/97	249		
	1/98-9/06	304		

Area X

The Area X data were generated from computed data at two gages, the Middle Fork of the Wichita River at Truscott and Middle Fork at Guthrie during the period of record.
Period of available data

Existing Water Quality data available: Oct 1961 - Sep 1998 (gaged and synthesized)
1. Flows: Middle Fork Wichita River nr Truscott: Oct 1971 - Sep 1976,
   Middle Fork Wichita River nr Guthrie: Jun 1994 - Sep 2006
2. Specific conductivity: Middle Fork Wichita River nr Guthrie: Jun 1994 - Sep 2006

Water quality data was needed for Oct 1998-Sep 2006. Recorded flows and specific conductivity data were available for the period, USGS regression coefficient were applied to available conductivity data to generate chloride, sulfate, and TDS data. USGS regression coefficients are presented in Table 14.

TABLE 14
Area VII and X USGS Regression Constants

	Gage	Chloride		Sulfate		Total Dissolved Solids	
Area		**C1**	**C2**	**C1**	**C2**	**C1**	**C2**
VII	Paducah	0.2966	3.705E-07	0.1589	-2.255E-06	0.7152	-2.638E-06
X	Guthrie (MF)	0.2310	1.809E-06	0.3391	-1.227E-05	0.8707	-1.473E-05

Hosston

Flow and water quality data at Hosston, LA were limited. Natural and modified water quality duration data for Hosston were generated using Denison natural and modified duration data. Ratios based on the previous Wichita River Project Reevaluation study duration data for Conditions 2 and 3 were used as a guide. The percent change between natural and modified conditions were used to calculate duration data for Conditions 4 and 5 in this study.

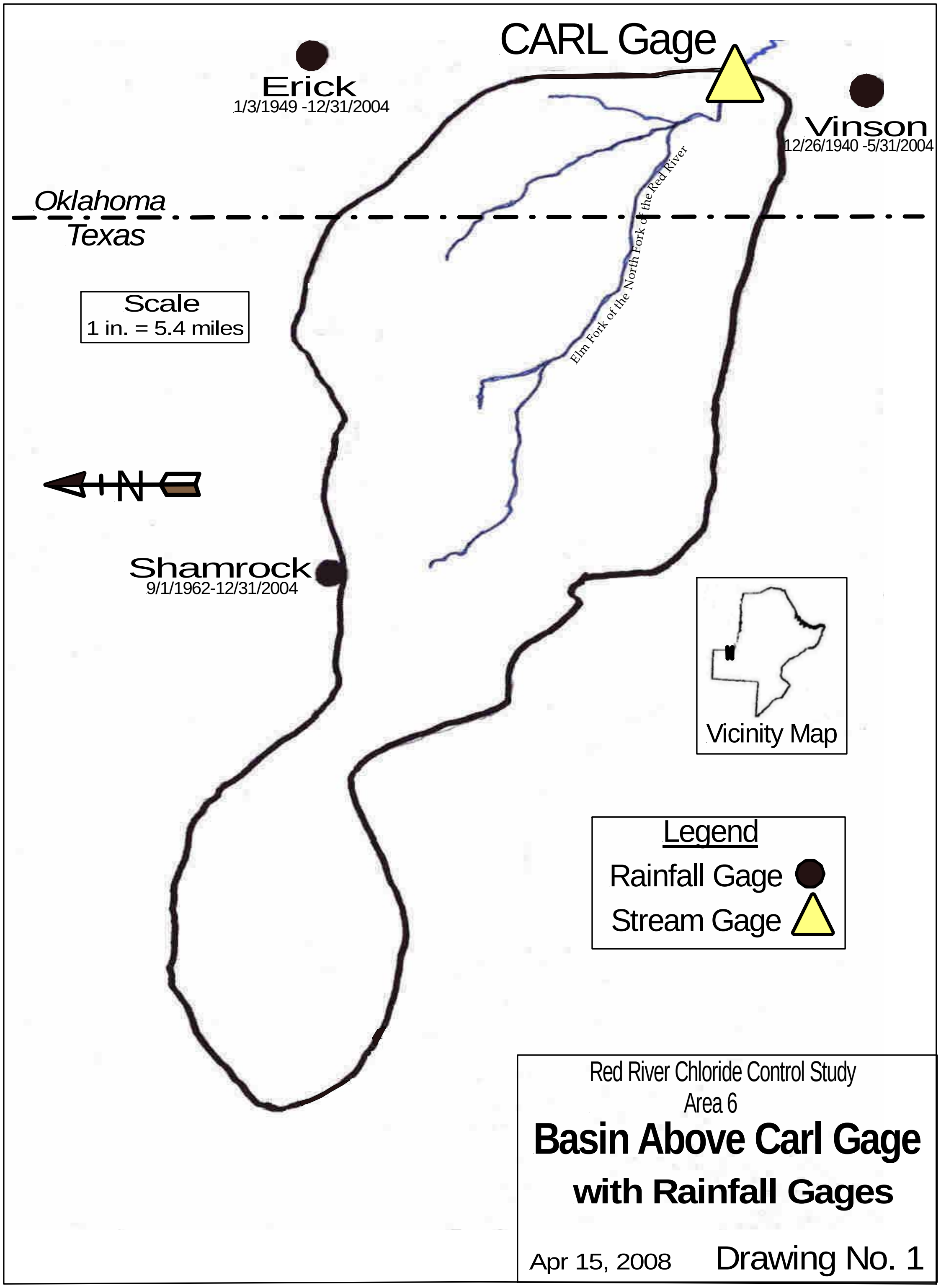
Water Quality Ratios

TABLE 15
Percent Increase for Natural Conditions

	1964 wy-Apr 1987 (cfs and T/D)				**May 1987-2006 WY (cfs and T/D)**			
Location	**Flow cfs**	**Cl tons/ day**	**SO_4 tons/ day**	**TDS tons/ day**	**Flow cfs**	**Cl tons/ day**	**SO_4 tons/ day**	**TDS tons/ day**
Area V		240.0	220.0	790.0		240.0	220.0	790.0
Area VIII					*5.9*	*179.0*	*44.0*	*356.0*
TOTAL HOLDOUTS		***240***	***220***	***790***		***419***	***264***	***1146***
Average Flow and Load								
Burkburnett	1207	3000	1902	7983				
Terral	2039	3319	1792	8627	2854	3951	2545	10895
Gainesville	2769	3770	1845	9517	3908	4952	3001	13154
Denison	4556	3655	2345	10629	6661	5025	3123	14375
% Increase								
Burkburnett		1.08	1.12	1.10				
Terral		1.07	1.12	1.09		1.11	1.10	1.11
Gainesville		1.06	1.12	1.08		1.08	1.09	1.09
Denison		1.07	1.09	1.07		1.08	1.08	1.08

TABLE 16
Modified Conditions Ratios by Condition/Gage

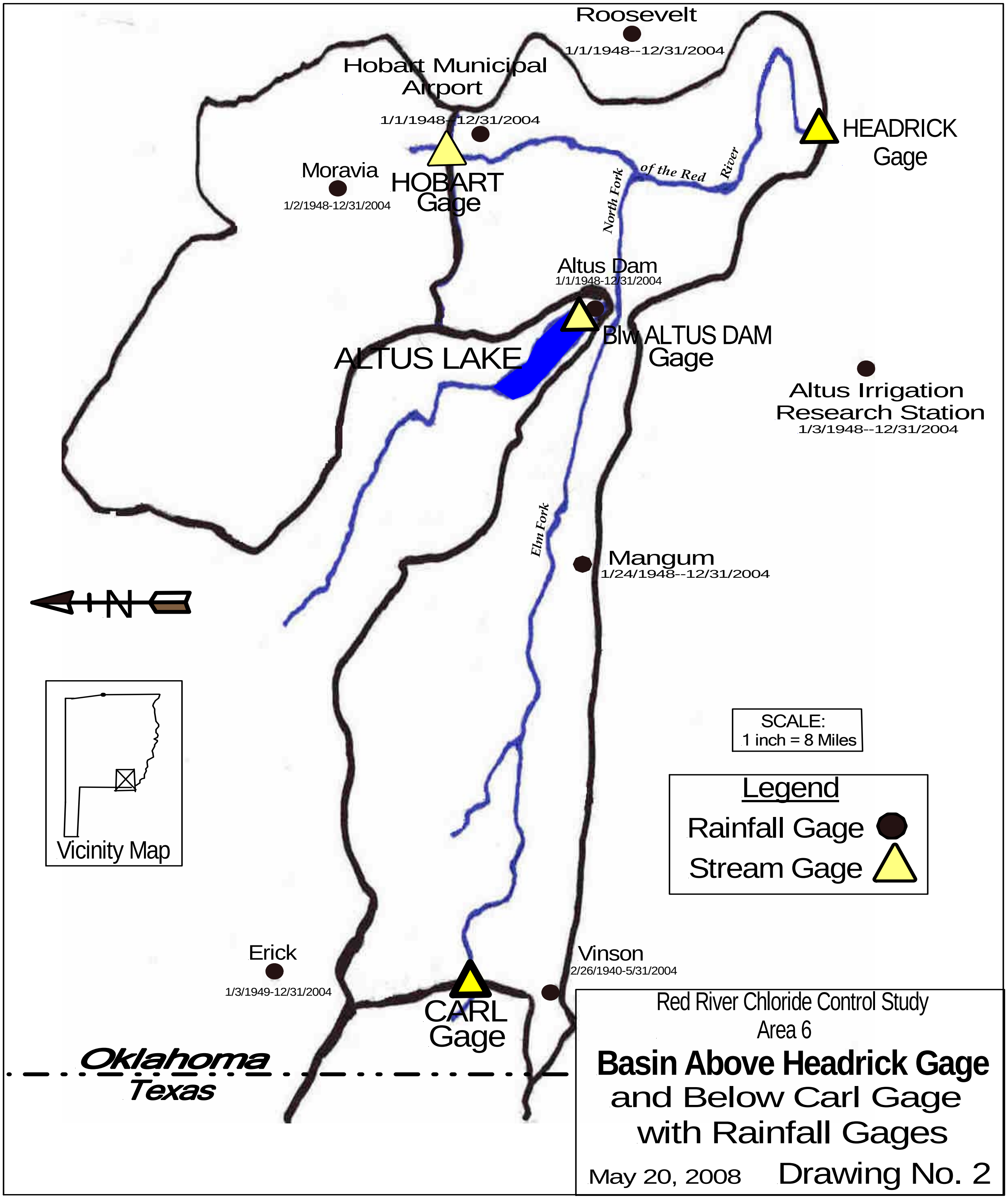
	Condition 2			Condition 3		
Gage	**Cl**	**SO_4**	**TDS**	**Cl**	**SO_4**	**TDS**
Terral	0.884	0.886	0.889	0.812	0.841	0.834
Gainesville	0.901	0.895	0.901	0.840	0.853	0.852
Denison	0.902	0.909	0.912	0.841	0.872	0.868
	Condition 4			**Condition 5**		
Terral	0.773	0.879	0.817	0.708	0.837	0.762
Gainesville	0.807	0.888	0.901	0.752	0.846	0.788
Denison	0.808	0.903	0.855	0.752	0.867	0.811
	Conditions 2-3			**Conditions 4-5**		
Gage	**Cl**	**SO_4**	**TDS**	**Cl**	**SO_4**	**TDS**
Burkburnett	0.923	0.893	0.907	0.789	0.884	0.819
Headrick				0.191	0.947	0.468



Red River Chloride Control Study
Area 6

Basin Above Carl Gage
with Rainfall Gages

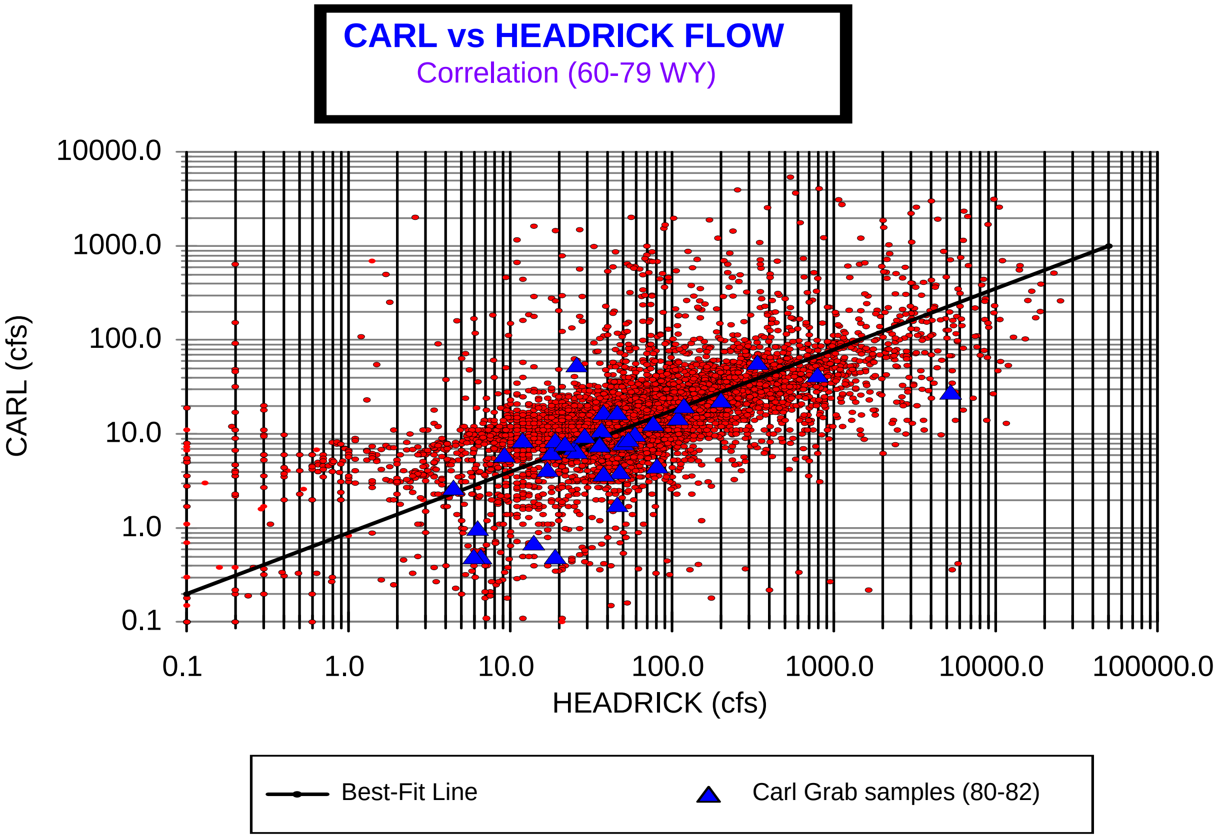
Apr 15, 2008 Drawing No. 1



Red River Chloride Control Study
Area 6

Basin Above Headrick Gage
and Below Carl Gage
with Rainfall Gages

May 20, 2008 Drawing No. 2

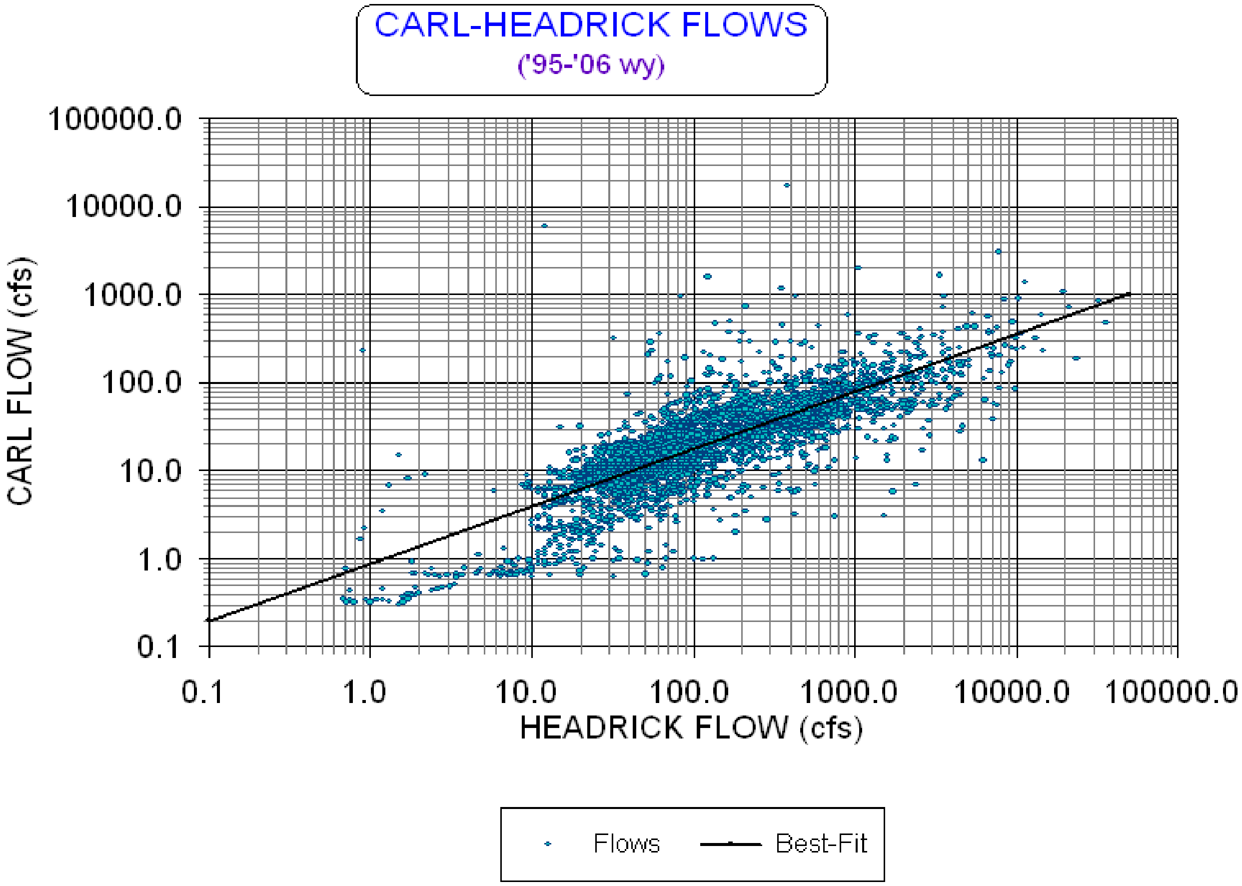


Red River Chloride Control Study
Area 6

Carl - Headrick

Flow Correlation
1960-1979 WY

Apr 29, 2008 Drawing No. 3

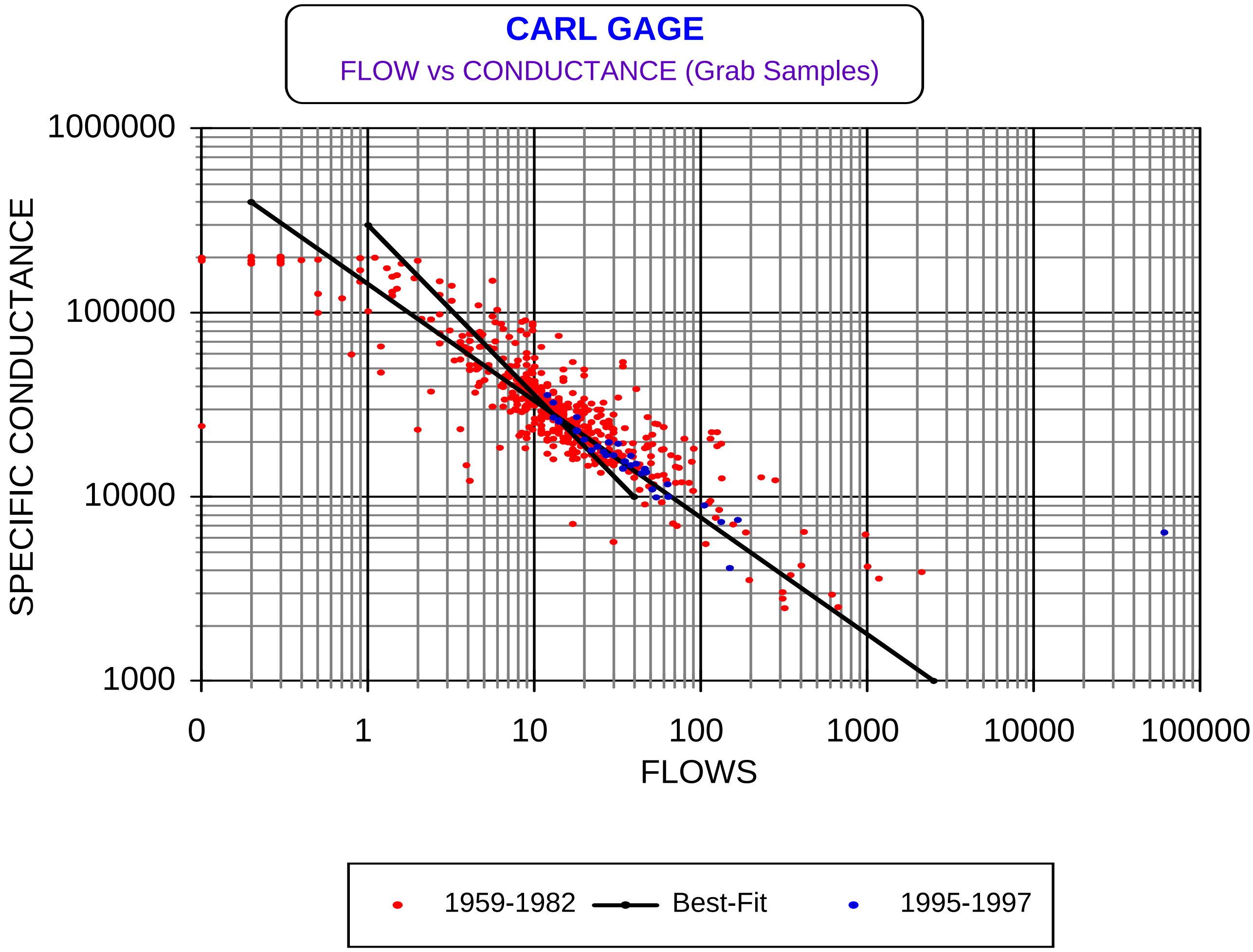


Red River Chloride Control Study
Area 6

Carl - Headrick

Flow Correlation
1995-2006 WY

Apr 29, 2008 Drawing No. 4

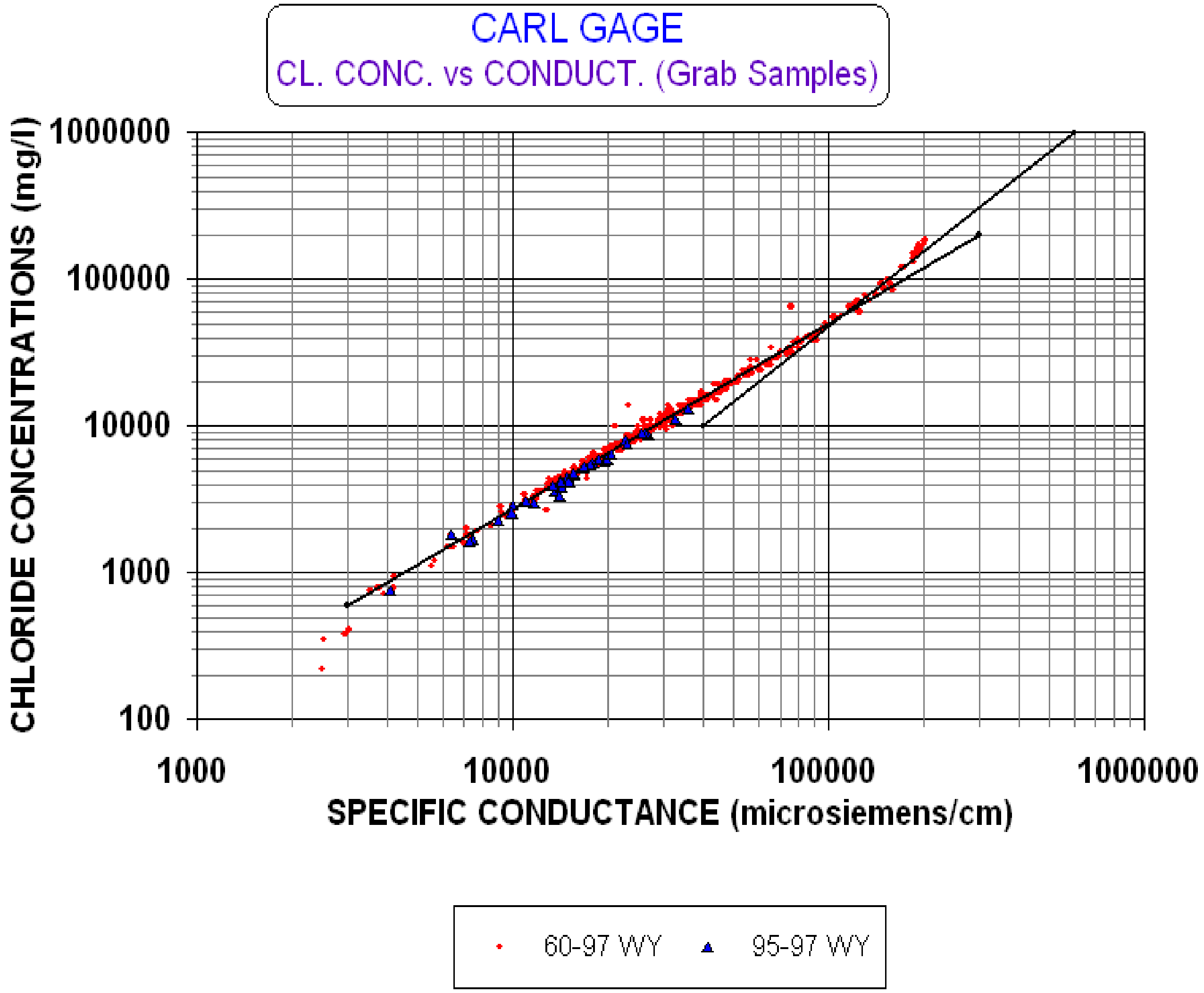


Red River Chloride Control Study
Area 6

Carl Gage

Flows vs. Specific Conductance

Apr 28, 2008 Drawing No. 5

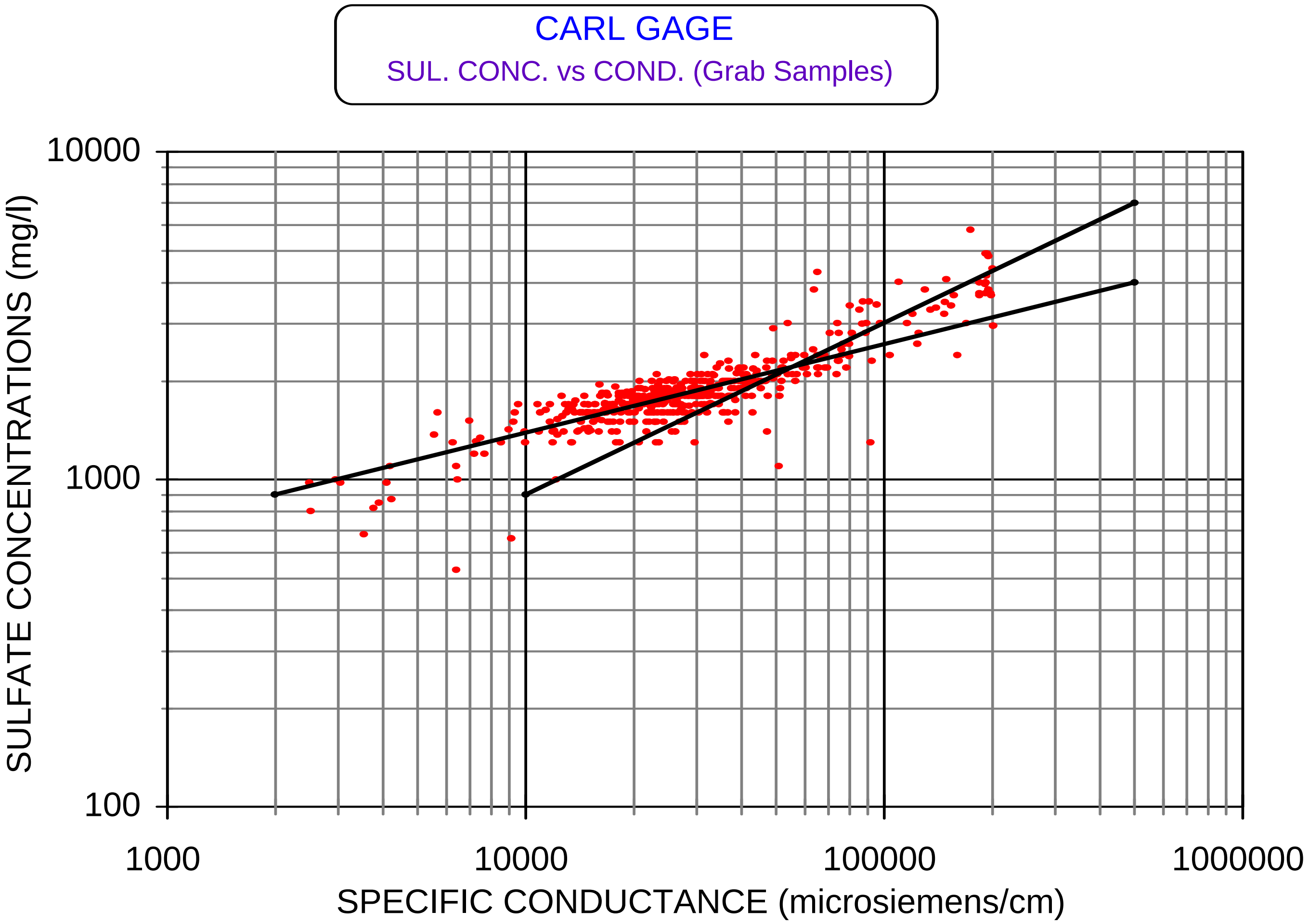


Red River Chloride Control Study
Area 6

Carl Gage

Cl Conc. vs. Specific Conductance

Apr 28, 2008 Drawing No. 6

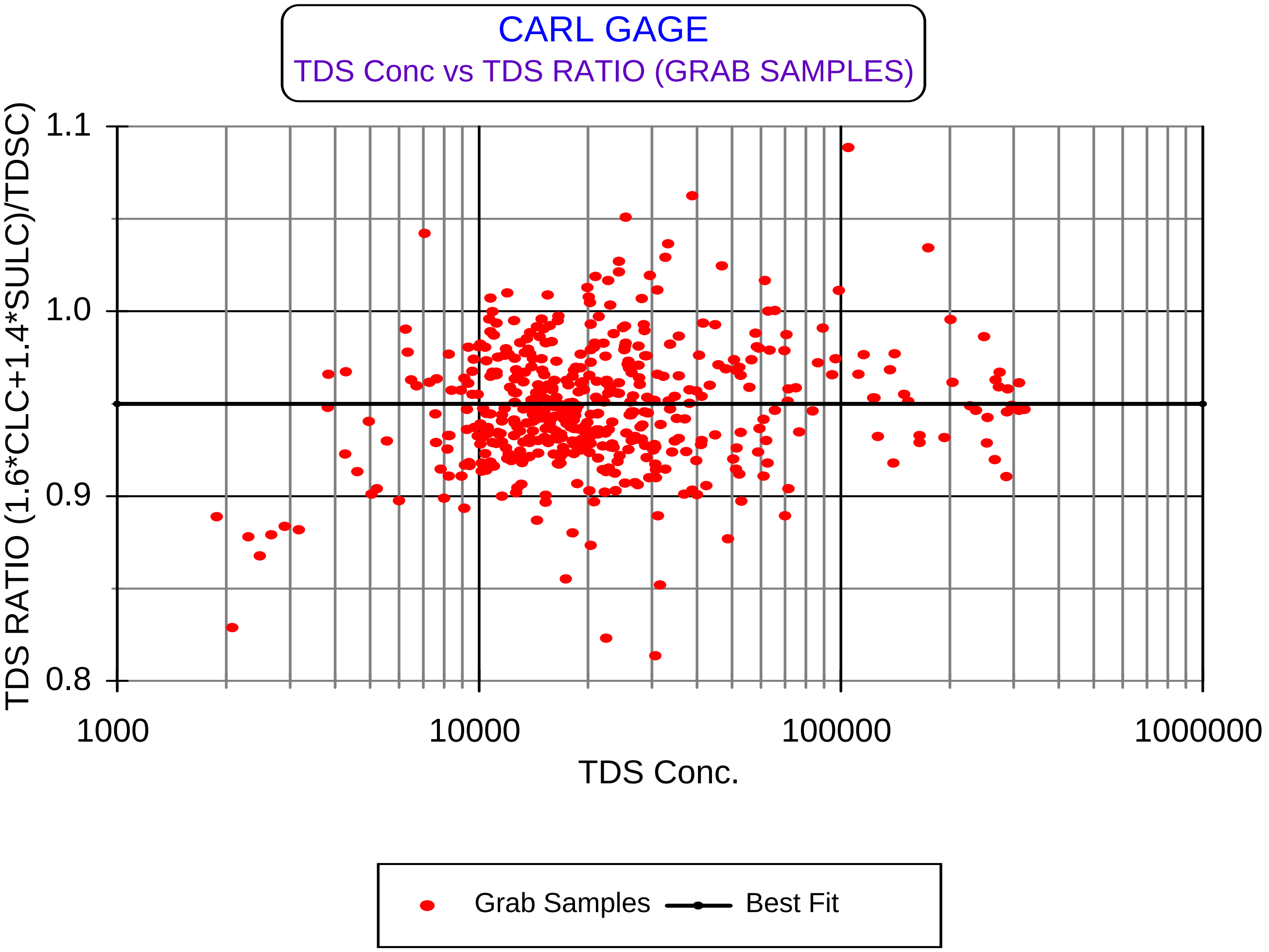


Red River Chloride Control Study
Area 6

Carl Gage

Sul Conc. vs. Specific Conductance

Apr 28, 2008 Drawing No. 7

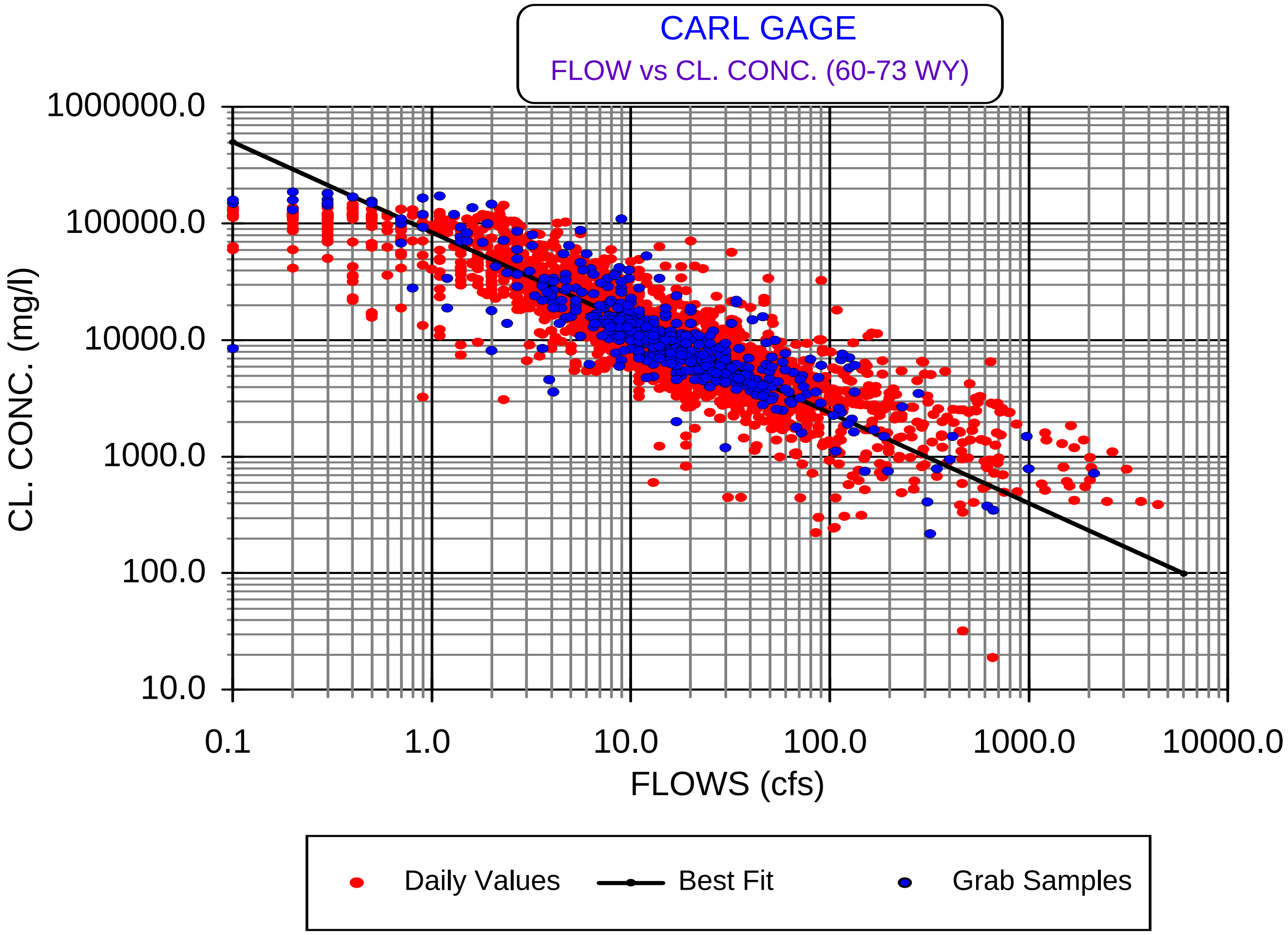


Red River Chloride Control Study
Area 6

Carl Gage

TDS Conc vs. TDS Ratio

Apr 29, 2008 Drawing No. 8

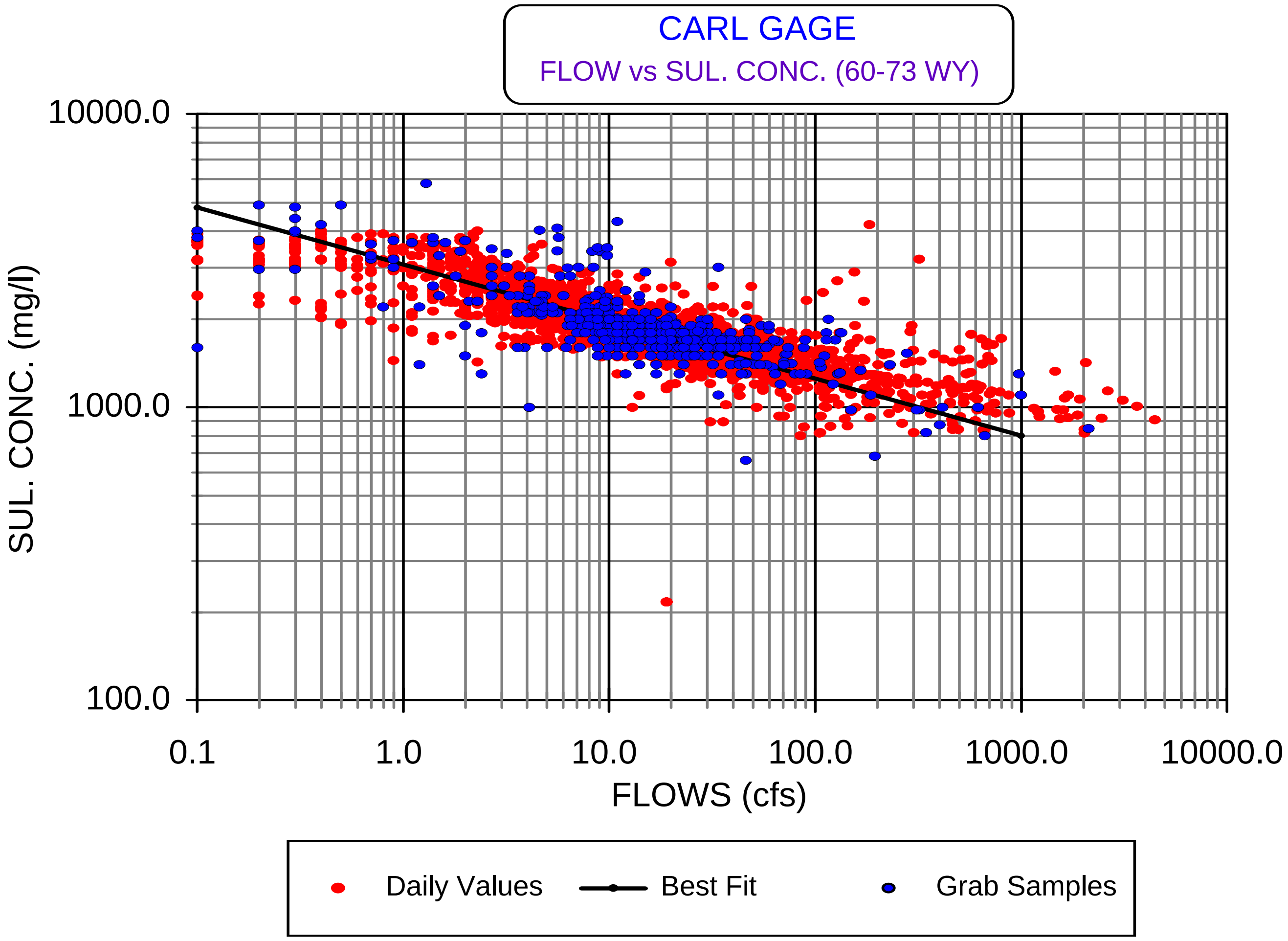


Red River Chloride Control Study
Area 6

Carl Gage

Flow vs Chloride Conc.

Apr 29, 2008 Drawing No. 9

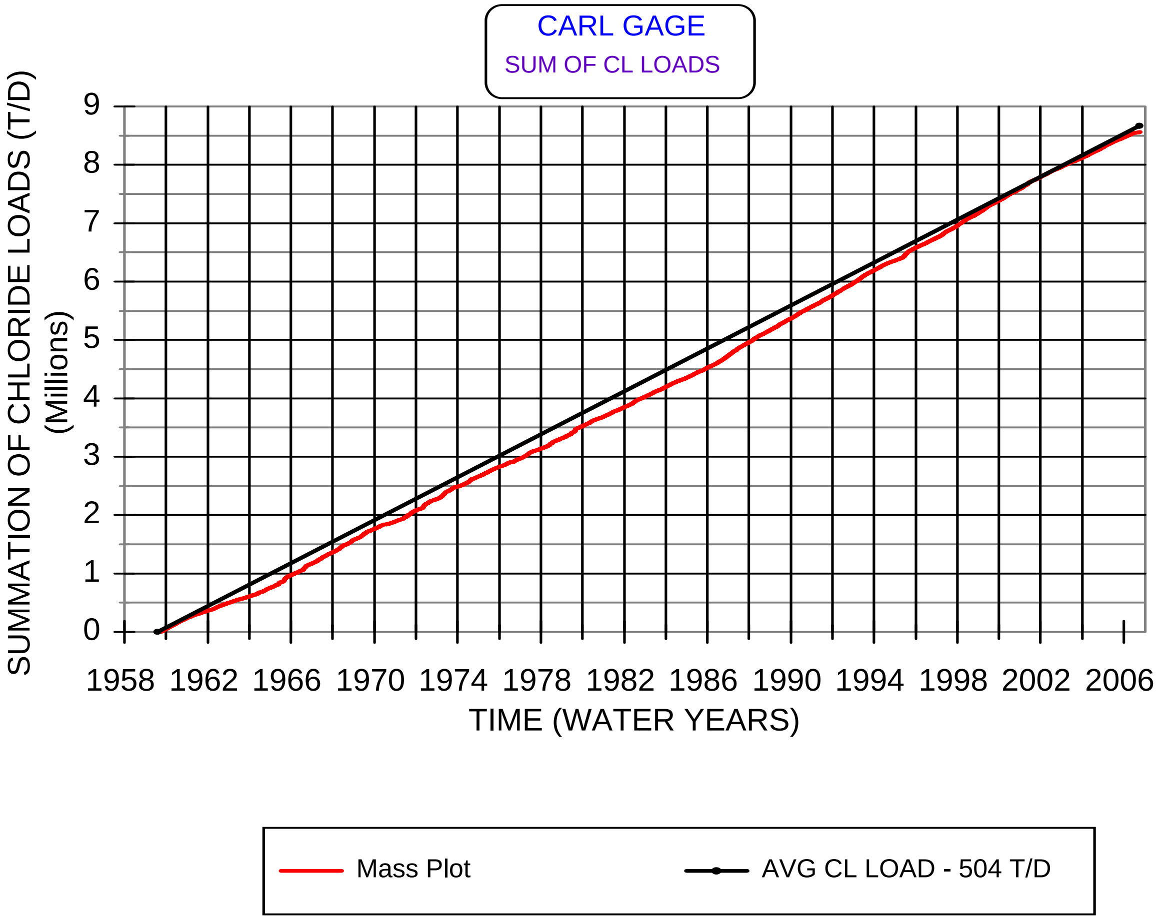


Red River Chloride Control Study
Area 6

Carl Gage

Flow vs Sulfate Conc.

Apr 29, 2008 Drawing No. 10

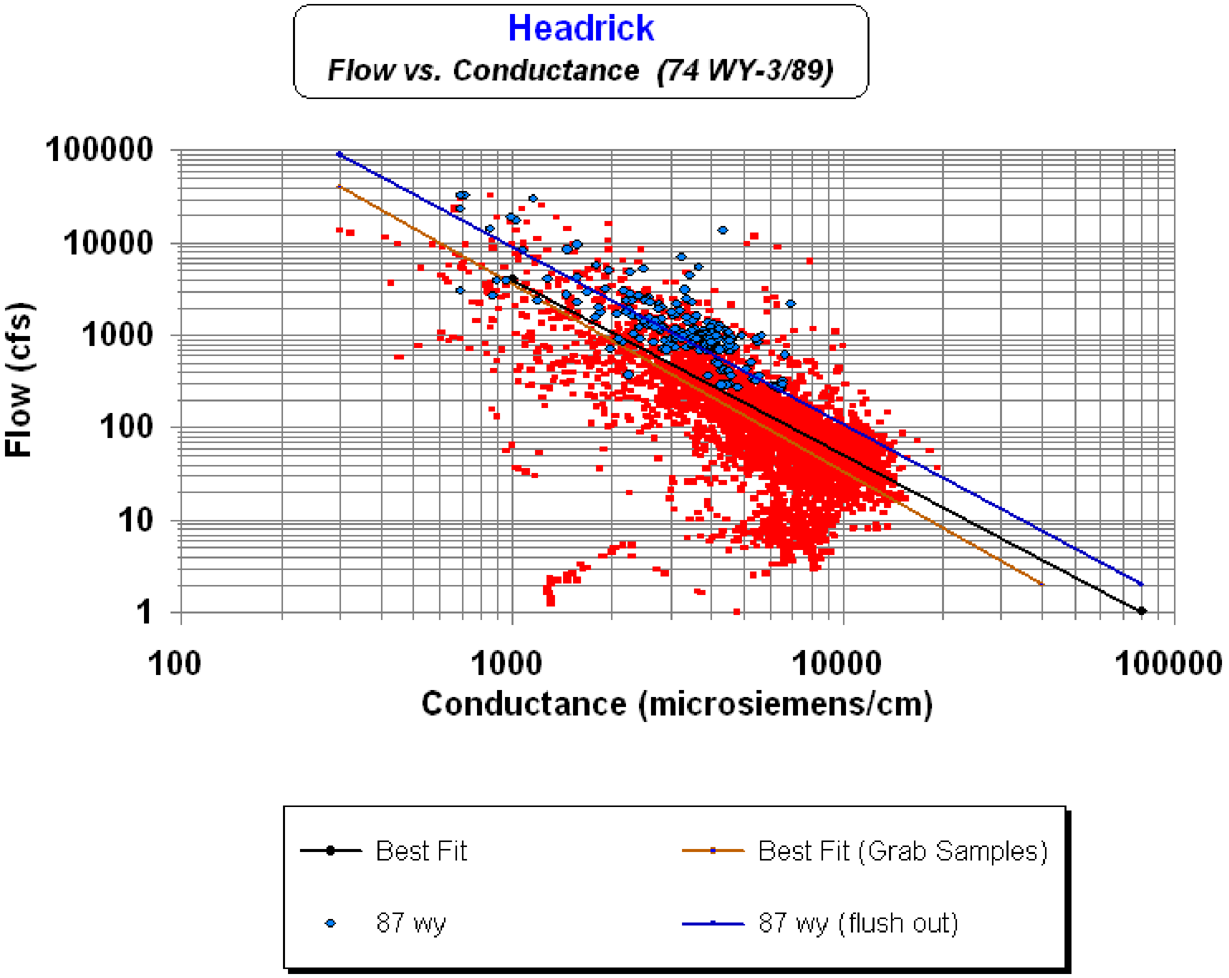


Red River Chloride Control Study
Area 6

Carl Gage

Mass Plot of Cl Loads

Apr 29, 2008 Drawing No. 11

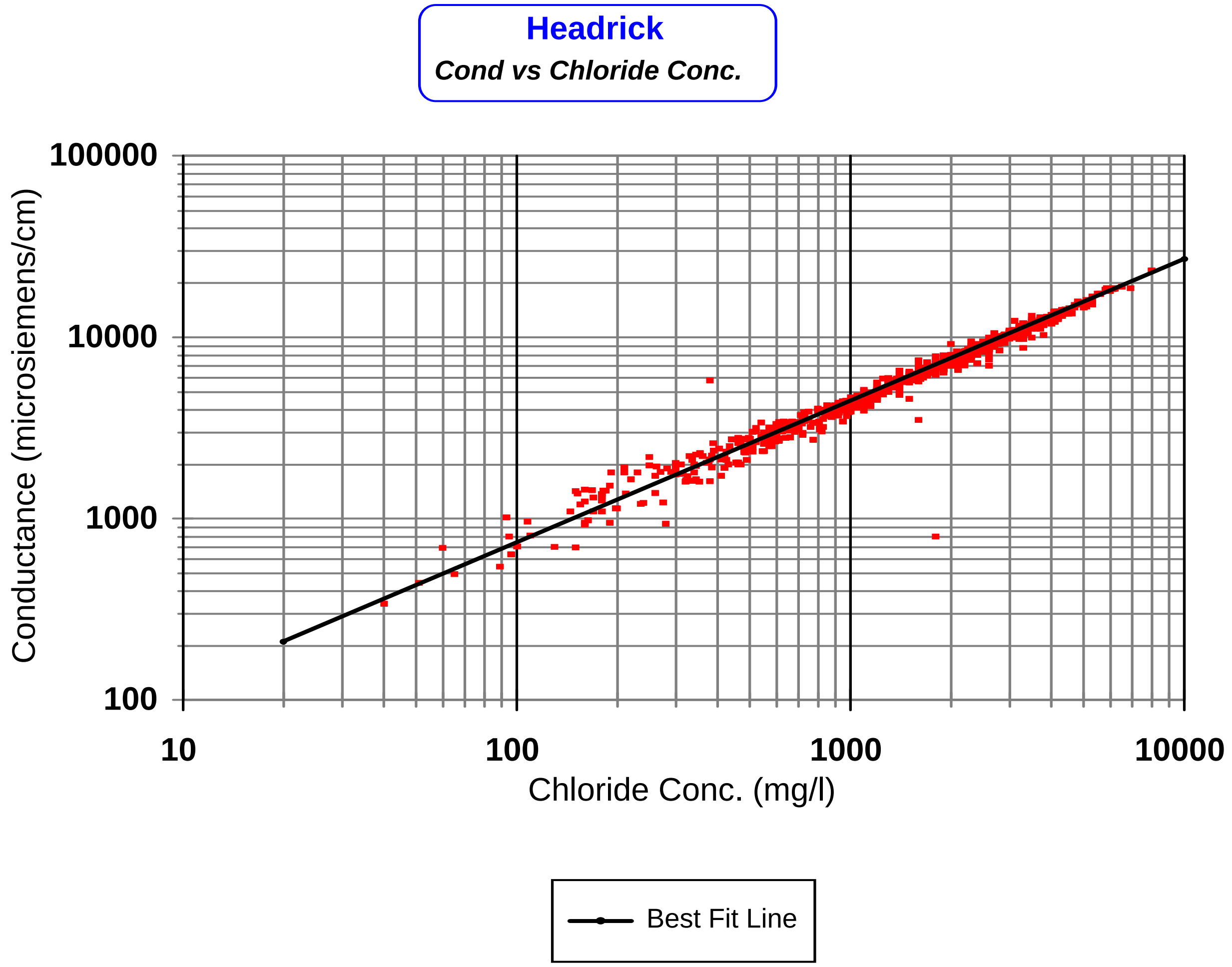


Red River Chloride Control Study
Area 6

Headrick Gage

Flow
vs.
Specific Conductance

Jun 9, 2008 Drawing No. 12

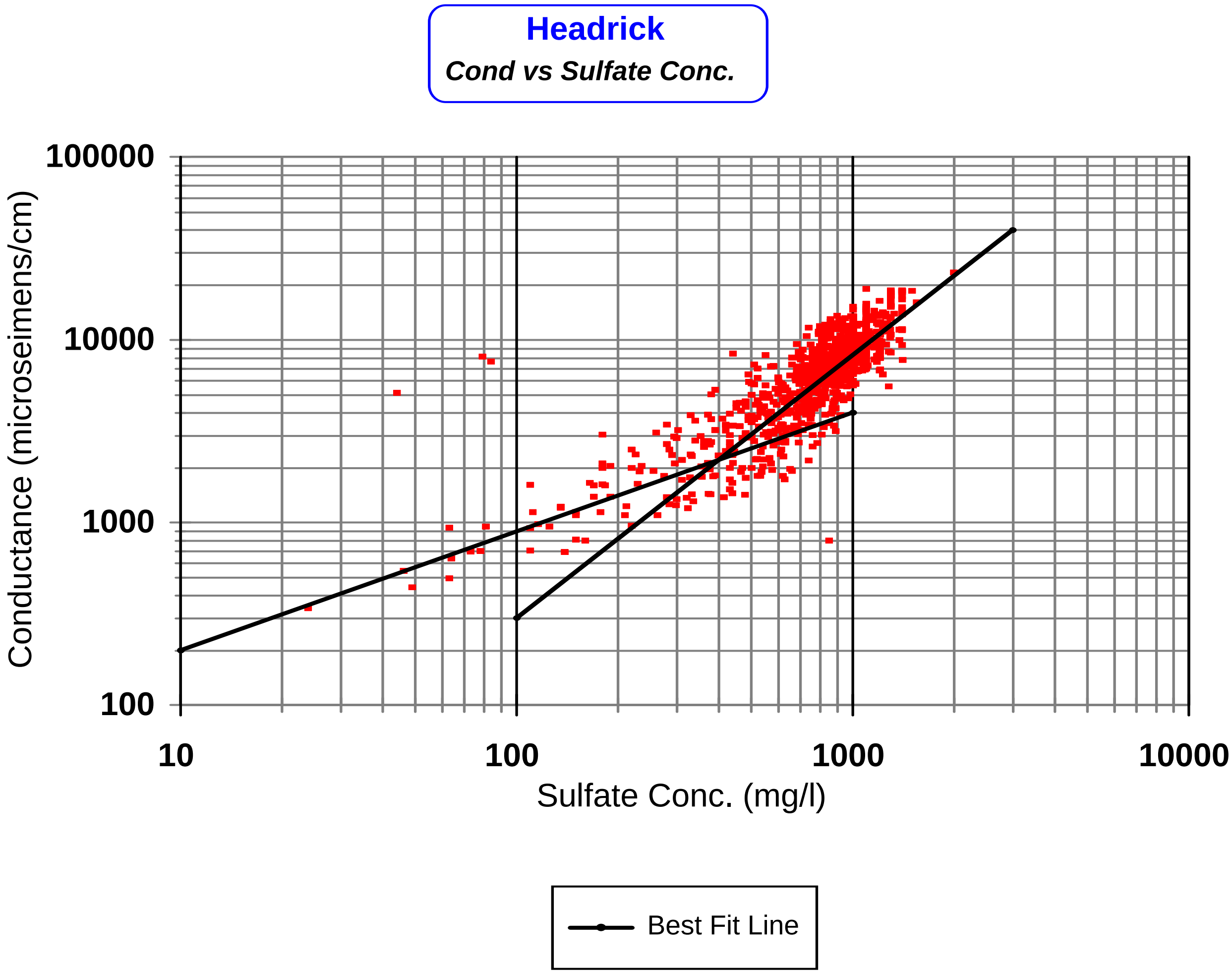


Red River Chloride Control Study
Area 6

Headrick Gage

Chloride Concentration
vs.
Specific Conductance

Jun 13, 2008 Drawing No. 13

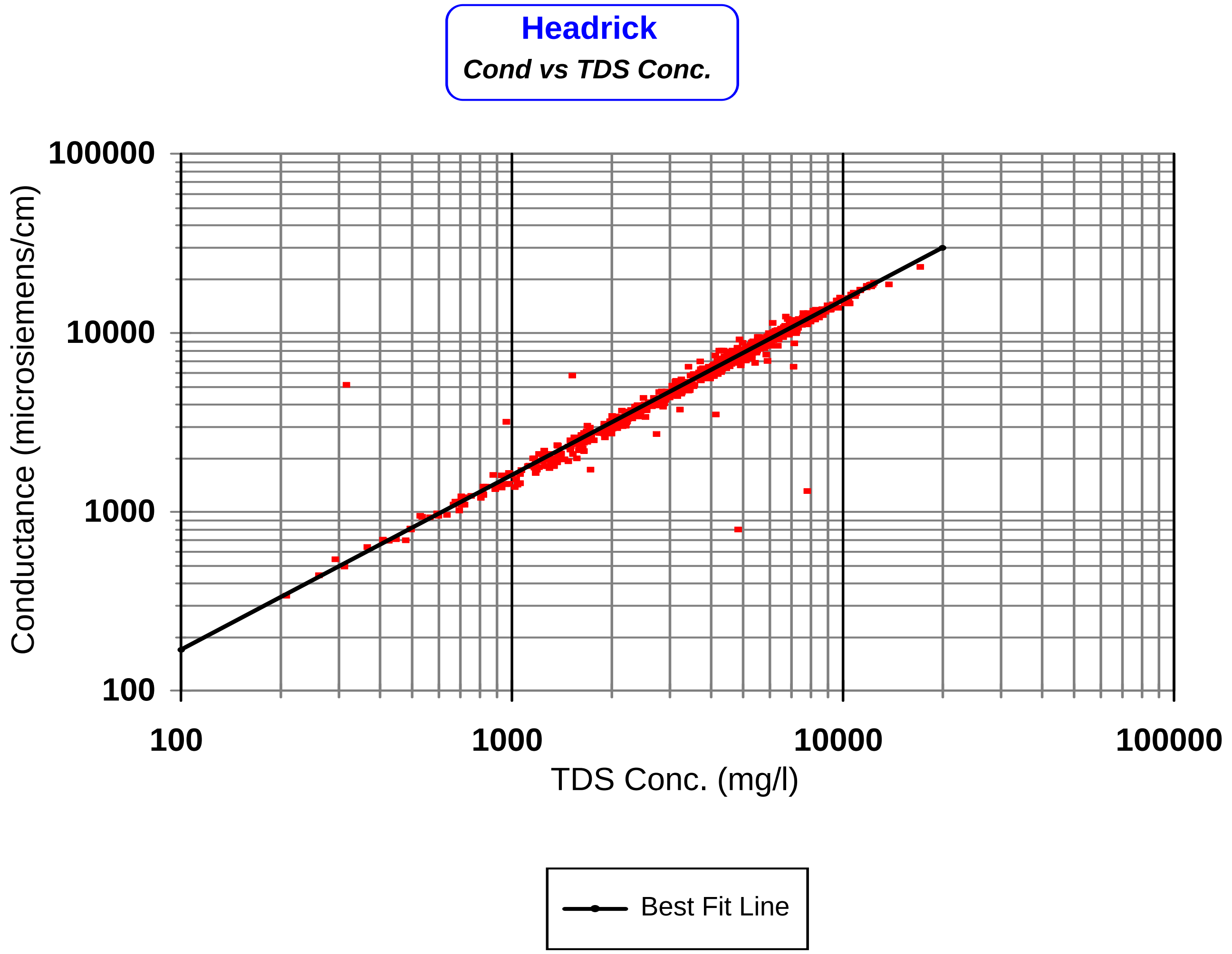


Red River Chloride Control Study
Area 6

Headrick Gage

Sulfate Concentration
vs.
Specific Conductance

Jun 13, 2008 Drawing No. 14

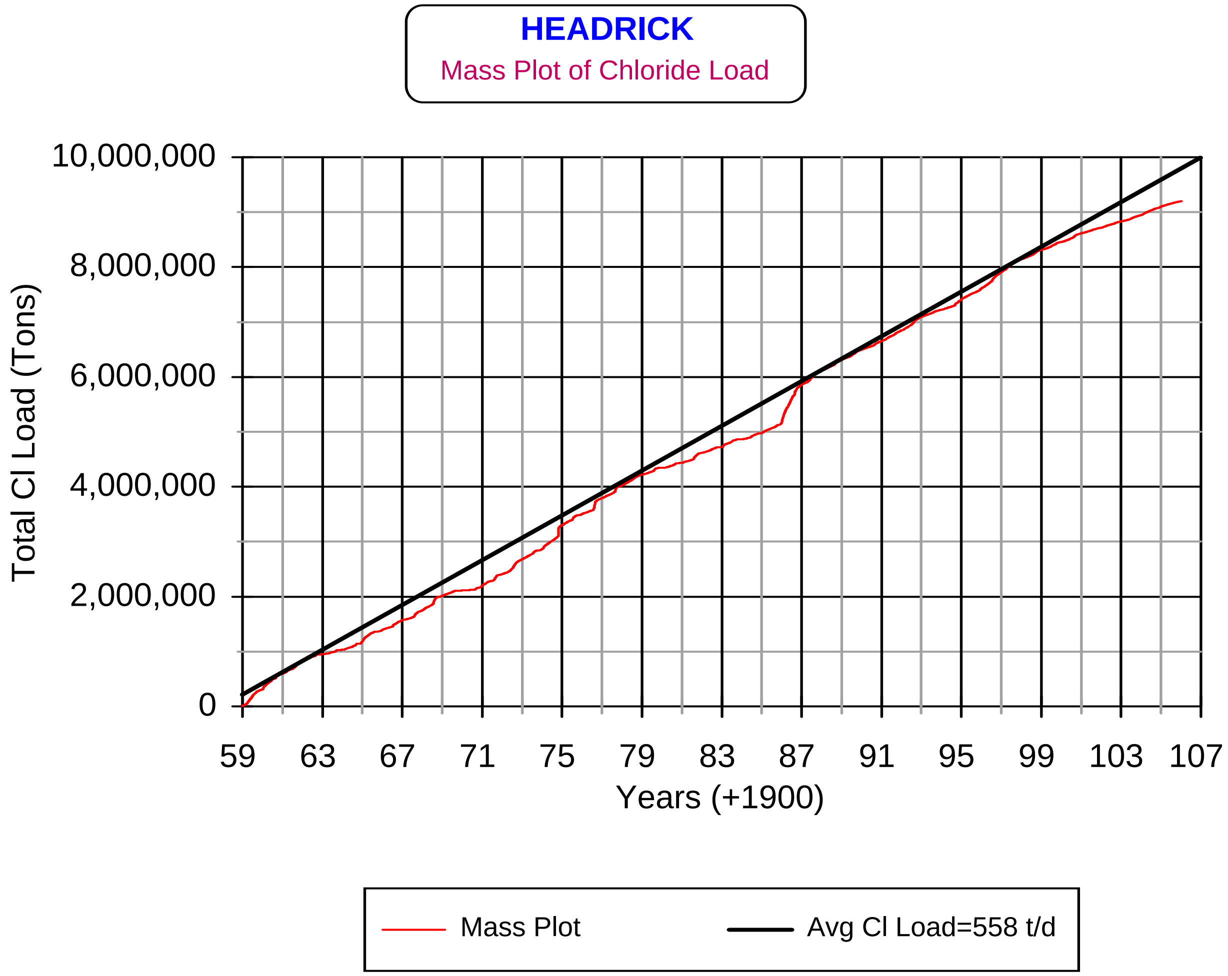


Red River Chloride Control Study
Area 6

Headrick Gage

TDS vs Specific Conductance

Jun 30, 2008 Drawing No. 15

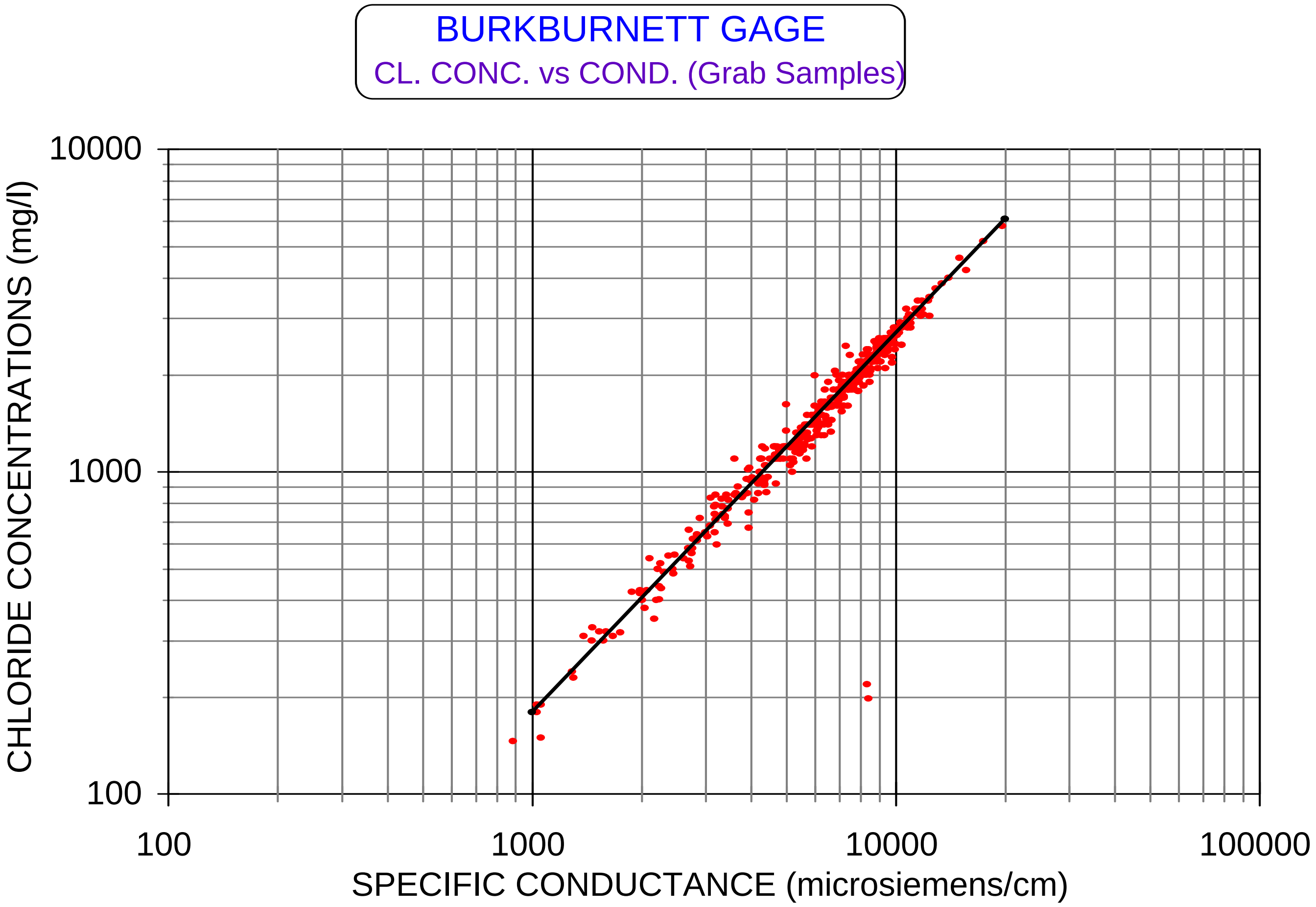


Red River Chloride Control Study
Area 6

Headrick Gage

Mass Plot of Chloride Loads

Jun 16, 2008 Drawing No. 16



Red River Chloride Control Study
Area 6

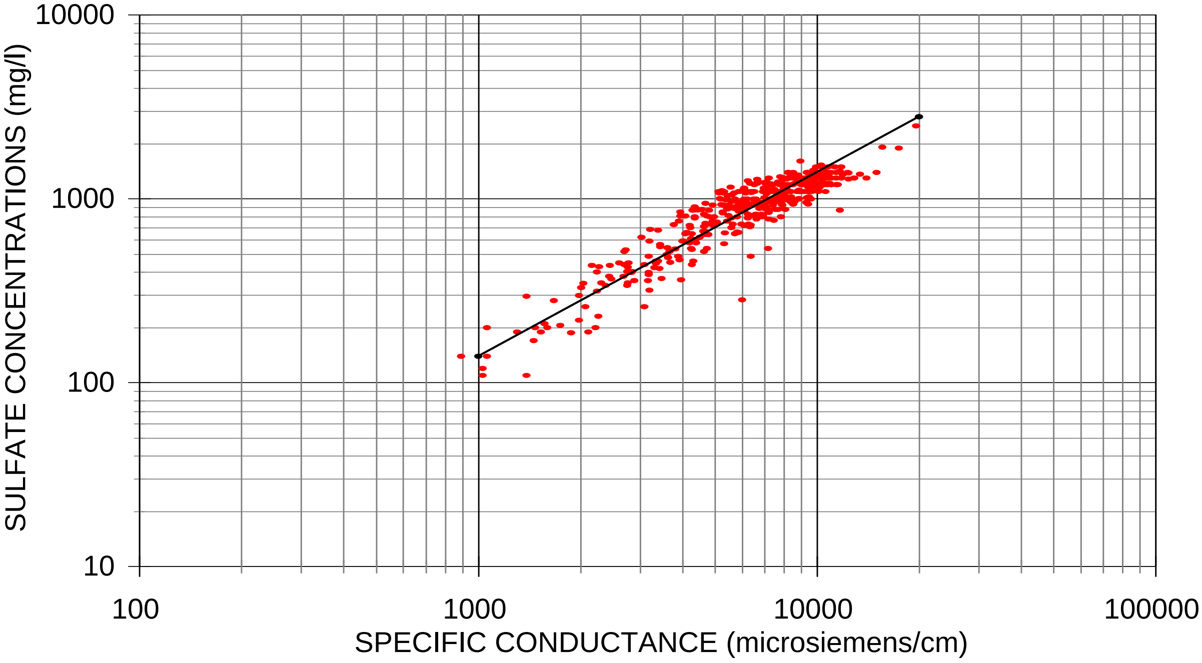
Burkburnett Gage

Chloride Concentration
vs.
Specific Conductance

Jun 8, 2010 Drawing No. 17

BURKBURNETT GAGE

SUL. CONC. vs COND. (Grab Samples)



Red River Chloride Control Study

Area 6

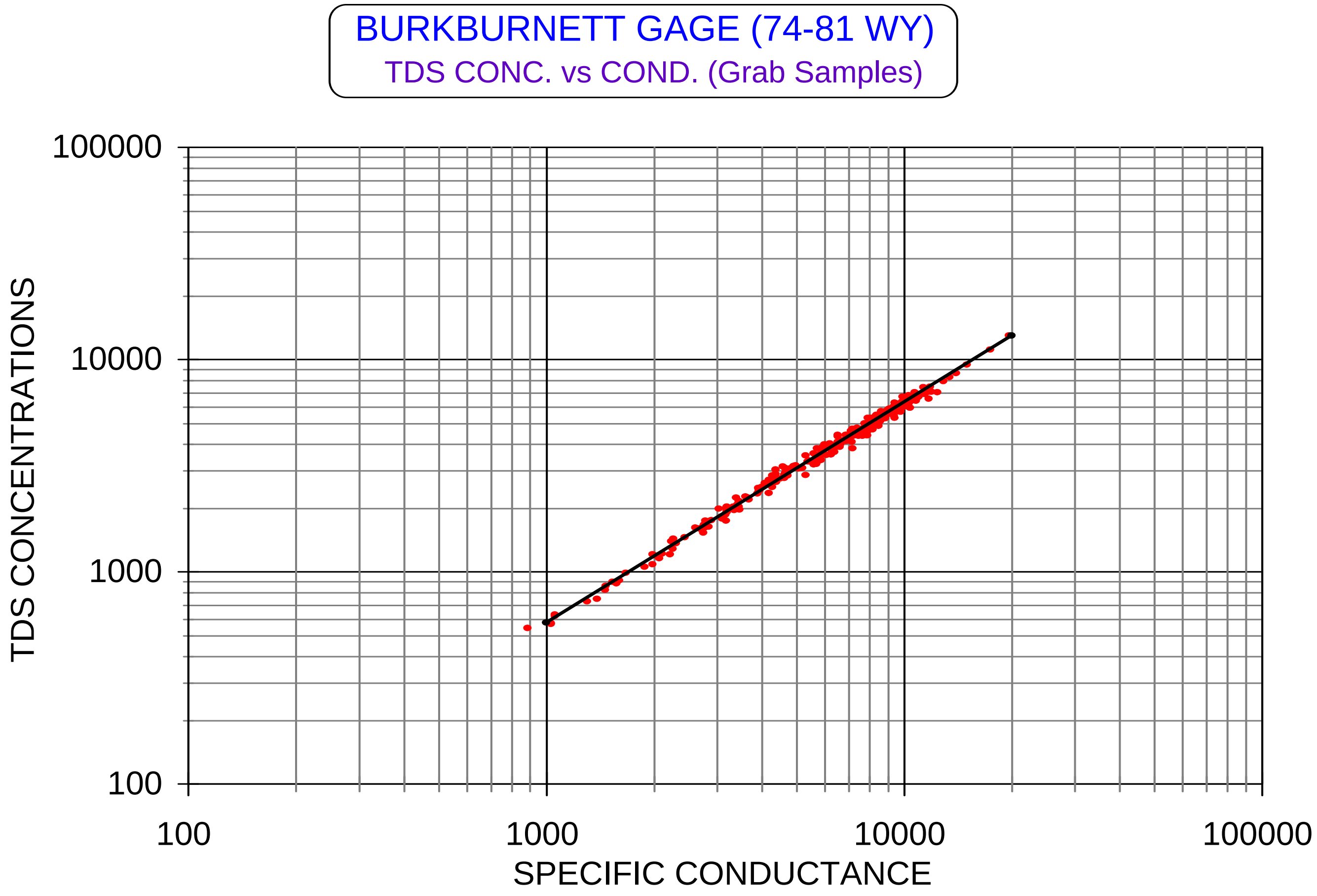
Burkburnett Gage

Sulfate Concentration

vs.

Specific Conductance

Jun 8, 2010 Drawing No. 18

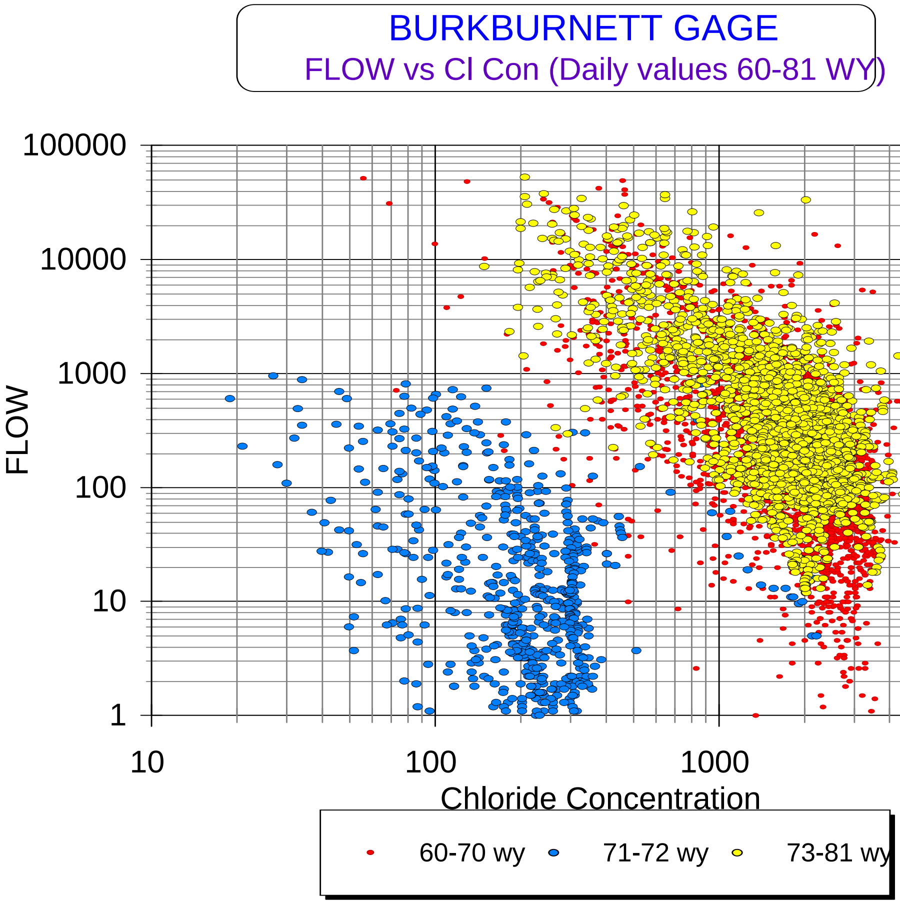


Red River Chloride Control Study
Area 6

Burkburnett Gage

TDS Concentration
vs.
Specific Conductance

Jun 8, 2010 Drawing No. 19

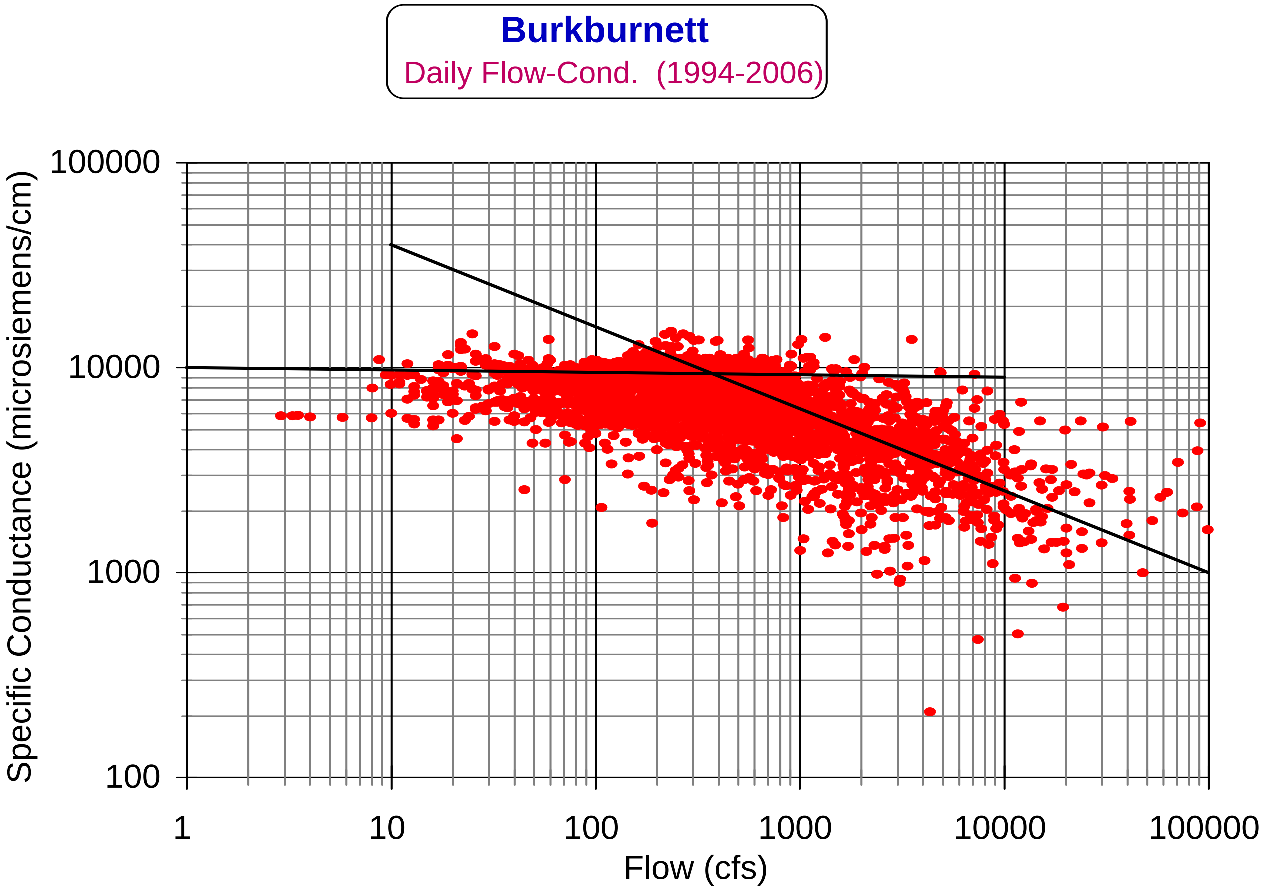


Red River Chloride Control Study
Area 6

Burkburnett Gage

Flow vs.
Chloride Concentration
(1960-1981 WY)

Jun 8, 2010 Drawing No. 20



Red River Chloride Control Study
Area 6

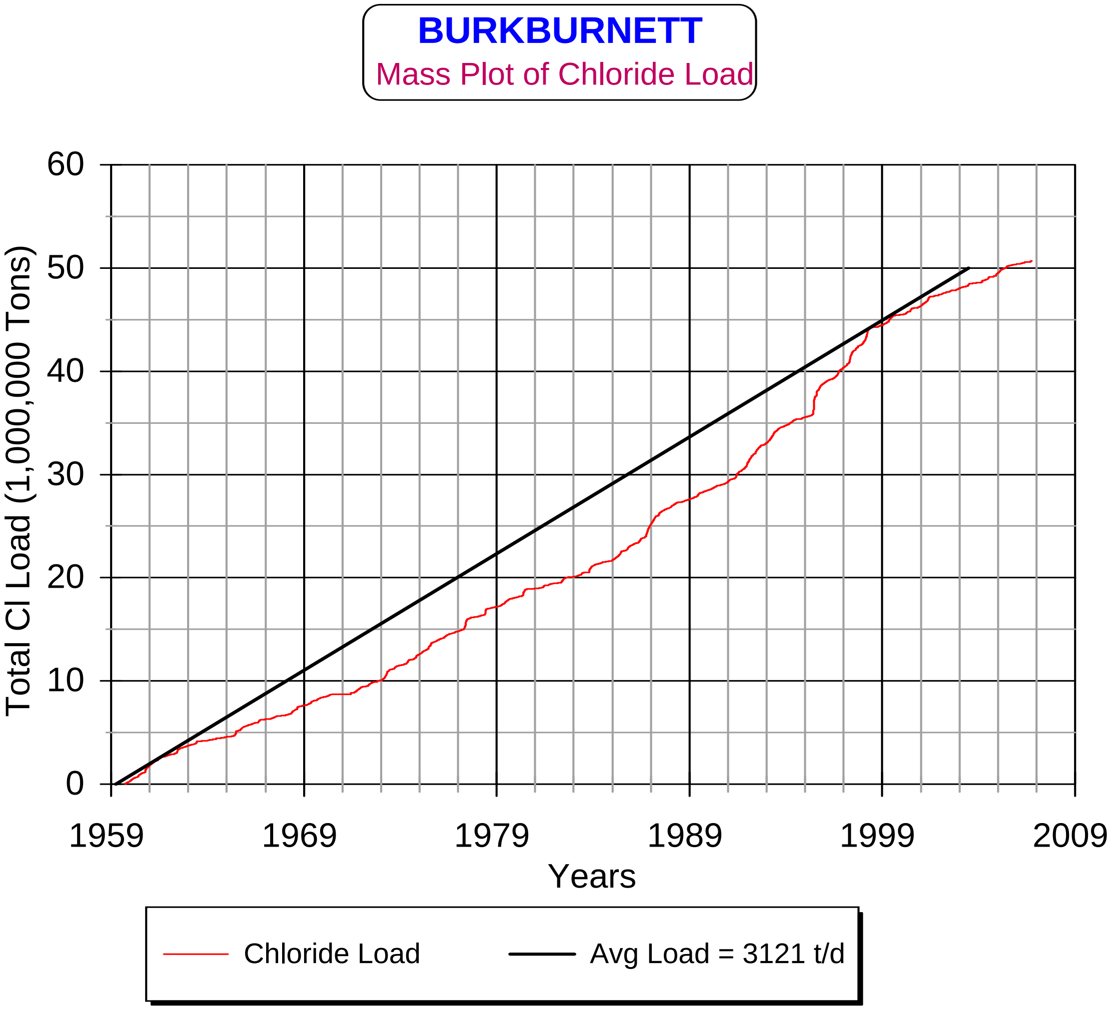
Burkburnett Gage

Flow vs.

Specific Conductance

(1995-2006 WY)

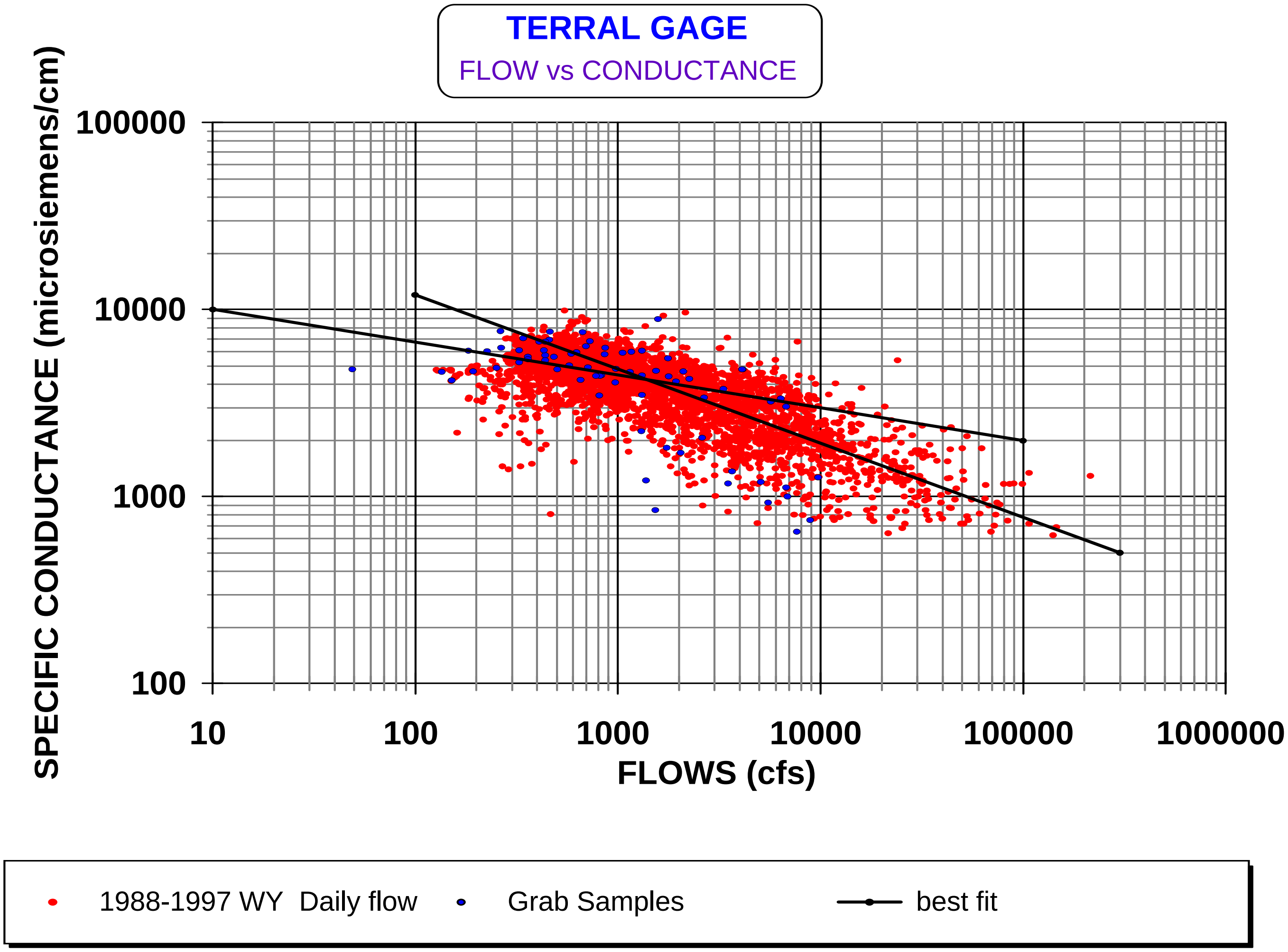
Jun 8, 2010 Drawing No. 21



Red River Chloride Control Study
Area 6

Burkburnett Gage
Mass Plot of Chloride Loads

Jun 10, 2010 Drawing No. 22



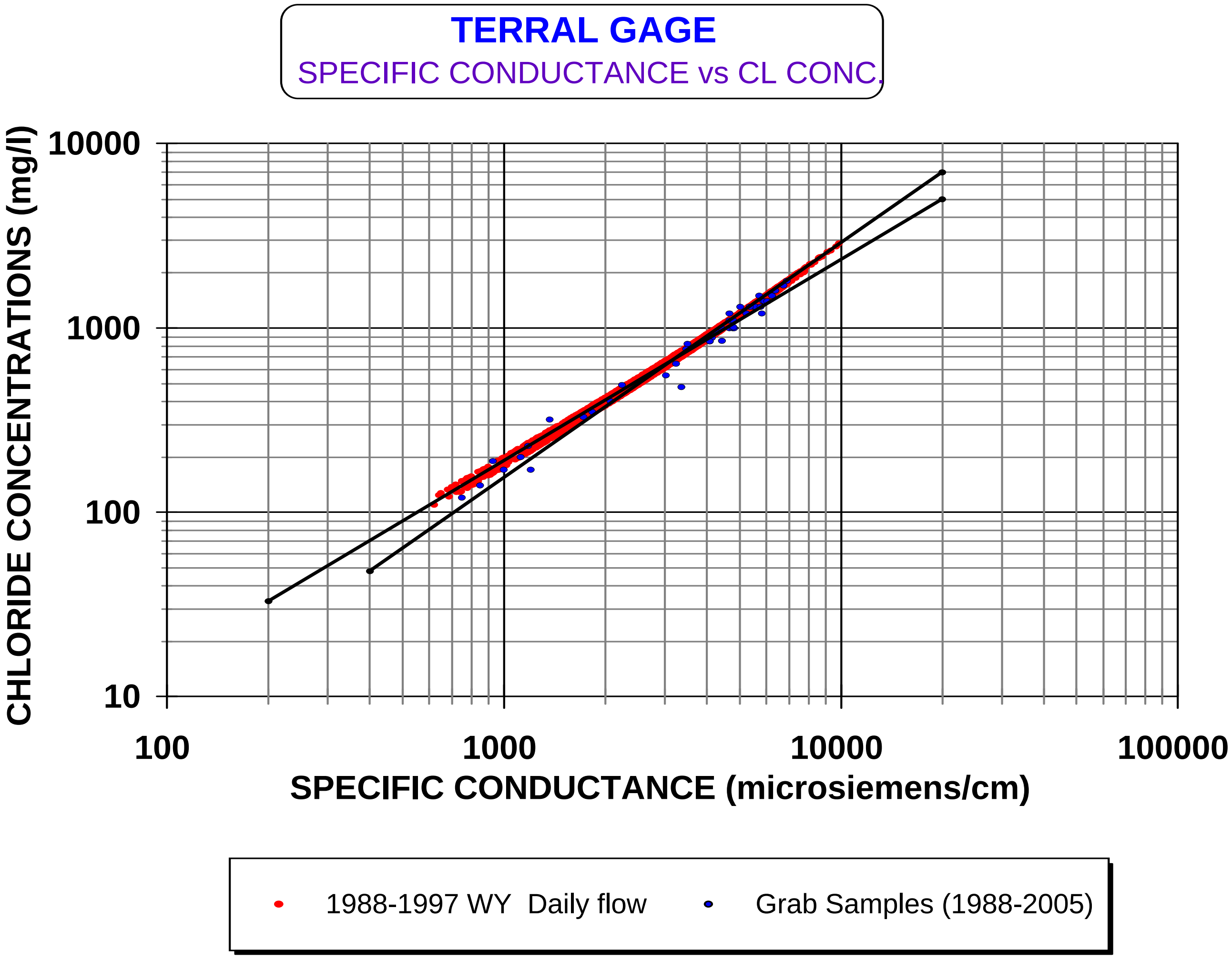
Red River Chloride Control Study
Area 6

Terral Gage

Flow vs.

Specific Conductance

Jun 10, 2010 Drawing No. 23

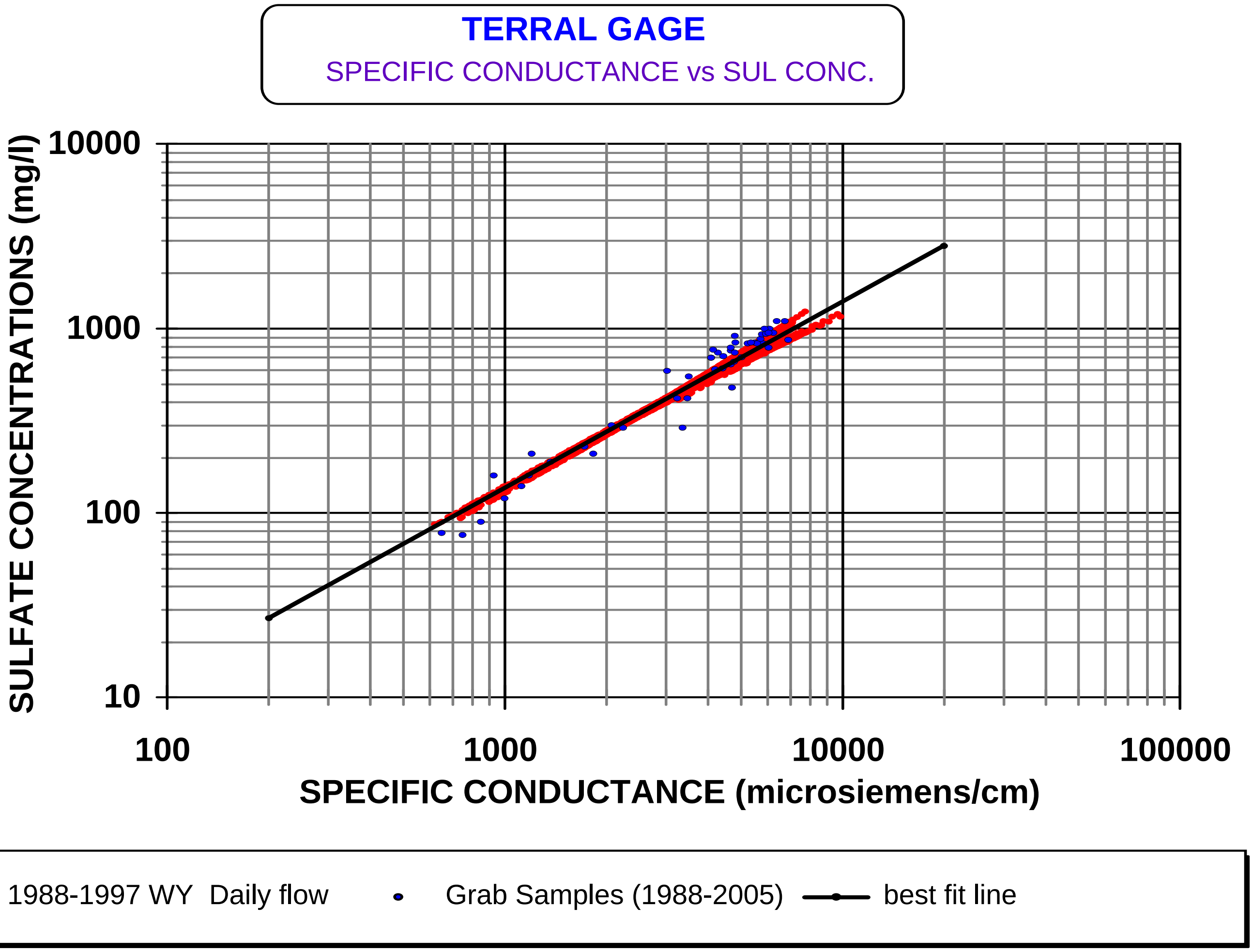


Red River Chloride Control Study
Area 6

Terral Gage

Chloride Concentration vs.
Specific Conductance

Jun 10, 2010 Drawing No. 24



Red River Chloride Control Study
Area 6

Terral Gage

Sulfate Concentration vs.
Specific Conductance

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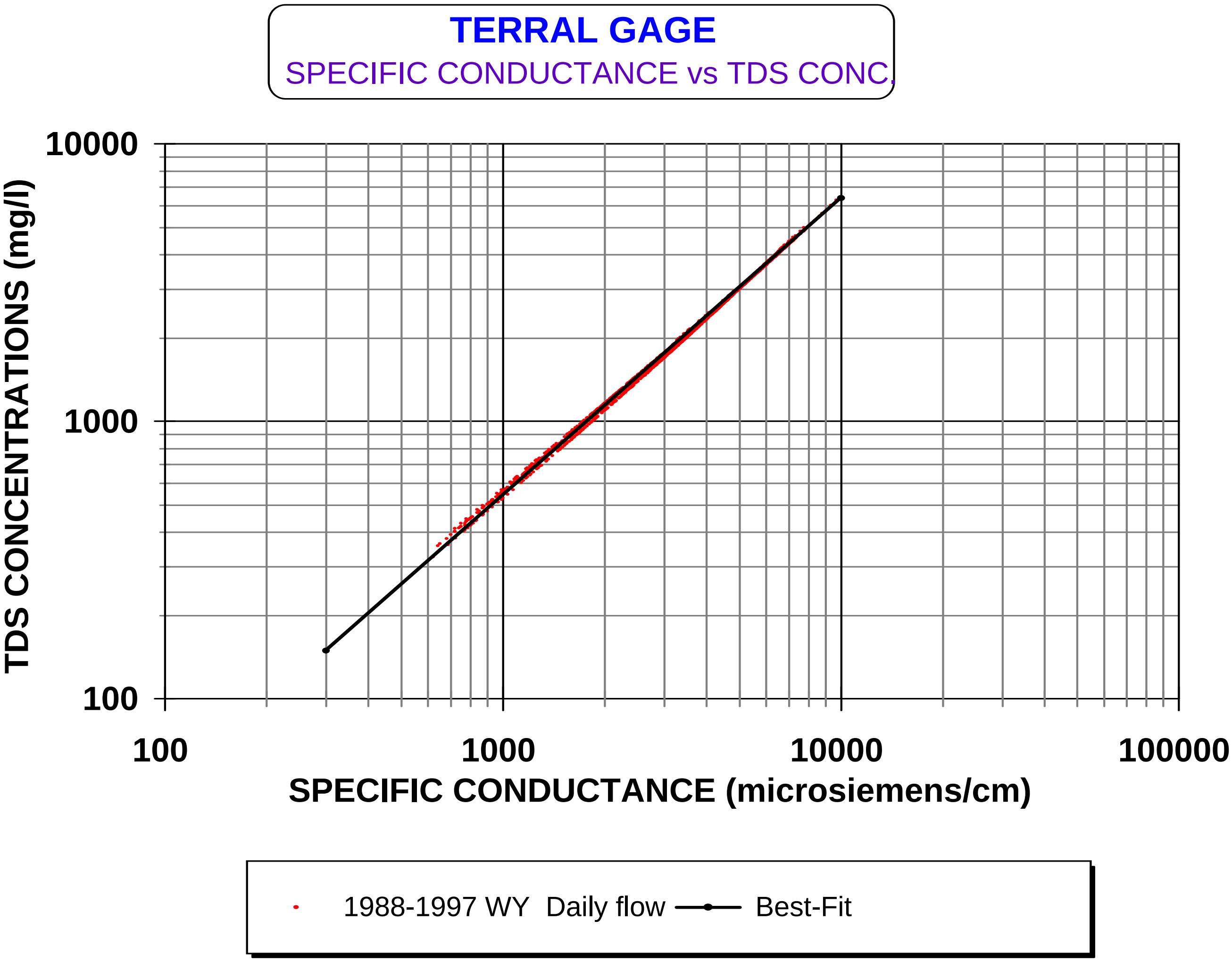
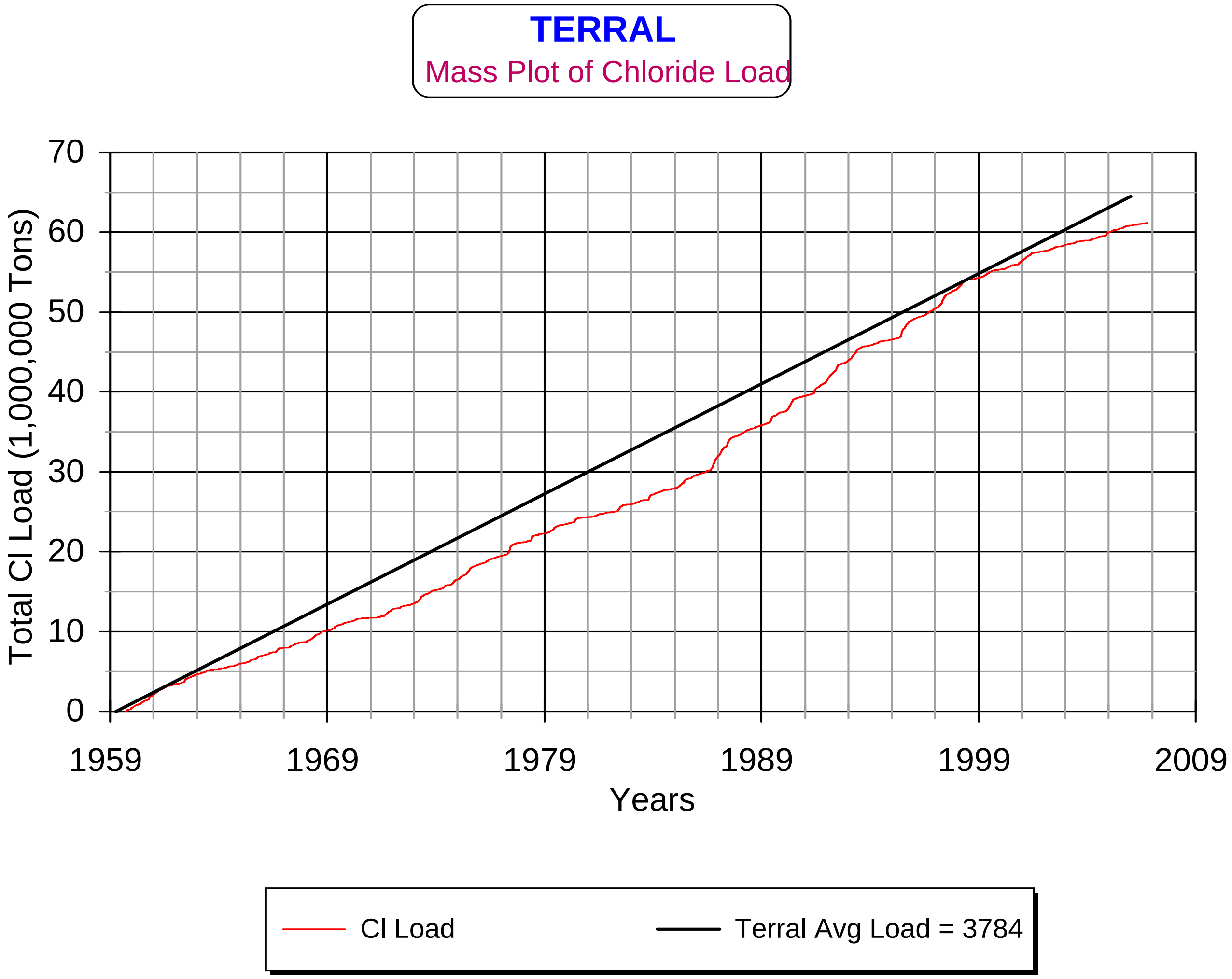


Red River Chloride Control Study
Area 6

Terral Gage

TDS Concentration vs.
Specific Conductance

Jun 10, 2010 Drawing No. 26

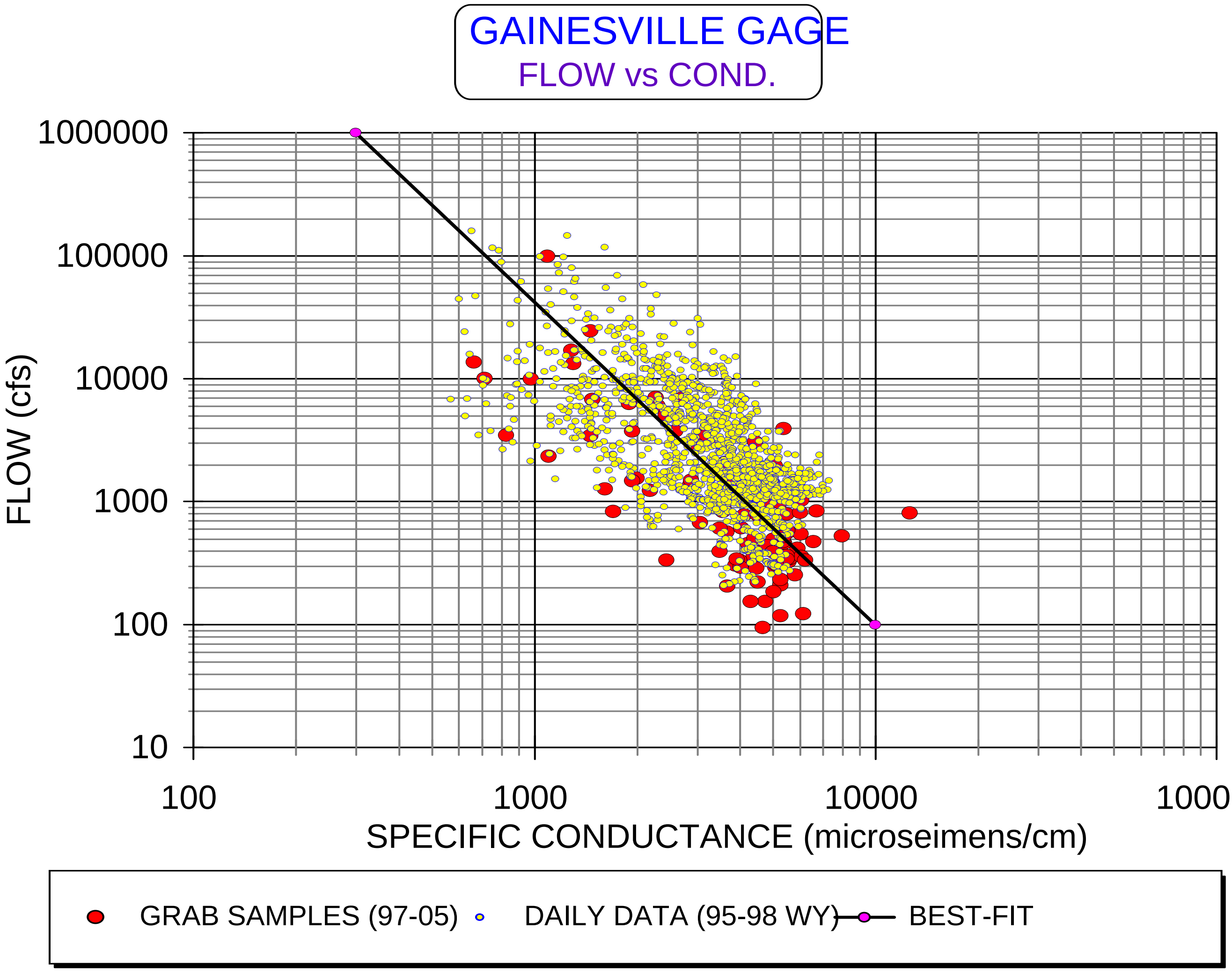


Red River Chloride Control Study
Area 6

Terral Gage

Mass Plot of Chloride Loads

Jun 10, 2010 Drawing No. 27

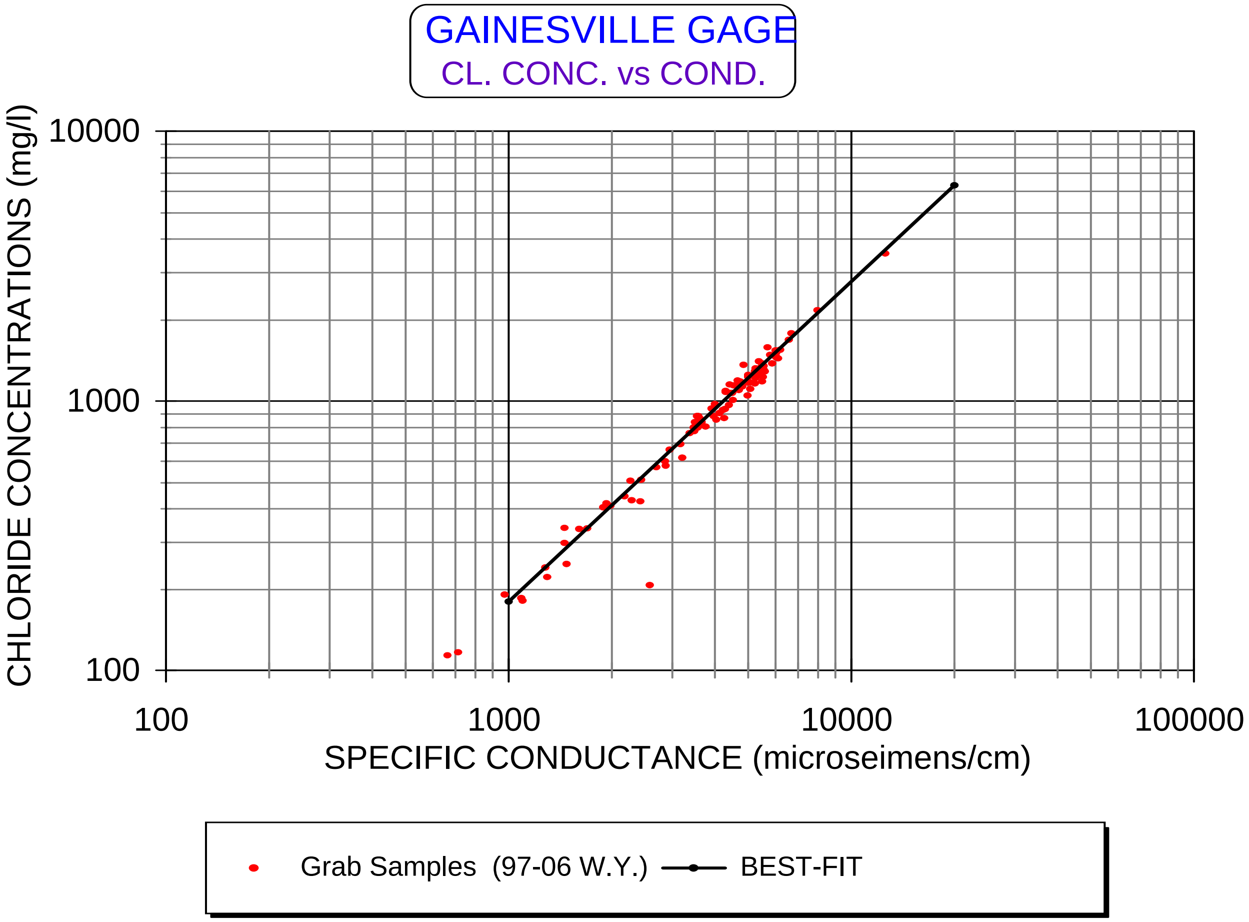


Red River Chloride Control Study
Area 6

Gainesville Gage

Flow vs
Specific Conductance

Jun 13, 2010 Drawing No. 28

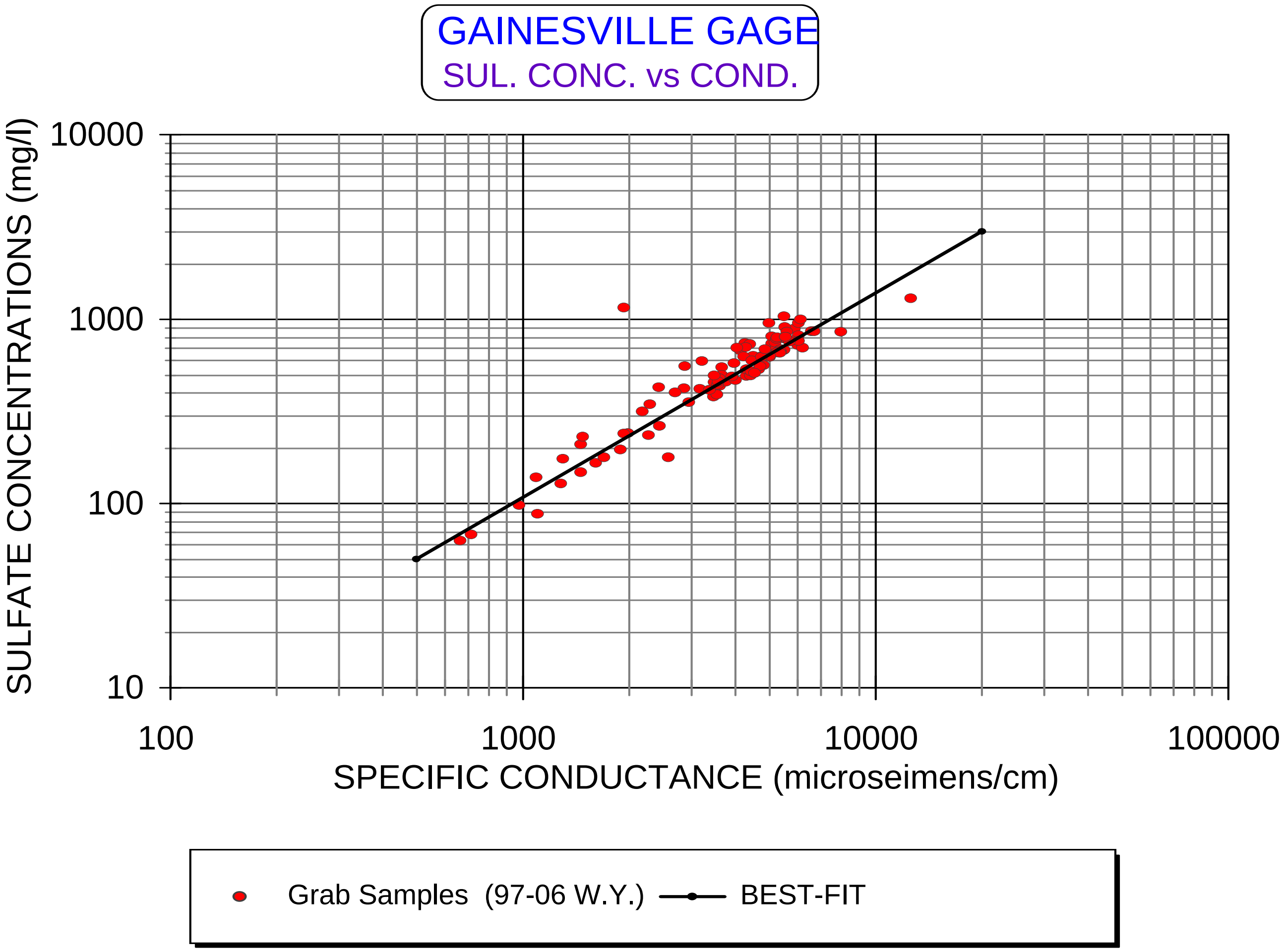


Red River Chloride Control Study
Area 6

Gainesville Gage

Chloride Concentration vs
Specific Conductance

Jun 13, 2010 Drawing No. 29

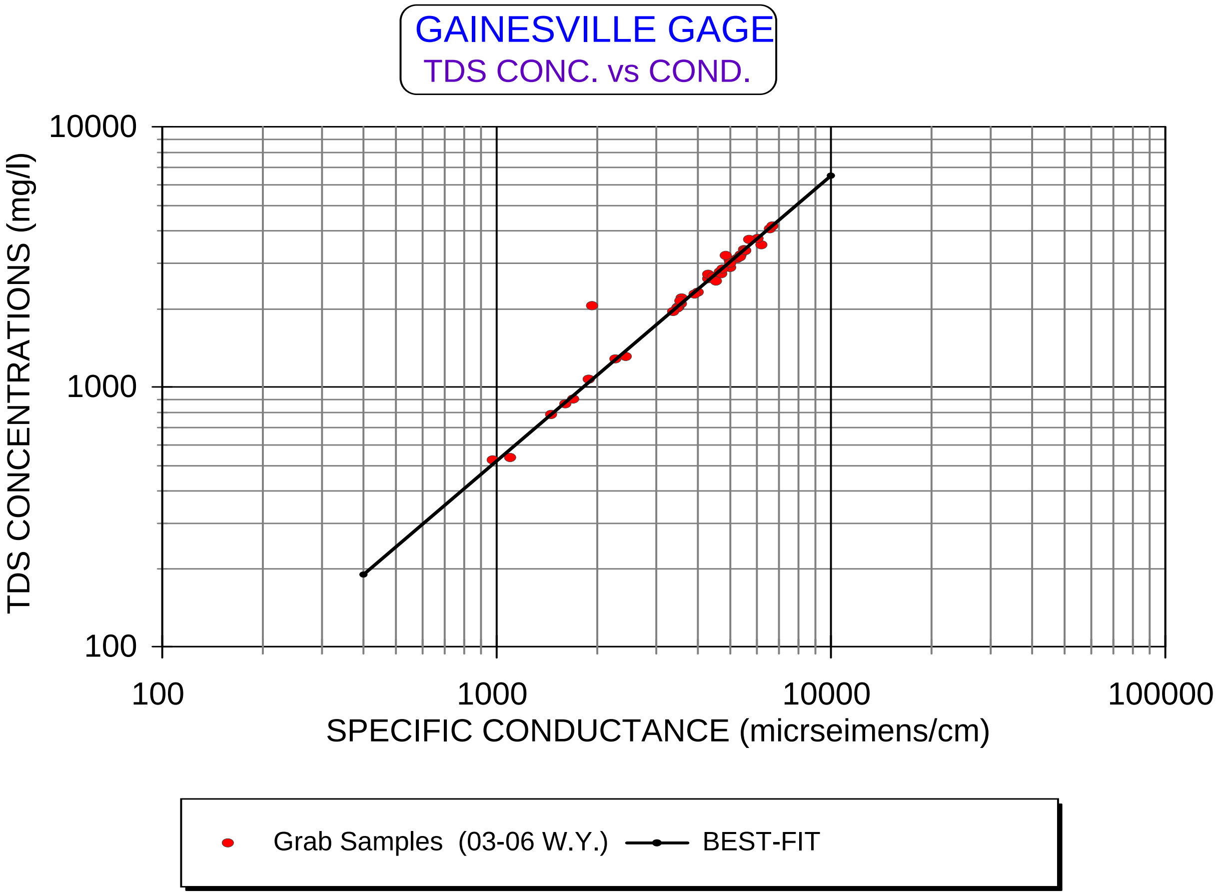


Red River Chloride Control Study
Area 6

Gainesville Gage

Sulfate Concentration vs
Specific Conductance

Jun 13, 2010 Drawing No. 30

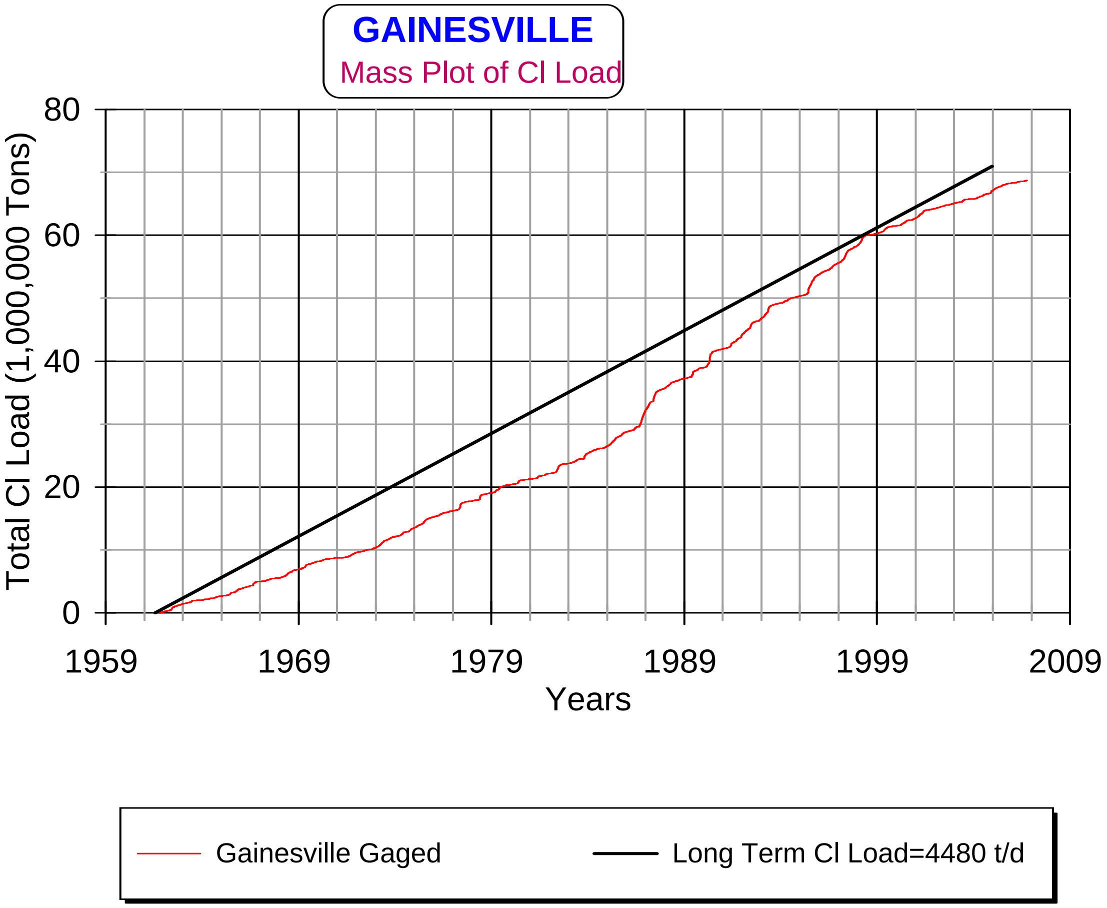


Red River Chloride Control Study
Area 6

Gainesville Gage

TDS Concentration vs
Specific Conductance

Jun 13, 2010 Drawing No. 31

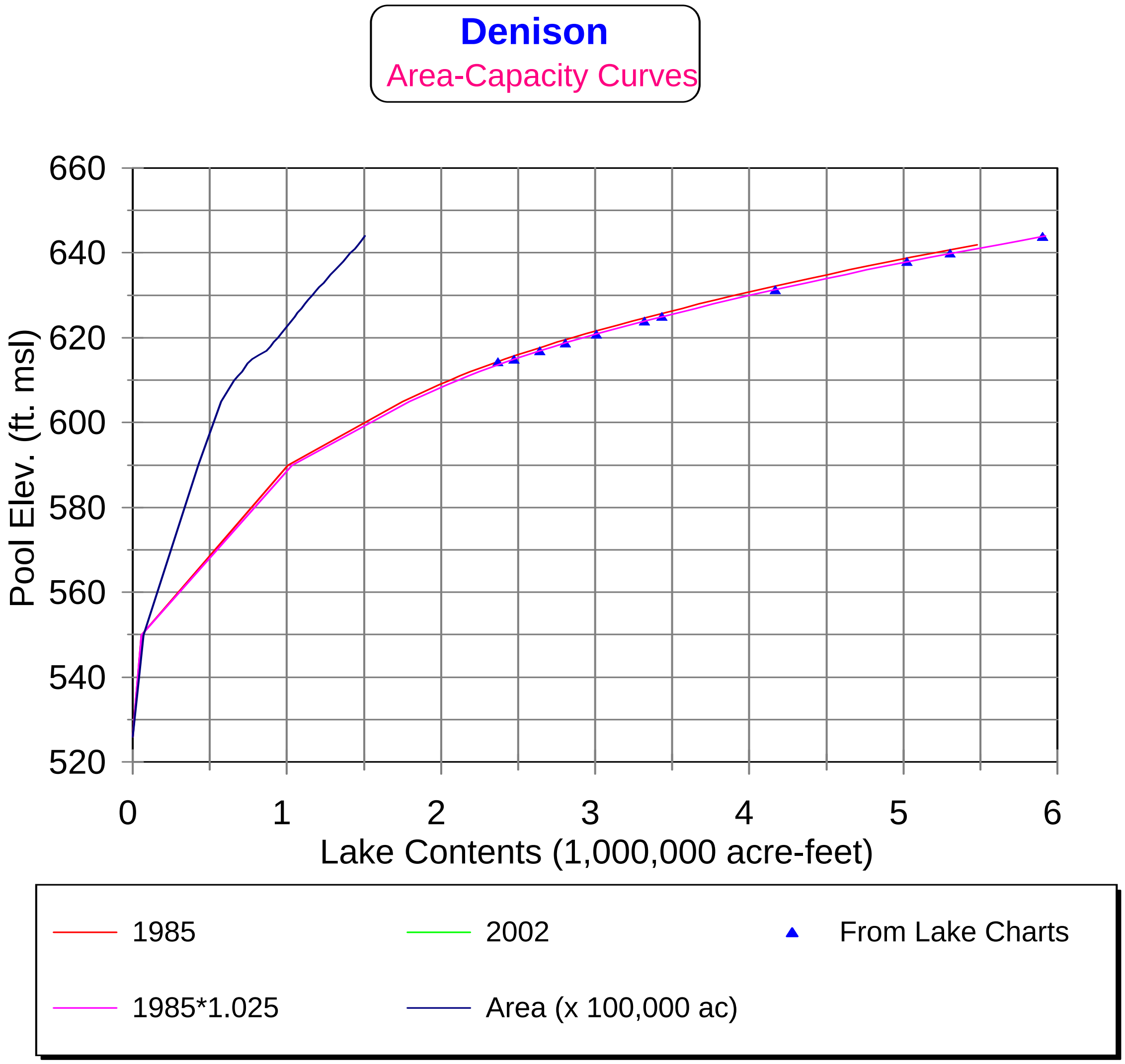


Red River Chloride Control Study
Area 6

Gainesville Gage

Mass Plot of Chloride Loads

Jun 13, 2010 Drawing No. 32

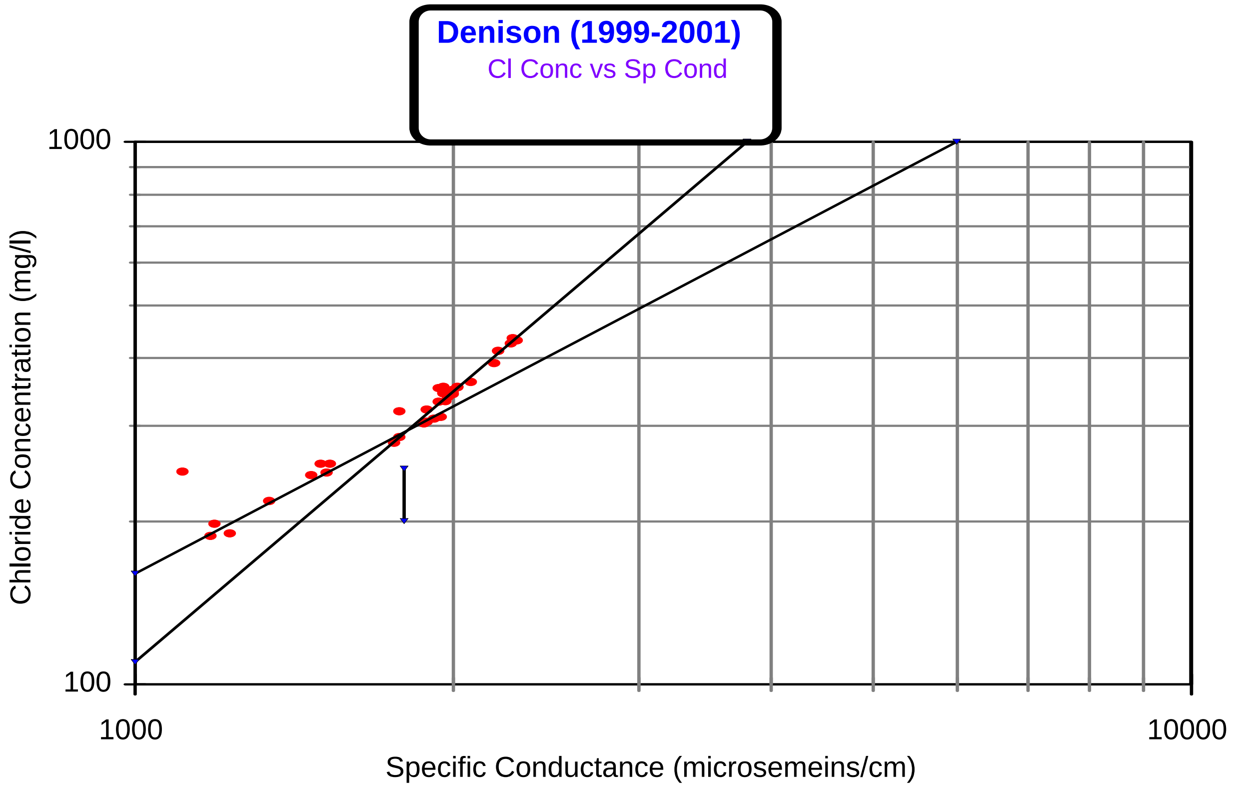


Red River Chloride Control Study
Area 6

Lake Texoma

Area-Capacity Curve

Jun 14, 2010 Drawing No. 33

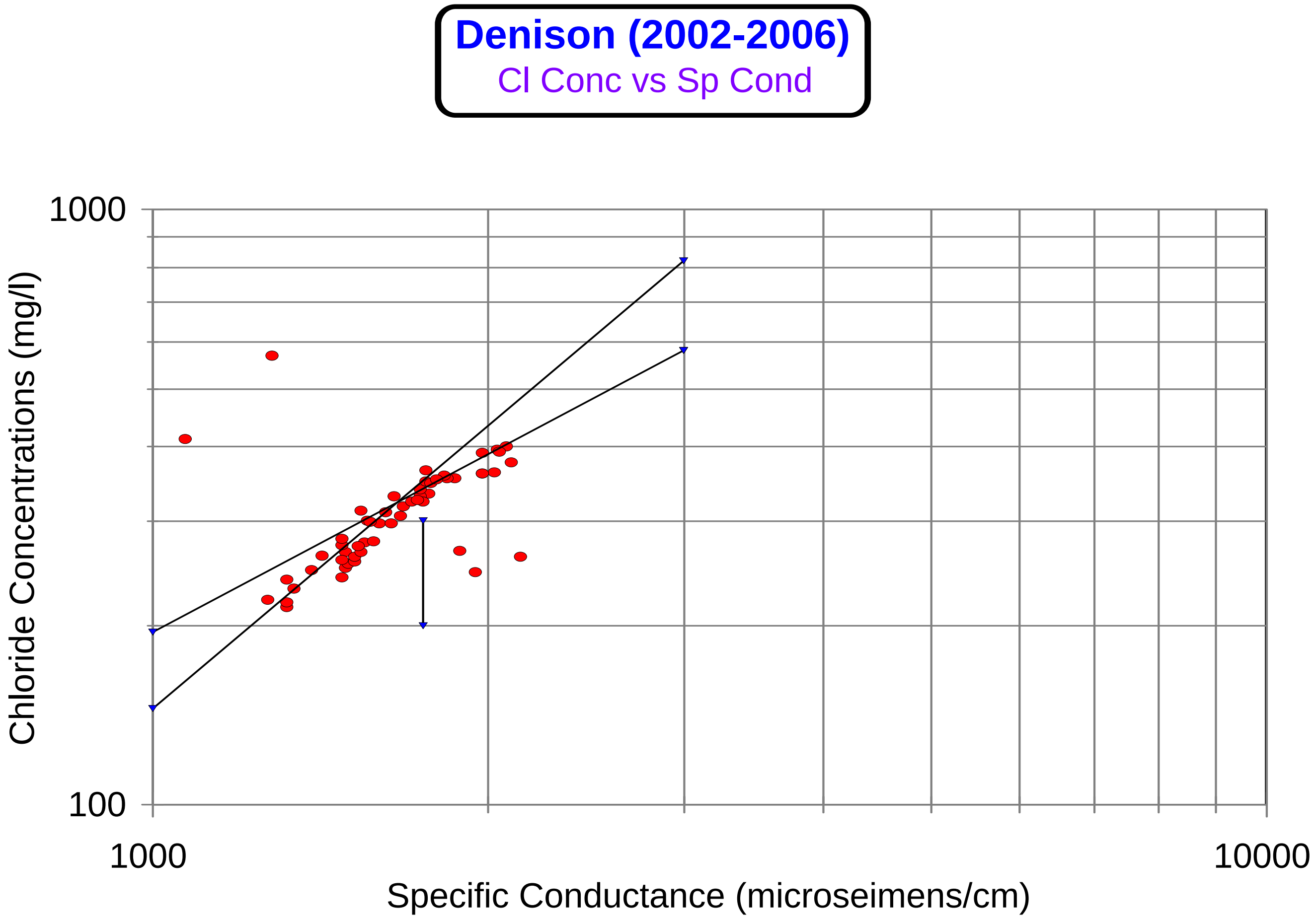


Red River Chloride Control Study
Area 6

Denison Gage

1999-2001 W.Y.
Chloride Concentration vs.
Specific Conductance

Jun 16, 2010 Drawing No. 34



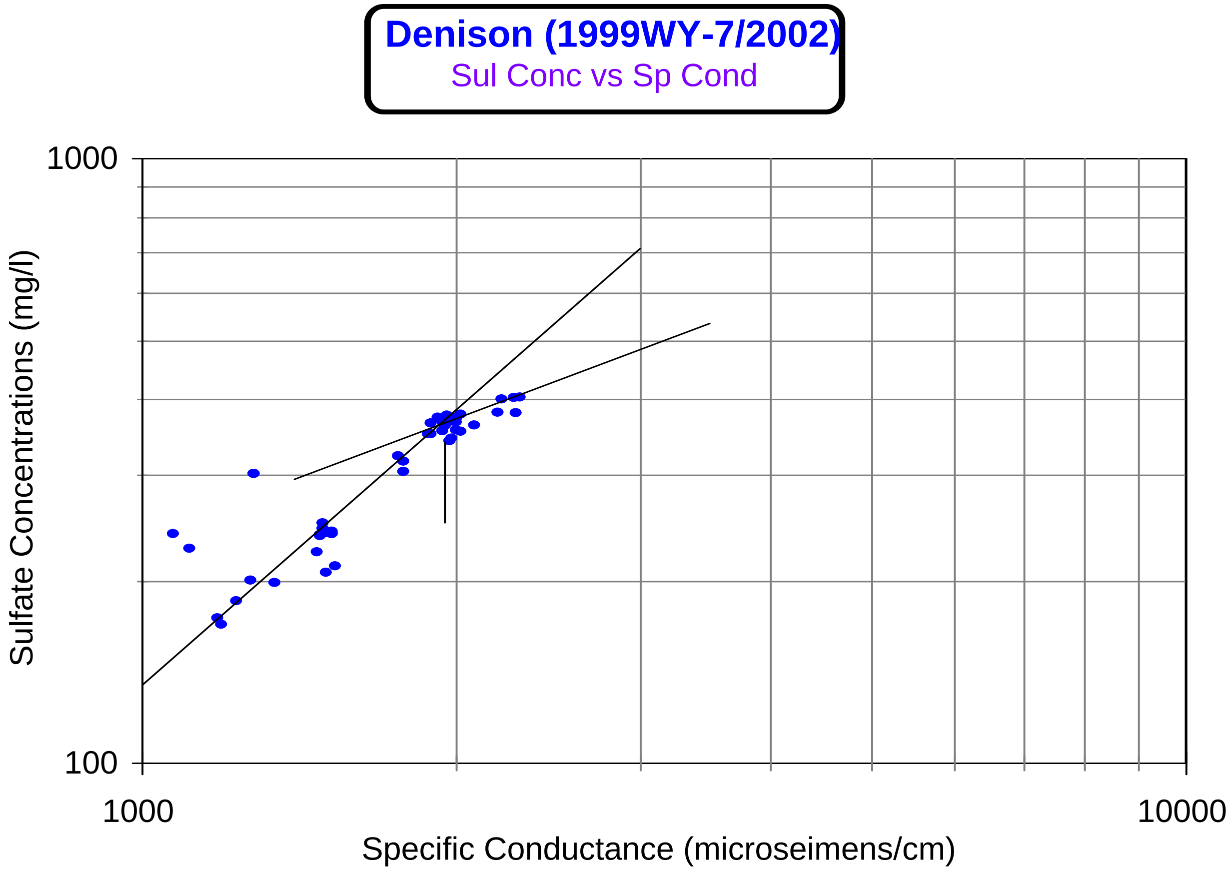
Red River Chloride Control Study
Area 6

Denison Gage

2002-2006 W.Y.

Chloride Concentration vs.
Specific Conductance

Jun 16, 2010 Drawing No. 35



Red River Chloride Control Study
Area 6

Denison Gage

1999-2001 W.Y.
Sulfate Concentration vs.
Specific Conductance

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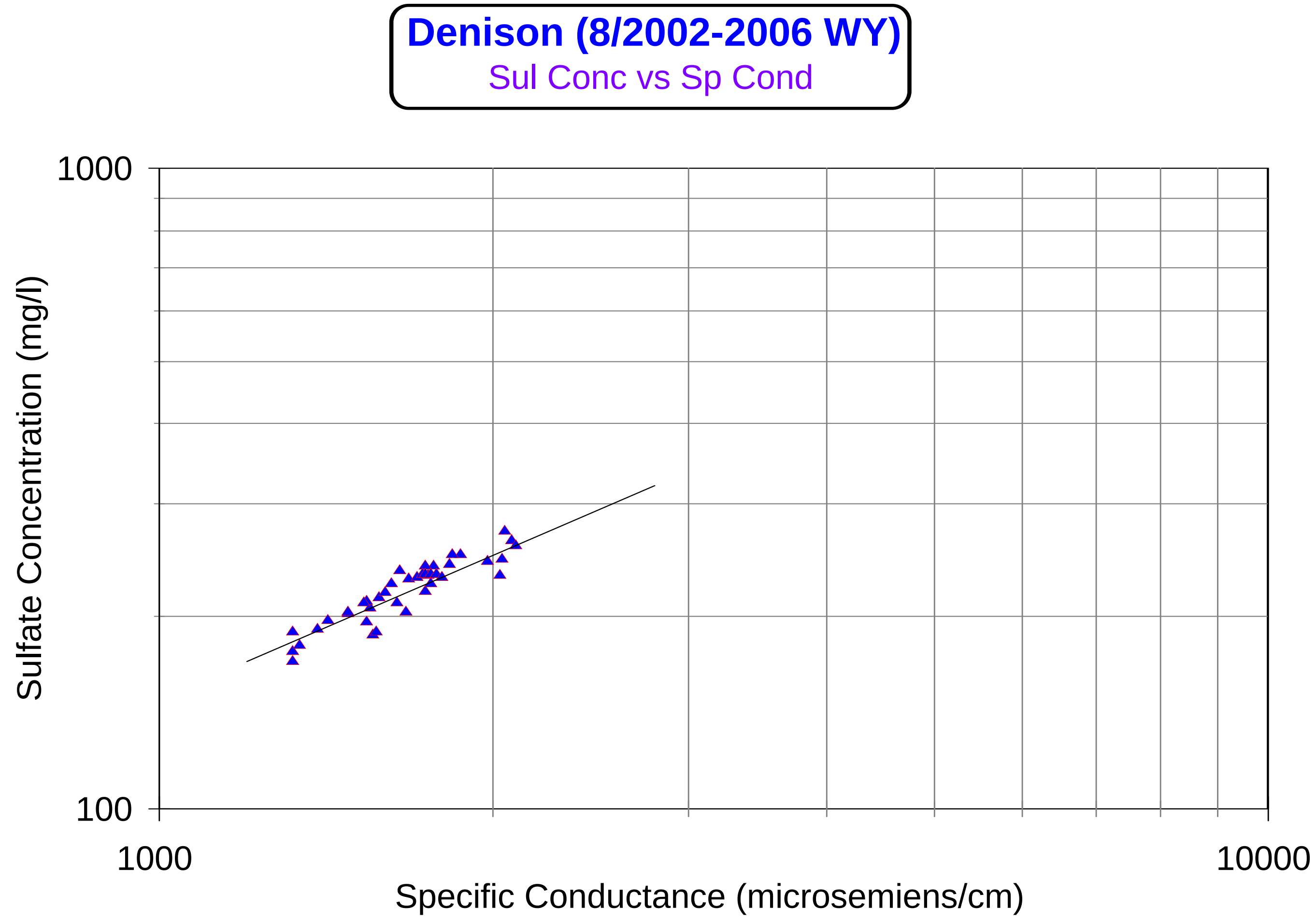
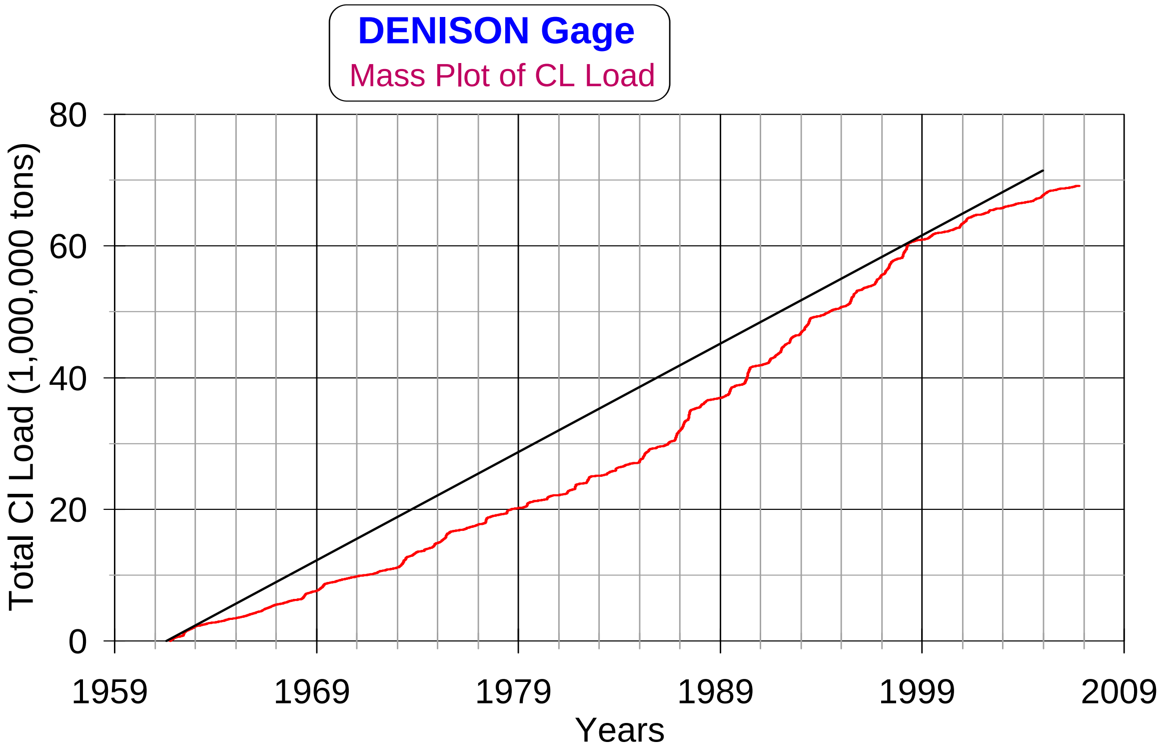


Red River Chloride Control Study
Area 6

Denison Gage

Aug 2002-2006 W.Y.
Sulfate Concentration vs.
Specific Conductance

Jun 17, 2010 Drawing No. 37



— Denison Gage

— Denison Avg Cl Load = 4515

Red River Chloride Control Study
Area 6

Denison Gage

Mass Plot of Chloride Loads

Jun 17, 2010

Drawing No. 38

Appendix B

CABLE MOUNTAIN RESERVOIR STUDY

TABLE OF CONTENTS

Section **Page No.**

TABLE INDEX

Table Page No.

PLATE INDEX

Plate No. Page No.

Cable Mountain Reservoir Study

Information from BOR report "Water Augmentation, W.C. Austin Project, March 2005"

- Approximate Location of the Dam site.
- Estimated Top-of -Dam Elevation: 1430 feet mean sea level (msl).
- Estimated Conservation plus inactive storage: 342,000 acre-feet.
- Estimated Top-of-Conservation Pool Area: 11,000 acres.
- Estimated Water Supply Yield: 100,000-120,000 acre-feet/year.

Cable Mountain Elevation-Area-Capacity Data

Using ArcMap and USGS digital elevation model data, a dam axis was chosen at the approximate location mentioned in the BOR report. The USGS DEM data used in this analysis had a 10-meter grid size resolution. This was considered adequate accuracy to obtain an estimate of Cable Mountain capacity. As mentioned earlier, a feasibility level study has not been performed for Cable Mountain. A clipped polygon shape file was created at the dam axis at the top of dam elevation. The shape file and all associated digital elevation model data and attributes were viewed in ArcCatalog. Microsoft Access and Excel were used to tabulate the shape file data. Table 7, located at the end of this section, presents the elevation/area/capacity data generated using this method. Please note that Table 7 contains area and capacity data from the streambed elevation to the proposed top of dam elevation.

Monthly Inflows

Period of record flow data at the Headrick gage on the North Fork of the Red River were used as inflows in the Cable Mountain yield analysis. Daily average flows for the period of record WY 59 – 06 were used to generate monthly total inflows. The monthly inflows for the period of record are presented as Table 8. The period of record used in this study did not include the POR drought for the area (1950-57) but did include the second most severe drought for the area (1963-1967). The purpose of this study was to verify BOR yield estimates.

Monthly Evaporation Data

Daily and monthly evaporation data were available for Lake Altus and Tom Steed Lake for portions of the period of record. When data was not available, historical monthly averages from both sites were used. National Climatic Data Center (NCDC) evaporation data were used for WY59 - 76. Table 1 presents the monthly evaporation data used in this study for the period of record.

Rainfall data was available at several sites in the area. USACE monthly charts for Lake Altus had the most consistent record of daily and monthly rainfall data. Table 10 shows the monthly rainfall values used.

Downstream Releases and Irrigation Withdrawals:

Water quality releases estimates were based on a 7-day volume, 2 year frequency data for the Headrick gage presented in the USGS Water Investigation Report 2002-4025, "Statistical

Summaries of Streamflow in Oklahoma Through 1999" by Robert Tortorelli, 2002. Water right releases were estimated. Irrigation withdrawals for Cable Mountain were based on average irrigation releases from Altus Lake for 2001-2008. These withdrawals were used as a starting point for each yield evaluation. One acre-foot withdrawals were used for non-irrigation months to satisfy the program. The estimated monthly withdrawals for water quality, water rights, and irrigation used in the Cable Mountain yield study are listed in Table 2.

Table 2
Withdrawal Schedule for Cable Mountain Lake

	Releases/Withdrawals (cfs)											
Type of Release	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Water Quality (cfs)	7	7	7	7	7	7	7	7	7	7	7	7
Water Rights (cfs)	0	0	0	0	0	3	3	3	3	3	0	0
Water Supply/Irrigation (A.F)	1	1	1	1	1	1760	11650	11350	1210	1	1	1

Cable Mountain Drainage Area

Lake Altus makes very few downstream releases due to the drawdown experienced during irrigation seasons. The drainage area above Lake Altus was considered non-contributing to Cable. Drainage area for Cable Mountain was estimated by subtracting the Lake Altus drainage area from the total drainage area at the Headrick gage. Table 3 presents the drainage areas.

Table 3
Drainage Areas

Location	Drainage Area (Sq. Mi.)
Headrick Gage	3845
Altus Lake	2116
Cable Mountain Res.	1729

Cable Mountain Sedimentation Rate

The sedimentation rate for Cable Mountain was estimated from the Lake Altus annual sediment rates. The Lake Altus annual sedimentation rate was determined by calculating the total loss in storage during the life of the project. The total loss in storage was then divided by the number of years to produce an annual sedimentation rate. Table 4 presents the conservation storage capacities for 1940 and 2007 at Lake Altus. Table 5 presents the average annual sedimentation rate for Lake Altus.

Table 4
Lake Altus Conservation Pool Storage

Date	Storage
	(Ac. Ft.)
Dec 1940	156668
2007	128919

Table 5
Altus Lake Sedimentation Rate

Item	Amount
Difference in Capacity	27749 Acre-Feet
Number of years	66.5 years
Average Annual Sediment	417 A.F./Yr

The average annual sedimentation rate for Lake Altus was used to estimate a sedimentation rate for Cable Mountain. The contributing drainage area for Cable Mountain was divided by the contributing drainage area for Lake Altus to produce a drainage area ratio of 0.817. The drainage area ratio was applied to the average annual sedimentation rate of Lake Altus to estimate an average annual sedimentation rate of 341 acre feet/year for Cable Mountain Reservoir.

Assuming a 100-year project life for Cable Mountain, total loss of storage during the project life was calculated at 34,100 acre-feet. For the yield study, a top of inactive pool elevation 1,378 was chosen as the top of the inactive pool. Inactive storage used in the yield study was 32,982 acre feet.

Reservoir Routing Guidelines

The USACE reservoir yield program WSROUT was used to analyze the yield of Cable Mountain. WSROUT uses monthly input data and calculates monthly changes in storage. The program calculates monthly changes in storage from precipitation on the pool and inflows, and losses from evaporation and withdrawals for water quality/water rights and municipal/irrigation uses. The top of conservation pool is used as the beginning storage for each evaluation. The top of the inactive pool and corresponding storage is also input. The program assumes inactive pool storage is not available for use in the routing. The program assumes total monthly storage never exceeds the top of conservation storage. In effect, the program assumes that all storage above top of conservation pool is released and not stored. As a result, total monthly storage never exceeds total conservation storage. All input data is cycled to simulate 1000 months of data (approximately 83 years).

The information available from the BOR on Cable Mountain included a top of dam elevation but did not include a proposed top of conservation pool elevation only an estimate of conservation storage. As a result, dependable yield runs were made for elevations and corresponding storage in five foot increments below proposed top of dam. Several yield runs were made at each elevation starting with the withdrawal rates listed in Table 6. Water supply withdrawals were increased on successive runs to achieve a drawdown to the top of the inactive pool which lasted a short time and then allowed the conservation storage to recover. Drawdown periods greater than 7 years (84 months) were considered questionable due to concerns that the basin would not support the yields achieved in these runs. Results of the storage-yield study for Cable Mountain Reservoir are listed in table 10. A plot of the yield versus storage data is presented in Plate 6.

Table 6
Storage-Yield Results

Pool Elevation (ft. msl)	Conservation Storage* (Acre feet)	Yield (mgd)	Length of Drawdown (Months)
1425	435247	101.6	180
1420	354661	95.0	162
1415	283192	86.7	75
1410	220360	72.0	68
1405	166940	58.0	66
1400	120670	46.0	42
1395	80069	36.0	32
1390	48471	29.0	27
1385	25000	15.0	16

*conservation storage minus inactive storage

Table 7
Cable Mountain Reservoir
Elevation/Area/Capacity Table

Elevation	Area (acres)	Capacity (acre-feet)		Elevation	Area (acres)	Capacity (acre-feet)
1342	0	0		1388	4760	71279
1344	3	3		1390	5390	81453
1346	7	13		1392	6114	92900
1348	14	34		1394	6916	105947
1350	20	67		1396	7660	120531
1352	37	120		1398	8331	136552
1354	110	260		1400	8760	153651
1356	302	642		1402	9148	171562
1358	543	1493		1404	9552	190252
1360	736	2780		1406	10096	209867
1362	898	4420		1408	10857	230766
1364	1038	6358		1410	11708	253342
1366	1253	8629		1412	12405	277490
1368	1507	11354		1414	13060	302945
1370	1774	14631		1416	13762	329760
1372	2039	18441		1418	14473	357988
1374	2297	22778		1420	15185	387643
1376	2546	27618		1422	15928	418743
1378	2923	32982		1424	16695	451357
1380	3321	39226		1426	17439	485483
1382	3678	46228		1428	18262	521162
1384	3997	53911		1430	19280	558705
1386	4328	62228				

Table 8
Monthly Inflows (acre-feet) for Cable Mountain

	MONTHS											
YEAR	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
1959										97412	5637	55662
1960	60839	132596	75722	32265	18864	46267	61197	9560	5279	282063	32752	50472
1961	41455	41357	40452	28279	22197	237256	26214	14828	29306	31560	62834	13809
1962	11818	7424	5885	32906	26926	263206	24451	30518	62059	19805	8722	9371
1963	5362	19313	18817	6601	22531	80385	2153	539	7038	8306	2395	1729
1964	1612	18774	3391	1584	16831	36195	606	549	7113	1008	22806	4646
1965	3851	2958	3096	9060	13132	82887	3975	546	197701	152700	16704	17621
1966	10768	16862	14718	6747	4776	1221	680	16927	31607	7073	2942	2384
1967	2891	2789	1951	46149	17157	12819	42596	1742	19896	4397	2309	3336
1968	4040	3458	5991	18872	104875	116529	49076	13782	10453	57857	18908	10075
1969	6873	7184	18062	12503	338618	23892	7911	28370	10563	4626	4225	4595
1970	4016	3816	5079	6239	17531	7920	30	498	13216	665	117	656
1971	976	1226	1381	75	266	39852	6217	18366	89980	54060	18164	14308
1972	4969	4292	2447	11232	51519	56094	5822	814	9557	4127	5803	2305
1973	17975	5401	82159	170963	37383	99529	11051	4921	84567	58124	8521	8608
1974	8690	6621	22291	13380	118075	7821	1855	6337	58974	26021	76517	15371
1975	13722	38996	30514	23503	26528	74629	186150	80215	13726	14281	30061	12062
1976	9619	7829	7742	48769	39810	26839	5944	1550	87954	7156	6944	5386
1977	6770	6298	5311	20174	744466	69943	13770	29684	11830	8505	8749	8238
1978	7805	8360	9186	8002	208150	164287	9764	6282	15548	6991	6708	6818
1979	8734	9583	22649	13982	27815	54088	14596	11177	3403	2624	9406	4795
1980	5909	5535	5181	5763	227743	36132	3332	1028	972	1203	1715	5354
1981	3151	2974	5850	9993	14588	45090	2033	2590	684	26825	8580	4005
1982	5823	13486	8041	4131	183085	178352	28342	8195	4547	3548	3792	5374
1983	5401	6593	18982	8879	22803	28708	7935	834	141	204317	19887	9477
1984	10244	8387	12861	15552	5673	10779	2726	1432	712	1076	2246	5744
1985	9320	5134	17763	19777	8289	25702	5114	3411	7799	52121	20340	7817
1986	6090	5311	5201	4087	17900	99041	19565	89851	31125	683977	205774	98667
1987	96609	121962	199341	79185	443435	190167	58919	24416	40503	16874	15367	19651
1988	42340	27795	170208	87663	70616	24962	11688	4441	92549	16681	13250	11877
1989	12888	12334	19234	19329	71528	376986	26890	25163	72422	16240	12479	11676
1990	21744	11767	82214	61390	126235	247851	16433	16161	17948	9623	17574	12204
1991	12746	7762	7062	7730	92502	194459	15355	11873	26776	11617	22378	102177
1992	34023	24282	33697	24876	19179	132762	59332	24467	46097	8163	84559	68373
1993	48053	51657	71182	128973	634794	58089	79869	42549	20824	11869	10465	11948
1994	11157	9871	15819	18845	28653	10115	8084	8380	2030	6522	23318	8218
1995	7360	5846	7691	8010	44217	549897	43107	307569	146941	68169	33634	33244
1996	31989	26989	23546	17546	12003	40330	20706	120801	165554	47380	54662	86837
1997	54910	151469	78496	633366	271382	154180	56220	116053	82269	55807	55280	119967
1998	96696	140166	339641	80589	49764	16449	7219	5649	5354	9859	41427	13526
1999	11452	10779	18967	42006	112791	149919	36344	14198	4886	5067	5614	23200
2000	8458	9198	90606	50397	40027	40247	27862	3914	1517	13085	10547	7109
2001	11220	27842	22677	12215	283271	68177	8568	6688	13699	3414	6251	5995
2002	7207	10665	5948	33685	6007	6357	6991	3588	1900	19525	9347	9623
2003	8273	6416	7376	6290	8741	43949	1966	1188	25786	3800	2541	2903
2004	6279	3946	86699	26969	10134	14305	23058	5869	7652	49469	80385	21087
2005	32607	20796	14049	9729	12774	16799	6149	55209	27398	21013	4748	5751
2006	5189	4627	6413	3686	14061	10509	1755	11185	9123			

Table 9
Monthly Evaporation (inches) at Cable Mountain

MONTHS												
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1959	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.98	3.85	2.61
1960	2.05	3.08	5.55	9.80	9.13	10.60	9.76	10.61	7.86	4.90	4.21	2.28
1961	2.16	2.49	6.03	8.96	11.93	8.46	10.71	11.09	8.19	6.82	2.97	1.56
1962	2.69	6.05	8.91	6.61	11.17	7.96	10.75	14.38	5.69	6.15	3.60	2.47
1963	2.69	2.94	7.81	8.18	9.99	11.07	15.44	12.55	8.76	9.68	4.75	2.94
1964	2.69	3.02	6.93	11.01	11.86	10.50	15.97	14.05	7.89	6.03	3.24	2.81
1965	2.77	3.14	3.78	8.21	10.39	11.56	13.48	11.04	12.00	6.39	5.83	6.13
1966	2.69	3.53	6.83	7.53	10.99	11.33	12.46	9.61	5.09	6.40	6.49	2.81
1967	2.69	2.94	6.18	6.88	9.91	12.72	13.37	12.79	6.82	10.28	3.58	2.78
1968	2.69	2.94	5.55	7.03	8.40	9.61	11.28	11.50	7.43	5.90	3.69	2.81
1969	2.69	2.94	5.55	7.92	8.76	10.81	14.75	12.28	7.45	5.18	3.69	2.81
1970	2.69	2.94	5.55	7.35	11.90	12.27	14.93	13.25	9.46	6.64	3.69	2.81
1971	2.69	2.94	5.55	9.42	11.65	13.07	13.53	8.71	7.47	5.43	3.69	2.81
1972	2.69	2.94	8.20	10.11	9.61	11.66	12.55	10.96	8.67	5.95	3.69	2.81
1973	2.69	2.94	5.42	6.28	9.72	10.96	11.61	12.31	5.96	6.42	3.69	2.81
1974	2.69	2.94	7.01	10.44	10.56	12.54	15.33	10.98	6.06	4.67	3.16	2.81
1975	2.69	2.94	5.05	7.03	8.09	10.25	8.65	10.13	6.96	6.98	3.69	2.81
1976	2.69	2.94	5.55	6.91	7.96	10.41	10.84	12.59	6.75	4.77	3.69	2.81
1977	2.69	2.94	5.55	7.58	8.79	10.51	12.58	10.92	8.17	5.90	3.69	2.81
1978	2.49	1.73	5.79	9.24	8.36	11.59	15.03	11.25	7.61	7.40	2.88	2.02
1979	0.86	1.87	5.25	6.17	8.06	9.89	11.26	10.11	8.65	8.58	3.37	2.72
1980	0.25	2.04	5.48	8.49	7.27	12.67	16.93	13.86	8.71	7.29	3.92	2.18
1981	2.59	3.62	5.44	8.07	8.73	10.62	12.86	9.97	8.91	4.30	4.05	2.17
1982	1.86	2.76	6.05	7.84	8.17	8.55	11.56	11.91	9.39	6.66	3.83	2.17
1983	1.86	1.68	4.47	6.71	9.24	9.58	14.41	12.95	10.56	6.27	3.62	4.59
1984	1.86	1.74	5.53	8.28	10.55	11.18	13.50	11.34	9.73	5.31	3.80	3.40
1985	2.79	3.33	4.74	8.21	10.15	10.89	12.18	11.55	8.54	4.21	2.42	2.79
1986	2.50	2.24	6.85	7.70	7.98	9.02	14.22	9.38	7.33	4.29	4.01	3.98
1987	2.79	3.08	6.20	8.51	9.32	9.64	11.51	10.89	7.97	5.96	3.78	2.75
1988	2.76	3.77	6.02	7.93	9.90	11.74	11.46	12.11	7.70	5.04	4.83	3.46
1989	2.79	3.24	5.92	8.91	8.08	8.74	11.69	8.68	8.00	7.51	4.51	3.19
1990	2.61	3.06	6.10	6.20	9.18	13.66	12.32	10.54	8.18	6.82	4.16	3.41
1991	2.45	3.59	7.25	8.00	8.71	10.27	12.24	10.35	6.71	7.10	1.91	1.97
1992	1.87	1.18	1.07	2.24	3.25	9.00	3.60	3.19	2.00	0.00	6.94	2.12
1993	8.37	1.70	4.87	7.00	7.72	10.06	12.95	11.84	7.85	5.76	2.98	3.15
1994	2.10	2.93	6.27	9.10	7.57	12.55	12.59	12.30	8.21	5.46	1.50	1.48
1995	2.33	2.80	5.07	6.82	7.86	9.31	12.93	10.33	6.05	7.74	3.99	2.80
1996	2.35	3.18	6.22	9.95	11.60	10.74	11.60	7.80	6.02	6.45	2.51	2.32
1997	2.41	2.29	6.54	5.28	8.10	9.20	11.96	9.87	8.68	5.84	4.00	2.45
1998	2.39	2.94	5.18	7.25	10.17	14.05	15.10	11.82	9.81	6.07	3.37	2.47
1999	3.42	5.10	3.89	7.10	8.57	9.23	13.14	13.11	8.52	6.86	5.01	3.89
2000	3.43	5.18	6.11	7.77	10.44	8.51	12.53	15.38	10.88	5.08	2.54	2.24
2001	2.03	2.39	4.24	7.49	9.26	12.23	15.51	10.99	7.68	7.44	3.54	3.01
2002	3.99	4.54	6.63	6.09	7.98	10.76	10.34	12.15	9.40	3.93	3.71	2.30
2003	3.17	3.07	5.46	8.78	9.73	8.85	14.30	11.87	6.96	6.57	3.97	3.68
2004	2.97	3.00	5.89	6.98	10.32	9.27	10.80	9.66	9.36	4.79	2.32	3.13
2005	1.83	2.37	5.28	8.11	7.79	10.92	12.40	9.14	9.40	5.64	5.47	3.32
2006	4.85	4.94	7.04	9.61	10.87	12.12	13.86	12.44	7.99	6.63	4.10	2.37

Table 10
Monthly Rainfall (inches) at Cable Mountain

MONTHS												
YEAR	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
1959										4.56	0.14	3.80
1960	0.85	1.58	0.67	0.00	2.53	3.41	5.00	2.48	0.88	6.31	0.03	2.36
1961	0.09	1.50	2.53	0.79	2.26	6.67	4.02	1.65	2.78	1.96	2.30	0.73
1962	0.13	0.04	0.15	3.16	1.84	7.31	3.77	0.83	4.04	1.99	0.93	0.86
1963	0.00	0.30	1.69	0.95	3.93	2.64	1.21	2.48	1.91	0.94	2.20	0.28
1964	0.53	2.72	0.36	0.21	4.74	2.04	0.36	2.05	2.70	0.71	4.18	0.60
1965	0.20	0.92	0.87	2.13	3.60	5.53	1.17	2.63	5.37	4.32	0.08	2.08
1966	0.72	0.80	0.43	2.14	0.20	1.13	1.04	5.69	2.24	0.67	0.10	0.39
1967	0.03	0.05	1.17	1.34	1.67	3.12	3.20	0.91	3.74	1.28	0.28	0.86
1968	1.91	1.97	1.22	1.75	4.98	2.44	5.14	1.70	0.93	2.02	3.90	0.74
1969	0.03	2.08	2.30	0.69	7.25	2.70	1.43	3.54	4.22	2.07	0.22	0.71
1970	0.09	0.07	2.67	2.51	2.82	1.52	0.40	1.34	2.16	1.11	0.41	0.31
1971	0.35	1.19	0.00	0.22	2.67	4.03	3.30	3.25	6.43	4.26	0.74	2.19
1972	0.07	0.15	0.40	1.38	2.50	2.49	1.24	1.67	0.29	5.06	1.87	0.34
1973	2.86	0.68	4.90	4.00	2.16	2.69	2.49	0.44	7.17	3.33	0.66	0.11
1974	0.05	0.12	1.17	3.62	3.01	0.96	0.02	5.75	5.10	3.70	0.98	1.13
1975	1.62	2.31	1.30	0.89	4.57	4.24	7.00	3.59	2.34	1.52	2.11	1.32
1976	0.00	0.13	0.80	4.95	3.14	3.96	1.03	1.42	6.67	2.75	0.32	0.08
1977	0.57	1.68	0.50	3.17	13.84	1.28	1.04	6.36	0.83	2.21	1.42	0.04
1978	0.46	1.87	0.36	1.31	8.18	4.16	0.35	1.86	2.19	0.01	2.63	0.25
1979	2.01	0.73	2.37	3.05	4.07	3.41	4.25	2.76	0.00	1.95	1.54	0.70
1980	1.45	0.66	1.40	1.10	15.28	0.31	0.00	1.48	0.84	0.78	0.58	1.88
1981	0.16	0.55	2.19	4.40	4.44	5.63	1.12	2.00	0.46	5.00	1.42	0.26
1982	1.64	0.45	2.17	1.42	8.23	7.84	3.47	0.45	1.69	0.19	1.88	0.98
1983	1.82	1.45	3.42	1.07	3.60	2.36	0.17	0.65	0.92	11.42	1.12	0.41
1984	0.17	1.11	1.78	1.28	0.39	3.75	0.53	0.42	0.16	1.00	1.87	4.12
1985	1.45	1.88	3.38	3.41	0.32	8.02	1.21	2.17	4.58	4.90	1.39	0.33
1986	0.00	0.68	0.81	3.12	5.08	4.87	1.94	5.17	8.93	6.63	2.26	0.87
1987	1.42	3.35	1.40	0.03	13.70	3.91	1.97	1.94	3.28	2.68	0.32	4.55
1988	1.01	0.03	4.76	5.15	0.52	1.52	1.39	0.76	8.18	0.92	1.04	0.45
1989	1.65	1.16	1.40	0.00	4.57	8.64	0.82	3.59	5.05	1.47	0.00	0.08
1990	1.71	3.54	4.11	3.54	3.92	1.93	4.27	2.72	2.29	0.79	3.40	0.79
1991	1.08	0.00	1.89	1.29	7.25	7.38	0.77	3.04	3.81	2.30	1.23	4.48
1992	1.12	0.94	1.02	2.36	3.28	9.16	3.78	4.35	2.66	0.00	6.94	2.12
1993	2.19	2.04	1.66	4.54	6.90	2.09	3.04	3.30	2.18	1.63	0.94	1.20
1994	0.23	1.10	2.36	3.84	2.69	2.54	2.69	0.76	1.06	1.77	4.53	0.21
1995	1.30	0.01	3.12	2.64	6.17	6.93	2.31	6.09	8.55	0.96	0.14	0.79
1996	0.01	0.00	0.58	0.07	1.90	3.34	5.49	8.21	3.17	0.89	1.89	0.17
1997	0.42	3.75	0.08	9.28	3.45	3.07	3.21	4.98	3.20	3.17	0.79	3.08
1998	1.71	1.92	5.46	0.59	2.14	0.09	0.62	0.97	0.43	4.06	3.33	1.07
1999	2.05	0.16	2.93	3.37	6.04	8.23	1.87	1.58	1.08	2.87	0.42	2.88
2000	0.30	1.71	5.13	2.69	3.45	6.82	1.22	0.00	1.13	4.83	1.95	1.54
2001	1.76	2.51	1.08	0.78	8.80	0.99	0.11	4.42	2.39	0.13	2.39	0.19
2002	2.52	0.80	1.49	4.76	1.77	2.38	3.12	1.32	1.77	5.96	0.78	2.50
2003	0.00	0.94	0.77	2.39	2.60	6.23	0.32	2.96	0.81	0.88	0.93	0.34
2004	3.07	2.12	3.86	2.99	0.28	8.10	2.27	3.00	1.90	5.37	6.68	0.58
2005	2.04	0.79	1.09	0.98	3.45	3.01	1.97	6.09	4.72	3.63	0.00	0.22
2006	0.16	0.00	2.51	0.45	3.90	3.01	1.30	3.91	1.00	4.31	0.24	2.56

Table 11
Denison Gage Durations

	Percent of Time Equaled or Exceeded								
Parameter	**1**	**5**	**10**	**20**	**50**	**80**	**90**	**95**	**99**
	mg/l								
Natural Cl	581	461	441	417	343	273	245	223	174
Modified Cl. - Plan 4	512	406	388	367	302	240	216	196	153
Modified Cl. - Plan 5	476	378	361	342	281	224	201	183	143
Natural Sul	430	394	325	292	238	167	117	104	81
Modified Sul - Plan 4	423	388	320	287	234	164	115	102	80
Modified Sul - Plan 5	416	381	314	282	230	161	113	101	78
Natural TDS	1788	1342	1286	1220	1009	785	683	606	505
Modified TDS - Plan 4	1666	1250	1198	1137	940	731	636	565	470
Modified TDS - Plan 5	1580	1186	1136	1078	892	694	604	536	446

Table 12
Gainesville Gage Durations

	Percent of Time Equaled or Exceeded								
Parameter	**1**	**5**	**10**	**20**	**50**	**80**	**90**	**95**	**99**
	mg/l								
Natural Cl	2006	1713	1599	1393	990	576	396	282	155
Modified Cl. - Plan 4	3148	2728	2512	2188	1369	588	378	259	135
Modified Cl. - Plan 5	2932	2542	2340	2039	1276	547	352	241	125
Natural Sul	1253	954	855	733	536	307	205	149	84
Modified Sul - Plan 4	1988	1616	1452	1234	838	357	215	151	82
Modified Sul - Plan 5	1894	1540	1383	1176	798	339	205	144	78
Natural TDS	4980	4255	3924	3500	2541	1487	1040	759	410
Modified TDS - Plan 4	7436	6885	6081	3998	1720	1097	771	400	388
Modified TDS - Plan 5	7171	6398	5972	5284	3442	1459	920	633	244

Table 13
Terral Gage Durations

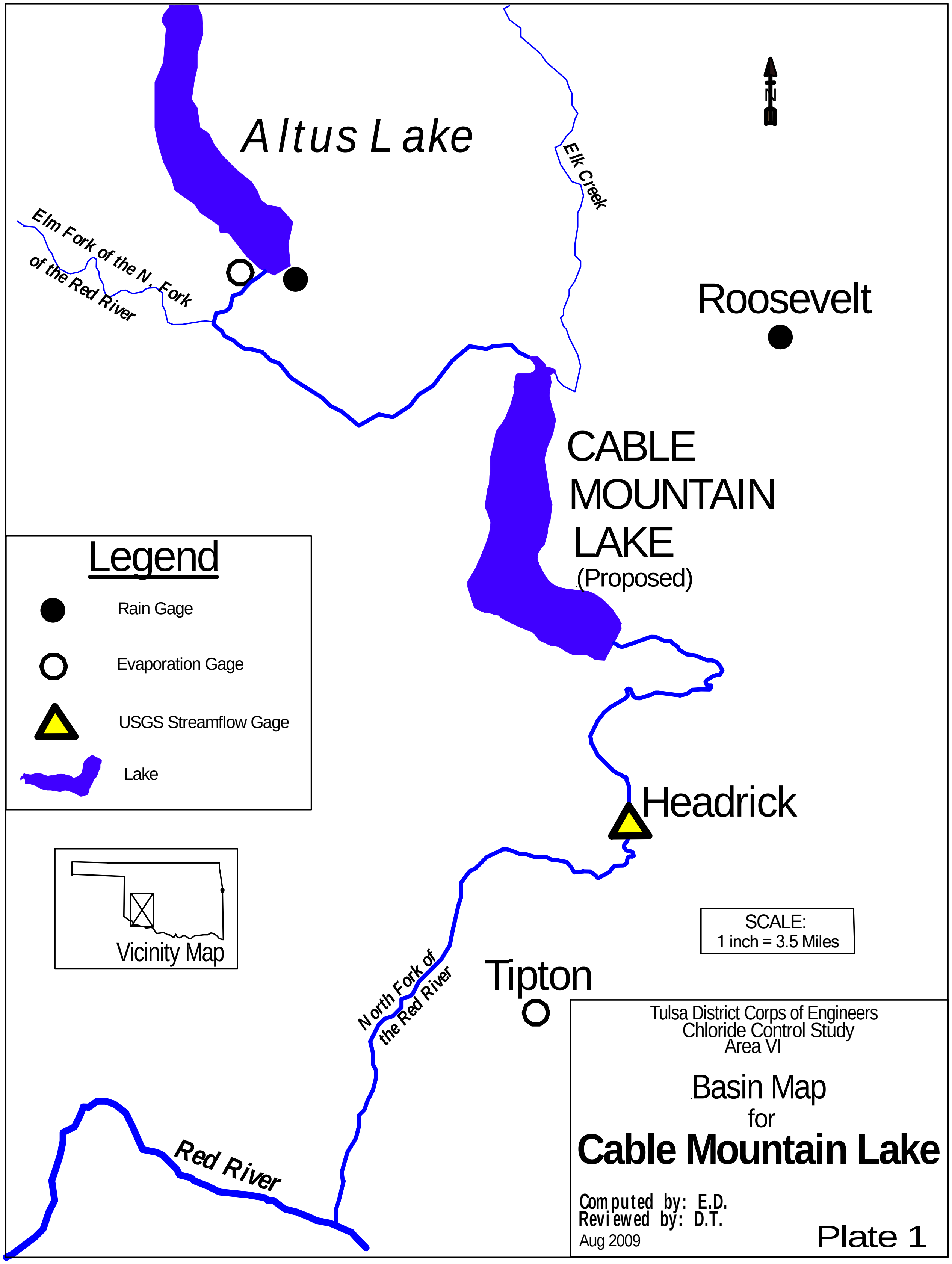
	Percent of Time Equaled or Exceeded								
Parameter	**1**	**5**	**10**	**20**	**50**	**80**	**90**	**95**	**99**
	mg/l								
Natural Cl	2209	1929	1782	1593	1266	748	497	359	190
Modified Cl. - Plan 4	3392	2964	2741	2446	1934	855	483	324	166
Modified Cl. - Plan 5	3107	2714	2510	2240	1772	783	443	297	150
Natural Sul	1136	1014	945	876	719	455	317	232	126
Modified Sul - Plan 4	1989	1772	1652	1536	1246	581	353	238	123
Modified Sul - Plan 5	1888	1682	1568	1458	1183	552	335	226	114
Natural TDS	5318	4679	4368	3957	3265	2048	1409	1032	573
Modified TDS - Plan 4	8684	7610	7118	6448	5254	2442	1441	983	522
Modified TDS - Plan 5	8099	7098	6638	6014	4902	2277	1345	917	480

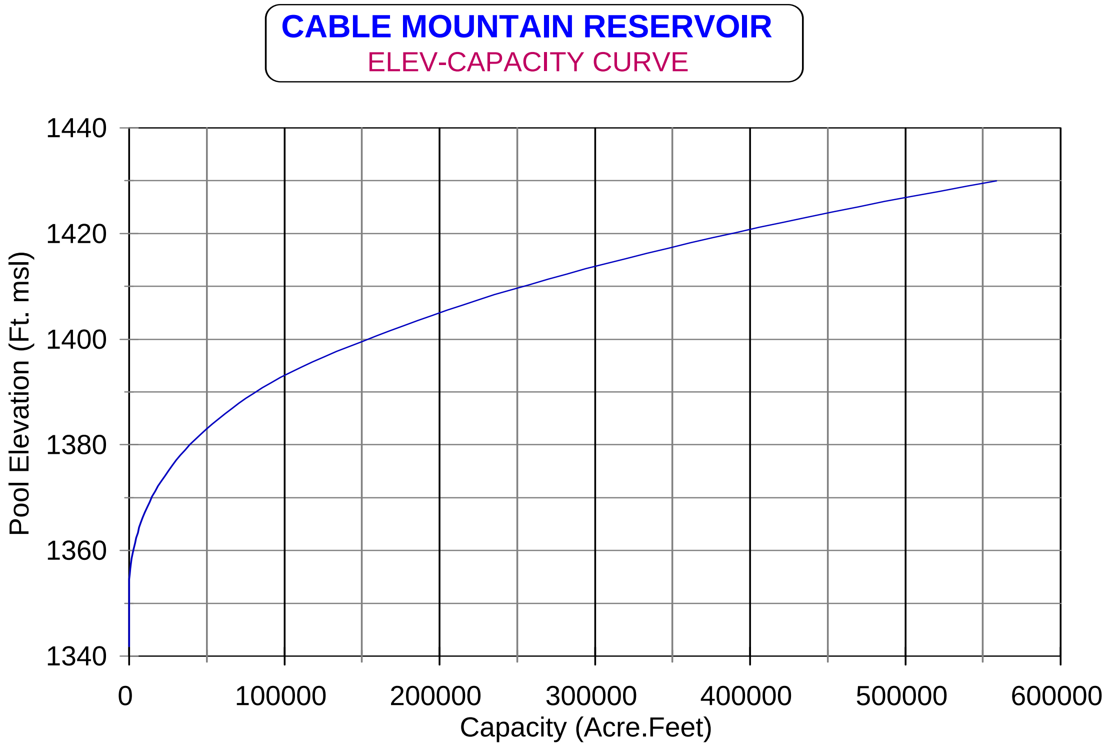
Table 14
Burkburnett Gage Durations

	Percent of Time Equalled or Exceeded								
Parameter	**1**	**5**	**10**	**20**	**50**	**80**	**90**	**95**	**99**
	mg/l								
Natural Cl	4014	3393	3033	2675	1999	1199	825	555	194
Modified Cl. - Plans 4- 5	6112	5186	4576	4094	2787	1429	884	578	186
Natural Sul	1931	1664	1562	1451	1176	785	571	415	166
Modified Sul - Plans 4-5	3300	2883	2701	2505	1881	1034	688	472	174
Natural TDS	9399	8048	7438	6754	5224	3286	2347	1638	657
Modified TDS - Plans 4-5	14848	12845	11914	10710	7583	4044	2597	1749	617

Table 15
Headrick Gage Durations

	Percent of Time Equalled or Exceeded								
	1	**5**	**10**	**20**	**50**	**80**	**90**	**95**	**99**
	mg/l								
Natural Cl	5709	4298	3718	2940	1807	797	457	263	0
Modified Cl. - Plans 4- 5	324	274	255	234	180	115	93	74	51
Natural Sul	1621	1343	1246	1112	860	552	401	215	0
Modified Sul - Plans 4-5	667	639	616	575	449	358	311	264	203
Natural TDS	11821	9150	8222	6825	4529	2263	1427	814	0
Modified TDS - Plans 4-5	1549	1461	1405	1308	1004	789	664	544	409


Altus Lake
Elk Creek
N
Elm Fork of the N. Fork of the Red River
Roosevelt
CABLE MOUNTAIN LAKE (Proposed)
Legend
● Rain Gage
○ Evaporation Gage
△ USGS Streamflow Gage
Lake
Headrick
Vicinity Map
SCALE: 1 inch = 3.5 Miles
Tipton
North Fork of the Red River
Red River
Tulsa District Corps of Engineers
Chloride Control Study
Area VI
Basin Map
for
Cable Mountain Lake
Computed by: E.D.
Reviewed by: D.T.
Aug 2009
Plate 1

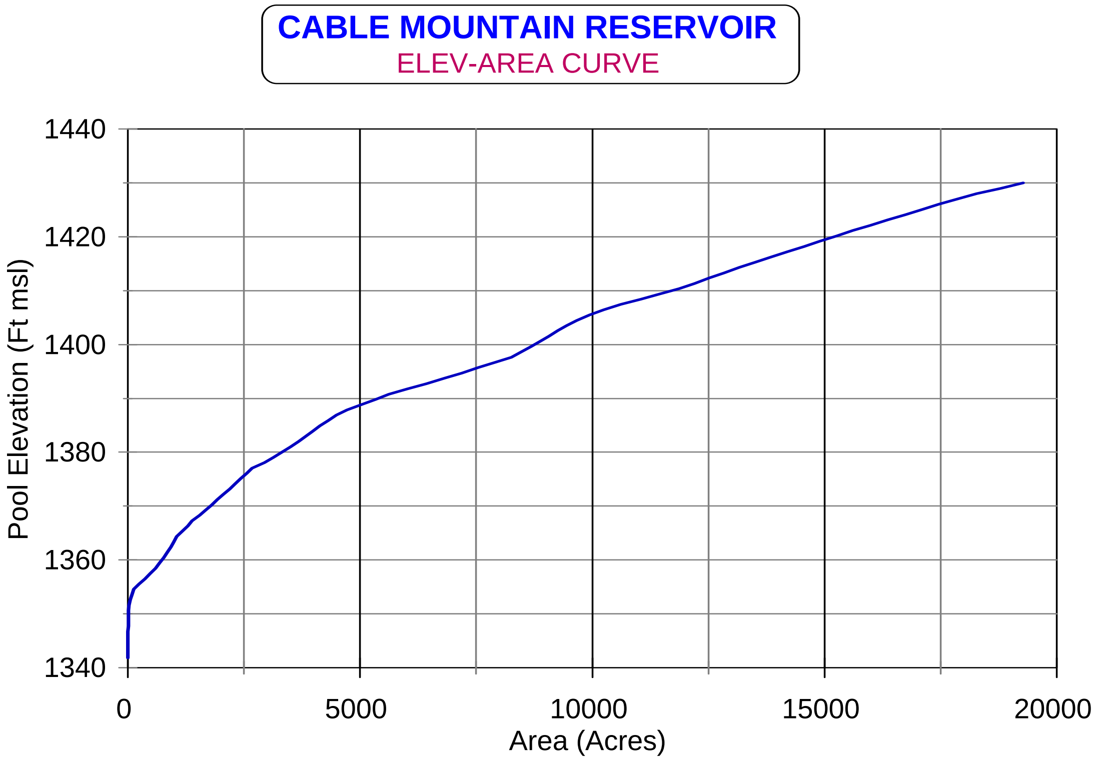


Tulsa District Corps of Engineers
Chloride Control Study
Area VI

Elevation-Capacity Curve
for
Cable Mountain Lake

Computed by: E.D.
Reviewed by: D.T.
Aug 2009

Plate 2

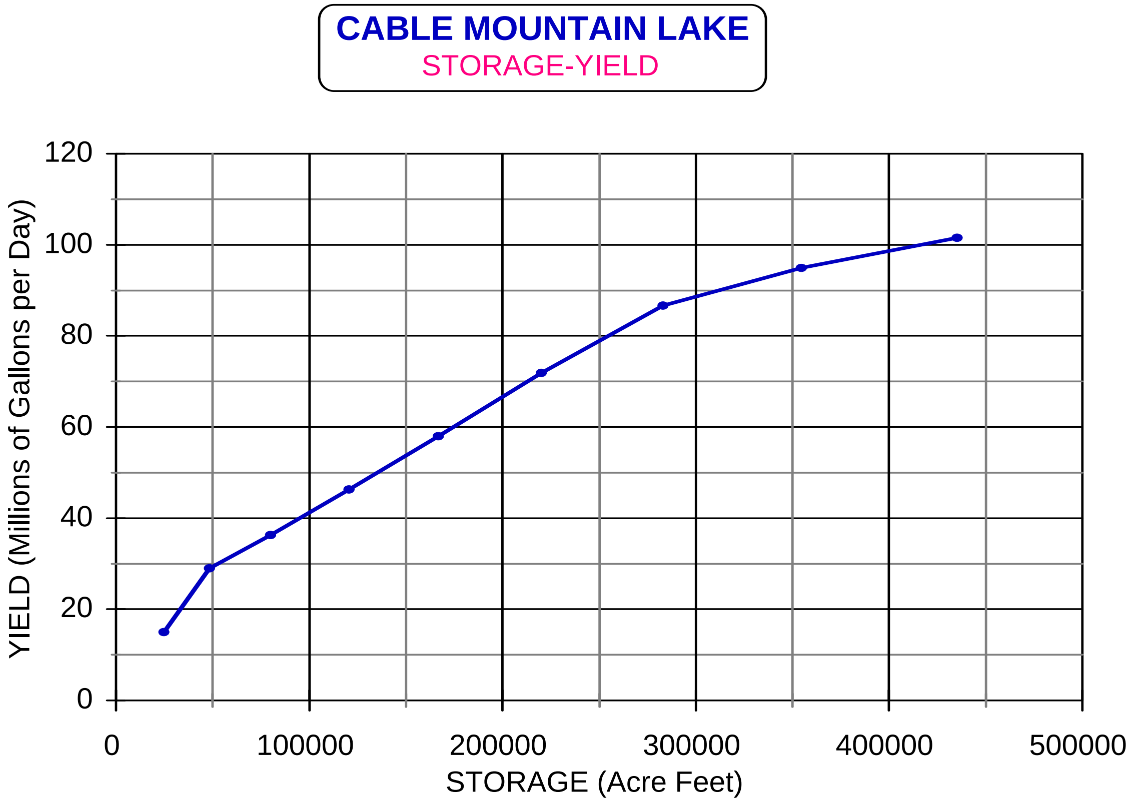


Tulsa District Corps of Engineers
Chloride Control Study
Area VI

Elevation-Area Curve
for
Cable Mountain Lake

Computed by: E.D.
Reviewed by: D.T.
Aug 2009

Plate 3



Tulsa District Corps of Engineers
Chloride Control Study
Area VI

Storage-Yield Curve

for

Cable Mountain Lake

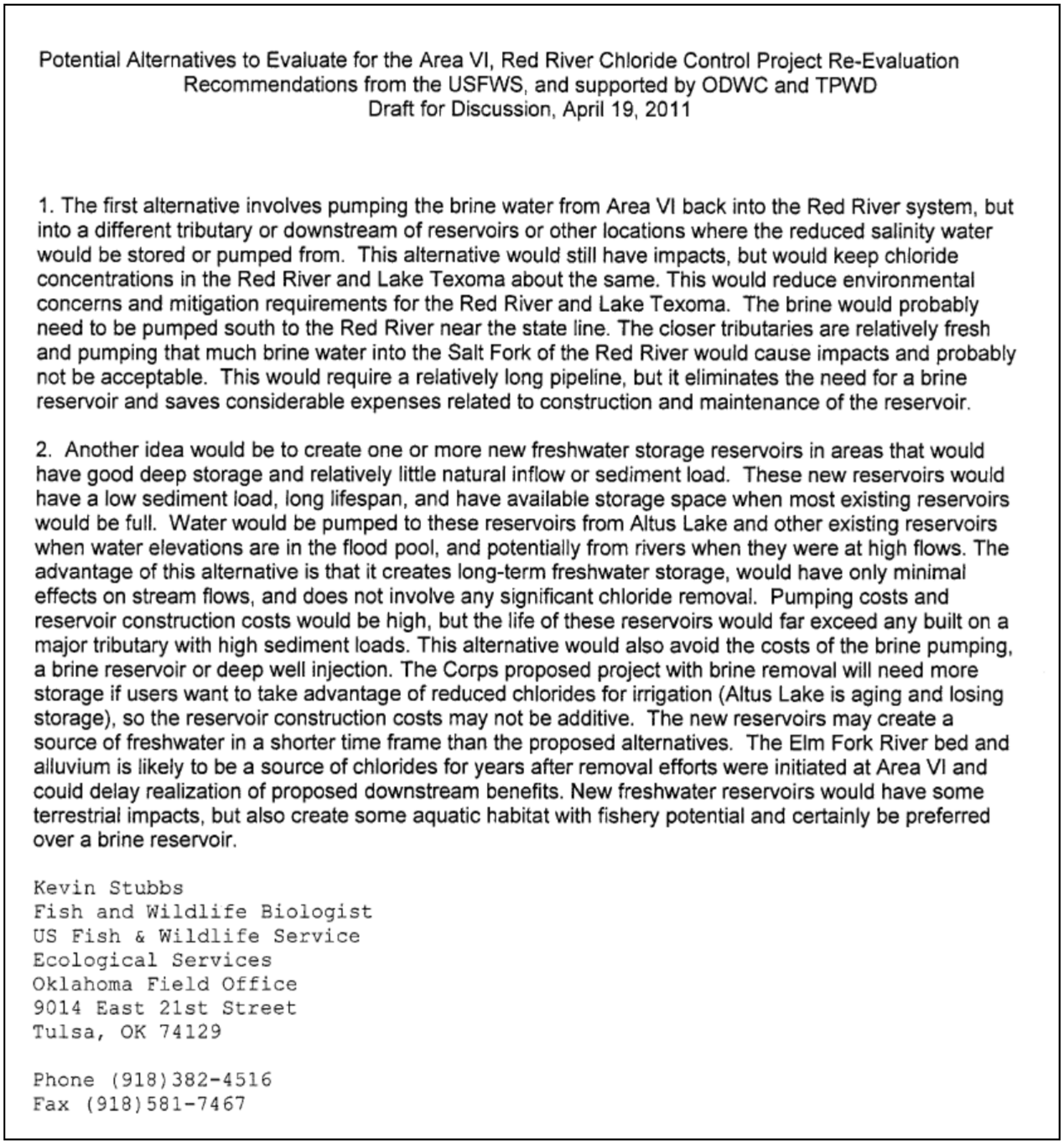
Computed by: E.D.
Reviewed by: D.T.
Aug 2009

Plate 4

Appendix C

USFWS Ideas

. The Oklahoma Ecological Services Field Office of the U.S. Fish and Wildlife Service has recommended ideas for rerouting the brine emissions or not controlling the brine emission at all. Neither of these ideas would reduce chlorides in the Red River Basin and would, therefore, not meet the intent of Congress. These ideas were recommended by the Oklahoma Ecological Services Field Office in a short one page draft discussion paper on 19 April 2011. The ideas are supported by the Oklahoma Department of Wildlife Conservation and the Texas Parks and Wildlife Department. The two ideas include (1) collecting brine from the Area VI source and pumping it overland, via pipeline, to the state line where it would be discharged into the Red River, and (2) not collecting any brine from Area VI, but instead, creating new freshwater storage reservoirs in the region that would have “a long lifespan” and “relatively little natural inflow or sediment load” yet have sufficient capacity to store excess water pumped from existing reservoirs or pumped from rivers when at high flows.



Potential Alternatives to Evaluate for the Area VI, Red River Chloride Control Project Re-Evaluation
Recommendations from the USFWS, and supported by ODWC and TPWD
Draft for Discussion, April 19, 2011

1. The first alternative involves pumping the brine water from Area VI back into the Red River system, but into a different tributary or downstream of reservoirs or other locations where the reduced salinity water would be stored or pumped from. This alternative would still have impacts, but would keep chloride concentrations in the Red River and Lake Texoma about the same. This would reduce environmental concerns and mitigation requirements for the Red River and Lake Texoma. The brine would probably need to be pumped south to the Red River near the state line. The closer tributaries are relatively fresh and pumping that much brine water into the Salt Fork of the Red River would cause impacts and probably not be acceptable. This would require a relatively long pipeline, but it eliminates the need for a brine reservoir and saves considerable expenses related to construction and maintenance of the reservoir.

2. Another idea would be to create one or more new freshwater storage reservoirs in areas that would have good deep storage and relatively little natural inflow or sediment load. These new reservoirs would have a low sediment load, long lifespan, and have available storage space when most existing reservoirs would be full. Water would be pumped to these reservoirs from Altus Lake and other existing reservoirs when water elevations are in the flood pool, and potentially from rivers when they were at high flows. The advantage of this alternative is that it creates long-term freshwater storage, would have only minimal effects on stream flows, and does not involve any significant chloride removal. Pumping costs and reservoir construction costs would be high, but the life of these reservoirs would far exceed any built on a major tributary with high sediment loads. This alternative would also avoid the costs of the brine pumping, a brine reservoir or deep well injection. The Corps proposed project with brine removal will need more storage if users want to take advantage of reduced chlorides for irrigation (Altus Lake is aging and losing storage), so the reservoir construction costs may not be additive. The new reservoirs may create a source of freshwater in a shorter time frame than the proposed alternatives. The Elm Fork River bed and alluvium is likely to be a source of chlorides for years after removal efforts were initiated at Area VI and could delay realization of proposed downstream benefits. New freshwater reservoirs would have some terrestrial impacts, but also create some aquatic habitat with fishery potential and certainly be preferred over a brine reservoir.

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USFWS Idea 1. Idea 1 involves the pumping of captured brine at Area VI directly to the Red River eliminating the need for a brine storage reservoir or deep well injection of captured brines. The USFWS considered pumping to other Red River tributaries, primarily the Salt Fork of the Red River, but due to the low chloride loads in those tributaries, environmental impacts were deem too great. The USFWS suggests that the brine would enter the Red River near the OK/TX state line. Pumping the Area VI brine to the Red River would require a pipeline approximately 30 miles in length. The OK/TX state line is located at Red River mile 1,050. The Childress gage on the Prairie Dog Town Fork of the Red River is located at river mile 1,061, eleven miles upstream of the OK/TX state line. The Burkburnett gage is located at river mile 933, 117 miles downstream of the TX/OK state line.

The USFWS does not indicate the intended benefit of the idea but the USFWS does indicate the idea would maintain the high concentrations of dissolved solids in the Red River and, thereby, Lake Texoma. Diverting the chloride load from Area VI would reduce the chloride load along the North Fork of the Red River and would provide a source of water usable for irrigation. However, to have sufficient water from this source when needed for summer irrigation, the most likely measure would be a storage reservoir and the most likely site would be the Cable Mountain site identified by the Bureau of Reclamation. It is unclear if the USFWS is therefore indirectly supporting the construction of the Cable Mountain Dam or if the need for a storage reservoir was imagined as part of Idea 1. Without a reservoir to store the resulting relatively low chloride flows of the North Fork, there would be negligible benefits of pumping brine to the Red River because the North Fork is relative “dry” throughout the summer when irrigation water is needed. In contrast, the pumping costs to divert the brine to the Red River would be higher than for other measures that would remove brine from the Red River.

The Prairie Dog Town Fork of the Red River basin contains four of the ten major identified sources of brine pollution in the Red River basin. These source areas are Area XI (Prairie Dog Town Fork and its tributaries west of Texas State Highway 70), Area XIII (Jonah Creek NW of Childress, TX), Area XIV (Salt Creek NW of Childress, TX) and Area XV (Little Red River approximately 28 miles west of Estelline, TX). These four major source areas are estimated to emit an average daily load of 810 tons/day of chlorides. Along with these four major source areas, countless minor brine sources exist in the Prairie Dog Town Fork basin.

Under existing/natural conditions, the chloride load from Area VI enters the Red River at river mile 987, the confluence of the North Fork with the main stem of the Red River. The areas downstream of this point are impacted by the loads from the Area VI sources. The USFWS Idea 1 would change the areas impacted by the Area VI chloride loads. The USFWS proposes to pump the Area VI loads directly to the Red River at river mile 1,050. This idea would increase the chloride loads for the reach between river mile 1050, the TX/OK state line, and river mile 987, the confluence of the North Fork and the main stem of the Red River. The Red River downstream of river mile 987 is currently impacted by Area VI loads so no change in chloride loads and concentration should be experienced downstream of this point.

To estimate impacts of the USFWS Idea 1 to the reach between river mile 1050 and mile 987, available flow and water quality data for the Childress gage at river mile 1061 were evaluated. The Childress gage had a complete period of record data set for flow but limited water quality data was available. Average daily conductivity data was available for WY 69-82 and WY 95-97. Discrete water quality sampling data was available throughout the period of record. The available water quality data were used to develop conductivity to chloride/sulfate/TDS correlations. Regression analyses were performed to develop a best fit line which was then used to generate daily water quality data. Using the generated water quality data, a concentration duration analysis was performed for each constituent for the data available.

To estimate the impacts of pumping the captured Area VI brines to Red River mile 1050, the daily pumped flows and load were added to the available daily flow/water quality data at the Childress gage. A concentration duration analysis was performed to compare flows and concentrations under existing conditions and modified conditions under USFWS Idea 1. A natural conditions data set was not generated for this analysis. Existing conditions, which represent the operation of the ring dike at Area V near Estelline Springs, TX was considered adequate. The concentration duration data for the Childress gage is presented in the Tables 1, 2, and 3.

Table 1
Childress Gage, Prairie Dog Town Fork, Red River
Chloride Concentration Duration

	% of Time Equaled or Exceeded, mg/l								
	1	**5**	**10**	**20**	**50**	**80**	**90**	**95**	**99**
Existing Conditions	39131	35950	33986	31727	26622	11750	5561	3497	2076
Modified w/ Area VI	112366	65633	56866	46107	33860	14933	7230	4335	2474

Table 2
Childress Gage, Prairie Dog Town Fork, Red River
Sulfate Concentration Duration

	% of Time Equaled or Exceeded, mg/l								
	1	**5**	**10**	**20**	**50**	**80**	**90**	**95**	**99**
Existing Conditions	5210	4960	4805	4619	4176	2610	1698	1301	964
Modified w/ Area VI	4806	4218	4085	3901	3455	2556	1760	1333	982

Table 3
Childress Gage, Prairie Dog Town Fork, Red River
TDS Concentration Duration

% of Time Equaled or Exceeded, mg/l									
	1	**5**	**10**	**20**	**50**	**80**	**90**	**95**	**99**
Existing Conditions	68812	63690	60500	56817	48405	22935	11583	7582	4710
Modified w/ Area VI	203460	117500	96980	81730	60780	28400	14450	9128	5482

USFWS Idea 1 would improve the water quality of Reaches 14a and 14b on the North Fork and Elm Fork of the Red River as proposed by Conditions 4 and 5 by USACE. Water quality is expected to be the same as the concentration duration data presented in Tables 6 and 7 in Exhibit B and Tables 6 and 7 in Exhibit C for Reaches 14a and 14b. USFWS Idea 1 would not improve water quality in the Red River reaches below river mile 987 as proposed by Conditions 4 and 5 by USACE. Water quality is expected to be the same as concentration duration presented as Tables 1-5 in Exhibit B and Tables 1-5 in Exhibit C for Reaches 1-5 for the USFWS idea. The USFWS idea would degrade water quality in the Red River reach between river mile 987 and 1050 by adding approximately 423 tons/day of chlorides to the reach. The USFWS idea would improve flows for the reach between river mile 987 and river mile 1050 by adding an additional 2 cfs to existing conditions flow. This addition to flow should improve flows for the reach during low flow periods.

USFWS Idea 2. The USFWS proposes to construct one or more new freshwater storage reservoirs in areas that would have good deep storage and relatively low natural inflow and sediment load. The USFWS proposes to pump water from Lake Altus and other existing reservoirs when these lakes have flood storage available. The USFWS also proposes to pump water into the proposed lakes from rivers in the area when they are at high flows.

Lake Altus and Tom Steed Reservoir are the only two reservoirs that exist in southwestern Oklahoma from which stored flood water could be pumped to the USFWS proposed reservoirs. Lake Altus was constructed by the BOR and is managed by the Lugert-Altus Irrigation District to supply local irrigation and industrial demand. Lake Altus has a high demand during summer months and is typically drawn down from 15 to 35 feet into the conservation pool at the end of the irrigation season. Tom Steed Reservoir supplies regional municipal demand to southwestern Oklahoma and is typically drawn down 3-7 feet into the conservation pool at the end of their high demand season.

A routing method was developed to take historical flood release flows from Altus and Tom Steed Reservoirs and rout these flows to a USFWS proposed reservoir. The period of record used in the analysis was WY1980 - WY2010. This period of record was chosen because Tom Steed Reservoir began flood control operations in 1980. Construction and operational costs were not evaluated, only the availability of water. Pumping from rivers during high flows was not evaluated due to the low sediment load requirement stated in the USFWS idea.

Flood releases for the period of record from Altus Lake and Tom Steed Reservoir were routed to the USFWS proposed reservoir using the Cable Mountain Reservoir area capacity data developed during this study. (Note: It was assumed that all of the flood releases could be captured and pumped to the proposed reservoir. In reality, it would not be economically feasible to pump large flood flows. To utilize the pumping capacity of a realistic pumping plant, a supplemental storage reservoir would be required to first capture the flood releases.) No local inflow was included in the routing per the USFWS idea description. Monthly precipitation which fell on the lake surface was included as inflow. Monthly evaporation for the Cable Mountain study was used to determine monthly evaporation losses. Monthly evaporation losses were subtracted from monthly pool contents.

In an attempt to determine the yield of the proposed reservoir, irrigation withdrawals similar to those used in the Cable Mountain Reservoir evaluation were used in the evaluation of the USFWS proposed reservoir. The irrigation withdrawals occur during the months of June through September with July and August being the months with the highest demand. Cable Mountain irrigation withdrawals are presented in Table 2 of Appendix B. No water quality releases were used in the USFWS evaluation. The irrigation withdrawals and annual mgd equivalents are presented in Table 4.

TABLE 4
USFWS IRRIGATION DEMAND
DAY SECOND FEET (DSF)/MONTH EQUIVALENT TO MGD

MGD	**DAY SECOND FEET/MONTH**					
	JUNE	**JULY**	**AUGUST**	**SEPT**	**DSF/YR**	**AF/YR**
1	76	503	490	52	1121	2224
10	759	5027	4897	522	11205	22225
15	1139	7540	7346	783	16808	33339
20	1519	10053	9795	1044	22411	44452
30	2278	15080	14692	1566	33616	66677
40	3038	20107	19589	2088	44822	88904
60	4556	30160	29384	3133	67233	133357
80	6075	40214	39178	4177	89644	177809

In this evaluation, based on the assumptions above, there would be sufficient yield to supply 10 mgd from the USFWS reservoir 100% of the time. Yields higher than 10 mgd can only be supplied less than 100% time. Table 5 presents the yield duration results along with the ending pool elevation. Even though the Cable Mountain elevation area capacity data was used in this evaluation, do not confuse the yield of the USFWS reservoir yield with the Cable Mountain yield estimated during this study. The Cable Mountain yield analysis included inflows from the Elm Fork of the Red River, Elk Creek, and flood releases from Altus Lake. The USFWS reservoir includes inflows only from flood releases from Altus Lake and Tom Steed Reservoir. Yields of 30 mgd and greater will result in target yields being met at lower percentages of time. At yields of 30 mgd and greater, the lake will remain at or near the top of the inactive pool elevation with every cfs of inflow being used to supply irrigation demand.

Table 5
USFWS Reservoir
Yield Duration Results

Yield (mgd)	% of Time	End of Period Pool Elevation
1	100	1417.40
10	100	1403.70
15	93.69	1395.28
20	86.04	1383.57
30	74.33	1342.00
40	65.22	1342.00
60	52.01	1342.00
80	41.42	1342.00
100	34.39	1342.00

*elevation1342.00 streambed elevation
**elevation 1430.00 top of dam

Using the Cable Mountain elevation area capacity data as a foundation, new elevation area capacity data were generated to represent a reservoir which was much deeper and as a result had reduced surface area. The smaller surface area was expected to result in reduced evaporation losses and an increase in yield. An identical routing was performed using the synthesized elevation area capacity data. Yield duration results with corresponding end of period pool elevations are presented in Table 6. In this evaluation using the synthesized data, a yield of up to 20 mgd could be supplied 100% of the time. Yields of 40 mgd and greater will result in target yields being met at lower percentages of time. At yields of 40 mgd and greater, the lake will remain at or near the top of the inactive pool elevation with every cfs of inflow being used to supply irrigation demand. Be aware that the elevation area capacity data used in this evaluation is synthesized and similar topography is not known to exist in Southwestern Oklahoma. The purpose of the synthesized evaluation was to determine if there was a remote opportunity to identify a reservoir proposed by the USFGS. It appears to be highly unlikely that the idea would be technically feasible and further unlikely that the idea would be economically feasible.

Table 6
USFWS Reservoir Synthesized Elevation Area Capacity Data
Yield Duration Results

Yield (mgd)	% of Time	End of Period Pool Elevation
10	100	1520.12
20	100	1469.09
25	96.71	1444.49
30	87.86	1422.90
40	74.21	1342.00
60	56.69	1342.00
80	44.42	1342.00
100	36.31	1342.00

*elevation 1342.0 streambed elevation
**elevation 1530.0 top of dam

The construction and operation of the USFWS proposed reservoir will result in impacts to flow on the Red River basin. The USFWS proposed reservoir will effectively eliminate 2,237 square miles of drainage area from Lake Texoma. This drainage area is often considered noncontributing to Lake Texoma because it is located above existing flood control projects. This drainage area still contributes flow to the upper Red River basin as shown by the storage and yield available from the USFWS proposed reservoir. The largest impacts will be as a decrease in higher flows since the inflows to the USFWS proposed reservoir are represented as flood releases from Altus Lake and Tom Steed Reservoir. The USFWS appears to believe that the elimination of flood flows from a significant portion of the North Fork of the Red River will result in little or no impacts to low flows. Flood or higher flows recharge the alluvial aquifers associated with the Red River and its tributaries. Alluvial aquifers provide much of the base flow during periods of low flow. By eliminating flood flows from a significant portion of the North Fork basin, low flows may also be impacted.

<end of report>